Synthesis of Functionalized Thioxanthones, Indenones, Indoles, and Anthraquinones by Regioselective Palladium (0)-Catalyzed Cross-Coupling Reactions

Dissertation

zur

Erlangung des Doktorgrades

doctor rerum naturalium (Dr. rer. nat.)

der Mathematisch-Naturwissenschaftlichen Fakultät

der Universität Rostock

vorgelegt von

Dhafer Saber Khalaf Zinad geb. am 28 August 1978, Mosul, IRAQ

Rostock, January 2012

urn:nbn:de:gbv:28-diss2012-0017-1

Die vorliegende Arbeit entstand in der Zeit von July **2009** bis August **2011** am Institut für Chemie der Universität Rostock

Erinreichung der Dissertation:

1- Dekan: **Prof. Dr. Christoph Schick**, Mathematisch-Naturwissenschaftliche Fakultät, Universtät Rostock.

2- Gutachter: **Prof. Dr. A. Stephen K. Hashmi**, Organisch-Chemisches Institut, Fakultät für Chemie und Geowissenschaften, Ruprech-karls-Universtät Heidelberg.

3- Gutachter: **Prof. Dr. Peter Langer,** Institut für Chemie, Mathematisch-Naturwissenschaftliche Fakultät, Univestät Rostock.

Tag der Abgabe: October, 2011

Prüfer Hauptfach: **Prof. Dr. Peter Langer**

Wissenschaftliches Kolloquium: 31. 01. 2012

Dedication

To The Spirit of my Beloved Father …

Will not forget you …

Acknowledgment

First of all, I am thankful to the Merciful, Omniscient Almighty ALLAH with his help and blessing always.

I would like to express my deep thanking to all who added to the successful completion of my PhD.

Special thanks and appreciation to Prof. Dr. Dr. h.c. Peter Langer for his guidance and support.I always found him ready to facilitate my research by effective discussions. I feel honor to express my sincere thanks to him.

Many thanks to Prof. Dr. Hartmut Laatsch due to his exceptional support during my research in the Institute of Organic and Bimolecular Chemistry in Göttingen University.

I would like also to express my thanks to Dr.Holger Feist for his valuable guidance. I am also thankful to Dr.Martin Hein, Dr.Dirk Michalik, Dr.Alexander Villinger and all the technical members in NMR, IR, MS, X-ray laboratories in the institute of chemistry in Rostock university for their help and continuously support .

Thanks a lot to Dr.Munawer Hussain for his nice contribution and useful cooperation.

I feel grateful to my lab colleagues especially Friedrich Erben for his nice lab fellow and providing me nice atmosphere in the lab.

Many thanks to Prof. Dr.Layla Abdulla Mustafa, Ibrahim, Raeed, Anwer, Ahmed Nafe, Ghazwan, Ahmed Salem, Omer, Nadi, Verena Wolf, Nawaz, Iftikhar, Hung, Marcello and all of my colleagues and teachers in Mosul University in Iraq.

I would like to thank DAAD Foundation for providing me the financial supports during my PhD. many thanks to Mrs.Margret Steuernagel, Mrs.Sandra Wojciechowsky for their dedication to support and facilitate me in all related problems.

Thanks a lot and appreciation to Prof. Dr. Salah Al-abbasi the Iraqi Cultural Attache in Berlin for his continuous support.

Finally, I would like to express my heartiest gratitude and respect to my great parents for their love, support, salutary advices and emboldening attitude that kept my spirit alive.

Thanks a lot to all members of my family. My brothers and sisters: Dr.Yasser, Asmaa, Huda, Dr.Hany, Omar, Younis…Thank you all for your support and encouragement. I am grateful to all of you. May ALLAH give me the courage, strength and opportunity that I can support every one of you.

Special thanks to my wonderful wife (Huda) and my nice Son (Zaid) who they suffered with me a lot during my hard time with chemistry. Without them I am unable to find myself and the life will be without meaning.

I owe to all of you in my life!

Dhafer Saber

University of Rostock

Germany, **2011**

Table of Contents

Abbreviations

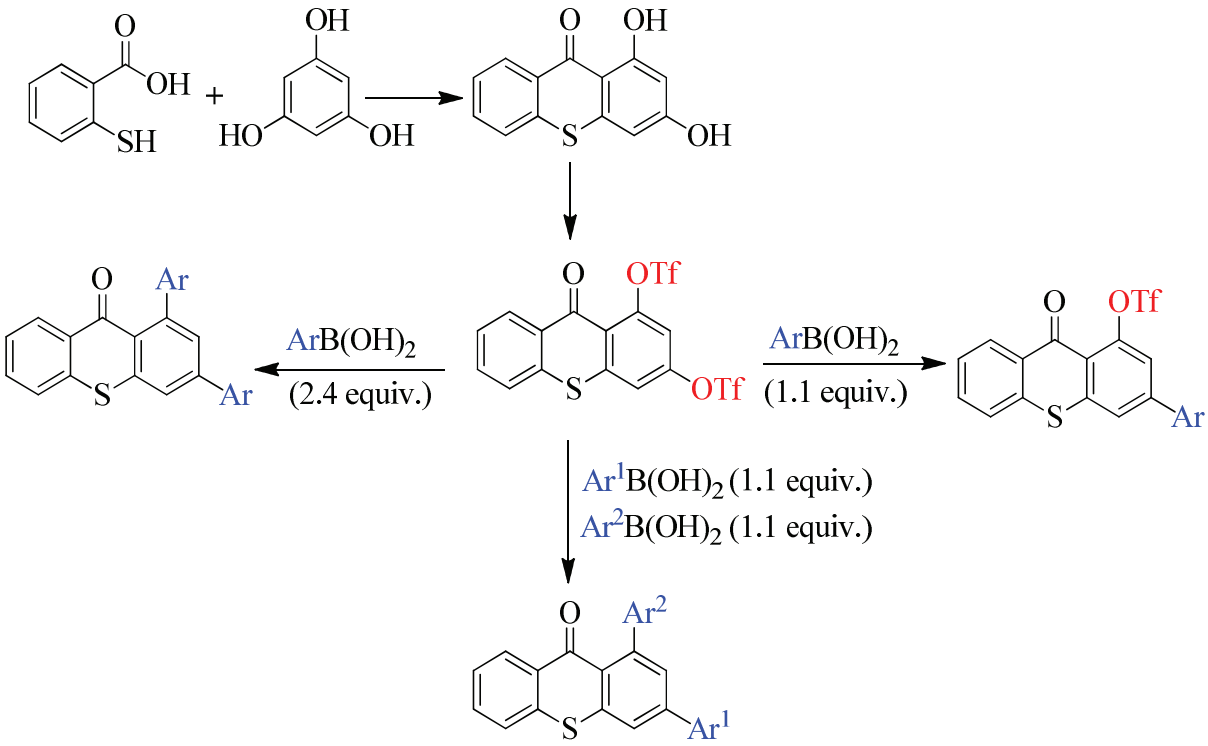
Ar	Aryl
APT	Attached Proton Test
calcd	Calculated
DEPT	Distortion-less Enhancement by polarization Transfer
EI	Electron Impact
ESI	Electrospray Ionization
EtOAc	Ethyl Acetate
Hz	Hertz
HRMS	High Resolution Mass Spectrometry
IR	Infrared Spectroscopy
MS	Mass Spectrometry
Mp	Melting Point
Ph	Phenyl
NBS	N-bromosuccinimide
NEt_3	Triethylamine
NMR	Nuclear Magnetic Resonance
HMBC	Hetronuclear Multiple Bond Correlation
NOESY	Nuclear Overhauser and Exchange Spectroscopy
Tf_2O	Trifluoromethanesulfonic Anhydride
THF	Tetrahydrofurane
TLC	Thin Layer Chromatography
TMS	Trimethylsilane

Summary

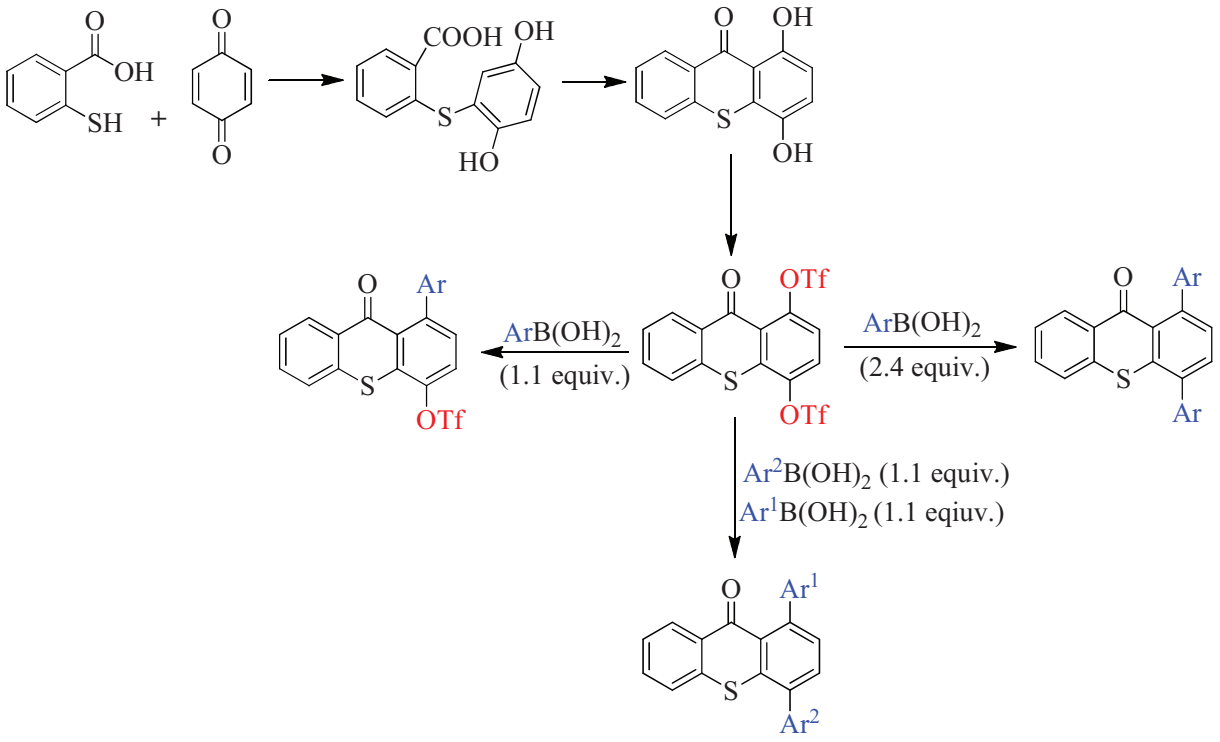
The task of my thesis was to study palladium(0)-catalyzed cross-coupling reactions (Suzuki and Heck reaction). Different types of bis(triflates) and dibromides of different substrates (thioxanthons, indenones, indoles, naphthaquinones) were studied.

1,3- Dihydroxythioxanthones and 1,4-dihydroxythioxanthones as substrates were synthesized in the laboratory from available chemicals and known procedures.

The palladium(0)-catalyzed Suzuki-Miyaura cross-coupling reaction of bis(triflates) of 1,3-dihydroxythioxanthones afforded 1,3-diarylthioxanthones. The reactions proceeded with very good yield and excellent site-selectivity. The first attack takes place at carbon atom C-3. In general, the site-selectivity of palladium(0)-catalyzed reactions is controlled by electronic and steric effects. The oxidative addition of palladium usually occurs first at the most electron deficient and sterically less hindered position. The regioselectivity of the formation of mono-adducts for bis(triflates) of 1,3-dihydroxythioxanthone is due to the fact that carbon atom C-3 is sterically less hindered than carbon atom C-1. Therefore, the first attack occurred at this position.

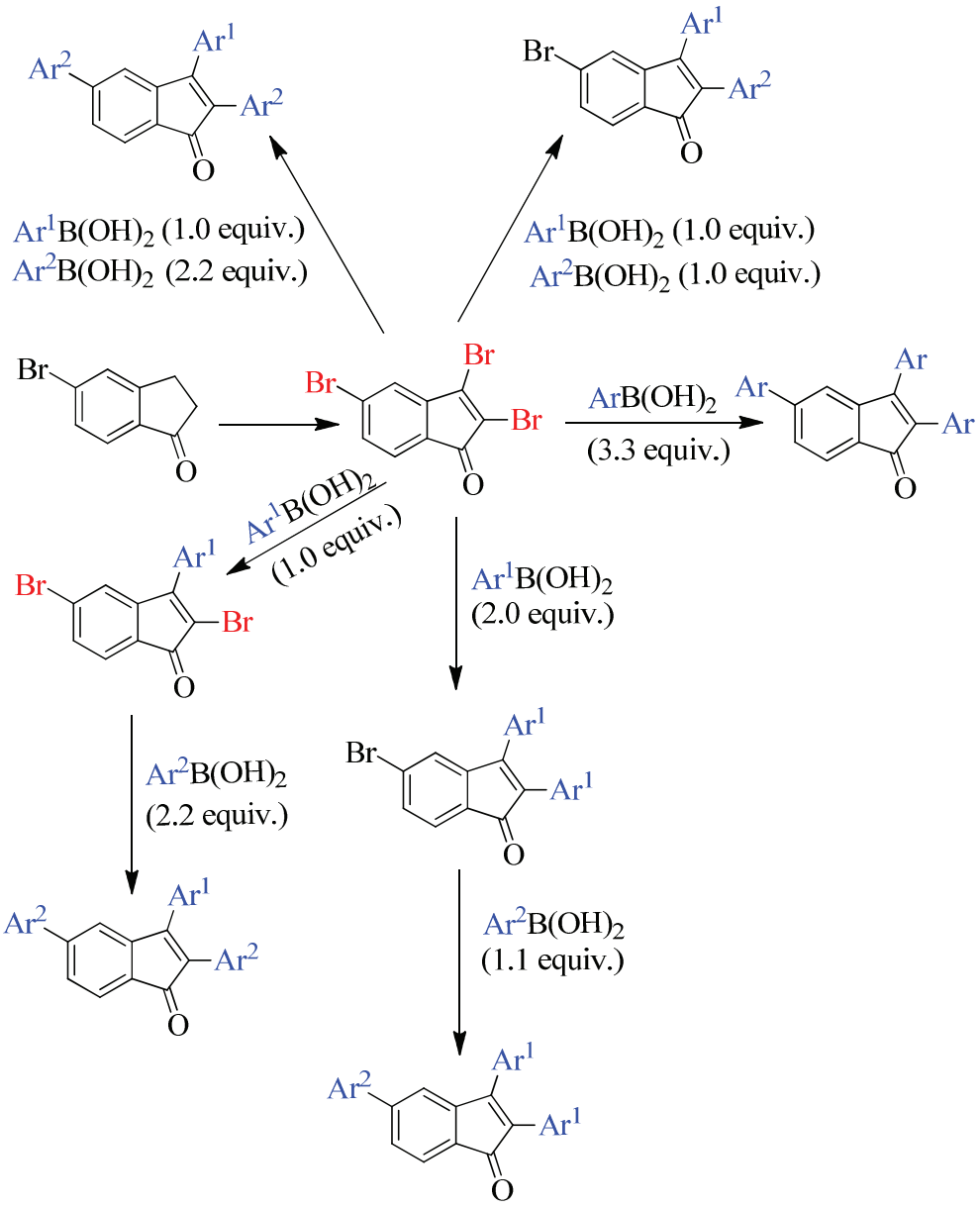


The Suzuki-Miyaura cross-coupling reactions of bis(triflates) of 1,4-dihydroxythioxanthones afforded 1,4-diarylthioxanthones. The reaction again proceeded with excellent site-selectivity in favour of carbon atom C-1 which is more electron-deficient than carbon atom C-4. The attack at carbon atom C-4 is hindered by the lone pairs of the sulfur atom. Therefore, the first attack takes place at position 1.



Various 1,3- and 1,4-diarylthioxanthones with different electron-donating and withdrawing groups were prepared in high yields and excellent site-selectivity. $Pd(PPh_3)_4$ was used as an optimal catalyst for the synthesis (5 mol% per cross-coupling reaction).

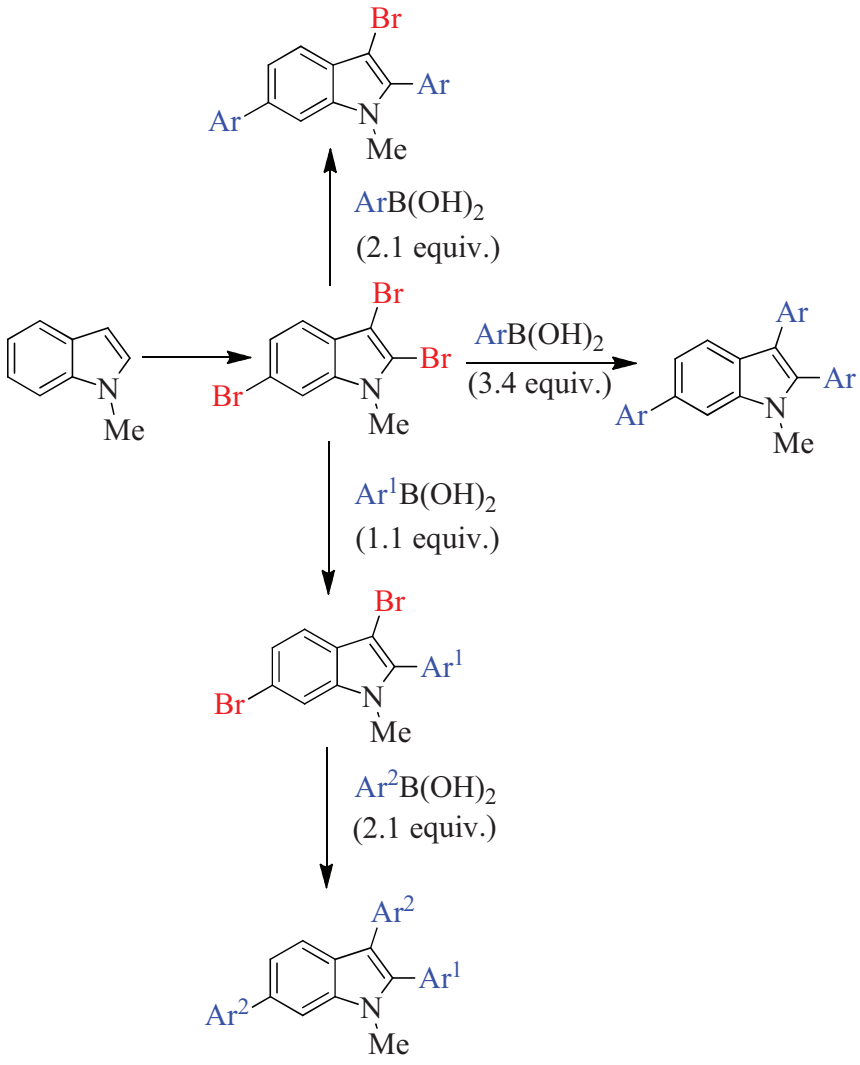
2,3,5-Tribromoinden-1-one was prepared from commercially available 5-bromoinden-1-one. The Suzuki-Miyaura reaction of this substrate was studied also in my thesis. The site-selective Suzuki-Miyaura cross-coupling reaction of 2,3,5-tribromoinden-1-one with one equivalent of different arylboronic acids, having both electron-donating and withdrawing groups, afforded 3-aryl-2,5-dibromo-1*H*-inden-1-one in high yields and excellent site-selectivity. $Pd(PPh_3)_4$ (3 mol%) was used for this coupling reaction as a catalyst. The first attack occurred at carbon atom C-3.



The palladium(0)-catalyzed Suzuki-Miyaura cross-coupling reactions to give di- and triarylinden-1-ones proceeded with high yields and very good site-selectivity. The second attack takes place in favour of carbon atom C-2 of tribromominden-1-one. The site-selectivity can be explained by the fact that carbon atom C-3 is considerablly more electron-deficient than positions 2 and 5. Carbon atom C-2 is sterically more hindered than C-5 and electronically less deficient.

The site-selectivity in favour of position 5 might be explained by chelation of the catalyst to the carbonyl oxygen atom which may enhance the rate in favour of position 2.

The Suzuki-Miyaura cross-coupling reaction of 2,3,6-tribromo-1-methyl-1*H*-indole with different arylboronic acids, both electron-donating and withdrawing groups, were studied also in my thesis.



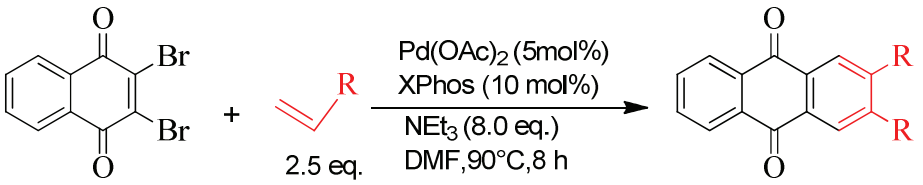
2-Aryl-3,6-dibromo-1-methyl-1*H*-indoles were synthesized in high yields and excellent site-selectivity for both electron-donating and withdrawing groups of the arylboronic acids used. $Pd(PPh_3)_4$ (3 mol%), a solvent mixture of toluene/1,4-dioxane (4:1), and K_3PO_4(1.5 equiv.) as the base were most suitable conditions for this reaction. Both symmetrical and unsymmetrical di- and triaryl-1-methyl-1*H*-indoles were prepared in this project in high yields and very good site-selectivities for both electron-donating and withdrawing groups.

The first attack occurred at carbon atom C-2 and the site-selectivity of 2,3,6-tribromo-1-methyl-1*H*-indole was explained by the fact that position 2 is considerably more electron-deficient than positions 3 and 6. Carbon atom C-6 is sterically less-hindered than C-3, therefore the second attack occurred at C-6. The synthesis of 2,3,6-triaryl-1-methyl-1*H*-indoles, containing different aryl groups, was proceeded as a one-pot synthesis with sequential addition of the reagents. Other products were synthesized after isolation of the product of the first coupling reaction from the first step and its reaction with a second boronic acid in a second cross-coupling reaction.

The synthesis of functionalized anthraquinones by domino twofold 6π-electrocyclization reactions of 2,3-dibromonaphthaquinone was studied also in my thesis. The Heck reaction of 2,3-dibromonaphthaquinone with different types of alkenes (acrylate and styrene), having both electron-donating and withdrawing groups, afforded substituted anthraquinones. The temperature played an important effect in this reaction. The yields significantly decreased when the temperature was increased. A clean reaction was observed when the reaction was carried out at 90°C. $Pd(OAc)_2$ (5 mol%) and Buchwald ligand XPhos (10 mol%) were used for the reaction. The products, which are not readily available by other methods, were formed in only one step under relatively mild conditions.

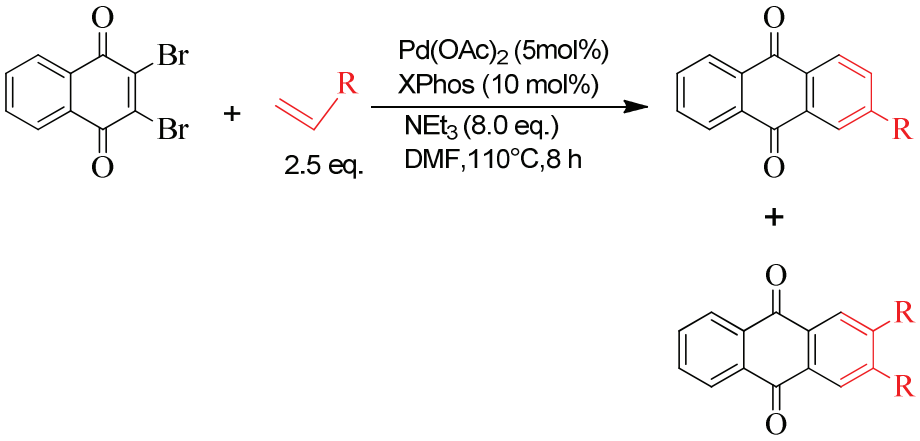
Method (1)

At 90°C



Method (2)

At 110°C



1. Introduction

1.1 General Introduction

Carbon-carbon bond forming reactions played an enormously decisive and important role in shaping chemical synthesis of organic compounds. Classical reactions, for example aldol and Grignard-type reactions, the Diels-Alder, Wittig and related reactions, allow chemists to construct increasingly complex carbon frameworks and thus enabled the synthesis of a myriad of organic compounds.

During the second half of the 20th century, transition metals started to play an important role in organic chemistry and this has led to the development of a large number of transition metal-catalyzed reactions for creating organic molecules. Transition metals have a unique ability to activate various organic compounds and through this activation they can catalyze the formation of new bonds. In 2005, the Nobel Prize in chemistry was awarded to metal-catalyzed reactions for the formation of carbon-carbon double bonds. In 2010, the Nobel Prize in chemistry is awarded to the formation of carbon-carbon single bonds through palladium-catalyzed cross-coupling reactions[1].

1.2 Characteristic Features of Palladium-Catalyzed Reactions

There are several features which make reactions involving palladium-catalysts and reagents particularly useful and versatile among many transition metals used for organic synthesis. Most importantly, Pd catalysts offer an abundance of possibilities of carbon-carbon bond formation. No other transition metal can offer such versatile methods for carbon-carbon bond formations as Pd. Tolerance of Pd-catalysts and reagents to many functional groups, such as carbonyl and hydroxyl groups, is the second important feature. Pd-catalyzed cross-coupling reactions can be carried out without protection of these functional groups. However, reactions involving Pd should be carried out carefully as Pd(0)-reagents and catalysts are sensitive to oxygen and moisture. It is sufficient to apply precautions to avoid oxidation of coordinated phosphines and Pd(0). [2]

Palladium is a noble and expensive metal. The toxicity of Pd has posed no serious problems so far. Numbers of industrial processes, particularly for the production of fine chemicals based

on Pd-catalyzed reactions, have been developed and are currently being operated and reflect the advantages of using Pd catalysts commercially [3].

1.3 Palladium-Catalyzed Cross-Coupling Reactions

Based on transition-metal catalysis, the newly acquired ability to form carbon-carbon bonds between functionalized and sensitive substrates provided new opportunities, particularly in total synthesis, but also in medicinal and process chemistry as well as in chemical biology and nanotechnology. Various types of palladium-catalyzed cross-coupling reactions are known in organic synthesis, such as Heck, Stille, Suzuki, Sonogashira, Tsuji-Trost, and the Negishi reactions (Figure 1). The increasing popularity of these reactions in synthesis is seen in every issue of modern scientific journals dedicated to organic synthesis or organometallic chemistry and catalysis[4].

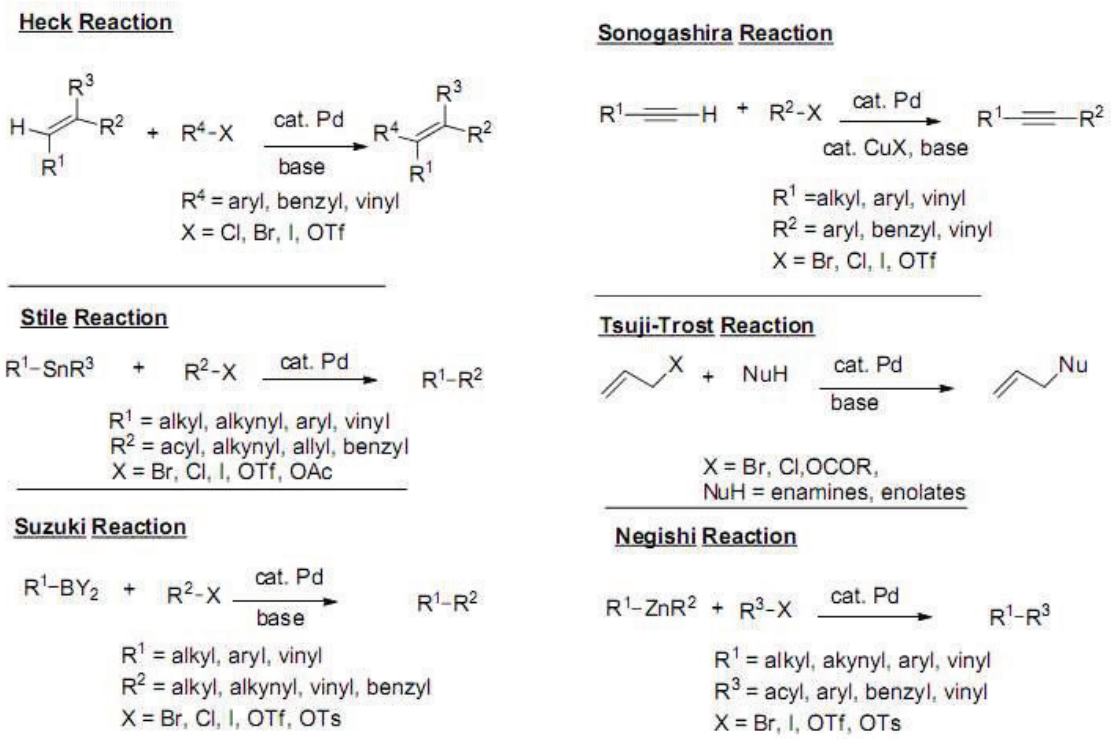


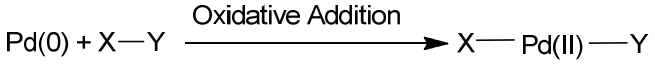
Figure 1: Types of palladium-catalyzed cross-coupling reactions (picture taken from *Angew.Chem. Ind. Ed.* **2005**, 44, 4442).

With regard to the application in industry, the shown coupling reactions offer the opportunity of shorter and more selective routes for a number of fine chemicals as compared to traditional stoichiometric organic transformations. Thus, it is not surprising that, since the early 1990s, more and more palladium-catalyzed reactions are transferred from academic protocols to industrial scale. Therefore, during the last decade, the development of new catalysts which are more productive and more active continues to be a major goal of organometallic chemistry and homogeneous catalysis[5].

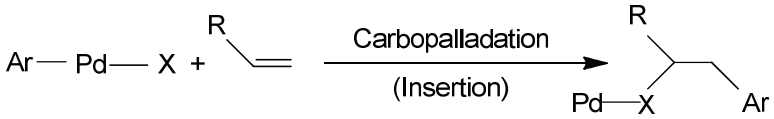
1.4 Fundamental Reactions of Palladium Compounds

The reaction mechanism and the synthetic applications of Pd-catalyzed cross-coupling reactions proceed according to the following major steps[6,7](Figure 2).

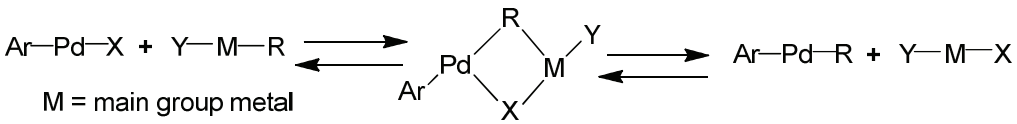
1. **Oxidative Addition**: The 'oxidative' addition is the addition of a molecule X-Y to Pd(0) with cleavage of its covalent bond, forming two new bonds. Since the two previously non-bonding electrons of Pd are involved in bonding, the Pd increases its formal oxidation state by two units, namely, Pd(0) is oxidized to Pd(II).



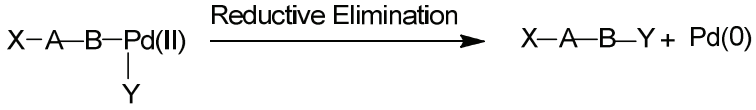
2. **Insertion:** The term 'insertion' is somewhat misleading. The insertion should be understood as the migration of the adjacent ligand from the Pd to the Pd-bound unsaturated ligand. The reaction below is called 'insertion' of an alkene to a (Ar-Pd-X) bond mainly by inorganic chemists. Some organic chemists prefer to use the term 'carbo-palladation' of alkenes.



3. **Transmetallation:** Organometallic compounds M-R and hydrides M-H of main group metals (M= Mg, Zn, B, Al, Sn, Si, Hg) react with Pd complexes (Ar-Pd-X) formed by oxidative addition, and the organic group or hydride is transferred to Pd by substituting X with R or H. In other words, alkylation of Pd or hydride formation takes place and this process is called transmetallation.



4. **Reductive Elimination:** it is a uni-molecular decomposition pathway, and the reverse of oxidative addition. Reductive elimination (or reductive coupling) involves loss of two ligands of *cis* configuration from the Pd center, and their combination gives rise to a single elimination product as it has been shown below. By reductive elimination, both the coordination number and the formal oxidation state of Pd(II) are reduced by two units to generate Pd(0), and hence the reaction is named 'reductive' elimination. The regenerated Pd(0) species undergo oxidative addition again. In this way, a catalytic cycle is completed by a reductive elimination step[8].



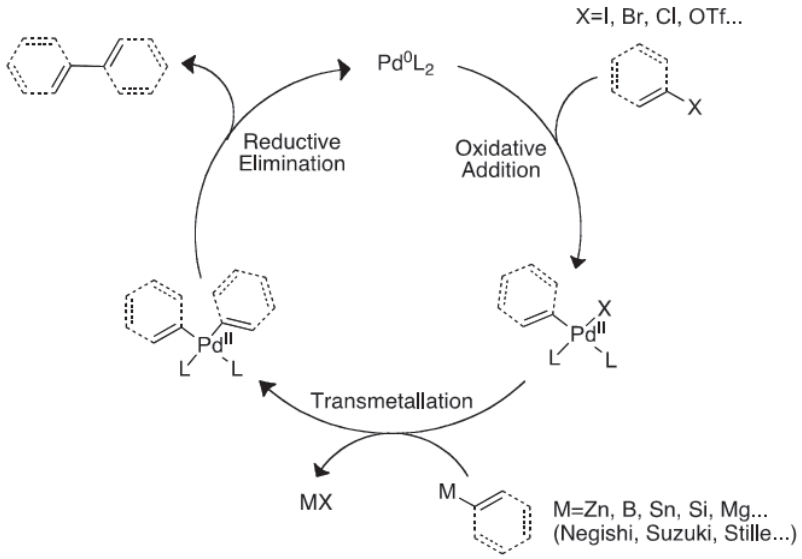


Figure 2: General mechanism for palladium-catalyzed cross-coupling reactions (picture taken from *Molecules*, **2011**, *16*, 951-969).

1.5 Palladium-Catalyzed Suzuki-Miyaura Cross-Coupling Reaction

The Suzuki-Miyaura cross-coupling reaction represents an extremely useful method for the synthesis of biaryls and is widely applied in organic chemistry. The reaction involves, for example, the palladium-catalyzed cross-coupling between organoboron compounds and aryl halides. The scope of the reaction is not restricted to aryl derivatives, but includes also alkyl, alkenyl and alkynyl compounds. The reaction also works well with triflates (the OH group is converted into OTf by triflic anhydride); thus, phenolic compounds can be arylated by this method. Boronic esters, boranes or boronic acids can be used [9]. Since its discovery, the Suzuki-Miyaura cross-coupling reaction has seen significant advancement and became one of the most powerful carbon-carbon bond forming methods in organic synthesis. The Suzuki reaction represents one of the, if not the most, widely used methods for aryl-aryl bond formation in modern organic synthesis. Biaryl systems have a lot of advantages in many scientific and economic fields, from natural products to ligands for asymmetric catalysis, pharmaceutical compounds, and nanomaterials. Extensive research efforts have recently been extended to develop further the utility and efficiency of the Suzuki reaction within this context[10].

The reaction has important advantages including functional group compatibility, low toxicity of reagents and intermediates, easy availability of boron derivatives, high thermal stability and tolerance toward oxygen and aqueous solvents[11].

Recently, organic chemists have turned their work to the application of this reaction for the synthesis of more complex molecules, by using successive Suzuki-Miyaura cross-coupling reactions with substrates containing two or more possible reactive sites[12].

The mechanism usually involves three steps (Figure 3). In the first step of the reaction, the oxidative addition of organic halides or triflates to the Pd(0) complex to form an organo-palladium halide (R_1-Pd (II)-X) takes place. This step is then followed by transmetallation with a boronic acid derivative to give a diorgano-palladium complex (R_1-Pd-R_2). In the final step of the reaction, this complex undergoes a reductive elimination resulting in the formation of a carbon-carbon bond and regeneration of the catalyst[13].

Many factors are affecting both the oxidative addition and transmetallation steps and then affect the rate of Suzuki reactions. For example, the reactivity of the reacting substrates has an important role to play on the oxidative addition step. Generally, the reactivity of various substrates in Suzuki reactions is observed in the following order, Ar-I > Ar-Br > Ar-OTf > Ar-Cl. The base supports the transmetallation step of the Suzuki reaction. Different types of bases

are used in this reaction, e.g. potassium carbonate, potassium phosphate and cesium carbonate, which enhances the rate of the transmetalation by increasing the nucleophilicity of the organo-boran compound by formation of an organo-borate containing a tetravalent boron atom[14].

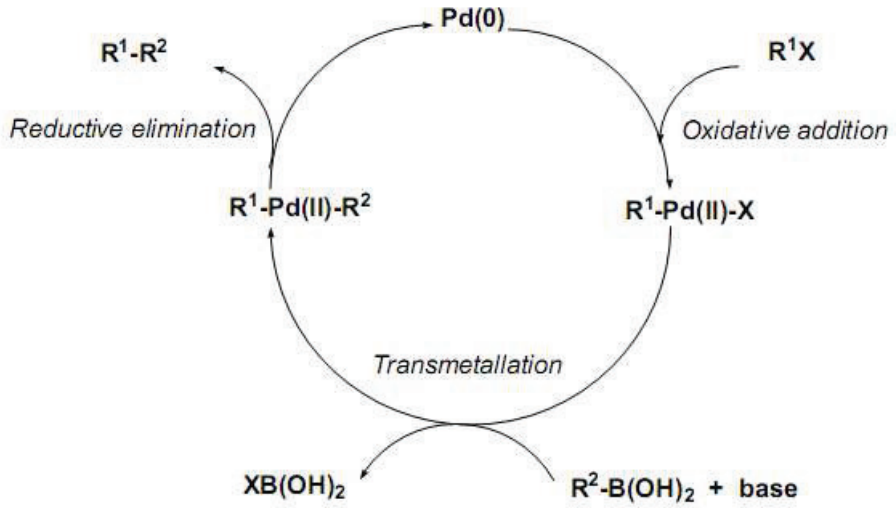


Figure 3: Catalytic cycle of the Suzuki reaction

The Suzuki-Miyaura cross-coupling reaction is the only one among metal-catalyzed cross-coupling reactions which can be run in biphasic (organic/ aqueous) or aqueous environments in addition to organic solvents[15].

Organo-boron derivatives can tolerate a broad range of functional groups, such as organic halides, carbonyls, etc. The electronegativity of boron is about 2.0 which is close to the value of carbon of 2.5 and is higher than the electronegativities of lithium, magnesium, or most of the transition metals which range from 0.86 to 1.75. Therefore, the boronic compounds are air-stable and also water tolerant. The starting materials and borate by-products are not toxic[16].

In organic synthesis, two kinds of palladium compounds, namely Pd(II) salts and Pd(0) complexes are used. Pd(II) compounds are mainly used as oxidizing reagents, or as catalysts for some reactions. Pd(0) complexes are often used as catalysts. Pd(II) compounds such as $PdCl_2$ and $Pd(OAc)_2$ are stable and commercially available. They can be used in two ways: as unique stoichiometric oxidizing agents and as precursors of Pd(0) complexes. $Pd(OAc)_2$ is commercially available, stable and soluble in organic solvents. Commercially available $Pd(OAc)_2$,

$PdCl_2(PPh_3)_2$, $Pd(PPh_3)_4$, $Pd_2(dba)_3$ are generally used as precursors of Pd(0) catalysts with or without addition of phosphine ligands. $Pd(PPh_3)_4$ is a light-sensitive, air unstable, yellowish green catalyst and a coordinatively saturated Pd(0) complex which is widely used as a catalyst for palladium-catalyzed cross-coupling reactions[17].

As these catalysts serve as a source of electrons in the reaction; the electron-rich ligands are often the key for a successful reaction. Sterically hindered and electron-rich phosphines serve the purpose in a best way. Many chemists all over the world are trying to synthesize most useful ligands which can be employed to achieve the best results in the field of palladium-catalyzed chemistry. Buchwald and co-workers[18] recently have developed electron-rich, bulky biphenyl phosphine ligands, such as S-Phos, X-Phos, and others.

Langer and coworkers extensively studied site-selective Suzuki-Miyaura cross-coupling reactions of poly-halogenated hetero-aromatic and aromatic compounds or their triflates. In this context, regioselective Suzuki-Miyaura cross-coupling reactions of 2,3-dibromo-1*H*-inden-1-one (**a**), 2,3-dibromobenzofuran (**b**), 2,3-dibromo-1-methyl-1*H*-indole (**c**), 2,3,4-tribromothiophene (**d**), 2,3,5-tribromothiophene (**e**), 3,4,5-tribromo-1-methyl-1*H*-pyrazole (**f**), perchloropyrimidine (**g**) and perbromofuran (**h**) were reported (Figure 4) [19a-h].

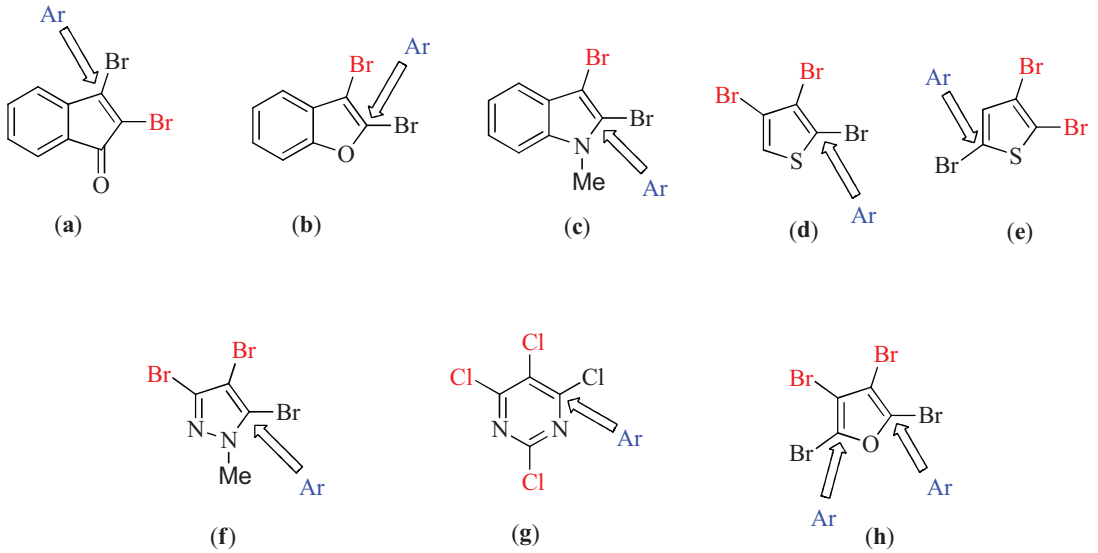


Figure 4: Site-selective Suzuki cross-coupling reactions of various halides studied in Langer's group

Site-selective Suzuki-Miyaura cross-coupling reactions of bis(triflate) substrates and subsequently the site-selectivity of the reaction were studied as well (Figure 5). The use of aryl triflates instead of aryl halides is particularly important in organic synthesis because it can provide a way of forming a carbon-carbon bond at a phenolic site, which is often useful when appropriate halides are unavailable.[20]

Langer's group also reported the regioselective synthesis by Suzuki-Miyaura cross-coupling reactions of different hydroxylated substrates, e. g. (3,4-dihydroxyphenyl)(phenyl)methanone (**i**) 2-((4-hydroxyphenyl)sulfonyl)phenol (**j**) 1,2-dihydroxyanthracene-9,10-dione (**k**) phenyl 1,4-dihydroxy-2-naphthoate (**l**) 7,8-dihydroxy-2-phenyl-4*H*-chromen-4-one (**m**), 1,2,3,4-tetrahydro-9,10-dihydroxyanthracen-1-one (**n**) 5,10-dihydroxy-11*H*-benzo[*b*]fluoren-11-one (**o**).[21a-g]
All mentioned substrates proceeded with very good yields and excellent site-selectivity.

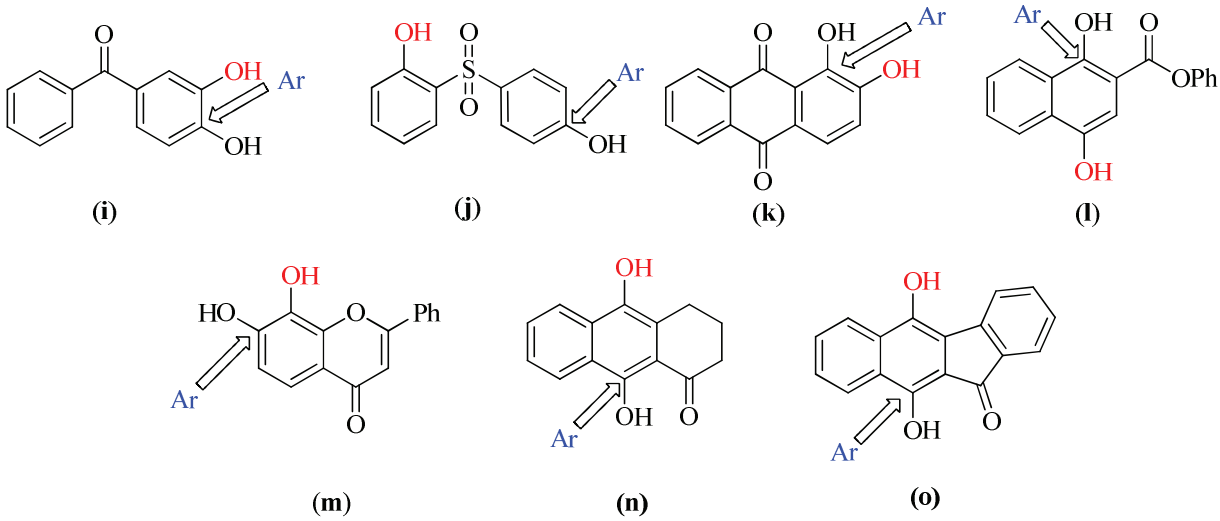


Figure 5: Site-selective Suzuki cross-coupling reactions of dihydroxylated substrates studied in Langer's group

In general, complex compounds can be prepared by successive Suzuki-Miyaura cross-coupling reactions of substrates containing one, two or more possible reactive sites. The regioselectivity can be explained by electronic and steric parameters. The first attack usually occurs at the more electrons deficient and sterically less hindered position[22].

1.6 Palladium-Catalyzed Heck Cross-Coupling Reaction

The Mizoroki–Heck reaction is the palladium-catalyzed C-C coupling reaction between aryl halides or vinyl halides with activated alkenes in the presence of Pd(0) catalyst and a base. Pd(II) acetate or Pd(II) chloride in combination with different ligands, such as triphenyl phosphine(PPh_3), S-Phos, X-Phos, tricyclohexylphosphine (PCy_3) were used as catalysts to give the corresponding substituted alkenes[23].

In general, the reaction proceeds with high stereo- and regioselectivity. The reaction was discovered independently by Heck and Mizoroki in the early 1970s. After further development in the 1980s and 1990s, the synthesis community benefited enormously from the Heck reaction, especially for the synthesis of pharmaceuticals and agrochemicals[24]. The intramolecular Heck reaction has been well-established as a powerful tool for the construction of complex polycyclic ring systems in the context of natural product synthesis.

In Heck reactions, the reactivity depends on the substituted olefins: more substituted olefins resulted in a slower reaction. However, electron-poor olefins provided higher yields (electron-withdrawing groups such as ester, ether, carboxylic acid, nitriles, located at the olefin). The type of leaving group also plays an important role. The reactivity order is I > Br > Cl.

The generally accepted reaction mechanism is shown in Figure 6. The reaction begins with the oxidative addition of the aryl-X compound (X = I, Br, Cl, OTf, OTs, etc) to an active ligated Pd(0) center to form the respective Pd(II) species.

Subsequent coordination and then insertion of the alkene at the Pd(II) center generates an alkyl palladium complex. After rotation of the carbon–carbon bond, hydride elimination takes place and the substituted alkene is released as the terminal product. Finally, the active Pd(0) catalyst is regenerated with base.

Besides the typical intermolecular reactions of aryl halides with ethylene, styrenes, acrylates, enol ethers, etc., intramolecular variants exist, which form unsaturated carba- or heterocycles. Furthermore, the Heck reaction has proven to be very useful as part of novel domino reactions[25].

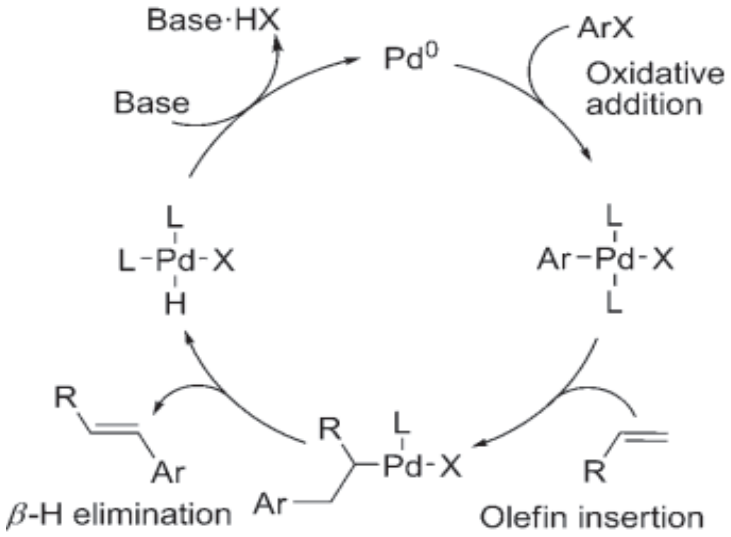


Figure 6: general reaction mechanism of Heck cross-coupling reaction (picture taken from *Angew.Chem. Int. Ed.* **2010**, *49*, 9047-9050).

The combination of the Heck cross-coupling reaction with electrocyclization reactions provides a convenient access to a variety of carbacyclic frameworks. Pioneering work in this field was reported by de Meijere and co-workers. Benzene derivatives have been prepared by double Heck reactions of aliphatic 1,2-dibromoalkenes to give hexatrienes and subsequent thermal-6π-electrocyclization of the latter. The electrocyclization can proceed smoothly, if the central double bond of the triene system is not involved in a stable aromatic 6π-system[26]. Langer's group later studied the application of this concept to various halogenated compounds, e.g. twofold Heck cross coupling reactions of 2,3-dibromoindenone (**a**) 2,3dibromo-N-methylindole (**b**) 2,3-dibromobenzothiophene(**c**), 2,3-dibromofuran (**d**) 2,3dibromothiophene (**e**) 2,3-dibromobenzofuran (**f**) (Figure 7) [27a-e].

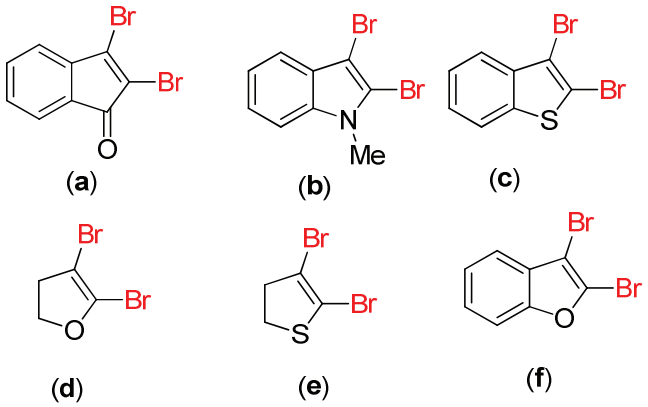


Figure 7: Heck reaction of vicinal dibromide studied in Langer's Group

In conclusion, the Pd(0)-catalyzed Heck cross-coupling reaction of dibrominated substrates can provide a cyclization and aromatization by a subsequent electrocyclization. The synthesis of the products following this type of reaction can be achieved in only one-step under relatively mild conditions.

2. Synthesis of Functionalized Dihydroxy-9*H*-thioxanthen-9-ones.

2.1 General Introduction:

The first part of my work was concerned to the synthesis of functionalized thioxanthones based on site-selective Suzuki-Miyaura cross-coupling reactions. In the literature, it has been reported that thioxanthones show a variety of properties. These types of compounds have considerable pharmacological relevance and occur in various natural products[28]. Thioxanthone derivatives have been studied extensively owing to their medicinal properties, such as antihistaminic, antiparasitic, neuroleptic, and antitumor activities[29-33]. Lucanthone and hycanthone, a metabolite, represent bioactive natural products with thioxanthone core structure[34]. A series of hycanthone derivatives have been recently reported to display high levels of *in vivo* activity against murine pancreatic adenocarcinoma[35-37]. Thioxanthone-dioxide is also known to exhibit significant pharmacological activities, including antitumor, cytotoxic and monoamine oxidase (MAO) inhibitory activity[38]. A number of plants such as *cartoxylum cochinchinense (Lour.)*, contain thioxanthone derived natural products and have been used as traditional medicines to treat fever, coughing, diarrhoea, itching, ulcers and abdominal complaints[39]. The thioxanthone class of drugs are effective in the systematic treatment of psychoses; they are most appropriately used in the therapy of schizophrenia, organic psychoses and other idiopathic psychotic illness. These drugs have other clinically useful properties including anti-emetic, anti-nausea, anti-histamine and the ability to potentiate the analgesics sedatives and general anaesthetic action[40]. Thioxanthones are also important in the field of material sciences. Various derivatives of thioxanthones are used as activators in the photo polymerization of ethylene-derived unsaturated monomers (particularly acrylate derivatives)[41]. Moreover, alkyl-, alkoxy- and hydroxy-substituted thioxanthones are particularly useful as heat and ultraviolet stabilizers of polyolefins[42].

Several methods were used for the synthesis of thioxanthones[39,43]. A rather general procedure is based on the condensation of substituted potassium 2-chlorobenzoates with thiophenols or on the condensation of substituted thiosalicylic acids with benzene derivatives to give 2-phenylmercaptobenzoic acids which are subsequently cyclized by reaction with sulphuric acid, [44,45], $AlCl_3$[30,33] or polyphosphoric acid (PPA)[32]. However, these classical methods have some disadvantages, such as low yields, long reaction times, use of large amounts of concentrated sulphuric acid, and lack of regiochemical control in the ring closure step. Moreover, some of

these methods require several synthetic steps, because the starting materials are not readily available, and are limited to activated benzoic acids and benzene derivatives containing electron-withdrawing groups.

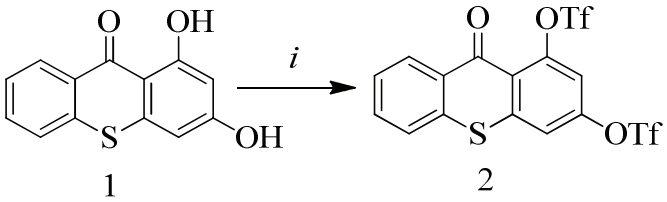
1,3-Dihydroxy-9*H*-thioxanthen-9-one was prepared, following a known procedure,[46] by $AlCl_3$ mediated reaction of thiosalicylic acid with 1,3,5-trihydroxybenzene.

1,4-Dihydroxy-9*H*-thioxanthen-9-one was synthesized by cyclization of 2-[(2,5-di-hydroxyphenyl)sulfanyl]benzoic acid. The latter was prepared from benzoquinone and thiosalicylic acid in acetic acid or other solvents (such as diethyl ether or ethanol) at room temperature and the reaction occurs as a 1,4-addition of the nucleophile at the conjugated bond system of the quinone with participation of one carbonyl group (which is typical of quinones), followed by rearrangement of the adduct to produce dihydroxy-substituted biphenyl sulfide [47].

2.2 Site-Selective Suzuki–Miyaura Cross-Coupling Reactions of the Bis(triflates) of 1,3-Dihydroxy-9*H*-thioxanthen-9-one.

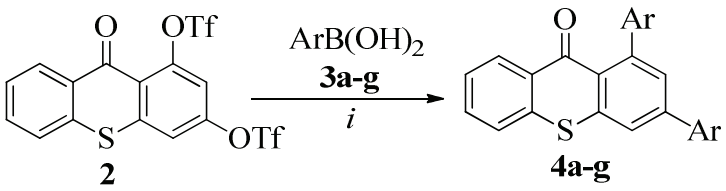
Results and discussion:

1,3-Dihydroxy-9*H*-thioxanthen-9-one **1** was prepared following a known procedure [46]. The hydroxyl group can be transformed to triflates by treatment with triflic anhydride in the presence of pyridine as a base. The triflic anhydride was added at -78°C and the mixture was allowed to warm to room temperature. Based on the above mentioned procedure, compound **1** was converted to the bis(triflate) **2** which was isolated as a yellow solid in 80% yield (Scheme1).



Scheme 1: Synthesis of **2**. *Reagents and conditions*: *i*, CH_2Cl_2, **1** (1.0 equiv.), Et_3N (4.0 equiv.), Tf_2O (2.4 equiv.), -78°C → 20°C, 8 h.

The Suzuki–Miyaura cross-coupling reaction of **2** with arylboronic acids **3a–g** (2.4 equiv.) afforded the 1,3-diarylthioxanthones **4a–g** (Scheme 2, Table 1). The structures of all products were confirmed by spectroscopic methods. Very good yields were obtained both for reactions of electron-rich and poor arylboronic acids. The best yields were obtained when the reactions were carried out using $Pd(PPh_3)_4$ (10 mol%) as catalyst, K_3PO_4 (3.0 equiv.) as base and when the reaction was carried out using 1,4-dioxane as a solvent at 90°C for 8 h.



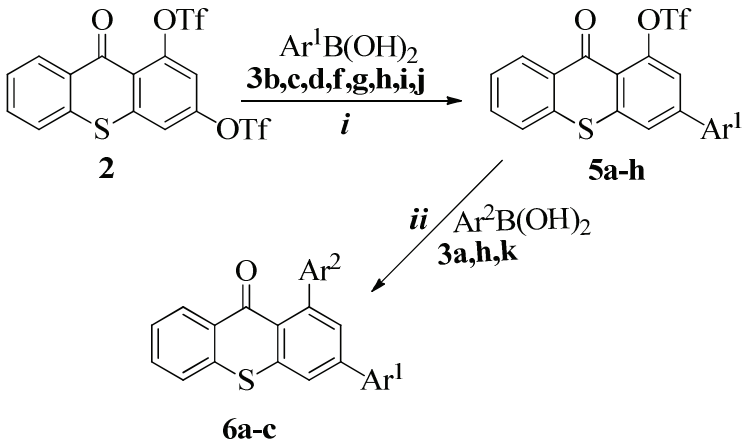
Scheme 2: Synthesis of **4a-g**. *Reagents and conditions*: *i*, **2** (1.0 equiv.), **3a-g** (2.4 equiv.), $Pd(PPh_3)_4$ (10 mol%), K_3PO_4 (3.0 equiv.), 1,4-dioxane, 90°C, 8 h.

Table 1: Synthesis of **4a-g**

3	**4**	**Ar**	**4**(%)[a]
a	**a**	2-(MeO)C_6H_4	**90**
b	**b**	4-EtC_6H_4	**81**
c	**c**	4-*t*BuC_6H_4	**86**
d	**d**	3,5-$Me_2C_6H_3$	**77**
e	**e**	4-MeC_6H_4	**84**
f	**f**	4-ClC_6H_4	**70**
g	**g**	3-(CF_3)C_6H_4	**75**

[a] Yields of isolated products.

The Suzuki–Miyaura reaction of **2** with arylboronic acids **3b,c,d,f,g,h,i,j** (1.1 equiv.) resulted in the formation of the 3-aryl-1-(trifluorosulfonyloxy)-thioxanthones **5a-h** in a good yields and excellent site-selectivity (Scheme 3, Table 2).



Scheme 3: Synthesis of **5a-h** and of **6a-c**. *Reagents and conditions*: *i*, **2** (1.0 equiv.), **3b,c,d,f,g,h,i,j** (1.1 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (1.5 equiv.), THF, 60°C, 8 h; *ii*, **5b,c,f** (1.0 equiv.), **3a,h,k** (1.1 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (1.5 equiv.), 1,4-dioxane, 90°C, 6 h

Table 2: Synthesis of **5a-g** and **6a-c**

5	6	Ar^1	%(5)[a]	Ar^2	%(6)[a]
a		4-$(MeO)C_6H_4$	**87**		
b	**a**	4-EtC_6H_4	**84**	2-$(MeO)C_6H_4$	**82**
c	**b**	4-*t*BuC_6H_4	**75**	4-$(MeO)C_6H_4$	**79**
d		3,5-$Me_2C_6H_3$	**82**		
e		C_6H_5	**71**		
f	**c**	4-ClC_6H_4	**78**	3,4-$(MeO)_2C_6H_3$	**71**
g		3-$(CF_3)C_6H_4$	**81**		
h		4-FC_6H_4	**80**		

[a] Yields of isolated products.

It was proved to be important to carry out the reaction at 60 instead of 90°C in order to induce a good site-selectivity and to avoid double attack. Good yields were again obtained both for reactions of electron rich and poor arylboronic acids. The structure of compound **5b** (Figure 7) and **5c** (Figure 8) were independently confirmed by X-ray crystal structure analysis. The thioxanthone moiety is slightly twisted out of plane. The structures of all products were confirmed by spectroscopic methods.

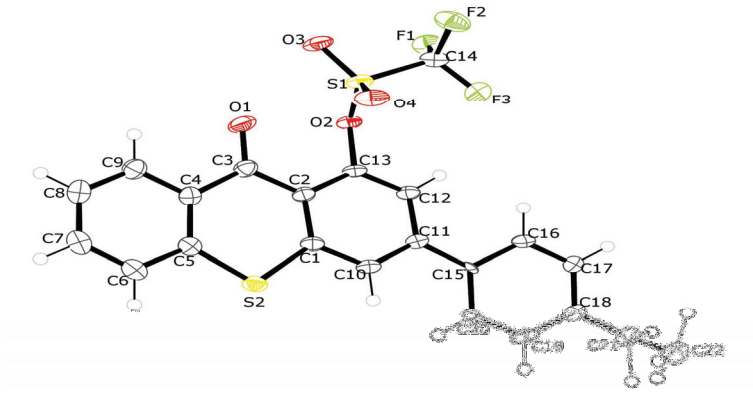


Figure 7: Molecular structure of compound **5b**

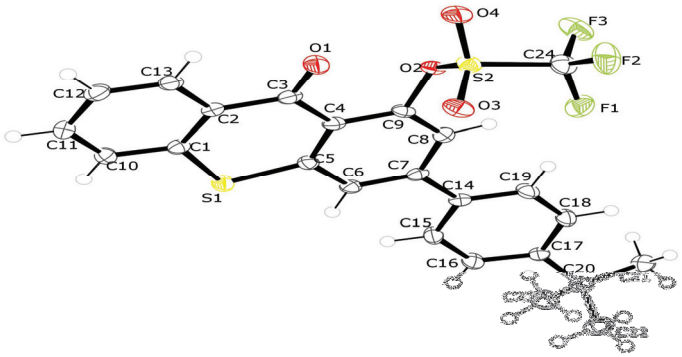


Figure 8: Molecular structure of compound **5c**

Compounds **6a-c** were synthesized by two steps. After isolation of the products of the mono-adducts **5b,c,f** from the first step, the second arylboronic acids **3a,h,k** were added for the second cross-coupling reaction which afforded 1,3-diarylthioxanthones **6a-c** in 71-82% yields (Scheme 3, Table 2). It is important to carry out the first coupling reaction at 60°C for 8 h using THF as a suitable solvent for this step to improve the yield and site-selectivity. The second coupling cross-coupling step was done at 90°C for 6 h using 1,4-dioxane as a solvent. Very good yields are again obtained to prepare the unsymmetrical 1,3-diarylthioxanthones **6a-c** with both electron-donating and withdrawing groups.

The structure of compound **6b** was independently confirmed by X-ray crystal structure analysis (Figure 9). The structures of all products were confirmed by spectroscopic methods.

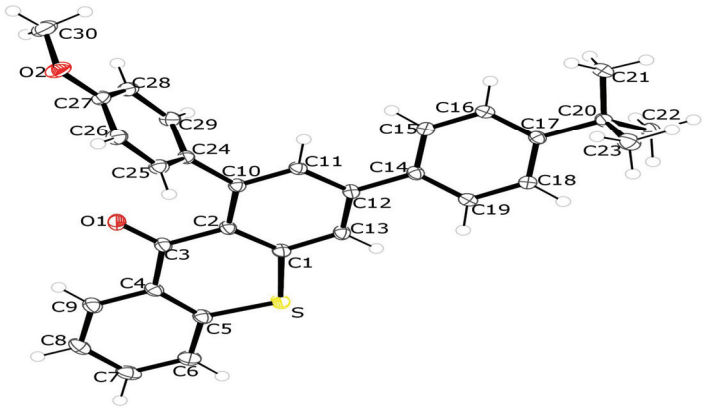


Figure 9: Molecular structure of compound **6b**

Products **5a**, **5f** were selected for optimization studies (Table 3). Thioxanthone **5a** is derived from an electron-rich arylboronic acid, while **5f** is derived from an electron-poor arylboronic acid. During the optimization we have found that the best yields were obtained when the reactions were carried out at 60°C.

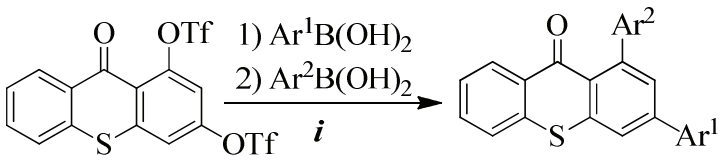
Table 3: Optimization table for synthesis of **5a**, **5f** at 60°C for 8 h

Entry	Base[(a)]	Solvent[(b)]	Catalyst[(c)]	% (**5a**)[d]	% (**5f**)[e]
1	K_2CO_3 (1 mL, 2 M)	dioxane	$[Pd(PPh)_3Cl_2]$	35	24
2	K_2CO_3 (1 mL, 2 M)	THF	$[Pd(PPh)_3Cl_2]$	41	32
3	K_2CO_3 (1 mL, 2 M)	dioxane	$[Pd(PPh_3)_4]$	46	37
4	K_2CO_3 (1 mL, 2 M)	THF	$[Pd(PPh_3)_4]$	41	33
5	K_3PO_4 (1.5 equiv.)	dioxane	$[Pd(PPh)_3Cl_2]$	55	47
6	K_3PO_4 (1.5 equiv.)	THF	$[Pd(PPh)_3Cl_2]$	66	50
7	K_3PO_4 (1.5 equiv.)	dioxane	$[Pd(PPh_3)_4]$	63	57
8	**K_3PO_4 (1.5 equiv.)**	**THF**	$[Pd(PPh_3)_4]$	**87**	**78**

[a] (1.5equiv.) per (0.197 mmol) of **2.** [b] (5ml) per (0.197 mmole) of **2.**
[c] (5mol%) per (0.197 mmole) of **2.** [(d ,e)] Yield of isolated product.

Higher temperatures led to the formation of significant amounts of bis-arylated products. In addition, it is important to use exactly 1.1 equiv. of the arylboronic acids per cross-coupling reaction. The use of 1,4-dioxane as the solvent gave the best results in the case of the synthesis of 1,3-diarylthioxanthones **4**. It was observed that employment of THF was advantageous in the case of monoarylated products **5**. The employment of potassium phosphate gave better yields than the use of an aqueous solution of potassium carbonate, The use of $Pd(PPh_3)_4$ gave higher yields than $Pd(PPh_3)_2Cl_2$.

The sequential addition of two different arylboronic acids to **2** allowed for the direct synthesis of 1,3-diarylthioxanthone **6d** in only one step in 75% yield (Scheme 4, Table 4). Based on my findings related to the synthesis of monoarylated products **5**, the first step of the one-pot reaction was carried out at 60°C while the second step was carried out at 90°C. One portion of the catalyst (5 mol%) was added at the start of the reaction.



2 **6d**

Scheme 4: Synthesis of **6d**. *Reagents and conditions*: *i*, 1) **2** (1.0 equiv.), **3l** (1.1 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (1.5 equiv.), 1,4-dioxane, 60°C, 6 h; 2) **3h** (1.1 equiv.), 90°C, 6 h.

Table 4: Synthesis of **6d**

3	**6**	**Ar^1**	**Ar^2**	**%(6)[a]**
l , h	**d**	2-MeC_6H_4	4-$(MeO)C_6H_4$	**75**

[a] Yields of isolated products

The Suzuki-Miyaura cross-coupling reactions of the bis(triflates) of 1,3-dihydroxyanthraquinone proceeds by initial attack at position 1 (next to the carbonyl group) which can be explained by the fact that position 1 is electronically more deficient than positions 2 and 3. In addition, a chelation of the catalyst by the carbonyl group might play a role. In contrast, the Suzuki–Miyaura reactions of **2** proceed by initial attack at position 3. The different site-selectivity is surprising. Obviously, the regiodirecting effect of the carbonyl group of this compound seems to be less pronounced than in case of the bis(triflates) of 1,2- and 1,3-dihydroxyanthraquinone. Therefore, the sterically less hindered position 3 was attacked first (Figure 10).

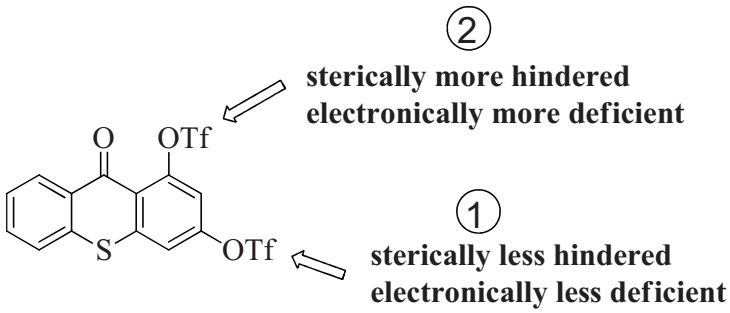


Figure 10: Possible explanation for the site-selectivity of the reactions of bis (triflate) **2**

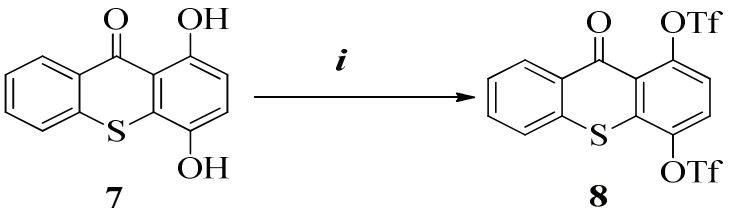
2.3 Conclusion

An efficient synthesis of different arylated thioxanthones by Suzuki-Miyaura cross-coupling reactions of the bis(triflate) of 1,3-dihydroxythioxanthone was studied and reported. The reactions were achieved with very good yields and excellent site-selectivity. The first attack appeared at carbon atom C-3, while the second one was at C-1. The steric effect played an important effect in this case and directed the selectivity in favour of carbon atom C-3.

2.4 Site-Selective Suzuki–Miyaura Cross-Coupling Reactions of the Bis(triflates) of 1,4- Dihydroxy-9*H*-thioxanthen-9-one.

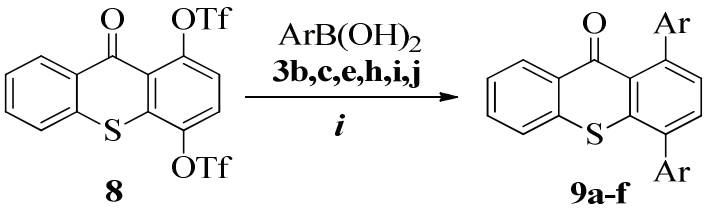
Results and discussion:

Palladium-catalyzed Suzuki cross-coupling reactions of the bis(triflate) of 1,4-dihydroxy-9*H*-thioxanthen-9-one, which has been synthesized by a known procedure,[47] was studied. 1,4-Dihydroxy-9*H*-thioxanthen-9-one **7** was transformed into its bis(triflate) **8** in 87% yield (Scheme 5) by treatment with triflic anhydride in the presence of a mixture of Et_3N and pyridine (1:2). The triflic anhydride was added at -78°C under an argon atmosphere and the reaction mixture was allowed to warm to room temperature and stirred for further 8 h. The best yields were obtained when a mixture of base in this reaction was used.



Scheme 5: Synthesis of **8**, *Reagents and conditions*: *i*, CH_2Cl_2, **7** (1.0 equiv.), Et_3N/pyridine (Mix.) 1:2(4.0 equiv.), Tf_2O (2.4 equiv.), -78°C → 20°C, 8 h.

The Suzuki-Miyaura reaction of **8** with (2.4 equiv.) of arylboronic acids **3b,c,e,h,i,j** resulted in 1,4-diarylthioxanthones **9a-f** in (80-92%) yields (Scheme 6, Table 5). The reactions were carried out nearly at the same conditions as reported for the synthesis of products **4**.



Scheme 6: Synthesis of **9a-f**. *Reagents and conditions*: *i*, **8** (1.0 equiv.), **3b,c,e,h,i,j** (2.4 equiv.), $Pd(PPh_3)_4$ (10 mol%), K_3PO_4 (3.0 equiv.), THF, 90°C, 8 h.

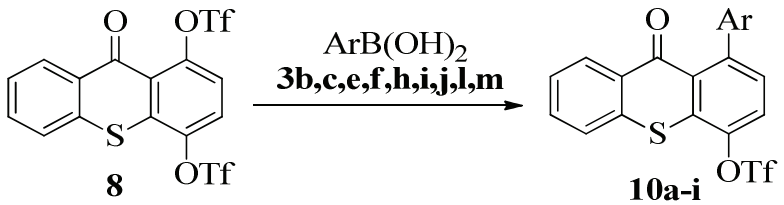
Table 5: Synthesis of **9a-f**

3	**9**	Ar	**9** (%)[a]
b	**a**	4-EtC_6H_4	**80**
c	**b**	*t*BuC_6H_4	**83**
e	**c**	4-MeC_6H_4	**84**
h	**d**	4-(MeO)C_6H_4	**92**
i	**e**	C_6H_5	**91**
j	**f**	4-FC_6H_4	**82**

[a] Yields of isolated products.

The best yields were obtained when the reactions were carried out using $Pd(PPh_3)_4$ (10 mol %) as catalyst, K_3PO_4 (3.0 equiv.) as base and when the reaction was carried out using THF as a solvent at 90°C for 8 h. The structures of all products were confirmed by spectroscopic methods. Very good yields were obtained in both reactions for electron-rich and poor arylboronic acids.

1-Aryl-4-(trifluorosulfonyloxy)-thioxanthones **10a-i** were synthesized by Suzuki cross-coupling reaction of **8** with arylboronic acids **3b,c,e,f,h,i,j,l.m** (1.1 equiv.). Different arylboronic acids with both electron-donating and withdrawing group and sterically hindered arylboronic acid (2-MeC_6H_4) were used for the synthesis. The reactions were achieved in high yields (76-90%) and excellent site-selectivity (Scheme 7, Table 6). The best conditions for the synthesis of mono-adducts were found when the reaction was carried out at 65°C for 8 h using $Pd(PPh_3)_4$ (5 mol% per cross-coupling reaction) as catalyst, K_3PO_4 (1.5 equiv.) as base and when the reaction was carried out using THF as a solvent.



Scheme 7: Synthesis of **10a-i**. *Reagents and conditions*: *i*, **8** (1.0 equiv.), **3b,c,e,f,h,i,j,l,m** (1.1 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (1.5 equiv.), THF, 65°C, 8 h.

Table 6: Synthesis of **10a-i**

3	**10**	Ar	**10** (%)[a]
b	**a**	4-EtC_6H_4	**90**
c	**b**	4-*t*BuC_6H_4	**76**
e	**c**	4-MeC_6H_4	**87**
f	**d**	4-ClC_6H_4	**84**
h	**e**	4-(MeO)C_6H_4	**81**
i	**f**	C_6H_5	**88**
j	**g**	4-FC_6H_4	**82**
l	**h**	2-MeC_6H_4	**76**
m	**i**	3-MeC_6H_4	**79**

[a] Yields of isolated products.

The structure of compound **10a** (Figure 11) was independently confirmed by X-ray crystal structure analysis. The aryl groups and the thioxanthone moiety are only slightly twisted out of plane. The heterocyclic moiety is twisted out of plane. The structures of all products were confirmed by spectroscopic methods.

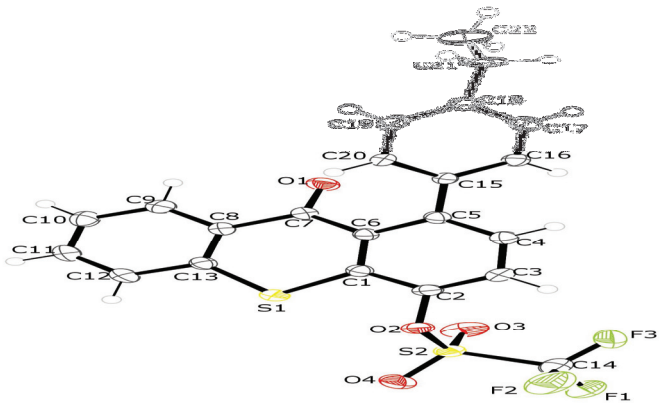


Figure 11: Molecular structure of compound **10a**

Products **10e, 10d** were selected for optimization studies (Table 7). Thioxanthone **10e** is derived from an electron-rich arylboronic acid, while **10d** is derived from an electron-poor arylboronic acid.

Table 7: Optimization table for synthesis of **10e, 10d** at 65C^{o} for 8 h

Entry	Base[(a)]	Solvent[(b)]	Catalyst[(c)]	%(10e)[d]	%(10d)[e]
1	K_2CO_3	Dioxane	$[Pd(PPh)_3Cl_2]$	33	22
2	K_2CO_3	THF	$[Pd(PPh)_3Cl_2]$	44	39
3	K_2CO_3	Dioxane	$[Pd(PPh_3)_4]$	41	40
4	K_2CO_3	THF	$[Pd(PPh_3)_4]$	42	33
5	K_3PO_4	Dioxane	$[Pd(PPh)_3Cl_2]$	51	48
6	K_3PO_4	THF	$[Pd(PPh)_3Cl_2]$	56	50
7	K_3PO_4	Dioxane	$[Pd(PPh_3)_4]$	60	52
8	**K_3PO_4**	**THF**	$[Pd(PPh_3)_4]$	**81**	**84**

[a] (1.5eq) per (0.197mmole) of **8.** [b] (5ml) per (0.197mmol) of **8.**
[c] (5mol%) per (0.197 mmol) of **8.** [(d ,e)] Yield of isolated product.

It was observed that the employment of THF as a solvent was advantageous in the case of the synthesis of mono-adducts **10**. Also, potassium phosphate gave better yields than the use of an

aqueous solution of potassium carbonate. The use of $Pd(PPh_3)_4$ (5 mol% per cross-coupling reaction) gave higher yields than $Pd(PPh_3)_2Cl_2$.

The structure of compound **10e** was unambiguously confirmed by 2D-NMR techniques (Figure 12).

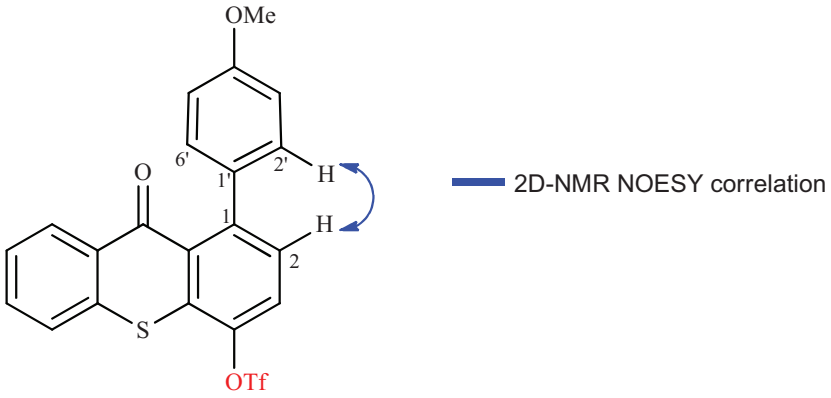
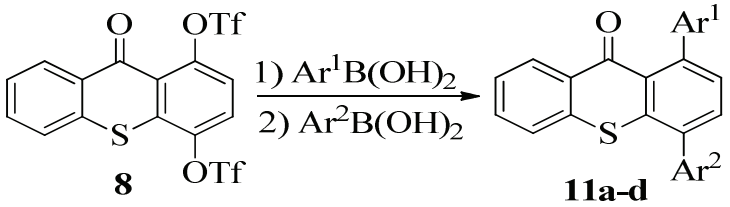


Figure 12: NOESY experiment of compound **10e**

In the NOESY spectrum, an interaction was observed between the aromatic protons attached to the carbon atom C-2 of thioxanthone ring to the aromatic protons of the attached boronic acid ring attached to carbon atoms C-2' and C-6'. This confirmed that the first attack of boronic acid takes place at carbon atom C-1 of the bis(triflate). These correlations are not observed, if the boronic acid is attached to carbon atom C-4 of the bis(triflate).

The one-pot reaction of **8** with two different arylboronic acids allowed for the synthesis of 1,4-diarylthioxanthones **11a-d** in only one step and in very good yields (84-90%) (Scheme 8, Table 8).



Scheme 8: Synthesis of **11a-d**. *Reagents and conditions*: *i*, 1) **8** (1.0 equiv.), **3h,j,h,h** (1.1 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (1.5 equiv.), THF, 65°C, 8 h; 2) **3e,h,c,n** (1.1 equiv.), 90°C, 6 h.

Based on our findings related to the synthesis of mono-aryl products **5**, the first step of the one-pot reaction was carried out at 65°C and the second step was carried out at 90°C. One portion of the catalyst (5 mol%) was added at the start of the reaction.

Table 8: Synthesis of **11a-d**

3	**11**	**Ar^1**	**Ar^2**	**%(11)[a]**
h , e	**a**	4-(OMe)C_6H_4	4-MeC_6H_4	**90**
j , h	**b**	4-FC_6H_4	4-(OMe)C_6H_4	**88**
h , c	**c**	4-(OMe)C_6H_4	4-*t*BuC_6H_4	**84**
h , n	**d**	4-(OMe)C_6H_4	3-ClC_6H_4	**89**

[a] Yields of isolated products.

The reaction of bis(triflate) **8** proceeds by initial attack at the sterically more hindered position 1. This might be explained as follows: carbon atom C-1 is the most electron-deficient position, but it is sterically more hindered than positions 4 and 3. In case of compound **2**, the first attack occurs at the sterically less hindered position 3. The attack to carbon atom C-4 of thioxanthone **8** is hindered by the lone pairs of the sulfur atom. Therefore, the attack occurs at position 1.

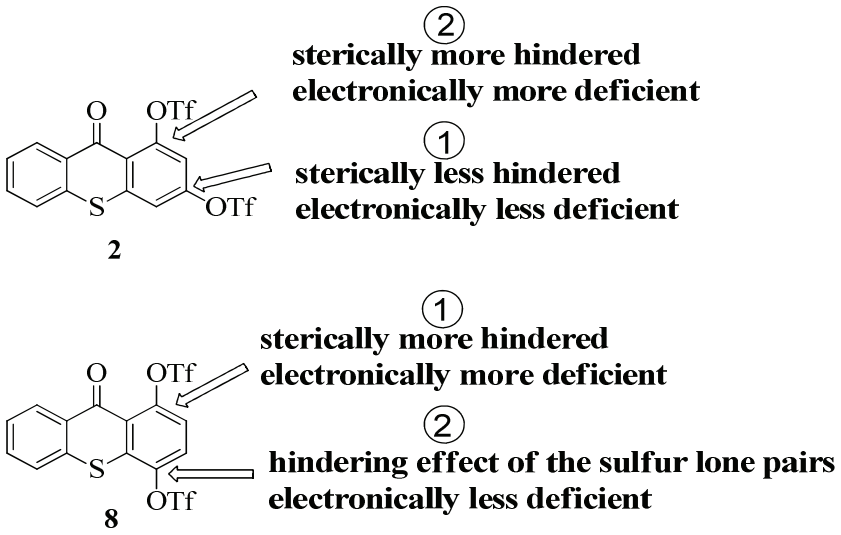


Figure 12: Possible explanation for the site-selectivity of the reactions of bis(triflates) **2** and **8**

2.5 Conclusion

The synthesis of various arylated thioxanthones by Pd(0)-catalyzed Suzuki cross-coupling reactions of the bis(triflates) of 1,3- and 1,4-dihydroxy-9*H*-thioxanthen-9-one were studied and reported. The first attack of the Suzuki reactions of **2** proceeded in favour of carbon atom C-3, while for compound **8**, the Suzuki reactions preceded in favour of carbon atom C-1. Electronic and steric effects were the responsible reasons of the site-selective Suzuki reaction in 1,3- and 1,4-dihydroxy-9*H*-thioxanthen-9-one.

3. Site-Selective Synthesis of Arylated-1*H*-inden-1-ones by Suzuki-Miyaura Cross-Coupling Reactions of 2,3,5-Tribromo-1*H*-inden-1-one.

3.1 General Introduction

Arylated indenones represent a pharmacologically important molecular entity [48] For example, 2,3-diarylindenones have been studied as ligands for the estrogen receptor [48a]. 3-Arylindenone-2-carboxylic acid derivatives have been studied as selective inhibitors of fibroblast growth factor receptor-1 tyrosine kinase[48d]. Indenones also occur in several biologically relevant natural products, such as euplectin containing both a benzofuran and an inden-1-one substructure[49]. Other examples include neo-lignans isolated from the fruits of *Virola sebifera*[50]. Pauciflorol F is a 2,3-diarylindanone which has been prepared by palladium catalyzed Larock cyclization, hydrogenation and subsequent epimerization[51]. 2,3-Diarylindenones are available by classic methods which include, for example, intramolecular Friedel-Crafts acylations,[52a] reactions of phthalides or 1*H*-indene-1,3(2*H*)-diones with Grignard reagents,[52b,c] and synthetic transformations of dibenzoylmethane,[52d] benzophenone derivatives,[52e] or diphenyl acetylene[52f]. Transition metal-catalyzed syntheses of 2,3-diarylinden-1-ones include the Larock cyclization[51] and related processes[53].

Reactions of functionalized indenones, such as hydrogenations, reactions of the carbonyl group or conjugate additions, have been widely studied. We were interested in palladium-catalyzed cross-coupling reactions of halogenated inden-1-ones. While reactions of 2,3-dibromo-1*H*-inden-1-one with amines, Grignard reagents, and CH-acidic compounds were reported nearly a century ago,[54] transition metal-catalyzed reactions of this molecule were unknown until our recent report[55] in this field. Site-selective palladium catalyzed reactions of dibromofuranones, which are closely related to 2,3-dibromoindenones, have been previously reported by Bellina and coworkers[56].

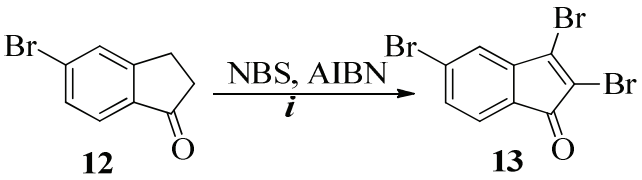
In general, site-selective palladium(0)-catalyzed cross-coupling reactions of polyhalogenated heterocycles are of considerable current interest in organic chemistry because they allow a facile assembly of complex heterocycles in only one step[57,58].

I have studied what are, to the best of my knowledge, the first site-selective Suzuki-Miyaura cross-coupling reactions of 2,3,5-tribromoinden-1-one. These reactions provide a convenient

approach to various arylated inden-1-ones. Interestingly, my starting material, 2,3,5-tribromo-1*H*-inden-1-one, represents a new compound which has, to the best of our knowledge, not been synthesized or studied before.

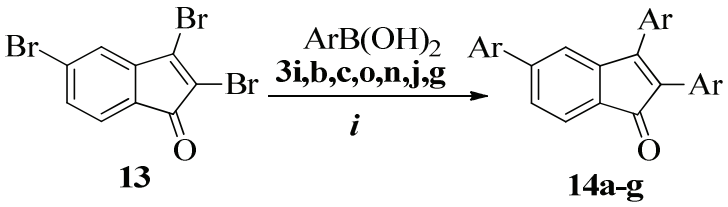
Results and Discussion:

2,3,5-Tribromo-1*H*-inden-1-one **13** was prepared in 62% yield by reaction of commercially available 5-bromoindan-1-one with NBS in the presence of AIBN (Scheme 9). While 2,3-dibromoinden-1-one is known,[59] the synthesis of **13** has, to the best of our knowledge, not been previously reported.



Scheme 9: Synthesis of **13**. *Conditions: i*, **12** (1.0 equiv.), NBS (3.5 equiv.), AIBN (10 mol %), benzene, reflux, 7 h.

The Suzuki-Miyaura cross-coupling reaction of **13** with 3.3 equiv. of arylboronic acids **3i,b,c,o,n,j,g** afforded the 2,3,5-triaryl-1*H*-inden-1-ones **14a-g** in (76-88%) yields (Scheme 10, Table 9). The best yields were obtained using 3.3 equiv. of the arylboronic acid, $Pd(PPh_3)_4$ (5 mol %) as catalyst, K_2CO_3 (2 M, 1 mL) as base and 1,4-dioxane as solvent at 70°C for 6 h. Compounds **14** could be prepared in equally good yields using $Pd(PPh_3)_2Cl_2$ as the catalyst. Similar conditions were used for the Suzuki reaction of 2,3-dibromoinden-1-one[55]. Different types of arylboronic acids were used in this reaction. The reactions were successful for both electron-rich and electron-poor arylboronic acids. The highest yield was obtained using **3b** as electron-rich boronic acid (88%).



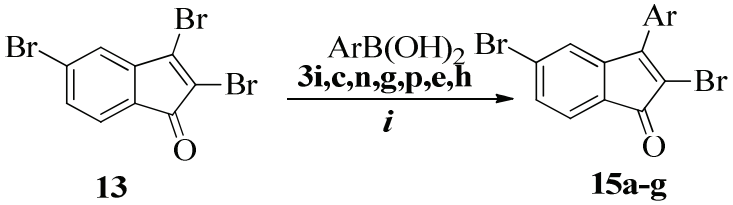
Scheme 10: Synthesis of **14a-g**. *Conditions: i*, $ArB(OH)_2$ **3i,b,c,o,n,j,g** (3.3 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_2CO_3 (2 M, 1 mL), 1,4-dioxane, 70°C, 6 h.

Table 9: Synthesis of 2,3,5-triaryl-indenone **14a-g**

3	**14**	Ar	%(**14**) [a]
i	**a**	C_6H_5	**83**
b	**b**	4-EtC_6H_4	**88**
c	**c**	4-*t*BuC_6H_4	**85**
o	**d**	3-$(MeO)C_6H_4$	**76**
n	**e**	3-ClC_6H_4	**79**
j	**f**	4-FC_6H_4	**81**
g	**g**	3-$(CF_3)C_6H_4$	**78**

[a] Yields of isolated products.

Pd(0)-catalyzed Suzuki-Miyaura cross-coupling reactions of **13** with (1.0 equiv.) of arylboronic acids **3i,c,n,g,p,e,h** afforded the 3-aryl-2,5-dibromo-1*H*-inden-1-ones **15a-g** in (78-92%) yields and with excellent site-selectivity (Scheme 11, Table 10). The first attack occurred at carbon atom C-3. The yields dropped when more than exactly (1.0 equiv.) of the boronic acids were used. The reactions were carried out using $Pd(PPh_3)_4$ (3 mol % per cross-coupling reaction) as the catalyst. In case of **15c**, $Pd(PPh_3)_2Cl_2$ (3 mol%) was employed as well. K_3PO_4 (1.5 equiv.) was used instead of K_2CO_3 to achieve the best conditions for site-selectivity in the reaction.



13 **15a-g**

Scheme 11: Synthesis of **15a-g**. *Conditions: i*, $ArB(OH)_2$ **3i,c,n,g,p,e,h** (1.0 equiv.), $Pd(PPh_3)_4$ OR $Pd(PPh_3)_2Cl_2$ (3 mol %), K_3PO_4 (1.5 equiv.), 1,4-dioxane, 45°C, 9 h.

It is important to carry out the reactions at 45 instead of 70°C for this coupling. Significant amounts of side-products, derived from multifold coupling, were formed when the temperature was too high. The reactions could be successfully carried out with both electron-rich and poor arylboronic acids. The highest yield was obtained using **3h** as boronic acid among the other types used for the reaction which afforded **15g** in (92%) yield and excellent site-selectivity.

Table 10: Synthesis of 2,5-dibromo-3-aryl-indenone **15a-g**

3	**15**	Ar	% (**15**) [a]
i	**a**	C_6H_5	**83**
c	**b**	4-*t*BuC_6H_4	**86**
n	**c**	3-ClC_6H_4	**82**[b]
g	**d**	3-(CF_3)C_6H_4	**80**
p	**e**	4-(OCF_3)C_6H_4	**78**
e	**f**	4-MeC_6H_4	**86**
h	**g**	4-(MeO)C_6H_4	**92**

[a] Yields of isolated products, [b] $Pd(PPh_3)_2Cl_2$ was used.

The structures of all products were confirmed by spectroscopic methods. The structure of **15d** was independently confirmed by X-ray crystal structure analysis [60] (Figure 13).The aryl group and the indenone moiety is twisted out of plane.

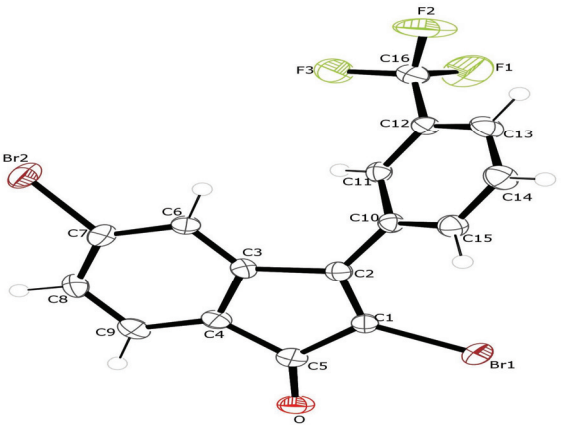
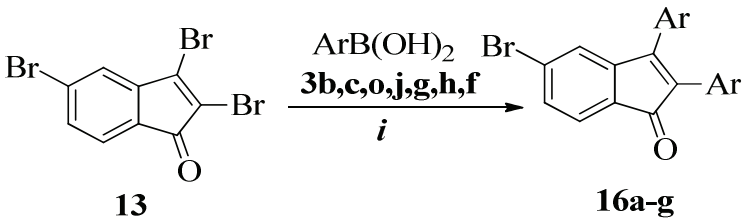


Figure 13: Molecular structure of compound **15d**

2,3-Diaryl-5-bromo-1*H*-inden-1-one **16a-g** was prepared by reaction of **13** with (2.0 equiv.) of arylboronic acids **3b,c,o,j,g,h,f** in (75-88%) yields (Scheme 12, Table 11). The best yields were obtained using exactly (2.0 equiv.) of the arylboronic acids, $Pd(PPh_3)_4$ (5 mol %) as catalyst, K_3PO_4 (3.0 equiv.) as base with 1,4-dioxane at 60°C for 6 h. The reactions were successful for both electron-rich and poor arylboronic acids (Table 11) and the structures of all products were confirmed by spectroscopic methods.



Scheme 12: Synthesis of **16a-g**. *Conditions: i*, $ArB(OH)_2$ **3b,c,o,j,g,h,f** (2.0 equiv.), $Pd(PPh_3)_4$ (5 mol %), K_3PO_4 (3.0 equiv.), 1,4-dioxane, 60°C, 6 h.

Table 11: Synthesis of 5-bromo-2,3-diaryl-indenone **16a-g**

3	**16**	Ar	% (**16**) [a]
b	**a**	4-EtC_6H_4	**88**
c	**b**	4-*t*BuC_6H_4	**83**
o	**c**	3-(MeO)C_6H_4	**75**
j	**d**	4-FC_6H_4	**78**
g	**e**	3-(CF_3)C_6H_4	**77**
h	**f**	4-(MeO)C_6H_4	**85**
f	**g**	4-ClC_6H_4	**87**

[a] Yields of isolated products.

The structure of **16g** was independently confirmed by X-ray crystal structure analysis (Figure 14). The aryl groups and the indenone moiety are twisted out of plane.

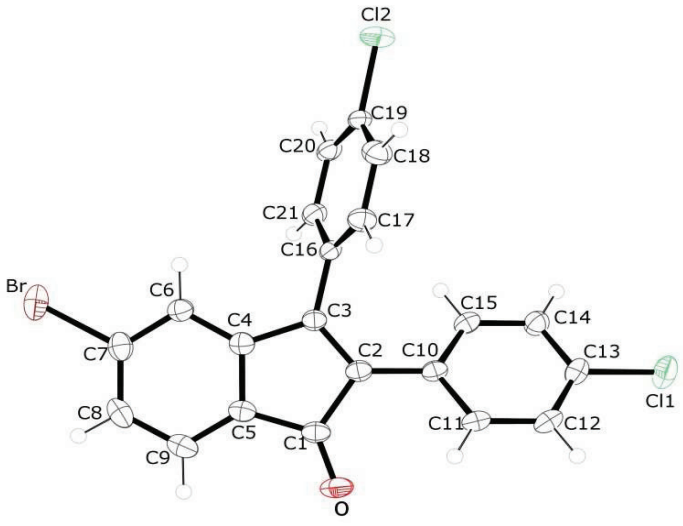
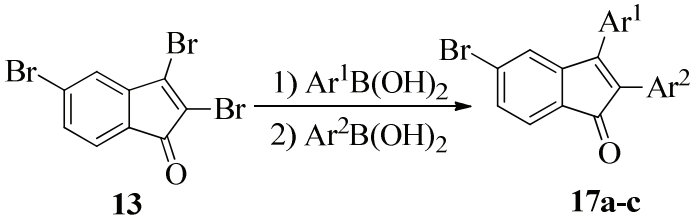


Figure 14: Molecular structure of compound **16g**

The one-pot synthesis reaction of **13** with two different arylboronic acids, which were sequentially added, afforded the unsymmetrical 2,3-diaryl-5-bromo-1*H*-inden-1-ones **17a-c** containing two different aryl groups (Scheme 13, Table 12). To achieve a good site-selectivity in favour of position 3 of the substrate, it was proved that the first coupling step should carried out at 45°C for 9 h and the second step at 60°C for 6 h.



13 **17a-c**

Scheme 13: Synthesis of **17a-c**. *Conditions:*1) $Ar^1B(OH)_2$ **3b,f,f** (1.0 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (3.0 equiv.), 1,4-dioxane, 45°C, 9 h; 2) $Ar^2B(OH)_2$ **3h,b,h** (1.0 equiv.), 60°C, 6 h.

Table 12: Synthesis of **17a-c**

3	**17**	Ar^1	Ar^2	% (**17**)[a]
b , h	**a**	4-EtC_6H_4	4-$(MeO)C_6H_4$	**80**
f , b	**b**	4-ClC_6H_4	4-EtC_6H_4	**79**
f , h	**c**	4-ClC_6H_4	4-$(MeO)C_6H_4$	**82**

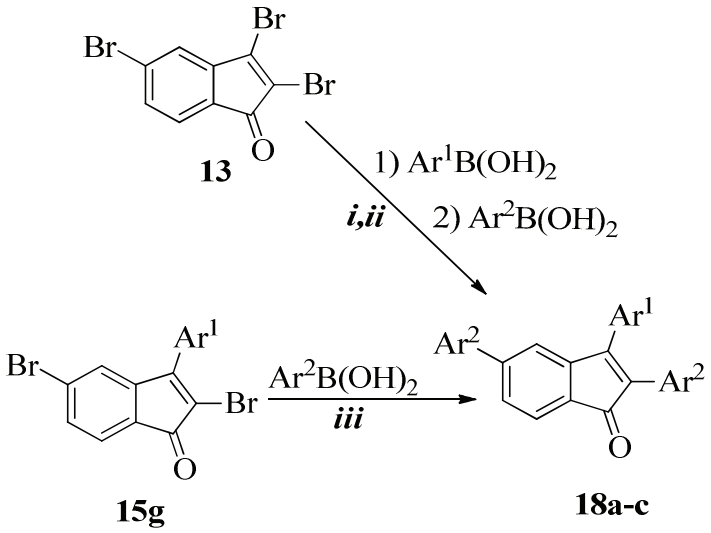
[a] Yields of isolated products.

The one-pot reaction was carried out in one step without isolating the first cross-coupling product. The second boronic acids **3h,b,h** was added after a period of 9 h for the first coupling reaction (which was done at 45°C) to ensure full conversion of the starting material of the first coupling product. The reaction was carried out in very good yields (79-82%) and excellent site-selectivity.

The synthesis of the 2,3,5 triaryl-1*H*-inden-1-ones containing two different arylboronic acids were studied also and afforded **18a-c**. The reaction of **15g** with (2.2 equiv.) of **3c** afforded **18a** in (78%) yield (Scheme 14, Table). The one-pot reaction of **13** with **(**1.0 equiv.) of **3f** and with (2.2

equiv.) of **3b** afforded **18b** in (81%) yield. Compound **18c** was prepared in very good overall yield (84%) (Scheme 14, Table 13).

During the synthesis of **18a-c** as a one-pot reaction (sequential addition), the temperature and the stoichiometry again played an important role.



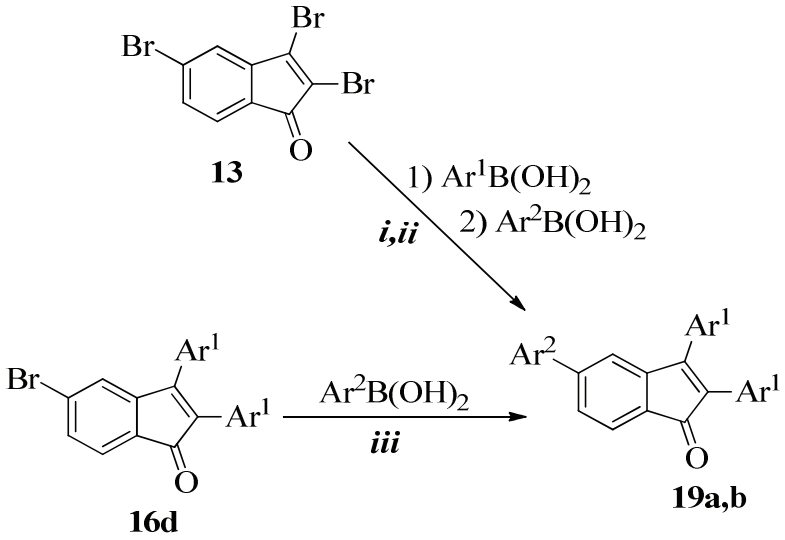
Scheme 14: Synthesis of **18a-c**. *Conditions: i*, $Ar^1B(OH)_2$ **3f,f** (1.0 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (4.5 equiv.), 1,4-dioxane, 45°C, 9 h, *: ii*, $Ar^2B(OH)_2$ **3b,h** (2.2 equiv.), 60°C, 6 h, : *iii*, $Ar^2B(OH)_2$ **3c** (2.2 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_2CO_3 (2 M, 1 mL), 1,4-dioxane, 70°C, 6 h.

Table 13: Synthesis of **18a-c**

3	**18**	Ar^1	Ar^2	% (**18**)[a]
h , c	**a**	4-(MeO)C_6H_4	4-*t*BuC_6H_4	**78**[b]
f , b	**b**	4-ClC_6H_4	4-EtC_6H_4	**81**[c]
f , h	**c**	4-ClC_6H_4	4-(MeO)C_6H_4	**84**[c]

[a] Yields of isolated products, [b] Yields based on **15g**, [c] Overall yield based on **13**.

The reaction of **16d** with (1.1 equiv.) of **3o** afforded **19a** in (88%) yield (Scheme 15, Table 14). The one-pot synthesis reaction (sequential addition) of **13** with (2.2 equiv.) of **3q** and with (1.1 equiv.) of **3h** afforded **19b** in (86 %) yield.



Scheme 15: Synthesis of **19a,b**. *Conditions: i*, $Ar^1B(OH)_2$ **3q** (2.0 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (4.5 equiv.), 1,4-dioxane, 60°C, 6 h: *ii*, $Ar^2B(OH)_2$ **3h** (1.1 equiv.), 70°C, 6 h: *iii*, **16d** (1.0 equiv.), $Ar^2B(OH)_2$ **3o** (1.1 equiv.), $Pd(PPh_3)_4$ (3 mol%), K_2CO_3 (2 M, 1 mL), 1,4-dioxane, 70°C, 6 h.

Table 14: Synthesis of **19a, 19b**

3	**19**	Ar^1	Ar^2	%(**19**)[a]
j , o	**a**	4-FC_6H_4	3-(MeO)C_6H_4	**88**[b]
q , h	**b**	4-$(CF_3)C_6H_4$	4-(MeO)C_6H_4	**86**[c]

[a] Yields of isolated products, [b] Yield based on **16d**,

[c] Overall yield for one-pot synthesis based on **13**.

During the optimization of the one-pot synthesis of compounds **19a**, **19b**, the temperature was 60°C for the first cross-coupling step and was then increased to 70°C for the second step. The stoichiometry (2.0 equiv. for the first step and 1.1 equiv. for the second step) proved to be important. The structure of **19b** was independently confirmed by X-ray crystal structure analysis [60] (Figure 15). Two of the three aryl groups of **19b** are twisted out of plane.

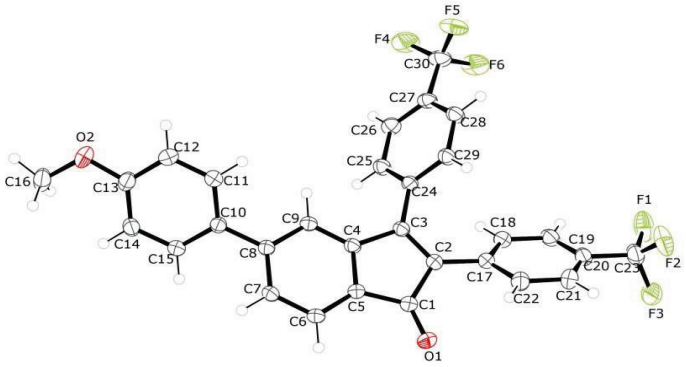


Figure 15: Molecular structure of compound **19b**

The development of a site-selective one-pot process, which sequentially introduces three different aryl groups in one step, failed. However, the synthesis of such molecules can be realized by reaction of 2,3-diaryl-5-bromoinden-1-ones **17a-c** with arylboronic acids.

The order of the reactivity of the three different positions of 2,3,5-tribromoinden-1-one is C-3 > C-2 > C-5. The site-selectivity can be explained by the fact that carbon atom C-3 is considerable more electron-deficient than positions 2 and 5. The second attack occurred at carbon atom C-2 which is sterically more hindered than position 5 and electronically less deficient.

This result was surprising because it does not follow the rule suggested by Handy and Zhang for the prediction of the site-selectivity of palladium-catalyzed reactions of polyhalogenated substrates. For the prediction of the selectivity, the ^{1}H NMR spectrum of the non-halogenated parent compounds is studied which reflects the electronic situation of the different positions. According to the rule of the authors, the first attack should occur at that position which has the higher chemical shift value of the respective proton. In case of the ^{1}H NMR spectrum of inden-1-one, which is the parent molecule of 2,3,5-tribromoinden-1-one **13**, the chemical shift of proton 5-H is significantly shifted downfield with regard to proton 2-H which is the most up-field resonating proton of the molecule. In contrast, proton 3-H resonates most downfield of all protons of inden-1-one. Therefore, the rule of Handy and Zhang correctly predicts the selectivity in favour of position 3, but not the selectivity in favour of position 2 (with respect to position 5). The selectivity in favour of position 5 might be explained by chelation of the catalyst to the carbonyl oxygen atom which may enhance the rate in favour of position 2 (Figure 16).

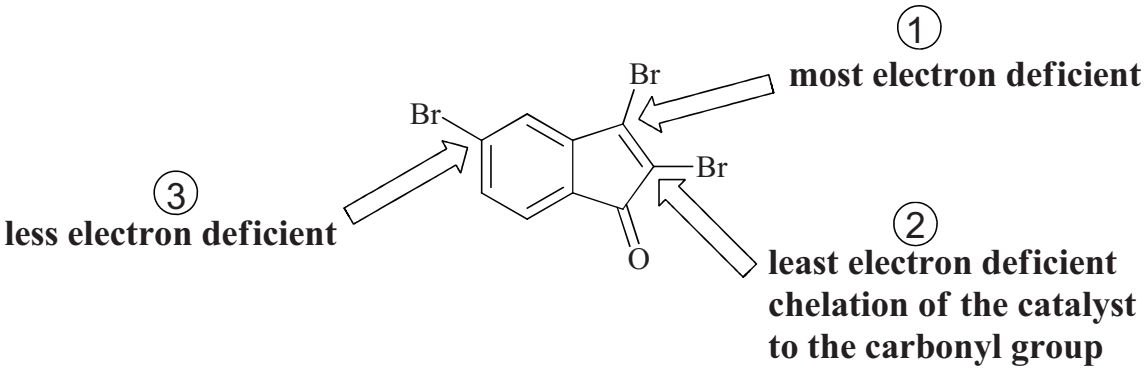


Figure 16: Possible explanation for the site-selectivity of the reactions of **13**

3.2 Conclusion

I have studied the site-selective Suzuki-Miyaura cross-coupling reactions of 2,3,5-tribromo-1*H*-inden-1-one, a novel brominated indenone derivative, which provide a convenient and site-selective approach to various arylated inden-1-ones in good yields. The order of the selectivity is C-3 > C-2 > C-5. Carbon atom C-3 is the most electron deficient position; thus, the first attack takes place there. The selectivity in favor of position C-2 can be explained by chelation of the catalyst to the neighboring carbonyl group.

4. Synthesis of Arylated 1-Methyl-1*H*-indoles by Suzuki-Miyaura Cross-Coupling Reactions of 2,3,6-Tribromo-1-methyl-1*H*-indole.

4.1 General Introduction

Alkaloids are groups of natural products containing nitrogen in a cyclic system and occur naturally in plants and other living organisms. These types of compounds nearly always contain their nitrogen as part of a heterocyclic system with few exceptions and are often complex in structure and usually show specific pharmacological activity. For example, some alkaloids show antifungal activity such as the aporphine alkaloid liriodenine which displays a broad activity spectrum against fungi, such as the yeast *Candila albicans, Trichophyton mentagrophytes,* and has high activity against phytopathogenic fungi[61].

Many reviews have been written on indole and its derivatives[62,63]. A wide variety of naturally occurring, biologically active brominated indole alkaloids have been isolated from marine invertebrates, including bryozoans, coelenterates, sponges and tunicates. 2,3,6-Tribromo-1-methyl-1*H*-indole has been isolated from red *alga Laurencia brongniartii* which possess anti-bacterial and anti-fungal properties. In addition, the central importance of the indole derivatives in living organisms has inspired chemists to design and synthesize indole-containing compounds[64]. Arylated indoles are of considerable pharmacological relevance, due to their anti-inflammatory, anti-arthritic and anti-pyretic properties[65]. For example 2,3-bis(4-methoxyphenyl)indole (′indoxole′) has been shown to possess a stronger anti-inflammatory activity than common drugs, such as aspirin and indomethacin[66] . Based on these findings, novel COX-2 inhibitors for the treatment of arthritic pain have recently been developed [67].

Many methods for the synthesis of *N*-methylarylindoles, for example the Fisher indole synthesis, is the best known and most widely used method. The Ullman-type coupling methodology, involving the combination of an indole with an aryl halide in the presence of base and a copper catalyst at high temperatures, is an important alternative. Methods that operate under milder conditions and utilize aryl bismuth and aryl lead reagents have been developed. While all of these methods are useful in their own right, each of them suffers from one or more limitations including a lack of generality, the use stoichiometric quantities of toxic reagents, or the need to employ harsh reaction conditions[68].

In recent years, a number of site-selective palladium(0)-catalyzed cross-coupling reactions of polyhalogenated heterocycles have been developed [69]. The site-selectivity of these reactions is

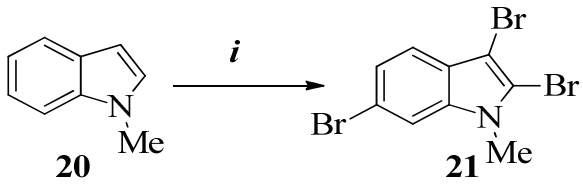
generally influenced by electronic and steric parameters. Recently, Langer and coworkers reported the synthesis of different aryl-substituted compounds using polyhalogenated substrates and also reported the site-selective Suzuki-Miyaura cross-coupling reactions of 2,3-dibromo-1-methyl-1*H*-indole[19a-h].

A number of Suzuki-Miyaura reactions of mono-halogenated indoles have been reported[70]. Ohta *et al.* studied the site-selective Suzuki-Miyaura reactions of *N*-TBDS-3,6-dibromoindole[71]. The first attack occurred at carbon atom C-6. Gribble and Liu reported the synthesis of symmetrical *N*-phenylsulfonyl-2,3-diarylindoles by twofold Suzuki-Miyaura reactions of 2,3-dihalo-*N*-(phenylsulfonyl)indoles[72]. The reactions were carried out using $Pd(OAc)_2/P(o\text{-}Tol)_3$ and K_2CO_3 in acetone/H_2O (2:1) or DMF (70°C).

The Suzuki-Miyaura reactions of *N*-sulfonyl- and *N*-acyl-2,3,4,5-tetrabromopyrrole and of unprotected 2,3,4,5-tetrabromopyrrole gave unsatisfactory results (with regard to yield and site-selectivity). In contrast, the reactions of *N*-methyl-2,3,4,5-tetrabromopyrrole proceeded in good yields and with excellent site-selectivity. The synthesis of 2,3,6-triaryl-1-methyl-1*H*-indoles by Suzuki-Miyaura cross-coupling reactions have, to the best of our knowledge, not been reported before. The reactions indeed proceed in very good yields and excellent site-selectivity.

Results and Discussion:

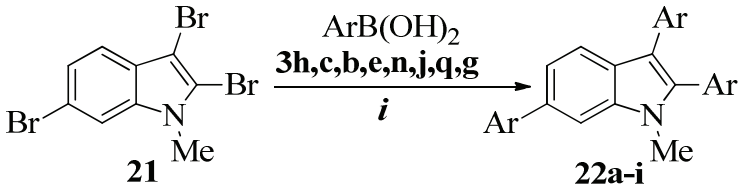
2,3,6-Tribromo-1-methyl-1*H*-indole **21** was prepared in (70%) yield using a known procedure, [27b] from commercially available 1-methyl-1*H*-indole **20** with NBS (3.4 equiv.) (Scheme16).



Scheme 16: Bromination of 1-methyl-1*H*-indole **20**, Reagents *and conditions*: *i*, THF, NBS (3.4 equiv.), -78°C → 20°C, 14 h.

The Pd(0)-catalyzed Suzuki-Miyaura cross-coupling reaction of 2,3,6-tribromo-1-methyl-1*H*-indole **21** with (3.4 equiv.) of arylboronic acids **3h,c,b,e,f,n,j,q,g** afforded the 2,3,6-triaryl-1-methyl-1*H*-indole **22a-i** in (78-87%) yields (Scheme 17, Table 15). The best yields were

obtained using $Pd(PPh_3)_4$ (5 mol%) as a catalyst, K_2CO_3 (2 M, 1 mL) as base and 1,4-dioxane at 110°C for 8 h.



Scheme 17: Synthesis of **22a-i**. *Reagents and conditions*: *i*, **21** (1.0 equiv.), **3h,c,b,e,f,n,j,q,g** (3.4 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_2CO_3 (2 M, 1 mL), 1,4-dioxane, 110°C, 8 h.

Table 15: Synthesis of 2,3,6-triaryl-1-methyl-1*H*-indole **22a-i**

3	**22**	Ar	% (**22**) [a]
h	**a**	4-(MeO)C_6H_4	**87**
c	**b**	4-*t*BuC_6H_4	**85**
b	**c**	4-EtC_6H_4	**82**
e	**d**	4-MeC_6H_4	**87**
f	**e**	4-ClC_6H_4	**85**
n	**f**	3-ClC_6H_4	**80**
j	**g**	4-FC_6H_4	**84**
q	**h**	4-(CF_3)C_6H_4	**82**
g	**i**	3-(CF_3)C_6H_4	**78**

[a] Yields of isolated products.

Different types of arylboronic acid having both electron-donating and withdrawing groups were used in the reaction (Table 15). The structures of all products were confirmed by spectroscopic methods.

Products **22c, 22g** were selected for optimization studies (Table 16). Compound **22c** is derived from an electron-rich arylboronic acid, while **22g** is derived from an electron-poor arylboronic acid. The best yields were obtained when the reactions were carried out at 110°C for 8 h. the use of 1,4-dioxane as solvent gave the best results; the employment of an aqueous

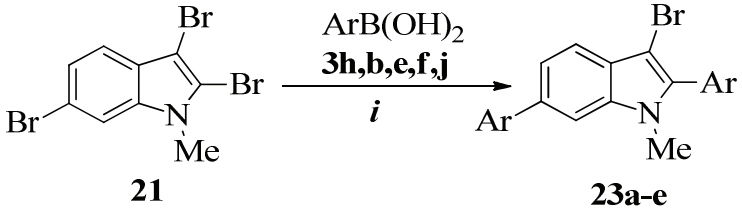
solution of potassium carbonate gave better yields than the use of potassium phosphate as base. The use of $Pd(PPh_3)_4$ (5 mol%) gave higher yields than $Pd(PPh)_3Cl_2$ or $Pd(OAc)_2$ (3 mol%), $(Cy)_3P$ or SPhos (6 mol%) as a catalyst.

Table 16: Optimization table for synthesis of **22c, 22g**

Entry	Conditions	%(**22c**)[a]	%(**22g**)[a]
1	$Pd(PPh)_3Cl_2$ (5mol%),aq. K_2CO_3 (2 M)	55	48
2	$Pd(PPh)_3Cl_2$ (5mol%), K_3PO4 (4.5 equiv.)	52	40
3	**$Pd(PPh_3)_4$ (5mol%),aq. K_2CO_3 (2 M)**	**82**	**84**
4	$Pd(PPh_3)_4$ (5mol%), K_3PO4 (4.5 equiv.)	65	53
5	$Pd(OAc)_2$(3mol%), SPhos (6mol%),aq.K_2CO_3 (2 M)	75	71
6	$Pd(OAc)_2$(3mol%), $(Cy)_3P$ (6mol%),aq.K_2CO_3 (2 M)	63	52
7	$Pd(OAc)_2$ (3mol%), $(Cy)_3P$ (6mol%), K_3PO4 (4.5 equiv.)	53	48

[a] Yields of isolated products.,all reactions were carried out in dioxane(110°C, 8h).

2,6-Diaryl-3-bromo-1-methyl-1*H*-indoles **23a-e** was prepared by reaction of **21** with arylboronic acids **3h,b,e,f,j** (2.1 equiv.) The reaction was carried out in good yields (73-83%) and excellent site-selectivity (Scheme 18, Table 17). The first attack occurred at carbon atom C-2 and C-6, while position 3 remained free. The reactions were best carried out at 90°C using exactly (2.1 equiv.) of the boronic acid and (5 mol%) of $Pd(PPh_3)_4$ as a catalyst. Both electron donating and withdrawing groups were examined in this reaction. K_3PO_4 (3.0 equiv.) was used as a suitable base in this case instead of K_2CO_3.



21 **23a-e**

Scheme 18: Synthesis of **23a-e**. *Reagents and conditions*: *i*, **21**(1.0 equiv.), **3h,b,e,f,j** (2.1 equiv.), $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (3.0 equiv.), 1,4-dioxane, 90°C, 8 h.

Table 17: Synthesis of **23a-e**

3	**23**	Ar	%(**23**)[a]
h	**a**	4-(MeO)C_6H_4	**83**
b	**b**	4-EtC_6H_4	**79**
e	**c**	4-MeC_6H_4	**73**
f	**d**	4-ClC_6H_4	**80**
j	**e**	4-FC_6H_4	**83**

[a] Yields of isolated products.

The structures of compound **23a** (Figure 17) and compound **23b** (Figure 18) were independently confirmed by X-ray crystal structure analysis. Both aryl groups and the indole moiety are twisted out of plane.

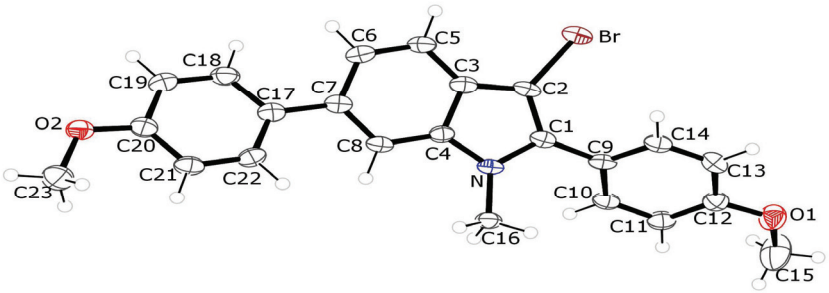


Figure 17: Molecular structure of compound **23a**

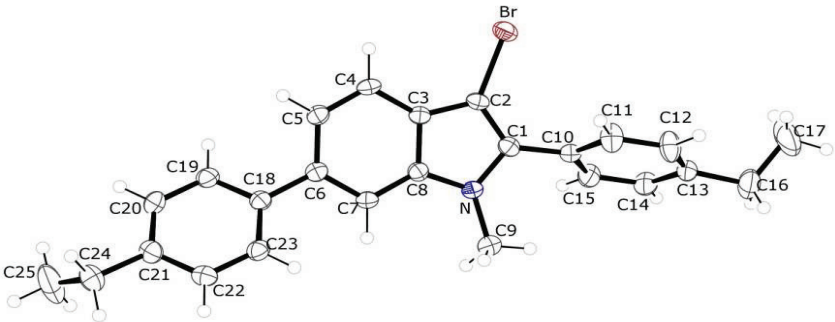
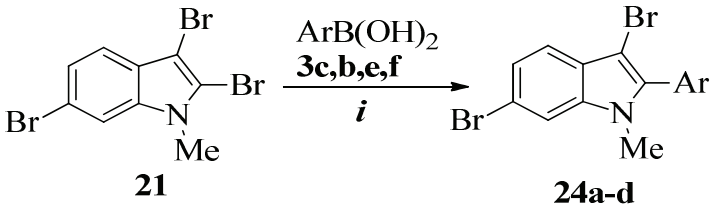


Figure 18: Molecular structure of compound **23b**

The Suzuki-Miyaura cross-coupling reaction of **21** with arylboronic acids **3c,b,e,f** (1.1 equiv.) afforded the 2-aryl-3,6-dibromo-1-methyl-1*H*-indole **24a-d** in (77-84%) yields and with a very good site-selectivity (Scheme 19, Table 18).



21 **24a-d**

Scheme 19: Synthesis of **24a-d**. *Reagents and conditions*: *i*, **21**(1.0 equiv.), **3c,b,e,f** (1.1 equiv.), $Pd(PPh_3)_4$ (3 mol%), K_3PO_4 (1.5 equiv.), toluene/1,4-dioxane (4:1), 65°C, 8h.

The reactions were carried out using $Pd(PPh_3)_4$ (3 mol%) as the suitable catalyst. It is important to carry out the reactions at 65°C instead of 90°C.

Table 18: Synthesis of **24a-d**

3	**24**	Ar	% (**24**)[a]
c	**a**	4-*t*BuC_6H_4	**84**
b	**b**	4-EtC_6H_4	**83**
e	**c**	4- MeC_6H_4	**77**
f	**d**	4-ClC_6H_4	**79**

[a] Yields of isolated products.

Compounds **24a**, **24d** were selected for optimization studies (Table 19). **24a** is derived from an electron-rich arylboronic acid, while **24d** is derived from an electron-poor arylboronic acid. During the optimization, we have found that the best yields were obtained when the reactions were carried out at 65°C. Significant amounts of side-products, derived from multi-fold coupling, were formed when the temperature was higher than 65°C. A solvent mixture of toluene/1,4-dioxane (4:1), K_3PO_4 (1.5 equiv.) as base, and $Pd(PPh_3)_4$ (3 mol%) as a catalyst were used. The structures of all products were confirmed by spectroscopic methods.

Table 19: Optimization table for the synthesis of **24a, 24d**

Entry	solvent	base	ligand	Temp.°C	% (24a)[a]	% (24d)[a]
1	dioxane	2 M K_2CO_3	$(PPh_3)_4Pd$	70 °C	mixture	mixture
2	dioxane	2 M K_2CO_3	Cy_3P, $Pd(OAc)_2$	70 °C	mixture	mixture
3	dioxane	2 M K_2CO_3	SPhos, $Pd(OAc)_2$	70 °C	mixture	mixture
4	dioxane	2 M K_2CO_3	$(PPh_3)_2PdCl_2$	70 °C	mixture	mixture
5	dioxane	1.5eq. K_3PO_4	$(PPh_3)_4Pd$	65 °C	mixture	mixture
6	dioxane	1.5eq. K_3PO_4	Cy_3P, $Pd(OAc)_2$	65 °C	mixture	mixture
7	toluene	2 M K_2CO_3	$(PPh_3)_4Pd$	65°C	No reaction	No reaction
8	toluene	2 M K_2CO_3	$(PPh_3)_4Pd$	70 °C	No reaction	No reaction
9	dioxane/ toluene (1:1)	2 M K_2CO_3	$(PPh_3)_4Pd$	65 °C	mixture	mixture
10	dioxane/ toluene (4:1)	1.5eq. K_3PO_4	$(PPh_3)_4Pd$	65 °C	30%	25%
11	**dioxane/ toluene (1:4)**	**1.5eq. K_3PO_4**	**$(PPh_3)_4Pd$**	**65 °C**	**84[a]%**	**79[a]%**

[a] Yields of isolated products.

The structure of compound **24b** was independently confirmed by 2D-NMR experiments. In the HMBC spectrum, the aromatic proton of the attached boronic acid at C-2' showed a strong coupling with C-2 of the indole ring. The same is true also with the proton at C-6'.This confirmed that the first attack of boronic acid **3b** occurred at carbon atom C-2 of the tribromoindole.

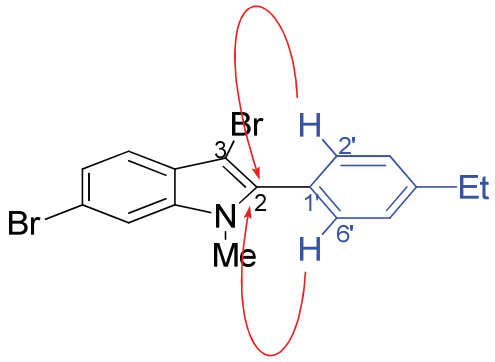
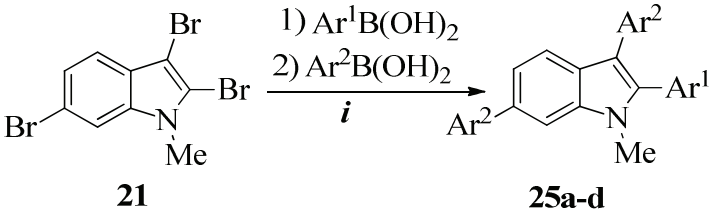


Figure 19: 2D-NMR correlations of the compound **24b**

Unsymmetrical 2,3,6-triaryl-1-methyl-1*H*-indoles **25a-d** were prepared by site-selective Suzuki cross-coupling reactions. A one-pot synthesis was carried out for product **25a**. The first cross-coupling reaction happened by reaction of **21** with (1.1 equiv.) of **3j** at 65°C for 8 h; K_3PO_4 (1.5 equiv.) as a base, a mixture of solvents toluene/ 1,4-dioxane (4:1), and $Pd(PPh_3)_4$ (5 mol%) as catalyst were used. Then, **3c** was added (2.1 equiv.) for the second cross-coupling reaction which afforded product **25a** in good yield (74%) containing two different aryl groups. Based on our finding for the synthesis of **24a-d**, compounds **25b-d** was synthesized in two steps. After isolating the first product of the first cross-coupling step, the second boronic acid was added for the second catalysed cross-coupling reaction.

Products **25b-d** were isolated in good yields (72-82%) (Scheme 20, Table 20). To achieve a good site-selectivity in favour of position 2 of the substrate, it is important that the first step is carried out at 65°C for 8 h and the second step at 90°C for the period of 8 h. In both steps $Pd(PPh_3)_4$ was used as a catalyst. Both electron-donating and withdrawing groups were examined for the synthesis of compounds **25a-d**.



21 **25a-d**

Scheme 20: Synthesis of **25a-d**. *Reagents and conditions*: *i*, 1) $Ar^1B(OH)_2$ **3j,c,f,c** (1.1 equiv.) , $Pd(PPh_3)_4$ (5 mol%), K_3PO_4 (1.5 equiv.), toluene/1,4-dioxane (4:1), 65°C, 8 h, 2) $Ar^2B(OH)_2$ **3c,h,h,a** (2.1 equiv.), K_2CO_3 (2 M, 1 mL), 1,4-dioxane, 90°C, 8h.

Table 20: Synthesis of **25a-d**

3	**25**	Ar^1	Ar^1	%(**25**)[a]
j , c	**a**	4-FC_6H_4	4-*t*BuC_6H_4	**74**[c]
c , h	**b**	4-*t*BuC_6H_4	4-(OMe)C_6H_4	**81**[b]
f , h	**c**	4-ClC_6H_4	4-(OMe)C_6H_4	**82**[d]
c , a	**d**	4-*t*BuC_6H_4	2-(OMe)C_6H_4	**72**[b]

[a] Yields of isolated products, [b,d] Yields based on **24a,24d**

[c] Yields based on **21** as one-pot reaction.

The order of reactivity of the three different positions of 2,3,6-tribromo-1-methyl-1*H*-indole is C-2 > C-6 > C3. The first attack was happened at carbon atom C-2. The site-selectivity can be explained by the fact that carbon atom C-2 is considerable more electron-deficient than positions 3 and 6. The second attack occurred at position 6 which is sterically less hindered than position 3 and electronically less deficient than position 2. Carbon atom C-3 is more hindered and more electron-deficient than C-6.

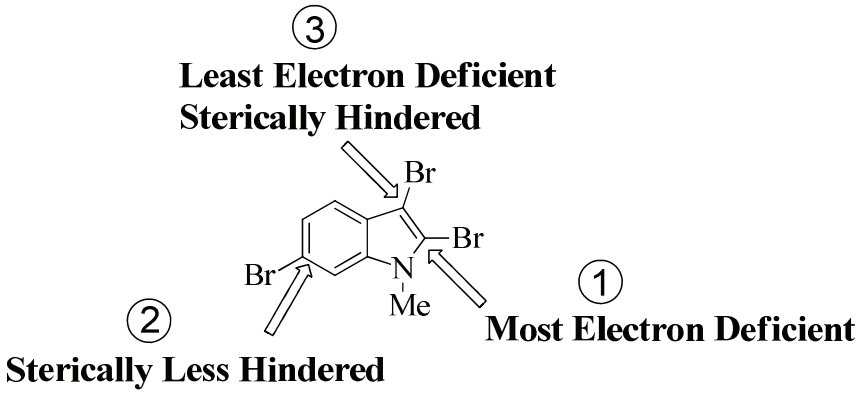


Figure 20: Possible explanation for the site-selectivity of the reactions of **21**

4.2 Conclusion

Pd(0)-catalyzed site-selective Suzuki-Miyaura cross-coupling reactions of 2,3,6-tribromo-1-methyl-1*H*-indole afforded various arylated indoles in high yield and excellent site-selectivity. The site-selectivity can be explained according to electronic and steric reasons. The order of the selectivity is C-2 > C-6 > C-3. Carbon atom C-2 is the most electron-deficient and it was the first position attacked.

.

5. Synthesis of Functionalized Anthraquinones by Domino Twofold Heck-6π-Electrocyclization Reactions of 2,3-Dibromonaphthaquinone.

5.1 General Introduction

Anthraquinones or anthracene-9,10-diones are essential chemical constituents of fungi, lichens and higher plants which possess a broad spectrum of biological activities including antibacterial, anti-inflammatory, and antiviral properties[73a,b]. For example, the anthracyclines constitute an important class of antitumor agents and antibiotics, which include several prominent compounds such as daunorubicin, adriamycin and aclarubicin[74].

Most naturally occurring anthracyclines are isolated in O-glycosylated form, but some of them, such as saintopin, are found as aglycons[70]. Simple hydroxylated anthraquinones (such as chrysophanic acid, vismiaquinone, anthragallol, questin, and several others) are also widely distributed in nature[76a,b]. While most of them are found as aglycons, some derivatives, such as pulmatin, occur in O-glycosylated form[77].

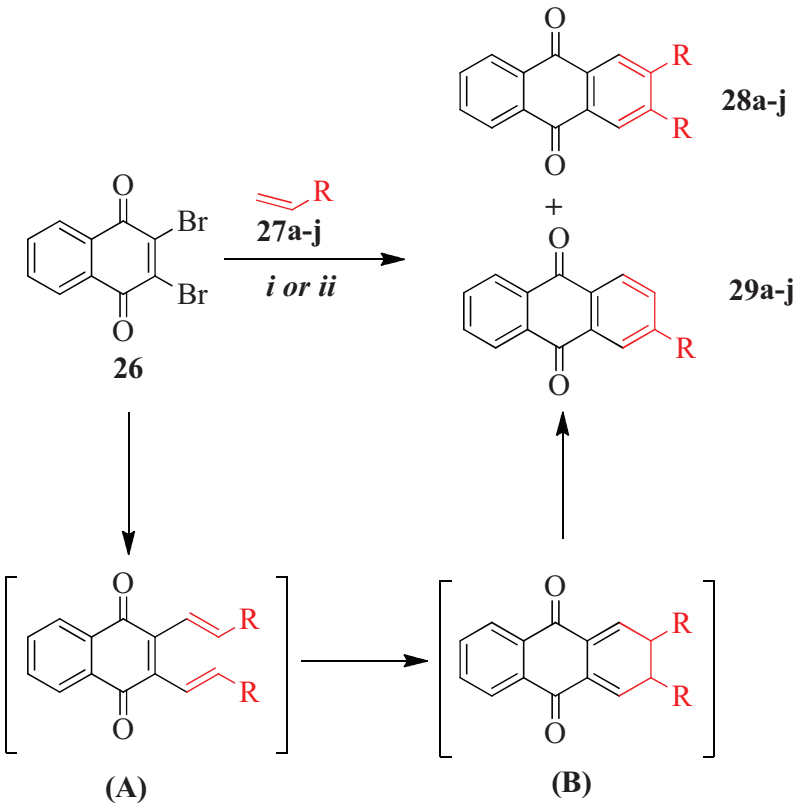
Anthraquinone derivatives show a very good antitumor activity against cancer cells[78]. On the other hand, anthraquinones are widely used as antihelminthic as well as inhibitor agents[79]. Many applications of aryl-substituted anthraquinones exist in material sciences, due to their redox, UV and luminescence properties[80a-d]. They have been also used as stabilizers of light-modulating fluids. Anthraquinones provide the basis of several natural dyes as well[81].

Current methods for the synthesis of anthraquinones are based on regioselective annulation reactions, such as Diels-Alder cycloadditions of naphthaquinones, reactions of lithiated species with suitable electrophiles, and Friedel-Craft condensations[82].

Palladium-catalyzed coupling reactions of Heck type is the most versatile method for C-C bond formation[83]. Application of the Heck reaction in the synthesis of natural and non-natural products is well reviewed by de Meijere and Meyer[84]. Extensive methodological refinements over the last decade, particularly with regard to solvents, catalysts and additives, have greatly improved the synthetic efficiacy of these reactions, as a result of which they are now finding almost routine use in complex organic synthesis. Polyhalogenated molecules represent interesting substrates in Pd(0)-catalyzed cross-coupling reactions[69]. In this chapter, I show my results related to the synthesis of functionalized anthraquinones by domino[85] twofold Heck-6π-electrocyclization reactions of 2,3-dibromonaphthoquinone.

Results and Discussion:

Different types of acrylates and styrenes **27a-j** with both electron-donating and withdrawing groups were used in this study. The Heck reaction of 2,3-dibromonaphthoquinone **26** with **27a** (2.5 equiv.) afforded **28a** in 76% yield (Scheme 21, Table 21). The formation of **28a** can be explained by twofold Heck reaction (intermediate **A**) and subsequent 6π-electrocyclization to give intermediate **B**. Dehydrogenation of the latter afforded **28a**. The best yields were obtained when the reactions were carried out using $Pd(OAc)_2$ (5 mol%) and the biaryl mono-phosphine ligand XPhos (10 mol%), which was recently developed by Buchwald and co-workers [18] (Figure 21).



Scheme 21: Synthesis of **28a-j** and **29a-j**. *Conditions*: *i*, method 1) $Pd(OAc)_2$ (5 mol%), XPhos (10 mol%), NEt_3 (8.0 equiv.), DMF, 90°C, 8 h; method 2) *ii*, $Pd(OAc)_2$ (5 mol%), XPhos (10 mol%), NEt_3 (8.0 equiv.), DMF, 110°C, 8 h.

The reaction was carried out in DMF at 90°C for 8 hours (method 1). The temperature played an important role in these reactions. The yields significantly decreased when the temperature was increased. A clean reaction was observed when it was carried out at 90°C.

Compound **29a** was isolated as a separable mixture in 44% yield following method 2 (110°C). Decomposition was observed when the reaction was carried out at temperatures higher than 120°C. The formation of **29a**, which contains only one alkyl group, can be explained by the fact that thermal conditions have an effect on the electrocyclization providing intermediate B.

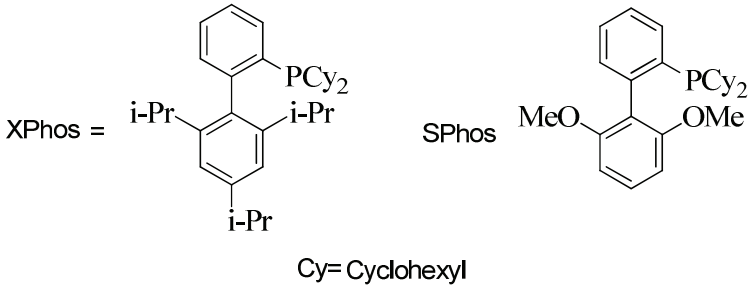


Figure 21: Biaryl mono-phosphine ligands developed by Buchwald and co-workers

Table 21: Synthesis of **28a-j** and **29a-j**

28,29	27	Method 1, Yield of 28(%)[a]	Method 2, Yields of 28and 29(%)[a]
a	4-ClC_6H_4	76	Traces+44
b	3-ClC_6H_4	71	–[b]
c	4-*t*BuC_6H_4	80	–[b]
d	4-MeC_6H_4	78	–[b]
e	4-FC_6H_4	72	–[b]
f	4-*t*BuOC_6H_4	–[b]	Traces+59
g	CO_2Et	79	25+37
h	CO_2*t*Bu	82	30+60
i	CO_2*i*Octadecyl	–[b]	Traces+46
j	CO_2EtMeO	–[b]	Traces+71

[a] Yields of isolated products. [b] Experiment was not carried out.

The Heck reaction of 2,3-dibromonaphthoquinone **26** with styrenes **27b-e** afforded **28b-e** in (71-80%) yields (method 1). When we have applied the reactions using method 2, compound **29f** was isolated in (59%) yield as a separable mixture; **27f** was used as alkene for this reaction

(Scheme 1, Table 1). All products were confirmed by spectroscopic methods. The structure of compound **28c** was confirmed independently by X-ray crystallography (Figure 22).

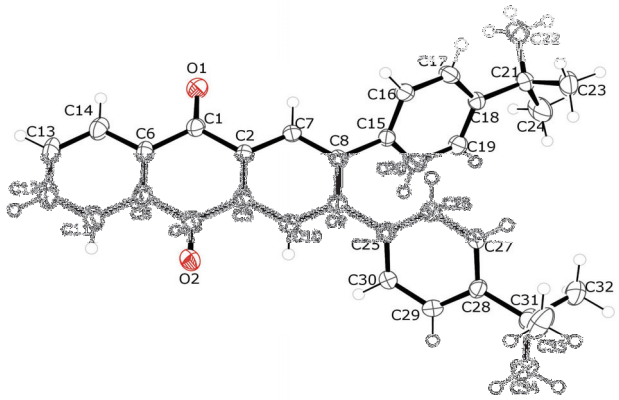


Figure 22: Molecular structure of compound **28c**

The $Pd(OAc)_2$ catalyzed reaction of **26** with acrylates **27g**, **27h** afforded anthraquinones **28g** (79%), **28h** (82%) following method 1. At higher temperature (110°C) and using method 2, a separable mixture of **28g,h** and **29g**,**h** was obtained, respectively (Scheme 21, Table 21). Educt **27j** afforded **29j** in 71% yield. The product distribution was again dependent on the reaction temperature. All products have been confirmed by spectroscopic methods.

Compound **28g** was used for the optimization of the conditions for this project (Table 22). We have found that di-substituted anthraquinones **28** were generally formed in good yields when the reaction was carried out at 90°C, while mono-substituted anthraquinones **29** were predominantly formed at 110°C as a separable mixture with **28**. $Pd(OAc)_2$ (5mol%) and XPhos (10 mol%) was used as an efficient catalyst for such type of reactions. The choice of the solvent also played an important role. No conversion was observed for non-polar solvents such as toluene. The successful employment of DMF can be explained by its polarity and high boiling point.

Table 22: Optimization table for synthesis of **28g**

Entry	Catalyst	Temp.°C	(**28g**)[a] %
1	$Pd(OAc)_2$ (5 mol%), $P(Cy)_3$ (10 mol%)	90	40
2	$Pd(PPh_3)_2Cl_2$ (5 mol%)	90	25
3	$Pd(PPh_3)_4$ (5 mol%)	90	30
4	**$Pd(OAc)_2$ (5 mol%), XPhos (10 mol%)**	**120**	**25+37[b]**
5	**$Pd(OAc)_2$ (5 mol%), XPhos (10 mol%)**	**90**	**79**

[a] Yields of isolated products,all reactions were carried out in DMF and NEt_3 as a base,

b Yield of isolated by-product **29g**

5.2 Conclusion

An efficient synthesis of functionalized anthraquinones by domino 'twofold Heck-6π-electrocyclization' reactions of 2,3-dibromonaphthoquinone was studied. The products, which are not readily available by other methods, were formed in only one step under relatively mild conditions. The temperature played an important role during the optimization of the reaction conditions.

6. Abstract

Due to the importance and wide-range applications of carbon-carbon bond forming reactions in organic synthesis, palladium(0)-catalyzed Suzuki cross-coupling reactions of 1,3- and 1,4-dihydroxy-9*H*-thioxanthen-9-one, 2,3,5-tribromoinden-1-one, 2,3,6-tribromo-1-methyl-1*H*-indole and Heck reactions of 2,3-dibromonaphthaquinone were studied in my thesis. The Pd(0)-catalyzed Suzuki cross-coupling reaction of the bis(triflates) of 1,3-dihydroxythioxanthones afforded 1,3-diarylthioxanthones in high yields and excellent site-selectivity. The site-selectivity was explained by steric-hindered effect, while electronic effect was responsible for the site-selective Suzuki cross-coupling reaction of the bis(triflates) of 1,4-dihydroxythioxanthones. A wide scope of symmetrical and unsymmetrical aryl indenones and indoles from brominated substrates were synthesized using Pd(0)-catalyzed Suzuki cross-coupling reactions. Electronic and steric parameters again played an important role for the site-selectivity. An efficient synthesis of substituted anthraquinones by domino twofold Heck-6π-electrocyclization reactions of 2,3-dibromonaphthaquinone was studied. The products were formed in only one step under relatively mild conditions. The temperature played an important effect during the optimization.

In German

Aufgrund der großen Bedeutung und breiten Anwendbarkeit von C-C-Knüpfungsreaktionen in der organischen Synthese wurden in meiner Dissertation Palladium(0)-katalysierte Suzuki-Kreuzkupplungsreaktionen an 1,3- und 1,4-Dihydroxy-9*H*-thioxanthen-9-on, 2,3,5-Tribrominden-1-on, 2,3,6-Tribrom-1-methyl-1*H*-indol sowie Heck-Reaktionen an 2,3-Dibromnaphthochinon in großem Umfang untersucht. Die Palladium(0)-katalysierte Suzuki-Kreuzkupplung an Bis(triflaten) von 1,3-Dihydroxythioxanthonen ergab 1,3-Diarylthioxanthone in hohen Ausbeuten und mit hoher Regioselektivität. Die Regioselektivität lässt sich in diesem Fall durch sterische Hinderung erklären, während sie bei Bis(triflaten) von 1,4-Dihydroxythioxanthonen von elektronischen Effekten gesteuert wird.

Darüber hinaus wurden mittels Palladium(0)-katalysierter Suzuki-Kreuzkupplungsreaktionen in großem Umfang symmetrisch und unsymmetrisch substituierte Arylindenone und -indole ausgehend von bromierten Ausgangsstoffen dargestellt. Auch hier spielten sterische und elektronische Einflüsse eine große Rolle hinsichtlich der Regioselektivität.

Außerdem wurde eine effiziente Synthese von substituierten Anthrachinonen durch eine zweifache Heck-6π / Electrocyclisierungsreaktion ausgehend von 2,3-Dibromnaphthochinon erschlossen. Die Produkte wurden in nur einem Schritt unter relativ milden Bedingungen gebildet. Dabei spielte die Temperatur eine entscheidende Rolle.

7. Experimental Section

7.1 General: Equipment, Chemicals and Work Technique

Reactions were carried out under inert atmosphere (Argon 4.6) in order to simultaneously exclude oxygen and water when appropriate. Pressure tubes were used to avoid condenser. Solvents for reactions were dried and distilled by standard methods or purchased from Merck, Aldrich, Acros Organics, and others whenever exclusion of water was desired. Solvents for liquid chromatography and extraction were always distilled prior to use and partly reused after fractional distillation (*n*-heptane, ethyl acetate).

^{1}H NMR Spectroscopy: Bruker: AM 250, Bruker ARX 300, Bruker ARX 500; δ = 0.00 ppm for Tetramethylsilane; d = 2.04 ppm for Acetone-d_6; δ = 7.26 ppm for ($CDCl_3$); 2.50 ppm for DMSO-d; Characterization of the signal fragmentations: s = singlet, d = doublet, dd = double of doublet, t = triplet, q = quartet, m = multiplet, br = broadly. Spectra were evaluated according to first order rule. All coupling constants are indicated as (*J*).

^{13}C NMR Spectroscopy: Bruker: AM 250, (62.9 MHz); Bruker: ARX 300, (75 MHz), Bruker: ARX 500, (125 MHz) Ref: 29.84 ± 0.01 ppm and 206.26 ± 0.13 ppm for $(CD_3)_2CO$. d = 128.00 ppm for benzene-d_6; δ = 77.00 ppm for $CDCl_3$. The multiplicity of the carbon atoms was determined by the DEPT 135 and APT technique (APT = Attached Proton Test) and quoted as CH_3, CH_2, CH and C for primary, secondary, tertiary and quaternary carbon atoms. Characterization of the signal fragmentations: quart = quartet the multiplicity of the signals was determined by the DEPT recording technology and/or the APT recording technology.

Mass Spectroscopy: AMD MS40, AMD 402 (AMD Intectra), Varian MAT CH 7, MAT 731.

High Resolution mass spectroscopy: Finnigan MAT 95 or Varian MAT 311; Bruker FT CIR, AMD 402 (AMD Intectra).

Infrared Spectroscopy (IR)

Nicolet 205 FT-IR, Nicolet Protége 460 FT-IR. Peaks are given the following assignments: w = weak, m = medium, s = strong.

Elemental Analysis

LECO CHNS-932, Thermoquest Flash EA 1112.

Melting Points

Micro heating table HMK 67/1825 Kuestner (Büchi Apparatus), Leitz Labolux 12 Pol with heating table Mettler FP 90. Melting points are uncorrected.

X-ray Structures

Bruker X8Apex diffractometer with CCD camera (Mo K_α radiation and graphite monochromator, $\lambda = 0.71073$ Å).

Column Chromatography: Chromatography was performed over Merck silica gel 60 (0,063 - 0,200 mm, 70 - 230 mesh) as normal and/or over mesh silica gel 60 (0,040 - 0,063 mm, 200 -400 mesh) as Flash Chromatography. All solvent were distilled before use.

Thin Layer Chromatography (TLC): Merck DC finished foils silica gel 60 F 254 on aluminum foil and Macherey finished foils Alugram ® Sil G/UV254. Detection under UV light with 254 nm and/or 366 nm without dipping reagent, as well as with anisaldehyde sulfuric acid reagent (1 mL anisaldehyde consisting in 100 mL stock solution of 85% methanol, 14% acetic acid and 1% sulfuric acid).

7.2 General Procedures

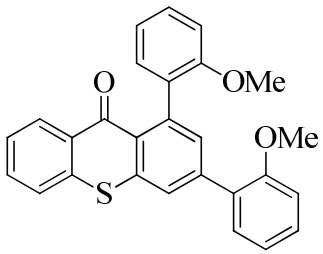
Site-Selective Suzuki–Miyaura Reactions of the Bis(triflate) of 1,3-Dihydroxythioxanthone

Synthesis of 9-oxo-9*H*-thioxanthene-1,3-diyl bis(trifluoro-methanesulfonate) (2): To a solution of **1** (0.34g, 1.39 mmol) in CH_2Cl_2(20 mL) was added Et_3N (0.77 mL, 5.56 mmol), at 20°C under an argon atmosphere. After stirring for 10 min at -78°C, Tf_2O (0.56 mL, 3.34 mmol) was added. The mixture was allowed to warm to 20°C and stirred for further 8 h. The reaction mixture was filtered and the filtrate was concentrated in vacuo. The residue was chromatographed without work up (flash silica gel, heptanes-EtOAc) and **2** was isolated as a yellow solid (0.57 g, 80%), Mp.149-150°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.11(d, 1H, J = 2.37 Hz, ArH), 7.45-7.51(m, 3H, ArH), 7.58-7.65 (m, 1H, ArH), 8.50 (dd, 1H, J = 1.02, 8.50 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -72.3, -73.2. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 114.7 (CH), 118.6 (q, $J_{F,C}$ = 321.3 Hz, CF_3), 118.7 (q, $J_{F,C}$ = 320.9 Hz, CF_3), 118.9, 125.4, 127.7 (CH), 129.9 (C), 130.3, 133.3 (CH), 134.3, 142.7, 149.9, 150.8 (C), 177.8 (CO). IR (KBr): ν = 3081, 3030, 2958, 2923, 2851, 1728 (w), 1602, 1599, 1590 (m), 1554, 1465 (w), 1426 (s), 1399 (m), 1317, 1295 (w), 1246 (m), 1198 (s), 1150 (m), 1133, 1099 (s), 1080 (m), 1033 (w), 989, 929, 904, 884, 819, 807, 798 (m), 768 (w), 751, 714 (m), 684, 666, 655, 635 (w), 590, 569, 542, 530 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 508 ([M+H]$^+$, 100), 347 (28), 283 (62), 255 (19). HRMS (EI, 70 eV): calcd for $C_{15}H_6F_6O_7S_3$ [M]$^+$: 507.91744; found: 507.916890.

General Procedure for Suzuki–Miyaura cross-coupling Reactions: A THF solution (4-5 mL), K_3PO_4 (1.5 equiv. per cross-coupling), $Pd(PPh_3)_4$ (5 mol% per cross-coupling) and arylboronic acid **3** (1.1 equiv. per cross-coupling) was stirred at 60-90°C for 8 h. After cooling to 20°C, distilled H_2O was added. The organic and the aqueous layers were separated and the latter was extracted with CH_2Cl_2. The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purified by column chromatography (flash silica gel, heptanes-EtOAc).

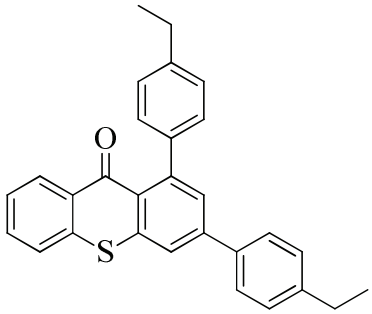
Synthesis of 1,3-diarylthioxanthones 4a-g:

1,3-Bis(2-methoxyphenyl)-9*H*-thioxanthen-9-one (4a): Starting with **2** (100 mg, 0.197 mmol),



2-methoxyphenylboronic acid **3a** (72 mg, 0.47 mmol), Pd $(PPh_3)_4$ (23 mg, 10 mol %), K_3PO_4 (125 mg, 0.59 mmol) and 1,4-dioxane (5 mL), **4a** was isolated as a light yellow solid (75 mg, 90%); reaction temperature: 90°C for 8 h. Mp.163-165°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.72 (s, 3H, OCH_3), 3.76 (s, 3H, OCH_3), 6.87 (dd, 1H, J = 0.71, 8.19 Hz, ArH), 6.93 (d, 1H, J = 8.04 Hz, ArH), 6.97-7.02 (m, 2H, ArH), 7.19-7.36 (m, 6H, ArH), 7.46 (d, 2H, J = 1.79 Hz, ArH), 7.68 (d, 1H, J = 1.77 Hz, ArH), 8.23 (dt, 1H, J = 0.96, 8.01 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 55.5 (OCH_3), 55.7 (OCH_3), 110.3, 111.4, 120.7, 121.0, 125.3, 125.9, 126.1 (CH), 127.0 (C), 128.4, 129.1, 129.4, 129.8, 130.9, 131.5 (CH), 131.6 (C), 131.8 (CH), 132.7, 136.2, 137.1, 141.2, 141.5, 156.1, 156.3 (C), 181.0 (CO). IR (KBr): ν = 3377, 3056, 2997, 2930, 2833, 2247 (w), 1640, 1587 (s), 1536 (w), 1492, 1460, 1434 (s), 1485 (m), 1299, 1270 (m), 1238 (s), 1178, 1157, 1117 (m), 1074, 1057, 1047 (w), 1022 (s), 963 (w), 924 (m), 906, 877, 851(w), 834 (m), 807, 785, 771 (w), 746, 736, 722 (s), 678, 666 (m), 645, 615, 574, 552 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 423 ($[M-H]^+$, 100), 394 (29), 377 (39). HRMS (EI, 70 eV): calcd for $C_{27}H_{20}O_3S$ $[M]^+$: 424.11277; found: 424.11227.

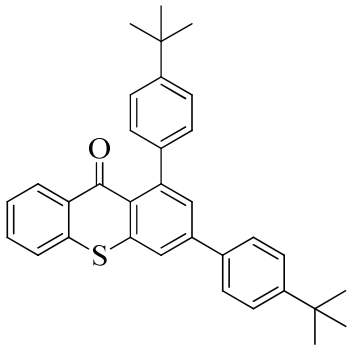
1,3-Bis(4-ethylphenyl)-9*H*-thioxanthen-9-one (4b): Starting with **2** (100 mg, 0.197 mmol),



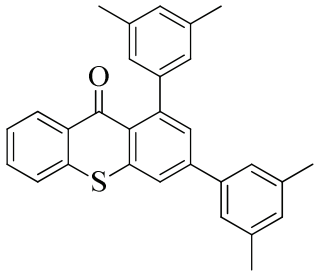
4-ethylphenylboronic acid **3b** (70 mg, 0.47 mmol), Pd$(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and 1,4-dioxane (5 mL), **4b** was isolated as a light yellow solid (67 mg, 81%); reaction temperature: 90°C for 8 h. Mp.179-181°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ =1.18 (t, 3H, J = 7.59 Hz, CH_3), 1.21 (t, 3H, J = 7.59 Hz, CH_3), 2.60 (q, 2H, J = 7.59 Hz, CH_2), 2.67 (q, 2H, J = 7.59 Hz, CH_2), 7.17-7.22 (m, 6H, ArH), 7.26-7.32 (m, 1H, ArH), 7.40 (d, 1H, J = 1.86 Hz, ArH), 7.40-7.46 (m, 2H, ArH), 7.50 (d, 2H, J = 8.25 Hz, ArH), 7.64 (d, 1H, J = 1.86 Hz, ArH), 8.26 (dd, 1H, J = 0.75, 8.49 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 15.3 (CH_3), 15.5 (CH_3), 28.6 (CH_2), 28.7 (CH_2), 122.9, 125.2 (CH), 125.9 (C), 126.1, 127.3, 127.4, 127.9, 128.6, 129.4, 129.8 (CH), 131.6 (C), 131.8 (CH), 135.9, 136.0, 138.9, 140.9, 142.6, 143.4, 145.1, 140.8 (C), 180.7 (CO). IR (KBr): ν = 3050, 3022, 2961, 2927, 2891, 2871, 2853 (w), 1644 (s), 1612 (w), 1588 (s), 1556, 1537 (w), 1510 (m), 1469, 1455 (w), 1432 (m), 1380, 1316 (w), 1298 (s), 1286 (m), 1231, 1184, 1162 (w), 1152, 1115, 1074 (m), 1051 (w), 1031 (m), 1017, 966 (w), 924

(m), 892, 875(w), 833 (m), 821 (s), 770 (w), 749, 720 (s), 672 (m), 659, 651, 640, 615, 591, 574, 566 (w), 553 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 420 ($[M]^+$, 53), 419 ($[M-H]^+$, 100), 404 (11). HRMS (EI, 70 eV): calcd for $C_{29}H_{23}OS$ $[M-H]^+$: 419.14641; found: 419.14579.

1,3-Bis(4-(*tert*-butyl)phenyl)-9*H*-thioxanthen-9-one (4c): Starting with **2** (100 mg, 0.197 mmol), 4-*tert*-butylphenylboronic acid **3c** (84 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and 1,4-dioxane (5 mL), **4c** was isolated as a light yellow solid (80 mg, 86%); reaction temperature: 90°C for 8 h. Mp.123-125°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.28 (s, 9H, $3CH_3$), 1.33 (s, 9H, $3CH_3$), 7.20 (d, 2H, 8.49 Hz, ArH), 7.28-7.33 (m, 1H, ArH), 7.35-7.40 (m, 3H, ArH), 7.42-7.48 (m, 4H, ArH), 7.54 (d, 2H, J = 8.6 Hz, ArH), 7.66 (d, 1H, J = 1.89 Hz, ArH), 8.27 (d, 1H, J = 7.80 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.3 (CH_3), 30.5 (CH_3), 33.4, 33.5 (C), 121.9, 123.8, 124.2, 124.9, 125.1 (CH), 125.6 (C), 126.0, 126.7, 128.6, 128.8 (CH), 130.6 (C), 130.7 (CH), 134.7, 134.9, 137.9, 139.5, 142.3, 145.7, 148.3, 151.0 (C), 179.7 (CO). IR (KBr): ν = 3389, 3051, 3030, 2952, 2901, 2865 (w), 1638 (s), 1611 (w), 1588 (s), 1556, 1537 (w), 1511 (m), 1475 (w), 1461, 1434 (m), 1416 (w), 1381, 1360 (m), 1317 (w), 1299 (s), 1267 (m), 1231, 1201 (w), 1157,1109 (m), 1175, 1144, 1032, 1014, 961 (w), 924 (m), 890, 867 (w), 822,754 (s), 746 (m), 719 (s), 697, 671, 671, 656, 646, 613 (w), 581 (s), 563, 549, 541 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 476 ($[M]^+$, 64), 475 ($[M-H]^+$, 100), 462 (15), 461 (46). HRMS (ESI): calcd for $C_{33}H_{33}OS$ $[M+H]^+$: 477.22470; found: 477.22430.

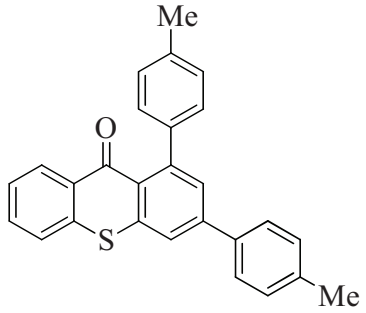


1,3-Bis(3,5-dimethylphenyl)-9*H*-thioxanthen-9-one (4d): Starting with **2** (100 mg, 0.197 mmol), 3,5-dimethylphenylboronic acid **3d** (71 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and 1,4-dioxane (5 mL), **4d** was isolated as a light yellow solid (64 mg, 77%); reaction temperature: 90°C for 8 h. Mp.159-161°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 2.31 (s, 6H, $2CH_3$), 2.32 (s, 6H, $2CH_3$), 6.88 (brs, 2H, ArH), 6.98 (d, 2H, J = 6.39 Hz, ArH), 7.22 (brs, 2H, ArH), 7.30-7.36 (m, 1H, ArH), 7.40 (d, 1H, J = 1.83 Hz, ArH), 7.48-7.49 (m, 2H, ArH), 7.66 (d, 1H, J = 1.86 Hz, ArH), 8.27 (d, 1H, J = 7.80 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 20.3 (CH_3), 20.5 (CH_3), 122.1 (CH), 124.1 (C), 124.2, 124.7 (CH), 125.0 (C), 125.1, 127.6, 128.3,

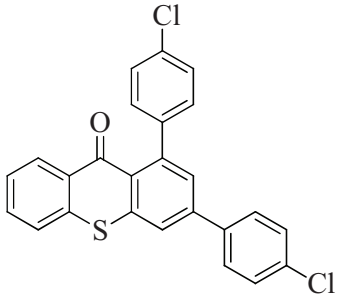


128.7, 129.3, 130.6, 130.7 (CH), 134.9, 136.2, 137.6, 137.7, 138.0, 142.5, 142.6, 145.8 (C), 179.7 (CO). IR (KBr): ν = 3269, 3004, 2914, 2854, 2729 (w), 1640 (s), 1601 (m), 1587 (s), 1540 (m), 1503, 1494, 1468 (w), 1432 (m), 1398 (w), 1382, 1373 (m), 1332, 1315 (w), 1300 (s), 1279 (m), 1245, 1204, 1185, 1168 (w), 1150 (m), 1137, 1117, 1100, 1080 (w), 1034 (m), 1011, 966, 940 (w), 912, 889, 875 (m), 842 (s), 813, 806 (m), 769 (w), 752, 744, 719 (s), 703, 697, 692, 672, 651, 643 (m), 603 (w), 591 (m), 569, 540 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 420 ($[M]^+$, 54), 419 ($[M-H]^+$, 100), 405 (39). HRMS (ESI): calcd for $C_{29}H_{25}OS$ $[M+H]^+$: 421.16210; found: 421.16300.

1,3-Di-*p*-tolyl-9*H*-thioxanthen-9-one (4e): Starting with **2** (100 mg, 0.197 mmol), 4-methylphenylboronic acid **3e** (64 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and 1,4-dioxane (5 mL), **4e** was isolated as a light yellow solid (65 mg, 84%); reaction temperature: 90°C for 8 h. Mp.175-177°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.31(s, 3H, CH_3), 2.36 (s, 3H, CH_3), 7.15-7.19 (m, 6H, ArH), 7.27-7.32 (m, 1H, ArH), 7.39 (d, 1H, J =1.89 Hz, ArH), 7.44 (d, 1H, J =1.17 Hz, ArH), 7.48 (d, 3H, J = 8.25 Hz, ArH), 7.63 (d, 1H, J =1.89 Hz, ArH), 8.27 (dd, 1H, J = 0.78, 8.61 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 20.2 (CH_3), 20.4 (CH_3), 121.9, 124.2 (CH), 124.9 (C), 125.1, 126.2, 126.8, 127.6, 128.2, 128.7, 128.8 (CH), 130.5 (C), 130.7 (CH), 134.7, 134.9, 135.3, 137.8, 137.9, 139.7, 142.3, 145.7 (C), 179.7 (CO). IR (KBr): ν = 3044, 3022, 2952, 2919, 2857 (w), 1631 (s), 1613 (w), 1588 (s), 1556, 1537 (w), 1511 (m), 1462 (w), 1433 (m), 1415, 1380, 1316, 1192 (w), 1256 (m), 1116, 1107, 1075 (m), 1044 (w), 1031 (m), 1017 (w), 983, 961, 945 (w), 923 (s), 888, 877, 848, 837 (w), 811, 803 (s), 787 (m), 768 (w), 757, 748 (s), 725, 717, 675 (m), 659, 649, 631, 612, 586 (w), 568, 536 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 392 ($[M]^+$, 49), 391 ($[M-H]^+$, 100). HRMS (ESI): calcd for $C_{27}H_{21}OS$ $[M+H]^+$: 393.13080; found: 393.13090.

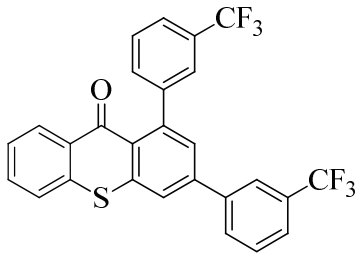


1,3-Bis(4-chlorophenyl)-9*H*-thioxanthen-9-one (4f): Starting with **2** (100 mg, 0.197 mmol), 4-chloro phenylboronic acid **3f** (73 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and 1,4-dioxane (5 mL), **4f** was isolated as a light yellow solid (60 mg, 70%); reaction temperature: 90°C for 8 h. Mp.230-231°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.19 (d, 2H, J = 3.72 Hz, ArH), 7.31-7.39 (m, 6H,



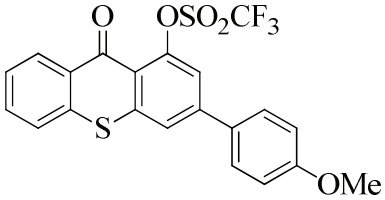
ArH), 7.46-7.54 (m, 4H, ArH), 7.66 (d, 1H, J = 1.66 Hz, ArH), 8.27 (d, 1H, J = 7.88 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 122.6, 124.3 (CH), 125.1 (C), 125.4, 127.1, 127.6, 127.9, 128.2, 128.3, 129.7 (CH), 130.2 (C), 131.1 (CH), 131.9, 134.2, 134.8, 135.9, 138.4, 140.8, 141.3, 144.6 (C), 179.4 (CO). IR (KBr): ν = 3064, 3041, 2920, 2851 (w), 1640, 1589 (s), 1537 (w), 1490 (s), 1470 (w), 1434 (m), 1414, 1397, 1375 (w), 1317, 1298 (m), 1284, 1263, 1234, 1186 (w), 1158 (m), 1107 (w), 1090 (s), 1076 (m), 1032, 1031 (w), 1012 (s), 926 (m), 892, 873, 844 (w), 832 (m), 816, 806, 747 (s), 727, 713 (m), 693 (w), 680, 651 (m), 643, 626, 602 (w), 567, 553 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 433 ([M+H]$^+$, 44), 432 ([M]$^+$, 27), 431 ([M-H]$^+$, 56), 199 (100), 181 (49), 165 (16). HRMS (EI, 70 eV): calcd for $C_{25}H_{14}Cl_2OS$ [M]$^+$: 432.01369; found: 432.01221.

1,3-Bis(3-(trifluoromethyl)phenyl)-9*H*-thioxanthen-9-one (4g): Starting with **2** (100 mg, 0.197 mmol), 3-(trifluoromethyl)phenylboronic acid **3g** (89 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and 1,4-dioxane (5 mL), **4g** was isolated as a light yellow solid (74 mg, 75%); reaction temperature: 90°C for 8 h. Mp.167-169°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.32-7.38 (m, 2H, ArH), 7.42-7.54 (m, 6H, ArH), 7.56-7.62 (m, 1H, ArH), 7.58-7.59 (m, 1H, ArH), 7.73 (d, 1H, J = 1.90 Hz, ArH), 7.77 (d, 1H, J = 7.68 Hz, ArH), 7.83 (brs, 1H, ArH), 8.22-8.26 (m, 1H, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -62.6, -62.3. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 122.7 (q, $J_{F,C}$ = 3.7 Hz, CH), 122.9 (q, $J_{F,C}$ = 272.5 Hz, CF_3), 123.2 (q, $J_{F,C}$ = 272.5 Hz, CF_3),123.2 (q, $J_{F,C}$ = 3.9 Hz, CH), 123.3 (CH), 123.6 (q, $J_{F,C}$ = 3.9 Hz, CH), 124.4 (CH), 124.5 (q, $J_{F,C}$ = 3.9 Hz, CH), 125.4 (C), 125.6, 127.2, 128.0, 128.6, 128.7 (CH), 129.5 (q, $J_{F,C}$ = 32.2 Hz, C-CF_3), 129.7 (CH), 130.1 (C), 130.3 (CH), 130.9 (q, $J_{F,C}$ = 32.5 Hz, C-CF_3), 131.2 (CH), 134.7, 138.3, 138.7, 141.2, 142.9, 144.4 (C), 179.3 (CO). IR (KBr): ν = 3270, 3063, 2959, 2852 (w), 1641 (s), 1615 (w), 1588 (s), 1547, 1496, 1486, 1462, 1455 (w), 1435 (m), 1380 (w), 1326, 1304 (s), 1268, 1251, 1226 (m), 1195 (w), 1174 (m), 1154, 1112, 1095, 1069, 1052 (s), 1033, 1000, 961, 928, 897, 887, 871, 859 (m), 797, 755 (s), 748 (m), 720, 698 (m), 686, 672, 654 (s), 627, 611, 562, 542 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 500 ([M]$^+$, 45), 499 ([M-H]$^+$, 100), 356 (19), 277 (07), 240 (08). HRMS (EI, 70 eV): calcd for $C_{27}H_{13}F_6OS$ [M-H]$^+$: 499.05858; found: 499.058160.

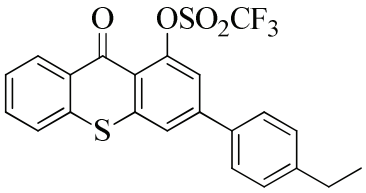


Synthesis of 3-Aryl-1-(trifluorosulfonyloxy)-thioxanthones 5a-h:

3-(4-Methoxyphenyl)-9-oxo-9*H*-thioxanthen-1-yl trifluoromethanesulfonate (5a): Starting with **2** (100 mg, 0.197 mmol), 4-methoxyphenylboronic acid **3h** (33 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **5a** was isolated as a light yellow solid (80 mg, 87%); reaction temperature: 60°C for 8 h. Mp.186-188°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.81 (s, 3H, OCH_3), 6.96 (d, 2H, J = 8.85 Hz, ArH), 7.33 (d, 1H, J = 1.10 Hz, ArH), 7.41-7.58 (m, 5H, ArH), 7.64 (d, 1H, J = 1.74 Hz, ArH), 8.53 (dd, 1H, J = 1.10, 8.2 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.4. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 55.5 (OCH_3), 114.9 (CH), 118.9 (q, $J_{F,C}$ = 321.3 Hz, CF_3), 119.1 (CH), 120.3 (C), 123.4, 125.4, 126.9, 128.5 (CH), 129.2 (C), 130.1 (CH), 130.2 (C), 132.6 (CH), 135.3, 141.0, 145.4, 150.4, 161.0 (C), 178.5 (CO). IR (KBr): ν = 3082, 3063, 2841, 1651 (w), 1635, 1594 (s), 1558 (w), 1523 (m), 1471, 1460 (w), 1435 (m), 1425 (s), 1404 (w), 1389 (m), 1328, 1317, 1307 (w), 1286, 1256, 1242, 1219 (m), 1191 (s),1135, 1126, 1111(m), 1060 (w), 1030 (m), 1007 (w), 958, 904, 889, 881 (m), 848 (w), 832 (s), 811, 799 (m), 782, 759 (w), 745 (s), 725 (w), 712, 661, 653, 637 (m), 595 (s), 582, 567, 527 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 466 ($[M]^+$, 100), 334 (13), 305 (44), 262 (17). HRMS (EI, 70 eV): calcd for $C_{21}H_{13}F_3O_5S_2$ $[M]^+$: 466.01510; found: 466.015129.

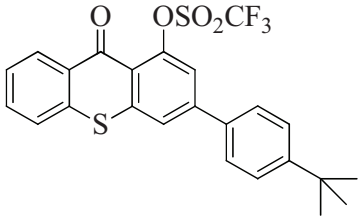


3-(4-Ethylphenyl)-9-oxo-9*H*-thioxanthen-1-yl trifluoromethanesulfonate (5b): Starting with **2** (100 mg, 0.197 mmol), 4-ethylphenylboronic acid **3b** (32 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **5b** was isolated as a yellow solid (77 mg, 84%); reaction temperature: 60°C for 8 h. Mp.158-160°C (CH_2Cl_2/EtOH 1:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.21 (t, 3H, J =7.59 Hz, CH_3), 2.65 (q, 2H, J =7.59 Hz, CH_2), 7.27 (d, 2H, J = 8.32 Hz, ArH), 7.35 (d, 1H, J = 0.96 Hz, ArH), 7.38-7.44 (m, 2H, ArH), 7.46 (d, 2H, J = 8.32 Hz, ArH), 7.50-7.56 (m, 1H, ArH), 7.66 (d, 1H, J = 1.74 Hz, ArH), 8.52 (dd, 1H, J = 1.05, 8.13 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.4. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 14.4 (CH_3), 27.6 (CH_2), 117.4 (q, $J_{F,C}$ = 321.1 Hz, CF_3), 118.4 (CH), 120.4 (C), 122.9, 124.4, 125.9, 126.1, 127.9, 129.0 (CH), 129.1 (C), 131.6 (CH), 133.5, 134.3, 139.9, 144.8, 145.3, 149.3 (C), 177.5 (CO). IR (KBr): ν = 3052, 2960, 2929, 2871 (w), 1641, 1602, 1589 (s), 1524 (m), 1454, 1444 (w), 1422 (s), 1386, 1316, 1303, 1240 (m), 1221, 1186 (s), 1157 (w), 1134, 1123 (s), 1110 (m), 1080, 1060, 1033, 1018 (w), 955, 899 (s), 862



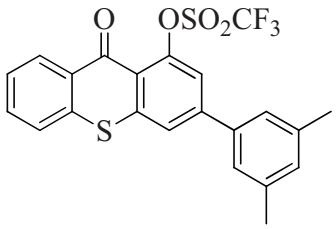
(w), 839 (m), 811, 798 (s), 759 (w), 745 (s), 714 (m), 666, 659, 637 (w), 595, 577, 569 (s), 531 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 464 ($[M]^+$, 100), 332 (14), 303 (39), 275 (17), 260 (19). HRMS (EI, 70 eV): calcd for $C_{22}H_{15}F_3O_4S_2$ $[M]^+$: 464.03584; found: 464.03590.

3-(4-(*Tert*-butyl)phenyl)-9-oxo-9*H*-thioxanthen-1-yl trifluoromethanesulfonate (5c): Starting



with **2** (100 mg, 0.197 mmol), 4-*tert*-butyl phenylboronic acid **3c** (39 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **5c** was isolated as a yellow solid (73 mg, 75%); reaction temperature: 60°C for 8 h. Mp.170-172°C (CH_2Cl_2/EtOH 1:1). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.30 (s, 9H, $3CH_3$), 7.36 (d, 1H, J = 0.90 Hz, ArH), 7.38-7.46 (m, 2H, ArH), 7.48-7.57 (m, 5H, ArH), 7.68 (d, 1H, J = 1.68 Hz, ArH), 8.52 (dd, 1H, J =1.08, 8.10 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.4. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 31.2 (CH_3), 31.9 (C), 118.9 (q, $J_{F,C}$ = 321.0 Hz, CF_3), 119.5 (CH), 120.7 (C), 124.0, 125.4, 126.4, 126.9, 130.1 (CH), 130.2 (C), 132.7 (CH), 134.1, 135.3, 141.0, 145.8, 150.4, 153.2 (C), 178.6 (CO). IR (KBr): ν = 3087, 3050, 3022, 2966, 2920, 2872, 2854 (w), 1630, 1602, 1589 (s), 1524 (m), 1480 (w), 1465, 1437 (m), 1424 (s), 1384 (m), 1362, 1325 (w), 1305 (m), 1278 (w), 1241 (m), 1217, 1193 (s), 1171 (m), 1131, 1105 (s), 1078, 1059, 1035, 1024, 1014 (w), 958, 903 (s), 890 (m), 829 (s), 810 (m), 801 (s), 760 (m), 753 (s), 712 (m), 666, 658, 651, 637 (w), 588 (s), 568, 537, 529 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 493 ($[M+H]^+$, 17), 492 ($[M]^+$, 59), 478 (28), 477 (100), 316 (36). HRMS (EI, 70 eV): calcd for $C_{24}H_{19}F_3O_4S_2$ $[M]^+$: 492.06714; found: 492.06645.

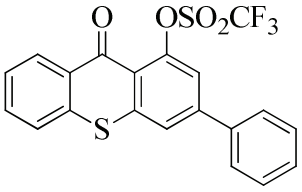
3-(3,5-Dimethylphenyl)-9-oxo-9*H*-thioxanthen-1-yl trifluoromethanesulfonate (5d): Starting



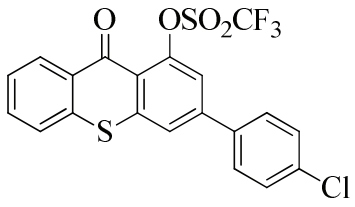
with **2** (100 mg, 0.197 mmol), 3,5-dimethylphenylboronic acid **3d** (33 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **5d** was isolated as a yellow solid (75 mg, 82%); reaction temperature: 60°C for 8 h. Mp.221-223°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 2.34 (s, 6H, $2CH_3$), 7.04 (brs, 1H, ArH), 7.14 (brs, 2H, ArH), 7.35 (d, 1H, J = 0.96 Hz, ArH), 7.39-7.48 (m, 2H, ArH), 7.52-7.58 (m, 1H, ArH), 7.67 (d, 1H, J =1.71 Hz, ArH), 8.53 (dd, 1H, J =1.02, 7.68 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.4. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 20.4 (CH_3), 117.9 (q, $J_{F,C}$ = 321.1 Hz, CF_3), 118.7 (CH), 119.7 (C), 123.3, 124.0, 124.4, 125.9, 129.1 (CH), 129.2 (C), 130.3, 131.6 (CH), 134.3, 136.0, 138.1, 139.9, 145.2, 149.2 (C), 177.6 (CO). IR (KBr): ν = 3152, 3115,

3059, 2951, 2917, 2849 (w), 1631, 1601, 1588 (s), 1555 (w), 1534 (m), 1503, 1483 (w), 1427 (s), 1408 (w), 1375, 1302 , 1248 (m), 1217, 1197, 1186, 1130 (s), 1081 (m) , 1031, 1004 (w), 964, 911 (m), 894, 888 (s), 871 (m), 842, 813, 803 (s), 760 (w), 727 (w), 715, 686, 660 (m), 630 (w), 609 (m), 589 (s), 568 (m), 545, 537 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 464 ($[M]^+$, 100), 303 (46), 275 (27). HRMS (EI, 70 eV): calcd for $C_{22}H_{15}F_3O_4S_2$ $[M]^+$: 464.03584; found: 464.03623.

9-Oxo-3-phenyl-9*H*-thioxanthen-1-yl trifluoromethanesulfonate (5e): Starting with **2** (100 mg, 0.197 mmol), phenylboronic acid **3i** (26 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **5e** was isolated as a yellow solid (61 mg, 71%); reaction temperature: 60°C for 8 h. Mp.163-165°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.36 (d, 1H, J = 0.87 Hz, ArH), 7.39-7.47 (m, 5H, ArH), 7.50-7.56 (m, 3H, ArH), 7.67 (d, 1H, J = 1.68 Hz, ArH), 8.50 (dd, 1H, J = 1.11, 8.16 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.3. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 118.9 (q, $J_{F,C}$ = 321.0 Hz, CF_3), 119.6 (CH), 120.9 (C), 124.3, 125.4, 127.0, 127.2, 129.4, 129.7, 130.0 (CH), 130.1 (C), 132.7 (CH), 135.3, 137.0, 141.1, 145.8, 150.4 (C), 178.5 (CO). IR (KBr): ν = 3083, 3062, 3023, 2917, 2848 (w), 1635, 1606, 1588 (s), 1531 (m), 1506, 1463, 1448 (w), 1423 (s), 1404 (w), 1388 (m), 1345, 1321 (w), 1306 (m), 1277 (w), 1242, 1218 (m), 1189 (s), 1169, 1157 (m), 1135, 1124, 1109 (s), 1081, 1032 (m), 999 (w), 956, 902, 876 (s), 843 (w), 810, 802, 761, 748 (s), 716, 684, 673, 666 (m), 622 (w), 637 (w), 597, 585 (s), 568 (m), 530 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 436 ($[M]^+$, 100), 275 (49), 247 (48), 245 (16). HRMS (ESI): calcd for $C_{20}H_{12}F_3O_4S_2$ $[M+H]^+$: 437.01240; found: 437.01280.

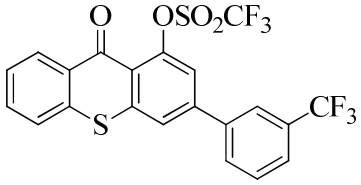


3-(4-Chlorophenyl)-9-oxo-9*H*-thioxanthen-1-yl trifluoromethanesulfonate (5f): Starting with **2** (100 mg, 0.197 mmol), 4-chlorophenylboronic acid **3f** (34 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **5f** was isolated as a yellow solid (72 mg, 78%); reaction temperature: 60°C for 8 h. Mp.133-135°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.34 (d, 1H, J = 0.80 Hz, ArH), 7.42-7.51 (m, 6H, ArH), 7.57 (d, 1H, J = 8.25 Hz, ArH), 7.67 (d, 1H, J = 1.67 Hz, ArH), 8.45 (dd, 1H, J = 1.01, 7.95 Hz, ArH). ^{19}F NMR (282.4 MHz,$CDCl_3$): δ = -73.3. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 118.7 (q, $J_{F,C}$ = 321.1 Hz, CF_3), 119.5 (CH), 121.1 (C), 124.2, 125.4, 127.1, 128.5 (CH), 129.6 (C), 129.7, 130.2, 132.8 (CH), 135.2, 135.5, 136.1, 141.2, 144.5, 150.4



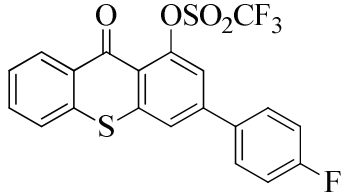
(C), 178.5 (CO). IR (KBr): ν = 3087, 3060, 3023, 2956, 2918, 2849 (w), 1714, 1673, 1668 (w), 1639, 1606, 1590 (s), 1531 (w), 1503 (m), 1463, 1456 (w), 1426 (s), 1380 (m), 1319 (w), 1303 (m), 1276, 1262 (w), 1242 (m), 1219, 1190 (s), 1167, 1159 (w), 1135, 1126 (s), 1112 (w), 1090 (s), 1049, 1033 (w), 1010 (m), 955 (s), 928 (w), 902, 890 (s), 845 (w), 832 (m), 811, 799 (s), 760 (m), 748 (s), 717, 712 (m), 692 (w), 666, 659, 654, 630 (m), 595, 586 (s), 567 (m), 558, 537 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 470 ($[M+H]^+$, 100), 338 (11), 311 (19), 310 (12), 309 (47), 281 (41), 274 (12), 245 (22). HRMS (ESI): calcd for $C_{20}H_{11}F_3ClO_4S_2$ $[M+H]^+$: 470.97340; found: 470.97450.

9-Oxo-3-(3-(trifluoromethyl)phenyl)-9*H*-thioxanthen-1-yl trifluoromethanesulfonate (5g):



Starting with **2** (100 mg, 0.197 mmol), 3-(trifluoromethyl)phenylboronic acid **3g** (41 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **5g** was isolated as a yellow solid (80 mg, 81%); reaction temperature: 60°C for 8 h. Mp.176-177°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.35 (d, 1H, J = 1.14 Hz, ArH), 7.40-7.48 (m, 2H, ArH), 7.54-7.62 (m, 2H, ArH), 7.67-7.74 (m, 3H, ArH), 7.77 (brs, 1H, ArH), 8.52 (dd, 1H, J = 1.11, 8.16 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.3, -62.7. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 118.9 (q, $J_{F,C}$ = 323.9 Hz, CF_3), 119.7 (CH), 121.4 (C), 123.7 (q, $J_{F,C}$ = 272.5 Hz, CF_3), 124.0 (q, $J_{F,C}$ = 3.79 Hz, CH), 124.6, 125.4 (CH), 126.3 (q, $J_{F,C}$ = 3.66 Hz, CH), 127.2, 130.0 (CH), 130.1 (C), 130.2, 130.6 (CH), 131.9 (q, $J_{F,C}$ = 32.5 Hz, C-CF_3), 132.9 (CH), 135.1, 137.9, 141.4, 144.2, 150.4 (C), 178.4 (CO). IR (KBr): ν = 3083, 3062, 3023, 2918, 2851 (w), 1630, 1609, 1589 (s), 1537, 1502, 1461 (w), 1424 (s), 1386 (m), 1336 (s), 1303, 1267, 1240, 1224 (m), 1204 (s), 1166 (m), 1123 (s), 1078, 1066 (m), 1033, 1000 (w), 963 (s), 906, 877 (m), 814, 801 (s), 777 (w), 761, 750 (m), 734 (w), 717, 661 (m), 685 (s), 566, 657, 647, 633, 623 (w), 595 (s), 568 (m), 533 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 503 ($[M]^+$, 46), 375 (42), 311 (100), 283 (15), 242 (27), 214 (16), 186 (29), 158 (13). HRMS (EI, 70 eV): calcd for $C_{21}H_{10}F_6O_4S_2$ $[M]^+$: 503.99192; found: 503.99228.

3-(4-Fluorophenyl)-9-oxo-9*H*-thioxanthen-1-yl trifluoromethanesulfonate (5h): Starting with



2 (100 mg, 0.197 mmol), 4-flourophenylboronic acid **3j** (30 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **5h** was isolated as a yellow solid (71 mg, 80%); reaction temperature: 60°C for 8 h. Mp.179-181°C. ^{1}H

NMR (300 MHz, $CDCl_3$): δ = 7.13 (t, 2H, J = 8.52 Hz ArH), 7.30 (d, 1H, J = 1.02 Hz, ArH), 7.38-7.45 (m, 2H, ArH), 7.49-7.58 (m, 3H, ArH), 7.63 (d, 1H, J = 1.74 Hz, ArH), 8.50 (dd, 1H, J = 0.90, 7.80 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -111.1, -73.3. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 116.5 (d, $J_{F,C}$ = 21.9 Hz, CH), 118.9 (q, $J_{F,C}$ = 321.2 Hz, CF_3), 119.5 (CH), 120.9 (C), 124.1, 125.4, 127.0 (CH), 129.1 (d, $J_{F,C}$ = 8.46 Hz, CH), 130.1, 132.8 (CH), 133.1, 133.2, 135.2, 141.2, 144.7, 150.4 (C), 163.8 (d, $J_{F,C}$ = 250.9 Hz, C-F), 178.8 (CO). IR (KBr): v = 3070, 2953, 2921, 2851 (w), 1637(m), 1591 (s), 1531 (w), 1514 (m), 1488, 1435 (w), 1421 (s), 1383 (m), 1321 (w), 1302 (m), 1281 (w), 1241(m), 1207, 1191 (s), 1163 (m), 1137, 1116 (s), 1079 (m) , 1034, 1014, 993 (w), 957, 903 (s), 876 (m), 854 (w), 838, 810, 792, 754, 741 (s), 715, 665, 659 (m), 636 (w), 590 (s), 569 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 454 ($[M]^+$, 100), 294 (10), 293 (49), 265 (52), 263 (14). HRMS (ESI): calcd for $C_{20}H_{11}F_4O_4S_2$ $[M+H]^+$: 455.00290; found: 455.00300.

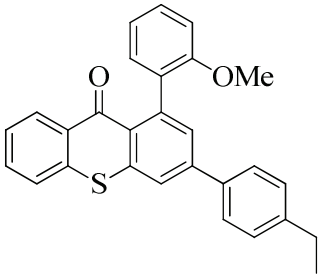
Synthesis of unsymmetrical diarylthioxanthones 6a-d:

***General procedure (A) for Suzuki cross-coupling reactions*:** The reaction was carried out in a pressure tube. To a THF suspension (4-5 mL) of 1,3-bis(triflates) **2 (**100 mg, 0.197 mmol), $Pd(PPh_3)_4$ (5 mol%) and of the $Ar^1B(OH)_2$ (1.1 equiv.), K_3PO_4 (1.5 equiv.) was added. The mixture was heated at the indicated temperature (60°C) under Argon atmosphere for the indicated period of time (8 h) and cooled to room temperature, then diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in *vacuo*. The residue was purified by flash chromatography silica gel (EtOAc/ heptanes). Then to a 1,4-dioxane (4-5 mL) suspension of products 5 (b,c,f)**,** $Pd(PPh_3)_4$ (5 mol%) and of the $Ar^2B(OH)_2$ (1.1 equiv.), K_3PO_4 (1.5 equiv.) was added. The reaction mixture was further heated at (90°C) for (6 h). The reaction mixture was again cooled to room temperature and diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in *vacuo*. The residue was purified by flash chromatography (silica gel, EtOAc/ heptanes).

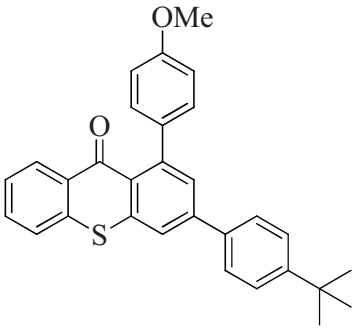
***General procedure (B) for Suzuki cross-coupling reactions*:** The reaction was carried out in a pressure tube. To a THF suspension (4-5 mL) of 1,3-bis(triflates) **2** (100 mg, 0.197 mmol), $Pd(PPh_3)_4$ (5 mol%) and of the $Ar^1B(OH)_2$ (1.1 equiv.), K_3PO_4 (1.5 equiv.) was added. The mixture was heated at the indicated temperature (60°C) under Argon atmosphere for the indicated period of time (8 h) and cooled to room temperature, then $Ar^2B(OH)_2$ (1.1 equiv.) was

added, the reaction mixture was further heated at (90°C) for (6 h). The reaction mixture was again cooled to room temperature and diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in *vacuo*. The residue was purified by flash chromatography (silica gel, EtOAc/ heptanes).

3-(4-Ethylphenyl)-1-(2-methoxyphenyl)-9*H*-thioxanthen-9-one (6a): Starting with **5b** (77 mg, 0.166 mmol), 2-methoxyphenylboronic acid **3a** (28 mg, 0.182 mmol), (10 mg, 5 mol%) K_3PO_4 (53 mg, 0.25 mmol) and 1,4-dioxane (5 mL), *following the general procedure A*, **6a** was isolated as a yellow solid (57 mg, 82%); reaction temperature: 90°C for 6 h. Mp.185-187°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.20 (t, 3H, J = 7.59 Hz CH_3), 2.63 (s, 2H, J =7.59 Hz, CH_2), 3.58 (s, 3H, OCH_3), 6.88 (dd, 1H, J = 0.66, 8.19 Hz, ArH), 7.02 (td, 1H, J = 1.02, 7.44 Hz, ArH), 7.23 (d, 3H, J = 7.68 Hz, ArH), 7.28-7.35 (m, 2H, ArH), 7.42 (d, 1H, J = 1.86 Hz, ArH), 7.46-7.48 (m, 2H, ArH), 7.53 (d, 2H, J = 8.25 Hz, ArH), 7.66 (d, 1H, J = 1.86 Hz, ArH), 8.23 (dt, 1H, J = 0.96, 8.10 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 15.5 (CH_3), 28.6 (CH_2), 55.5 (OCH_3), 110.3, 120.7, 123.2, 125.3, 126.1 (CH), 127.0 (C), 127.3, 128.5, 128.9, 129.1, 129.4, 131.4, 131.5 (CH), 132.7, 136.0, 136.2, 138.0, 142.2, 143.7, 144.9, 156.0 (C), 180.9 (CO). IR (KBr): ν = 3272, 3109, 3061, 3012, 2964, 2865, 2238, 1922, 1899 (w), 1643, 1589 (s), 1538, 1514, 1494, 1461, 1452, 1435 (m), 1385 (w), 1301 (s), 1278 (m), 1241 (s), 1228, 1189, 1180 (w), 1156, 1117, 1074, 1052 (m), 1032 (w), 1020 (s), 964, 938 (w), 925 (m), 896, 871, 838 (w), 826 (s), 802(m), 769 (w), 751, 741, 719 (s), 677, 660 (m), 647, 636, 629, 623, 593, 577, 552 (w), 536 (m) cm^{-1}.GC-MS (EI, 70 eV): m/z (%) = 422 ([M]$^+$, 4), 391 ([M]$^+$, 100), 376 (65). HRMS (EI, 70 eV): calcd for $C_{28}H_{22}O_2S$ [M]$^+$: 422.13350; found: 422.13464.

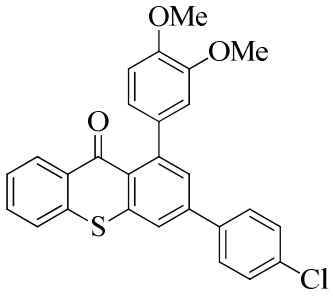


3-(4-(*Tert*-butyl)phenyl)-1-(4-methoxyphenyl)-9*H*-thioxanthen-9-one (6b): Starting with **5c** (73 mg, 0.148 mmol), 4-methoxyphenylboronic acid **3h** (25 mg, 0.163 mmol), $Pd(PPh_3)_4$ (9 mg, 5 mol%), K_3PO_4 (47 mg, 0.22 mmol) and 1,4-dioxane (5 mL), *following the general procedure A*, **6b** was isolated as a yellow solid (53 mg, 79%); reaction temperature: 90°C for 6 h. Mp.178-180°C (CH_2Cl_2/EtOH 1:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.28 (s, 9H, $3CH_3$), 3.79 (s, 3H, OCH_3), 6.89 (d, 2H, J = 8.70 Hz, ArH), 7.19 (d, 2H, J = 8.70 Hz,



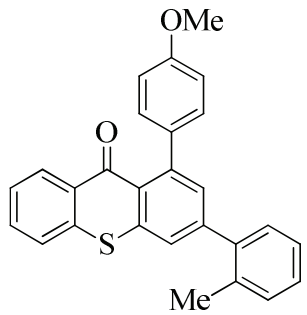
ArH), 7.29-7.34 (m, 1H, ArH), 7.40-7.48 (m, 5H, ArH), 7.54 (d, 2H, J = 8.52 Hz, ArH), 7.65 (d, 1H, J = 1.83 Hz, ArH), 8.27 (dd, 1H, J = 0.75, 8.52 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 31.3 (CH_3), 34.7 (C), 55.2 (OCH_3), 113.4, 122.9, 125.2 (CH), 125.9 (C), 126.0, 126.2, 127.0, 129.1, 129.4, 129.7 (CH), 131.6 (C), 131.7 (CH), 135.7, 135.8, 136.0, 139.0, 143.0, 146.0, 152.0, 158.6 (C), 180.9 (CO). IR (KBr): v = 3092, 3051, 3005, 2950, 2902, 2865, 2830 (w), 1642 (s), 1607 (m), 1587 (s), 1557, 1537 (w), 1507 (s), 1460, 1432 (m), 1415, 1379, 1359, 1316 (w), 1297 (s), 1279 (m), 1238 (s), 1176 (m), 1163 (w), 1152, 1111, 1074, 1028 (m), 1015, 961 (w), 923 (m), 891, 867 (w), 818 (s), 769 (w), 754 (s), 730, 722 (m), 709 (w), 675 (m), 653, 633, 611 (w), 573, 542 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 450 ([M]$^+$, 77), 449 ([M-H]$^+$, 100). HRMS (ESI): calcd for $C_{30}H_{27}O_2S$ [M+H]$^+$: 451.17260; found: 451.17250.

3-(4-Chlorophenyl)-1-(3,4-dimethoxyphenyl)-9*H*-thioxanthen-9-one (6c): Starting with **5f** (72



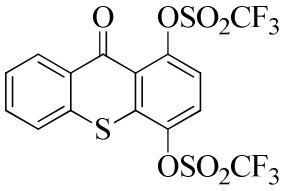
mg, 0.153 mmol), 3,4-dimethoxyphenylboronic acid **3k** (31 mg, 0.168 mmol), $Pd(PPh_3)_4$ (9 mg, 5 mol%), K_3PO_4 (49 mg, 0.23 mmol) and 1,4-dioxane (5 mL), *following the general procedure A*, **6c** was isolated as a yellow solid (50 mg, 71%); reaction temperature: 90°C for 6 h. Mp.168-170°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.79 (s, 3H, OCH_3), 3.87 (s, 3H, OCH_3), 6.77 (d, 1H, J = 1.86 Hz, ArH), 6.81 (dd, 1H, J = 1.92, 8.16 Hz, ArH), 6.88 (d, 1H, J = 8.16 Hz, ArH), 7.32-7.39 (m, 4H, ArH), 7.48-7.55 (m, 4H, ArH), 7.62 (d, 1H, J = 1.9 Hz, ArH), 8.25 (dd, 1H, J = 0.84, 8.70 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 54.8, 54.9 (OCH_3), 109.7, 110.7, 119.1, 122.0, 124.3, 125.4, 127.6, 128.1, 128.3, 128.6 (CH), 130.7 (C), 130.9 (CH), 134.0, 134.7, 134.8, 136.1, 138.1, 141.1, 145.5, 147.2, 147.5 (C), 179.8 (CO). IR (KBr): v = 3052, 2989, 2957, 2925, 2850, 2829, 2247 (w), 1643 (s), 1609 (w), 1589 (m), 1537(w), 1513, 1491, 1469, 1462, 1454, 1434, 1417 (m), 1401, 1372, 1331 (w), 1296 (m), 1281 (w), 1257, 1240, 1216, 1185, 1170, 1153, 1136, 1122, 1102, 1092, 1077, 1056 (m), 1027, 1013 (s), 952, 932 (w), 909, 894, 875, 863 (m), 841 (w), 825 (m), 816 (s), 804, 789, 761 (m), 747, 721 (s), 683, 662, 652, 646, 629, 618, 600, 583, 541 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 458 ([M]$^+$, 100), 457 ([M-H]$^+$, 74), 443 (24), 371 (17), 214 (14). HRMS (EI, 70 eV): calcd for $C_{27}H_{19}ClO_3S$ [M]$^+$: 458.07379; found: 458.074006.

1-(4-Methoxyphenyl)-3-(o-tolyl)-9*H*-thioxanthen-9-one (6d): Starting with **2** (100 mg, 0.197 mmol), 2-methylphenylboronic acid **3l** (29 mg, 0.22 mmol), 4-methoxyphenylboronic acid **3h** (34 mg, 0.22 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and 1,4-dioxane (5 mL), *following the general procedure B*, **6d** was isolated as a yellow solid (60 mg, 75%); reaction temperature: at 60°C for 8 h, at 90°C for 6 h. Mp.168-170°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.37 (s, 3H, CH_3), 3.77 (s, 3H, OCH_3), 6.88 (d, 2H, J = 8.73 Hz, ArH), 7.17-7.23 (m, 7H, ArH), 7.31-7.36 (m, 1H, ArH), 7.42 (d, 1H, J =1.74 Hz, ArH), 7.47-7.52 (m, 2H, ArH), 8.28 (dd, 1H, J = 0.84, 8.64 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 20.4 (CH_3), 55.2 (OCH_3), 113.4, 125.2, 125.4 (CH), 125.9 (C), 126.1, 126.3, 128.3, 129.2, 129.5, 129.7, 130.7 (CH), 131.7 (C), 131.8, 131.9 (CH), 135.3, 135.5, 135.9, 138.4, 139.6, 144.8, 145.6, 158.6 (C), 181.2 (CO). IR (KBr): ν = 3399, 3057, 2950, 2928, 2861, 2834 (w), 1641 (s), 1607 (m), 1588 (s), 1536(w), 1508 (s), 1489, 1461 (w), 1435 (m), 1409, 1384, 1316 (w), 1295 (m), 1241 (s), 1175, 1156 (m), 1115, 1077, 1053 (w), 1032 (m), 962 (w), 923 (m), 879, 894(w), 826 (s), 808, 786, 769 (w), 755, 723 (s), 680, 667 (m), 643, 613 (w), 573 (m), 556, 536 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 408 ($[M]^+$, 70), 407 ($[M-H]^+$, 100). HRMS (EI, 70 eV): calcd for $C_{27}H_{20}O_2S$ $[M]^+$: 408.11785; found: 408.11643.



Site-Selective Suzuki-Miyaura Cross-Coupling Reactions of the Bis(triflate) of 1,4-Dihydroxythioxanthone

Synthesis of 9-oxo-9H-thioxanthene-1,4-diyl bis(trifluoromethanesulfonate) (8): To a solution of **7** (0.40 g, 1.63 mmol) in CH_2Cl_2 (20 mL) was added a mixture base from Et_3N and pyridine 1:2 (0.34 mL, 2.46 mmol of Et_3N and 0.40 mL, 4.10 mmol of pyridine), at 20 °C under an argon atmosphere. After stirring for 10 min at -78°C, Tf_2O (0.66 mL, 3.91mmol) was added. The mixture was allowed to warm to 20°C and stirred for further 8 h. The reaction mixture was filtered and the filtrate was concentrated in vacuo. The residue was chromatographed without work up (flash silica gel, heptanes-EtOAc) and **8** was isolated as a yellow solid (0.72 g, 86.7%), Mp.140-142°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.29 (d, 1H, J = 8.91 Hz, ArH), 7.48-7.58 (m, 2H, ArH), 7.62-7.67 (m, 2H, ArH), 8.50 (dd, 1H, J = 1.41, 8.10 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.2, -73.9. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 118.5, 118.7 (q, $J_{F,C}$ = 317.6, 321.0 Hz, CF_3), 120.9 (CH), 124.2 (C), 124.8, 126.1, 128.0 (CH), 129.5 (C), 130.2 (CH), 133.2 (C), 133.5 (CH), 135.2, 143.4, 148.7 (C), 178.0 (CO). IR

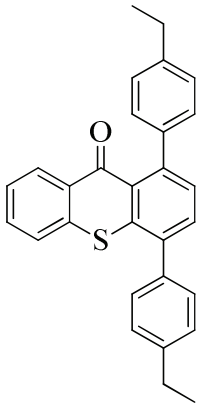


(KBr): ν = 3080, 2961, 2904 (w), 1649, 1592 (w), 1429 (m), 1412, 1388, 1318, 1302 (w), 1257 (s), 1236, 1216, 1199 (m), 1078, 1010 (s), 907, 882, 850 (m), 789, 758 (s), 740 (m), 691, 673, 660, 646, 620, 607 (w), 589 (m), 569, 529 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 508 ($[M+H]^+$, 43), 375 (40), 311 (100), 311 (100), 283 (14), 242 (27). HRMS (EI, 70 eV): calcd for $C_{15}H_6F_6O_7S_3$ $[M]^+$: 507.91744; found: 507.91799.

***General procedure for Suzuki–Miyaura cross-coupling reactions*:** A THF solution (4-5 mL), K_3PO_4 (1.5 equiv. per cross-coupling), $Pd(PPh_3)_4$ (5 mol% per cross-coupling) and arylboronic acid **3** (1.1 equiv. per cross-coupling) was stirred at 65-90°C for 8 h. After cooling to 20°C, distilled H_2O was added. The organic and the aqueous layers were separated and the latter was extracted with CH_2Cl_2. The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purified by column chromatography (flash silica gel, heptanes-EtOAc).

Synthesis of 1,4-diarylthioxanthones 9a-f :

1,4-Bis(4-ethylphenyl)-9*H*-thioxanthen-9-one (9a): Starting with **8** (100 mg, 0.197 mmol), 4-ethylphenylboronic acid **3b** (71 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **9a** was isolated as a yellow solid (66 mg, 80%); reaction temperature: 90°C for 8 h. Mp.130-132°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.25-1.31 (m, 6H, $2CH_3$), 2.64-2.75 (m, 4H, $2CH_2$), 7.12-7.18 (m, 2H, ArH), 7.21-7.31 (m, 5H, ArH), 7.33-7.47 (m, 6H, ArH), 8.19 (dd, 1H, J = 1.20, 8.19 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 14.2, 14.4 ($2CH_3$), 27.6, 27.7 ($2CH_2$), 124.5, 125.1 (CH), 125.9 (C), 126.5, 126.9, 127.1, 128.2, 128.6, 128.8 (CH), 130.2 (C), 130.6, 131.0 (CH), 134.8, 135.4, 136.5, 137.7, 139.7, 141.4, 143.7, 143.8 (C), 181.2 (CO) . IR (KBr): ν = 3270, 3053, 3024, 2961, 2929, 2872 (w), 1730 (m), 1642 (s), 1610 (w), 1589 (m), 1547, 1511, 1494, 1474, 1462 (w), 1433 (s), 1408, 1377, 1358 (w), 1304, 1273, 1250, 1215 (m), 1184, 1160, 1137, 1115 (w), 1080, 1072 (m), 1045, 1027 (w), 1013 (m), 970, 934, 886 (w), 822,757, 734 (s), 717, 690 (m), 651 (w), 640 (m), 612, 602 (w), 534 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 420 ($[M]^+$, 61), 419 ($[M-H]^+$, 100), 404 (12), 391 (13). HRMS (EI, 70 eV): calcd for $C_{29}H_{23}OS$ $[M-H]^+$: 419.14641; found: 419.14575.

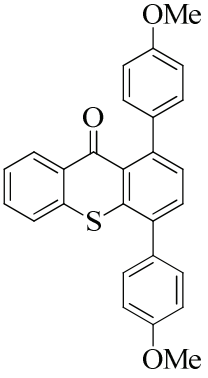


1,4-Bis(4-(*tert*-butyl)phenyl)-9*H*-thioxanthen-9-one (9b): Starting with **8** (100 mg, 0.197 mmol), 4-*tert*-butylphenylboronic acid **3c** (84 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **9b** was isolated as a yellow solid (78 mg, 83%); reaction temperature: 90°C for 8 h. Mp.108-110°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.33 (s, 9H, $3CH_3$), 1.35 (s, 9H, $3CH_3$), 7.20-7.31 (m, 3H, ArH), 7.35-7.45 (m, 8H, ArH), 7.47 (d, 2H, J = 8.29 Hz, ArH), 8.20 (dd, 1H, J = 1.17, 9.57 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 30.4, 30.5 (CH_3), 33.5, 33.8 (C), 123.9, 124.4, 124.6, 125.0, 126.6 (CH), 127.1 (C), 128.1, 128.2, 128.9 (CH), 130.2 (C), 130.6, 131.0 (CH), 134.6, 135.4, 136.4, 137.6, 139.4, 143.7, 148.2, 150.5 (C), 181.2 (CO. IR (KBr): ν = 3025, 2959, 2902, 2866, 2712, 2257, 1909, 1726 (w), 1638 (s), 1614 (w), 1589 (m), 1563, 1543 (w), 1509, 1461 (m), 1433 (s), 1392, 1360 (w), 1308 (m), 1289 (w), 1267, 1256 (m), 1237 (w), 1212, 1203 (m), 1168, 1161, 1138 (w), 1112 (m), 1105, 1080, 1047, 1025 (w), 1014 (m), 973, 961, 935 (w), 917, 905, 847 (m), 835 (w), 821 (s), 801, 759, 748 (m), 724 (s), 700, 687, 666 (w), 648 (m), 625, 611, 604, 590 (w), 568 (s) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 476 ([M]$^+$, 81), 475 ([M-H]$^+$, 100), 461 (51), 419 (14). HRMS (EI, 70 eV): calcd for $C_{33}H_{31}OS$ [M-H]$^+$: 475.20901; found: 475.20877.

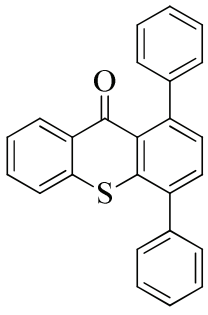
1,4-Di-*p*-tolyl-9*H*-thioxanthen-9-one (9c): Starting with **8** (100 mg, 0.197 mmol), 4-methylphenylboronic acid **3e** (64 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **9c** was isolated as a yellow solid (65 mg, 84%); reaction temperature: 90°C for 8 h. Mp.160-162°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.35 (s, 3H, CH_3), 2.39 (s, 3H, CH_3), 7.14-7.15 (m, 4H, ArH), 7.21-7.32 (m, 6H, ArH), 7.34-7.41 (m, 3H, ArH), 8.18 (dd, 1H, J =1.18, 7.93 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 20.3, 20.4 ($2CH_3$), 124.4, 125.1, 126.8 (CH), 127.1 (C), 127.7, 128.1, 128.4, 128.5, 128.7 (CH), 130.2 (C), 130.6, 130.9 (CH), 134.6, 135.2, 135.4, 136.5, 137.4, 137.7, 139.6, 143.8 (C), 181.1 (CO). IR (KBr): ν = 3271, 3027, 2961, 2914, 2859, 2726, 2253 (w), 1642 (s), 1615 (w), 1589 (s), 1574, 1557, 1494, 1547 (w), 1512 (m), 1463 (w), 1434 (s) , 1378, 1358 (w), 1305 (s), 1285 (w), 1250, 1234, 1204 (m) , 1183, 1159, 1139 (w), 1107 (m) , 1080, 1070, 1045, 1033 (w), 1016 (m), 971, 956, 934, 917, 896, 864, 848, 838 (w), 805 (s), 773 (w), 758, 736, 728 (s), 688, 661, 650 (w), 642 (m), 627, 621, 613, 601, 585 (w), 556 (m), 544

(w), 530 (s) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 392 ($[M]^+$, 56), 391 ($[M-H]^+$, 100). HRMS (EI, 70 eV): calcd for $C_{27}H_{19}OS$ $[M-H]^+$: 391.11511; found: 391.11509.

1,4-Bis(4-methoxyphenyl)-9*H*-thioxanthen-9-one (9d): Starting with **8** (100 mg, 0.197 mmol), 4-methoxyphenylboronic acid **3h** (72 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **9d** was isolated as a yellow solid (77 mg, 92%); reaction temperature: 90°C for 8 h. Mp.193-194°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 3.83 (s, 3H, OCH_3), 3.84 (s, 3H, OCH_3), 6.89 (d, 2H, J = 8.66 Hz, ArH), 6.98 (d, 2H, J = 8.66 Hz, ArH), 7.16-7.25 (m, 3H, ArH), 7.28-7.49 (m, 6H, ArH), 8.19 (dd, 1H, J = 1.02, 8.01 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 55.2, 55.4 ($2OCH_3$), 113.5, 114.0, 125.5, 126.2 (CH), 128.1(C), 129.1, 129.2, 129.8 (CH), 130.8 (C), 130.9 (CH), 131.3 (C), 131.7, 132.1(CH), 135.8, 136.4, 137.8, 138.4, 144.4, 158.5, 159.8 (C), 182.4 (CO) . IR (KBr): ν = 3061, 3031, 3004, 2952, 2921, 2852, 2834, 2537, 2350, 2285, 2252, 2052, 1907 (w), 1634, 1606, 1589 (s), 1575 (m), 1556, 1547 (w), 1509 (s), 1462 (m), 1432 (s), 1409, 1377, 1358 (w), 1310, 1302, 1287 (m), 1239 (s), 1193 (m), 1174 (s), 1117 (w), 1105 (m), 1081, 1049 (w), 1026 (s), 1008, 965, 935, 927, 918, 903, 877, 864, 832 (w), 815 (s), 788, 773 (w), 759, 724 (s), 689 (w), 662, 651, 644 (m), 629, 609, 594 (w), 569 (m), 542 (s) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 425 ($[M+H]^+$, 51), 424 ($[M]^+$, 99), 423 ($[M-H]^+$, 100), 380 (11). HRMS (EI, 70 eV): calcd for $C_{27}H_{20}O_3S$ $[M]^+$: 424.11277; found: 424.11145.



1,4-Diphenyl-9*H*-thioxanthen-9-one (9e): Starting with **8** (100 mg, 0.197 mmol), phenylboronic acid **3i** (57 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **9e** was isolated as a yellow solid (65 mg, 91%); reaction temperature: 90°C for 8 h. Mp.193-195°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.27 (t, 4H, J = 7.50 Hz, ArH), 7.31-7.36 (m, 4H, ArH), 7.38-7.47 (m, 7H, ArH), 8.18 (dd, 1H, J = 1.05, 8.04 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 124.5, 125.2, 125.5, 126.8, 126.9 (CH), 127.0 (C), 127.6, 127.7, 128.2, 128.6, 128.7 (CH), 130.1 (C), 130.7, 130.9 (CH), 135.3, 136.5, 137.5, 137.9, 142.5, 144.0 (C), 180.9 (CO). IR (KBr): ν = 3269, 3077, 3055, 3045, 3023, 2917, 2849 (w), 1638 (s), 1622 (m), 1589 (s), 1574 (w), 1548 (m) , 1519, 1514 (w) , 1491 (m), 1462 (w), 1441 (m), 1429 (s), 1358 (w), 1313, 1306 (s), 1286, 1251, 1235 (m), 1177 (w), 1163, 1115, 1076, 1069, 1049 (m), 1033 (w), 1022 (m), 1001, 975, 961 (w), 934 (m), 908, 875, 717, 690, 852



(w), 838, 823 (m), 811, 767 (w), 752, 730, 692 (s), 652, 638, 619, 609, 604 (m), 548 (w), 530 (s) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 364 ($[M]^+$, 50), 363 (($[M-H]^+$, 100). HRMS (EI, 70 eV): calcd for $C_{25}H_{15}OS$ $[M-H]^+$: 363.08381; found: 363.08337.

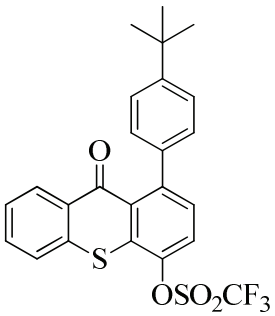
1,4-Bis(4-fluorophenyl)-9*H*-thioxanthen-9-one (9f): Starting with **8** (100 mg, 0.197 mmol), 4-flourophenylboronic acid **3j** (66 mg, 0.47 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **9f** was isolated as a yellow solid (65 mg, 82%); reaction temperature: 90°C for 8 h. Mp.186-188°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.04 (t, 2H, J = 8.76 Hz, ArH), 7.14 (d, 2H, J = 8.70 Hz, ArH), 7.17-7.23 (m, 3H, ArH), 7.27-7.51 (m, 6H, ArH), 8.18 (dd, 1H, J = 1.05, 8.61 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -115.9, -112.6. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 113.9 (d, $J_{F,C}$ = 21.5 Hz, CH), 114.8 (d, $J_{F,C}$ = 21.7 Hz, CH), 124.5, 125.4 (CH), 127.1 (C), 128.2 (CH), 128.4 (d, $J_{F,C}$ = 7.87 Hz, CH), 128.7 (CH), 129.9 (C), 130.4 (d, $J_{F,C}$ = 8.27 Hz, CH), 130.9, 131.0 (CH), 133.3 (d, $J_{F,C}$ = 3.35 Hz, C), 135.0, 136.8, 137.1 (C), 138.3 (d, $J_{F,C}$ = 3.61 Hz, C), 143.1 (C), 160.7 (d, $J_{F,C}$ = 245.5 Hz, C-F), 161.9 (d, $J_{F,C}$ = 248.6 Hz, C-F), 180.8 (CO). IR (KBr): ν = 3072, 3045, 2961, 2920, 2850 (w), 1639 (s), 1600 (m), 1590 (s), 1558, 1550 (w), 1506 (s), 1463 (w), 1434 (s), 1406, 1359 (w), 1307 (m), 1288, 1279, 1259 (w), 1220 (s), 1168 (w), 1157, 1090 (m), 1070, 1043, 1033 (w), 1013 (m), 961 (w), 931 (m), 866 (w), 845 (m), 823, 797 (s), 785 (m), 760, 738 (s), 688 (w), 660, 650, 641 (m), 630, 608 (w), 591 (m), 553, 533 (s) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 400 ($[M]^+$, 59), 399 ($[M-H]^+$, 100). HRMS (EI, 70 eV): calcd for $C_{25}H_{31}F_2OS$ $[M-H]^+$: 399.06497; found: 399.06452.

Synthesis of 1-Aryl-4-(trifluorosulfonyloxy)-thioxanthones 10a-i:

1-(4-Ethylphenyl)-9-oxo-9*H*-thioxanthen-4-yltrifluoromethanesulfonate (10a): Starting with **8** (100 mg, 0.197 mmol), 4-ethylphenylboronic acid **3b** (32 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10a** was isolated as a yellow solid (82 mg, 90%); reaction temperature: 65°C for 8 h. Mp.196-198°C (CH_2Cl_2/EtOH 1:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.23 (t, 3H, J = 7.6 Hz, CH_3), 2.67 (q, 2H, J = 7.6 Hz, CH_2), 7.10 (d, 2H, J = 8.20 Hz, ArH), 7.15-7.20 (m, 2H, ArH), 7.25 (d, 1H, J = 8.4 Hz, ArH), 7.27-7.41 (m, 1H, ArH), 7.49-7.54 (m, 3H, ArH), 8.19 (dd, 1H, J = 0.99, 8.10 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.1. ^{13}C NMR

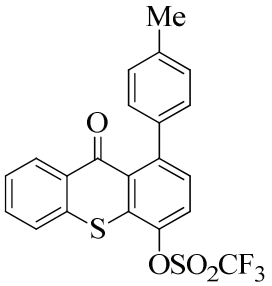
(75.5 MHz, $CDCl_3$): δ = 14.2 (CH_3), 27.6 (CH_2), 117.6 (q, $J_{F,C}$ = 318.7 Hz, CF3), 122.1, 124.8, 126.1, 126.6, 126.7 (CH), 128.2 (C), 128.6, 129.1 (CH), 130.0 (C), 131.4 (CH), 132.8, 138.1, 142.2, 142.4, 145.0, 179.3 (CO). IR (KBr): ν = 3060, 3028, 2960, 2928, 2870, 2852 (w), 1644 (s), 1614 (w), 1593, 1580 (m), 1555, 1511, 1454 (w), 1430 (s), 1372, 1316 (w), 1303 (m), 1274, 1260 (w), 1247 (m), 1219, 1205, 1186 (s), 1160 (m), 1134 (s), 1114, 1079, 1049, 1034, 1017, 971 (m), 883 (s), 857, 836, 831 (m), 802, 756, 739 (s), 724 (m), 693, 666, 652 (w), 640 (s), 632 (m), 603, 590 (s), 566, 535 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 464 ($[M]^+$, 26), 331 (100), 302 (89), 274 (24). HRMS (EI, 70 eV): calcd for $C_{22}H_{15}F_3O_4S_2$ $[M]^+$: 464.03584; found: 464.03664.

1-(4-(*Tert*-butyl)phenyl)-9-oxo-9*H*-thioxanthen-4-yltrifluoromethanesulfonate(10b): Starting

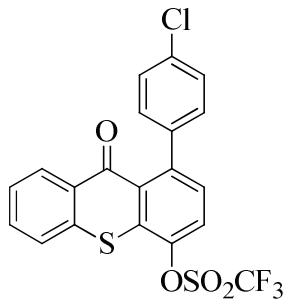


with **8** (100 mg, 0.197 mmol), 4-*tert*-butylphenylboronic acid **3c** (39 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10b** was isolated as a yellow solid (74 mg, 76%); reaction temperature: 65°C for 8 h. Mp.181-183°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.32 (s, 9H, $3CH_3$), 7.13 (d, 2H, J = 8.48 Hz, ArH), 7.27 (d, 1H, J = 8.48 Hz, ArH), 7.35-7.39 (m, 3H, ArH), 7.52 (d, 1H, J = 8.48 Hz, ArH), 7.55-7.60 (m, 2H, ArH), 8.22 (dd, 1H, J = 0.99, 8.07 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.1. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 30.4 ($3CH_3$), 33.6 (C), 117.6 (q, $J_{F,C}$ = 320.8 Hz, CF_3), 122.1, 123.9, 124.8, 126.1, 126.5 (CH), 128.2 (C), 128.6, 129.3 (CH), 130.1 (C), 131.4 (CH), 132.8, 137.8, 142.4, 145.0, 149.1 (C), 179.4 (CO). IR (KBr): ν = 3106, 3071, 3027, 2959, 2903, 2865 (w), 1643 (s), 1614 (w), 1591, 1582 (m), 1507, 1474, 1461 (w), 1419 (s), 1373, 1316 (w), 1305 (m), 1283, 1263, 1247, 1238 (w), 1214 (s), 1187 (m), 1269, 1160 (w), 1130 (s), 1115 (m), 1078, 1052, 1035,1014 (w), 972 (m), 906 (w), 884 (s), 854 (w), 844, 821 (m), 796 (s), 765 (w), 758 (m), 747 (w), 735 (s), 720 (m), 686, 666, 653, 632 (w), 603 (s), 593 (m), 573, 564 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 492 ($[M]^+$, 41), 477 (13), 359 (68), 344 (23), 303 (63), 302 (100), 274 (15). HRMS (EI, 70 eV): calcd for $C_{24}H_{19}F_3O_4S_2$ $[M]^+$: 492.06714; found: 492.06628.

9-Oxo-1-(*p*-tolyl)-9*H*-thioxanthen-4-yl trifluoromethanesulfonate (10c): Starting with **8** (100 mg, 0.197 mmol), 4-methylphenylboronic acid **3e** (30 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10c** was isolated as a yellow solid (77 mg, 87%); reaction temperature: 65°C for 8 h. Mp.130-132°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.37 (s, 3H, CH_3), 7.09 (d, 2H, J = 8.16 Hz, ArH), 7.16-7.19 (m, 2H, ArH), 7.25 (d, 1H, J = 8.61 Hz, ArH), 7.35-7.42 (m, 1H, ArH), 7.52-7.57 (m, 3H, ArH), 8.22 (d, 1H, J = 8.16 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.1. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 21.37 (CH_3), 118.6 (q, $J_{F,C}$ = 320.7 Hz, CF_3), 123.1, 125.9, 127.2, 127.7, 128.9 (CH), 129.2 (C), 129.6, 130.1 (CH), 131.1 (C), 132.4 (CH), 132.5, 133.8, 137.1, 138.9, 143.4, 146.1 (C), 180.4 (CO). IR (KBr): ν = 3290, 3090, 3055, 3028, 2953, 2921, 2850, 2666 (w), 1652 (s), 1614 (w), 1589, 1582 (m), 1552, 1515, 1463 (w), 1436 (m), 1424 (s), 1407 (m), 1312 (w), 1301, 1294, 1248 (m), 1206, 1190 (s), 1166 (w), 1157 (m), 1137, 1131 (s), 1109 (m), 1076, 1050, 1034, 1017 (w), 968 (m), 945, 934 (w), 883 (s), 872 (m), 851 (w), 834, 801 (s), 780 (m), 760, 732 (s), 689, 675, 649, 639 (w), 618, 601, 590 (s), 571 (m), 563, 552 (w), 533 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 450 ($[M]^+$, 43), 317 (100), 302 (78), 274 (17). HRMS (EI, 70 eV): calcd for $C_{21}H_{13}F_3O_4S_2$ $[M]^+$: 450.02019; found: 450.01967.

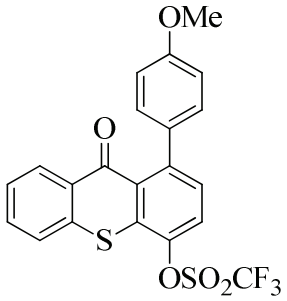


1-(4-Chlorophenyl)-9-oxo-9*H*-thioxanthen-4-yl trifluoromethanesulfonate (10d): Starting with **8** (100 mg, 0.197 mmol), 4-chlorophenylboronic acid **3f** (34 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10d** was isolated as a yellow solid (78 mg, 84%); reaction temperature: 65°C for 8 h. Mp.133-135°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.12 (d, 2H, J = 8.45 Hz, ArH), 7.22 (d, 1H, J = 8.45 Hz, ArH), 7.33 (d, 2H, J = 8.45 Hz, ArH), 7.38-7.43 (m, 1H, ArH), 7.54-7.61 (m, 3H, ArH), 8.22 (d, 1H, J = 8.12 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.1. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 118.6 (q, $J_{F,C}$ = 320.8 Hz, CF_3), 123.3, 126.0, 127.3, 128.4, 129.1, 129.7, 129.9 (CH), 130.7, 131.2 (C), 132.7 (CH), 132.9, 133.4, 133.8, 140.4, 143.8, 144.7 (C), 180.1 (CO). IR (KBr): ν = 3281, 3097, 3066, 2922, 2853, 2667, 2554 (w), 1649 (s), 1614 (w), 1588 (m), 1568, 1551, 1492, 1464, 1455 (w), 1424 (s), 1407, 1397 (m), 1377, 1315 (w), 1302, 1294 (m), 1277, 1247, 1238 (w), 1223, 1205, 1209, 1188 (s), 1158 (m), 1135, 1129 (s), 1090, 1077 (m), 1048, 1035 (w), 1012, 971 (m), 881 (s), 871 (m), 847, 834 (m), 815, 805, 759 (s), 739 (w), 734 (s), 711, 686, 665 (w), 647, 631 (m), 615, 601 (s), 588 (m), 568, 555,



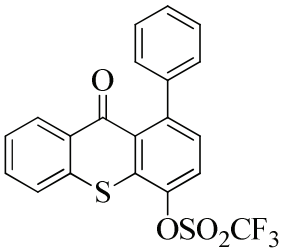
538 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 470 ($[M+H]^+$, 38), 337 (100), 302 (68), 274 (26), 245 (14). HRMS (EI, 70 eV): calcd for $C_{20}H_{10}F_3ClO_4S_2$ $[M]^+$: 469.96556; found: 469.96474.

1-(4-Methoxyphenyl)-9-oxo-9*H*-thioxanthen-4-yl trifluoromethanesulfonate (10e): Starting



with **8** (100 mg, 0.197 mmol), 4-methoxyphenylboronic acid **3h** (33 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10e** was isolated as a yellow solid (74 mg, 81%); reaction temperature: 65°C for 8 h. Mp.162-164°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.79 (s, 3H, OCH_3), 6.89 (d, 2H, J = 8.31 Hz, ArH), 7.12 (d, 2H, J = 8.31 Hz, ArH), 7.25 (d, 1H, J = 8.31 Hz, ArH), 7.35-7.41 (m, 1H, ArH), 7.50-7.56 (m, 3H, ArH), 8.21 (d, 1H, 8.31 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.1. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ= 54.2 (OCH_3), 112.6 (CH),117.6 (q, $J_{F,C}$ = 320.9 Hz, CF_3), 122.1, 124.8, 126.1, 128.0 (CH), 128.1 (C), 128.6, 129.1 (CH), 130.1 (C), 131.4 (CH), 131.5, 132.8, 133.0, 142.3, 144.7, 158.0 (C), 179.5 (CO). IR (KBr): ν = 3290, 3104, 3071, 3034, 2996, 2950, 2934, 2907, 2853, 2833, 1682 (w), 1652 (s), 1607 (w), 1589, 1589 (m), 1567, 1552 (w), 1513 (m), 1464, 1455 (w), 1424 (s), 1375, 1353, 1314 (w), 1303, 1295 (m), 1271 (w), 1248, 1241 (m), 1224, 1202, 1191, 1178 (s), 1164, 1157 (w), 1131 (s), 1108 (m), 1078, 1055, 1035 (w), 1026, 972 (m), 885 (s), 846 (m), 832 (w), 819, 807 (s), 779 (w), 761, 734 (s), 690, 673 (w), 650, 643 (m), 619, 599, 592 (s), 574, 544 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 466 ($[M]^+$, 36), 333 (100), 302 (31), 274 (10). HRMS (EI, 70 eV): calcd for $C_{21}H_{13}F_3O_5S_2$ $[M]^+$: 466.01510; found: 466.05129.

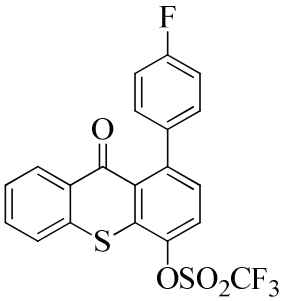
9-Oxo-1-phenyl-9*H*-thioxanthen-4-yl trifluoromethanesulfonate (10f): Starting with **8** (100



mg, 0.197 mmol), phenylboronic acid **3i** (27 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10f** was isolated as a yellow solid (76 mg, 88%); reaction temperature: 65°C for 8 h. Mp.178-180°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.17-7.21 (m, 1H, ArH), 7.26 (d, 2H, J = 8.37 Hz, ArH), 7.35-7.42 (m, 4H, ArH), 7.53-7.57 (m, 3H, ArH), 8.21 (dd, 1H, J = 0.90, 8.01 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.1. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 117.6 (q, $J_{F,C}$ = 318.8 Hz, CF_3), 122.1, 124.9, 126.2, 126.3, 126.7, 127.1 (CH), 128.2 (C), 128.6, 129.0 (CH), 129.9 (C), 131.5 (CH), 131.6, 132.8, 140.9, 142.5, 145.0 (C), 179.2 (CO). IR (KBr): ν = 3274, 3064, 2960, 1901 (w), 1667 (w), 1645 (s), 1622 (w), 1587 (m), 1552, 1493, 1461 (m), 1427 (s), 1409

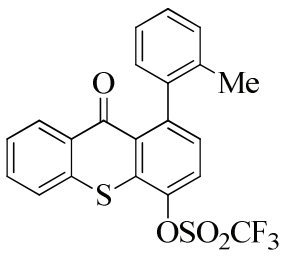
(m), 1315, 1305 (w), 1292 (m), 1260, 1251 (w), 1227, 1207, 1187 (s), 1158 (m), 1129 (s), 1112, 1079, 1054, 1034, 1020, 971 (m), 912 (w), 879 (s), 861 (w), 842 (s), 821 (w), 799 (s), 768 (m), 756 (s), 738, 732, 701, 695, 680 (m), 651 (w), 637 (m), 616 (w), 598 (s), 569, 554 (w), 535 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 436 ($[M]^+$, 36), 303 (100), 302 (45), 274 (38), 245 (12). HRMS (EI, 70 eV): calcd for $C_{20}H_{11}F_3O_4S_2$ $[M]^+$: 436.00454; found: 436.00406.

1-(4-Fluorophenyl)-9-oxo-9*H*-thioxanthen-4-yl trifluoromethanesulfonate (10g): Starting



with **8** (100 mg, 0.197 mmol), 4-flourophenylboronic acid **3j** (31 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10g** was isolated as a yellow solid (73 mg, 82%); reaction temperature: 65°C for 8 h. Mp.157-159°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.05 (t, 2H, J = 8.73 Hz, ArH), 7.12-7.18 (m, 2H, ArH), 7.23 (d, 1H, J = 8.21 Hz, ArH), 7.37-7.43 (m, 1H, ArH), 7.53-7.61 (m, 3H, ArH), 8.21 (d, 1H, J = 8.10 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -114.9, -73.1. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 114.1 (d, $J_{F,C}$ = 21.6 Hz, CH), 117.6 (q, $J_{F,C}$ = 320.9 Hz, CF_3), 122.2, 124.9, 126.3 (CH), 128.1(C), 128.4(d, $J_{F,C}$ = 7.98 Hz, CH), 128.6, 129.0 (CH), 129.7 (C), 131.6 (CH), 131.8, 132.8 (C), 136.7 (d, $J_{F,C}$ = 3.45 Hz, C), 142.7, 143.9 (C), 161.2 (d, $J_{F,C}$ = 245.4 Hz, C-F), 179.1 (CO). IR (KBr): ν = 3068, 3044, 2957, 2917, 2848 (w), 1649 (s), 1620, 1601 (w), 1589 (m), 1567, 1551 (w), 1510 (m), 1463 (w), 1429 (s), 1408 (m), 1370, 1316, 1303, 1293, 1248 (w), 1213 (s), 1188, 1156 (m), 1129 (s), 1092, 1078, 1048, 1034, 1012 (w), 972 (m), 883 (s), 871, 843 (m), 832 (s), 815 (m), 804 (s), 791 (m), 761 (s), 741 (w), 733 (m), 690, 674 (w), 650, 639 (m), 617, 598 (s), 588, 571 (m), 563, 549 (w), 537 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 454 ($[M+H]^+$, 33), 321 (100), 292 (42), 263 (13). HRMS (EI, 70 eV): calcd for $C_{20}H_{10}F_4O_4S_2$ $[M]^+$: 453.99511; found: 453.99530.

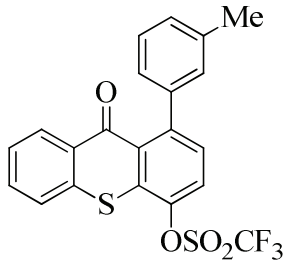
9-Oxo-1-(o-tolyl)-9*H*-thioxanthen-4-yl trifluoromethanesulfonate (10h): Starting with **8** (100



mg, 0.197 mmol), 2-methylphenylboronic acid **3l** (30 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10h** was isolated as a yellow solid (67 mg, 76%); reaction temperature: 65°C for 8 h. Mp.100-102°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.95 (s, 3H, CH_3), 6.97 (d, 1H, J = 7.23 Hz, ArH), 7.17 (d, 1H, J = 3.51 Hz, ArH), 7.19-7.29 (m, 3H, ArH), 7.33-7.39 (m, 1H, ArH), 7.54-7.58 (m, 3H, ArH), 8.22 (dd, 1H, J = 8.11 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.1. ^{13}C NMR (75.5 MHz,

$CDCl_3$): δ = 20.2 (CH_3), 118.6 (q, $J_{F,C}$ = 320.9 Hz, CF_3), 123.4, 125.6, 126.0, 127.2, 127.3, 127.4 (CH), 129.4 (C), 129.5, 129.6, 129.8 (CH), 130.3, 132.4 (C), 132.6 (CH), 133.9, 134.6, 141.9, 143.6, 145.5 (C), 179.6 (CO). IR (KBr): ν = 3292, 3063, 3018, 2953, 2922, 2857 (w), 1650 (s), 1592 (m), 1554, 1489 (w), 1425 (s), 1377 (w), 1301 (m), 1271 (w), 1261 (w), 1248 (m), 1209, 1188 (s), 1161 (m), 1133, 1118 (s), 1078, 1055, 1035 (w), 974 (m), 884 (s), 838 (m), 800 (s), 785 (w), 752, 737, 729 (s), 693, 675 (w), 650 (m), 602 (s), 568, 536 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 450 ($[M]^+$, 30), 435 (16), 317 (68), 302 (100), 274 (30). HRMS (EI, 70 eV): calcd for $C_{21}H_{13}F_3O_4S_2$ $[M]^+$: 450.02019; found: 450.02029.

9-Oxo-1-(m-tolyl)-9*H*-thioxanthen-4-yl trifluoromethanesulfonate (10i): Starting with **8** (100 mg, 0.197 mmol), 3-methylphenylboronic acid **3m** (30 mg, 0.22 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), K_3PO_4 (63 mg, 0.29 mmol) and THF (5 mL), **10i** was isolated as a yellow solid (70 mg, 79%); reaction temperature: 65°C for 8 h. Mp.151-153°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.37 (s, 3H, CH_3), 6.98 (d, 1H, J = 7.52 Hz, ArH), 7.02 (brs, 1H, ArH), 7.15 (d, 1H, J = 7.52 Hz, ArH), 7.22-7.27 (m, 2H, ArH), 7.36-7.42 (m, 1H, ArH), 7.51-7.57 (m, 3H, ArH), 8.22 (d, 1H, J = 8.14 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -73.1. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 20.5 (CH_3), 117.6 (q, $J_{F,C}$ = 320.7 Hz, CF_3), 122.1, 123.9, 124.9, 126.2, 126.9, 127.1, 127.4 (CH), 128.2 (C), 128.6, 129.0 (CH), 130.0 (C), 131.5 (CH), 132.8, 136.7, 140.8, 142.5, 145.1 (C), 179.2 (CO). IR (KBr): ν = 3283, 3061, 2961, 2922, 2859, 2736, 2668, 2554 (w), 1651 (s), 1613, 1605 (w), 1589 (m), 1568, 1552, 1537, 1484, 1463 (w), 1426 (s), 1387, 1314 (w), 1300, 1292 (m), 1261 (w), 1249 (m), 1230, 1202 (s), 1183, 1167, 1158 (m), 1131 (s), 1119 (m), 1094, 1078, 1035 (w), 970 (m), 900 (w), 880 (s), 864 (w), 840, 806, 792, 774 (s), 763 (w), 751 (s), 740 (w), 727, 702 (m), 692, 679, 653 (w), 634 (m), 600 (s), 568, 551 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 450 ($[M]^+$, 33), 317 (100), 302 (37), 288 (12). HRMS (EI, 70 eV): calcd for $C_{21}H_{13}F_3O_4S_2$ $[M]^+$: 450.02019; found: 450.01998.

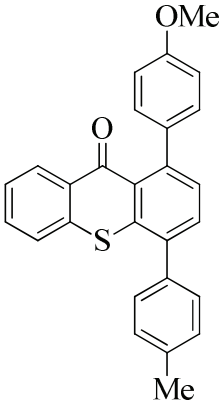


General procedure for the synthesis of unsymmetrical diarylthioxanthones 11a-d:

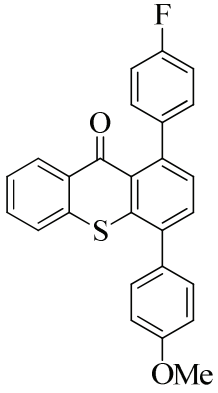
The reaction was carried out in a pressure tube. To a THF suspension (4-5 mL) of 1,4-bis(triflates) **8 (**100 mg, 0.197 mmol), $Pd(PPh_3)_4$ (5 mol%) and of the $Ar^1B(OH)_2$ (1.1 equiv.), K_3PO_4 (1.5 equiv.) was added. The mixture was heated at the indicated temperature at (65°C) under Argon atmosphere for the indicated period of time (8 h) and cooled to room temperature, then $Ar^2B(OH)_2$ (1.1 equiv.) was added, the reaction mixture was further heated at (90°C) for (6

h). The reaction mixture was again cooled to room temperature and diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in *vacuo*. The residue was purified by flash chromatography (silica gel, EtOAc/ heptanes).

1-(4-Methoxyphenyl)-4-(*p*-tolyl)-9*H*-thioxanthen-9-one (11a): Starting with **8** (100 mg, 0.197mmol), 4-methoxyphenylboronic acid **3h** (33 mg, 0.22 mmol), 4-methylphenylboronic acid **3e** (29 mg, 0.22 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **11a** was isolated as a yellow solid (72 mg, 90%); reaction temperature: at 65°C for 8 h, at 90°C for 6 h. Mp.160-162°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.39 (s, 3H, CH_3), 3.79 (s, 3H, OCH_3), 6.89 (d, 2H, J = 8.76 Hz, ArH), 7.16-7.22 (m, 2H, ArH), 7.24-7.45 (m, 9H, ArH), 8.18 (dd, 1H, J = 1.08, 8.04 Hz, ArH).^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 21.44 (CH_3), 55.2 (OCH_3), 113.5, 125.5, 126.2 (CH), 128.1 (C), 129.1, 129.2, 129.4, 129.6, 129.8 (CH), 131.4 (C), 131.7, 132.0 (CH), 135.7, 135.8, 136.4, 137.5, 138.5, 138.6, 144.5, 158.6 (C), 182.4 (CO). IR (KBr): ν = 3055, 3029, 3008, 2955, 2918, 2857, 2835 (w), 1635 (s), 1606, 1591 (m), 1576, 1548 (w), 1512 (m), 1461 (w), 1434 (s), 1410, 1384, 1359 (w), 1318, 1307, 1290 (m), 1271 (w), 1254 (m), 1241 (s), 1172 (m), 1161, 1118, 1105, 1080, 1073 (w), 1149,1026, 1019 (m), 973, 964, 935 (w), 920 (m), 902, 865, 854, 834 (w), 825 (m), 813 (s), 772 (w), 758, 731, 719 (s), 687, 660 (w), 651, 644 (m), 634, 609, 593 (w), 563 (m), 547 (w), 537 (s) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 409 ($[M+H]^+$, 23), 408 ($[M]^+$, 76), 407 ($[M-H]^+$, 100). HRMS (ESI): calcd for $C_{27}H_{21}O_2S$ $[M+H]^+$: 409.12568; found: 409.12630.

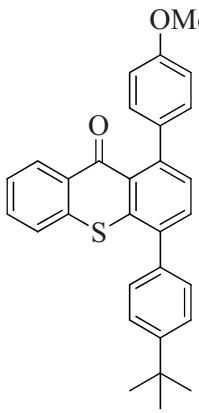


1-(4-Fluorophenyl)-4-(4-methoxyphenyl)-9*H*-thioxanthen-9-one (11b): Starting with **8** (100 mg, 0.197 mmol), 4-flourophenylboronic acid **3j** (30 mg, 0.22 mmol), 4-methoxyphenylboronic acid **3h** (33 mg, 0.22 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **11b** was isolated as a yellow solid (71 mg, 88%); reaction temperature: at 65°C for 8 h, at 90°C for 6 h. Mp.194-196°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.80 (s, 3H, OCH_3), 7.05 (q, 4H, J = 8.76 Hz, ArH), 7.19-7.24 (m, 3H, ArH), 7.28-7.48 (m, 6H, ArH), 8.19 (dd, 1H, J = 1.05, 8.01 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -116.2. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 54.3 (OCH_3), 113.1



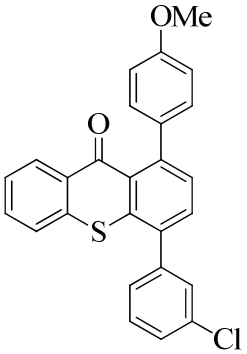
(CH), 113.9 (d, $J_{F,C}$ = 21.5 Hz, CH), 124.5, 125.2 (CH), 127.0 (C), 128.2 (CH), 128.4 (d, $J_{F,C}$ = 7.99 Hz, CH), 128.7 (CH), 129.6 (C), 129.8 (CH), 129.9 (C), 130.8, 131.1 (CH) 135.4, 137.1, 137.9 (C), 138.5 (d, $J_{F,C}$ = 3.42 Hz, C), 142.7, 158.9 (C), 160.8 (d, $J_{F,C}$ = 245.4 Hz, C-F), 180.9 (CO). IR (KBr): ν = 3057, 3031, 2954, 2920, 2850, 2251 (w), 1633 (s), 1601 (m), 1589 (s), 1574, 1548 (w), 1509 (s), 1461 (m), 1434 (s), 1359 (w), 1305, 1307, 1290 (m), 1245, 1219 (s), 1174, 1157 (m), 1105, 1092, 1081, 1045 (w), 1022 (s), 965, 931, 914, 896, 877, 867 (w), 844 (m), 828, 821 (s), 795 (m), 777 (w), 760, 731, 725 (s), 700, 689 (w), 662, 649, 641 (m), 628 (w), 607, 593 (m), 561, 550 (m), 535 (s) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 412 ($[M]^+$, 78), 411 ($[M-H]^+$, 100), 368 (14). HRMS (EI, 70 eV): calcd for $C_{26}H_{16}FO_2S$ $[M-H]^+$: 411.08496; found: 411.08493.

4-(4-(*Tert*-butyl)phenyl)-1-(4-methoxyphenyl)-9*H*-thioxanthen-9-one (11c): Starting with **8**



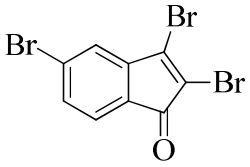
(100 mg, 0.197 mmol), 4-methoxyphenylboronic acid **3h** (33 mg, 0.22 mmol), 4-*tert*-butylphenylboronic acid **3c** (39 mg, 0.22 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **11c** was isolated as a yellow solid (75 mg, 84%); reaction temperature: at 65°C for 8 h, at 90°C for 6 h. Mp.212-214°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.35 (s, 9H, $3CH_3$), 3.80 (s, 3H, OCH_3), 6.89 (d, 2H, J = 8.64 Hz, ArH), 7.18 (d, 2H, J = 8.70 Hz, ArH), 7.22-7.43 (m, 7H, ArH),7.47 (d, 2H, J = 8.31 Hz, ArH), 8.18 (dd, 1H, J = 0.90, 7.89 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 30.4 (CH_3), 33.8 (C), 54.2 (OCH_3), 112.5, 124.5, 124.6, 125.1 (CH), 127.0 (C), 128.1, 128.3, 128.8, 129.8 (CH), 130.3 (C), 130.6, 131.0 (CH), 134.5, 134.8, 135.4, 136.5, 137.6, 143.4, 150.5, 157.5 (C), 181.4 (CO). IR (KBr): ν = 3059, 2997, 2959, 2931, 2903, 2866, 2834, 2248 (w), 1640, 1633 (s), 1606, 1589 (m), 1575, 1558, 1544 (w), 1510 (s), 1461 (m), 1350 (w), 1433 (s), 1410, 1360 (w), 1306 (m), 1290, 1271 (w), 1240 (s), 1174 (m), 1139 (w), 1113, 1105 (m), 1081 (w), 1049 (m), 1026, 1015 (m), 972, 935, 918, 907, 888, 863, 847, 838 (w), 817 (s), 779 (w), 759 (m), 744 (w), 729 (s), 688 (w), 649 (m), 630, 621, 607, 594 (w), 568, 545 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 451 ($[M+H]^+$, 28), 450 ($[M]^+$, 91), 449 ($[M-H]^+$, 100), 435 (12). HRMS (EI, 70 eV): calcd for $C_{30}H_{25}O_2S$ $[M-H]^+$: 449.15698; found: 449.15660.

4-(3-Chlorophenyl)-1-(4-methoxyphenyl)-9*H*-thioxanthen-9-one (11d): Starting with **8** (100 mg, 0.197 mmol), 4-methoxyphenylboronic acid **3h** (33 mg, 0.22 mmol), 3-chlorophenylboronic acid **3n** (34 mg, 0.22 mmol), $Pd(PPh_3)_4$ (23 mg, 10 mol%), K_3PO_4 (125 mg, 0.59 mmol) and THF (5 mL), **11d** was isolated as a yellow solid (75 mg, 89%); reaction temperature: at 65°C for 8 h, at 90°C for 6 h. Mp.190-191°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.79 (s, 3H, OCH_3), 6.88 (d, 2H, J = 8.73 Hz, ArH), 7.17 (d, 2H, J = 8.73 Hz, ArH), 7.24 (d, 1H, J = 7.62 Hz, ArH), 7.28-7.46 (m, 8H, ArH), 8.18 (dd, 1H, J = 1.08, 8.04 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 55.2 (OCH_3), 113.6, 125.5, 126.4, 128.0 (CH), 128.2 (C), 128.7, 129.2, 129.3, 129.8, 129.9, 130.0 (CH), 131.3 (C), 131.9 (CH), 134.6, 135.5, 135.9, 137.1, 137.3, 140.3, 145.2, 158.7 (C), 182.2 (CO). IR (KBr): ν = 3100, 3070, 3053, 2998, 2947, 2931, 2902, 2831 (w), 1650 (s), 1633 (s), 1605 (w), 1588 (m), 1575, 1564, 1546 (w), 1510 (m), 1462, 1454 (w), 1432 (s), 1407, 1365 (w), 1307, 1299 (m), 1288 (w), 1237 (s), 1178 (m), 1165, 1155, 1121 (w), 1106, 1074, 1049, 1025 (m), 963 (w), 941 (m), 928, 898, 885, 866 (w), 841 (m), 819 (s), 783, 779 (m), 762 (s), 748 (w), 734 (s), 715, 692 (m), 665, 645, 623, 609, 583, 571 (w), 546 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) = 428 ($[M]^+$, 72), 427 ($[M-H]^+$, 100), 413 (10). HRMS (EI, 70 eV): calcd for $C_{26}H_{16}ClO_2S$ $[M-H]^+$: 427.05540; found: 427.05524.



Site-Selective Synthesis of Arylated Indenones by Suzuki–Miyaura Cross-Coupling Reactions of 2,3,5-Tribromoinden-1-one

Synthesis of 2,3,5-Tribromo-1*H*-inden-1-one (13): A round bottom flask was equipped with condenser. Benzene suspension (35 mL) of 5-bromo-indanone **12** (1.50 g, 7.10 mmol), N-bromosccinamide (4.43 g, 24.9 mmol) and AIBN (0.12 g, 10 mol %) was refluxed under Argon for 7 h and then cooled to 20°C. Reaction mixture was quenched with triethylamine (1 mL) and benzene was evaporated in *vacuo*. Then reaction mixture was diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated *in vacuo*. The residue was purified by flash chromatography (silica gel, heptanes). **14** were isolated as light yellow crystalline solid (1.60 g, 62%).Mp.160-161°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.26 (d, 1H, J = 7.65 Hz, ArH), 7.28 (d, 1H, J = 1.50 Hz, ArH), 7.41 (dd, 1H, J = 1.62, 7.65 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 123.8 (C), 124.0, 124.7 (CH), 127.6, 129.4 (C), 132.6 (CH), 144.1, 144.6 (C), 185.4 (CO). IR (KBr): ν = 3416,

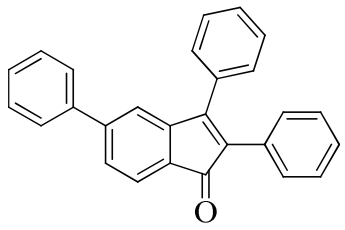


3084, 3015, 2922, 2850, 2674 (w), 1722 (s), 1594, 1584 (w), 1540, 1438, 1401, 1337 (m), 1260, 1218 (w), 1200 (s), 1094 (m), 1085, 1054 (s), 1041(m), 959 (w), 933, 876 (s), 811(m), 764, 691, 680 (s), 618, 593, 577 (m). GC-MS (EI, 70 eV): *m/z* (%) = 370 ([(M+H), ^{81}Br, ^{81}Br, ^{81}Br]$^+$, 13), 368 ([(M+H), ^{79}Br, ^{81}Br, ^{81}Br]$^+$, 41), 366 ([(M+H), ^{79}Br, ^{79}Br, ^{81}Br]$^+$, 42), 364 ([(M+H), ^{79}Br, ^{79}Br, ^{79}Br]$^+$, 15), 287 (100), 259 (23), 178 (17). HRMS (EI, 70 eV): calcd for $C_9H_3Br_3O$ [M, ^{81}Br, ^{81}Br, ^{81}Br]$^+$: 369.76671; found: 369.76599, calcd for $C_9H_3Br_3O$ [M, ^{79}Br, ^{81}Br, ^{81}Br]$^+$: 367.76876; found: 367.76801, calcd for $C_9H_3Br_3O$ [M, ^{79}Br, ^{79}Br, ^{81}Br]$^+$: 365.77081; found: 365.77001, calcd for $C_9H_3Br_3O$ [M, ^{79}Br, ^{79}Br, ^{79}Br]$^+$: 363.77285; found: 363.77181.

***General procedure (A) for Suzuki cross-coupling reactions of brominated indenone* (13):** The reaction was carried out in a pressure tube. To a 1,4-dioxane suspension (3-5 mL) of the brominated indenone, $Pd(PPh_3)_4$ or $Pd(PPh_3)_2Cl_2$ (3-5 mol%) and of the arylboronic acid (1.0-1.1 per cross coupling), K_3PO_4 (1.5 equiv. per cross coupling) or an aqueous solution of K_2CO_3 (2 M, 1 mL) was added. The mixture was heated at the indicated temperature (45-70°C) under Argon atmosphere for the indicated period of time (6-9 h). The reaction mixture was diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in *vacuo*. The residue was purified by flash chromatography (silica gel, EtOAc/ heptanes).

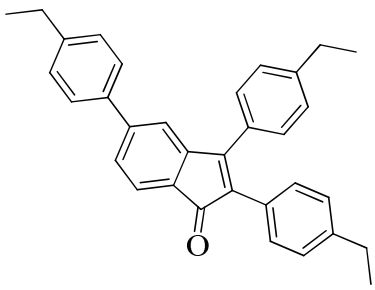
Synthesis of triaryl-1*H*-inden-1-ones 14a-g:

2,3,5-Triphenyl-1*H*-inden-1-one (14a): Starting with **13** (80 mg, 0.22 mmol), $Pd(PPh_3)_4$ (13 mg, 5 mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and phenylboronic acid **3i** (88 mg, 0.72 mmol), **16a** was isolated as a brownish yellow solid (65 mg, 83%). reaction temperature: 70°C for 6 h. Mp.182-183°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.17-7.21 (m, 5H, ArH), 7.26-7.42 (m, 10H, ArH), 7.46-7.49 (m, 2H, ArH), 7.57 (d, 1H, *J* = 7.44 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 120.5, 123.4, 127.2, 127.5, 127.8, 128.1, 128.3, 128.5, 128.9, 129.3 (CH), 129.5 (C), 130.0 (CH), 130.7, 132.7, 133.2, 140.4, 146.1, 146.8, 154.8 (C), 196.1 (CO). IR (KBr): ν = 3388, 3054, 3030, 2955, 2921, 2849 (w), 1704, 1597 (s), 1573, 1485, 1467, 1442 (w), 1355 (m), 1340, 1331, 1279, 1263, 1184 (w), 1177 (m), 1160, 1143 (w), 1097, 1079, 1063, 1029 (m), 1012, 1000, 963 (w), 939 (m), 917 (w), 894, 850, 837, 793, 778 (m), 758 (s), 742 (w), 727, 690 (s), 672, 657, 638 (m), 616 (w), 596 (m),



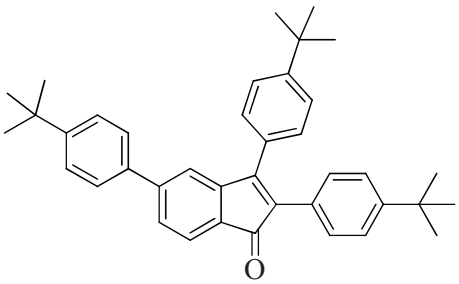
577, 563 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 358 ($[M]^+$, 100), 357 (40), 341 (11). 326 (11), 252 (15). HRMS (EI, 70 eV): calcd for $C_{27}H_{18}O$ $[M]^+$: 358.13522; found: 358.13517.

2,3,5-Tris (4-ethylphenyl)-1*H*-inden-1-one (14b): Starting with **13** (80 mg, 0.22 mmol),



$Pd(PPh_3)_4$ (13 mg, 5 mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and 4-ethylphenylboronic acid **3b** (108 mg, 0.72 mmol), **14b** was isolated as a brownish yellow solid (85 mg, 88%). reaction temperature: 70°C for 6 h. Mp.104-105°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ=1.16-1.23 (m, 9H, $3CH_3$), 2.54 (q, 2H, *J* = 7.5 Hz, CH_2), 2.56-2.66 (m, 4H, $2CH_2$), 7.02 (d, 2H, *J* = 8.22 Hz, ArH), 7.13-7.27 (m, 9H, ArH), 7.36 (dd, 1H, *J* = 1.35, 7.47 Hz, ArH), 7.40 (d, 2H, *J* = 8.16 Hz, ArH), 7.52 (d, 1H, *J* = 7.44 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 14.1, 14.2, 14.5 (CH_3), 27.5, 27.6, 27.8 (CH_2), 119.3, 122.2, 126.0, 126.1, 126.6 (CH), 127.2 (C), 127.2, 127.3, 127.6 (CH), 128.4 (C), 128.9 (CH), 129.1, 131.7, 136.8, 142.7, 143.5, 144.5, 145.3, 145.6, 153.2 (C), 195.4 (CO). IR (KBr): *v* = 3380, 3023, 2962, 2928, 2873 (w), 1698 (s), 1651, 1633 (w), 1595 (s), 1538, 1516, 1500 (w), 1455 (m), 1410, 1376 (w), 1351 (m), 1336, 1259 (w), 1181 (m), 1142, 1116 (w), 1095, 1071, 1048, 1017, 1012 (m), 965 (w), 936 (m), 895, 865, 851 (w), 821, 786 (s), 740, 729, 703, 674, 660, 638, 623 (w), 568 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 442 ($[M]^+$, 100), 413 (26), 207 (26). HRMS (EI, 70 eV): calcd for $C_{33}H_{30}O$ $[M]^+$: 442.22912; found: 442.22947.

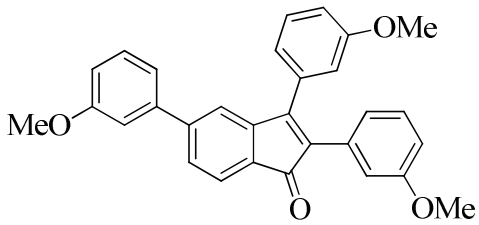
2,3,5-Tris (4-*tert*-butylphenyl)-1*H*-inden-1-one (14c): Starting with **13** (80 mg, 0.22 mmol),



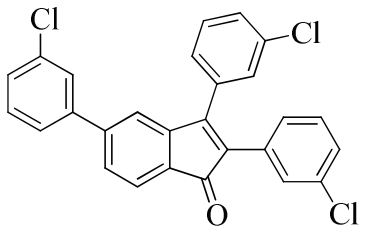
$Pd(PPh_3)_4$ (13 mg, 5 mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and 4-*tert*-butylphenylboronic acid **3c** (129 mg, 0.72 mmol), **14c** was isolated as a brownish yellow solid (98 mg, 85%). reaction temperature: 70°C for 6 h. Mp.98-100°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.23 (s, 9H, $3CH_3$), 1.27 (s, 9H, $3CH_3$), 1.29 (s, 9H, $3CH_3$), 7.16-7.23 (m, 4H, ArH), 7.28-7.46 (m, 10H, ArH), 7.53 (d, 1H, *J* = 7.41 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 31.2 ($6CH_3$), 31.3 ($3CH_3$), 34.6, 34.7, 34.9 (C), 120.5, 123.2, 125.0, 125.7, 125.8, 126.9, 127.0 (CH), 128.0 (C), 128.3 (CH), 129.5 (C), 129.6 (CH), 129.9, 132.6, 146.4, 146.5, 150.6, 151.4, 152.4, 154.2 (C), 196.6 (CO). IR (KBr): *v* = 3086, 3035, 2958, 2927, 2903, 2866, 2183, 2161, 1737 (w), 1704 (s), 1637, 1667, 1658, 1651, 1642, 1620 (w), 1598 (m), 1536,

1547, 1526, 1519, 1512, 1495 (w), 1462 (m), 1446, 1423, 1402, 1392 (w), 1362, 1351, 1268, 1187, 1112, 1093, 1069, 1015, 938 (m), 821 (s), 785 (m), 766, 756, 726, 708, 693, 648, 637, 613, 595 (w), 579 (m), 558 (s), 538, 528 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 526 ($[M]^+$, 100), 511 (60). 248 (27). HRMS (EI, 70 eV): calcd for $C_{39}H_{42}O$ $[M]^+$: 526.32302; found: 526.32394.

2,3,5-Tris-(3-methoxyphenyl)-1*H*-inden-1-one (14d): Starting with **13** (80 mg, 0.22 mmol), $Pd(PPh_3)_4$ (13 mg, 5 mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and 3-methoxyphenylboronic acid **3o** (109 mg, 0.72 mmol), **14d** was isolated as a brownish yellow solid (75 mg, 76%). reaction temperature: 70°C for 6 h. Mp.163-165°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 3.60 (s, 3H, OCH_3), 3.65 (s, 3H, OCH_3), 3.78 (s, 3H, OCH_3), 6.71-6.90 (m, 6H, ArH), 6.93 (dt, 1H, *J* = 1.08, 7.56 Hz, ArH), 7.00 (t, 1H, *J* = 1.80 Hz, ArH), 7.05-7.14 (m, 2H, ArH), 7.25-7.31 (m, 3H, ArH), 7.40 (dd, 1H, *J* = 1.44, 7.41 Hz, ArH), 7.56 (d, 1H, *J* = 7.47 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 54.5, 54.7, 54.8 (OCH_3), 112.6, 112.7, 113.1, 113.6, 114.3, 114.6, 119.1, 120.0, 120.2, 121.9, 122.7, 127.0, 128.5 (CH), 129.0 (C), 129.3, 129.5 (CH), 131.4, 132.5, 133.4, 141.3, 145.4, 146.1, 154.3, 158.5, 159.2, 159.4 (C), 195.3 (CO). IR (KBr): *v* = 3371, 3070, 2999, 2921, 2852, 2830 (w), 1698, 1599, 1581 (s), 1461, 1465, 1453, 1440, 1432, 1317, 1351, 1329, 1319, 1301 (m), 1290, 1281, 1262, 1236, 1218, 1182, 1165 (s), 1136, 1101, 1079, 1056 (m), 1046, 1032 (s), 992, (w), 962 (m), 923, 907 (w), 879 (m), 845 (s), 795 (m), 784, 767 (s), 739 (w), 729, 699, 685, 675 (s), 641, 621, 603, 590, 554 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 448 ($[M]^+$, 100), 417 (11). HRMS (EI, 70 eV): calcd for $C_{30}H_{24}O_4$ $[M]^+$: 448.16691; found: 448.16680.

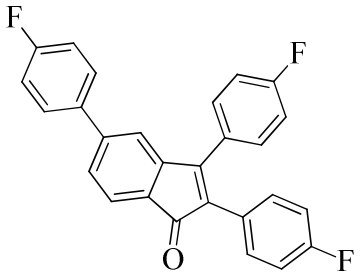


2,3,5-Tris (3-chlorophenyl)-1*H*-inden-1-one (14e): Starting with **13** (80 mg, 0.22 mmol), $Pd(PPh_3)_4$ (13 mg, 5 mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and 3-chlorophenylboronic acid **3n** (113 mg, 0.72 mmol), **14e** was isolated as a brownish yellow solid (80 mg, 79%). reaction temperature: 70°C for 6 h. Mp.135-137°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.01 (dt, 1H, *J* = 1.31, 7.27 Hz, ArH), 7.09-7.24 (m, 5H, ArH), 7.28-7.44 (m, 8H, ArH), 7.58 (d, 1H, *J* = 7.44 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 120.3, 123.8, 125.4, 126.6, 127.3, 128.0, 128.1, 128.2, 128.3, 128.4, 129.5 (CH), 129.5 (C), 129.8, 129.9, 130.2, 130.6 (CH), 131.9, 132.5, 134.0, 134.2, 134.9, 135.2,

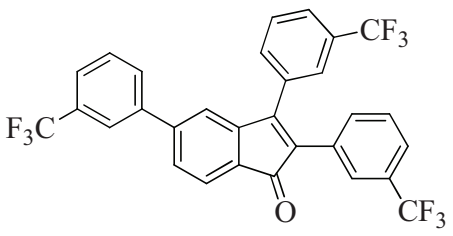


141.9, 145.5, 145.6, 154.0 (C), 194.9 (CO). IR (KBr): ν = 3384, 2058, 2955, 2921, 2851 (w), 1699 (s), 1596, 1579, 1561 (m), 1488 (w), 1461(m), 1437, 1423 (w), 1402, 1344, 1328 (m), 1297, 1259, 1249, 1218 (w), 1186 (m), 1163,1149 (w), 1078, 1063 (m), 996, 979 (w), 957 (m), 914, 905 (w), 892, 875, 851, 799 (m), 779, 769, 743, 713 (s), 689 (m), 682, 667 (s), 650, 637, 602, 592, 574, 556, 545 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 464 ([M, ^{37}Cl, ^{37}Cl, $^{35}Cl]^+$, 37), 462 ([M, ^{37}Cl,^{35}Cl, ^{35}Cl,]$^+$, 98), 460 ([M, ^{35}Cl, ^{35}Cl, ^{35}Cl,]$^+$, 100), 425 (42), 362 (21), 326 (31). HRMS (EI, 70 eV): calcd for $C_{27}H_{15}Cl_3O$ [M, ^{35}Cl, ^{35}Cl, ^{35}Cl,]$^+$: 460.01830; found: 460.01750.

2,3,5-Tris (4-fluorophenyl)-1*H*-inden-1-one (14f): Starting with **13** (80 mg, 0.22 mmol), $Pd(PPh_3)_4$ (13 mg, 5 mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and 4-fluorophenylboronic acid **3j** (101 mg, 0.72 mmol), **14f** was isolated as a brownish yellow solid (73 mg, 81%). reaction temperature: 70°C for 6 h. Mp.236-237°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 6.90 (t, 2H, *J* = 8.79 Hz, ArH), 7.03-7.10 (m, 4H, ArH), 7.15-7.20 (m, 3H, ArH), 7.29-7.34 (m, 2H, ArH), 7.37 (dd, 1H, *J* = 1.35, 7.47 Hz, ArH), 7.42-7.47 (m, 2H, ArH), 7.56 (d, 1H, *J* = 7.44 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -113.6, -112.8, -110.3. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 114.4 (d, $J_{F,C}$ = 21.5 Hz, CH), 114.9 (d, $J_{F,C}$ = 21.6 Hz, CH), 115.3 (d, $J_{F,C}$ = 21.8 Hz, CH), 119.1, 122.6 (CH), 125.4 (d, $J_{F,C}$ = 3.37 Hz, C), 126.5 (CH), 127.3 (d, $J_{F,C}$ = 3.54 Hz, C), 128.9 (d, $J_{F,C}$ = 8.21 Hz, CH), 128.2 (C), 129.5 (d, $J_{F,C}$ = 8.28 Hz, CH), 130.8 (d, $J_{F,C}$ = 7.98 Hz, CH), 131.4 (C), 135.3 (d, $J_{F,C}$ = 3.25 Hz, C), 144.8, 144.9, 152.5 (C), 161.5 (d, $J_{F,C}$ = 248.8 Hz, C-F), 161.7 (d, $J_{F,C}$ = 249.3 Hz, C-F), 162.0 (d, $J_{F,C}$ = 250.8 Hz, C-F), 194.6 (CO). IR (KBr): ν = 3375, 3059, 2956, 2922, 2851 (w), 1697, 1592 (s), 1515, 1496, 1463 (m), 1430, 1410, 1402 (w), 1350 (m), 1328, 1299, 1275, 1260 (w), 1220 (s), 1185 (m), 1158 (s), 1143, 1094, 1070, 1012 (m), 964, 950, 935, 908, 871, 857 (w), 827, 812, 799 (s), 787, 748, 740 (m), 722, 712, 700, 661, 620 (w), 569, 557, 538 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 412 ([M]$^+$, 100), 395 (11), 288 (13). HRMS (EI, 70 eV): calcd for $C_{27}H_{15}F_3O$ [M]$^+$: 412.10695; found: 412.10706.



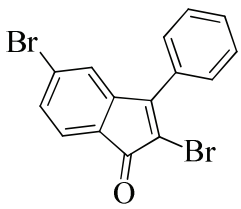
2,3,5-Tris (3-(trifluoromethyl)phenyl)-1*H*-inden-1-one (14g): Starting with **14** (80 mg, 0.22 mmol), $Pd(PPh_3)_4$ (13 mg, 5mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and 3-(trifluoromethyl)phenylboronic acid **3g** (137 mg, 0.72 mmol), **14g** was isolated as a brownish yellow solid (96 mg, 78%). reaction



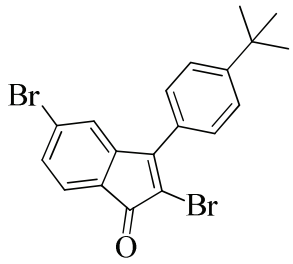
temperature: 70°C for 6 h. Mp.155-156°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.20 (d, 1H, J = 1.17 Hz, ArH), 7.31-7.44 (m, 4H, ArH), 7.48 (dd, 2H, J = 1.17, 7.49 Hz, ArH), 7.52-7.66 (m, 7H, ArH), 7.71 (brs, 1H, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -63.1, -63.0, -62.7. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 120.4 (CH), 123.5 (q, $J_{F,C}$ = 272.7 Hz, CF_3), 123.7 (q, $J_{F,C}$ = 272.0 Hz, CF_3), 123.8 (q, $J_{F,C}$ = 271.3 Hz, CF_3), 123.9 (q, $J_{F,C}$ = 3.81 Hz, CH), 124.1 (CH), 124.9 (q, $J_{F,C}$ = 3.62 Hz, CH), 125.2 (q, $J_{F,C}$ = 3.50 Hz, CH), 125.3 (q, $J_{F,C}$ = 3.83 Hz, CH), 126.5 (q, $J_{F,C}$ = 3.82 Hz, CH), 126.7 (q, $J_{F,C}$ = 3.90 Hz, CH), 128.6, 128.8, 129.6, 129.9, 130.5 (CH), 130.7 (C), 130.6 (q, $J_{F,C}$ = 22.6 Hz, C-CF_3), 130.7 (q, $J_{F,C}$ = 22.4 Hz, C-CF_3), 130.6 (q, $J_{F,C}$ = 24.8 Hz, C-CF_3), 131.6 (CH), 132.7, 132.9 (C), 133.1 (CH), 140.8, 145.4, 145.7, 154.1(C), 194.7 (CO). IR (KBr): νO = 3390, 3065, 2922, 2850 (w), 1706, 1600 (m), 1483, 1469 (w), 1438, 1429, 1361 (m), 1327, 1314 (s), 1303, 1283, 1241 (m), 1212 (w), 1182, 1162, 1112, 1098, 1067 (s), 1031 (m), 999, 955, 917, 907, 895, 849, 817 (m), 798 (s), 782, 769, 738 (m), 698, 689 (s), 677, 654 (m), 636, 621, 601, 533 (w) cm^{1}. GC-MS (EI, 70 eV): *m/z* (%) = 562 ([M]$^{+}$, 100), 493 (16). HRMS (EI, 70 eV): calcd for $C_{30}H_{15}F_9O$ [M]$^{+}$: 562.09737; found: 562.09757.

Synthesis of 3-aryl-2,5-dibromo-1*H*-inden-1-ones 15a-g:

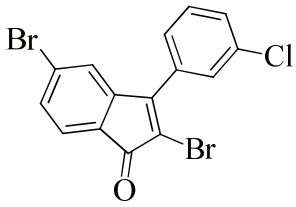
2,5-Dibromo-3-phenyl-1*H*-inden-1-one (15a): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (9 mg, 3 mol%), 1,4-dioxane (5 mL), K_3PO_4 (86 mg, 0.41 mmol) and phenylboronic acid **3i** (33 mg, 0.27 mmol), **15a** was isolated as a brownish yellow solid (82 mg, 83%). reaction temperature: 45°C for 9 h. Mp.108-110 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.19-7.20 (m, 1H, ArH), 7.32-7.37 (m, 2H, ArH), 7.45-7.57 (m, 5H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 119.1 (C), 124.7, 128.1 (CH), 128.5, 128.8 (C), 128.9 (CH), 130.5 (C), 130.6, 131.6 (CH), 146.3, 155.8 (C), 188.6 (CO). IR (KBr): ν = 3422, 3087, 3062, 2921, 2850 (w), 1728 (s), 1681 (w), 1599, 1557 (m), 1498 (w), 1485, 1442, 1397, 1342 (m), 1299, 1282 (w), 1266 (m), 1190 (w), 1176, 1149, 1098, 1076, 1051, 1028 (m), 1000, 979, 966 (w), 931, 917, 875, 833, 814 (m), 785 (w), 769, 755, 714 (m), 688 (s), 663, 634, 611, 586 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 366 [(M+H), ^{81}Br, ^{81}Br]$^{+}$, 51), 364 [(M+H), ^{79}Br, ^{81}Br]$^{+}$, 100), 362 [(M+H), ^{79}Br, ^{79}Br]$^{+}$, 51), 285 (27), 176 (51). HRMS (EI, 70 eV): calcd for $C_{15}H_8Br_2O$ [M, ^{81}Br, ^{81}Br]$^{+}$: 365.88955; found: 365.88983, calcd for $C_{15}H_8Br_2O$ [(M, ^{79}Br, ^{81}Br]$^{+}$: 363.89160; found: 363.89154, calcd for $C_{15}H_8Br_2O$ [M, ^{79}Br, ^{79}Br]$^{+}$: 361.89364; found: 361.89368.



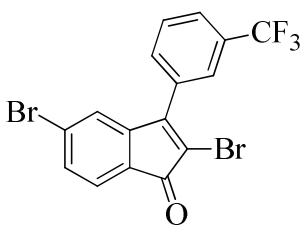
2,5-Dibromo-3-(4-*tert*-butylphenyl)-1*H*-inden-1-one (15b): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (9 mg, 3mol%), 1,4-dioxane (5 mL), K_3PO_4 (86 mg, 0.41mmol) and 4-*tert*-butylphenylboronic acid **3c** (49 mg, 0.27 mmol), **15b** was isolated as a brownish yellow solid (98 mg, 86%). reaction temperature: 45°C for 9 h. Mp.146-148°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.32 (s, 9H, $3CH_3$), 7.26-7.38 (m, 3H, ArH), 7.48-7.55 (m, 4H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 31.2 ($3CH_3$), 35.1, 118.5 (C), 124.5, 124.8, 125.9 (CH), 127.6 (C), 128.0 (CH), 128.6, 128.7 (C), 131.5 (CH), 146.3, 154.2, 155.8 (C), 188.7 (CO). IR (KBr): ν = 3427, 3088, 3028, 2960, 2903, 2865 (w), 1720 (s), 1682 (w), 1600, 1592, 1564 (m), 1495, 1463 (w), 1447 (m), 1400, 1362, 1339 (m), 1309 (w), 1288, 1271, 1190, 1176 (w), 1155, 1106, 1092, 1047, 1016 (m), 929 (s), 878 (m), 849 (w), 834, 811 (s), 770 (m), 746 (w), 717, 686, 632 (s), 588 (w), 550 (s) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 420 [(M+H), ^{79}Br, ^{81}Br]$^+$, 49), 418 [(M+H), ^{79}Br, ^{79}Br]$^+$, 24), 405 (100), 377 (17), 202 (11). HRMS (EI, 70 eV): calcd for $C_{19}H_{16}Br_2O$ [(M, ^{79}Br, ^{81}Br]$^+$: 419.95420; found: 419.95474, calcd for $C_{19}H_{16}Br_2O$ [M, ^{79}Br, ^{79}Br]$^+$: 417.95624; found: 417.95723.



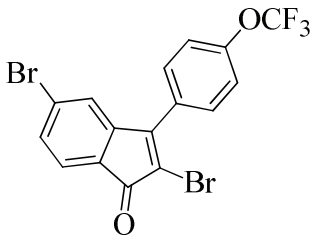
2,5-Dibromo-3-(3-chlorophenyl)-1*H*-inden-1-one (15c): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (9 mg, 3 mol%), 1,4-dioxane (5 mL), K_3PO_4 (86 mg, 0.41 mmol) and 3-chlorophenylboronic acid **3n** (42 mg, 0.27 mmol), **15c** was isolated as a brownish yellow solid (87 mg, 80%). reaction temperature: 45°C for 9 h. Mp.120-122°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.15 (d, 1H, J = 1.05 Hz, ArH), 7.35-7.45 (m, 5H, ArH), 7.51-7.52 (m, 1H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 120.8 (C), 124.5, 125.0, 126.2, 128.0 (CH), 128.1, 129.0 (C), 130.3, 130.6, 131.8 (CH), 132.3, 135.1, 145.9, 154.3 (C), 188.2 (CO). IR (KBr): ν = 3415, 3064, 2918, 2849, 2156, 2137 (w), 1721 (s), 1682 (w), 1598, 1585, 1553 (m), 1519, 1504 (w), 1469, 1446, 1420, 1397, 1336 (m), 1302 (w), 1272 (m), 1221, 1179, 1166, 1152 (w), 1097, 1090, 1080, 1050 (m), 997 (w), 950 (m), 909 (w), 884, 834, 817 (m), 786 (s), 767 (m), 746, 732 (w), 712 (m), 705 (s), 682 (m), 665 (w), 649, 638 (m), 618, 599 (w), 588 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 400 [(M+H), ^{81}Br, ^{81}Br]$^+$, 63), 398 [(M+H), ^{79}Br, ^{81}Br]$^+$, 100), 396 [(M+H), ^{79}Br, ^{79}Br]$^+$, 43), 319 (33), 210 (29), 174 (20). HRMS (EI, 70 eV): calcd for $C_{15}H_7Br_2ClO$ [M, ^{81}Br, ^{81}Br]$^+$: 399.85058; found: 399.85075, calcd for $C_{15}H_7Br_2ClO$ [M, ^{79}Br, ^{81}Br]$^+$: 397.85262; found: 397.85271, calcd for $C_{15}H_7Br_2ClO$ [M, ^{79}Br, ^{79}Br]$^+$: 395.85467; found: 395.85501.



2,5-Dibromo-3-(3-(trifluoromethyl)phenyl)-1*H*-inden-1-one (15d): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (9 mg, 3 mol%), 1,4-dioxane (5 mL), K_3PO_4 (86 mg, 0.41 mmol) 3-(trifluoromethyl)phenylboronic acid **3g** (51 mg, 0.27 mmol), **15d** was isolated as a brownish yellow solid (94 mg, 80%). reaction temperature: 45°C for 9 h. Mp.111-113°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.12 (d, 1H, J = 0.96 Hz, ArH), 7.35-7.42 (m, 2H, ArH), 7.61-7.74 (m, 3H, ArH), 7.81 (brs, 1H, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -62.8. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 123.6 (q, $J_{F,C}$ = 272.8 Hz, CF_3), 124.4 (CH), 125.0 (q, $J_{F,C}$ = 3.85 Hz, CH), 125.1 (CH), 127.2 (q, $J_{F,C}$ = 3.56 Hz, CH), 128.1, 129.1 (C), 129.7, 131.3 (CH), 131.5 (C), 131.6 (q, $J_{F,C}$ = 32.80 Hz, C-CF_3), 132.0 (CH), 145.8, 154.2 (C), 188.1 (CO). IR (KBr): ν = 3413, 3074, 2959, 2929, 2854 (w), 1716 (m), 1582, 1614 (w), 1595, 1586, 1556 (m), 1491(w), 1449, 1428, 1404, 1345 (m), 1326 (s), 1296, 1265 (w), 1250 (m), 1182 (w), 1165, 1150 (m), 1122, 1094, 1073, 1054 (s), 934, 926, 880, 861, 833, 818 (m), 800 (s), 766, 718, 703 (m), 697 (s), 677, 651, 622, 600, 585 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 434 [(M+H), ^{81}Br, ^{81}Br]$^+$, 48), 432 [(M+H), ^{79}Br, ^{81}Br]$^+$, 100), 430 [(M+H), ^{79}Br, ^{79}Br]$^+$, 51), 351 (35), 244 (36). HRMS (EI, 70 eV): calcd for $C_{16}H_7F_3Br_2O$ [M, ^{81}Br, ^{81}Br]$^+$: 433.87693; found: 433.87701, calcd for $C_{16}H_7F_3Br_2O$ [M, ^{79}Br, ^{81}Br]$^+$: 431.87898; found: 431.87878, calcd for $C_{16}H_7F_3Br_2O$ [M, ^{79}Br, ^{79}Br]$^+$: 429.88103; found: 429.88063.

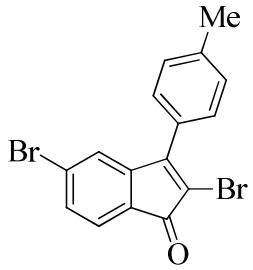


2,5-Dibromo-3-(4-(trifluoromethoxy)phenyl)-1*H*-inden-1-one (15e): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (9 mg, 3 mol%), 1,4-dioxane (5 mL), K_3PO_4 (86 mg, 0.41 mmol) and 4-(trifluoromethoxy)phenylboronic acid **3p** (56 mg, 0.27 mmol), **15e** was isolated as a brownish yellow solid (95 mg, 78%). reaction temperature: 45°C for 9 h. Mp.113-115°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.18-7.19 (m, 1H, ArH), 7.32-7.38 ((m, 4H, ArH), 7.61 (d, 2H, J = 8.85 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -57.6. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 118.8 (C), 119.4 (q, $J_{F,C}$ = 259.6 Hz, OCF_3), 120.2, 123.5, 123.9 (CH), 127.2, 127.9, 128.0 (C), 128.9, 130.8 (CH), 144.9, 149.5, 153.3 (C), 187.2 (CO). IR (KBr): ν = 3024, 3089, 2921, 2850 (w), 1729, 1609, 1597, 1590, 1504 (m), 1446,1399, 1342 (w), 1301 (m), 1246, 1205, 1149, 1116, 1049, 1052, 1017 (s), 969, 953 (w), 925 (m), 887 (w), 832, 816, 802, 765 (m), 732 (w), 717, 688 (m), 666, 644, 631 (w), 619 (m), 537 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 450 ([(M+H), ^{81}Br, ^{81}Br]$^+$, 50), 448 ([(M+H), ^{79}Br, ^{81}Br]$^+$, 100),

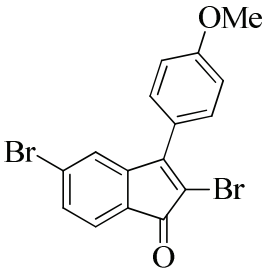


446 ([(M+H), ^{79}Br, ^{79}Br]$^+$, 51), 367 (29), 260 (21). HRMS (EI, 70 eV): calcd for $C_{16}H_7F_3Br_2O_2$ [M, ^{81}Br, ^{81}Br]$^+$: 449.87185; found: 449.87170, calcd for $C_{16}H_7F_3Br_2O_2$ [M, ^{79}Br, ^{81}Br]$^+$: 447.87389; found: 447.87345, calcd for $C_{16}H_7F_3Br_2O_2$ [M, ^{79}Br, ^{79}Br]$^+$: 445. 87594; found: 445.87555.

2,5-Dibromo-3-*p*-tolyl-1*H*-inden-1-one (15f): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (9 mg, 3 mol%), 1,4-dioxane (5 mL), K_3PO_4 (86 mg, 0.41 mmol) and *p*-tolylboronic acid **3e** (37 mg, 0.27 mmol), **15f** was isolated as a brownish yellow solid (88 mg, 86%). reaction temperature: 45°C for 9 h. Mp.129-131°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ= 2.38 (s, 3H, CH_3), 7.21-7.22 (m, 1H, ArH), 7.29 (d, 2H, *J* = 8.07 Hz, ArH), 7.33-7.37 (m, 2H, ArH), 7.26 (d, 2H, *J* = 8.19 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ= 21.7 (CH_3), 118.5 (C), 124.6, 124.7 (CH), 127.7 (C), 128.1 (CH), 128.6, 128.7 (C), 129.6, 131.5 (CH), 141.2, 146.3, 155.9 (C), 188.6 (CO). IR (KBr): ν = 3424, 3089, 3027, 2915, 2850 (w), 1729 (s), 1599, 1590, 1564, 1556, 1444 (m), 1398 (w), 1343, 1289, 1270, 1184, 1150, 1097, 1053 (m), 1019 (w), 928, 880, 835 (m), 810 (s), 779 (w), 765, 720, 715, 687 (m), 654 (w), 631, 588 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 380 ([(M+H), ^{81}Br, ^{81}Br]$^+$, 50), 378 ([(M+H), ^{79}Br, ^{81}Br]$^+$, 100), 376 ([(M+H), ^{79}Br, ^{79}Br]$^+$, 52), 297 (25), 189 (50). HRMS (EI, 70 eV): calcd for $C_{16}H_{10}Br_2O$ [M, ^{81}Br, ^{81}Br]$^+$: 379.90520; found: 379.90577, calcd for $C_{16}H_{10}Br_2O$ [M, ^{79}Br, ^{81}Br]$^+$: 377.90725; found: 377.90739, calcd for $C_{16}H_{10}Br_2O$ [M, ^{79}Br, ^{79}Br]$^+$: 375.90929; found: 375.90918.



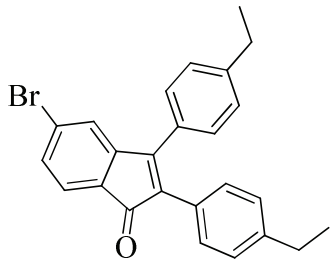
2,5-Dibromo-3-(4-methoxyphenyl)-1*H*-inden-1-one (15g): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (9 mg, 3 mol%), 1,4-dioxane (5 mL), K_3PO_4 (86 mg, 0.41 mmol) and 4-methoxyphenylboronic acid **3h** (41 mg, 0.27 mmol), **15g** was isolated as a brownish yellow solid (99 mg, 92%). reaction temperature: 45°C for 9 h. Mp.194-195°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ= 3.84 (s, 3H, OCH_3), 6.70 (d, 2H, *J* = 8.88 Hz, ArH), 7.26 (d, 1H, *J* = 0.93 Hz, ArH), 7.32-7.36 (m, 2H, ArH), 7.56 (d, 2H, *J* = 8.85 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ= 55.5 (OCH_3), 114.4 (CH), 117.8, 122.8 (C), 124.5, 124.7 (CH), 128.5, 128.8 (C), 130.0, 131.5 (CH), 146.3, 155.5, 161.5 (C), 188.7 (CO). IR (KBr): ν = 3409, 3070, 3025, 2985, 2955, 2921, 2850, 2282, 2035 (w), 1715, 1597 (s), 1567, 1555 (m), 1503 (s), 1470 (w), 1444, 1419 (m), 1401(w), 1341, 1307, 1275 (m), 1257 (s), 1193 (w), 1173



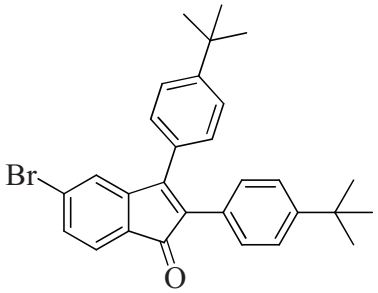
(s), 1152, 1118, 1102, 1091, 1052 (m), 1017 (s), 954 (w), 927 (m), 873 (w), 822, 813 (s), 782, 766, 732, 712, 690, 632, 621, 576 (m), 528 (s) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 396 ([(M+H), ^{81}Br, $^{81}Br]^+$, 52), 394 ([(M+H), ^{79}Br, $^{81}Br]^+$, 100), 392 ([(M+H), ^{79}Br, $^{79}Br]^+$, 53), 313 (10), 191 (09), 163 (34). HRMS (EI, 70 eV): calcd for $C_{16}H_{10}Br_2O_2$ [M, ^{81}Br, $^{81}Br]^+$: 395.90011; found: 395.90004, calcd for $C_{16}H_{10}Br_2O_2$ [M, ^{79}Br, $^{81}Br]^+$: 393.90216; found: 393.90164, calcd for $C_{16}H_{10}Br_2O_2$ [M, ^{79}Br, $^{79}Br]^+$: 391.90421; found: 391.90370.

Synthesis of symmetrical 2,3-diaryl-5-bromo-1*H*-inden-ones 16a-g:

5-Bromo-2,3-bis(4-ethylphenyl)-1*H*-inden-1-one (16a): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5mL), K_3PO_4 (172 mg, 0.81 mmol) and 4-ethylphenylboronic acid **3b** (82 mg, 0.55 mmol), **16a** was isolated as a brownish yellow solid (100 mg, 88%). reaction temperature: 60°C for 6 h. Mp.102-104°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.15 (t, 3H, *J* = 7.56 Hz, CH_3), 1.23 (t, 3H, *J* = 7.56 Hz, CH_3), 2.55 (q, 2H, *J* = 7.59 Hz, CH_2), 2.64 (q, 2H, *J* = 7.59 Hz, CH_2), 7.03 (d, 2H, *J* = 8.43 Hz, ArH), 7.14 (d, 2H, *J* = 8.31 Hz, ArH), 7.19-7.24 (m, 5H, ArH), 7.33-7.38 (m, 2H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 14.1, 14.2 (CH_3), 27.7, 28.8 (CH_2), 123.9, 124.6, 127.7 (CH), 128.1 (C), 128.4, 128.5 (CH), 129.5, 129.6 (C), 129.9, 131.4 (CH), 132.9, 144.1, 145.9, 147.5, 153.6 (C), 195.0 (CO). IR (KBr): *v* = 3389, 3068, 3034, 2961, 2923, 2851, 1737, 1731 (w), 1702 (s), 1590, 1576, 1501, 1454, 1411, 1350 (m), 1328 (w), 1259, 1174, 1116, 1095, 1068 (m), 1047, 1017 (s), 961, 953 (w), 930, 883, 862, 837(m), 819 (s), 801 (m), 765, 743, 735, 718 (w), 699, 661, 648, 638, 582, 564, 527 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 416 ([M, $^{79}Br]^+$, 100), 387 (36), 263 (23). HRMS (EI, 70 eV): calcd for $C_{25}H_{21}BrO$ [M, $^{79}Br]^+$: 416.07703; found: 416.07706.

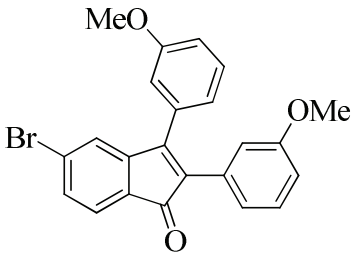


5-Bromo-2,3-bis(4-*tert*-butylphenyl)-1*H*-inden-1-one (16b): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol) and 4-*tert*-butylphenylboronic acid **3c** (98 mg, 0.55 mmol), **16b** was isolated as a brownish yellow solid (107 mg, 83%). reaction temperature: 60°C for 6 h. Mp188-190°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.22 (s, 9H, $3CH_3$), 1.29 (s, 9H, $3CH_3$), 7.15 (d, 2H, *J* = 8.49 Hz, ArH), 7.19-7.26 (m, 5H, ArH), 7.34-7.39 (m, 4H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 31.3 ($6CH_3$), 34.7,

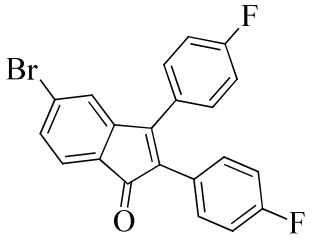


34.9 (C), 123.9, 124.7, 125.1, 125.9 (CH), 127.4 (C), 128.2 (CH), 129.3, 129.5 (C), 129.6, 131.3 (CH), 132.8, 147.7, 151.0, 152.8, 153.5 (C), 195.7 (CO). IR (KBr): ν = 3099, 3058, 3046, 3027, 2960, 2928, 2903, 2865 (m), 1707 (s), 1602, 1589, 1577 (m), 1556, 1459 (w), 1459, 1396, 1362, 1349, 1262 (m), 1199, 1181, 1113, 1104, 1092 (w), 1069, 1050, 1014 (m), 975, 958 (w), 933, 865, 857, 850, 841, 829 (m), 818 (s), 779, 739, 730 (m), 654, 635, 625, 566 (w), 559 (s) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 474 ([M, $^{81}Br]^+$, 75), 472 ([M, $^{79}Br]^+$, 73), 459 (100), 457 (98), 194 (16). HRMS (EI, 70 eV): calcd for $C_{29}H_{29}BrO$ [M, $^{81}Br]^+$: 474.13758; found: 474.13802; calcd for $C_{29}H_{29}BrO$ [M, $^{79}Br]^+$: 472.13963; found: 472.13921.

5-Bromo-2,3-bis(3-methoxyphenyl)-1*H*-inden-1-one (16c): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol) and 3-methoxyphenylboronic acid **3o** (83 mg, 0.55 mmol), **18c** was isolated as a brownish yellow solid (86 mg, 75%). reaction temperature: 60°C for 6 h. Mp.164-166°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.59 (s, 3H, OCH_3), 3.65 (s, 3H, OCH_3), 6.72-6.89 (m, 6H, ArH), 7.10 (t, 1H, J = 7.68 Hz, ArH), 7.18-7.20 (m, 1H, ArH), 7.31 (t, 1H, J = 7.90 Hz, ArH), 7.33-7.39 (m, 2H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 55.1, 55.3 (OCH_3), 113.7, 114.4, 115.0, 115.3, 120.6, 122.5, 124.1, 124.8 (CH), 128.4 (C), 129.2 (CH), 129.3 (C), 130.2 (CH), 131.5 (C), 131.7 (CH), 133.3, 133.5, 147.2, 154.2, 159.2, 159.9 (C), 195.1 (CO). IR (KBr): ν = 3400, 3070, 2999, 2954, 2919, 2849, 2833 (w), 1709, 1590, 1575 (s), 1479, 1453,1426 (m), 1401 (w), 1348, 1329, 1286 (m), 1263 (w), 1228 (m), 1171, 1132, 1093 (m), 1042 (s), 960 (m), 929, 919 (w), 887, 879, 832 (m), 786, 772 (s), 721, 688 (s), 647 (m), 606 (w), 593 (m), 566, 556 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 422 ([M, $^{81}Br]^+$, 71), 420 ([M, $^{79}Br]^+$, 100), 389 (15), 298 (15), 226 (36). HRMS (EI, 70 eV): calcd for $C_{23}H_{17}BrO_3$ [M, $^{81}Br]^+$: 422.03351; found: 422.03271, calcd for $C_{23}H_{17}BrO_3$ [M, $^{79}Br]^+$: 420.03556; found: 420.03447.

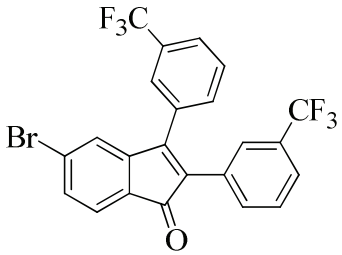


5-Bromo-2,3-bis(4-fluorophenyl)-1*H*-inden-1-one (16d): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol) and 4-fluorophenylboronic acid **3j** (77 mg, 0.55 mmol), **16d** was isolated as a brownish yellow solid (84 mg, 78%). reaction temperature: 60°C for 6 h. Mp.184-185°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.90 (t, 2H, J = 8.61 Hz, ArH), 7.07 (t, 2H, J = 8.61 Hz, ArH), 7.13-7.18 (m, 3H, ArH), 7.24-7.29 (m, 2H, ArH), 7.34-7.41 (m, 2H, ArH). ^{19}F



NMR (282.4 MHz, $CDCl_3$): δ = -112.3, -109.8. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 115.4 (d, $J_{F,C}$ = 21.7 Hz, CH), 116.4 (d, $J_{F,C}$ = 21.9 Hz, CH), 124.2, 124.6 (CH), 126.1 (d, $J_{F,C}$ = 3.56 Hz, C), 127.9 (d, $J_{F,C}$ = 3.49 Hz, C), 128.5, 129.1 (C), 130.4 (d, $J_{F,C}$ = 8.31 Hz, CH), 131.8 (d, $J_{F,C}$ = 7.71 Hz, CH), 131.9 (CH), 132.5, 146.9, 152.9 (C), 162.9 (d, $J_{F,C}$ = 249.3 Hz, CF), 163.2 (d, $J_{F,C}$ = 251.2 Hz, CF), 194.9 (CO). IR (KBr): ν = 3407, 3076, 3047, 2922, 2852, 2158, 1895 (w), 1709 (s), 1596, 1584, 1575 (s), 1511(m), 1499 (s), 1456, 1404, 1351, 1330, 1301 (m), 1278 (w), 1224 (s), 1178 (m), 1159 (s), 1093, 1065, 1050, 1015, 941, 927, 880, 864, 856, 845 (m), 825, 818 (s), 800, 776, 744, 732, 694, 662, 631, 619, 592, 567(m), 546, 532 (s) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 398 ([(M+H), $^{81}Br]^+$, 98), 396 ([(M+H), $^{79}Br]^+$, 100), 317 (52), 288 (79). HRMS (EI, 70 eV): calcd for $C_{21}H_{11}F_2BrO$ [M, $^{81}Br]^+$: 397.99354; found: 397.99335, calcd for $C_{21}H_{11}F_2BrO$ [M, $^{79}Br]^+$: 395.99559; found: 395.99534.

5-Bromo-2,3-bis(3-(trifluoromethyl)phenyl)-1*H*-inden-1-one (16e): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol) and 3-(trifluoromethyl)phenylboronic acid **3g** (104 mg, 0.55 mmol), **16e** was isolated as a brownish yellow solid (105 mg, 77%). reaction temperature: 60°C for 6 h. Mp.150-152°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.15 (d, 1H, *J* = 1.02 Hz, ArH), 7.32-7.57 (m, 9H, ArH), 7.15 (brs, 1H, *J* = 7.68 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -63.1, -63.0. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 123.3 (q, $J_{F,C}$ = 272.8 Hz, CF_3), 123.4 (q, $J_{F,C}$ = 272.5 Hz, CF_3), 124.7, 124.8 (CH), 125.1 (q, $J_{F,C}$ = 3.54 Hz, CH), 125.2 (q, $J_{F,C}$ = 3.58 Hz, CH), 126.6 (q, $J_{F,C}$ = 3.69 Hz, CH), 126.7 (q, $J_{F,C}$ = 3.76 Hz, CH), 128.8 (C), 128.9, 129.9 (CH), 130.4 (C), 130.9 (q, $J_{F,C}$ = 32.5 Hz, C-CF_3), 131.5 (CH), 132.0 (q, $J_{F,C}$ = 32.9 Hz, C-CF_3), 132.5 (CH), 132.5, 132.8 (C), 133.1 (CH), 146.2, 153.5 (C), 194.0 (CO). IR (KBr): ν = 3070, 2923, 2851, 2143 (w), 1704 (s), 1600, 1583 (m), 1479 (w), 1442 (m), 1403 (w), 1354 (m), 1324, 1313, 1295 (s), 1276, 1261, 1163 (m), 1120, 1097, 1068 (s), 1051 (m), 1000 (w), 951 (m), 932 (w), 911, 881, 861, 840 (m), 806 (s), 781, 769, 740, 720 (m), 698 (s), 672, 658 (m), 650, 642, 631, 621 (w), 595 (m), 530 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 498 ([(M+H), $^{81}Br]^+$, 98), 496 ([(M+H), $^{79}Br]^+$, 100), 417 (20), 397 (22), 320 (30). HRMS (EI, 70 eV): calcd for $C_{23}H_{11}F_6BrO$ [M, $^{81}Br]^+$: 497.98715; found: 497.98627, calcd for $C_{23}H_{11}F_6BrO$ [M, $^{79}Br]^+$: 495.98920; found: 495.98898.



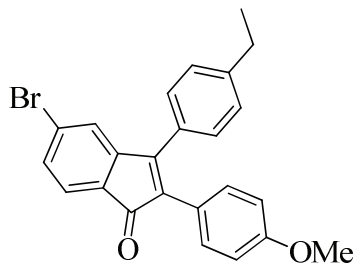
5-Bromo-2,3-bis(4-methoxyphenyl)-1*H*-inden-1-one (16f): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol) and 4-methoxyphenylboronic acid **3h** (83 mg, 0.55 mmol), **18f** was isolated as a brownish yellow solid (98 mg, 85%). reaction temperature: 60°C for 6 h. Mp.126-128°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.72 (s, 3H, OCH_3), 3.79 (s, 3H, OCH_3), 6.75 (d, 2H, J = 8.91 Hz, ArH), 6.88 (d, 2H, J = 8.85 Hz, ArH), 7.16 (d, 2H, J = 8.94 Hz, ArH), 7.21 (brs, 1H, ArH), 7.25 (d, 2H, J = 8.82 Hz, ArH), 7.33-7.34 (m, 2H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 55.2, 55.34 (OCH_3), 113.1, 113.8 (CH), 122.9 (C), 123.2, 123.8 (CH), 124.6, 128.1, 129.6 (C), 130.1, 131.2, 131.3 (CH), 132.2, 147.6, 152.6, 159.4, 160.5 (C), 195.7 (CO). IR (KBr): ν = 3409, 3071, 3026, 2987, 2956, 2920, 2850, 1898 (w), 1715, 1597, 1555, 1503, 1444 (s), 1420, 1401, 1342, 1307, 1275 (m), 1257, 1173 (s), 1152, 1118, 1103, 1091, 1052 (m), 1017 (s), 954 (w), 927 (m), 872 (w), 821 (s), 782, 766, 732, 712, 690, 632, 621, 588, 576 (m), 528 (s) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 422 ([M, ^{81}Br]$^+$, 98), 420 ([M, ^{79}Br]$^+$, 100), 405 (12), 255 (13), 226 (26). HRMS (EI, 70 eV): calcd for $C_{23}H_{17}BrO_3$ [M, ^{81}Br]$^+$: 422.03351; found: 422.03360, calcd for $C_{23}H_{17}BrO_3$ [M, ^{79}Br]$^+$: 420.03556; found: 420.03547.

5-Bromo-2,3-bis(4-chlorophenyl)-1*H*-inden-1-one (16g): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol) and 4-chlorophenylboronic acid **3f** (86 mg, 0.55 mmol), **16g** was isolated as a brownish yellow solid (102 mg, 87%). reaction temperature: 60°C for 6 h. Mp.172-174°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.09 (d, 2H, J = 8.64 Hz, ArH), 7.14-7.22 (m, 5H, ArH), 7.33-7.40 (m, 4H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 124.4, 124.6 (CH), 128.4, 128.6 (C), 128.7 (CH), 129.1 (C), 129.6, 129.7 (CH), 130.3 (C), 131.2, 132.0 (CH), 132.5, 134.5, 135.9, 146.6, 153.1 (C), 194.5 (CO). IR (KBr): ν = 3419, 3089, 3075, 3063, 2919, 2850 (w), 1715 (s), 1601, 1586, 1574, 1557, 1484, 1454, 1395, 1348 (m), 1330, 1305, 1282, 1265, 1210 (w), 1174, 1150 (m), 1087 (s), 1063, 1045 (m), 1013 (s), 974, 955, 946 (w), 929, 877, 858, 832, 821 (m), 812 (s), 776 (m), 740 (w), 726 (m), 715, 707, 688, 647, 630, 626, 618, 589 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 430 ([M, ^{81}Br, ^{35}Cl, ^{35}Cl]$^+$, 100), 428 ([(M+H), ^{79}Br, ^{35}Cl, ^{35}Cl]$^+$, 61), 395 (20), 314 (30), 286 (30), 250 (53). HRMS (EI, 70 eV): calcd for $C_{21}H_{11}Cl_2BrO$ [M, ^{79}Br, ^{35}Cl, ^{35}Cl]$^+$: 427.93648, found: 427.93635.

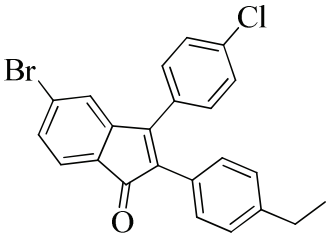
***General procedure (B) for Suzuki cross-coupling reactions of brominated indenone* (13):** The reaction was carried out in a pressure tube. To a 1,4-dioxane suspension (3-5 mL) of the brominated indenone, $Pd(PPh_3)_4$ or $Pd(PPh_3)_2Cl_2$ (5 mol%) and of the $Ar^1B(OH)_2$ (1.0 equiv. per cross-coupling), K_3PO_4 (1.5 equiv. per cross coupling) or an aqueous solution of K_2CO_3 (2 M, 1 mL) was added. The mixture was heated at the indicated temperature (45°C) under Argon atmosphere for the indicated period of time (9 h) and cooled to room temperature. Then $Ar^2B(OH)_2$ (1.0-1.1 equiv. per cross-coupling) was added and reaction mixture was further heated (6 h) at 60°C. The reaction mixture was again cooled to room temperature and diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in *vacuo*. The residue was purified by flash chromatography (silica gel, EtOAc/ heptanes).

Synthesis of unsymmetrical 2,3-diaryl-5-bromo-1*H*-inden-ones 17a-c:

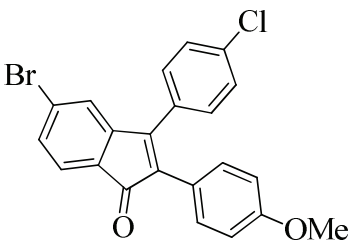
5-Bromo-3-(4-ethylphenyl)-2-(4-methoxyphenyl)-1*H*-inden-1-one (17a): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), was added 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol), 4-ethylphenylboronic acid **3b** (40 mg, 0.27 mmol) and 4-methoxyphenylboronic acid **3h** (41 mg, 0.27 mmol) *following the general procedure B*, **17a** was isolated as a brownish yellow solid (92 mg, 80%). reaction temperature: at 45°C for 9h, at 60°C for 6 h. Mp.120-122°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.21 (t, 3H, J = 7.59 Hz, CH_3), 2.63 (q, 2H, J = 7.62 Hz, CH_2), 3.71 (s, 3H, OCH_3), 6.73 (d, 2H, J = 8.91 Hz, ArH), 7.13-7.22 (m, 7H, ArH), 7.31-7.34 (m, 2H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 15.2 (CH_3), 28.8 (CH_2), 55.2 (OCH_3), 113.7 (CH), 122.8 (C), 123.8, 124.4 (CH), 128.2 (C), 128.4, 128.5 (CH), 129.5, 129.6 (C), 131.2, 131.3 (CH), 132.5, 145.8, 147.6, 152.8, 159.4 (C), 195.7 (CO). IR (KBr): ν = 3419, 3079, 2997, 2962, 2925, 2852, 2836 (w), 1709 (s), 1600, 1589, 1577, 1514, 1500, 1453, 1444 (m), 1400, 1349, 1329, 1293 (w), 1248, 1183 (s), 1049, 1117, 1093 (w), 1065, 1049, 1029, 1017 (m), 930 (s), 880, 852 (m), 838, 820 (s), 774 (m), 743, 733, 717 (w), 699 (m), 681, 660, 649, 632 (w), 582, 561, 540, 526 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 420 ([M, ^{81}Br]$^+$, 100), 418 ([M, ^{79}Br]$^+$, 96), 239 (19). HRMS (EI, 70 eV): calcd for $C_{24}H_{19}BrO_2$ [M, ^{81}Br]$^+$: 420.05425; found: 420.05468; calcd for $C_{24}H_{19}BrO_2$ [M, ^{79}Br]$^+$: 418.05629; found: 418.05624.



5-Bromo-3-(4-chlorophenyl)-2-(4-ethylphenyl)-1*H*-inden-1-one (17b): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), was added 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol), 4-chlorophenylboronic acid **3f** (42 mg, 0.27 mmol) and 4-ethylphenylboronic acid **3b** (40 mg, 0.27 mmol) following *the general procedure B*, **17b** was isolated as a brownish yellow solid (92 mg, 79%). reaction temperature: at 45°C for 9h, at 60°C for 6 h. Mp.133-134°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.14 (t, 3H, J = 7.59 Hz, CH_3), 2.54 (q, 2H, J = 7.59 Hz, CH_2), 7.02-7.11 (m, 4H, ArH), 7.13 (brs, 1H, ArH), 7.23 (d, 2H, J = 8.57 Hz, ArH), 7.33-7.35 (m, 4H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 15.2 (CH_3), 28.7 (CH_2), 124.2, 124.3 (CH), 127.2 (C), 127.9 (CH), 128.4, 129.2 (C), 129.4, 129.8, 129.9 (CH), 130.8 (C), 131.6 (CH), 133.8, 135.4, 144.6, 147.1, 152.0 (C), 195.1 (CO). IR (KBr): ν = 3390, 3082, 3060, 3030, 2964, 2917, 2871, 2849 (w), 1705 (s), 1597, 1582, 1574 (m), 1508 (w), 1484, 1450, 1396, 1349, 1328 (m), 1259 (w), 1171, 1148 (m), 1120, 1108 (w), 1088 (s), 1068, 1047 (m), 1012 (s), 969, 951 (w), 930, 875, 860, 853 (m), 827, 819 (s), 779, 742, 733, 716, 692, 654, 637, 620, 589, 569, 534 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 426 ([M, ^{37}Cl, ^{81}Br]$^+$, 26), 424 ([M, ^{35}Cl, ^{81}Br]$^+$, 100), 422 ([M, ^{35}Cl, ^{79}Br]$^+$, 76), 409 (33), 263 (28). HRMS (EI, 70 eV): calcd for $C_{23}H_{16}BrClO$ [M, ^{35}Cl, ^{79}Br]$^+$: 422.00676; found: 422.00555.



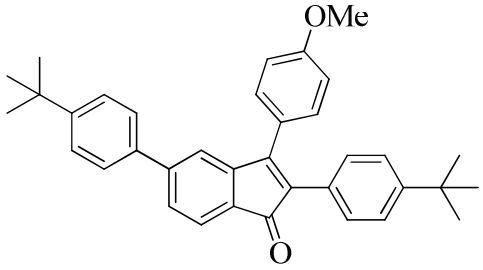
5-Bromo-3-(4-chlorophenyl)-2-(4-methoxyphenyl)-1*H*-inden-1-one (17c): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), was added 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol), 4-chlorophenylboronic acid **3f** (42 mg, 0.27 mmol) and 4-methoxyphenylboronic acid **3h** (41 mg, 0.27 mmol) following *the general procedure B*, **17c** was isolated as a brownish yellow solid (95 mg, 82%). reaction temperature: at 45°C for 9h, at 60°C for 6 h. Mp.170-171°C. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.71 (s, 3H, OCH_3), 6.74 (d, 2H, J = 8.43 Hz, ArH), 7.11-7.18 (m, 3H, ArH), 7.23 (d, 2H, J = 8.10 Hz, ArH), 7.31-7.36 (m, 4H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 54.2 (OCH_3), 112.8 (CH), 121.2 (C), 123.1 (CH), 127.4, 128.1 (C), 128.4, 128.8 (CH), 129.9 (C), 130.3, 130.4 (CH), 132.2, 134.3, 146.2, 150.0, 158.6 (C), 194.3 (CO). IR (KBr): ν = 3041, 3059, 3018, 2958, 2930, 2838 (w), 1709, 1600, 1576 (s), 1510, 1485, 1455, 1445 (m), 1416, 1407, 1396 , 1352 , 1329 (w), 1295 (m), 1251, 1174 (s), 1152, 1114 (w), 1090 (s), 1065, 1047 (m), 1024, 1013 (s), 974, 957, 946 (w), 929 (s), 879, 846 (m), 828, 812 (s), 779, 742, 734, 717,



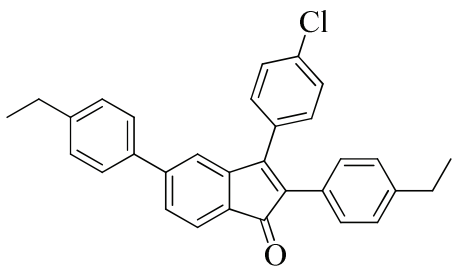
691, 654 (m), 643, 632, 618, 590 (w), 566, 536 (s) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 426 ([(M+H), ^{81}Br, $^{35}Cl]^+$, 100), 424 ([M+H), ^{79}Br, $^{35}Cl]^+$, 77), 267 (16), 239 (37). HRMS (EI, 70 eV): calcd for $C_{22}H_{14}BrClO_2$ [M, ^{81}Br, $^{35}Cl]^+$: 425.98397; found: 425.98350; calcd for $C_{22}H_{14}BrClO_2$ [M, ^{79}Br, $^{35}Cl]^+$: 423.98602; found: 423.98530.

Synthesis of unsymmetrical 2,3,5-triaryl-1*H*-inden-ones 18a-c and 19a,b:

2,5-Bis(4-*tert*-butylphenyl)-3-(4-methoxyphenyl)-1*H*-inden-1-one (18a): Starting with **15g** (78 mg, 0.199 mmol), $Pd(PPh_3)_4$ (11 mg, 5 mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and 4-*tert*-butylphenylboronic acid **3c** (82 mg, 0.43 mmol), *following the general procedure A*, **18a** was isolated as a brownish yellow solid (77 mg, 78%). reaction temperature: 70°C for 6 h. Mp.188-190°C. ^1H NMR (300MHz, $CDCl_3$): δ = 1.22 (s, 9H, $3CH_3$), 1.27 (s, 9H, $3CH_3$), 3.77 (s, 3H, OCH_3), 6.85 (d, 2H, *J* = 8.61 Hz, ArH), 7.15-7.23 (m, 4H, ArH), 7.29-7.44 (m, 8H, ArH), 7.52 (d, 1H, *J* = 8.54 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.2, 30.3 (CH_3), 33.5, 33.6 (C), 54.3 (OCH_3), 114.3, 120.3, 123.1 (CH), 123.1 (C), 125.1, 125.8, 126.9, 127.0 (CH), 128.0 (C), 129.6, 130.2 (CH), 132.2, 137.6, 146.2, 146.3, 149.5, 150.4, 153.0, 159.3 (C), 195.4 (CO). IR (KBr): *v* = 3033, 2958, 2923, 2855 (w), 1700, 1597 (s), 1510, 1499, 1463 (m), 1493, 1405, 1392 (w), 1352 (m), 1332, 1307, 1290, 1266 (w), 1248, 1175 (s), 1111, 1092, 1070 (m), 1040 (w), 1023 (s), 958, 948, 941, 931, 908, 896, 867, 856 (w), 821 (s), 808, 784, 740, 729, 690, 649 (m), 638, 629, 610 (w), 573, 543, 534 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 500 ($[M]^+$, 100), 485 (70), 235 (21). HRMS (EI, 70 eV): calcd for $C_{36}H_{36}O_2$ $[M]^+$: 500.27098; found: 500.27155.

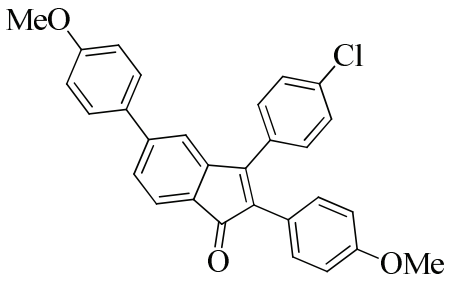


3-(4-Chlorophenyl)-2,5-bis(4-ethylphenyl)-1*H*-inden-1-one (18b): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (262 mg, 1.23 mmol), 4-chlorophenylboronic acid **3f** (43 mg, 0.27 mmol) and 4-ethylphenylboronic acid **3b** (89 mg, 0.59 mmol) following *the general procedure B*, **18b** was isolated as a brownish yellow solid (99 mg, 81%). reaction temperature: at 45°C for 9h, at 70°C for 6 h. Mp.133-134°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 1.15 (t, 3H, *J* = 7.62 Hz, CH_3), 1.19 (t, 3H, *J* = 7.62 Hz, CH_3), 2.55 (q, 2H, *J* = 7.59 Hz, CH_2), 2.61 (q, 2H, *J* = 7.59 Hz, CH_2),

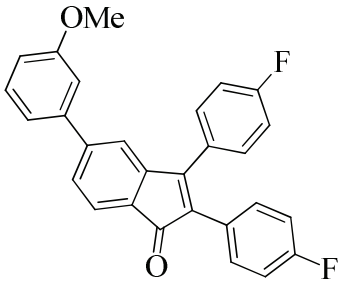


7.04 (d, 2H, *J* = 8.25 Hz, ArH), 7.12 (d, 2H, *J* = 8.28 Hz, ArH), 7.17-7.21 (m, 3H, ArH), 7.26-7.34 (m, 4H, ArH), 7.37-7.41 (m, 3H, ArH), 7.54 (d, 1H, *J* = 7.44 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 14.2, 14.5 (CH_3), 27.5, 27.6 (CH_2), 119.0, 122.5, 126.1, 126.2 (CH), 126.6 (C), 126.7, 127.4 (CH), 128.1 (C), 128.2, 128.8, 129.0 (CH), 130.4, 132.5, 134.0, 136.6, 143.2, 143.7, 144.9, 145.8, 151.6 (C), 195.0 (CO). IR (KBr): *v* = 3391, 3024, 2961, 2926, 2870, 1907, 1789 (w), 1706, 1595 (s) 1515 (w), 1485, 1462, 1455 (m), 1410, 1373 (w), 1351 (m), 1260 (w), 1181, 1142 (m), 1087 (s), 1069, 1049 (m), 1012 (s), 963, 948, 935, 894, 862, 850 (w), 819 (s), 784, 741, 717 (m), 700, 670, 654, 638, 621, 571 (w) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 448 ([M]$^+$, 100), 433 (18), 419 (16). HRMS (EI, 70 eV): calcd for $C_{31}H_{25}ClO$ [M]$^+$: 448.15884; found: 448.15899.

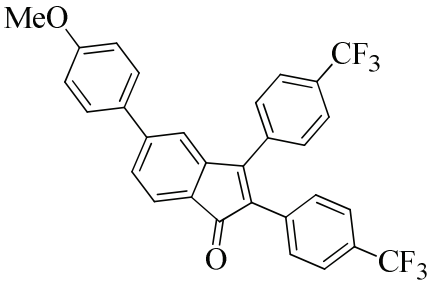
3-(4-Chlorophenyl)-2,5-bis(4-methoxyphenyl)-1*H*-inden-1-one (18c): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (262 mg, 1.23 mmol), 4-chlorophenylboronic acid **3f** (42 mg, 0.27 mmol) and 4-ethylphenylboronic acid **3b** (90 mg, 0.59 mmol) following *the general procedure B*, **18c** was isolated as a brownish yellow solid (104 mg, 84%). reaction temperature: at 45°C for 9h, at 70°C for 6 h. Mp.201-203°C. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 3.81 (s, 3H, OCH_3), 3.85 (s, 3H, OCH_3), 6.74 (d, 2H, *J* = 8.80 Hz, ArH), 6.88 (d, 2H, *J* = 8.72 Hz, ArH), 7.13-7.18 (m, 3H, ArH), 7.26-7.36 (m, 5H, ArH), 7.42 (d, 2H, *J* = 8.70 Hz, ArH), 7.52 (d, 1H, *J* = 7.47 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 55.2 (OCH_3), 55.4 (OCH_3), 113.8, 114.3, 119.5 (CH), 122.8 (C), 123.5, 126.6, 128.3 (CH), 128.7 (C), 129.3, 130.0, 131.3 (CH), 131.5, 132.7, 133.0, 135.0, 146.1, 146.4, 151.7, 159.4, 160.0 (C), 196.2 (CO). IR (KBr): *v* = 3377, 3057, 3042, 3010, 2951, 2925, 2835 (w), 1697 (s), 1608 (w), 1591 (s), 1516 , 1486, 1462, 1455, 1442 (m), 1413, 1398, 1348, 1331, 1307 (w), 1286 (m), 1246, 1173 (s), 1141, 1087, 1071, 1039, 1013 (m), 936, 893, 850 (w), 836 (m), 822 (s), 811, 797, 786, 744, 738, 727, 718 (m), 699, 655, 621(w), 571, 562 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 452 ([M, ^{35}Cl]$^+$, 100), 226 (12). HRMS (EI, 70 eV): calcd for $C_{29}H_{21}ClO_3$ [M, ^{35}Cl]$^+$: 452.11737; found: 452.11804.



2,3-Bis(4-fluorophenyl)-5-(3-methoxyphenyl)-1*H*-inden-1-one (19a): Starting with **16d** (79 mg, 0.20 mmol), $Pd(PPh_3)_4$ (8 mg, 3 mol%), 1,4-dioxane (5 mL), K_2CO_3 (2 M, 1 mL) and 3-methoxyphenylboronic acid **3o** (33 mg, 0.22 mmol), *following the general procedure A*, **21a** was isolated as a yellow solid (74 mg, 88%). reaction temperature: 70°C for 6 h. Mp.175-177°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.78 (s, 3H, OCH_3), 6.84-6.94 (m, 3H, ArH), 6.99-7.10 (m, 4H, ArH), 7.14-7.21 (m, 3H, ArH), 7.26-7.35 (m, 3H, ArH), 7.41 (dd, 1H, J = 1.41, 7.44 Hz, ArH), 7.56 (d, 1H, J = 7.47 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -112.9, -110.4. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 55.4 (OCH_3), 113.2, 113.3 (CH), 115.3 (d, $J_{F,C}$ = 21.5 Hz, CH), 116.3 (d, $J_{F,C}$ = 21.7 Hz, CH), 119.7, 120.4, 123.5 (CH), 126.5 (d, $J_{F,C}$ = 3.50 Hz, C), 127.7 (CH), 128.5 (d, $J_{F,C}$ = 3.53 Hz, C), 129.4 (C), 130.0 (CH), 130.5 (d, $J_{F,C}$ = 8.26 Hz, CH), 131.7 (d, $J_{F,C}$ = 8.11 Hz, CH), 132.3, 141.7, 145.7, 146.8, 153.6, 160.0 (C), 162.4 (d, $J_{F,C}$ = 248.6 Hz, C), 163.2 (d, $J_{F,C}$ = 250.3 Hz, C), 195.7 (CO). IR (KBr): ν = 3393, 3066, 3034, 2919, 2850 (w), 1704, 1596 (s), 1738, 1731 (w), 1704 (s), 1667, 1651, 1644, 1633 (w), 1596 (s), 1575 (m), 1510, 1538 (w), 1510, 1495, 1463 (m), 1437, 1417, 1406 (w), 1351 (m), 1316, 1298, 1279, 1263, 1248 (w), 1223, 1211(s), 1186, 1171, 1160, 1154 (m), 1101, 1080, 1071, 1049, 1023, 965, 951, 944, 877(w), 849 (s), 838 (m), 816 (s), 800, 793 (w), 772 (s), 747, 736, 712, 696, 676 (m), 666, 629, 608 , 581(w), 568 (m), 548, 536 (s) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 424 ([M]$^+$, 100). HRMS (EI, 70 eV): calcd for $C_{28}H_{18}F_2O_2$ [M]$^+$: 424.12694; found: 424.12692.



5-(4-Methoxyphenyl)-2,3-bis(4-(trifluoromethyl)phenyl)-1*H*-inden-1-one (19b): Starting with **13** (100 mg, 0.27 mmol), $Pd(PPh_3)_4$ (15 mg, 5 mol%), 1,4-dioxane (5 mL), K_3PO_4 (172 mg, 0.81 mmol), 4-(trifluoromethyl)phenylboronic acid **3q** (102 mg, 0.54 mmol) and 4-methoxyphenylboronic acid **3h** (42 mg, 0.27 mmol) following *the general procedure B*, **19b** was isolated as a yellow solid (124 mg, 86%). reaction temperature: at 60°C for 9h, at 70°C for 6 h. Mp.200-201°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.77 (s, 3H, OCH_3), 6.89 (d, 2H, J = 8.76 Hz, ArH), 7.17 (s, 1H, ArH), 7.28 (d, 2H, J = 8.10 Hz, ArH), 7.41-7.48 (m, 7H, ArH), 7.59 (d, 1H, J = 7.50 Hz, ArH), 7.65 (d, 2H, J = 8.13 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -62.8, -62.7. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 55.4 (OCH_3), 114.4, 120.2 (CH), 123.6 (q, $J_{F,C}$ = 272.6 Hz, CF_3), 123.8 (q, $J_{F,C}$ = 270.3 Hz, CF_3), 124.1 (CH), 125.2



(q, $J_{F,C}$ = 3.83 Hz, CH), 126.2 (q, $J_{F,C}$ = 3.75 Hz, CH), 127.4 (CH), 128.2 (C), 128.3, 128.9 (CH), 130.0 (q, $J_{F,C}$ = 31.5 Hz, C-CF_3), 130.2 (CH), 131.5 (q, $J_{F,C}$ = 33.0 Hz, C-CF_3), 132.3, 132.7, 133.9, 136.0, 145.2, 146.9, 154.4, 160.2 (C), 194.8 (CO). IR (KBr): *v* = 3078, 2999, 2962, 2918, 2849, 2837 (w), 1699 (s), 1667, 1660, 1651, 1613 (w), 1593(s), 1574 (m), 1557, 1539 (w), 1520, 1471(m), 1463, 1455, 1435, 1416, 1410, 1354 (w), 1418, 1410 (m), 1318, 1280 (s), 1264 (m), 1244, 1160 (s), 1148 (m), 1120, 1112, 1068, 1058 (s), 1033 (m), 1016 (s), 964, 937, 916, 987, 867, 856 (m), 819 (s), 799, 781 (m), 766, 756 (w), 730, 719, 709, 698, 618, 601, 554 (m) cm^{-1}. GC-MS (EI, 70 eV): *m/z* (%) = 524 ($[M]^+$, 100). HRMS (EI, 70 eV): calcd for $C_{30}H_{18}F_6O_2$ $[M]^+$: 524.12055; found: 524.12079.

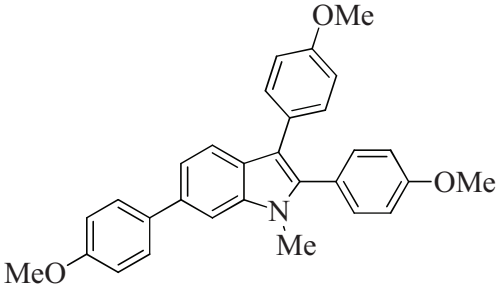
Site-Selective Synthesis of Arylated-1-methyl-1*H*-indole by Suzuki–Miyaura Cross-Coupling Reactions of 2,3,6-tribromo-1-methyl-1*H*-indole

Synthesis of 2,3,6-tribromo-1-methyl-1*H*-indole (21): To a THF solution (50 mL) of *N*-methylindole **20** (0.96 g, 7.34 mmol) was portion wise added NBS (4.40 g, 24.9 mmol) at -78°C and the solution was stirred at this temperature for 4 h and then at 20°C for 14 h. To the solution was added water (25 mL). The organic and the aqueous layer were separated and the latter was extracted with CH_2Cl_2 (3 x 30 mL). The combined organic layers were washed with a saturated aqueous solution of $NaHCO_3$, dried (Na_2SO_4), filtered and concentrated in vacuo. The residue was purified by flash silica column chromatography (pure heptanes) to yield **21** as a yellowish solid (1.85 g, 69.5%), Mp.94-96°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.57 (s, 3H, NCH_3), 7.12 (dd, 1H, *J* = 1.56, 8.49 Hz, ArH), 7.17-7.20 (m, 1H, ArH), 7.25 (d, 1H, *J* = 1.26 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 32.4 (NCH_3), 92.9 (C), 112.5 (CH), 115.6, 116.6 (C), 120.0, 124.0 (CH), 125.7, 136.7 (C). IR (KBr): *v* = 3207, 3105, 3069, 2935, 2860, 2817, 2679 (w), 1494 (m), 1452 (s), 1410 (m), 1359 (w), 1321, 1314 (s), 1287 (m), 1226 (s), 1195, 1182, 1132 (w), 1112 (m), 1081 (w), 1048 (m), 946 (s), 847, 839 (w), 829, 790 (s), 731 (m), 666 (w), 649 (m), 597 (w), 582 (s), 562 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 369 ([(M+H), ^{79}Br, ^{81}Br, ^{81}Br]$^+$, 97), 367 ([(M+H), ^{79}Br, ^{79}Br, ^{81}Br]$^+$, 100), 365 ([(M+H), ^{79}Br, ^{79}Br, ^{79}Br]$^+$ 34), 354 (18), 352 (19). HRMS (EI, 70 eV): calcd for $C_9H_6Br_3N$ [M, ^{79}Br, ^{81}Br, ^{81}Br]$^+$: 368.80040; found 368.80051, calcd for $C_9H_6Br_3N$ [M, ^{79}Br, ^{79}Br, ^{81}Br]$^+$: 366.80244; found 366.80225, calcd for $C_9H_6Br_3N$ [M, ^{79}Br, ^{79}Br, ^{79}Br]$^+$: 364.80449; found 364.80426.

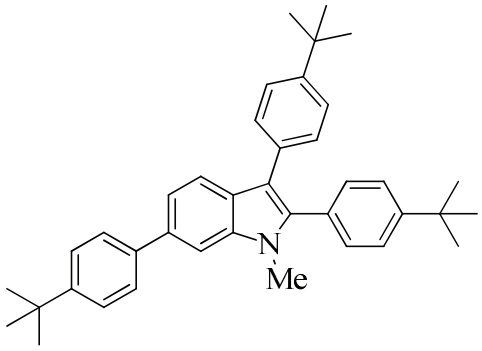
***General procedure (A) for Suzuki cross-coupling reactions of brominated N-methylindole* (21):** The reaction was carried out in a pressure tube. To a 1,4-dioxane or a mixture solvent (for mono cross-coupling reactions) of toluene/1,4-dioxane (4:1) (3-5 mL) suspension of the brominated -N-methylindole, $Pd(PPh_3)_4$ (3-5 mol%) and of the arylboronic acid (1.1 per cross coupling), K_3PO_4 (1.5 equiv. per cross coupling) or an aqueous solution of K_2CO_3 (2 M, 1 mL) was added. The mixture was heated at the indicated temperature (65-110°C) under Argon atmosphere for the indicated period of time (8 h). The reaction mixture was diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in *vacuo*. The residue was purified by flash chromatography (silica gel, EtOAc/ heptanes).

Synthesis of 2,3,6-triaryl-1-methyl-1*H*-indole 22a-i:

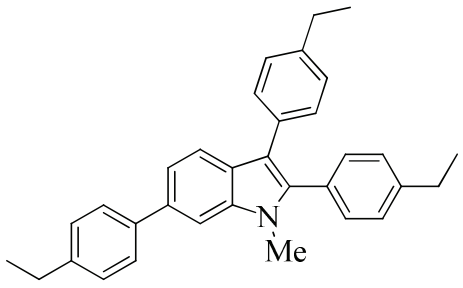
2,3,6-Tris(4-methoxyphenyl)-1-methyl-1*H*-indole (22a): Starting with **21** (100 mg, 0.27 mmol), 4-methoxyphenylboronic acid **3h** (142 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22a** was isolated as a white solid (107 mg, 87%); reaction temperature: 110°C for 8 h, Mp.124-126°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.67 (s, 3H, NCH_3), 3.72 (s, 3H, OCH_3), 3.75 (s, 3H, OCH_3), 3.78 (s, 3H, OCH_3), 6.68 (d, 1H, *J* = 2.94 Hz, ArH), 6.75-6.94 (m, 6H, ArH), 7.14-7.16 (m, 3H, ArH), 7.30 (dd, 1H, *J* = 1.50, 8.28 Hz, ArH), 7.44 (d, 1H, *J* = 0.99 Hz, ArH), 7.55 (d, 2H, *J* = 8.76 Hz, ArH), 7.68 (d, 1H, *J* = 8.25 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.9 (NCH_3), 55.2, 55.3, 55.4 (OCH_3), 107.6, 113.8, 114.2 (CH), 114.3 (C), 114.8, 116.0, 119.6 (CH), 124.2, 126.1, 127.8 (C), 128.4, 130.8, 132.3 (CH), 135.2, 137.6, 137.7, 149.5, 157.5, 158.7, 159.3 (C). IR (KBr): *v* = 3053, 3037, 2994, 2961, 2928, 2838, 1607, 1573, 1551 (w), 1515 (m), 1478 (w), 1466, 1455, 1440 (m), 1426, 1392, 1370, 1338, 1303 (w), 1286 (m), 1239, 1173 (s), 1148, 1107, 1089 (m), 1036, 1026 (s), 961, 944, 932, 856 (w), 838 (m), 820, 809, 795 (s), 755 (m), 729, 721 (w), 688 (m), 646, 640, 628, 625 (w), 611 (s), 586, 576 (m), 556 (w), 537 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 449 ($[M]^+$, 100), 435 (11), 434 (36). HRMS (EI, 70 eV): calcd for $C_{30}H_{27}O_3N$ $[M]^+$: 449.19855; found: 449.19913.



2,3,6-Tris(4-(*tert*-butyl)phenyl)-1-methyl-1*H*-indole (22b): Starting with **21** (100 mg, 0.27 mmol), 4-*tert*-butylphenylboronic acid **3c** (166 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22b** was isolated as a white solid (123 mg, 85%); reaction temperature: 110°C for 8 h, Mp.116-117°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.24 (s, 9H, $3CH_3$), 1.28 (s, 9H, $3CH_3$), 1.30 (s, 9H, $3CH_3$), 3.60 (s, 3H, NCH_3), 6.16-7.21(m, 5H, ArH), 7.30-7.37 (m, 3H, ArH), 7.39 (d, 3H, *J* = 3.54 Hz, ArH), 7.49 (d, 1H, *J* = 1.05 Hz, ArH), 7.57 (d, 2H, *J* = 8.49 Hz, ArH), 7.76 (d, 1H, *J* = 8.04 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 31.0 (NCH_3), 31.3, 31.4, 31.5 (CH_3), 34.4, 34.5, 34.7 (C), 107.9 (CH), 114.7 (C), 119.8, 119.9, 125.4, 125.5, 125.7 (CH), 126.4 (C), 127.1 (CH), 128.9 (C), 129.3, 130.8 (CH), 132.2, 135.4, 137.8, 138.2, 139.7, 148.0, 149.5, 150.9 (C). IR (KBr): *v* = 3029 (w), 2956 (s), 2902, 2865 (m), 1911, 1673, 1604, 1548, 1519 (w), 1461 (s), 1426, 1392 (w), 1361 (s), 1335, 1318, 1307 (w), 1267 (m), 1201, 1181, 1166 (w), 1108 (m), 1086, 1047 (w), 1014, 947 (m), 921, 907 (w), 860 (m), 835, 809 (s), 769, 756 (w), 732 (m), 711, 699, 672, 651 (w), 623, 599 (m), 554 (s) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 528 ($[M+H]^+$, 38), 527 ($[M]^+$, 100), 513 (11), 512 (26), 471 (12), 249 (9). HRMS (EI, 70 eV): calcd for $C_{39}H_{45}N$ $[M]^+$: 527.35465; found: 527.35464.

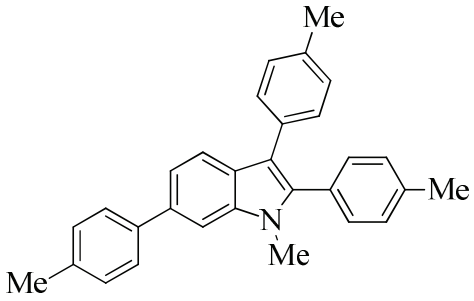


2,3,6-Tris(4-ethylphenyl)-1-methyl-1*H*-indole (22c): Starting with **21** (100 mg, 0.27 mmol), 4-ethylphenylboronic acid **3b** (140 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22c** was isolated as a white solid (99 mg, 82%); reaction temperature: 110°C for 8 h, Mp.116-117°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.14-1.24 (m, 9H, $3CH_3$), 2.52-2.66 (m, 6H, $3CH_2$), 3.60 (s, 3H, NCH_3), 7.03 (d, 2H, *J* = 8.31 Hz, ArH), 7.14-7.23 (m, 8H, ArH), 7.34 (dd, 1H, *J* = 1.56, 8.28 Hz, ArH), 7.48 (d, 1H, *J* = 1.02 Hz, ArH), 7.55 (d, 2H, *J* = 8.19 Hz, ArH), 7.74 (d, 1H, *J* = 8.28 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 15.3, 15.4, 15.7 (CH_3), 28.5, 28.6, 28.7 (CH_2), 31.0 (NCH_3), 107.9 (CH), 114.8 (C), 119.8, 119.9 (CH), 126.4 (C), 127.7, 127.9, 128.0, 128.2 (CH), 128.3 (C), 129.3, 130.2 (CH), 132.6, 135.6, 137.9, 138.3, 140.0, 141.2, 142.7, 144.1 (C). IR (KBr): *v* = 3020, 2963, 2929, 2872 (w), 1608, 1566, 1546 (w), 1517, 1463 (m), 1428, 1409,

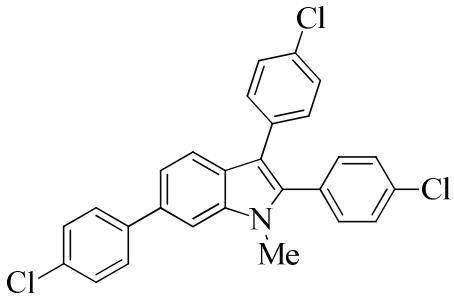


1392 (w), 1373 (m), 1341, 1317, 1256, 1229, 1182, 1147, 1118 (w), 1087 (m), 1059, 1047, 1014, 961 (w), 944 (m), 908, 855 (w), 830, 822, 806 (s), 753, 730, 700, 688, 664, 646, 640, 629 (w), 611 (m), 583, 564 (w), 535 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 444 ($[M+H]^+$, 37), 443 ($[M]^+$, 100). HRMS (ESI, 70 eV): calcd for $C_{33}H_{34}N$ $[M+H]^+$: 444.26858; found: 444.26845.

1-Methyl-2,3,6-tri-*p*-tolyl-1*H*-indole (22d): Starting with **21** (100 mg, 0.27 mmol), 4-methylphenylboronic acid **3e** (126 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22d** was isolated as a white solid (96 mg, 87%); reaction temperature: 110°C for 8 h, Mp.174-177°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 2.23 (s, 3H, CH_3), 2.30 (s, 3H, CH_3), 2.31 (s, 3H, CH_3), 3.58 (s, 3H, NCH_3), 6.99 (d, 2H, *J* = 7.86 Hz, ArH), 7.07-7.18 (m, 8H, ArH), 7.32 (dd, 1H, *J* = 1.53, 8.28 Hz, ArH), 7.46 (d, 1H, *J* = 1.02 Hz, ArH), 7.51 (d, 2H, *J* = 8.10 Hz, ArH), 7.71 (d, 1H, *J* = 8.31 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 21.1, 21.2, 21.4 (CH_3), 31.0 (NCH_3), 107.9 (CH), 114.8 (C), 119.8, 119.9 (CH), 126.4 (C), 127.3, 129.0, 129.2 (CH), 129.3 (C), 129.5, 129.7, 131.0 (CH), 132.4, 135.0, 135.6, 136.3, 137.8, 137.9, 138.3, 139.8 (C). IR (KBr): *v* = 3018, 2917, 2860, 2733, 1610, 1567, 1548 (w), 1518, 1468 (m), 1449, 1428, 1403, 1391 (w), 1373 (m), 1337, 1319, 1304, 1256, 1229, 1212, 1185, 1147, 1112 (w), 1087 (m), 1039, 1015, 971, 962 (w), 944, 852 (m), 840, 820, 810, 801 (s), 777, 755, 726 (m), 698, 689, 642, 633 (w), 612 (m), 577, 567, 539 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 402 ($[M+H]^+$, 33), 401 ($[M]^+$, 100), 371 (6). HRMS (ESI, 70 eV): calcd for $C_{30}H_{28}N$ $[M+H]^+$: 402.22163; found: 402.22112.

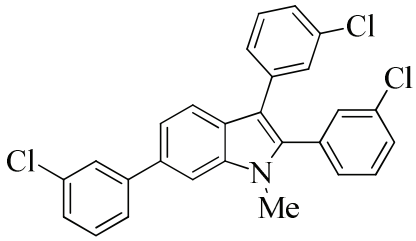


2,3,6-Tris(4-chlorophenyl)-1-methyl-1*H*-indole (22e): Starting with **21** (100 mg, 0.27 mmol), 4-chlorophenylboronic acid **3f** (145 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22e** was isolated as a white solid (108 mg, 85%); reaction temperature: 110°C for 8 h, Mp.218-222°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.60 (s, 3H, NCH_3), 7.10-7.21 (m, 6H, ArH), 7.29-7.37 (m, 5H, ArH), 7.47 (d, 1H, *J* = 1.02 Hz, ArH), 7.54 (d, 2H, *J* = 8.58 Hz, ArH), 7.68 (d, 1H, *J* = 8.22 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.0 (NCH_3), 107.1 (CH), 113.4 (C), 118.8, 119.1 (CH),

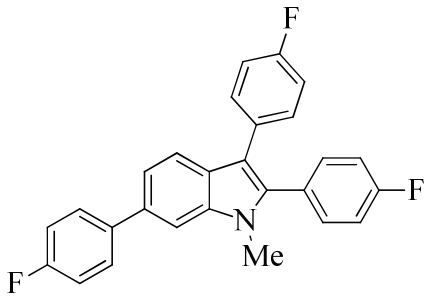


125.2 (C), 127.5, 127.6, 127.8, 127.9 (CH), 128.8 (C), 129.9 (CH), 130.7 (C), 131.2 (CH), 131.8, 132.2, 133.5, 133.9, 136.3, 136.9, 139.6 (C). IR (KBr): ν = 3078, 3031, 2923, 2852, 1899, 1614, 1598, 1568, 1543 (w), 1495 (m), 1461 (s), 1426, 1396 (w), 1370, 1334 (m), 1315, 1299 (w), 1254 (m), 1233, 1176, 1164 (w), 1088, 1013 (s), 957 (w), 946, 904 (m), 870 (w), 853 (s), 831, 821 (m), 811 (s), 760 (w), 746 (m), 732 (s), 720, 706 (m), 661, 644, 633, 625 (w), 614, 583 (m), 563, 541 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 464 ([M+H], ^{35}Cl, ^{35}Cl, $^{37}Cl)^+$, 29), 463 ([M, ^{35}Cl, ^{35}Cl, $^{37}Cl]^+$, 99), 462 ([(M+H), ^{35}Cl, ^{35}Cl, $^{35}Cl]^+$, 31), 461 ([M, ^{35}Cl, ^{35}Cl, $^{35}Cl]^+$, 100). HRMS (EI, 70 eV): calcd for $C_{27}H_{18}Cl_3N$ [M, ^{35}Cl, ^{35}Cl, $^{37}Cl]^+$: 463.04698; found: 463.04719, calcd for $C_{27}H_{18}Cl_3N$ [M, ^{35}Cl, ^{35}Cl, $^{35}Cl]^+$: 461.04993; found: 461.04975.

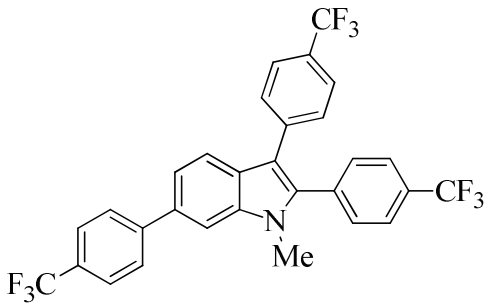
2,3,6-Tris(3-chlorophenyl)-1-methyl-1*H*-indole (22f): Starting with **21** (100 mg, 0.27 mmol), 3-chlorophenylboronic acid **3n** (145 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22f** was isolated as a white solid (101 mg, 80%); reaction temperature: 110°C for 8 h, Mp.120-123°C.



^1H NMR (300 MHz, $CDCl_3$): δ = 3.63 (s, 3H, NCH_3), 6.99-7.02 (m, 1H, ArH), 7.09-7.11 (m, 3H, ArH), 7.21-7.35 (m, 7H, ArH), 7.46-7.49 (m, 2H, ArH), 7.59-7.60 (m, 1H, ArH), 7.70 (d, 1H, J = 8.13 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.1 (NCH_3), 107.3 (CH), 113.4 (C), 118.9, 119.3, 124.5, 125.0 (CH), 125.3 (C), 125.8, 126.4, 126.9, 127.7, 128.3, 128.5, 128.6, 128.9, 129.0, 129.7 (CH), 132.1, 133.1, 133.4, 133.6, 133.8, 135.4, 136.3, 136.8, 143.0 (C). IR (KBr): ν = 3066, 2917, 2849 (w), 1592 (s), 1564 (w), 1550 (m), 1485 (w), 1467 (s), 1455 (m), 1427, 1410, 1397 (w), 1373 (s), 1334 (m), 1308, 1296 (w), 1256 (m), 1165, 1140 (w), 1099, 1088, 1077 (m), 1050, 1034, 995 (w), 963 (m), 910 (w), 894, 866, 856 (m), 825, 787, 781, 771, 758, 717, 700, 688, 676 (s), 661 (w), 646 (s), 603, 583, 557, 551, 541 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 464 [(M+H), ^{35}Cl, ^{35}Cl, $^{37}Cl]^+$, 29), 463 ([M, ^{35}Cl, ^{35}Cl, $^{37}Cl]^+$, 98), 462 ([(M+H), ^{35}Cl, ^{35}Cl, $^{35}Cl]^+$, 29), 461 ([M, ^{35}Cl, ^{35}Cl, $^{35}Cl]^+$, 100). HRMS (EI, 70 eV): calcd for $C_{27}H_{18}Cl_3N$ [M, ^{35}Cl, ^{35}Cl, $^{37}Cl]^+$: 463.04698; found: 463.04738, calcd for $C_{27}H_{18}Cl_3N$ [M, ^{35}Cl, ^{35}Cl, $^{35}Cl]^+$: 461.04993; found: 461.05006.

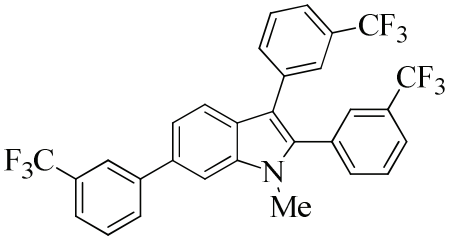
2,3,6-Tris(4-fluorophenyl)-1-methyl-1*H*-indole (22g): Starting with **21** (100 mg, 0.27 mmol), 

4-fluorophenylboronic acid **3j** (130 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22g** was isolated as a white solid (95 mg, 84%); reaction temperature: 110°C for 8 h, Mp.178-180°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.62 (s, 3H, NCH_3), 6.87-6.93 (m, 2H, ArH), 6.98-7.10 (m, 4H, ArH), 7.12-7.24 (m, 4H, ArH), 7.30 (dd, 1H, J = 1.56, 8.28 Hz, ArH), 7.45 (d, 1H, J = 1.02 Hz, ArH), 7.53-7.59 (m, 2H, ArH), 7.67 (d, 1H, J = 8.28 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -116.8, -116.6, -112.7. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 29.9 (NCH_3), 107.0 (CH), 113.3 (C), 114.2 (d, $J_{F,C}$ = 21.2 Hz, CH), 114.6 (d, $J_{F,C}$ = 21.4 Hz, CH), 114.7 (d, $J_{F,C}$ = 21.6 Hz, CH), 118.6, 119.1 (CH), 125.2 (C), 126.5 (d, $J_{F,C}$ =3.54 Hz, C), 127.9 (d, $J_{F,C}$ = 8.00 Hz, CH), 129.7 (d, $J_{F,C}$ = 3.28 Hz, C), 130.2 (d, $J_{F,C}$ = 7.76 Hz, CH), 131.8 (d, $J_{F,C}$ = 8.20 Hz, CH), 134.1, 136.3, 136.7 (C), 137.4 (d, $J_{F,C}$ = 3.19 Hz, C), 160.2 (d, $J_{F,C}$ = 245.1 Hz, C-F), 160.7 (d, $J_{F,C}$ = 246.1 Hz, C-F), 161.6 (d, $J_{F,C}$ = 248.1 Hz, C-F). IR (KBr): ν = 3068, 3043, 2961, 2853, 1907, 1891 (w), 1601, 1593, 1556 (m), 1513 (s), 1493 (m), 1463 (s), 1425, 1403 (w), 1367, 1335 (m), 1315, 1299 (w), 1258 (m), 1219, 1156, 1087, 1014 (s), 946 (m), 907 (w), 860, 837 (m), 819, 811, 800, 794 (s), 762 (w), 730 (m), 724, 686, 643, 628 (w), 608 (s), 576 (w), 566 (m), 538 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 414 ($[M+H]^+$, 30), 413 ($[M]^+$, 100), 397 (9). HRMS (EI, 70 eV): calcd for $C_{27}H_{18}F_3N$ $[M]^+$: 413.13859; found: 413.13909.

1-Methyl-2,3,6-tris(4-(trifluoromethyl)phenyl)-1*H*-indole (22h): Starting with **21** (100 mg, 0.27 mmol), 4-(trifluoromethyl)phenylboronic acid **3q** (177 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22h** was isolated as a white solid (127 mg, 82%); reaction temperature: 110°C for 8 h, Mp.200-202°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.67 (s, 3H, NCH_3), 7.30 (d, 2H, J = 1.56 Hz, ArH), 7.36-7.42 (m, 3H, ArH), 7.47 (d, 2H, J = 8.13 Hz, ArH), 7.56 (d, 1H, J = 0.84 Hz, ArH), 7.59-7.65 (m, 4H, ArH), 7.71-7.76 (m, 3H, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -62.7, -62.3, -62.3. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.2 (NCH_3), 107.7 (CH), 113.8 (C), 119.0, 119.7 (CH), 122.9 (q, $J_{F,C}$ = 273.3 Hz, CF_3), 123.5 (q, $J_{F,C}$ = 272.7 Hz, CF_3), 

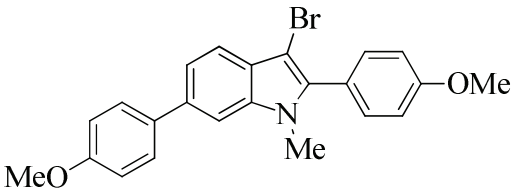
123.7 (q, $J_{F,C}$ = 272.0 Hz, CF_3), 124.4 (q, $J_{F,C}$ = 3.74 Hz, CH), 124.6 (q, $J_{F,C}$ = 3.79 Hz, CH), 124.9 (q, $J_{F,C}$ = 3.56 Hz, CH), 125.5 (C), 126.6 (CH), 127.0 (q, $J_{F,C}$ = 32.4 Hz, C-CF_3), 127.9 (q, $J_{F,C}$ = 32.4 Hz, C-CF_3), 128.8 (CH), 129.6 (q, $J_{F,C}$ = 32.6 Hz, C-CF_3), 130.3 (CH), 133.9, 134.0, 136.6, 137.1, 137.3, 144.5 (C). IR (KBr): ν = 3051, 2957, 2923, 2852, 2640 (w), 1613 (m), 1574, 1553, 1520, 1494 (w), 1465 (m), 1431, 1416, 1407, 1397, 1369 (w), 1321 (s), 1257 (m), 1187 (w), 1160 (m), 1105, 1089, 1163, 1012 (s), 960, 946 (w), 858, 841 (m), 828, 807 (s), 779, 771, 761, 742, 712 (w), 696 (m), 675, 654, 650 (w), 634, 614, 599 (m), 576 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 564 ($[M+H]^+$, 39), 563 ($[M]^+$, 100), 97 (10), 84 (13), 71 (18), 69 (27), 57 (28). HRMS (EI, 70 eV): calcd for $C_{30}H_{18}F_9N$ $[M]^+$: 563.12900; found: 563.12941.

1-Methyl-2,3,6-tris(3-(trifluoromethyl)phenyl)-1*H*-indole (22i): Starting with **21** (100 mg, 0.27 mmol), 3-(trifluoromethyl)phenylboronic acid **3g** (177 mg, 0.93 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (5 mL), **22i** was isolated as a white solid (120 mg, 78%); reaction temperature: 110°C for 8 h, Mp.158-160°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.66 (s, 3H, NCH_3), 7.28-7.46 (m, 8H, ArH), 7.48-7.58 (m, 4H, ArH), 7.71 (d, 1H, J = 8.34 Hz, ArH), 7.76-7.78 (m, 1H, ArH), 7.85 (brs, 1H, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -62.9, -62.8, -62.5. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 30.1 (NCH_3), 107.5 (CH), 113.7 (C), 118.9, 119.5 (CH), 121.6 (q, $J_{F,C}$ = 3.74 Hz, CH), 122.5 (q, $J_{F,C}$ = 3.75 Hz, CH), 122.7 (q, $J_{F,C}$ = 272.5 Hz, CF_3), 123.0 (q, $J_{F,C}$ = 272.5 Hz, CF_3), 123.1 (q, $J_{F,C}$ = 3.79 Hz, CH), 123.3 (q, $J_{F,C}$ = 272.5 Hz, CF_3), 124.2 (q , $J_{F,C}$ = 3.67 Hz, CH), 125.4 (q, $J_{F,C}$ = 3.76 Hz, CH), 126.7 (q, $J_{F,C}$ = 3.72 Hz, CH), 127.9, 128.2, 128.3, 129.7 (CH), 129.8 (q, $J_{F,C}$ = 25.3 Hz, C-CF_3), 130.1 (q, $J_{F,C}$ = 27.4 Hz, C-CF_3), 130.2 (q, $J_{F,C}$ = 30.7 Hz, C-CF_3), 130.9 (C), 131.8, 133.3 (CH), 134.0, 134.2, 136.4, 137.1, 141.8 (C). IR (KBr): ν = 3073, 3046, 2960, 2924, 2853, 1610, 1590, 1551, 1494, 1465, 1439, 1424, 1411, 1375 (w), 1334, 1326, 1308 (s), 1270 (w), 1251, 1159, 1112, 1094, 1071 (s), 1049, 1034 (m), 1000, 986, 964 (w), 912 (s), 879, 862, 829, 809 (m), 795 (s), 783 (m), 764 (w), 724 (m), 698 (s), 677 (w), 670 (s), 644, 622, 612, 595, 571, 528 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 564 ($[M+H]^+$, 27), 563 ($[M]^+$, 100), 547 (15), 69 (19). HRMS (ESI, 70 eV): calcd for $C_{30}H_{19}F_9N$ $[M+H]^+$: 564.13683; found: 564.13740.

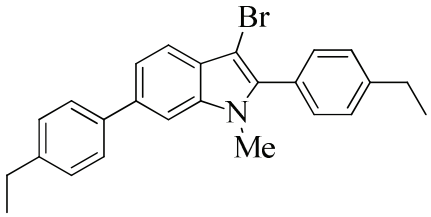


Synthesis of 2,6-diaryl-3-bromo-1-methyl-1*H*-indole 23a-e:

3-Bromo-2,6-bis(4-methoxyphenyl)-1-methyl-1*H*-indole (23a): Starting with **21** (100 mg, 0.27 mmol), 4-methoxyphenylboronic acid **3h** (86 mg, 0.57 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_3PO_4 (172 mg, 0.81 mmol) and 1,4-dioxane (5 mL), **23a** was isolated as a white solid (96 mg, 83%); reaction temperature: 90°C for 8 h, Mp.163-165°C (CH_2Cl_2/EtOH 1:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.58 (s, 3H, NCH_3), 3.77 (s, 3H, OCH_3), 3.79 (s, 3H, OCH_3), 6.87-6.98 (m, 4H, ArH), 7.31-7.37 (m, 4H, ArH), 7.49-7.54 (m, 3H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.6 (NCH_3), 54.3, 54.4 (OCH_3), 88.8 (C), 106.7, 112.9, 113.2, 118.3, 119.1 (CH), 121.5, 125.2 (C), 127.4, 130.9 (CH), 133.7, 134.9, 136.2, 137.3, 157.8, 158.8 (C). IR (KBr): *v* = 3033, 2998, 2961, 2932, 2833 (w), 1606 (m), 1573, 1562, 1542 (w), 1518, 1489, 1461, 1443, 1424 (m), 1372 (w), 1345, 1305, 1288, 1274 (m), 1246, 1175 (s), 1105, 1035 (m), 1019 (s), 950 (m), 864 (w), 845, 832 (m), 815, 804, 781 (s), 747, 732, 704, 687, 668, 643, 629 (w), 621, 600, 576 (m), 556 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 424 ([(M+H), ^{81}Br]$^+$, 25), 423 ([M, ^{81}Br]$^+$, 99), 422 ([(M+H), ^{79}Br]$^+$, 28), 421 ([M, ^{79}Br]$^+$, 100), 408 (34), 406 (33), 212 (13). HRMS (EI, 70 eV): calcd for $C_{23}H_{20}BrNO_2$ [M, ^{79}Br]$^+$: 421.06719; found: 421.06734, calcd for $C_{23}H_{20}BrNO_2$ [M, ^{81}Br]$^+$: 421.06515; found: 421.06567.

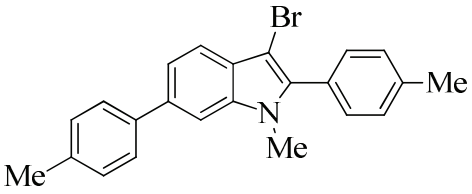


3-Bromo-2,6-bis(4-ethylphenyl)-1-methyl-1*H*-indole (23b): Starting with **21** (100 mg, 0.27 mmol), 4-ethylphenylboronic acid **3b** (85 mg, 0.57 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_3PO_4 (172 mg, 0.81 mmol) and 1,4-dioxane (5 mL), **23b** was isolated as a white solid (90 mg, 79%); reaction temperature: 90°C for 8 h, Mp.119-121°C (CH_2Cl_2/EtOH 1:1). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.19-1.26 (m, 6H, $2CH_3$), 2.59-2.70 (m, 4H, $2CH_2$), 3.61 (s, 3H, NCH_3), 7.24 (q, 4H, *J* = 8.31 Hz, ArH), 7.35 (d, 2H, *J* = 8.25 Hz, ArH), 7.39 (dd, 1H, *J* = 1.47, 8.19 Hz, ArH), 7.43 (d, 1H, *J* = 0.75 Hz, ArH), 7.50-7.57 (m, 3H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 15.3, 15.7 (CH_3), 28.6, 28.8 (CH_2), 31.7 (NCH_3), 89.9 (C), 108.1, 119.5, 120.4 (CH), 126.5 (C), 127.4 (CH), 127.6 (C), 127.8, 127.9, 130.6 (CH), 136.4, 137.4, 138.7, 139.6, 143.0, 144.9 (C). IR (KBr): *v* = 3050, 3019, 2966, 2930, 2872, 2853, 1517, 1492 (w), 1456 (s), 1423, 1410 (w), 1370, 1342 (m), 1309, 1272, 1231 (w), 1216 (m), 1182, 1139, 1115 (w), 1101 (m), 1051, 1017, 964 (w), 949 (s), 908,

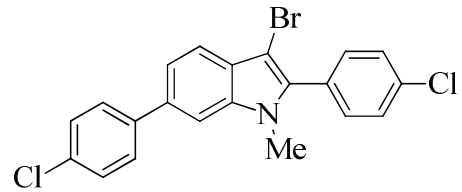


858 (w), 844, 835 (m), 812 (s), 771, 763 (m), 750, 732, 685, 676, 647, 631 (w), 619, 603 (m), 562 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 419 ([M, $^{81}Br]^+$, 99), 418 ([(M+H), $^{79}Br]^+$, 28), 417 ([M, $^{79}Br]^+$, 100], 404 (27), 402 (26). HRMS (EI, 70 eV): calcd for $C_{25}H_{24}BrN$ [M, $^{81}Br]^+$: 419.10662; found: 419.10785, calcd for $C_{25}H_{24}BrN$ [M, $^{79}Br]^+$: 417.10866; found: 417.10911.

3-Bromo-1-methyl-2,6-di-p-tolyl-1*H*-indole (23c): Starting with **21** (100 mg, 0.27 mmol), 4-methylphenylboronic acid **3e** (77 mg, 0.57 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_3PO_4 (172 mg, 0.82 mmol) and 1,4-dioxane (5 mL), **23c** was isolated as a white solid (78 mg, 73%); reaction temperature: 90°C for 8 h, Mp.135-137°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 2.30 (s, 3H, CH_3), 2.37 (s, 3H, CH_3), 3.62 (s, 3H, NCH_3), 7.06-7.11 (m, 1H, ArH), 7.21-7.27 (m, 3H, ArH), 7.33(d, 2H, *J* = 8.24 Hz, ArH), 7.39 (dd, 1H, *J* = 1.45, 8.24 Hz, ArH), 7.43 (brs, 1H, ArH), 7.49-7.57 (m, 3H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 21.1, 21.4 (CH_3), 31.7 (NCH_3), 89.9 (C), 107.9, 119.4, 120.8 (CH), 120.8, 123.1, 126.4 (C), 127.3, 129.2, 129.5, 130.5 (CH), 136.3, 136.6, 137.3, 138.7, 139.3 (C). IR (KBr): *ν* = 3022, 2916, 2852, 2729, 1908, 1613, 1556 (w), 1518, 1492 (m), 1455 (s), 1423 (w), 1368, 1341 (m), 1312, 1299, 1253, 1231 (w), 1218 (m), 1183, 1139 (w), 1105 (m), 1059, 1039, 1018, 965 (w), 950 (s), 939 (m), 907, 854 (w), 840, 821 (m), 806 (s), 779 (m), 748 (w), 721 (m), 687, 672, 649, 631 (w), 622, 598 (m), 570, 537 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 392 ([(M+H), $^{81}Br]^+$, 24), 391 ([M, $^{81}Br]^+$, 100), 390 [(M+H), $^{79}Br]^+$, 31), 389 ([M, $^{79}Br]^+$, 100), 295 (11), 294 (14). HRMS (EI, 70 eV): calcd for $C_{23}H_{20}BrN$ [M, $^{81}Br]^+$: 391.07532; found: 391.07571, calcd for $C_{23}H_{20}BrN$ [M, $^{79}Br]^+$: 389.07736; found: 389.07745.

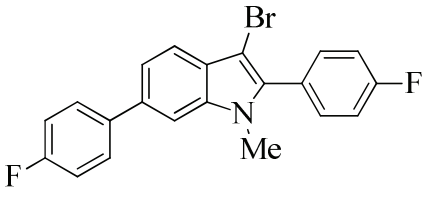


3-Bromo-2,6-bis(4-chlorophenyl)-1-methyl-1*H*-indole (23d): Starting with **21** (100 mg, 0.27 mmol), 4-chlorophenylboronic acid **3f** (89 mg, 0.57 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_3PO_4 (172 mg, 0.81 mmol) and 1,4-dioxane (5 mL), **23d** was isolated as a white solid (94 mg, 80%); reaction temperature: 90°C for 8 h, Mp.173-175°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 3.61 (s, 3H, NCH_3), 7.31-7.44 (m, 8H, ArH), 7.49-7.58 (m, 3H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.7 (NCH_3), 88.5 (C), 107.1, 118.8, 119.4 (CH), 125.8 (C), 127.6, 127.8, 127.9, 130.9 (CH), 131.2, 132.0, 134.0, 134.4, 136.4, 136.5, 139.4 (C) . IR (KBr): *ν* = 3069, 3054, 3013, 2961, 2924, 2872, 2851, 1598, 1557, 1542, 1498 (w), 1478, 1463 (m), 1426, 1399, 1367, 1340, 1306, 1296 (w), 1258 (m), 1236, 1213, 1180,



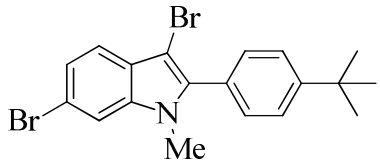
1124 (w), 1104 (m), 1089 (s), 1056 (m), 1009 (s), 950, 939 (m), 907, 861 (w), 838 (s), 823, 813 (m), 797 (s), 742, 733 (w), 725 (m), 715, 698, 673, 666, 648, 639, 626 (w), 609 (m), 592, 582, 538 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 431 ([(M+H), ^{81}Br, $^{35}Cl]^+$, 100), 430 ([M, ^{81}Br, $^{35}Cl]^+$, 15), 429 ([(M+H), ^{79}Br, $^{35}Cl]^+$, 63), 393 (8), 314 (10), 139 (16). HRMS (EI, 70 eV): calcd for $C_{21}H_{14}BrCl_2N$ [M, ^{81}Br, $^{35}Cl]^+$: 430.96607; found: 430.96755, calcd for $C_{21}H_{14}BrCl_2N$ [M, ^{79}Br, $^{35}Cl]^+$: 428.96812; found: 428.96935.

3-Bromo-2,6-bis(4-fluorophenyl)-1-methyl-1*H*-indole (23e): Starting with **21** (100 mg, 0.27 mmol), 4-fluorophenylboronic acid **3j** (79 mg, 0.57 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_3PO_4 (172 mg, 0.81 mmol) and 1,4-dioxane (5 mL), **23e** was isolated as a white solid (90 mg, 83%); reaction temperature: 90°C for 8 h, Mp.115-117°C. ^1H NMR (300 MHz, $CDCl_3$): δ = 3.60 (s, 3H, NCH_3), 7.06 (t, 2H, J = 5.22 Hz, ArH), 7.14 (t, 2H, J = 5.22 Hz, ArH), 7.35 (dd, 1H, J = 0.87, 4.92 Hz, ArH), 7.39-7.42 (m, 3H, ArH), 7.53-7.57 (m, 3H, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -116.3, -111.9. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 31.7 (NCH_3), 90.3 (C), 108.2 (CH), 115.5 (d, $J_{F,C}$ = 6.51 Hz, CH), 117.3 (d, $J_{F,C}$ = 6.83 Hz, CH), 119.7, 120.5 (CH), 126.2, 126.3 (C), 128.9 (d, $J_{F,C}$ = 7.92 Hz, CH), 132.5 (d, $J_{F,C}$ = 8.32 Hz, CH), 135.7, 137.3, 137.7, 138.1 (C), 162.3 (d, $J_{F,C}$ = 245.9 Hz, C-F), 162.9 (d, $J_{F,C}$ = 249.2 Hz, C-F). IR (KBr): ν = 2925, 2852 (w), 1603, 1591 (m), 1574, 1557 (w), 1539 (m), 1515, 1488 (s), 1456 (m), 1424, 1405, 1371, 1339, 1308, 1298 (w), 1229, 1158, 1100 (s), 1022 (w), 1010, 951 (m), 860 (w), 846, 834, 824 (w), 794 (s), 726, 718, 686, 667, 644, 629 (w), 619 (m), 599 (s), 566 (m), 536 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 399 ([M, $^{81}Br]^+$, 100), 398 ([(M+H), $^{79}Br]^+$, 25), 397 ([M, $^{79}Br]^+$, 99), 317 (11), 316 (15), 303 (14). HRMS (EI, 70 eV): calcd for $C_{21}H_{14}F_2BrN$ [M, $^{81}Br]^+$: 399.02517; found: 399.02549, calcd for $C_{21}H_{14}F_2BrN$ [M, $^{79}Br]^+$: 397.02722 found: 397.02732.

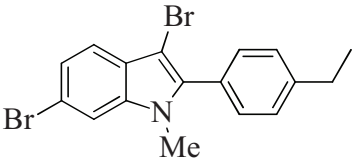


Synthesis of 3,6-dibromo-2-aryl-1-methyl-1*H*-indole 24a-e:

3,6-Dibromo-2-(4-(*tert*-butyl)phenyl)-1-methyl-1*H*-indole (24a): Starting with **21** (100 mg, 0.27 mmol), 4-*tert*-butylphenylboronic acid **3c** (52 mg, 0.29 mmol), $Pd(PPh_3)_4$ (10 mg, 3 mol%), K_3PO_4 (86 mg, 0.40 mmol) and toluene/1,4-dioxane (4:1) (5 mL), **24a** was isolated as a white solid (97 mg, 84%); reaction temperature: 65°C for 8 h, Mp.156-158°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.31 (s, 9H, $3CH_3$), 3.55 (s, 3H, NCH_3), 7.23 (dd, 1H, *J* = 1.92, 10.11 Hz, ArH), 7.31-7.46 (m, 6H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 31.3 (CH_3), 31.8 (NCH_3), 33.2, 90.0 (C), 112.7 (CH), 116.2 (C), 120.5, 123.7, 125.5 (CH), 126.2, 126.8 (C), 130.2 (CH), 137.5, 138.8, 151.9 (C). IR (KBr): *v* = 3026 (w), 2959 (m), 2901, 2865, 2707, 1920, 1868, 1731, 1681, 1599, 1563, 1556 (w), 1491, 1461, 1451, 1416 (m), 1405, 1390 (w), 1360 (m), 1336 (s), 1289, 1267 (w), 1217 (m), 1199, 1131 (w), 1109, 1053, 1014 (m), 968 (w), 945, 842, 800 (s), 738, 723, 689 (w), 654 (m), 628 (w), 615 (s), 589 (m), 576, 553, 543 (w) cm^{-1}.GC-MS (EI, 70 eV): m/z (%): 421 ([(M+H), ^{79}Br, ^{81}Br]$^+$, 100), 420 ([M, ^{79}Br, ^{81}Br]$^+$, 11), 419 (52), 408 (23), 406 (45), 404 (23), 378 (8). HRMS (EI, 70 eV): calcd for $C_{19}H_{19}Br_2N$ [M, ^{79}Br, ^{81}Br]$^+$: 420.98583; found: 420.98605.



3,6-Dibromo-2-(4-ethylphenyl)-1-methyl-1*H*-indole (24b): Starting with **21** (100 mg, 0.27 mmol), 4-ethylphenylboronic acid **24c** (44 mg, 0.29 mmol), $Pd(PPh_3)_4$ (10 mg, 3 mol%), K_3PO_4 (86 mg, 0.40 mmol) and toluene/1,4-dioxane (4:1) (5 mL), **24b** was isolated as a white solid (88 mg, 83%); reaction temperature: 65°C for 8 h, Mp.94-96°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.24 (t, 3H, CH_3), 2.67 (q, 2H, *J* = 7.59, CH_2), 3.56 (s, 3H, NCH_3), 7.20-7.26 (m, 2H, ArH), 7.29 (d, 3H, *J* = 8.40 Hz, ArH), 7.33-7.39(m, 1H, ArH), 7.42 (d, 1H, *J* = 1.41 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 15.3 (CH_3), 28.7 (CH_2), 31.7 (NCH_3), 90.1 (C), 112.7 (CH), 116.2 (C), 120.5, 123.7 (CH), 126.2, 127.1 (C), 128.0, 130.5 (CH), 137.5, 138.8, 145.1 (C). IR (KBr): *v* = 3070, 3022, 2960, 2868 (w), 1492, 1463, 1448 (m), 1414, 1371 (w), 1338 (m), 1305, 1289, 1231 (w), 1214 (m), 1183, 1130, 1117 (w), 1109, 1054 (m), 1040, 1015, 966 (w), 943, 934, 843, 837, 829 (s), 811 (w), 800 (s), 765, 734, 677 (w), 659 (m), 632 (w), 617 (m), 587 (s), 560 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 395 ([(M+H), ^{81}Br]$^+$, 49), 394 ([M, ^{81}Br]$^+$, 19), 393 ([(M-H), ^{81}Br]$^+$, 100), 392 ([M, ^{81}Br]$^+$, 11), 391 ([(M+H),



$^{79}Br]^+$, 51), 378 (32), 376 (16). HRMS (EI, 70 eV): calcd for $C_{17}H_{15}Br_2N$ [M, $^{81}Br]^+$: 394.95248; found: 394.95330, calcd for $C_{17}H_{15}Br_2N$ [M, $^{79}Br]^+$: 390.95658; found: 390.95765.

3,6-Dibromo-1-methyl-2-(*p*-tolyl)-1*H*-indole (24c): Starting with **21** (100 mg, 0.27 mmol), 4-methylphenylboronic acid **3e** (40 mg, 0.29 mmol), $Pd(PPh_3)_4$ (10 mg, 3 mol%), K_3PO_4 (86 mg, 0.40 mmol) and toluene/1,4-dioxane (4:1) (5 mL), **24c** was isolated as a white solid (79 mg, 77%), reaction temperature: 65°C for 8 h. ^1H NMR (300 MHz, $CDCl_3$): δ = 2.37 (s, 3H, CH_3), 3.54 (s, 3H, NCH_3), 7.21-7.32 (m, 5H, ArH), 7.35-7.39 (m, 1H, ArH), 7.42 (d, 1H, *J* = 1.77 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 21.4 (CH_3), 31.7 (NCH_3), 90.1 (C), 112.7 (CH), 116.2 (C), 120.5, 123.7 (CH), 126.2, 126.9 (C), 129.3, 130.4 (CH), 137.5, 138.8, 139.0 (C). IR (KBr): *v* = 3206, 3070, 3021 (w), 2918 (m), 2866, 2584, 2550, 2417, 2357, 2326, 2142, 1965, 1910, 1869, 1801, 1732, 1673, 1604, 1562 (w), 1492 (m), 1462, 1450 (s), 1419, 1370 (m), 1336 (s), 1289, 1217, 1182 (m), 1131 (w), 1110, 1054 (m), 1040 (w), 1018 (m), 964 (w), 943 (s), 830, 797 (s), 781 (m), 759, 736 (w), 720 (m), 677, 658, 633 (w), 620, 586 (s), 549 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 381 ([(M+H), $^{81}Br]^+$, 49), 380 ([M, $^{81}Br]^+$, 19), 379 ([(M+H), ^{79}Br, $^{81}Br]^+$, 100), 377 ([(M+H), $^{79}Br]^+$, 50), 218 (11), 204 (13). HRMS (EI, 70 eV): calcd for $C_{16}H_{13}Br_2N$ [M, $^{81}Br]^+$: 380.93683; found: 380.93821, calcd for $C_{16}H_{13}Br_2N$ [M, ^{79}Br, $^{81}Br]^+$: 378.93888; found: 378.93905, calcd for $C_{16}H_{13}Br_2N$ [M, $^{79}Br]^+$: 376.94093; found: 376.94069.

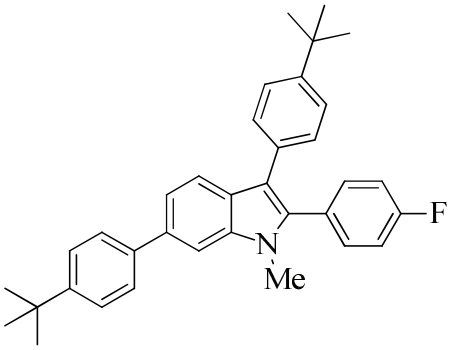
3,6-Dibromo-2-(4-chlorophenyl)-1-methyl-1*H*-indole (24d): Starting with **21** (100 mg, 0.27 mmol), 4-chlorophenylboronic acid **3f** (46 mg, 0.29 mmol), $Pd(PPh_3)_4$ (10 mg, 3 mol%), K_3PO_4 (86 mg, 0.40 mmol) and toluene/1,4-dioxane (4:1) (5 mL), **24d** was isolated as a white solid (86 mg, 79%), reaction temperature: 65°C for 8 h. ^1H NMR (300 MHz, $CDCl_3$): δ = 3.54 (s, 3H, NCH_3), 7.23-7.26 (m, 1H, ArH), 7.32-7.36 (m, 3H, ArH), 7.39-7.44 (m, 3H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 31.8 (NCH_3), 90.7 (C), 112.8 (CH), 116.7 (C), 120.8, 124.0 (CH), 126.1, 128.4 (C), 128.9, 131.9 (CH), 135.2, 137.4, 137.6 (C). IR (KBr): *v* = 3079, 3064, 2925, 2854, 1915, 1872, 1728, 1692, 1599, 1562, 1536, 1503, 1478 (w), 1461, 1454 (m), 1418, 1400, 1361 (w), 1336 (m), 1288, 1268, 1232, 1212, 1179, 1129, 1104 (w), 1088 (m), 1051, 1036 (w), 1011 (m), 966 (w), 944, 939 (m), 835 (s), 803 (m), 795 (s), 737 (w), 724 (m), 674, 648, 625 (w), 607 (m), 589 (s), 570 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 399 ([(M+H), ^{79}Br, ^{81}Br, $^{35}Cl]^+$, 100), 398 ([M, ^{79}Br, ^{81}Br, $^{35}Cl]^+$, 8), 397 ([(M+H), ^{79}Br, ^{79}Br, $^{35}Cl]^+$,

45), 204 (11). HRMS (EI, 70 eV): calcd for $C_{15}H_{10}Br_2ClN$ [M, ^{79}Br, ^{81}Br, $^{35}Cl]^+$: 398.88426; found: 398.88410, calcd for $C_{15}H_{10}Br_2ClN$ [M, ^{79}Br, ^{79}Br, $^{35}Cl]^+$: 396.88630; found: 396.88615.

***General procedure (B) for Suzuki cross-coupling Reactions of brominated N-methylindole* (21):** The reaction was carried out in a pressure tube. To a mixture solvent of toluene/dioxane (4:1) (5 mL) suspension of the brominated -N-methylindole, $Pd(PPh_3)_4$ (5 mol%) and of the $Ar^1B(OH)_2$ (1.1 equiv.), K_3PO_4 (1.5 equiv.) was added also. The mixture was heated at the indicated temperature (65°C) under Argon atmosphere for the indicated period of time (8 h) and cooled to room temperature. Then $Ar^2B(OH)_2$ (2.1 equiv.), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (3 mL) was added. The reaction mixture was further heated for 8 h at 110°C. The reaction mixture was again cooled to room temperature and diluted with water and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried (Na_2SO_4), filtered and the filtrate was concentrated in *vacuo*. The residue was purified by flash chromatography (silica gel, EtOAc/ heptanes).

Synthesis of unsymmetrical 2,3,6-triaryl-1-methyl-1*H*-indoles 25a-d:

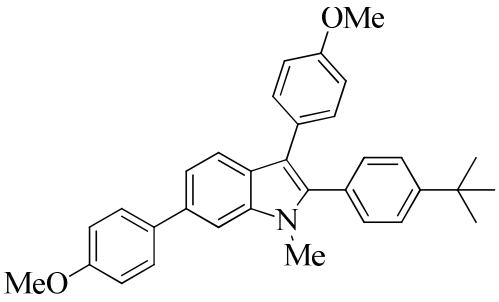
3,6-Bis(4-(*tert*-butyl)phenyl)-2-(4-fluorophenyl)-1-methyl-1*H*-indole (25a): Starting with **21**



(100 mg, 0.27 mmol), 4-flourophenylboronic acid **3j** (41 mg, 0.29 mmol), $Pd(PPh_3)_4$ (16 mg, 5 mol%), K_3PO_4 (86 mg, 0.40 mmol) and toluene/ 1,4-dioxane (4:1) (5 mL), 4-*tert*-butylphenylboronic acid **3c** (99 mg, 0.57 mmol), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (3 mL), following *the general procedure B*, **25a** was isolated as a yellowish solid (99 mg, 74%); reaction temperature: at 65°C for 8 h, at 110°C for 8 h, Mp.148-150°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.22(s, 9H, $3CH_3$), 1.29 (s, 9H, $3CH_3$), 3.56 (s, 3H, NCH_3), 6.97 (t, 2H, J = 8.64 Hz, ArH), 7.10-7.25 (m, 6H, ArH), 7.34 (dd, 1H, J = 1.35, 8.31 Hz, ArH), 7.40 (d, 2H, J = 8.34 Hz, ArH), 7.47 (d, 1H, J = 0.90 Hz, ArH), 7.56 (d, 2H, J = 8.31 Hz, ArH), 7.75 (d, 1H, J = 8.31 Hz, ArH). ^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -113.2. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.9 (NCH_3), 31.4, 31.5 (CH_3), 34.4, 34.5 (C), 107.9 (CH), 115.2 (C), 115.6 (d, $J_{F,C}$ = 21.5 Hz, CH), 120.1, 125.2, 125.7 (CH), 126.3 (C), 127.1 (CH), 128.1 (d, $J_{F,C}$ = 3.49 Hz, CH), 129.3 (CH), 131.9 (C), 132.4 (d, $J_{F,C}$ = 8.15 Hz, CH), 135.8, 136.9, 137.9, 139.6, 148.4, 149.7 (C), 162.6 (d, $J_{F,C}$ = 247.9 Hz, C-F). IR (KBr): ν = 3030 (w), 2957 (m), 2902, 2865, 2244, 1900, 1605, 1593, 1563, 1549 (w), 1516 (m), 1491 (w), 1462 (s),

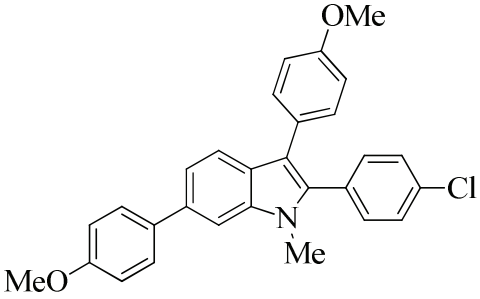
1426, 1404, 1392 (w), 1363 (m), 1334, 1319, 1307, 1296 (w), 1267 (m), 1221 (s), 1202 (w), 1156 (m), 1108, 1093, 1086, 1045, 1014 (w), 947 (m), 906 (s), 860 (m), 836, 823, 810, 802 (s), 761, 750 (w), 729 (s), 694, 672, 649 (w), 624, 604 (m), 561 (s), 538 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 490 ($[M+H]^+$, 61), 489 ($[M]^+$, 100), 474 (38), 444 (8), 229 (23), 215 (36), 201 (96), 189 (16), 183 (15), 134 (14). HRMS (EI, 70 eV): calcd for $C_{35}H_{36}FN$ $[M]^+$: 489.28263; found: 489.28253.

2-(4-(*Tert*-butyl)phenyl)-3,6-bis(4-methoxyphenyl)-1-methyl-1*H*-indole (25b): Starting with



24a (71 mg, 0.17 mmol), 4-methoxyphenylboronic acid **3h** (53 mg, 0.35 mmol), $Pd(PPh_3)_4$ (10 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (3 mL), following *the general procedure A*, **25b** was isolated as a yellowish solid (65 mg, 81%); reaction temperature: at 90°C for 8 h, Mp.184-186°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.27 (s, 9H, $3CH_3$), 3.62 (s, 3H, NCH_3), 3.72 (s, 3H, OCH_3), 3.78 (s, 3H, OCH_3), 6.76 (d, 2H, *J* = 8.76 Hz, ArH), 6.92 (d, 2H, *J* = 8.73 Hz, ArH), 7.16-7.18 (m, 4H, ArH), 7.31 (d, 3H, *J* = 8.28 Hz, ArH), 7.44 (d, 1H, *J* = 0.84 Hz, ArH), 7.56 (d, 2H, *J* = 8.70 Hz, ArH), 7.68 (d, 1H, *J* = 8.22 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 31.0 (NCH_3), 31.3 (CH_3), 34.7 (C), 55.2, 55.4 (OCH_3), 107.6, 113.7, 114.2 (CH), 114.5 (C), 119.7, 125.3 (CH), 122.1, 127.8 (C), 127.4, 128.7 (CH), 128.9 (C), 130.7, 130.9 (CH), 135.3, 137.8, 138.0, 150.9, 157.6, 158.7 (C). IR (KBr): *v* = 3033, 2996, 2953, 2902, 2866, 2832, 2248, 2059, 1886, 1714, 1650 (w), 1607 (m), 1573, 1548 (w), 1514 (s), 1492 (w), 1461 (s), 1440 (m), 1426, 1407, 1393 (w), 1363 (m), 1334, 1316, 1302 (w), 1278 (m), 1240, 1174 (s), 1108, 1089 (w), 1035 (s), 946, 906, 858 (m), 832, 807, 794 (s), 783, 760 (w), 727 (s), 688 (m), 648, 624 (w), 607 (s), 582, 558 (w), 531 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%): 476 ($[M+H]^+$, 36), 475 ($[M]^+$, 100), 460 (12). HRMS (ESI, 70 eV): calcd for $C_{33}H_{33}NO_2$ $[M+H]^+$: 476.25841; found: 476.25779.

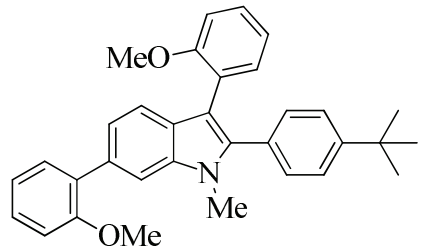
2-(4-Chlorophenyl)-3,6-bis(4-methoxyphenyl)-1-methyl-1*H*-indole (25c): Starting with **24d**



(67 mg, 0.17 mmol), 4-methoxyphenylboronic acid **3h** (54 mg, 0.35 mmol), $Pd(PPh_3)_4$ (10 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (3 mL), following *the general procedure A*, **25c** was isolated as a yellowish solid (62 mg, 82%); reaction temperature: at 90°C for 8

h, Mp.105-107°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.60 (s, 3H, NCH_3), 3.72 (s, 3H, OCH_3), 3.78 (s, 3H, OCH_3), 6.77 (d, 2H, *J* = 8.79 Hz, ArH), 6.92 (d, 2H, *J* = 8.79 Hz, ArH), 7.12-7.19 (m, 4H, ArH), 7.26-7.35 (m, 3H, ArH), 7.44 (brs, 1H, ArH), 7.55 (d, 2H, *J* = 8.67 Hz, ArH), 7.67 (d, 1H, *J* = 8.36 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 30.0 (NCH_3), 54.2, 54.4 (OCH_3), 106.6, 112.8, 113.2, 118.8 (CH), 125.1, 126.1 (C), 127.4, 127.7 (CH), 127.8, 129.4 (C), 129.8, 131.3 (CH), 133.0, 134.0, 134.7, 135.3, 137.0, 156.8, 157.8 (C). IR (KBr): *v* = 3033, 2999, 2958, 2920, 2836 (w), 1606 (m), 1572, 1546 (w), 1510, 1462 (s), 1441 (m), 1426, 1395 (w), 1368 (m), 1333, 1316, 1302 (w), 1279 (m), 1242, 1174, 1087, 1033, 1013 (s), 945 (m), 907, 887, 873 (w), 856, 826 (m), 815, 804, 794 (s), 760 (w), 725 (m), 698, 684, 649, 637, 618 (w), 603 (s), 578, 568 (w), 534 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 454 ($[M+H]^+$, 27), 453 ($[M]^+$, 100), 438 (25). HRMS (EI, 70 eV): calcd for $C_{29}H_{24}ClO_2N$ $[M]^+$: 453.14901; found: 453.14838.

2-(4-(*Tert*-butyl)phenyl)-3,6-bis(2-methoxyphenyl)-1-methyl-1*H*-indole (25d): Starting with



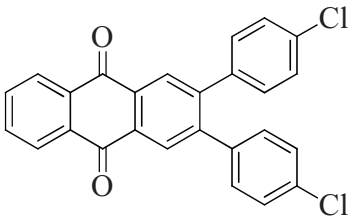
24a (71 mg, 0.17 mmol), 2-methoxyphenylboronic acid **3a** (54 mg, 0.36 mmol), $Pd(PPh_3)_4$ (10 mg, 5 mol%), K_2CO_3 (2 M, 1 mL) and 1,4-dioxane (3 mL), following *the general procedure A*, **25d** was isolated as a yellowish solid (58 mg, 72%); reaction temperature: at 90°C for 8 h, Mp.175-177°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.24 (s, 9H, $3CH_3$), 3.38 (s, 3H, NCH_3), 3.67 (s, 3H, OCH_3), 3.74 (s, 3H, OCH_3), 6.77-6.86 (m, 2H, ArH), 6.92-7.00 (m, 2H, ArH), 7.12-7.17 (m, 3H, ArH), 7.19-7.28 (m, 5H, ArH), 7.33-7.36 (m, 1H, ArH), 7.43-7.46 (m, 2H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 30.2 (NCH_3), 30.3 (CH_3), 33.6 (C), 53.8, 54.7 (OCH_3), 109.5, 109.9 (CH), 110.1 (C), 110.4 (CH), 118.3, 119.3, 119.8, 120.9 (CH), 123.4 (C), 123.9 (CH), 125.8 (C), 126.4, 126.9 (CH), 128.7 (C), 129.0, 130.0 (CH), 131.2, 131.4 (C), 131.7 (CH), 136.3, 138.0, 149.3, 155.7, 156.2 (C). IR (KBr): *v* = 3050 (w), 2954, 2924 (m), 2854, 1716, 1699, 1683, 1669, 1652, 1635, 1615, 1597, 1578, 1558, 1501 (w), 1457 (s), 1432 (m), 1406, 1394 (w), 1363 (m), 1333, 1313, 1289 (w), 1252, 1239 (s), 1178, 1160 (w), 1117, 1083, 1050 (m), 1025 (s), 947 (m), 932, 856, 838 (w), 825, 813, 792 (m), 749 (s), 699, 654 (m), 638 (w), 628 (m), 611, 592, 560, 544 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 476 ($[M+H]^+$, 36), 475 ($[M]^+$, 100). HRMS (EI, 70 eV): calcd for $C_{33}H_{33}NO_2$ $[M]^+$: 475.25058; found: 475.25047.

Synthesis of Functionalized Anthraquinones by Domino Twofold Heck–6π-Electrocyclization Reactions of 2,3-Dibromonaphthoquinone

***General procedure for the synthesis of mono- and disubstituted anthraquinones*:**

In a pressure tube (glass bomb) a suspension of $Pd(OAc)_2$ (11 mg, 5 mol%) and XPhos (48 mg, 10 mol%) in DMF (5 mL) was purged with argon and stirred at 20°C to give a yellowish or brownish clear solution. To the stirred solution were added **26** (316 mg, 1.0 mmol), NEt_3 (1.1 mL, 8.0 mmol) and the alkene **27a-j** (2.5 equiv.). The reaction mixture was stirred at 90°C (Method 1) or 110°C (Method 2) for 8 h. The solution was cooled to 20°C, poured into H_2O and CH_2Cl_2 (25 mL each), and the organic and the aqueous layer were separated. The latter was extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were washed with H_2O (3 x 20 mL), dried (Na_2SO_4), concentrated in vacuo and the residue was purified by chromatography (flash silica gel, heptanes/ EtOAc) to give **28** or **29**.

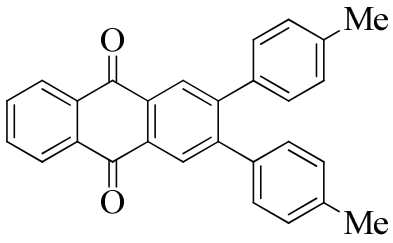
2,3-Bis(4-chlorophenyl)anthracene-9,10-dione (28a): Starting with **26** (316 mg, 1.0 mmol), 4-chlorostyrene **27a** (346 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **28a** was isolated as a yellowish solid (325 mg, 76%), reaction temperature: at 90°C for 8 h, Mp. 221-223°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.05 (d, 4H, *J* = 7.05 Hz, ArH), 7.20 (d, 4H, *J* = 8.52 Hz, ArH), 7.72-7.77 (m, 2H, ArH), 8.21 (s, 2H, ArH), 8.23-8.26 (m, 2H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 126.3, 127.7, 128.5, 129.9 (2CH), 131.5, 132.5, 133.1 (2C), 133.2 (2CH), 136.7, 143.9 (2C), 181.6 (2CO). IR (KBr): *ν* = 3316, 3073, 3054, 3028, 2961, 2924, 2851 (w), 1671, 1661, 1586 (s), 1565 (m), 1519, 1500 (w), 1490, 1477 (m), 1455, 1413, 1387 (w), 1329 (s), 1302, 1284 (m), 1258 (s), 1180, 1170, 1126 (w), 1087 (s), 1044 (w), 1011 (s), 969, 957 (w), 945 (s), 905 (w), 825, 796 (s), 762 (w), 748, 739, 728 (m), 712 (s), 688, 665, 644, 635, 586 (w), 560 (m), 534 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 431 ([(M+H), ^{35}Cl, ^{37}Cl]$^+$, 17), 430 ([M, ^{35}Cl, ^{37}Cl]$^+$, 69), 429 ([(M+H),^{35}Cl, ^{35}Cl]$^+$, 30), 428 ([M, ^{35}Cl, ^{35}Cl]$^+$, 100), 393 (59), 358 (21), 330 (11), 300 (31), 150 (25). HRMS (EI, 70 eV): calcd for $C_{26}H_{14}Cl_2O_2$ [M, ^{35}Cl, ^{37}Cl]$^+$: 430.03359; found: 430.03367, calcd for $C_{26}H_{14}Cl_2O_2$ [M, ^{35}Cl, ^{35}Cl]$^+$: 428.03654; found: 428.03595.



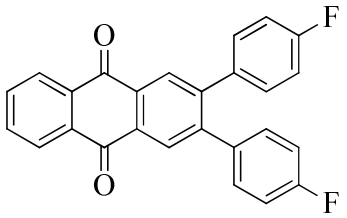
2,3-Bis(3-chlorophenyl)anthracene-9,10-dione (28b): Starting with **26** (316 mg, 1.0 mmol), 3-chlorostyrene **27b** (346 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **28b** was isolated as a yellowish solid (303 mg, 71%), reaction temperature: at 90°C for 8 h, Mp.150-152°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.93 (d, 2H, *J* = 7.85 Hz, ArH), 7.10-7.22 (m, 5H, ArH), 7.35-7.53 (m, 1H, ArH), 7.72-7.78 (m, 2H, ArH), 8.23 (s, 2H, ArH), 8.24 (m, 2H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 126.3, 126.8, 127.1, 128.4, 128.5, 128.6 (2CH), 131.6, 132.5 (2C), 133.3 (2CH), 133.4, 139.9, 143.8 (2C), 181.6 (2CO). IR (KBr): *v* = 3321, 3055, 3014, 2957, 2919, 2851, 1953, 1875, 1770, 1698 (w), 1670, 1584 (s), 1564 (m), 1477, 1469, 1463, 1418, 1395 (w), 1327, 1316 (s), 1286 (m), 1266, 1248 (s), 1167, 1129, 1097, 1078, 1052, 998, 977 (w), 952 (m), 928, 900, 884, 857 (w), 792, 784 (m), 755, 738 (w), 711, 702, 688 (s), 666 (m), 641, 621, 684, 656, 532 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 431 ([(M+H), ^{35}Cl, ^{37}Cl]$^+$, 19), 430 ([M, ^{35}Cl, ^{37}Cl]$^+$, 66), 429 ([(M+H), ^{35}Cl, ^{35}Cl]$^+$, 30), 428 ([M, ^{35}Cl, ^{35}Cl]$^+$, 100), 393 (84), 358 (24), 330 (12), 300 (36), 150 (32). HRMS (EI, 70 eV): calcd for $C_{26}H_{14}Cl_2O_2$ [M, ^{35}Cl, ^{37}Cl]$^+$: 430.03359; found: 430.03421, calcd for $C_{26}H_{14}Cl_2O_2$ [M, ^{35}Cl, ^{35}Cl]$^+$: 428.03654; found: 428.03696.

2,3-Bis(4-(*tert*-butyl)phenyl)anthracene-9,10-dione (28c): Starting with **26** (316 mg, 1.0 mmol), 4-*tert*-butylstyrene **27c** (400 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **28c** was isolated as a yellowish solid (377 mg, 80%), reaction temperature: at 90°C for 8 h, Mp.166-168°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.24 (s, 9H, $3CH_3$), 1.24 (s, 9H, $3CH_3$), 7.08 (d, 4H, *J* = 8.61 Hz, ArH), 7.21 (d, 4H, *J* = 8.58 Hz, ArH), 7.71-7.76 (m, 2H, ArH), 8.24-8.27 (m, 2H, ArH), 8.29 (s, 2H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 31.3 ($2CH_3$), 34.5 (2C), 125.0, 127.2, 129.3, 129.6 (2CH), 132.0, 133.8 (2C), 134.0 (2CH), 136.8, 146.4, 150.7 (2C), 183.1 (2CO). IR (KBr): *v* = 3325, 3063, 3033, 2959, 2923, 2853, 1737 (w), 1672 (s), 1610 (w), 1587 (s), 1513, 1493, 1475, 1462, 1414, 1390, 1361 (w), 1329 (s), 1310, 1290 (m), 1259 (s), 1201, 1186, 1168 (w), 1109, 1080 (m), 1022 (w), 1013 (m), 971, 960 (w), 946 (m), 929, 896, 851 (w), 832, 800, 791 (m), 752, 734 (w), 713 (s), 690, 666, 647 (w), 588 (m), 561, 529 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 473 ([M+H]$^+$, 21), 472 ([M]$^+$, 69), 457 ([M]$^+$, 100), 359 (13), 221 (16), 193 (23). HRMS (EI, 70 eV): calcd for $C_{34}H_{32}O_2$ [M]$^+$: 472.23968; found: 472.24008.

2,3-Di-*p*-tolylanthracene-9,10-dione (28d): Starting with **26** (316 mg, 1.0 mmol), 4-methylstyrene **27d** (295 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **28d** was isolated as a yellowish solid (302 mg, 78%), reaction temperature: at 90°C for 8 h, Mp.140-142°C. ^{1}H NMR (250 MHz, $CDCl_3$): δ = 2.24 (s, 3H, CH_3), 2.24 (s, 3H, CH_3), 6.97-6.99 (m, 7H, ArH), 7.66-7.69 (m, 2H, ArH), 8.18-8.22 (m, 5H, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 21.2 ($2CH_3$), 127.2, 128.9, 129.5, 129.6 (2CH), 132.0, 133.7 (2C), 134.0 (2CH), 136.8, 137.4, 146.3 (2C), 182.9 (2CO). IR (KBr): ν = 3324, 3015, 2914, 2857 (w), 1671 (m), 1609 (w), 1586 (m), 1513, 1478, 1453, 1391 (w), 1327 (s), 1309, 1287, 1271, 1255 (m), 1208, 1184, 1169 (w), 1127, 1113 (m), 1039 (w), 1017 (m), 971 (w), 946 (m), 923, 906, 863, 850, 841 (w), 820 (s), 794 (m), 758 (w), 727 (m), 710 (s), 670, 665, 642, 636, 605, 589, 565 (w), 547 (m) cm^{-1}.GC-MS (EI, 70 eV): m/z (%) : 389 ($[M+H]^+$, 31), 388 ($[M]^+$, 100), 373 (67), 187 (14). HRMS (EI, 70 eV): calcd for $C_{28}H_{20}O_2$ $[M]^+$: 388.14578; found: 388.14581.



2,3-Bis(4-fluorophenyl)anthracene-9,10-dione (28e): Starting with **26** (316 mg, 1.0 mmol), 4-fluorostyrene **27e** (305 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **28e** was isolated as a yellowish solid (285 mg, 72%), reaction temperature: at 90°C for 8 h, Mp.164-166°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 6.90 (t, 4H, J = 8.70 Hz, ArH), 7.05-7.11 (m, 4H, ArH), 7.69-7.76 (m, 2H, ArH), 8.21 (s, 2H, ArH), 8.23-8.26 (m, 2H, ArH).^{19}F NMR (282.4 MHz, $CDCl_3$): δ = -113.7, -112.8. ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 115.5 (d, $J_{F,C}$ = 21.6 Hz, 2CH), 127.3, 129.5 (2CH), 131.3 (d, $J_{F,C}$ = 8.21 Hz, 2CH), 132.4, 133.6 (2C), 134.2 (2CH), 135.4 (d, $J_{F,C}$ = 3.37 Hz, 2C), 145.3 (2C), 162.4 (d, $J_{F,C}$ = 248.6 Hz, 2C-F), 182.8 (2CO). IR (KBr): ν = 3319, 3182, 3058, 2923, 2853 (w), 1670 (s), 1600 (m), 1583, 1509 (s), 1477 (m), 1434, 1392 (w), 1327 (s), 1301, 1273, 1256 (m), 1221, 1157 (s), 1128, 1097 (m), 1044 (w), 1014 (m), 976 (w), 949, 924 (m), 864 (w), 834 (s), 816, 803, 792 (m), 760 (w), 730 (m), 710 (s), 666 (m), 638, 606, 588, 581, 565 (w), 546 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 397 ($[M+H]^+$, 29), 396 ($[M]^+$, 100), 338 (22), 318 (8). HRMS (EI, 70 eV): calcd for $C_{26}H_{14}F_2O_2$ $[M]^+$: 396.09564; found: 396.09500.



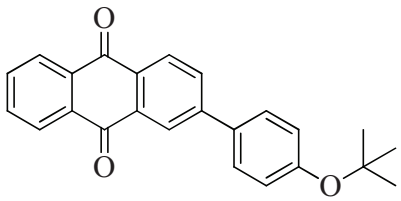
Diethyl 9,10-dioxo-9,10-dihydroanthracene-2,3-dicarboxylate (28g): Starting with **26** (316 mg, 1.0 mmol), ethylacrylate **27g** (250 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **28g** was isolated as a yellowish solid (278 mg, 79%), reaction temperature: at 90°C for 8 h, Mp.136-138°C. ^{1}H NMR(300 MHz, $CDCl_3$): δ = 1.36 (t, 3H, *J* = 7.14Hz, CH_3), 1.36 (t, 3H, *J* = 7.14 Hz, CH_3), 4.38 (q, 2H, *J* = 7.14 Hz, CH_2), 4.38 (q, 2H, *J* = 7.14 Hz, CH_2), 7.78-7.80 (m, 2H, ArH), 8.27-8.29 (m, 2H, ArH), 8.56 (s, 2H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 28.7 ($2CH_3$), 61.4 ($2OCH_2$), 126.6, 127.1 (2CH), 132.3, 133.6 (2C), 133.7 (2CH), 135.9 (2C), 165.1 (2CO), 180.7 (2CO). IR (KBr): *v* = 3072, 2957, 2926, 2856 (w), 1725 (s), 1627, 1666 (m), 1650, 1597 (w), 1462 (m), 1379, 1328 (w), 1272 (s), 1122, 1071 (m), 1039, 1017, 960, 862, 795, 768, 741, 704, 651, 610, 573, 553 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 352 ($[M]^+$, 6), 307 (19), 279 (100), 235 (11). HRMS (EI, 70 eV): calcd for $C_{20}H_{16}O_6$ $[M]^+$: 352.09414; found: 352.09347.

Di-*tert*-butyl 9,10-dioxo-9,10-dihydroanthracene-2,3-dicarboxylate (28h): Starting with **26** (316 mg, 1.0 mmol), 4-*tert*-butylacrylate **27h** (320 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **28h** was isolated as a yellowish solid (334 mg, 82%), reaction temperature: at 90°C for 8 h, Mp.172-174°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.56 (s, 9H, $3CH_3$), 1.56 (s, 9H, $3CH_3$), 7.73-7.80 (m, 2H, ArH), 8.23-8.29 (m, 2H, ArH), 8.44 (s, 2H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 28.2 ($2CH_3$), 83.3 (2C), 127.5, 127.9 (2CH), 132.3, 133.4 (2C), 134.6 (2CH), 138.5 (2C), 165.3 (2CO), 181.9 (2CO). IR (KBr): *v* = 3075, 3002, 2978, 2924, 2853 (w), 1724 (m), 1713, 1679 (s), 1630, 1613 (w), 1590 (m), 1522, 1478, 1456, 1404 (w), 1391, 1367, 1340 (m), 1254, 1151, 1135, 1123 (s), 1042 (w), 1021, 961, 936 (m), 927 (w), 842, 792 (m), 776, 750, 741, 719 (w), 707 (s), 691 (m), 656, 641, 605 (w), 566 (m) cm^{-1}.GC-MS (EI, 70 eV): m/z (%) : 409 ($[M+H]^+$, 31), 408 ($[M]^+$, 100), 297 (20), 234 (23), 150 (13). HRMS (ESI, 70 eV): calcd for $C_{24}H_{24}O_6Na$ $[M+Na]^+$: 431.14651; found: 431.14654.

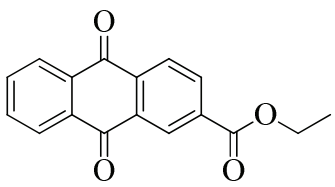
2-(4-Chlorophenyl)anthracene-9,10-dione (29a): Starting with **26** (316 mg, 1.0 mmol), 4-chlorostyrene **27a** (346 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **29a** was isolated as a yellowish solid (140 mg, 44%), reaction temperature: at 110°C for 8 h, Mp.180-182°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.06 (d, 2H, *J* =

8.52 Hz, ArH), 7.21 (d, 2H, *J* = 8.52 Hz, ArH), 7.41 (d, 1H, *J* = 8.58 Hz, ArH), 7.58 (d, 1H, *J* = 8.58 Hz, ArH), 7.70-7.95 (m, 2H, ArH), 8.23 (s, 1H, ArH), 8.24-8.41 (m, 2H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 125.4, 127.3, 128.6, 128.7, 129.4, 129.5, 130.9, 132.1 (CH), 132.5, 133.6, 134.1 (C), 134.3 (CH), 137.7, 145.0, 145.5 (C), 182.7, 183.1 (CO). IR (KBr): *v* = 3320, 3056, 3031, 2955, 2919, 2850 (w), 1671, 1587 (s), 1491, 1477 (m), 1455, 1419, 1390 (w), 1329, 1307, 1299, 1272, 1254 (s), 1210, 1184, 1174, 1157, 1127, 1106 (w), 1090 (s), 1045 (w), 1011 (s), 968 (w), 947, 931 (m), 906, 864 (w), 822 (s), 796 (m), 762, 748, 740 (w), 729 (m), 707 (s), 666, 644, 635 (m), 607, 586 (w), 562 (m), 534 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 319 ($[M+H]^+$, 22), 318 ($[M]^+$, 100), 290 (18), 262 (12), 226 (33). HRMS (EI, 70 eV): calcd for $C_{20}H_{11}ClO_2$ $[M]^+$: 318.04421; found: 318.04467.

2-(4-(*Tert*-butoxy)phenyl)anthracene-9,10-dione (29f): Starting with **26** (316 mg, 1.0 mmol), 4-*tert*-butoxystyrene **27f** (440 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **29f** was isolated as a yellowish solid (210 mg, 59%), reaction temperature: at 110°C for 8 h, Mp.100-111°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ =1.34 (s, 9H, $3CH_3$), 7.04 (d, 2H, *J* = 8.70 Hz, ArH), 7.56 (d, 2H, *J* = 8.70 Hz, ArH), 7.69-7.72 (m, 2H, ArH), 7.89 (dd, 1H, *J* = 1.98, 8.13 Hz, ArH), 8.21-8.26 (m, 3H, ArH), 8.41 (d, 1H, *J* = 1.83 Hz, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 28.9 (CH_3), 79.1(C), 124.3, 125.1, 127.1, 127.2, 127.9, 128.0 (CH), 131.7 (C), 131.9 (CH), 133.5, 133.6, 133.7, 133.9 (C), 134.0, 134.1 (CH), 146.4 (C), 156.6 (CO), 182.8, 183.3 (CO). IR (KBr): *v* = 3310, 3063, 3034, 2973, 2922, 2850 (w), 1673, 1589 (s), 1513 (m), 1480, 1456, 1425, 1388 (w), 1364, 1326, 1299, 1278, 1250, 1239 (m), 1156 (s), 1108, 1029, 1011, 971 (w), 954, 932 (m), 923 (w), 892 (s), 872 (w), 850 (s), 791 (w), 722 (m), 705 (s), 670, 636, 618, 569 (w), 535 (m) cm^{-1}.GC-MS (EI, 70 eV): m/z (%): 356 ($[M]^+$, 20), 300 (100), 272 (17), 244 (14), 215 (21). HRMS (ESI, 70 eV): calcd for $C_{24}H_{20}O_3$ $[M]^+$: 356.14070; found: 356.14105.

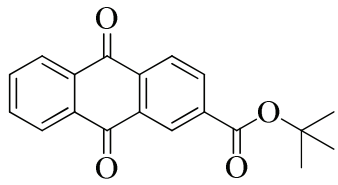


Ethyl 9,10-dioxo-9,10-dihydroanthracene-2-carboxylate (29g): Starting with **26** (316 mg, 1.0 mmol), ethylacrylate **27g** (250 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **29g** was isolated as a yellowish solid (104 mg, 37%+**28g**), reaction temperature: at 110°C for 8 h, Mp.143-145°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.38 (t, 3H, *J* =

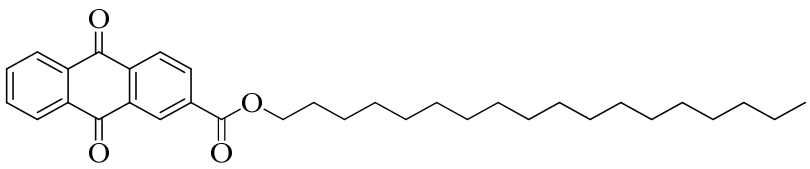


7.14 Hz, CH_3), 4.39 (q, 2H, J = 7.14 Hz, CH_2), 7.72-7.80 (m, 2H, ArH), 8.20-8.28 (m, 2H, ArH), 8.30 (s, 1H, ArH), 8.35 (dd, 1H, J = 1.68, 8.07 Hz, ArH), 8.84 (d, 1H, J = 1.29 Hz, ArH). ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 30.9 (CH_3), 61.9 (OCH_2), 127.3, 127.4, 127.5, 128.5 (CH), 133.3, 133.4, 133.5 (C), 134.3, 134.4, 134.5 (CH), 135.5, 136.0 (C), 165.0 (CO), 182.3, 182.5 (CO). IR (KBr): v = 3419, 3325, 3099, 3076, 3041, 2991, 2964, 2915, 2852 (w), 1717, 1674, 1588 (s), 1481, 1453, 1411, 1392, 1371 (w), 1330, 1316, 1292 (m), 1264, 1240 (s), 1162, 1108, 1083, 1025, 1015, 971, 928 (m), 908 (w), 869 (m), 818 (w), 797, 764 (m), 702 (s), 651 (w), 631 (m) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 280 ($[M]^+$, 34), 252 (49), 235 (100), 207 (26), 151 (41). HRMS (EI, 70 eV): calcd for $C_{17}H_{12}O_4$ $[M]^+$: 280.07301; found: 280.07294.

***Tert*-butyl 9,10-dioxo-9,10-dihydroanthracene-2-carboxylate (29h)**: Starting with **26** (316 mg, 1.0 mmol), 4-*tert*-butylacrylate **27h** (320 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **29h** was isolated as a yellowish solid (184 mg, 60%+**28h**), reaction temperature: at 110°C for 8 h, Mp.119-121°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.57 (s, 9H, $3CH_3$), 7.71-7.77 (m, 2H, ArH), 8.19-8.30 (m, 4H, ArH), 8.76-8.77 (m, 1H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 28.2 (CH_3), 82.5 (C), 127.3, 127.4, 128.4 (CH), 133.4, 133.5 (C), 134.2, 134.4, 134.5 (CH), 135.7, 138.0 (C), 164.1 (CO), 182.4, 182.6 (CO). IR (KBr): v = 3410, 3327, 2996, 2976, 2923, 2874, 2853 (w), 1712, 1674 (s), 1590 (m), 1483, 1476, 1462, 1391 (w), 1368, 1332 (m), 1274, 1246 (s), 1183 (w), 1154 (s), 1124, 1093 (m), 1036, 977, 968 (w), 930 (m), 894 (w), 865, 846, 793 (m), 764, 751 (w), 700 (s), 634 (m) cm^{-1}.GC-MS (EI, 70 eV): m/z (%) : 308 ($[M]^+$, 21), 253 (100), 235 (86), 208 (59), 151 (51). HRMS (ESI, 70 eV): calcd for $C_{19}H_{16}O_4$ $[2M+Na]^+$: 639.19844; found: 639.19859.

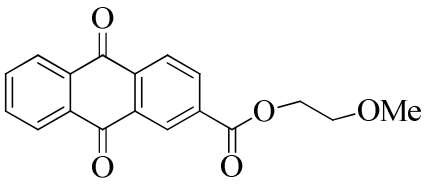


Octadecyl 9,10-dioxo-9,10-dihydroanthracene-2-carboxylate (29i): Starting with **26** (316 mg, 1.0 mmol), octadecylacrylate **27i** (325 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **29i** was isolated as a yellowish solid (231 mg, 46%), reaction temperature: at 110°C for 8 h, Mp.103-105°C.^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.16-1.19 [m, 35H, $16(CH_2)CH_3$], 4.32 (q, 2H, J = 6.75 Hz, CH_2), 7.73-7.75 (m, 2H, ArH), 8.21-8.29 (m, 2H, ArH), 8.30 (s, 1H, ArH), 8.35 (dd,



1H, *J* = 1.65, 8.10 Hz, ArH), 8.85 (d, 1H, *J* = 1.26 Hz, ArH).^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 14.1 (CH_3), 22.7, 26.0, 28.6, 29.2, 29.3, 29.5, 29.6, 29.6, 29.7 (CH_2), 66.1 (OCH_2), 127.3, 127.4, 127.5, 128.5 (CH), 133.3, 133.4, 133.5 (C), 134.3, 134.4, 134.5 (CH), 135.6, 136.0 (C), 165.1 (CO), 182.3, 182.5 (CO). IR (KBr): *v* = 2958 (w), 2915, 2848, 1720, 1670 (m), 1606 (w), 1589, 1472 (m), 1406, 1392, 1365, 1332, 1326, 1300 (w), 1265, 1242 (s), 1165 (m), 1126, 1097, 1050, 1027, 1018, 995, 980 (w), 947 (m), 928, 906, 867, 843, 818 (w), 799 (m), 763, 751, 741 (w), 717 (m), 706 (s), 646, 634, 567, 540 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 505 ($[M+H]^+$, 30), 504 ($[M]^+$, 100), 254 (69), 253 (30), 235 (12). HRMS (EI, 70 eV): calcd for $C_{33}H_{44}O_4$ $[M]^+$: 504.32341; found: 504.32231.

2-Methoxyethyl 9,10-dioxo-9,10-dihydroanthracene-2-carboxylate (29j): Starting with **26** (316 mg, 1.0 mmol), ethylene glycol methyl ether acrylate **27j** (325 mg, 2.5 mmol), $Pd(OAc)_2$ **(**11 mg, 5 mol%), XPhos (48 mg, 10 mol%), **29j** was isolated as a yellowish solid (220 mg, 71%), reaction temperature: at 110°C for 8 h, Mp.125°C. ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.38 (s, 3H, OCH_3), 3.69-3.73 (m, 2H, CH_2), 4.47-4.50 (m, 2H, OCH_2), 7.72-7.79 (m, 2H, ArH), 8.24-8.30 (m, 2H, ArH), 8.32 (brs, 1H, ArH), 8.38 (dd, 1H, *J* = 1.71, 8.10 Hz, ArH), 8.88-8.89 (m, 1H, ArH). ^{13}C NMR (75.5 MHz, $CDCl_3$): δ = 59.1 (OCH_3), 64.9 (CH_2), 70.3 (OCH_2), 127.4, 127.5, 127.5, 128.8 (CH), 133.4, 133.5, 133.6 (C), 134.4, 134.5, 134.7 (CH), 135.1, 136.1 (C), 165.1 (CO), 182.3, 182.6 (CO). IR (KBr): *v* = 3428, 3326, 3099, 3079, 3046, 2960, 2925, 2889, 2850, 2828, 2815, 1999, 1871 (w), 1717, 1674 (s), 1588 (m), 1477, 1463, 1440, 1416, 1404, 1373 (w), 1330, 1294 (m), 1266, 1242 (s), 1204, 1162 (m), 1115, 1106 (s), 1077 (m), 1021 (s), 979, 966 (w), 930 (m), 880, 874 (w), 862 (m), 824 (w), 795 (m), 775, 764 (w), 700 (s), 650 (w), 635 (m), 541 (w) cm^{-1}. GC-MS (EI, 70 eV): m/z (%) : 310 ($[M]^+$, 21), 278 (11), 235 (100), 207 (25), 179 (8), 151 (60), 58 (58). HRMS (EI, 70 eV): calcd for $C_{18}H_{14}O_5[M]^+$: 310.08358; found: 310.08340.



References

1. Nicolauo, K. C.; Bulger, P. G.; Sarlah, D. *Angew. Chem. Ind. Ed.* **2005**, *44*, 4442.

2. J. Tsuji, *Palladium Reagents and Catalysts*, Wiley, Chichester, **2004**.

3. Mark Hooper, *Platinum Metals Rev.* **2005**, *49*, 77.

4. a) *Applied Homogeneous Catalysis with Organometallic Compounds*, Cornils, B., and Herrmann.W. A., Ed.; Wiley-VCH: Weiheim, **1996**. b) *Handbook of Organopalladium Chemistry for Organic Synthesi*s; Negishi. E., de Meijere, A., Eds.; Wiley: New York, 2002. c) *Cross-Coupling Reactions*; Miyaura, N., Ed.; Springer: Berlin, **2000**.

5. Beller, M.; Zapf, A. *Chem. Commun*. **2005**, 431.

6. De Meijere, A.; Diederich, F. *Metal-Catalyzed Cross-Coupling Reactions*, 2nd-ed.; Wiley-VCH: Weinheim, Germany, **2004**; pp. 1-40.

7. Review on mechanistic studies: Amatore, C.; Jutand, A., *J. Organomet. Chem.* **1999**, *576*, 254.

8. Negishi, E., *Organopalladium Chemistry for Organic Synthesis*, Wiley, New York, **2002**, Vols. I and II.

9. Miyaura, N.; Suzuki, A. *J. Chem. Soc., Chem. Commun*. **1979**, *19*, 866.

10. Miyaura, N.; Yamada, K.; Suzuki, A. *Tetrahedron Lett*. **1979**, *20*, 3437.

11. Miyaura, N.; Suzuki, A. *Chem. Rev.* **1995**, *95*, 2457.

12. Kabri, Y.; Verhaeghe, P.; Gellis, A.; Vanelle, P. *Molecules* **2010**, *15*, 2949.

13. Soderquist, J. A.; Matos, K. *J. Org. Chem.* **1998**, *63*, 461.

14. Pelter, A.; Smith, K.; Brown, H. C. Borane Reagents; Academic; New York, **1988**.

15. Casalnuovo, A. L.; Calabrese, J. C. *J. Am. Chem. Soc*. **1990**, *112*, 4324.

16. Hassan, J.; Sévignon, M.; Gozzi, C.; Schulz, E.; Lemaire, M. *Chem. Rev*. **2002**, *102*,1359.

17. F. Ozawa, A. Kubo, and T. Hayashi, *Chem. Lett.* **1992**, 2177.

18. Buchwald, *Angew. Chem. Int. Ed.* **2004**, *43*, 1871. *Angew. Chem. Int. Ed.* **1999**, *38*, 2413.

19. a) Hussain, M.; Hung, N. T.; Khera, R.; Villinger, a.; Langer, P. *Tetrahedron. Lett*., **2010**, 52, 184. b) Hung, N.T.; Hussain, M.; Malik, I.; Villinger, A.; Langer, P., *Tetrahedron. Lett*. **2010**, *51*, 2420. c) Ibad, M.; Hussain, M.; Abid, O.; Ali, A.; Marwat I.; Zinad, D.S; Langer P., Synlett **2010**, 411. d) Toguem, S. M. T.; Villinger, A.; Langer, P. *Synlett* **2010**, 909. e) Toguem, S. M. T.; Villinger, A.; Langer, P. *Synlett* **2009**, 3311. f) Khera, R. A.; Ali, A.; Hussain, M.; Tater, J.; Villinger, A.; Langer, P. *Synlett*.,

2010, 1923. g) Hussain, M.; Hung, N. T.; Khera, R. A.; Malik, I.; Zinad, D. S.; Langer, P. *Adv. Syn.Catal*., **2010**, *352*, 1429. h) Hussain, M.; Khera, R.; Hung, N.T.; Langer, P., *Org*. *Biomol*. *Chem*. **2011**, *9*, 370.

20. Heck, F. R. *Palladium Reagents in Organic Synthesis*, Academic Press, New York, **1985**.

21. a) Nawaz, M.; Khera, R. A.; Malik, I.; Ibad, M. F.; Abid, O. R.; Villinger, A.; Langer, P. *Synlett*. **2010**, 979. b) Ali, A.; Khera, R. A.; Ibad, M. F.; Hussain, M.; Langer, P. *Synlett*. **2010**, 731. c) Mahal, A.; Villinger, A.; Langer, P. *Synlett* **2010**, 1085. d) Abid, O. R.; Ibad, M. F.; Nawaz, M.; Ali, A.; Sher, M.; Rama, N. H.; Villinger, A.; Langer, P. *Tetrahedron. Lett*. **2010**, *51*, 1541. e) Malik, I.; Hussain, M.; Hung, N.T.; Villinger, A.; Langer, P. *Synlett* **2010**, 2244. f) Salman, A.; Mahal, A.; Shkoor, M.; Hussain, M.; Villinger, A.; Langer, P. *Tetrahedron. Lett*. **2011**, *52*, 392. g) Salman, A.; Hussain, M.; Villinger, A.; Langer, P. *Synlett* **2010**, 3031.

22. Handy, S. T.; Sabatini, J. *Org. Lett*. **2006**, *8*, 1537.

23. Heck, R. F.; Nolley, J. P. *J. Org. Chem*. **1972,** *37*, 2320.

24. de Vries, J. G. *Can. J. Chem.* **2001**, *79*, 1086.

25. Xiao-Feng, W.; Anbarasan, P.; Neumann, H.; Beller, M., *Angew. Chem. Int. Ed.* **2010**, *49*, 9047.

26. Voigt, K.; von Zezschwitz, P.; Rosauer, K.; Lansky, A.; Adams, A.; Reiser, O.; de Meijere, A. *Eur.J.Org.Chem*.**1998**,1521.

27. a) Hussain, M., Dissertation, University of Rostock. b) Hussain, M.; Dang, T. T.; Langer, P. *Synlett* **2009**, 1822. c) Hussain, M.; Malik, I.; Langer, P. *Synlett* **2009**, 2691. d) Toguem, S. M. T.; Hussain, M.; Malik, I.; Villinger, A.; Langer, P. *Tetrahedron Lett.* **2009**, 50, 4962. e) Hussain, M.; Hung, N. T.; Langer, P. *Tetrahedron Lett.* **2009**, 50, 3929.

28. Wentland, M.; Perni, R.; Hlavac, A.; Corbett, T.; Coughlin, S. A.; Rake, J. *Bioorg. Med. Chem. Lett.* **1994**, *4*, 609.

29. Watanabe, M.; Pate, M.; Tsukazaki, M.; Furukawa, S. *Chem. Pharm. Bull.* **1989**, *37*, 36.

30. Showalter, H.; Angelo, M.; Berman, E. *J. Med. Chem.* **1988**, *31*, 1527.

31. Vacek, L.; Foster, H. *Chem. Abstr.* **1979**, *90*, 72060a.

32. Archer, S.; Mattoccia, L.; Cioli, D.; Seyed-Mozaffari, A.; Zayed, A. *J. Med. Chem.* **1988**, *31*, 254.

33. Laidlaw, G.; Collins, J.; Archer, S.; Rosi, D.; Schulenberg, J. *J. Org. Chem.* **1973**, *38*, 1743.

34. Rosi, D.; Peruzzoti, G.; Dennis, E.; Berberian, D.;Freele, H.; Tullar, B.; Archer, S. *Med. Chem.* **1967**, *10*, 867.

35. Perni, R.; Wentland, M.; Huang, J.; Powles, R.; Aldous, S.; Klingbeil, K.; Peverly, A.; Robinson, R.; Corbett, T.; Jones, J.; Mattes, K.; Rake, J.; Coughlin, S. A. *J. Med. Chem.* **1998**, *41*, 3645.

36. Kostakis, I.; Pouli, N.; Marakos, P.; Mikros, E.; Skaltsounis, A.; Leonce, S.; Atassi, G.; Renard, P. *Bioorg. Med. Chem.* **2001**, *9*, 2793.

37. Kolokythas, G.; Kostakis, I.; Pouli, N.; Marakos, P.; Kletsasb, D.; Pratsinis, B. *Bioorg. Med. Chem.* **2003**, *11*, 4591.

38. Harfenist, M.; Heuser, D.; Joyner, C.; Batchelor, J.; White, H. *J. Med.Chem.* **1996**, 39, 1857.

39. Zhao, J.; Larock, R. C. *J. Org. Chem.* **2007**, *72*, 583.

40. Belal, F.; Hefnawy, M.; Aly, F. *J. pharm. Biomed. Anal.* **1997**, *16*, 369.

41. Morita, H.; Mori, S.; Yamaoka, T. *Bull. Chem. Soc. Jpn.* **1988**, *61*, 191.

42. Shamipur, M.; Karami, A.; Yamini, Y.; Sharghi, H.; Sailmi, A. *J. Chem. Eng. Data* **2003**, 48, 1088-1091.

43. Ran, R.; Pittman, U. C. *J. Heterocycl. Chem.* **1993**, *30*, 1673.

44. Okabayashi, I.; Fujiwara, H. *J. Heterocycl. Chem.* **1994**, *31*, 733.

45. Okabayashi, I.; Fujiwara, H.; Tanaka, C. *J. Heterocycl. Chem.* **1991**, *28*, 1977.

46. Sharghi, H.; Beni, S. *Synthesis* **2004**, 2900.

47. Loskutov V.; Beregovaya I. *Rus.J.Org.Chem*. **2009**, 45, 9, 1405-1409.

48. a) Anstead, G. M.; Wilson, S. R.; Katzenellenbogen, J. A. *J. Med. Chem.* **1989**, *32*, 2163. b) Hajela, K.; Kapil, R. S. *Ind. J. Chem., Sect. B* **1995**, *34*, 361. c) McDevitt, R. E.; Malamas, M. S.; Manas, E. S.; Unwalla, R. J.; Xu, Z. B.; Miller, C. P.; Harris, H. A. *Bioorg. Med. Chem. Lett.* **2005**, *15*, 3137. d) Barvian, M. R.; Panek, R. L.; Lu, G. H.; Kraker, A. J.; Amar, A.; Hartl, B.; Hamby, J. M.; Showalter, H. D. H. *Bioorg. Med. Chem. Lett.* **1997**, *7*, 2903.

49. Mal, D.; Ranjan, S. *Org. Lett.* **2009**, *11*, 4398.

50. Harrowven, D. C.; Newman, N. A.; Knight, C. A. *Tetrahedron Lett.* **1998**, *39*, 6757.

51. Jeffrey, J. L.; Sarpong, R. *Org Lett.* **2009**, *11*, 5450.

52. a) Weitz, E.; Scheffer, A. *Chem. Ber.* **1921**, *54*, 2343. b) Bergmann, E. D. *J. Org. Chem.* **1956**, *21*, 461. c) Frank, R. L.; Eklund, H.; Richter, J. W.; Vanneman, C. R.; Wennerberg, A. N. *J. Am. Chem. Soc.* **1944**, *66*, 1. d) Beringer, F. M.; Forgione, P. S.; Yudis, M. D. *Tetrahedron* **1960**, *8*, 49. e) Koelsch, F. *J. Am. Chem. Soc.* **1932**, *54*, 2487. f) Eisch, J. J.; Kaska, W. C. *J. Am. Chem. Soc.* **1966**, *88*, 2976.

53. a) Jeffrey, J. L.; Sarpong, R. *Org. Lett.* **2009**, *11*, 5450. b) Morimoto, T.; Yamasaki, K.; Hirano, A.; Tsutsumi, K.; Kagawa, N.; Kakiuchi, K.; Harada, Y.; Fukumoto, Y.; Chatani, N.; Nishioka, T. *Org. Lett.* **2009**, *11*, 1777.

54. a) Liebermann, C. *Chem. Ber.* **1898**, *31*, 2083. b) Liebermann, C. **1899**, 32, 261. c) Liebermann, C. *Chem. Ber.* **1899**, *32*, 920. d) Liebermann, C. *Chem. Ber.* **1900**, 33, 569. e) Simonis, H.; Kirschten, C. *Chem. Ber.* **1912**, *45*, 567.

55. Hussain, M.; Nguyen, T. H.; Khera, R. A.; Villinger, A.; Langer, P. *Tetrahedron Lett.* **2011**, 52, 184.

56. a) Sulikowski, G. A.; Agnelli, F.; Corbett, R. M. *J. Org. Chem.* **2000**, *65*, 337. b) Bellina, F.; Anselmi, C.; Viel, S.; Mannina, L.; Rossi, R. *Tetrahedron* **2001**, *57*, 9997. c) Bellina, F.; Anselmi, C.; Rossi, R. *Tetrahedron Lett.* **2001**, *42*, 3851.

57. For reviews of cross-coupling reactions of polyhalogenated heterocycles, see: a) Schröter, S.; Stock, C.; Bach, T. *Tetrahedron* **2005**, *61*, 2245. b) Schnürch, M.; Flasik, R.; Khan, A. F.; Spina, M.; Mihovilovic, M. D.; Stanetty, P. *Eur. J. Org. Chem.* **2006**, 3283. c) Wang, R.; Manabe, K. *Synthesis* **2009**, 1405.

58. a) Dang, T. T.; Dang, T. T.; Ahmad, R.; Reinke, H.; Langer, P. *Tetrahedron Lett.* **2008**, *49*, 1698. b) Dang, T. T.; Villinger, A.; Langer, P. *Adv. Synth. Catal.* **2008**, *350*, 2109.

59. For the synthesis of 2,3-dibromoinden-1-one, see: Basurto, S.; Garcia, S.; Neo, A. G.; Torroba, T.; Marcos, C. F.; Miguel, D.; Barbera, J.; Blanca Ros, M.; de la Fuente, M. R. *Chem. Eur. J.* **2005**, *11*, 5362.

60. CCDC-xxx contain all crystallographic details of this publication and is available free of charge at www.ccdc.cam.ac.uk/conts/retrieving.html or can be ordered from the following address: Cambridge Crystallographic Data Centre, 12 Union Road, GB-Cambridge CB21EZ; Fax: (+44)1223-336-033; or deposit@ccdc.cam.ac.uk.

61. Hesse, M., *Helv. Chim. Acta.* **2002**, 283.

62. Humphrey, G.R.; Kuethe, J.T., *Chem. Rev.* **2006**, *106*, 2875.

63. Cacchi, S.and Fabrizi, G., *Chem. Rev.* **2005**, *105*, 2873.

64. Sezen, B. and Sames, D. *J. Am. Chem. Soc.* **2003**, *125*, 5274.

65. Shmeiss, N. A. M. M.; Ismail, M. M. F.; El-Diwani, H. I.; Hassan, A. B.; Nada, S. A. *Modell. Meas. Control C* **1997**, *55*, 11.

66. a) Glenn, E. M.; Bowman, B. J.; Kooyers, W.; Koslowske, T.; Myers, M. L. *J. Pharmacol. Exp. Ther.* **1967**, *155*, 157. b) Kaiser, D. G.; Glenn, E. M.; Johnson, R. H.; Johnston, R. L. *J. Pharmacol. Exp. Ther.* **1967**, *155*, 174. c) Whitehouse, M. W. *J. Pharm. Pharmacol.* **1967**, *19*, 590. d) Collier, H. O. J.; James, G. W. L.; Piper, P. J. *Brit. J. Pharmacol.* **1968**, *34*, 76. e) Brune, K.; Graf, P.; Glatt, M. *Agents Actions* **1976**, *6*, 159. f) Podos, S. M.; Becker, B. *Invest. Ophthalmol.* **1976**, *15*, 841. g) Spinelli, H. M.; Krohn, D. L. *Arch. Ophthalmol.* **1980**, *98*, 1106. h) Klug, R. D.; Krohn, D. L.; Breitfeller, J. M.; Dieterich, D. *Ophthalmic Res.* **1981**, *13*, 122.

67. McAdam, B. F.; Catella-Lawson, F.; Mardini, I. A.; Kapoor, S.; Lawson, J. A.; FitzGerald, G. A. *Proc. Natl. Acad. Sci. USA* **1999**, *96*, 272.

68. Old, D.; Harris, M. ; Buchawald, S., *Org. Lett.*, **2000**, *2* , 1403.

69. Schröter, S.; Stock, C.; Bach, T. *Tetrahedron* **2005**, *61*, 2245.

70. a) Ishikura, M.; Kamada, M.; Terashima, M. *Synthesis* **1984**, 936. b) Yang, Y.; Martin, A. R. *Synth. Commun.* **1992**, *22*, 1757. c) Carrera Jr., G. M.; Sheppard, G. S. *Synlett* **1994**, 93. d) Tidwell, J. H.; Peat, A. J.; Buchwald, S. L. *J. Org. Chem.* **1994**, *59*, 7164. e) Banwell, M. G.; Bissett, B. D.; Busato, S.; Cowden, C. J.; Hockless, D. C. R.; Holman, J. W.; Read, R. W.; Wu, A. W. *J. Chem. Soc., Chem. Commun.* **1995**, 2551. f) Merlic, C. A.; McInnes, D. M.; You, Y. *Tetrahedron Lett.* **1997**, *38*, 6787. g) Merlic, C. A.; McInnes, D. M. *Tetrahedron Lett.* **1997**, *38*, 7661. h) Moody, C. J.; Doyle, K. J.; Elliott, M. C.; Mowlem, T. J. *J. Chem. Soc., Perkin Trans.* 1 **1997**, 2413. i) Chu, L.; Fisher, M. H.; Goulet, M. T.; Wyvratt, M. J. *Tetrahedron Lett.* **1997**, 38, 3871. j) Carbonnelle, A.-C.; González-Zamora, E. G.; Beugelmans, R.; Roussi, G. *Tetrahedron Lett.* **1998**, *39*, 4467. k) Chi, S. M.; Choi, J.-K.; Yum, E. K.; Chi, D. Y. *Tetrahedron Lett.* **2000**, *41*, 919. For eactions of triflates, see: l) Joseph, B.; Malapel, B.; Mérour, J.Y. *Synth. Commun.* **1996**, *26*, 3289. m) Malapel-Andrieu, B.; Mérour, J.Y. *Tetrahedron* **1998**, *54*, 11079.

71. Kawasaki, I.; Yamashita, M.; Ohta, S. *Chem.Pharm. Bull.* **1996**, *44*, 1831.

72. a) Liu, Y.; Gribble, G. W. *Tetrahedron Lett.* **2000**,*41*, 8717. For metal-halide exchange, see: b) Liu, Y.; Gribble, G. W. *Tetrahedron Lett.* **2002**, *43*, 7135.

73. a) *Römpp Lexikon Naturstoffe* (Steglich, W.; Fugmann, B.; Lang-Fugmann, S. eds.), Thieme, Stuttgart: **1997**. b) Muzychkina, R. A., Natural Anthraquinones, Biological and Physicochemical Properties. House Phasis, Moscow, **1998**.

74. Review: Krohn, K. *Angew. Chem., Int. Ed. Engl.* **1986**, *25*, 790; *Angew. Chem.* **1986**, *98*, 788.

75. Ishiyama, D.; Futamata, K.; Futamata, M.; Kasuya, O.; Kamo, S. *J. Antibiot.* **1998**, *51*, 1069.

76. a) Dhananjeyan, M. R.; Milev, Y. P.; Kron, M. A.; Nair, M. G. *J. Med. Chem.* **2005**, *48*, 2822. b) Liu, R.; Zhu, W.; Zhang, Y.; Zhu, T.; Liu, H.; Fang, Y.; Gu, Q. *J. Antibiot.* **2006**, *59*, 362.

77. Diaz, F.; Chai, H.; Mi, Q.; Su, B.; Vigo, J. S.; Graham, J.; Cabieses, F.; Farnsworth, N.; Cordell, G.; Pezzuto, J.; Swanson, S.; Kinghorn, A. *J. Nat. Prod.* **2004**, *67*, 352.

78. Nair, M. G.; Cichewicz, R. H.; Seeram, N. P.; Zhang, Y. US Patent.6,875,746 B1, **2005**.

79. Cichewicz, R. H.; Nair, M. G.; McKerrow, J. US Patent. 6,903,076 B2, **2005**.

80. a) Gautrot, J. E.; Hodge, P.; Cupertino, D.; Helliwell, M. *New J. Chem.* **2006**, *30*, 1801. b) Showalter, H. D. H.; Berman, E. M.; Johnson, J. L.; Hunter, W. E. *Tetrahedron Lett.* **1985**, *26*, 157. c) Shcheglova, N. A.; Shigorin, D. N.; Dokunikhin, N. S. *Zh. Fiz. Khim.* **1966**, *40*, 1048; *Chem. Abstr.* **1966**, *65*, 9958b. d) Shcheglova, N. A.; Shigorin, D. N.; Dokunikhin, N. S. *Zh. Fiz. Khim.* **1965**, *39*, 3039; *Chem. Abstr.* **1965**, *64*, 12058f.

81. Dia, K.; Itoh, Y.; Kitade, Yatome, C. *Bull. Environ. Contam. Toxicol.* **1998**, *60*, 786.

82. Tamayo, N.; Echawarren, A.; Pareses, M.; Farine, F.; Noheda, P. *Tetrahedron Lett*.**1990**, *31*, 5189.

83. Heck, R.F., *J.Am.Chem.Soc*.**1968**, *90*, 5518.

84. De Meijere, A.; Meyer, F.*Angew.Chem*.**1994**, *33*, 2379.

85. a) Tietze, L. F.; Beifuss, U. *Angew. Chem., Int. Ed. Engl.* **1993**, *32*, 131; *Angew. Chem.* **1993**, 105, 137. b) Tietze, L. F. *Chem. Rev.* **1996**, *96*, 115.

X-ray Crystal Data

Data for compound 5b

Identification code	dz-t16	
Empirical formula	$C_{22}H_{15}F_3O_4S_2$	
Formula weight	464.46	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	*a* = 5.2396 (2) Å	α = 90.00°
	b = 19.5582 (9) Å	β = 96.074 (2)°
	c = 19.2611 (8) Å	γ = 90.00°
Volume	1962.74 (14) $Å^3$	
Z	4	
Density (calculated)	1.572 Mg /m^3	
Absorption coefficient	0.33 mm^{-1}	
F (000)	952	
Crystal size	0.99 × 0.18 × 0.05 mm^3	
Θ range for data collection	4.7–59.8°	
Reflections collected	21304	
Independent reflections	5620	
Absorption correction	multi-scan	
Max. and Min. transmission	0.984 and 0.737	
Refinement method	full-matrix	
Goodness-of-fit F2	1.046	
Final R indices [I >2σ (I)]	R1 = 0.0393, wR2 = 0.0942	
R indices (all data)	R1 = 0.0646, wR2 = 0.1056	

Data for compound 5c

Identification code	dz-t7	
Empirical formula	$C_{24}H_{19}F_3O_4S_2$	
Formula weight	492.51	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 5.4456 (3) Å	α = 90.00°
	b = 30.3961 (18) Å	β = 93.177 (4)°
	c = 12.9846 (8) Å	γ = 90.00°
Volume	2146.0 (2) $Å^3$	
Z	4	
Density (calculated)	1.524 Mg /m^3	
Absorption coefficient	0.31 mm^{-1}	
F (000)	1016	
Crystal size	0.87 × 0.06 × 0.04 mm^3	
Θ range for data collection	5.1–47.5°	
Reflections collected	21642	
Independent reflections	5175	
Absorption correction	multi-scan	
Max. and Min. transmission	0.988 and 0.777	
Refinement method	full-matrix	
Goodness-of-fit F2	0.932	
Final R indices [I >2σ (I)]	R1 = 0.0481, wR2 = 0.0919	
R indices (all data)	R1 = 0.1235, wR2 = 0.1070	

Data for compound 6b

Identification code	dz-t21	
Empirical formula	$C_{30}H_{26}O_2S$	
Formula weight	450.57	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	*a* = 5.6852 (4) Å	α = 90.00°
	b = 22.4121 (14) Å	β = 91.156 (2)°
	c = 17.7991 (11) Å	γ = 90.00°
Volume	2267.5 (3) $Å^3$	
Z	4	
Density (calculated)	1.320 Mg /m^3	
Absorption coefficient	0.17 mm^{-1}	
F (000)	952	
Crystal size	0.98 × 0.31 × 0.07 mm^3	
Θ range for data collection	5.9–62.7°	
Reflections collected	29126	
Independent reflections	7236	
Absorption correction	multi-scan	
Max. and Min. transmission	0.988 and 0.852	
Refinement method	full-matrix	
Goodness-of-fit F2	1.057	
Final R indices [I >2σ (I)]	R1 = 0.0432, wR2 = 0.1123	
R indices (all data)	R1 = 0.0594, wR2 = 0.1207	

Data for compound 10a

Identification code	dz-ppa6
Empirical formula	$C_{22}H_{15}F_3O_4S_2$
Formula weight	464.46
Temperature	173 (2) K
Wavelength	0.71073 Å
Crystal system	Tetragonal
Space group (H.-M.)	I 41/a
Space group (Hall)	-I 4ad
Unit cell dimensions	a = 29.1670 (5) Å α = 90 °
	b = 29.1670 (5) Å β = 90 °
	c = 9.5537 (2) Å γ = 90 °
Volume	8127.5 (3) $Å^3$
Z	16
Density (calculated)	1.518 Mg/m^3
Absorption coefficient	0.32 mm^{-1}
F (000)	3808
Crystal size	0.39 × 0.28 × 0.25 mm^3
Θ range for data collection	5.3–59.3°
Reflections collected	21080
Independent reflections	5857
Absorption correction	multi-scan
Max. and Min. transmission	0.925 and 0.886
Refinement method	full-matrix
Goodness-of-fit F2	1.048
Final R indices [I >2σ (I)]	R1 = 0.0377, wR2 = 0.0946
R indices (all data)	R1 = 0.0515, wR2 = 0.0994

Data for compound 15b

Identification code	dz-41	
Empirical formula	$C_{16}H_7Br_2F_3O$	
Formula weight	432.04	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	a = 13.3098 (6) Å	α = 90.00 °
	b = 14.9723 (7) Å	β = 92.189 (3) °
	c = 7.4196 (3) Å	γ = 90.00 °
Volume	1477.49 (11) $Å^3$	
Z	4	
Density (calculated)	1.942 Mg /m^3	
Absorption coefficient	5.52 mm^{-1}	
F (000)	832	
Crystal size	0.99 × 0.07 × 0.06 mm^3	
Θ range for data collection	5.4–57.7°	
Reflections collected	16758	
Independent reflections	4304	
Absorption correction	multi-scan	
Max. and Min. transmission	0.733 and 0.074	
Refinement method	full-matrix	
Goodness-of-fit F2	1.011	
Final R indices [I >2σ (I)]	R1 = 0.0318, wR2 = 0.0626	
R indices (all data)	R1 = 0.0580, wR2 = 0.0675	

Data for compound 16g

Identification code	dz-62a	
Empirical formula	$C_{21}H_{11}BrCl_2O$	
Formula weight	430.11	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic, $P\bar{1}$	
Space group (H.-M.)	P -1	
Space group (Hall)	-P 1	
Unit cell dimensions	*a* = 5.9376 (2) Å	α = 68.331 (2)°
	b = 11.9185 (5) Å	β = 80.137 (2)°
	c = 13.6971 (5) Å	γ = 82.890 (2)°
Volume	885.55 (6) $Å^3$	
Z	2	
Density (calculated)	1.613 Mg /m^3	
Absorption coefficient	2.63 mm^{-1}	
Crystal size	0.33 × 0.10 × 0.05 mm^3	
Θ range for data collection	5.7–56.8°	
Reflections collected	16383	
Independent reflections	4656	
Absorption correction	multi-scan	
Max. and Min. transmission	0.880 and 0.478	
Refinement method	full-matrix	
Goodness-of-fit F2	1.090	
Final R indices [I >2σ (I)]	R1 = 0.0433, wR2 = 0.0812	
R indices (all data)	R1 = 0.0632, wR2 = 0.0877	

Data for compound 19b

Identification code	dz-72b	
Empirical formula	$C_{30}H_{18}F_6O_2$	
Formula weight	524.44	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic, $P\bar{1}$	
Space group (H.-M.)	P -1	
Space group (Hall)	-P 1	
Unit cell dimensions	a = 7.2654 (3) Å	α = 111.919 (2)°
	b = 11.9138 (5) Å	β = 96.065 (2)°
	c = 14.8483 (6) Å	γ = 92.612 (2)°
Volume	1180.62 (8) $Å^3$	
Z	2	
Density (calculated)	1.475 Mg /m^3	
Absorption coefficient	0.12 mm^{-1}	
F (000)	536	
Crystal size	0.45 × 0.44 × 0.37 mm^3	
Θ range for data collection	5.6–60.0°	
Reflections collected	23250	
Independent reflections	6224	
Absorption correction	multi-scan	
Max. and Min. transmission	0.956 and 0.946	
Refinement method	full-matrix	
Goodness-of-fit F2	1.095	
Final R indices [I >2σ (I)]	R1 = 0.0389, wR2 = 0.1063	
R indices (all data)	R1 = 0.0467, wR2 = 0.1109	

Data for compound 23a

Identification code	dz-tri-15R1a	
Empirical formula	$C_{23}H_{20}BrNO_2$	
Formula weight	422.31	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	*a* = 14.3331 (10) Å	α = 90.00°
	b = 10.0572 (7) Å	β = 97.808 (3)°
	c = 26.376 (2) Å	γ = 90.00°
Volume	3766.9 (5) $Å^3$	
Z	8	
Density (calculated)	1.489 Mg /m^3	
Absorption coefficient	2.20 mm^{-1}	
F (000)	1728	
Crystal size	0.78 × 0.45 × 0.02 mm^3	
Θ range for data collection	5.1–50.6°	
Reflections collected	39122	
Independent reflections	9979	
Absorption correction	multi-scan	
Max. and Min. transmission	0.957 and 0.279	
Refinement method	full-matrix	
Goodness-of-fit F2	1.043	
Final R indices [I >2σ (I)]	R1 = 0.0530, wR2 = 0.1280	
R indices (all data)	R1 = 0.1032, wR2 = 0.1168	

Data for compound 23b

Identification code	dz-tri-10R2	
Empirical formula	$C_{25}H_{24}BrN$	
Formula weight	418.36	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group (H.-M.)	$P2_1/c$	
Space group (Hall)	-P 2ybc	
Unit cell dimensions	*a* = 13.0806 (7) Å	α = 90.00°
	b = 21.4854 (12) Å	β = 100.020 (3)°
	c = 7.3970 (5) Å	γ = 90.00°
Volume	2047.2 (2) $Å^3$	
Z	4	
Density (calculated)	1.357 Mg /m^3	
Absorption coefficient	2.02 mm^{-1}	
F (000)	864	
Crystal size	0.97 × 0.15 × 0.03 mm^3	
Θ range for data collection	6.3–44.5°	
Reflections collected	18092	
Independent reflections	4896	
Absorption correction	multi-scan	
Max. and Min. transmission	0.942 and 0.245	
Refinement method	full-matrix	
Goodness-of-fit F2	1.057	
Final R indices [I >2σ (I)]	R1 = 0.0443, wR2 = 0.0856	
R indices (all data)	R1 = 0.0915, wR2 = 0.0950	

Data for compound 28 c

Identification code	dz-3b2	
Empirical formula	$C_{34}H_{32}O_2$	
Formula weight	472.60	
Temperature	173 (2) K	
Wavelength	0.71073 Å	
Crystal system	Triclinic	
Space group (H.-M.)	P -1	
Space group (Hall)	-P 1	
Unit cell dimensions	*a* = 11.767 (9) Å	α = 94.95 (2)°
	b = 15.173 (10) Å	β = 99.729 (13)°
	c = 15.251 (11) Å	γ = 97.545 (16)°
Volume	2644 (3) $Å^3$	
Z	4	
Density (calculated)	1.187 Mg/ m^3	
Absorption coefficient	0.07 mm^{-1}	
F (000)	1008	
Crystal size	0.58 × 0.14 × 0.10 mm^3	
Θ range for data collection	6.5 - 59.1°	
Reflections collected	50656	
Independent reflections	13767	
Absorption correction	multi-scan	
Max. and Min. transmission	0.959 and 0.993	
Refinement method	full-matrix	
Goodness-of-fit F2	1.0436	
Final R indices [I >2σ (I)]	R1 = 0.0512, wR2 = 0.1291	
R indices (all data)	R1 = 0.0904, wR2 = 0.1427	

Declaration/Erklärung

Here by I declare that this work has so far neither submitted to the Faculty of Mathematics and Natural Sciences at the University of Rostock nor to any other scientific Institution for the purpose of doctorate. Further more, I declare that I have written this work by myself and that I have not used any other sources, other than mentioned earlier in this work.

Hiermit erkläre ich, daß diese Arbeit bisher von mir weder an der Mathematisch-Naturwissenschaftlichen Fakultät der Universität Rostock noch an einer anderen wissenschaftlichen Einrichtung zum Zwecke der Promotion eingereicht wurde.

Ferner erkläre ich, dass ich diese Arbeit selbständig verfasst und keine anderen als die darin angegebenen Hilfsmittel benutzt habe.

I hereby apply irrevocably to take oral examination in the form of a private viva voce and a public presentation.