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Convenient synthesis of thieno[3,2-b]indoles and thieno[3,4-b]indoles by sequential site-selective Suzuki- and double C-N coupling reaction

Ngo Nghia Pham, a,b,c Silvio Parpart, a Sevak Grigoryan, a,d Thang Ngoc Ngo, a Tuan Thanh Dang, a Tariel V. Ghochikyan, d Ashot S. Saghyan, d,e Peter Ehlers, a,b Peter Langer* a,b

a Institut für Chemie, Universität Rostock, Albert-Einstein-Str. 3a, 18059 Rostock, Germany. E-mail: peter.langer@uni-rostock.de; Tel: +49 381 4986410; Fax: +49 381 4986412. http://www.langer.chemie.uni-rostock.de/
b Leibniz Institut für Katalyse an der Universität Rostock e.V., Albert-Einstein-Str. 29a, 18059 Rostock, Germany
c Faculty of Chemistry, VNU University of Science Hanoi (VNU-HUS), 19 Le Thanh Tong, Hoan Kiem, Hanoi, Vietnam
d Yerevan State University, Faculty of Pharmacy and Chemistry, Alex Manoogian Str. 1, 0025 Yerevan, Armenia
e Scientific and Production Center “Armibiotecology” of NAS RA, Gyurjyan Str. 14, 0056 Yerevan, Armenia

Abstract: A convenient synthesis of thieno[3,2-b]indoles and thieno[3,4-b]indoles has been developed. The protocol involves a site-selective Suzuki reaction, followed by a double C-N coupling reaction using anilines, benzylamines as well as alkylamines. The yields range from good to excellent.

Keywords: catalysis; cyclizations; cross-coupling reactions; regioselectivity; heterocycles
Introduction

Thiophene is a five-membered heterocycle which occurs on earth mostly as a minority in petroleum. Despite this minority, thiophene possesses a great potential for application in many fields of daily life. In pharmacology, thiophene is considered as a bioisostere of benzene. Thus, replacing benzene by a thiophene moiety, scientists have discovered better alternatives for previously known drugs. For instance, Olanzapine has been applied as a thiophene-analog of Clozapine for the treatment of schizophrenia with lower risk of side effects (Fig. 1). In biological research, thiophenes may incorporated into structures of fluorescent markers for cell labeling, such as compound DTTO (Fig. 1). Finally, in material science, thiophene is integrated in various organic electronic structures with low oxidation potential and environmental stability. Among these polymers, those involving fused thiophenes belong to the most studied classes, since they represent promising candidates for OFET applications. For example, DTTQ (Fig. 1), which is a fused thiophene-quinoxaline based polymer, possesses increased photochemical stability.

In this regard, two fused derivatives comprised of thiophene and indole, namely thieno[3,2-b]indoles and thieno[3,4-b]indoles, have been considered to represent potential candidates for various applications. Former derivatives are known to possess antiviral properties. They also can be employed as building blocks of polymers for solar cell applications. For example, TI-DTBT3 (Fig. 1) is a donor-acceptor conjugated polymer which displays relatively high charge carrier mobility. As a result, the development of their syntheses has attracted increasing attention from synthetic chemists.
The first syntheses of thieno[3,2-b]indole and thieno[3,4-b]indole were carried out in 1982 by treating (a) substituted indole with thioamide\(^9\) and (b) 3-hydroxythiophene with hydrazine\(^10\) (Scheme 1). Unfortunately, these syntheses are not modular, thus not enabling a pathway to a large product library. Until 2000, there was no further report with respect to the enhancement of the synthetic elaboration of these two classes. Fortunately, the access to these thienoindoles has been facilitated during the last two decades owing to the development of palladium cross-coupling chemistry. With the high potential for creating new C-C and C-N bonds by palladium catalysts, a number of new synthetic methods for these classes have been developed. Generally, these protocols start with a Suzuki reaction to construct the C-C bond between the thiophene and the benzene ring, followed by different types of ring closures, such as (c) nitrene insertion\(^11\), (d) oxidative C-N coupling\(^12\) or (e) Cadogan cyclisation\(^13\) to furnish the desired products (Scheme 1).
In an attempt to synthesize thieno[3,2-b]indoles and thieno[3,4-b]indoles, we also disconnected these molecules first by a Suzuki reaction (Scheme 2). However, we chose (2-bromophenyl)boronic acid to generate a biaryl derivative which is capable of undergoing a subsequent double C-N coupling. This strategy has proven effective in our previous studies related to the preparation of different fused indoles. In this paper, we present our results for the synthesis of thieno[3,2-b]indole and thieno[3,4-b]indole derivatives.

Results and discussion
The synthesis of thieno[3,2-b]indoles was initiated by a site-selective Suzuki reaction of 2,3-dibromothiophene (1) adapting our previously documented conditions for the preparation of diindolothiophene. Under these conditions, 3-bromo-2-(2-bromophenyl) thiophene (2) was obtained in 82% yield (Scheme 3).

Scheme 3: Selective Suzuki reaction of 2,3-dibromothiophene

Subsequently, 3-bromo-2-(2-bromophenyl) thiophene (2) was employed as precursor for the double C-N coupling. To optimize this reaction, a brief ligand screening was conducted using the base NaOtBu in toluene with the palladium source Pd\textsubscript{2}dba\textsubscript{3}. During the optimization, the bidentate ligand dppf performed most effectively, generating 3a in excellent 97% yield (Table 1).

Table 1: Optimization for synthesis of thieno[3,2-b]indole 3a

<table>
<thead>
<tr>
<th>Entry</th>
<th>Ligand [mol%]</th>
<th>Yield\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PtBu\textsubscript{3}·HBF\textsubscript{4} \textsuperscript{a} [10%]</td>
<td>86%</td>
</tr>
<tr>
<td>2</td>
<td>dppf\textsuperscript{b} [5%]</td>
<td>97%</td>
</tr>
<tr>
<td>3</td>
<td>SPhos\textsuperscript{a} [10%]</td>
<td>65%</td>
</tr>
<tr>
<td>4</td>
<td>(S)-BINAP\textsuperscript{b} [5%]</td>
<td>67%</td>
</tr>
</tbody>
</table>

\textsuperscript{a}The yields were referred to as isolated yields.

With these optimized conditions in hand, the scope for the double C-N coupling was examined. In this regard, 15 different electron-rich amines were applied, giving corresponding thienoindoles 3a-o in good to excellent yields (Table 2). For electron-poor,
benzylic and aliphatic amines, application of dppe as ligand gave low yields of desired products. Thus, (S)-BINAP was employed as ligand, affording thienoindoles 3p-t in very good yields (Table 2). Overall, the highest yield was obtained for the electron-rich system 3f (98%), while the lowest occurred with the very large π-system 3o (72%). The reaction proceeded effectively even with sterically encumbering amines, in case of 3b and 3k in 77% and 89% yield, respectively.

Table 2: Synthesis of thieno[3,2-b]indoles 3a-t

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Product Structure</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a (97%)</td>
<td><img src="image" alt="3a" /></td>
<td>97%</td>
</tr>
<tr>
<td>3b (77%)</td>
<td><img src="image" alt="3b" /></td>
<td>77%</td>
</tr>
<tr>
<td>3c (83%)</td>
<td><img src="image" alt="3c" /></td>
<td>83%</td>
</tr>
<tr>
<td>3d (90%)</td>
<td><img src="image" alt="3d" /></td>
<td>90%</td>
</tr>
<tr>
<td>3e (90%)</td>
<td><img src="image" alt="3e" /></td>
<td>90%</td>
</tr>
<tr>
<td>3f (98%)</td>
<td><img src="image" alt="3f" /></td>
<td>98%</td>
</tr>
<tr>
<td>3g (91%)</td>
<td><img src="image" alt="3g" /></td>
<td>91%</td>
</tr>
<tr>
<td>3h (92%)</td>
<td><img src="image" alt="3h" /></td>
<td>92%</td>
</tr>
<tr>
<td>3i (87%)</td>
<td><img src="image" alt="3i" /></td>
<td>87%</td>
</tr>
<tr>
<td>3j (92%)</td>
<td><img src="image" alt="3j" /></td>
<td>92%</td>
</tr>
<tr>
<td>3k (89%)</td>
<td><img src="image" alt="3k" /></td>
<td>89%</td>
</tr>
<tr>
<td>3l (92%)</td>
<td><img src="image" alt="3l" /></td>
<td>92%</td>
</tr>
</tbody>
</table>
Next, we turned our attention to the synthesis of thieno[3,4-b]indoles, which was obtained starting from 3,4-dibromothiophene (4). Using the same conditions applied for the Suzuki reaction of 2,3-dibromothiophene, 3-bromo-4-(2-bromophenyl)thiophene (5) was afforded selectively in 78% yield (Scheme 4).

Again, we tested several ligands for the double C-N coupling of 5, under otherwise identical conditions. In this case, we became aware that the monodentate ligand PdBu3·HBF4 was most suitable for the reaction, giving thieno[3,4-b]indole 6a in 95% yield (Table 3).
Table 3: Optimization for the synthesis of thieno[3,4-b]indole 6a

<table>
<thead>
<tr>
<th>Entry</th>
<th>Ligand [mol%]</th>
<th>Yielda</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\text{P}t\text{Bu}_3\cdot\text{HBF}_4$ [10%]</td>
<td>95%</td>
</tr>
<tr>
<td>2</td>
<td>dppf [5%]</td>
<td>43%</td>
</tr>
<tr>
<td>3</td>
<td>SPhos [10%]</td>
<td>65%</td>
</tr>
<tr>
<td>4</td>
<td>(S)-BINAP [5%]</td>
<td>36%</td>
</tr>
</tbody>
</table>

* The yields were referred to as isolated yields.

Using optimized conditions, we assessed the scope of the double C-N coupling. Noticeably, obtained yields for corresponding products were slightly lower than those for thieno[3,2-b]indoles 3a-t (Table 4). The reason for this might refer to the lower stability of the thieno[3,2-b]indole derivatives.

Table 4: Synthesis of thieno[3,4-b]indole 6a-f

<table>
<thead>
<tr>
<th>5</th>
<th>$\text{H}_2\text{N}^-\text{R}$ + 1.5 equiv.</th>
<th>6a - 6f</th>
</tr>
</thead>
<tbody>
<tr>
<td>6a</td>
<td>$\text{Pd}_2\text{dba}_3$ 5 mol% ligand, NaO\text{tBu}, toluene</td>
<td>100 °C, 14 h</td>
</tr>
<tr>
<td>6b</td>
<td>$\text{PfBu}_3\cdot\text{HBF}_4$ 10 mol%</td>
<td>95%</td>
</tr>
<tr>
<td>6c</td>
<td>$\text{NaO}\text{tBu},$ toluene</td>
<td>65%</td>
</tr>
</tbody>
</table>

6a (95%) 6b (65%) 6c (83%)
Finally, we probed the feasibility of the method for the preparation of more structurally complex products, namely 5-substituted thieno[3,2-b]indoles. The synthesis started with two sequential site-selective Suzuki-reaction of 2,3,5-tribromothiophene (7) using our previously reported conditions. 2,3,5-tribromothiophene (7) was first converted to 2,3-dibromo-5-arylthiophenes 8a-d and finally to the corresponding products 9a-d (Table 5). Compared to the unsubstituted dibromothiophenes (Scheme 3 and 4), the yield of products obtained by the Suzuki reactions were remarkably lower in this case. It is most probably due to the presence of an additional aryl group at position 5 which might modulate the entire electronic nature of the molecule.

Table 5: Synthesis of 5-substituted precursors 9a-d for double C-N coupling

<table>
<thead>
<tr>
<th>R</th>
<th>8 (% yield)</th>
<th>9 (% yield)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>a (60%)</td>
<td>a (43%)</td>
</tr>
<tr>
<td>Cl</td>
<td>b (37%)</td>
<td>b (30%)</td>
</tr>
<tr>
<td>F</td>
<td>c (43%)</td>
<td>c (33%)</td>
</tr>
<tr>
<td>tBu</td>
<td>d (43%)</td>
<td>d (26%)</td>
</tr>
</tbody>
</table>

*The yields were referred to as isolated yields.*
With starting materials 9a-d in hand, we tested different ligands for the double C-N coupling. In this case, Buchwald’s biaryl ligand SPhos was most appropriate, furnishing corresponding thienoindole 10a in 96% yield (Table 6).

**Table 6: Optimization for the synthesis of 5-substituted thieno[3,2-b]indole 10a**

<table>
<thead>
<tr>
<th>Entry</th>
<th>Ligand [mol%]</th>
<th>Yield&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PtBu₃HBF₄ [10%]</td>
<td>84%</td>
</tr>
<tr>
<td>2</td>
<td>SPhos [10%]</td>
<td>96%</td>
</tr>
<tr>
<td>3</td>
<td>dppe [5%]</td>
<td>36%</td>
</tr>
<tr>
<td>4</td>
<td>Xantphos [5%]</td>
<td>43%</td>
</tr>
</tbody>
</table>

<sup>a</sup>The yields were referred to as isolated yields.

Applying optimized conditions, thienoindoles 10a-j were prepared with moderate to excellent yield (Table 7). Evidently, the conditions can be applied for both electron-rich and electron-poor aryl amines, generating corresponding thienoindoles 10a-j in the range of 45% to 95% yield. The highest yield was obtained for thienoindole 10a (95%), while the lowest were obtained from thienoindoles 10i and 10j (both 45%). No clear correlation between the yields and chemical structures of 5-substituted thieno[3,2-b]indoles was observed.

**Table 7: Synthesis of 5-substituted thieno[3,2-b]indoles 10a-j**
Conclusion

In conclusion, we developed a new synthetic pathway to thieno[3,2-b]indoles and thieno[3,4-b]indoles by site-selective Suzuki-reaction followed by double C-N coupling. In this protocol, electron-rich and electron-poor as well as aliphatic amines are compatible.
nucleophiles. Despite the similarity of the starting materials, it became apparent that the choice of ligand is crucial for the final ring-closing double C-N coupling.

Experimental section

General information

If not otherwise stated, employed chemicals were obtained from commercial sources without further purifications. Chemicals used for work-up and purification were distilled prior usage. Column chromatography was carried out with silica gel with particle size between 0.006 and 0.043 mm. Product characterization was carried out using following devices. Melting point: Micro-Hot-Stage GalenTM III Cambridge Instrument. NMR: Bruker AVANCE 250 II, Bruker AVANCE 300 III and Bruker AVANCE 500 built 2006, 2007 and 2001, respectively. IR: Nicolet 380 FT-IR spectrometer using ATR sampling technique. GC/MS (EI, 70 eV): Finnigan MAT 95-XP device using HP-5 capillary column with helium carrier gas and electron ionization (EI) scan technique at 90 eV. HRMS: Finnigan MAT 95 XP device.

Melting point was carried out without further correction. For HRMS measurement, only signals with deviations of less than ±2 mDa were accounted as correct. NMR-peaks were calibrated using standard peaks of chloroform (7.260 ppm for $^1$H, 72.160 ppm for $^{13}$C) and acetone (2.050 ppm for $^1$H, 29.840 ppm for $^{13}$C). For peak descriptions, following abbreviations were used. NMR spectroscopy: s (singlet), d (doublet), t (triplet), dd (doublet doublet), dt (doublet triplet), td (triplet doublet), ddd (doublet doublet doublet). IR spectroscopy: w (weak), m (medium), s (strong).

General procedure for the site-selective Suzuki reaction of 2,3-dibromothiophene and 3,4-dibromothiophene

2,3- or 3,4-Dibromothiophene (3 mmol), (2-bromophenyl)boronic acid (3.3 mmol), Pd(PPh$_3$)$_4$ (0.15 mmol), Na$_2$CO$_3$ (6 mmol) were added to a dried glass pressure tube. Next, the tube was evacuated and backfilled three times with argon. Afterwards, the solids were solved in 8 ml of 1,4-dioxane and 2 ml of distilled water. The tube was sealed by a Teflon cap and heated to 100 °C for 14 hours. After the reaction was finished (monitored by TLC), it was
allowed to cool to room temperature and Na₂SO₄ was added to the mixture, diluted with ethyl acetate and filtered. The solvent was removed under reduced pressure. The crude oil was purified by column chromatography using heptane.

3-Bromo-2-(2-bromophenyl)thiophene (2): White solid, mp. 63 – 64 °C, 82% yield. 

\[ \text{H NMR (500 MHz, Chloroform-}d_2) \delta = 7.69 (d, J = 8.0 \text{ Hz, 1H, CH}\text{ar}), 7.42 – 7.34 (m, 3H, CH\text{ar}), 7.28 (ddd, J = 8.0 \text{ Hz, J = 6.7 Hz, J = 2.5 Hz, 1H, CH}\text{ar}), 7.07 (d, J = 5.3 Hz, 1H, CH\text{thiophene}). \] 

\[ \text{C NMR (126 MHz, CDCl}_3) \delta = 137.3 (\text{C}\text{ar}, 134.0 (\text{C}\text{ar}, 133.1 (\text{C}\text{ar}, 132.9 (\text{C}\text{ar}, 130.6 (\text{C}\text{ar}, 127.3 (\text{C}\text{ar}, 126.2 (\text{C}\text{ar}, 125.2 (\text{C}\text{ar}, 111.2 (\text{C}\text{ar}). IR (ATR, cm\(^{-1}\)): } \tilde{\nu} = 3110 (w), 3085 (w), 3059 (w), 1528 (w), 1463 (m), 1419 (m), 1340 (m), 1148 (w), 1024 (m), 857 (m), 756 (s), 712 (s), 654 (m), 620 (m), 522 (m), 446 (m). MS (EI, 70 eV): m/z (\%) = 318 [M]\(^+\) (45), 239 (22), 158 (100), 114 (30), 79 (21). \] 

HRMS (EI): Calculated for C\(_{10}\)H\(_6\)Br\(_2\)S [M]\(^+\) 315.85515 found 315.85464, calculated for C\(_{10}\)H\(_6\)Br\(_8\)S [M]\(^+\) 317.85310 found 317.85281, calculated for C\(_{10}\)H\(_6\)Br\(_8\)S [M]\(^+\) 319.85105 found 319.85069.

3-Bromo-4-(2-bromophenyl)thiophene (5): Colorless oil, 78% yield. 

\[ \text{H NMR (500 MHz, Chloroform-}d_2) \delta = 7.67 (d, J = 8.1 \text{ Hz, 1H, CH}\text{ar}), 7.39 – 7.34 (m, 2H, CH\text{ar}), 7.31 – 7.24 (m, 3H, CH\text{ar}). \] 

\[ \text{C NMR (126 MHz, CDCl}_3) \delta = 141.5 (\text{C}\text{ar}, 136.6 (\text{C}\text{ar}, 132.9 (\text{C}\text{ar}, 132.0 (\text{C}\text{ar}, 129.8 (\text{C}\text{ar}, 127.2 (\text{C}\text{ar}, 124.9 (\text{C}\text{ar}, 124.5 (\text{C}\text{ar}, 123.3 (\text{C}\text{ar}, 112.4 (\text{C}\text{ar}). IR (ATR, cm\(^{-1}\)): } \tilde{\nu} = 3107 (w), 3057 (w), 1560 (w), 1525 (w), 1464 (m), 1425 (m), 1339 (m), 1257 (w), 1081 (w), 1026 (m), 921 (m), 852 (m), 792 (m), 751 (s), 710 (m), 653 (m), 451 (m). MS (EI, 70 eV): m/z (\%) = 320 (23), 318 [M]\(^+\) (43), 239 (31), 158 (100), 114 (26), 113 (20), 79 (24). \] 

HRMS (EI): Calculated for C\(_{10}\)H\(_6\)Br\(_2\)S [M]\(^+\) 315.85515 found 315.85490, calculated for C\(_{10}\)H\(_6\)Br\(_8\)S [M]\(^+\) 317.85310 found 317.85301, calculated for C\(_{10}\)H\(_6\)Br\(_8\)S [M]\(^+\) 319.85105 found 319.85073.

General procedure for the one-fold selective Suzuki reaction of 2,3,5-tribromothiophene

2,3,5-Tribromothiophene (10 mmol), arylboronic acid (11 mmol) and Pd(PPh\(_3\))\(_4\) (0.5 mmol) were dissolved in a mixture of 100 ml 1,4-dioxane/toluene (1:1) under argon atmosphere. To the reaction was added 40 ml aqueous 2M K\(_2\)CO\(_3\). The reaction was heated to 80 °C for 8 hours. After the reaction was finished (monitored by TLC), it was allowed to cool to room temperature. The mixture was extracted with dichloromethane three times. The combined organic phases were collected and dried with Na\(_2\)SO\(_4\), filtered and concentrated under vacuum. The residue was purified by column chromatography using heptane to obtain the pure product.
2,3-Dibromo-5-phenylthiophene (8a): White solid, mp. 68 – 69 °C, 60 % yield. \(^1\)H NMR (250 MHz, Chloroform-\(d\)) \(\delta = 7.53 – 7.45\) (m, 2H, \(\text{CH}_2\)), 7.44 – 7.32 (m, 3H, \(\text{CH}_3\)), 7.10 (s, 1H, \(\text{CH}_3\text{thiophene}\)). \(^{13}\)C NMR (63 MHz, CDCl\(_3\)) \(\delta = 145.6\) (\(\text{C}^\text{Ar}\)), 132.9 (\(\text{C}^\text{Ar}\)), 129.4 (2\(\text{CH}_2\)), 128.8 (\(\text{CH}_3\)), 125.8 (\(\text{CH}_3\)), 125.7 (2\(\text{CH}_2\)), 114.8 (\(\text{C}^\text{Ar}\)), 110.3 (\(\text{C}^\text{Ar}\)). IR (ATR, cm\(^{-1}\)): \(\nu = 3056\) (w), 1579 (w), 1486 (m), 1446 (m), 1320 (w), 1292 (w), 1069 (w), 997 (m), 948 (w), 815 (s), 747 (s), 682 (s), 625 (w), 549 (w). MS (EI, 70 eV): \(m/z\) (%) = 320 [M\(^+\), \(^{81}\)Br (43), 318 [M\(^+\)] (88), 316 (41), 158 (58), 114 (12), 91 (14), 82 (18), 79 (26), 77 (5), 69 (10), 44 (15), 43 (9), 32 (100). HRMS (EI): Calculated for \(\text{C}_{10}\text{H}_5\text{Br}_2\text{S}\) [M\(^+\)] 315.85526 found 315.85515, calculated for \(\text{C}_{10}\text{H}_5\text{Br}^{81}\text{BrS}\) [M\(^+\)] 317.85310 found 317.85326, calculated for \(\text{C}_{10}\text{H}_6^{81}\text{Br}_2\text{S}\) [M\(^+\)] 319.85105 found 319.85119.

2,3-Dibromo-5-(4-chlorophenyl)thiophene (8b): White solid, mp. 104 – 105 °C, 37% yield. \(^1\)H NMR (250 MHz, Chloroform-\(d\)) \(\delta = 7.45 – 7.32\) (m, 4H, \(\text{CH}_2\)), 7.08 (s, 1H, \(\text{CH}_3\text{thiophene}\)). \(^{13}\)C NMR (63 MHz, CDCl\(_3\)) \(\delta = 144.2\) (\(\text{C}^\text{Ar}\)), 134.7 (\(\text{C}^\text{Ar}\)), 131.4 (\(\text{C}^\text{Ar}\)), 129.6 (2\(\text{CH}_2\)), 126.9 (2\(\text{CH}_2\)), 126.2 (\(\text{CH}_3\text{thiophene}\)), 115.0 (\(\text{C}^\text{Ar}\)), 110.7 (\(\text{C}^\text{Ar}\)). IR (ATR, cm\(^{-1}\)): \(\nu = 3088\) (w), 3033 (w), 1484 (m), 1429 (w), 1402 (w), 1318 (w), 1091 (m), 997 (w), 801 (s), 733 (w), 674 (m), 575 (w), 546 (w). MS (EI, 70 eV): \(m/z\) (%) = 356 (16), 355 (8), 354 [M\(^+\), \(^{81}\)Br] (72), 353 (12), 352 [M\(^+\)] (100), 350 (43), 194 (17), 192 (46), 157 (11), 113 (15), 96 (8). HRMS (EI): Calculated for \(\text{C}_{10}\text{H}_5\text{Br}_2\text{ClS}\) [M\(^+\)] 349.81618 found 349.81584, calculated for \(\text{C}_{10}\text{H}_5\text{Br}^{81}\text{BrClS}\) 351.81413 found 351.81374, calculated for \(\text{C}_{10}\text{H}_5\text{Br}^{81}\text{Br}^{27}\text{ClS}\) [M\(^+\)] 351.81323 found 351.81323, calculated for \(\text{C}_{10}\text{H}_5\text{Br}^{81}\text{Br}^{27}\text{ClS}\) [M\(^+\)] 353.81118 found 353.81139, calculated for \(\text{C}_{10}\text{H}_6^{81}\text{Br}_2\text{ClS}\) [M\(^+\)] 353.81208 found 353.81139, calculated for \(\text{C}_{10}\text{H}_6^{81}\text{Br}_2^{27}\text{ClS}\) [M\(^+\)] 355.80913 found 355.80899.

2,3-Dibromo-5-(4-fluorophenyl)thiophene (8c): White solid, mp. 95 – 96 °C, 43% yield. \(^1\)H NMR (300 MHz, Chloroform-\(d\)) \(\delta = 7.44\) (dd, \(J = 8.8\) Hz, \(J = 6.1\) Hz, 2H, \(\text{CH}_2\)), 7.02 (s, 1H, \(\text{CH}_3\text{thiophene}\)). \(^{19}\)F NMR (282.4 MHz, CDCl\(_3\)) \(\delta = -112.5\) (\(\text{FC}^\text{Ar}\)). \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta = 163.1\) (d, \(J_{\text{C-F}} = 249.2\) Hz, \(\text{C}^\text{Ar}\)), 144.4 (\(\text{C}^\text{Ar}\)), 129.2 (d, \(J_{\text{C-F}} = 3.4\) Hz, \(\text{FC}^\text{Ar}\)), 127.5 (d, \(J_{\text{C-F}} = 8.2\) Hz, 2\(\text{CH}_2\)), 125.8 (\(\text{CH}_3\text{thiophene}\)), 116.4 (d, \(J_{\text{C-F}} = 22.0\) Hz, 2\(\text{CH}_2\)), 114.8 (\(\text{C}^\text{Ar}\)), 110.2 (\(\text{C}^\text{Ar}\)). IR (ATR, cm\(^{-1}\)): \(\nu = 3089\) (w), 1595 (w), 1494 (s), 1299 (m), 1232 (s), 1157 (m), 993 (m), 829 (s), 807 (s), 691 (m), 585 (m), 547 (m). MS (EI, 70 eV): \(m/z\) (%) = 336 [M\(^+\)] (100), 334 (48), 213 (6), 211 (6), 177 (8), 177 (76), 139 (6), 132 (20), 131 (13), 88 (11), 81 (7), 75 (6), 74 (4), 69 (6). HRMS (EI): Calculated for \(\text{C}_{10}\text{H}_5\text{Br}_2\text{FS}\) [M\(^+\)] 333.84573 found 333.84563, calculated for \(\text{C}_{10}\text{H}_5\text{Br}^{81}\text{BrFS}\) [M\(^+\)] 335.84368 found 335.84353, calculated for \(\text{C}_{10}\text{H}_5^{81}\text{Br}_2\text{FS}\) [M\(^+\)] 337.84163 found 337.84146.

2,3-Dibromo-5-(4-(tert-butyl)phenyl)thiophene (8d): White solid, mp. 59 – 60 °C, 43% yield. \(^1\)H NMR (300 MHz, Chloroform-\(d\)) \(\delta = 7.42\) (m, 4H, \(\text{CH}_4\)), 7.07 (s, 1H, \(\text{CH}_3\text{thiophene}\)), 1.34 (s, 9H, \(\text{tBu}\)). \(^{13}\)C NMR (75 MHz, CDCl\(_3\)) \(\delta = 152.0\) (\(\text{C}^\text{Ar}\)), 145.6 (\(\text{C}^\text{Ar}\)), 130.1 (\(\text{C}^\text{Ar}\)), 126.4
General procedure for the site-selective Suzuki reaction of 5-substituted 2,3-dibromothiophene

5-Substituted 2,3-dibromothiophene (3 mmol), (2-bromophenyl)boronic acid (3.3 mmol) and Pd(PPh₃)₄ (0.15 mmol) were dissolved in 30 ml of mixture 1,4-dioxane/toluene (1:1) under argon atmosphere. To the reaction was added 12 ml aqueous 2M K₂CO₃. The reaction was heated to 80 °C for 12 hours (monitored by TLC). After cooling to room temperature, it was extracted with dichloromethane three times. The organic phases were collected and dried with Na₂SO₄, filtered and concentrated under reduced pressure. The crude oil was subjected to column chromatography using heptane to obtain the pure product.

3-Bromo-2-(2-bromophenyl)-5-phenylthiophene (9a): White solid, mp. 83 – 84 °C, 43% yield. ¹H NMR (250 MHz, Chloroform-d) δ = 7.70 (dd, 3J = 8.0 Hz, 4J = 1.3 Hz, 1H, CH₆), 7.62 – 7.53 (m, 2H, CH₆), 7.47 – 7.27 (m, 6H, CH₆), 7.25 (s, 1H, CH₆thiophene). ¹³C NMR (63 MHz, CDCl₃) δ = 144.7 (C₈), 136.4 (C₉), 134.0 (CH₆), 133.3 (CH₆), 133.0 (C₈), 130.7 (CH₆), 129.3 (2CH₆), 128.5 (CH₆), 127.4 (CH₆), 126.0 (CH₆), 125.8 (2CH₆), 125.2 (C₈), 111.6 (C₈). IR (ATR, cm⁻¹): ν = 3094 (w), 1538 (w), 1473 (m), 1309 (w), 1239 (14), 232 (10), 129 (16), 113 (16), 77 (17), 51 (12), 112 (12). HRMS (EI): Calculated for C₁₆H₁₀Br₂S [M⁺] 391.88645 found 391.88593, calculated for C₁₆H₁₀Br²BrS [M⁺] 393.88440, calculated for C₁₆H₁₀Br²BrS₁ [M⁺] 395.88209 found 395.88209.

3-Bromo-2-(2-bromophenyl)-5-(4-chlorophenyl)thiophene (9b): Yellow oil, 37% yield. ¹H NMR (300 MHz, Chloroform-d) δ = 7.73 – 7.68 (m, 1H, CH₆), 7.52 (m, 2H, CH₆), 7.46 – 7.34 (m, 4H, CH₆), 7.31 (m, 1H, CH₆), 7.25 (s, 1H, CH₆thiophene). ¹³C NMR (75 MHz, CDCl₃) δ = 143.3 (C₈), 136.7 (C₉), 134.3 (C₉), 133.7 (C₈), 133.2 (CH₆), 132.9 (CH₆), 131.7 (C₈), 130.7 (CH₆), 129.4 (2CH₆), 127.4 (CH₆), 127.0 (2CH₆), 126.3 (CH₆), 125.1 (C₈), 111.8 (C₈). IR (ATR, cm⁻¹): ν = 3053 (w), 1502 (s), 1472 (s), 1446 (m), 1402 (w), 1324 (w), 1091
3-Bromo-2-(2-bromophenyl)-5-(4-fluorophenyl)thiophene (9c): White solid, mp. 66 – 67 °C, 33% yield. \(^1\)H NMR (250 MHz, Chloroform-\(d\)) \(\delta = 7.82 - 7.76\) (m, 1H, \(\text{CH}_2\)), 7.68 – 7.58 (m, 2H, \(\text{CH}_2\)), 7.55 – 7.43 (m, 2H, \(\text{CH}_2\)), 7.43 – 7.33 (m, 1H, \(\text{CH}_2\)), 7.28 (s, 1H, \(\text{CH}_\text{thiophene}\)), 7.24 – 7.13 (m, 2H, \(\text{CH}_2\)). \(^{19}\)F NMR (235 MHz, CDCl\(d\)) \(\delta = -113.03\) (CF\(3\)). \(^{13}\)C NMR (63 MHz, CDCl\(d\)) \(\delta = 162.9\) (d, \(^3\)J\(_{CF} = 248.5\) Hz, \(\text{FC}_2\)), 143.6 (C\(\alpha\)), 133.8 (C\(\alpha\)), 133.3 (C\(\alpha\)), 133.0 (C\(\alpha\)), 130.7 (CH\(\alpha\)), 129.6 (C\(\alpha\)), 129.5 (C\(\alpha\)), 127.6 (d, \(^3\)J\(_{CF} = 8.2\) Hz, 2CH\(\alpha\)), 127.4 (CH\(\alpha\)), 126.0 (d, \(^4\)J\(_{CF} = 1.3\) Hz, CH\(\alpha\)), 125.1 (C\(\alpha\)), 116.3 (d, \(^2\)J\(_{CF} = 21.9\) Hz, 2CH\(\alpha\)), 111.7 (C\(\alpha\)). IR (ATR, cm\(^{-1}\)): \(\tilde{\nu} = 3040\) (w), 1539 (w), 1508 (m), 1480 (s), 1423 (m), 1330 (m), 1300 (s), 1162 (s), 1097 (m), 1053 (m), 972 (m), 944 (m), 828 (s), 809 (s), 765 (s), 728 (s), 702 (m), 686 (s), 644 (s), 579 (s). MS (EI, 70 eV): m/z (%) = 414 (52), 413 (18), 412 [M\(^+\)] (100), 410 (49), 253 (10), 252 (61), 220 (12), 207 (21), 139 (10). HRMS (EI): Calculated for C\(_{18}\)H\(_9\)Br\(_2\)F\(_3\)S [M\(^+\)] 409.87730 found 409.87680, calculated for C\(_{18}\)H\(_9\)Br\(_2\)F\(_3\)S [M\(^+\)] 411.87498 found 411.87474, calculated for C\(_{20}\)H\(_{18}\)Br\(_2\)F\(_3\)S [M\(^+\)] 413.87293 found 413.87281.

3-Bromo-2-(2-bromophenyl)-5-(4-(tert-butyl)phenyl)thiophene (9d): White solid, mp. 96 – 97 °C, 26% yield. \(^1\)H NMR (300 MHz, Chloroform-\(d\)) \(\delta = 7.70\) (dd, \(^3\)J = 7.9 Hz, \(^4\)J = 0.9 Hz, 1H, \(\text{CH}_2\)), 7.55 – 7.50 (m, 2H, \(\text{CH}_2\)), 7.45 – 7.42 (m, 2H, \(\text{CH}_2\)), 7.42 – 7.40 (m, 1H, \(\text{CH}_2\)), 7.37 (dd, \(^3\)J = 7.6, \(^4\)J = 1.3 Hz, 1H, \(\text{CH}_2\)), 7.33 – 7.27 (m, 1H, \(\text{CH}_2\)), 7.22 (s, 1H, \(\text{CH}_\text{thiophene}\)), 1.35 (s, \(\text{CH}_3\)), 1.33 (C\(\alpha\)), 1.33 (CH\(\alpha\)), 1.30 (C\(\alpha\)), 1.30 (CH\(\alpha\)), 1.27 (C\(\alpha\)), 1.26 (2CH\(\alpha\)), 1.25 (2CH\(\alpha\)), 1.25 (C\(\alpha\)), 1.11 (C\(\alpha\)), 34.9 (C\(\text{Bu}\)), 31.5 (3CH\(\alpha\)). IR (ATR, cm\(^{-1}\)): \(\tilde{\nu} = 2959\) (m), 2864 (w), 1480 (m), 1458 (m), 1362 (w), 1268 (w), 1109 (w), 974 (w), 817 (s), 752 (s), 726(m), 671(m), 578 (w), 545(s). MS (EI, 70 eV): m/z (%) = 453 (11), 452 (37), 451 (16), 450 [M\(^+\)] (75), 448 (35), 438 (12), 437 (55), 436 (24), 435 (100), 433 (52), 407 (11), 260 (11), 258 (11), 234 (14), 202 (11), 189 (9), 124 (15), 115 (10), 113 (12), 41 (19). HRMS (EI): Calculated for C\(_{20}\)H\(_{18}\)Br\(_2\)S [M\(^+\)] 447.94905 found 447.94886, calculated for C\(_{20}\)H\(_{18}\)Br\(_2\)S [M\(^+\)] 449.94700 found 449.94680, calculated for C\(_{20}\)H\(_{18}\)Br\(_2\)S [M\(^+\)] 451.94495 found 451.94491.

General procedure for the synthesis of thieno[3,2-b]indoles

3-Bromo-2-(2-bromophenyl)thiophene (0.15 mmol), amine (0.225 mmol), Pd\(_2\text{dba}_3\) (0.0075 mmol), dpf or (S)-BINAP (0.0075 mmol) and NaO\(_2\text{Bu}\) (0.36 mmol) were added to a dried glass pressure tube. The tube was evacuated and backfilled three times with argon. 2 ml of...
dried toluene was added. The mixture was heated to 100 °C for 14 hours until completion
(monitored by TLC). After cooling to room temperature, the solvent was removed under
reduced pressure. The crude oil was subjected to column chromatography (heptane/ethyl
acetate) to obtain the pure product.

4-(p-Tolyl)-4H-thieno[3,2-b]indole (3a): Yellow solid, mp. 92 – 93 °C, 97% yield. 1H NMR
(300 MHz, Chloroform-d) δ = 7.82 – 7.77 (m, 1H, CHAr), 7.55 – 7.50 (m, 1H, CHAr), 7.47 (d,
J = 8.3 Hz, 2H, CHAr), 7.40 – 7.33 (m, 3H, CHAr), 7.30 – 7.19 (m, 2H, CHAr), 7.08 (d, J = 5.2
Hz, 1H, CHthiophene), 2.47 (s, 3H, Ar). 13C NMR (75 MHz, CDCl3) δ = 145.3 (CAr), 141.6 (CAr),
136.8 (CAr), 136.4 (CAr), 130.5 (2CHAr), 126.9 (CHAr), 125.2 (2CHAr), 123.0 (CHAr), 122.4
(CAr), 120.2 (CHAr), 119.1 (CHAr), 117.8 (CAr), 111.6 (CHAr), 111.2 (CHAr), 21.3 (CH3). IR
(ATR, cm⁻¹): ν = 3393 (w), 3109 (w), 3080 (w), 3056 (w), 3030 (w), 2917 (w), 2857 (w), 1600
(m), 1510 (s), 1450 (s), 1392 (m), 1337 (m), 1200 (m), 1085 (m), 1044 (m), 847 (m), 812 (m),
709 (s), 663 (m), 650 (m), 568 (m), 506 (m), 433 (m). MS (EI, 70 eV): m/z (%) = 264 (20),
263 [M⁺] (100), 262 (15), 248 (7), 247 (6), 128 (5). HRMS (EI): Calculated for C17H13NS [M⁺]
263.07632 found 263.07598.

4-(o-Tolyl)-4H-thieno[3,2-b]indole (3b): Yellow oil, 77% yield. 1H NMR (250 MHz, 
Chloroform-d) δ = 7.74 – 7.68 (m, 1H, CHAr), 7.34 – 7.29 (m, 2H, CHAr), 7.28 – 7.24 (m, 2H,
CHAr), 7.23 (d, J = 5.2 Hz, 1H, CHthiophene), 7.15 – 7.10 (m, 2H, CHAr), 7.01 – 6.95 (m, 1H,
CHAr), 6.70 (d, J = 5.2 Hz, 1H, CHthiophene), 1.94 (s, 3H, CH3). 13C NMR (63 MHz, CDCl3)
δ = 145.8 (CAr), 142.3 (CAr), 137.2 (CAr), 136.5 (CAr), 131.6 (CHAr), 128.6 (CHAr), 128.6 (CHAr),
127.2 (CHAr), 127.0 (CHAr), 122.9 (CHAr), 122.0 (CAr), 119.9 (CAr), 119.0 (CHAr), 117.1 (CAr),
111.3 (CHAr), 111.2 (CHAr), 17.9 (CH3). IR (ATR, cm⁻¹): ν = 3048 (w), 2917 (w), 1601 (w),
1505 (m), 1486 (m), 1451 (m), 1486 (m), 1450 (s), 1332 (m), 1082 (m), 820 (m), 734 (s), 649
(s), 431 (m). MS (EI, 70 eV): m/z (%) = 264 (21), 263 [M⁺] (100), 262 (47), 230 (16), 218 (11),
217 (13), HRMS (EI): Calculated for C17H13NS [M⁺] 263.07632 found 263.07591.

4-Phenyl-4H-thieno[3,2-b]indole (3c): Yellow oil, 83% yield. 1H NMR (300 MHz, 
Chloroform-d) δ = 7.86 – 7.79 (m, 1H, CHAr), 7.66 – 7.54 (m, 5H, CHAr), 7.45 – 7.39 (m, 1H,
CHAr), 7.38 (d, J = 5.2 Hz, 1H, CHthiophene). 13C NMR (75 MHz, CDCl3) δ = 145.1 (CAr), 141.4 (CAr), 139.0 (CAr), 129.9 (2CHPh), 127.0 (CHAr), 126.9 (CHAr), 125.2 (2CHPh), 123.2 (CHAr), 122.5 (CAr), 120.4 (CHAr),
119.1 (CHAr), 118.1 (CAr), 111.6 (CHAr), 111.2 (CHAr). IR (ATR, cm⁻¹): ν = 3083 (w), 3050 (w),
1594 (m), 1505 (s), 1449 (s), 1392 (m), 1337 (m), 1201 (m), 1086 (m), 839 (m), 779 (m), 737
(s), 696 (s), 653 (s), 430 (m). MS (EI, 70 eV): m/z (%) = 249 [M⁺] (100), 217 (6), 204 (9), 172
(5), 128 (8), 77 (9), 51 (13). HRMS (EI): Calculated for C16H11NS [M⁺] 249.06067 found
249.06073.
4-(3,5-Dimethylphenyl)-4H-thieno[3,2-b]indole (3d): Yellow solid, mp. 112 – 113 °C, 90% yield. $^1$H NMR (250 MHz, Chloroform-d) $\delta$ = 7.73 – 7.67 (m, 1H, CH$_\text{Ar}$), 7.51 – 7.44 (m, 1H, CH$_\text{Ar}$), 7.27 (d, $^3$J = 5.2 Hz, 1H, CH$_\text{thiophene}$), 7.22 – 7.09 (m, 4H, CH$_\text{Ar}$), 7.01 (d, $^3$J = 5.2 Hz, 1H, CH$_\text{thiophene}$), 6.95 (s, 1H, CH$_\text{Ar}$), 2.33 (s, 6H, CH$_\text{3}$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta$ = 145.2 (C$_\text{Ar}$), 141.4 (C$_\text{Ar}$), 139.7 (2C$_\text{Ar}$), 138.8 (C$_\text{Ar}$), 128.6 (C$_\text{Ar}$), 126.8 (C$_\text{Ar}$), 123.0 (CH$_\text{Ar}$), 122.9 (2CH$_\text{Ar}$), 122.4 (C$_\text{Ar}$), 120.2 (CH$_\text{Ar}$), 119.1 (CH$_\text{Ar}$), 117.8 (C$_\text{Ar}$), 111.8 (CH$_\text{Ar}$), 111.3 (CH$_\text{Ar}$), 21.5 (2CH$_\text{3}$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 3051 (w), 3006 (w), 2956 (m), 2915 (m), 2851 (w), 1731 (m), 1594 (m), 1504 (m), 1449 (m), 1343 (m), 1173 (m), 1090 (m), 839 (m), 815 (m), 738 (s), 701 (m), 568 (s). MS (EI, 70 eV): m/z (%) = 278 (21), 277 (100), 276 (7), 262 (8), 260 (7), 228 (5), 77 (5). HRMS (EI): Calculated for C$_{18}$H$_{16}$NS [M$^+$] 277.09197 found 277.09166.

4-(2,3-Dihydro-1H-inden-5-yl)-4H-thieno[3,2-b]indole (3e): Yellow solid, mp. 81 – 82 °C, 90% yield. $^1$H NMR (250 MHz, Chloroform-d) $\delta$ = 7.74 – 7.68 (m, 1H, CH$_\text{Ar}$), 7.49 – 7.42 (m, 1H, CH$_\text{Ar}$), 7.37 – 7.20 (m, 4H, CH$_\text{Ar}$), 7.15 (m, 2H, CH$_\text{Ar}$), 7.00 (d, $^3$J = 5.2 Hz, 1H, CH$_\text{thiophene}$), 2.92 (t, $^3$J = 7.4 Hz, 4H, CH$_2$), 2.10 (p, $^3$J = 7.5 Hz, 2H, CH$_2$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta$ = 146.2 (C$_\text{Ar}$), 145.4 (C$_\text{Ar}$), 143.1 (C$_\text{Ar}$), 141.7 (C$_\text{Ar}$), 137.1 (C$_\text{Ar}$), 126.8 (CH$_\text{Ar}$), 125.4 (CH$_\text{Ar}$), 123.3 (CH$_\text{Ar}$), 123.0 (CH$_\text{Ar}$), 122.3 (C$_\text{Ar}$), 121.4 (CH$_\text{Ar}$), 120.1 (CH$_\text{Ar}$), 119.0 (CH$_\text{Ar}$), 117.6 (C$_\text{Ar}$), 111.7 (CH$_\text{Ar}$), 111.3 (CH$_\text{Ar}$), 33.2 (CH$_2$), 32.7 (CH$_2$), 25.8 (CH$_2$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 2933 (w), 2837 (w), 1606 (w), 1505 (m), 1486 (m), 1451 (m), 1344 (m), 1099 (m), 820 (m), 736 (s), 648 (s), 426 (m). MS (EI, 70 eV): m/z (%) = 289 [M$^+$] (100), 255 (5), 172 (12), 115 (10). HRMS (EI): Calculated for C$_{19}$H$_{15}$NS [M$^+$] 289.09197 found 289.09201.

4-(4-(Methylthio)phenyl)-4H-thieno[3,2-b]indole (3f): White solid, mp. 91 – 92 °C, $^1$H NMR (250 MHz, Chloroform-d) $\delta$ = 7.69 – 7.63 (m, 1H, CH$_\text{Ar}$), 7.41 – 7.27 (m, 5H, CH$_\text{Ar}$), 7.21 (d, $^3$J = 5.2 Hz, 1H, CH$_\text{thiophene}$), 7.15 – 7.08 (m, 2H, CH$_\text{Ar}$), 6.92 (d, $^3$J = 5.2 Hz, 1H, CH$_\text{thiophene}$), 2.41 (s, 3H, SCH$_3$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta$ = 145.0 (C$_\text{Ar}$), 141.3 (C$_\text{Ar}$), 137.1 (C$_\text{Ar}$), 136.1 (C$_\text{Ar}$), 127.9 (2CH$_\text{Ar}$), 127.1 (C$_\text{Ar}$), 126.5 (2CH$_\text{Ar}$), 123.1 (CH$_\text{Ar}$), 122.5 (C$_\text{Ar}$), 120.4 (CH$_\text{Ar}$), 119.1 (CH$_\text{Ar}$), 118.0 (C$_\text{Ar}$), 111.4 (CH$_\text{Ar}$), 111.0 (CH$_\text{Ar}$), 16.2 (SCH$_3$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 3381 (w), 3095 (w), 3082 (w), 3046 (w), 2917 (w), 1591 (w), 1505 (s), 1491 (s), 1450 (s), 1393 (m), 1339 (m), 1294 (m), 1094 (m), 1044 (m), 1012 (m), 814 (s), 750 (s), 709 (m), 662 (s), 506 (m). MS (EI, 70 eV): m/z (%) = 295 [M$^+$] (100), 280 (68), 247 (22), 148 (10). HRMS (EI): Calculated for C$_{17}$H$_{15}$NS$_2$ 295.04839 found 295.04844.

4-(4-Methoxyphenyl)-4H-thieno[3,2-b]indole (3g): White solid, mp. 124 – 125 °C, 91% yield. $^1$H NMR (250 MHz, Chloroform-d) $\delta$ = 7.77 – 7.65 (m, 1H, CH$_\text{Ar}$), 7.46 – 7.34 (m, 3H, CH$_\text{Ar}$), 7.27 (d, $^3$J = 5.2 Hz, 1H, CH$_\text{thiophene}$), 7.22 – 7.08 (m, 2H, CH$_\text{Ar}$), 6.99 (m, 2H, CH$_\text{Ar}$), 6.95 (d, $^3$J = 5.2 Hz, 1H, CH$_\text{thiophene}$), 3.82 (s, 3H, CH$_3$O). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta$ = 158.5 (C$_\text{Ar}$), 145.6 (C$_\text{Ar}$), 141.9 (C$_\text{Ar}$), 131.8 (C$_\text{Ar}$), 126.9 (CH$_\text{Ar}$), 126.8 (2CH$_\text{Ar}$), 123.0 (CH$_\text{Ar}$), 122.2
(C₆H₅), 120.1 (CH₃), 119.1 (CH₃), 117.5 (C₆H₅), 115.1 (2CH₃), 111.4 (CH₃), 111.0 (CH₃), 55.7 (OCH₃). IR (ATR, cm⁻¹): ν = 3140 (w), 3097 (w), 3082 (w), 2838 (w), 1510 (m), 1243 (m), 1024 (m), 824 (m), 754 (s), 713 (m). MS (EI, 70 eV): m/z (%) = 279 [M⁺] (100), 264 (45), 236 (15), 191 (9), 140 (8). HRMS (EI): Calculated for C₁₇H₁₃ONS [M⁺] 279.07124 found 279.07129.

**4-(3-Methoxyphenyl)-4H-thieno[3,2-b]indole (3h):** Yellow oil, 92% yield. ¹H NMR (300 MHz, Chloroform-d) δ = 7.73 – 7.67 (m, 1H, CH₃), 7.54 – 7.48 (m, 1H, CH₃), 7.36 (t, ³J = 8.1 Hz, 1H, CH₃), 7.26 (d, ³J = 5.2 Hz, 1H, CH₃), 7.22 – 7.12 (m, 2H, CH₃), 7.12 – 7.06 (m, 1H, CH₃), 7.06 – 7.00 (m, 2H, CH₃), 6.84 (ddd, ³J = 8.4 Hz, ⁴J = 2.5 Hz, ⁵J = 0.9 Hz, 1H, CH₃), 3.76 (s, 3H, OCH₃). HRMS (EI): Calculated for C₁₇H₁₃ONS [M⁺] 279.07124 found 279.07129.

**4-(2-Methoxyphenyl)-4H-thieno[3,2-b]indole (3i):** Yellow oil, 87% yield. ¹H NMR (300 MHz, Chloroform-d) δ = 7.81 – 7.76 (m, 1H, CH₃), 7.50 – 7.41 (m, 2H, CH₃), 7.32 (d, ³J = 5.2 Hz, 1H, CH₃), 7.25 – 7.18 (m, 3H, CH₃), 7.18 – 7.08 (m, 2H, CH₃), 6.88 (d, ³J = 5.2 Hz, 1H, CH₃), 3.77 (s, 3H, OCH₃). HRMS (EI): Calculated for C₁₇H₁₃ONS [M⁺] 279.07124 found 279.07129.

**4-(3,5-Dimethoxyphenyl)-4H-thieno[3,2-b]indole (3j):** Yellow oil, 92% yield. ¹H NMR (300 MHz, Chloroform-d) δ = 7.74 – 7.66 (m, 1H, CH₃), 7.59 – 7.52 (m, 1H, CH₃), 7.28 (d, ³J = 5.2 Hz, 1H, CH₃), 7.24 – 7.11 (m, 2H, CH₃), 7.07 (d, ³J = 5.2 Hz, 1H, CH₃), 6.67 (d, ⁴J = 2.3 Hz, 2H, CH₃), 6.42 (t, ⁴J = 2.3 Hz, 1H, CH₃), 3.76 (s, 6H, OCH₃). HRMS (EI): Calculated for C₁₇H₁₃ONS [M⁺] 279.07124 found 279.07092.
1202 (m), 1150 (s), 1062 (m), 1037 (m), 813 (m), 737 (s). MS (El, 70 eV): m/z (%) = 310 (20), 309 [M]+ (100), 266 (12), 251 (13), 234 (5). HRMS (El): Calculated for C18H15O2NS [M]+ 309.08180 found 309.08198.

4-(2,4-Dimethoxyphenyl)-4H-thieno[3,2-b]indole (3k): Colorless solid, mp. 165 – 166 ºC, 89% yield. 1H NMR (250 MHz, Chloroform-d) δ = 7.83 – 7.76 (m, 1H, CHAr), 7.36 (d, 3J = 8.6 Hz, 1H, CHAr), 7.32 (d, 3J = 5.2 Hz, 1H, CHthiophene), 7.25 – 7.16 (m, 3H, CHAr), 6.87 (d, 3J = 5.2 Hz, 1H, CHthiophene), 6.71 (d, 4J = 2.6 Hz, 1H, CHAr), 6.63 (dd, 3J = 8.6 Hz, 4J = 2.6 Hz, 1H, CHAr), 3.91 (s, 3H, OCH3), 3.73 (s, 3H, OCH3). 13C NMR (63 MHz, CDCl3) δ = 160.5 (CAr), 156.3 (CAr), 146.2 (CAr), 142.5 (CAr), 129.4 (CAr), 126.4 (CHAr), 122.7 (CHAr), 122.1 (CHAr), 119.7 (CHAr), 118.9 (CHAr), 116.9 (CAr), 111.9 (CHAr), 111.5 (CHAr), 104.8 (CHAr), 100.2 (CHAr), 55.8 (OCH3), 55.8 (OCH3). IR (ATR, cm⁻¹): ν = 3087 (w), 3045 (w), 3005 (w), 2965 (w), 2931 (w), 2835 (w), 1611 (m), 1584 (m), 1518 (s), 1451 (s), 1305 (m), 1204 (s), 1158 (s), 1050 (m), 1022 (m), 928 (w), 827 (m), 740 (s), 651 (m), 581 (m). MS (El, 70 eV): m/z (%) = 309 (100), 294 (19), 251 (12), 223 (8). HRMS (El): Calculated for C18H15O2NS [M]+ 309.08180 found 309.08151.

4-(3,4,5-Trimethoxyphenyl)-4H-thieno[3,2-b]indole (3l): White solid, mp. 94 – 95 ºC, 92% yield. 1H NMR (250 MHz, Chloroform-d) δ = 7.75 – 7.67 (m, 1H, CHAr), 7.52 – 7.46 (m, 1H, CHAr), 7.30 (d, 3J = 5.2 Hz, 1H, CHthiophene), 7.26 – 7.10 (m, 2H, CHAr), 7.02 (d, 3J = 5.2 Hz, 1H, CHthiophene), 6.72 (s, 2H, CHAr), 3.87 (s, 3H, OCH3), 3.80 (s, 6H, OCH3). 13C NMR (63 MHz, CDCl3) δ = 154.1 (2CArOCH3), 145.2 (CAr), 141.6 (CAr), 137.0 (CAr), 134.7 (CAr), 127.1 (CHAr), 123.2 (CHAr), 122.4 (CHAr), 120.4 (CHAr), 119.2 (CHAr), 117.9 (CAr), 111.6 (CHAr), 111.2 (CHAr), 103.0 (2CAr), 61.2 (OCH3), 56.5 (2OCH3). IR (ATR, cm⁻¹): ν = 3082 (w), 3051 (w), 2926 (m), 2824 (w), 1593 (m), 1505 (m), 1450 (m), 1415 (m), 1289 (m), 1226 (m), 1124 (s), 1007 (m), 818 (m), 740 (m), 655 (m). MS (El, 70 eV): m/z (%) = 339 (100), 324 (75), 296 (10), 266 (9), 210 (9), 172 (13), 154 (8). HRMS (El): Calculated for C19H17O3NS [M]+ 339.09237 found 339.09217.

4-(4-(tert-Butyl)phenyl)-4H-thieno[3,2-b]indole (3m): Yellow oil, 92% yield. 1H NMR (250 MHz, Chloroform-d) δ = 7.75 – 7.67 (m, 1H, CHAr), 7.52 – 7.39 (m, 5H, CHAr), 7.26 (d, 3J = 5.2 Hz, 1H, CHthiophene), 7.20 – 7.12 (m, 2H, CHAr), 7.02 (d, 3J = 5.2 Hz, 1H, CHthiophene), 1.32 (s, 9H, tBu). 13C NMR (63 MHz, CDCl3) δ = 149.9 (CAr), 145.2 (CAr), 141.5 (CAr), 136.3 (CAr), 126.9 (CHAr), 126.7 (2CHAr), 124.7 (2CHAr), 123.0 (CHAr), 122.4 (CAr), 120.2 (CHAr), 119.1 (CHAr), 117.8 (CAr), 111.7 (CHAr), 111.3 (CHAr), 34.9 (CtBu), 31.6 (3CH3). IR (ATR, cm⁻¹): ν = 3049 (w), 2959 (m), 2901 (w), 2865 (w), 1602 (w), 1519 (s), 1451 (s), 1394 (m), 1337 (m), 1267 (m), 1205 (m), 1112 (m), 1086 (m), 1046 (m), 1016 (m), 922 (w), 825 (m), 705 (m), 648 (m), 552 (m). MS (El, 70 eV): m/z (%) = 305 (100), 290 (95), 275 (16), 262 (11), 172 (17), 131 (11). HRMS (El): Calculated for C20H19NS [M]+ 305.12327 found 305.12374.
4-(Naphthalen-1-yl)-4H-thieno[3,2-b]indole (3n): Colorless solid, mp. 141 – 142 °C, 78% yield. $^1$H NMR (300 MHz, Acetone-$d_6$) $\delta = 8.19 - 8.09$ (m, 2H, CH$_{Ar}$), 7.92 - 7.87 (m, 1H, CH$_{Ar}$), 7.79 - 7.70 (m, 2H, CH$_{Ar}$), 7.61 (ddd, $^3$J = 8.2 Hz, $^3$J = 6.8 Hz, $^4$J = 1.3 Hz, 1H, CH$_{Ar}$), 7.54 (d, $^3$J = 5.2 Hz, 1H, CH$_{thiophene}$), 7.45 (ddd, $^3$J = 8.2 Hz, $^3$J = 6.8 Hz, $^4$J = 1.3 Hz, 1H, CH$_{Ar}$), 7.32 - 7.27 (m, 1H, CH$_{Ar}$), 7.27 - 7.16 (m, 2H, CH$_{Ar}$), 7.06 - 6.99 (m, 1H, CH$_{Ar}$), 6.79 (d, $^3$J = 5.2 Hz, 1H, CH$_{thiophene}$). $^{13}$C NMR (75 MHz, Acetone-$d_6$) $\delta = 147.6$ (C$_{Ar}$), 144.0 (C$_{Ar}$), 135.8 (C$_{Ar}$), 135.6 (C$_{Ar}$), 131.2 (C$_{Ar}$), 129.8 (C$_{Ar}$), 129.5 (C$_{Ar}$), 128.4 (C$_{Ar}$), 128.0 (C$_{Ar}$), 127.7 (C$_{Ar}$), 126.9 (C$_{Ar}$), 126.7 (C$_{Ar}$), 123.9 (C$_{Ar}$), 123.8 (C$_{Ar}$), 123.0 (C$_{Ar}$), 121.1 (CH$_{Ar}$), 119.7 (CH$_{Ar}$), 117.9 (C$_{Ar}$), 112.3 (CH$_{Ar}$), 112.1 (CH$_{Ar}$). IR (ATR, cm$^{-1}$): $\tilde{\nu} = 3047$ (m), 1592 (w), 1575 (w), 1504 (m), 1448 (m), 1401 (m), 1327 (m), 1211 (m), 1110 (m), 1076 (m), 800 (m), 773 (m), 735 (s), 657 (m). MS (EI, 70 eV): m/z (%) = 299 (100), 265 (18), 149 (8), 127 (7). HRMS (EI): Calculated for C$_{29}$H$_{13}$NS [M]$^+$ 299.07632 found 299.07610.

4-(Anthracen-2-yl)-4H-thieno[3,2-b]indole (3o): Yellow solid, mp. 176 – 177 °C, 72% yield. $^1$H NMR (250 MHz, Chloroform-$d$) $\delta = 8.53$ (s, 1H, CH$_{Ar}$), 8.47 (s, 1H, CH$_{Ar}$), 8.25 – 8.14 (m, 2H, CH$_{Ar}$), 8.05 (m, 2H, CH$_{Ar}$), 7.90 – 7.78 (m, 1H, CH$_{Ar}$), 7.78 – 7.65 (m, 2H, CH$_{Ar}$), 7.59 – 7.47 (m, 2H, CH$_{Ar}$), 7.42 (d, $^3$J = 5.2 Hz, 1H, CH$_{thiophene}$), 7.37 – 7.18 (m, 3H, CH$_{Ar}$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta = 145.2$ (C$_{Ar}$), 141.5 (C$_{Ar}$), 135.7 (C$_{Ar}$), 132.3 (C$_{Ar}$), 131.9 (C$_{Ar}$), 131.7 (C$_{Ar}$), 130.2 (CH$_{Ar}$), 130.1 (C$_{Ar}$), 128.3 (CH$_{Ar}$), 128.0 (CH$_{Ar}$), 127.0 (CH$_{Ar}$), 126.5 (CH$_{Ar}$), 126.1 (CH$_{Ar}$), 126.0 (CH$_{Ar}$), 125.7 (CH$_{Ar}$), 123.7 (CH$_{Ar}$), 123.1 (CH$_{Ar}$), 122.6 (C$_{Ar}$), 122.3 (CH$_{Ar}$), 120.5 (CH$_{Ar}$), 119.1 (CH$_{Ar}$), 118.3 (C$_{Ar}$), 111.8 (CH$_{Ar}$), 111.4 (CH$_{Ar}$). IR (ATR, cm$^{-1}$): $\tilde{\nu} = 3049$ (w), 2954 (w), 1670 (w), 1592 (w), 1504 (m), 1450 (m), 1321 (m), 887 (m), 738 (s), 652 (m), 603 (m), 469 (m), 429 (m). MS (EI, 70 eV): m/z (%) = 349 (100), 315 (4), 176 (7). HRMS (EI): Calculated for C$_{24}$H$_{15}$NS [M]$^+$ 349.09179 found 349.09165.

4-(4-Fluorophenyl)-4H-thieno[3,2-b]indole (3p): White solid, mp. 117 – 118 °C, 91% yield. $^1$H NMR (300 MHz, Chloroform-$d$) $\delta = 7.75 - 7.68$ (m, 1H, CH$_{Ar}$), 7.50 - 7.41 (m, 2H, CH$_{Ar}$), 7.40 - 7.36 (m, 1H, CH$_{Ar}$), 7.28 (d, $^3$J = 5.2 Hz, 1H, CH$_{thiophene}$), 7.23 - 7.11 (m, 4H, CH$_{Ar}$), 6.95 (d, $^3$J = 5.2 Hz, 1H, CH$_{thiophene}$). $^{19}$F NMR (282 MHz, CDCl$_3$) $\delta = -114.59$ (FC$_{Ar}$). $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta = 161.2$ (d, $^1$J$_{CF} = 246.7$ Hz, CF$_{Ar}$), 145.2 (C$_{Ar}$), 141.6 (C$_{Ar}$), 134.6 (d, $^4$J$_{CF} = 3.1$ Hz, C$_{Ar}$), 127.1 (CH$_{Ar}$), 127.0 (d, $^3$J$_{CF} = 8.5$ Hz, 2CH$_{Ar}$), 123.2 (CH$_{Ar}$), 122.3 (C$_{Ar}$), 120.4 (CH$_{Ar}$), 119.1 (CH$_{Ar}$), 118.0 (C$_{Ar}$), 116.7 (d, $^2$J$_{CF} = 22.8$ Hz, 2CH$_{Ar}$), 111.2 (CH$_{Ar}$), 110.9 (CH$_{Ar}$). IR (ATR, cm$^{-1}$): $\tilde{\nu} = 3106$ (w), 3093 (w), 3050 (w), 1600 (w), 1510 (s), 1451 (m), 1340 (m), 1218 (m), 1090 (m), 826 (m), 740 (s), 708 (m), 571 (m), 515 (m). MS (EI, 70 eV): m/z (%) = 267 (100), 235 (9), 222 (9), 128 (5), 75 (10). HRMS (EI): Calculated for C$_{16}$H$_{15}$NFS [M]$^+$ 267.05125 found 267.05098.

4-(4-Chlorophenyl)-4H-thieno[3,2-b]indole (3q): Colorless solid, mp. 114 – 115 °C, 86% yield. $^1$H NMR (250 MHz, Chloroform-$d$) $\delta = 7.76 - 7.69$ (m, 1H, CH$_{Ar}$), 7.46 (m, 5H,
4-Benzyl-4H-thieno[3,2-b]indole (3r): Yellow oil, 81% yield. $^1$H NMR (250 MHz, Chloroform-\textit{d}) $\delta = 7.69$ (ddd, $^3J = 7.6$ Hz, $^4J = 1.5$ Hz, $^5J = 0.7$ Hz, 1H, CH$_x$), 7.25 (dd, $^4J = 1.4$ Hz, $^5J = 0.8$ Hz, 1H, CH$_x$), 7.23 (d, $^3J = 5.2$ Hz, 1H, CH$_x$), 7.10 – 7.03 (m, 5H, CH$_x$), 7.11 – 7.05 (m, 2H, CH$_x$), 6.44 (d, $^3J = 5.2$ Hz, 1H, CH$_x$), 5.36 (s, 2H$_{aliphatic}$, CH$_x$).

$^{13}$C NMR (63 MHz, CDCl$_3$) $\delta = 145.6$ (C$_x$), 141.7 (C$_x$), 137.3 (C$_x$), 128.9 (2CH$_x$), 127.7 (CH$_x$), 127.0 (CH$_x$), 126.8 (2CH$_x$), 122.7 (CH$_x$), 122.1 (C$_x$), 119.5 (CH$_x$), 119.1 (CH$_x$), 116.7 (C$_x$), 110.7 (CH$_x$), 110.3 (CH$_x$), 48.9 (CH$_x$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 3422 (w), 3081 (w), 3054 (w), 3025 (w), 2921 (w), 2852 (w), 1733 (w), 1583 (w), 1507 (m), 1463 (m), 1349 (m), 1161 (m), 736 (s), 695 (m), 654 (s), 430 (m). MS (EI, 70 eV): $m/z$ (%) = 285 (32), 283 (100), 247 (12), 128 (10), 75 (18). HRMS (EI): Calculated for C$_{16}$H$_{10}$N$_{37}$CIS [M]$^+$ 285.01875 found 285.01936.

4-(4-methoxybenzyl)-4H-thieno[3,2-b]indole (3s): Colorless oil, 95% yield. $^1$H NMR (250 MHz, Chloroform-\textit{d}) $\delta = 7.68$ (m, 1H, CH$_x$), 7.28 (d, $^3J = 8.3$ Hz, 1H, CH$_x$), 7.22 (d, $^3J = 5.2$ Hz, 1H, CH$_x$), 7.20 – 7.12 (m, 1H, CH$_x$), 7.12 – 7.04 (m, 1H, CH$_x$), 7.00 (d, $^3J = 8.6$ Hz, 2H, CH$_x$), 6.82 (d, $^3J = 5.2$ Hz, 1H, CH$_x$), 6.20 (d, $^3J = 8.6$ Hz, 2H, CH$_x$), 5.28 (s, 2H$_{aliphatic}$, CH$_x$), 3.65 (s, 3H, OCH$_3$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta = 159.2$ (C$_x$), 145.5 (C$_x$), 141.7 (C$_x$), 129.4 (2CH$_x$), 128.2 (2CH$_x$), 126.9 (CH$_x$), 122.7 (CH$_x$), 122.1 (C$_x$), 119.4 (CH$_x$), 119.1 (CH$_x$), 116.6 (C$_x$), 116.3 (C$_x$), 114.3 (2CH$_x$), 110.7 (CH$_x$), 110.3 (C$_x$), 55.4 (OCH$_3$), 48.4 (CH$_x$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 3105 (w), 3051 (w), 3024 (w), 2997 (m), 2955 (m), 2915 (w), 2832 (m), 1613 (m), 1584 (m), 1508 (s), 1457 (s), 1439 (m), 1348 (m), 1245 (s), 1161 (s), 1025 (m), 807 (s), 735 (s), 653 (s), 430 (m). MS (EI, 70 eV): $m/z$ (%) = 294 (6), 293 [M]$^+$ (28), 121 (100), 78 (10). HRMS (EI): Calculated for C$_{18}$H$_{15}$NS [M]$^+$ 293.08689 found 293.08643.

4-Pentyl-4H-thieno[3,2-b]indole (3t): Yellow oil, 75% yield. $^1$H NMR (250 MHz, Chloroform-\textit{d}) $\delta = 7.76$ (ddd, $^3J = 7.8$ Hz, $^4J = 1.3$ Hz, $^5J = 0.7$ Hz, 1H, CH$_x$), 7.43 – 7.35 (m, 2H, CH$_x$), 7.34 – 7.26 (m, 1H, CH$_x$), 7.17 (ddd, $^3J = 8.1$ Hz, $^3J = 7.0$ Hz, $^4J = 1.2$ Hz, 1H, CH$_x$), 7.08 (d, $^3J = 5.2$ Hz, 1H, CH$_x$), 4.27 (t, $^3J = 7.1$ Hz, 2H$_{aliphatic}$, CH$_x$), 2.00 – 1.74 (m, 2H$_{aliphatic}$, CH$_x$), 1.34 (m, 4H$_{aliphatic}$, 2CH$_x$), 0.98 – 0.80 (m, 3H$_{aliphatic}$, CH$_x$). $^{13}$C NMR (63
MHz, CDCl$_3$) $\delta = 145.5$ (C$_{Ar}$), 141.4 (C$_{Ar}$), 126.8 (CH$_{Ar}$), 122.4 (CH$_{Ar}$), 121.9 (C$_{Ar}$), 119.1 (CH$_{Ar}$), 119.0 (CH$_{Ar}$), 116.0 (C$_{Ar}$), 110.5 (CH$_{Ar}$), 110.0 (CH$_{Ar}$), 45.4 (CH$_3$, penty), 29.6 (CH$_2$, penty), 29.4 (CH$_2$, penty), 22.5 (CH$_2$, penty), 14.1 (CH$_3$, penty). IR (ATR, cm$^{-1}$): $\tilde{\nu} = 3081$ (w), 3052 (w), 2954 (m), 2927 (m), 2856 (m), 1610 (w), 1509 (m), 1123 (m), 1348 (m), 1317 (m), 1162 (m), 1079 (m), 1017 (w), 815 (w), 735 (s), 653 (m), 431 (m). MS (EI, 70 eV): $m/z$ (%) = 243 [M]$^+$ (30), 186 (100), 115 (12). HRMS (EI): Calculated for C$_{15}$H$_{17}$NS [M]$^+$ 243.10762 found 243.10811.

**General procedure for the synthesis of thieno[3,4-b]indoles**

3-Bromo-2-(2-bromophenyl)thiophene (0.15 mmol), amine (0.225 mmol), Pd$_2$dba$_3$ (0.0075 mmol), PtBu$_3$HBF$_4$ (0.015 mmol) and NaOlbu (0.36 mmol) were added to a dried glass pressure tube. The tube was evacuated and backfilled three times with argon. 2 ml of dried toluene was added. The mixture was heated to 100 °C for 14h until the reaction completed (monitored by TLC). After cooling to room temperature, the solvent was removed under reduced pressure. The crude oil was subjected to column chromatography (heptane/ethyl acetate) to obtain the pure product.

**4-(p-Tolyl)-4H-thieno[3,4-b]indole (6a):** Yellow oil, 95% yield. $^1$H NMR (250 MHz, Chloroform-d$_3$) $\delta = 7.86$ (dt, $^3J = 7.6$ Hz, $^4J = 1.0$ Hz, 1H, CH$_{Ar}$), 7.54 (m, 1H, CH$_{Ar}$), 7.50 (s, 1H, CH$_{Ar}$), 7.49 (s, 1H, CH$_{Ar}$), 7.47 – 7.21 (m, 4H, CH$_{Ar}$), 7.14 (ddd, $^3J = 7.6$ Hz, $^4J = 6.6$ Hz, $^6J = 1.7$ Hz, 1H, CH$_{Ar}$), 6.59 (m, 1H, CH$_{Ar}$), 2.36 (s, 3H, CH$_3$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta = 148.1$ (C$_{Ar}$), 146.3 (C$_{Ar}$), 136.8 (C$_{Ar}$), 136.1 (C$_{Ar}$), 133.5 (C$_{Ar}$), 130.5 (2CH$_{Ar}$), 126.5 (CH$_{Ar}$), 124.4 (2CH$_{Ar}$), 121.5 (CH$_{Ar}$), 120.3 (C$_{Ar}$), 119.8 (CH$_{Ar}$), 110.6 (CH$_{Ar}$), 109.9 (CH$_{Ar}$), 92.6 (CH$_{Ar}$), 21.3 (CH$_3$). IR (ATR, cm$^{-1}$): $\tilde{\nu} = 3399$ (w), 3101 (w), 3030 (w), 2917 (w), 2859 (w), 1608 (w), 1576 (m), 1512 (s), 1449 (m), 1397 (m), 1321 (m), 1223 (m), 1152 (m), 1108 (w), 1020 (w), 928 (w), 816 (m), 740 (s), 619 (m), 499 (m). MS (EI, 70 eV): $m/z$ (%) = 263 (100), 247 (8), 218 (12), 128 (7). HRMS (EI): Calculated for C$_{17}$H$_{13}$NS [M]$^+$ 263.07632 found 263.07634.

**4-(o-Tolyl)-4H-thieno[3,4-b]indole (6b):** Yellow oil, 65% yield. $^1$H NMR (300 MHz, Acetone-d$_6$) $\delta = 8.02 – 7.92$ (m, 2H, CH$_{Ar}$), 7.89 – 7.79 (m, 1H, CH$_{Ar}$), 7.79 (d, $^4J = 2.5$ Hz, 1H, CH$_{thiophene}$), 7.58 (d, $^3J = 8.2$ Hz, 1H, CH$_{Ar}$), 7.48 – 7.32 (m, 2H, CH$_{Ar}$), 7.16 (m, 1H, CH$_{Ar}$), 6.93 (d, $^3J = 8.2$ Hz, 1H, CH$_{Ar}$), 6.51 (d, $^4J = 2.5$ Hz, 1H, CH$_{thiophene}$), 2.22 (s, 3H, CH$_3$). $^{13}$C NMR (75 MHz, Acetone-d$_6$) $\delta = 149.9$ (C$_{Ar}$), 147.5 (C$_{Ar}$), 141.0 (C$_{Ar}$), 137.8 (C$_{Ar}$), 134.1 (C$_{Ar}$), 131.2 (CH$_{Ar}$), 129.5 (CH$_{Ar}$), 127.5 (CH$_{Ar}$), 126.9 (CH$_{Ar}$), 122.3 (CH$_{Ar}$), 121.3 (CH$_{Ar}$), 120.8 (C$_{Ar}$), 120.4 (CH$_{Ar}$), 112.0 (CH$_{Ar}$), 110.5 (CH$_{Ar}$), 93.2 (CH$_{Ar}$), 18.2 (CH$_3$). IR (ATR, cm$^{-1}$): $\tilde{\nu} = 3412$ (w), 3103 (w), 3052 (w), 2919 (w), 2853 (w), 1577 (m), 1499 (m), 1450 (m), 1395
(m), 1316 (m), 1227 (m), 1151 (m), 824 (m), 741 (s), 622 (m), 445 (m). MS (EI, 70 eV): m/z (%) = 264 (21), 263 [M]+ (100), 262 (41), 260 (11), 231 (16), 228 (11), 218 (20), 217 (32), 216 (11), 204 (15), 128 (17). HRMS (El): Calculated for C_{17}H_{19}NS [M]+ 263.07632 found 263.07567.

4-(4-(tert-Butyl)phenyl)-4H-thieno[3,4-b]indole (6c): Yellow oil, 83% yield. 1H NMR (250 MHz, Chloroform-d) δ = 7.78 (m, 1H, CHAr), 7.48 (m, 4H, CHAr), 7.41 (s, 1HAr), 7.33 (ddd, 3J = 8.3 Hz, 4J = 1.2 Hz, 5J = 0.7 Hz, 1H, CHAr), 7.25 (dd, 3J = 7.1 Hz, 4J = 1.3 Hz, 1H, CHAr), 7.18 (s, 1H, CHAr), 7.09 – 7.02 (m, 1H, CHAr), 1.33 (s, 9H, tBu). 13C NMR (63 MHz, CDC13) δ = 149.2 (CAr), 148.1 (CAr), 146.2 (CAr), 136.8 (CAr), 133.5 (CAr), 126.8 (2CHAr), 126.5 (CHAr), 123.9 (2CHAr), 121.5 (CHAr), 120.4 (CAr), 119.8 (CHAr), 110.5 (CHAr), 110.0 (CHAr), 92.7 (CHAr), 34.8 (Cebu), 31.6 (3CH3). IR (ATR, cm⁻¹): ν = 3401 (w), 3053 (w), 2958 (m), 2865 (w), 1605 (w), 1578 (m), 1517 (s), 1451 (m), 1399 (m), 1323 (m), 1224 (m), 1190 (m), 1152 (m), 1017 (w), 827 (m), 742 (s), 622 (m), 552 (m). MS (EI, 70 eV): m/z (%) = 305 [M]+ (97), 290 (100), 275 (18), 262 (8), 172 (20), 131 (40), 109 (9). HRMS (El): Calculated for C_{22}H_{19}NS [M]+ 305.12372 found 305.12400.

4-(3,5-Dimethoxyphenyl)-4H-thieno[3,4-b]indole (6d): Yellow oil, 85% yield. 1H NMR (300 MHz, Chloroform-d) δ = 7.85 (m, 1H, CHAr), 7.52 – 7.45 (m, 2H, CHAr), 7.33 (ddd, 3J = 8.4 Hz, 4J = 7.3 Hz, 5J = 1.3 Hz, 1H, CHAr), 7.15 (td, 3J = 7.3 Hz, 4J = 1.3 Hz, 1H, CHAr), 6.81 (d, 4J = 2.3 Hz, 2H, CHAr), 6.68 (d, 4J = 2.5 Hz, 1H, CHthieno[3,4-b]indole), 6.45 (t, 4J = 2.3 Hz, 1H, CHAr), 3.85 (s, 6H, OCH3). 13C NMR (75 MHz, CDC13) δ = 161.9 (2CAr), 147.7 (CAr), 145.8 (CAr), 141.2 (CAr), 133.5 (CAr), 126.6 (CHAr), 121.5 (CAr), 120.6 (CAr), 120.1 (CHAr), 110.8 (CHAr), 110.4 (CHAr), 102.6 (2CHAr), 98.4 (CHAr), 93.3 (CHAr), 55.7 (2OCH3). IR (ATR, cm⁻¹): ν = 3388 (w), 3102 (w), 3056 (w), 2998 (w), 2929 (w), 2837 (w), 1591 (s), 1498 (m), 1451 (s), 1293 (m), 1258 (s), 1202 (s), 1149 (s), 1056 (m), 929 (m), 823 (m), 742 (s), 689 (m), 627 (m). MS (EI, 70 eV): m/z (%) = 310 (21), 290 [M]+ (100), 294 (22), 264 (8), 251 (19), 250 (18), 234 (10), 191 (6), 178 (11), 128 (9). HRMS (El): Calculated for C_{18}H_{15}O_{2}NS [M]+ 309.08180 found 309.08182.

4-(3,4,5-Trimethoxyphenyl)-4H-thieno[3,4-b]indole (6e): Colorless solid, mp. 96 – 97 °C, 81% yield. 1H NMR (300 MHz, Chloroform-d) δ = 7.87 (ddd, 3J = 7.7 Hz, 4J = 1.3 Hz, 5J = 0.7 Hz, 1H, CHAr), 7.50 (d, 4J = 1.8 Hz, 1H, CHthieno[3,4-b]indole), 7.40 (ddd, 3J = 8.2 Hz, 4J = 1.3 Hz, 5J = 0.7 Hz, 1H, CHAr), 7.33 (ddd, 3J = 8.2 Hz, 5J = 7.0 Hz, 4J = 1.3 Hz, 1H, CHAr), 7.16 (ddd, 3J = 7.7 Hz, 5J = 7.0 Hz, 4J = 1.3 Hz, 1H, CHAr), 6.85 (s, 2H, CHAr), 6.61 (d, 4J = 2.5 Hz, 1H, CHthieno[3,4-b]indole), 3.94 (s, 3H, CH3), 3.89 (s, 6H, CH3). 13C NMR (75 MHz, CDC13) δ = 154.2 (2CArOCH3), 148.1 (CAr), 146.3 (CAr), 136.5 (CAr), 135.1 (CAr), 133.4 (CAr), 126.6 (CHAr), 121.6 (CHAr), 120.4 (CAr), 120.0 (CHAr), 110.9 (CHAr), 110.0 (CHAr), 102.2 (2CHAr), 92.7 (CHAr), 61.2 (OCH3), 56.5 (2OCH3). IR (ATR, cm⁻¹): ν = 3101 (m), 3056 (w), 2999 (m), 2929 (m), 2829

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4-(Anthracen-2-yl)-4H-thieno[3,4-b]indole (6f): Light yellow solid, mp. 171 – 172 ºC, 78% yield. $^1$H NMR (250 MHz, Chloroform-$_d$) $\delta$ = 8.50 (s, 1H, CH$_{Ar}$), 8.44 (s, 1H, CH$_{Ar}$), 8.24 – 8.13 (m, 2H, CH$_{Ar}$), 8.11 – 7.96 (m, 2H, CH$_{Ar}$), 7.91 (ddd, $^3$J = 7.5 Hz, $^4$J = 1.3 Hz, $^5$J = 0.7 Hz, 1H, CH$_{Ar}$), 7.79 (dd, $^3$J = 9.0 Hz, $^4$J = 2.1 Hz, 1H, CH$_{Ar}$), 7.59 – 7.44 (m, 4H, CH$_{Ar}$), 7.36 (ddd, $^3$J = 8.3 Hz, $^3$J = 7.3 Hz, $^4$J = 1.3 Hz, 1H, CH$_{Ar}$), 7.20 (td, $^3$J = 7.5 Hz, $^4$J = 1.0 Hz, 1H, CH$_{Ar}$), 6.76 (d, $^4$J = 2.5 Hz, 1H, CH$_{thiophene}$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta$ = 147.9 (C$_{Ar}$), 146.0 (C$_{Ar}$), 136.4 (C$_{Ar}$), 133.5 (C$_{Ar}$), 132.4 (C$_{Ar}$), 132.0 (C$_{Ar}$), 131.9 (C$_{Ar}$), 130.4 (C$_{Ar}$), 130.1 (C$_{Ar}$), 128.4 (CH$_{Ar}$), 128.1 (CH$_{Ar}$), 126.7 (CH$_{Ar}$), 126.6 (CH$_{Ar}$), 126.1 (CH$_{Ar}$), 125.9 (CH$_{Ar}$), 125.7 (CH$_{Ar}$), 123.2 (CH$_{Ar}$), 121.6 (CH$_{Ar}$), 121.3 (CH$_{Ar}$), 120.7 (C$_{Ar}$), 120.3 (CH$_{Ar}$), 110.9 (CH$_{Ar}$), 110.2 (CH$_{Ar}$), 93.2 (CH$_{Ar}$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 3093 (w), 3050 (w), 2956 (w), 1628 (w), 1573 (m), 1451 (m), 1389 (w), 1216 (w), 891 (m), 742 (s), 472 (m). MS (EI, 70 eV): $m/z$ (%) = 349 (100), 304 (48), 174 (24), 152 (20), 128 (6). HRMS (EI): Calculated for C$_{28}$H$_{23}$NS [M$^+$] 349.09197 found 349.09161.

General procedure for the synthesis of 5-substituted thieno[3,2-b]indoles

5-substituted 3-bromo-2-(2-bromophenyl)thiophene (0.15 mmol), amine (0.225 mmol), Pd$_2$dba$_3$ (0.0075 mmol), SPhos (0.015 mmol) and NaO$_2$Bu (0.36 mmol) were added to a dried glass pressure tube. The tube was evacuated and backfilled three times with argon. 2 ml of dried toluene was added. The mixture was heated to 100 ºC for 14h until the reaction completed (monitored by TLC). After cooling to room temperature, the solvent was removed under reduced pressure. The crude oil was subjected to column chromatography (heptane/ethyl acetate) to obtain the pure product.

2-Phenyl-4-(p-tolyl)-4H-thieno[3,2-b]indole (10a): White solid, mp. 164 – 165 ºC, 95% yield. $^1$H NMR (300 MHz, Chloroform-$_d$) $\delta$ = 7.75 – 7.69 (m, 1H, CH$_{Ar}$), 7.65 – 7.58 (m, 2H, CH$_{Ar}$), 7.48 – 7.40 (m, 3H, CH$_{Ar}$), 7.37 – 7.29 (m, 4H, CH$_{Ar}$), 7.25 – 7.15 (m, 4H, CH$_{Ar}$), 2.42 (s, 3H, CH$_3$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta$ = 145.9 (C$_{Ar}$), 145.4 (C$_{Ar}$), 141.1 (C$_{Ar}$), 137.0 (C$_{Ar}$), 136.3 (C$_{Ar}$), 135.5 (C$_{Ar}$), 130.5 (2CH$_{Ar}$), 129.1 (2CH$_{Ar}$), 127.7 (CH$_{Ar}$), 125.8 (2CH$_{Ar}$), 125.3 (2CH$_{Ar}$), 123.1 (CH$_{Ar}$), 122.5 (C$_{Ar}$), 120.4 (CH$_{Ar}$), 119.0 (CH$_{Ar}$), 116.9 (C$_{Ar}$), 111.1 (CH$_{Ar}$), 107.6 (CH$_{Ar}$), 21.3 (CH$_3$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 3047 (m), 2916 (w), 1594 (m), 1512 (s), 1451 (s), 1421 (m), 1336 (m), 1211 (w), 1113 (w), 1068 (m), 917 (w), 827 (m), 802 (m), 755 (s), 727 (s), 689 (s), 619 (w), 574 (w). MS (EI, 70 eV): $m/z$ (%) = 341 (8), 340 (26), 339 [M$^+$].
2,4-Diphenyl-4H-thieno[3,2-b]indole (10b): White solid, mp. 156 – 157 °C, 61% yield. 

\[ \text{H NMR (250 MHz, Chloroform-}d) \delta = 7.84 - 7.69 (m, 2H, CH}_2, 7.68 - 7.66 (m, 1H, CH\text{=N}), 7.48 - 7.34 (m, 5H, CH\text{=N}), 7.47 - 7.35 (m, 4H, CH\text{=N}), 7.33 - 7.23 (m, 3H, CH\text{=N}). \]

\[ ^{13}\text{C NMR (63 MHz, CDCl}_3) \delta = 146.0 (C\text{=N}), 145.2 (C\text{=N}), 141.0 (C\text{=N}), 138.9 (C\text{=N}), 135.4 (C\text{=N}), 130.0 (2CH\text{=N}), 129.1 (2CH\text{=N}), 127.8 (CH\text{=N}), 127.0 (CH\text{=N}), 125.8 (2CH\text{=N}), 125.4 (2CH\text{=N}), 123.2 (CH\text{=N}), 122.7 (C\text{=N}), 120.6 (CH\text{=N}), 119.1 (CH\text{=N}), 117.2 (C\text{=N}), 111.1 (CH\text{=N}), 107.6 (CH\text{=N}). \]

IR (ATR, cm\(^{-1}\)): \( \nu = 3047 (\text{w}), 2921 (\text{w}), 1593 (\text{m}), 1526 (\text{w}), 1500 (\text{s}), 1450 (\text{s}), 1421 (\text{m}), 1342 (\text{m}), 1213 (\text{w}), 1069 (\text{w}), 819 (\text{m}), 752 (\text{s}), 741 (\text{s}), 691 (\text{s}), 663 (\text{m}), 615 (\text{w}). \)

MS (EI, 70 eV): \( m/z (\%) = 327 (6), 326 (24), 325 [M'] (100), 324 (22), 323 (7), 322 (4), 291 (6), 146 (4). \)

HRMS (EI): Calculated for C\text{23}H\text{17}NS [M'] 339.10762 found 339.10710.


\[ \text{H NMR (250 MHz, Chloroform-}d) \delta = 7.80 - 7.73 (m, 1H, CH\text{=N}), 7.68 - 7.61 (m, 2H, CH\text{=N}), 7.48 (d, 3J = 8.9 Hz, 2H, CH\text{=N}), 7.43 - 7.38 (m, 1H, CH\text{=N}), 7.35 (d, 3J = 7.6 Hz, 2H, CH\text{=N}), 7.31 - 7.18 (m, 4H, CH\text{=N}), 7.07 (d, 3J = 8.9 Hz, 2H, CH\text{=N}), 3.88 (s, 3H, OCH\text{=N}). \]

\[ ^{13}\text{C NMR (63 MHz, CDCl}_3) \delta = 158.6 (C\text{=N}), 145.9 (C\text{=N}), 145.7 (C\text{=N}), 141.5 (C\text{=N}), 135.5 (C\text{=N}), 131.6 (C\text{=N}), 129.1 (2CH\text{=N}), 127.7 (CH\text{=N}), 127.0 (2CH\text{=N}), 125.8 (2CH\text{=N}), 123.1 (C\text{=N}), 122.4 (CH\text{=N}), 120.3 (CH\text{=N}), 119.0 (CH\text{=N}), 116.6 (C\text{=N}), 115.1 (2CH\text{=N}), 110.9 (CH\text{=N}), 107.4 (CH\text{=N}), 55.7 (CH\text{=N}). \]

IR (ATR, cm\(^{-1}\)): \( \nu = 2925 (\text{w}), 1509 (\text{s}), 1490 (\text{m}), 1451 (\text{s}), 1245 (\text{s}), 1212 (\text{m}), 1193 (\text{m}), 1179 (\text{m}), 1168 (\text{m}), 1151 (\text{m}), 1106 (\text{m}), 1070 (\text{m}), 1028 (\text{s}), 833 (\text{m}), 804 (\text{m}), 752 (\text{s}), 736 (\text{s}), 687 (\text{s}), 653 (\text{w}), 583 (\text{s}), 563 (\text{w}). \)

MS (EI, 70 eV): \( m/z (\%) = 357 (8), 356 (25), 355 [M'] (100), 340 (13), 312 (9), 311 (4), 310 (6), 278 (4), 178 (4). \)

HRMS (EI): Calculated for C\text{23}H\text{15}ONS [M'] 325.09197 found 325.09163.

4-(4-Fluorophenyl)-2-phenyl-4H-thieno[3,2-b]indole (10d): White solid, mp. 120 – 121 °C, 90% yield. 

\[ \text{H NMR (250 MHz, Chloroform-}d) \delta = 7.83 - 7.75 (m, 1H, CH\text{=N}), 7.71 - 7.63 (m, 2H, CH\text{=N}), 7.63 - 7.52 (m, 2H, CH\text{=N}), 7.49 - 7.35 (m, 3H, CH\text{=N}), 7.34 - 7.23 (m, 6H, CH\text{=N}). \]

\[ ^{19}\text{F NMR (282 MHz, CDCl}_3) \delta = -114.40 (\text{FC}\text{=N}). \]

\[ ^{13}\text{C NMR (63 MHz, CDCl}_3) \delta = 161.41 (d, ^{1}\text{J}_{\text{CF}} = 247.0 \text{ Hz, FC}\text{=N}), 146.2 (C\text{=N}), 145.4 (C\text{=N}), 141.2 (C\text{=N}), 135.3 (C\text{=N}), 134.9 (d, ^{4}\text{J}_{\text{CF}} = 3.0 \text{ Hz, CF\text{=N}}), 129.1 (2CH\text{=N}), 127.9 (CH\text{=N}), 127.3 (d, ^{3}\text{J}_{\text{CF}} = 8.5 \text{ Hz, 2CH\text{=N}}), 125.8 (2CH\text{=N}), 123.3 (CH\text{=N}), 122.6 (C\text{=N}), 120.7 (CH\text{=N}), 119.1 (CH\text{=N}), 117.1 (C\text{=N}), 117.0 (d, ^{2}\text{J}_{\text{CF}} = 22.8 \text{ Hz, 2CH\text{=N}}), 110.8 (CH\text{=N}), 107.2 (CH\text{=N}). \]

IR (ATR, cm\(^{-1}\)): \( \nu = 3076 (\text{w}), 2923 (\text{w}), 1506 (\text{s}), 1451 (\text{s}), 1424 (\text{m}), 1342 (\text{m}), 1210 (\text{s}), 1149 (\text{w}), 1092 (\text{m}), 1069 (\text{m}), 1012 (\text{w}), 843 (\text{s}), 803 (\text{s}), 684 (\text{s}), 652 (\text{w}), 575 (\text{m}), 562 (\text{m}). \)

MS (EI, 70 eV): \( m/z (\%) = 345 (7), 344 (25), 343 [M'] (100), 342 (20), 309 (7), 171 (6), 154 (7), 146 (4), 121 (4), 120 (6), 95 (4), 77 (4), 75 (7). \)

HRMS (EI): Calculated for C\text{22}H\text{14}NFS [M'] 343.08255 found 343.0823.
2-(4-Chlorophenyl)-4-(3,5-dimethylphenyl)-4H-thieno[3,2-b]indole (10e): White solid, mp. 105 – 106 °C, 62% yield. 1H NMR (250 MHz, Chloroform-d) δ = 7.78 – 7.70 (m, 1H, CHAr), 7.56 (d, J = 8.6 Hz, 2H, CHAr), 7.52 – 7.46 (m, 1H, CHAr), 7.40 – 7.35 (m, 1H, CHAr), 7.32 (d, J = 8.6 Hz, 2H, CHAr), 7.25 – 7.21 (m, 1H, CHAr), 7.20 – 7.13 (m, 3H, CHAr), 7.04 (m, 1H, CHAr), 2.41 (s, 6H, CH3). 13C NMR (63 MHz, CDCl3) δ = 154.3 (CAr), 144.2 (CAr), 141.2 (CAr), 139.8 (2CAr), 138.6 (CAr), 134.0 (CAr), 133.4 (CAr), 129.2 (2CHAr), 128.9 (CHAr), 126.9 (2CHAr), 125.9 (CAr), 123.3 (CAr), 123.1 (2CHAr), 122.4 (CAr), 120.5 (CHAr), 119.1 (CAr), 111.3 (CHAr), 108.1 (CHAr), 21.6 (2CH3). IR (ATR, cm⁻¹): ν = 2916 (w), 2854 (w), 1595 (m), 1477 (m), 1451 (s), 1348 (m), 1314 (w), 1285 (w), 1169 (w), 1090 (m), 1011 (w), 828 (m), 801 (s), 737 (s), 703 (m), 687 (m), 672 (m), 551 (w). MS (EI, 70 eV): m/z (%) = 390 (11), 389 (42), 388 (31), 387 [M⁺] (100), 372 (10), 193 (3), 168 (3). HRMS (EI): Calculated for C26H18N3ClS [M⁺] 427.08430 found 427.084213, calculated for C26H18N37ClS [M⁺] 427.08135 found 427.08135.

4-(4-(tert-Butyl)phenyl)-2-(4-chlorophenyl)-4H-thieno[3,2-b]indole (10f): White solid, mp. 137 – 138 °C, 61% yield. 1H NMR (250 MHz, Chloroform-d) δ = 7.75 – 7.69 (m, 1H, CHAr), 7.57 – 7.49 (m, 5H, CHAr), 7.49 – 7.43 (m, 3H, CHAr), 7.32 – 7.25 (m, 2H, CHAr), 7.23 – 7.16 (m, 2H, CHAr), 1.38 (s, 9H, tBu). 13C NMR (63 MHz, CDCl3) δ = 150.1 (CAr), 145.3 (CAr), 144.3 (CAr), 141.1 (CAr), 136.0 (CAr), 134.0 (CAr), 133.3 (CAr), 129.2 (2CHAr), 126.9 (4CHAr), 124.9 (2CHAr), 123.3 (CHAr), 122.4 (CAr), 120.5 (CHAr), 119.1 (CHAr), 117.2 (CAr), 111.2 (CHAr), 108.0 (CHAr), 34.9 (Cmbu), 31.6 (3CH3). IR (ATR, cm⁻¹): ν = 2956 (m), 2902 (w), 1516 (m), 1487 (m), 1450 (s), 1361 (w), 1339 (w), 1261 (w), 1089 (s), 1012 (s), 834 (m), 802 (s), 791 (s), 746 (s), 672 (w), 628 (w), 551 (m). MS (EI, 70 eV): m/z (%) = 418 (11), 417 (39), 416 (28), 415 [M⁺] (100), 402 (12), 401 (9), 400 (30), 385 (12), 186 (11). HRMS (EI): Calculated for C26H22NCIS [M⁺] 415.11560 found 415.11531, calculated for C26H22N37CIS [M⁺] 417.1265 found 417.11365.

2-(4-Chlorophenyl)-4-mesityl-4H-thieno[3,2-b]indole (10g): White solid, mp. 105 – 106 °C, 87% yield. 1H NMR (250 MHz, Chloroform-d) δ = 7.86 – 7.76 (m, 1H, CHAr), 7.57 (d, J = 8.6 Hz, 2H, CHAr), 7.33 (d, J = 8.6 Hz, 2H, CHAr), 7.28 – 7.20 (m, 2H, CHAr), 7.08 (s, 2H, CHAr), 7.00 – 6.92 (m, 2H, CHAr), 2.43 (s, 3H, CH3), 1.91 (s, 6H, CH3). 13C NMR (63 MHz, CDCl3) δ = 145.4 (CAr), 144.4 (CAr), 141.3 (CAr), 138.7 (CAr), 137.4 (2CAr), 134.1 (CAr), 133.3 (CAr), 132.9 (CAr), 129.4 (2CAr), 129.2 (2CHAr), 126.8 (2CHAr), 123.2 (CHAr), 121.9 (CAr), 120.0 (CHAr), 119.1 (CHAr), 116.2 (CAr), 110.9 (CHAr), 107.4 (CHAr), 21.3 (CH3), 17.7 (2CH3). IR (ATR, cm⁻¹): ν = 2950 (w), 2916 (w), 1603 (w), 1501 (s), 1484 (s), 1450 (m), 1314 (m), 1213 (w), 1179 (w), 1010 (w), 852 (w), 827 (m), 800 (s), 739 (s), 677 (w), 552 (w). MS (EI, 70 eV): m/z (%) = 404 (11), 403 (38), 402 (29), 401 [M⁺] (100), 386 (4), 368 (3), 247 (3), 232 (3), 231 (3). HRMS (EI): Calculated for C25H20N3ClS [M⁺] 401.09995 found 401.09960, calculated for C25H20N37ClS [M⁺] 403.09700 found: 403.09786.
4-(3-Fluorophenyl)-2-(4-fluorophenyl)-4H-thieno[3,2-b]indole (10h): White solid, mp. 156 – 157 °C, 62% yield. $^1$H NMR (250 MHz, Chloroform-$d$) $\delta$ = 7.80 – 7.73 (m, 1H, CH$_{Ar}$), 7.66 – 7.58 (m, 2H, CH$_{Ar}$), 7.58 – 7.48 (m, 2H, CH$_{Ar}$), 7.41 (ddd, $^3$J = 8.0 Hz, $^4$J = 2.0 Hz, $^5$J = 1.1 Hz, 1H, CH$_{Ar}$), 7.37 – 7.30 (m, 1H, CH$_{Ar}$), 7.30 – 7.20 (m, 3H, CH$_{Ar}$), 7.16 – 7.03 (m, 3H, CH$_{Ar}$). $^{19}$F NMR (235 MHz, CDCl$_3$) $\delta$ = 110.36 (FC$_{Ar}$), -114.04 (FC$_{Ar}$). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta$ = 163.5 (d, $^1$J$_{CF}$ = 248.1 Hz, CF$_{Ar}$), 162.6 (d, $^1$J$_{CF}$ = 247.9 Hz, CF$_{Ar}$), 146.0 (C$_{Ar}$), 145.1 (C$_{Ar}$), 140.6 (C$_{Ar}$), 140.4 (d, $^3$J$_{CF}$ = 10.0 Hz, C$_{Ar}$), 131.6 (d, $^4$J$_{CF}$ = 3.5 Hz, C$_{Ar}$), 131.1 (d, $^3$J$_{CF}$ = 9.2 Hz, CH$_{Ar}$), 127.4 (d, $^3$J$_{CF}$ = 8.0 Hz, 2CH$_{Ar}$), 123.5 (CH$_{Ar}$), 122.8 (C$_{Ar}$), 121.1 (CH$_{Ar}$), 120.6 (d, $^4$J$_{CF}$ = 3.2 Hz, CH$_{Ar}$), 119.2 (CH$_{Ar}$), 117.7 (C$_{Ar}$), 116.0 (d, $^2$J$_{CF}$ = 21.9 Hz, 2CH$_{Ar}$), 113.8 (d, $^2$J$_{CF}$ = 21.1 Hz, CH$_{Ar}$), 112.4 (d, $^2$J$_{CF}$ = 23.4 Hz, CH$_{Ar}$), 111.0 (CH$_{Ar}$), 107.5 (CH$_{Ar}$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 3052 (w), 1592 (m), 1531 (m), 1490 (s), 1452 (m), 1364 (w), 1261 (w), 1222 (s), 1145 (s), 1080 (w), 977 (w), 934 (w), 870 (w), 828 (m), 806 (s), 777 (m), 725 (s), 708 (m), 694 (s), 667 (s), 630 (w), 581 (w). MS (EI, 70 eV): m/z (%) = 363 (7), 361 [M]$^+$ (100), 360 (21), 359 (6), 266 (4). HRMS (El): Calculated for C$_{26}$H$_{13}$NF$_2$S [M]$^+$ 361.07313 found 361.07251.

4-(4-(tert-Butyl)phenyl)-2-(4-fluorophenyl)-4H-thieno[3,2-b]indole (10i): White solid, mp. 118 – 119 °C, 85% yield. $^1$H NMR (300 MHz, Chloroform-$d$) $\delta$ = 7.72 – 7.67 (m, 1H, CH$_{Ar}$), 7.59 – 7.41 (m, 7H, CH$_{Ar}$), 7.20 – 7.15 (m, 3H, CH$_{Ar}$), 7.04 – 6.95 (m, 2H, CH$_{Ar}$), 1.34 (s, 9H, tBu). $^{13}$C NMR (75 MHz, CDCl$_3$) $\delta$ = 162.6 (d, $^1$J$_{CF}$ = 247.5 Hz, CF$_{Ar}$), 150.1 (C$_{Ar}$), 145.3 (C$_{Ar}$), 144.6 (C$_{Ar}$), 141.1 (C$_{Ar}$), 136.1 (C$_{Ar}$), 131.9 (d, $^4$J$_{CF}$ = 3.3 Hz, C$_{Ar}$), 127.5 (d, $^3$J$_{CF}$ = 8.0 Hz, 2CH$_{Ar}$), 126.8 (2CH$_{Ar}$), 124.9 (2CH$_{Ar}$), 123.2 (CH$_{Ar}$), 122.6 (C$_{Ar}$), 120.5 (CH$_{Ar}$), 119.0 (CH$_{Ar}$), 116.9 (C$_{Ar}$), 116.1 (d, $^2$J$_{CF}$ = 21.9 Hz, 2CH$_{Ar}$), 111.2 (CH$_{Ar}$), 107.8 (CH$_{Ar}$), 34.9 (C$_{Bu}$), 31.6 (3C$_{Bu}$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 2963 (w), 1602 (w), 1497 (m), 1451 (m), 1361 (w), 1342 (w), 1213 (s), 1159 (m), 1096 (w), 1013 (w), 840 (s), 804 (s), 787 (m), 738 (s), 674 (m), 633 (w), 552 (s). MS (EI, 70 eV): m/z (%) = 401 (8), 400 (29), 399 [M]$^+$ (100), 385 (10), 384 (35), 369 (16), 342 (9), 266 (10), 192 (8), 178 (26). HRMS (El): Calculated for C$_{26}$H$_{22}$NFS [M]$^+$ 399.14515 found 399.14496.

2-(4-(tert-Butyl)phenyl)-4-mesityl-4H-thieno[3,2-b]indole (10j): White solid, mp. 181 – 182 °C, 45% yield. $^1$H NMR (250 MHz, Chloroform-$d$) $\delta$ = 7.83 – 7.76 (m, 1H, CH$_{Ar}$), 7.58 (d, $^3$J = 8.6 Hz, 2H, CH$_{Ar}$), 7.39 (d, $^3$J = 8.6 Hz, 2H, CH$_{Ar}$), 7.20 (m, 2H, CH$_{Ar}$), 7.07 (s, 2H, CH$_{Ar}$), 6.96 (s, 1H, CH$_{Indole}$), 6.95 – 6.90 (m, 1H, CH$_{Ar}$), 2.42 (s, 3H, CH$_{3}$), 1.91 (s, 6H, CH$_{3}$), 1.34 (s, 9H, tBu). $^{13}$C NMR (63 MHz, CDCl$_3$) $\delta$ = 150.8 (C$_{Ar}$), 146.1 (C$_{Ar}$), 145.5 (C$_{Ar}$), 141.2 (C$_{Ar}$), 138.6 (C$_{Ar}$), 137.5 (2C$_{Ar}$), 133.1 (C$_{Ar}$), 132.8 (C$_{Ar}$), 129.4 (2CH$_{Ar}$), 126.0 (2CH$_{Ar}$), 125.4 (2CH$_{Ar}$), 122.8 (CH$_{Ar}$), 122.1 (C$_{Ar}$), 119.8 (CH$_{Ar}$), 118.9 (CH$_{Ar}$), 115.5 (C$_{Ar}$), 110.8 (CH$_{Ar}$), 106.7 (CH$_{Ar}$), 34.8 (C$_{Bu}$), 31.4 (3C$_{Bu}$), 21.3 (CH$_{3}$), 17.7 (2CH$_{3}$). IR (ATR, cm$^{-1}$): $\tilde{\nu}$ = 2957 (w), 2921 (w), 1502 (m), 1484 (m), 1452 (m), 1357 (w), 1335 (w), 1218 (w), 937 (w), 836 (m), 807 (s), 743 (s), 574 (w), 531 (m). MS (EI, 70 eV): m/z (%) = 425 (7), 424 (31), 423
[M]$^+$ (100), 410 (4), 409 (13), 408 (45), 393 (10), 204 (4), 190 (5). HRMS (EI): Calculated for C$_{29}$H$_{29}$NS [M]$^+$ 423.20152 found 423.20115.

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Reference


