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Programmed Site-selective Palladium Catalyzed Arylations of Thieno[3,2-*b*]thiophene

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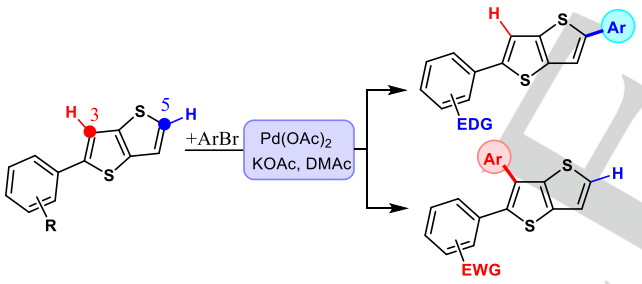
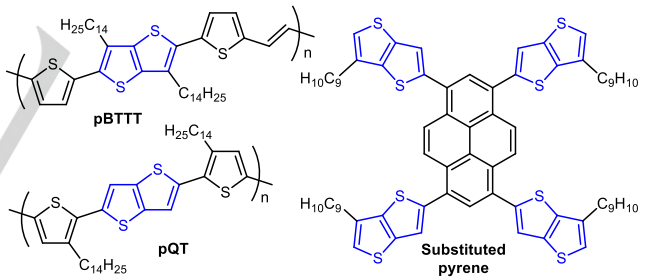
Abstract: Mono-, di-, tri- and tetra-arylated thieno[3,2-*b*]thiophenes were synthesized by direct site-selective Pd-catalyzed C-H activation reactions with various aryl bromides in the presence of a phosphine-free $Pd(OAc)_2$/KOAc catalyst system in DMAc. The arylation of 2-arylthieno[3,2-*b*]thiophene took place at the C-3 position when the 2-aryl substituents bear electron-withdrawing groups, and at the C-5 position when they are bulky and possess electron-donating groups.



INTRODUCTION

Recently, the direct palladium-catalyzed arylation of arenes and heteroarenes by C-H bond activation using aryl halides have been extensively developed.[1,2] It has become a powerful methodology[2] for rapid construction and diversification of highly functionalized molecules. Until now, palladium-catalyzed arylation method has found successful applications in the synthesis of bioactive natural products, drugs, and fine chemicals. In addition, it plays an essential role in agrochemical industries as well as in material sciences. Compared with classical cross-coupling reactions (Stille, Suzuki-Miyaura, Neigishi, Kumada, etc.),[3-6] the palladium-catalyzed C-H functionalization shows several advantages concerning the unnecessary pre-functionalization of the substrates and preparation of organometallic reagents. In this context, direct C-H bond activation has proved to be a straightforward and efficient tool for chemists in terms of atom-economy, less undesired waste, and more environmentally friendly reaction conditions.

In recent decades, a large number of research related to the employment of functionalized thieno[3,2-*b*]thiophene as a basic building block have rapidly gained much attention. Thieno[3,2-*b*]thiophene has been known as an important building block in the structures of semiconductor polymers, molecular electronics and electronic devices.[7,8] Because of intermolecular sulfur–sulfur interactions, organic materials containing thieno[3,2-*b*]thiophene moiety may increase the electronic transport between neighbouring molecules. In addition, the electronic properties, the solubility and the molecular packing of various materials could be significantly changed when substituents were introduced into the core structure of the materials.[7,8]



Scheme 1. Structures of polymers (**pBTTT** and **pQT**) and a pyrene-based organic semiconductor containing the thieno[3,2-*b*]thiophene building block

For the purpose of fine-tuning the electronic and physical properties of thieno[3,2-b]thiophene-containing materials, many synthetic methods have been developed, especially those using conventional Pd-catalyzed cross-coupling reactions. The liquid-crystalline semiconducting polymers pBTTT and pQT9-11 showed valuable high charge-carrier mobility for transistor performance. The semiconductive polymers containing thieno[3,2-b]thiophene (pBTTT and pQT) were prepared by the palladium-catalyzed Stille cross-coupling reactions between 2,5-dibromothieno[3,2-b]thiophene and various substituted 2-thienylstannanes. Similarly, isoindigo-based low bandgap conjugated polymers towards application in photovoltaic devices were synthesized by the Stille cross-coupling reaction of 2,5-bis(trimethylstannyl)thieno[3,2-b]thiophene and 6,6'-dibromoisoindigo.12 The star-shaped organic semiconductor 1,3,6,8-tetera(thieno[3,2-b]thien-2-yl)pyrene13 obtained from the

Stille cross-coupling reaction of 1,3,6,8-tetrabromopyrene and tributyl-(6-nonylthieno[3,2-*b*]thien-2-yl)-stannane was successsfully applied in the development of new light-emitting diodes (OLEDs). Several well-soluble thieno[3,2-*b*]thiophene-based oligomers[14] and 2,5-di(2-azulenyl)thieno[3,2-*b*]thiophenes,[15] which were constructed *via* the Suzuki-Miyaura cross-coupling reactions of 2,5-disubstituted thieno[3,2-*b*]thiophenyl pinacolato boronic ester and 2-iodoazulene or 2-bromo- or 2,5-dibromothieno[3,2-*b*]thiophene, showed high hole mobilities, small transition energies, and high-order orientations in the crystalline state. These *p*-channel organic field-effect transistors (OFET) demonstrated promising performance due to the presence of thieno[3,2-*b*]thiophene moiety.[7,16,17] Fluorescent boron-nitrogen heteroacenes[18] containing the thieno[3,2-*b*]thiophene building block were constructed by the Suzuki-Miyaura cross-coupling reaction of dibromothieno[3,2-*b*]thiophene isomers and 2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)benzenamine, followed by the insertion of boron atoms with phenyldicholorborane.

Obviously, the functionalization of thieno[3,2-*b*]thiophene building block plays a remarkable role in the development of novel organic materials with promising electronic properties. In 2010, Knochel and Kunz reported the full functionalization of all four positions of thieno[3,2-b]thiophene by selective multiple magnesiations of 2,5-dichlorothieno[3,2-b]thiophene.19 Very recently, Miura and co-workers20 published a study on a convenient palladium-catalyzed direct alkenylation of thieno[3,2-b]thiophene. This protocol gave a facile synthetic route to achieve regioselectively mono- and di- alkenylated thieno[3,2-b]thiophenes at the C-2 and/or C-5 positions. Multiarylated thieno[3,2-b]thiophenes via sequential Suzuki-Miyaura cross-coupling reactions between tetrabromothieno[3,2-*b*]thiophene and various arylboronic acids were reported in our recent work.[21]

In this context, the direct arylation of thieno[3,2-*b*]thiophene *via* site-selective C-H bond activation is straightforward since it provides a more environmental-friendly and atom-economical approach to multiarylated thieno[3,2-*b*]thiophene without the employment of halogenated thieno[3,2-*b*]thiophenes or preparation of corresponding organometallic reagents.

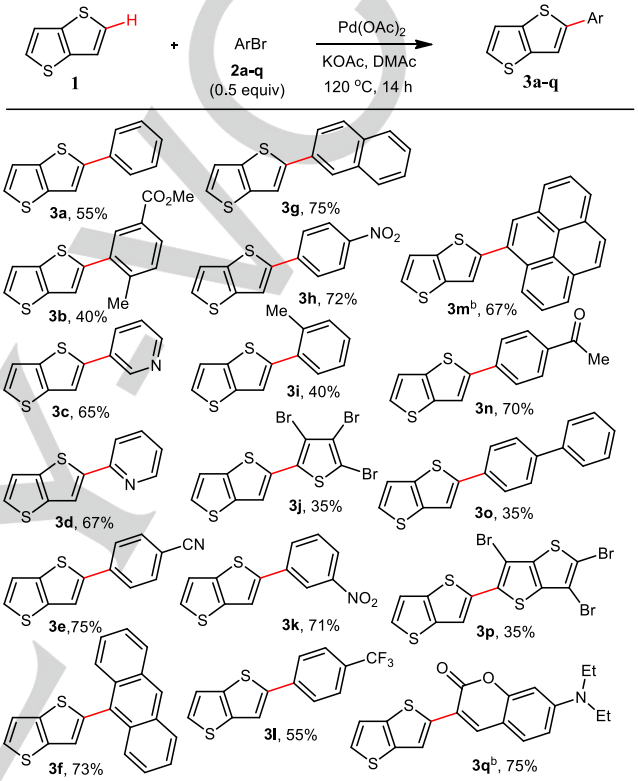
Herein, to the best of our knowledge, we wish to report a new and efficient route for the synthesis of mono-, di-, tri- and tetraarylated thieno[3,2-*b*]thiophenes with controllable site-selectivity by the palladium-catalyzed direct arylation reactions of thieno[3,2-*b*]thiophene with aryl bromides using low catalyst loading.

RESULTS AND DISCUSSION

First, the starting material compound, thieno[3,2-b]thiophene 1 was synthesized using Fuller's procedure.[22]

A pioneering work reported by Ohta et al.[23] in 1990 for direct arylation of thiophene, furan, and thiazole gave medium to good yields using 5 mol% of $Pd(PPh_3)_4$ as catalyst. Since this high-impact discovery, the direct arylation of heterocycles has been studied thoroughly and proved to be a powerful tool for construction of (hetero)biaryl frameworks.[24,25] Noticeably, Doucet and co-workers have recently described an efficient phosphine-free palladium-catalyzed functionalization of thiophene.[26-29] Their catalytic systems, composed of $Pd(OAc)_2$ as catalyst and a base (K_2CO_3, KOAc, or Cs_2CO_3) in an organic solvent (DMAc, DMF,…), are efficient for direct site-selective arylation of functionalized thiophenes.

Table 1. Pd-catalyzed arylation of thieno[3,2-*b*]thiophene **1** with aryl bromides **2(a-q)**[a,b].



[a]Reaction conditions: **1** (0.2 mmol), **2(a-q)** (0.1 mmol), $Pd(OAc)_2$ (1 mol%), KOAc (0.2 mmol), DMAc (2 mL); isolated yields are given. [b] $PdCl(C_3H_5)dppb$ was used.

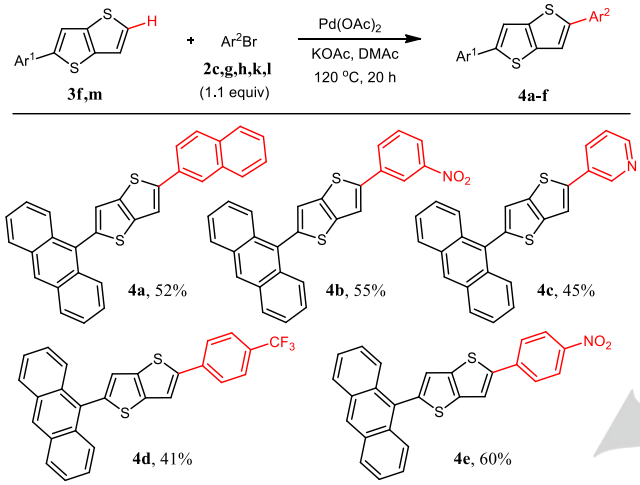
In principle, the reactivities of thiophene and thieno[3,2-*b*]thiophene are similar. Therefore, we applied Doucet's protocol for the direct arylation of thieno[3,2-*b*]thiophene with various aryl bromides. As expected, the arylation of **1** was successfully conducted with various commercially available bromoarenes in the presence of Pd(OAc)2/KOAc as catalyst/base in DMAc.

The C-H arylation reactions of 1 (2.0 equiv) with various aryl bromides (1.0 equiv) resulted in the site-selective formation of a series of 2-Arylthieno[3,2-b]thiophenes 3a-q in moderate to good yields (35 – 75%) (Table 1). After extensive screening with regards to temperature, solvent, base, and water additive, Pd(OAc)2 without ligand was found to be an efficient catalyst for the direct arylation of thieno[3,2-b]thiophene. All reactions were carried out at 120-150° C (Table 1, see SI). The optimized reaction conditions were compatible with a wide range of functional groups, such as nitro, dialkylamino, ester, cyano, or heterocyclic substituents. Generally, the arylation reaction gave

10.1002/asia.201700562

better yields with aryl bromides bearing electron-withdrawing groups (**2e**, **2h, 2k**, **2n**, and **2q**) than with aryl bromides bearing electron-donating groups (**2i** and **2o**). However, 9-bromoanthracene **2f** and 3-bromonaphthalene **2g** also afforded the corresponding 2-substituted thieno[3,2-*b*]thiophene **3f** and **3g** in good yields**.** For the synthesis of compounds **3m** and **3q**, dppb ligand was employed because the two corresponding aryl bromides, **2m** and **2p**, did not work well under the present phosphine-free palladium-catalyzed reaction condition.[30]

Table 2. Pd-catalyzed arylation of 2-Arylthieno[3,2-*b*]thiophenes **3f, m** with aryl bromides[a].



[a]Reaction conditions: **3(f,m)** (0.1 mmol), **2** (0.11 mmol), $Pd(OAc)_2$ (1 mol%), KOAc (0.1 mmol), DMAc (1.5 mL); isolated yields are given.

In order to perform a second aryltion of 2-arylated thieno[3,2-*b*]thiophenes, the C-H activation reactions of 2-Aryl[1]thieno[3,2-*b*]thiophenes **3f** or **3m** (1.0 equiv.) with various aryl halides **2c**, 2**g**, 2**h**, 2**k**, or **2l** (1.1 equiv) resulted in the highly site-selective formation of unsymmetrical 2-Aryl[1]-5-Aryl[2]thieno[3,2-*b*]thiophenes **4a**-**f** in acceptable yields (41 – 60%) (Table 1).
To confirm the site-selectivity at the C-2 and C-5 positions of thieno[3,2-*b*]thiophene in our arylation reaction, the structure of **4a** was well characterized by ^{1}H NMR and ^{13}C NMR spectra in combination with X-ray crystal structure analysis (Figure 1).

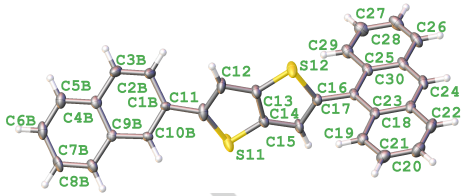
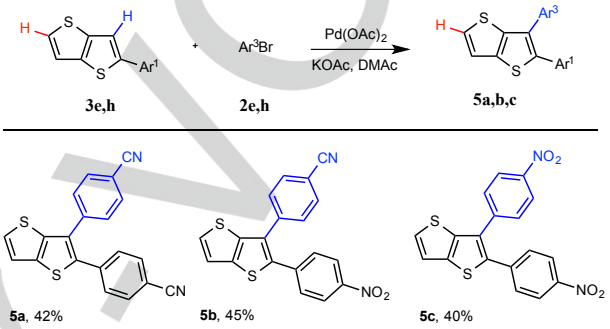


Figure 1. X-Ray crystal structure of **4a**[38]

The similar site-selectivity in the direct arylation of thiophene and thieno[3,2-*b*]thiophene is predictable since they share analogous structural characteristics.

Interestingly, the direct C-H arylation of 2-Aryl[1]-thieno[3,2-*b*]thiophenes **3e** and **3h** (1.0 equiv) with various aryl halides, such as **2e** and **2h** (1.1 equiv), resulted in the abnormal site-selective formation of 2-Aryl[1]-3-Aryl[2]thieno[3,2-*b*]thiophenes **5a-c** in 40 – 45% yields (Table 3). In an attempt to the structures as well as the site-selectivity in the direct arylation of **3e** and **3h**, the structure **5c** was elucidated by NMR spectroscopic method and X-ray crystal structure analysis (Figure 2).

Table 3. Synthesis of 2,3-diarylthieno[3,2-*b*]thiophenes **5a-c** from 2-arylthieno[3,2-*b*]thiophene **3e,h** and aryl bromides **2e,h.**



[a]Reaction conditions: 3(e,h) (0.2 mmol), 2 (0.22 mmol), Pd(OAc)2 (1 mol%), KOAc (0.2 mmol), DMAc (2.5 mL); isolated yields are given.

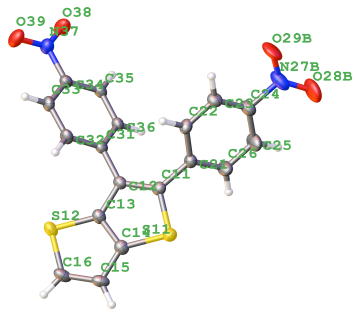


Figure 2. X-Ray crystal structure of **5c**[38]

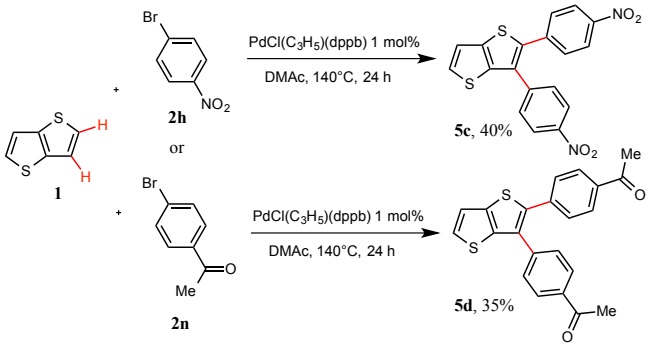


Figure 3. Synthesis of 2,3-diarylthieno[3,2-*b*]thiophenes **5c** and **5d** from **1** and aryl bromides **2.**

To further investigate the abnormal site-selectivity of the direct arylation of 2-substituted thieno[3,2-*b*]thiophene, we conducted the diarylation reaction of thieno[3,2-*b*]thiophene **1** (1.0 equiv) with **2h** or **2n** (3.0 equiv) (Figure 3). In our expectation, two corresponding 2,3-diarylthieno[3,2-*b*]thiophenes, **5c** and **5d**, were also obtained with 40% and 35% yields, respectively. In these reactions, the more reactive catalyst, $PdCl(C_3H_5)(dppb)$, was employed instead of $Pd(OAc)_2$ since the latter showed sluggish conversion. Under this phosphine-supported condition, the same site-selectivity at the C-2 and C-3 positions was observed.

Considering the mechanism of the direct arylation via C-H bond activation, three potential pathways have been proposed for the C-C cross-coupling reactions.[25,31,32] In our catalytic system, the essential role of the base, KOAc, would support for the concerted metalation deprotonation (CMD) pathway. This CMD mechanism has been thoroughly studied and can be applied in reactions of similar aromatic compounds.[33,34] In an aromatic ring, the more acidic proton is normally activated favourably.[35]

Table 4. Resonances of C-3, C-5, and C-6 protons of several 2-arylthieno[3,2-*b*]thiophenes*.

Compounds	H3, δ(ppm)	H5, δ(ppm)	H6, δ(ppm)
3e	7.60	7.44	7.27
3f	7.35	7.36	7.47
3l	7.56	7.40	7.25
3n	7.63	7.43	7.28
3g	7.61	7.36	7.27
3h	7.66	7.46	7.28
3k	7.62	7.44	7.28

*see supporting information for more details

In order to get an insight into the site-selectivity of the arylation of thieno[3,2-*b*]thiophene, the resonances of the related protons on the thieno[3,2-*b*]thiophene moiety of several 2-arylthieno[3,2-*b*]thiophene were compared (Table 4). In the 2-arylated thieno[3,2-*b*]thiophene scaffolds, the electronic effect of a strong electron-withdrawing group (EWG) on the C-2 atom may have significant influence on the proton on the adjacent position, the C-3 atom.

Indeed, the acidity of the proton at the C-3 position is higher than that of the proton at the C-5 position as indicated by the NMR data. Table 4 shows that when the 2-aryl substituent of a 2-Arylthieno[3,2-*b*]thiophene possesses an electron-withdrawing group, such as cyano (**3e**), nitro (**3k**, **3h**), trifluoromethyl (**3l**), or acetyl (**3n**), especially at its *para* position, the resonance of the C-3 proton is noticeably higher than that of the C-5 proton. Obviously, this evidence reveals that the acidity of the C-3 proton in 2-(EWG-aryl)thieno[3,2-*b*]thiophenes is increased. Hence, the subsequent direct arylation took place more favourably at the C-3 position.

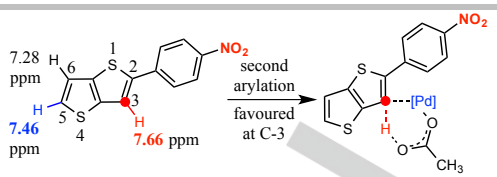


Figure 4. Possible interpretation of selective formation of 2,3-diarylthieno[3,2-*b*]thiophenes

Interestingly, the site-selectivity of the second and the third direct arylations of 2-arylthieno[3,2-*b*]thiophenes **3f** and **3g** were again observed at the C-5 and C6 positions on the other sites of the thieno[3,2-*b*]thiophene scaffold (Figure 6). The more reactive sites in these cases are still in good agreement with the CMD mechanism.[25] In fact, the arylation reaction of **3f** or **3g** (1.0 equiv) with **2h** or **2l** (3.0 equiv) furnished two corresponding 2-$Aryl^1$-5,6-$(Aryl^2)_2$thieno[3,2-*b*]thiophenes, **6a** and **6b,** with 20 and 32% yields, respectively (Figure 5). In these cases, the site-selectivity of the third arylation results from the increased acidity of the C-6 proton due to the EWG at the C-5 position. In addition the steric hindrance caused by the fused aromatic ring systems at the C-2 position, namely, the anthracene and the naphthalene substituents, also contributes to the observed site-selectivity.

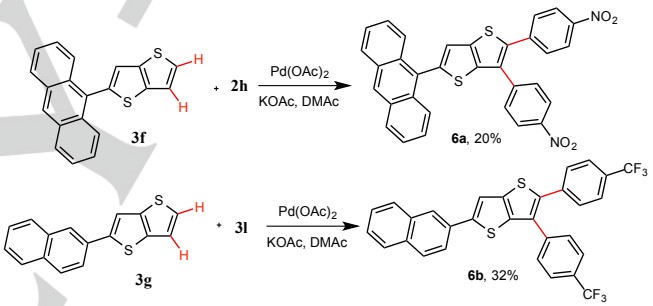


Figure 5. Synthesis of 2,3,5-triarylthieno[3,2-*b*]thiophenes **6a-b** from 2-arylthieno[3,2-*b*]thiophene **3**f or **3g** and the aryl bromide **2h** or **2l.**

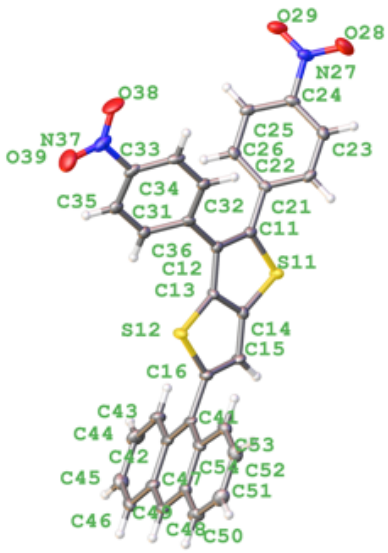


Figure 6. X-Ray crystal structure of **6a**[38]

The 2,3,5-triarylthieno[3,2-*b*]thiophenes **6c** and **6d** were also directly synthesized from the arylation of thieno[3,2-*b*]thiophene in 50% and 46% yields, respectively (Figure 7).

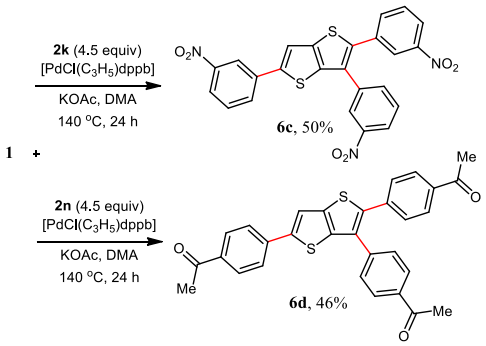


Figure 7. Synthesis of 2,3,5-triarylthieno[3,2-*b*]thiophenes **6c** and **6d** from thieno[3,2-*b*]thiophene **1** and aryl bromide **2k** or **2n**, respectively.

In summary, when the 2-arylsubstituent bearing an EWG, the sequential direct arylations take place first at the C-3 position, then at the C-5 position, and finally at the C-6 position due to the activation of the corresponding C-H bonds (Figure 8).

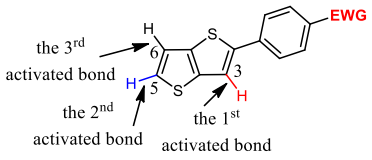


Figure 8. Sequential direct arylations of 2-arylthieno[3,2-*b*]thiophenes.

The one-pot synthesis of 2,3,5,6-tetrarylthieno[3,2-*b*]thiophene **7** could be achieved from the direct arylation of thieno[3,2-*b*]thiophene **1** with the aryl bromide **2n** in 25% yield (Figure 9).

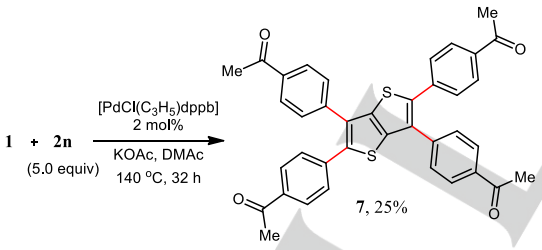


Figure 9. Synthesis of 2,3,5,6-tetra(4-acetylphenyl)thieno[3,2-b]thiophene **7** from **1** and 4-bromoacetophenone **2n**.

Conclusions

In conclusion, we have developed an efficient and straightforward method for the direct site-selective palladium-catalyzed arylation reactions of simple thieno[*3,2-b*]thiophene. This versatile method allows the synthesis of a large number of mono-, di-, tri- and tetraarylated thieno[3,2-*b*]thiophenes under phosphine-free conditions with controllable site-selectivity. Interestingly, the sequential arylations of the 2-arylthieno[3,2-*b*]thiophenes took place at predictable positions, either at the C-3 or at the C-5 position in the thieno[3,2-*b*]thiophene skeleton, depending on the nature and the size of the 2-aryl substituents. In terms of low catalyst loading, simple reaction conditions, and a wide range of functional group tolerance, to our opinion, this current procedure is convenient and useful for further applications in materials science.

Experimental Section

General: NMR spectra were recorded on a Bruker Avance spectrometer (500 MHz for ^{1}H and 125 MHz for ^{13}C). MS measurements were conducted with a Q-TOF Micro WATERS instrument using ionization electrospray positive (ESI) method. The intensities for the X-ray determination of **4a, 5c**, and **6a** were collected on a D8 QUEST Bruker (Germany) instrument at 100 K with Mo Kα radiation (λ = 0.71073 Å) using a TRIUMPH monochromator. Melting points were measured on a Stuart-Scientific SMP3 apparatus without correction. THF were dried and distilled over sodium benzophenone ketyl just before used. Anhydrous DMAc and other commercially available reagents were used without further purification. All C-H activation reactions were performed in argon atmosphere.

General procedure for the synthesis of 2-arylthieno[3,2-*b*]thiophene 3a-q

*Procedure **A***: Thieno[3,2-*b*]thiophene **1** (2.0 equiv), KOAc (2.0 equiv), an aryl bromide **2** (1.0 equiv), and $Pd(OAc)_2$ (0.01 equiv) was dissolved in DMAc which was saturated with argon. The resulting reaction mixture was heated at 120 – 150 °C under argon atmosphere until TLC (*n*-hexane/ethyl acetate) showed the complete consumption of the starting material. The reaction mixture was cooled to room temperature and filtered to remove insoluble impurities. The filtrate was diluted with ethyl acetate, washed with water (3 times), dried over Na_2SO_4, and concentrated under reduced pressure by rotary evaporation. The residue was purified by SiO_2-column chromatography (*n*-hexane/ethyl acetate) to give the C-H activation cross-coupling product.

*Procedure **B***: Procedure **B** was similar to procedure **A** except that the phosphine-based complex [PdCl(C_3H_5)dppb] (dppb: bis(diphenylphosphino)butane) (0.01 equiv) was used as catalyst instead of $Pd(OAc)_2$.[30,36,37]

*2-(4-Nitrophenyl)thieno[3,2-b]thiophene **3h**:* Following procedure **A**, from thieno[3,2-*b*]thiophene (28 mg, 0.2 mmol, 2.0 equiv), 1-bromo-4-nitrobenzene (20 mg, 0.1 mmol, 1.0 equiv), $Pd(OAc)_2$ (0.5 mg, 0.02 mmol, 0.01 equiv), KOAc (19.6 mg, 0.2 mmol, 2.0 equiv), DMAc (2.0 mL), **3h** was obtained as a pale yellow needles (18.8 mg, 72%). Mp 110-112 °C; ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 8.25 (2 H, d, *J* = 8.5 Hz), 7.75 (2 H, d, *J* = 8.5 Hz), 7.66 (1 H, s), 7.47 (1 H, d, *J* = 5.0 Hz), 7.29 (1 H, d, *J* = 5.5 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 146.8, 143.1, 141.0, 140.4, 128.9, 125.9, 124.5, 119.7, 117.9. HRMS-ESI: *m/z* calcd for $C_{12}H_7NO_2S_2Na$ $[M+Na]^+$ 283.9816, found 283.9833.

7-Diethylaminocoumarin-3-ylthieno[3,2-b]thiophene ***3q***: Following procedure **B**, from **1** (70 mg, 0.5 mmol, 2.0 equiv) and 7-diethylaminocoumarin-3-yl bromide **2q** (74 mg, 0.25 mmol, 1.0 equiv), **3q** was isolated as orange crystals (66 mg, 75%). Mp 132-133 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 7.95 (1 H, s), 7.82 (1 H, s), 7.35 (1 H, d, *J* = 5.5 Hz), 7.30 (1 H, d, *J* = 9.0 Hz), 7.22 (1 H d, *J* = 5.0 Hz), 6.59 (1 H, dd, *J* = 9.0 Hz and 2.5 Hz), 6.50 (1 H, d, *J* = 2.5 Hz), 3.40 (4 H, q, *J* = 7.0 Hz), 1.22 (6 H, t, *J* = 7.0 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 160.1, 155.5, 150.6, 140.0, 139.8, 138.7, 136.8, 128.9, 127.3, 119.4, 117.8, 114.8, 109.3, 108.7, 97.0, 44.8, 12.5; HRMS-ESI: *m/z* calcd for $C_{19}H_{18}NO_2S_2$ $[M+H]^+$ 356.0778, found 356.0789.

3a: White solid (23.7 mg, 55%). Mp 68-70 °C; ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.62 (2 H, d, *J* = 8.0 Hz), 7.48 (1 H, s), 7.39 (2 H, t, *J* = 8.0 Hz), 7.35 (1 H, d, *J* = 5.5 Hz), 7.28 (1 H, t, *J* = 8.0 Hz), 7.24 (1 H, d, *J* = 5.0 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 146.3, 143.0, 138.5, 131.0, 128.9, 127.8, 126.8, 125.8, 119.6, 115.3.

3b: Colorless liquid (23 mg, 40%). ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 8.11 (1 H, d, *J* = 2.0 Hz), 7.93 (1 H, dd, *J* = 8.0 Hz and 2.0 Hz), 7.38 (1 H, d, *J* = 5.0 Hz), 7.37 (1 H, d, *J* = 8.0 Hz), 7.28 (1 H, d, *J* = 5.0 Hz), 7.25 (1 H, d, *J* = 6.0 Hz, overlapped by $CHCl_3$ residue).

3c: Yellow solid (28.4 mg, 65%). Mp 87-89 °C; ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 8.62 (1 H, d, *J* = 2.0 Hz), 8.24 (1 H, dd, *J* = 5.0 Hz and 1.5 Hz), 7.59 (1 H, dt, *J* = 7.5 Hz and 2.0 Hz), 7.12 (1 H, d, *J* = 5.5 Hz), 7.04 (1 H, d, *J* = 8.0 Hz and 5.0 Hz), 6.99 (1 H, s), 6.98 (1 H, d, *J* = 5.0 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 148.7, 146.8, 142.1, 140.1, 139.2, 132.8, 130.8, 127.8, 123.7, 119.5, 116.4. Structure of **3c** was independently determined by X-Ray analysis (data not shown).

3d: Yellow solid (29 mg, 67%). Mp 82-83 °C; ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 8.58 (1 H, dt, *J* = 5.0 Hz and 1.5 Hz), 7.78 (1 H, s), 7.69 (2 H, m), 7.41 (1 H, d, *J* = 5.5 Hz), 7.28 (1 H, d, *J* = 5.5 Hz), 7.16 (1 H, m); ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 152.8, 149.7, 146.7, 140.7, 139.8, 136.6, 128.1, 122.9, 119.9, 118.7, 116.8; HRMS-ESI: *m/z* calcd for $C_{11}H_8NS_2$ $[M+H]^+$ 218.0098, found 218.0109.

3e[40]**:** White solid (36.2 mg, 75%). Mp 94-95 °C; ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.69 (2 H, d, *J* = 8.0 Hz), 7.65 (2 H, d, *J* = 8.5 Hz), 7.59 (1 H, s), 7.45 (1 H, d, *J* = 5.5 Hz), 7.27 (1 H, d, *J* = 5.5 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 143.6, 140.2, 139.9, 139.1, 132.8, 128.6, 125.9, 119.6, 118.8, 117.3; 110.8; HRMS-ESI: *m/z* calcd for $C_{13}H_7NS_2Na$ $[M+Na]^+$ 263.9918, found 263.9926.

3f[40]: White solid (46.1 mg, 75%). Mp 133-134 °C; ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 8.54 (1 H, s), 8.03 (2 H, d, *J* = 8.5 Hz), 7.97 (2 H, d, *J* = 8.5 Hz), 7.47 (3 H, m), 7.41 (2 H, m), 7.35 (2 H, m); ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 141.0, 140.4, 139.2, 131.8, 131.2, 128.5, 128.4, 128.3, 126.7, 126.5, 126.1, 125.3, 121.6, 119.5.

3g[40]: White solid (40 mg, 75%). Mp 115-116 °C; ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 8.06 (1 H, d, *J* = 1.0 Hz), 7.85 (2 H, d, *J* = 8.0 Hz), 7.82 (1 H, d, *J* = 7.5 Hz), 7.75 (1 H, dd, *J* = 8.5 Hz and 2.0 Hz), 7.61 (1 H, s), 7.47 (2 H, m), 7.37 (1 H, d, *J* = 5.0 Hz), 7.27 (1 H, d, *J* = 5.5 Hz); ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 146.4, 140.2, 138.7, 133.6, 132.9, 132.2, 128.7, 128.1, 127.8, 127.0, 126.7, 126.1, 124.2, 124.1, 119.6, 115.7.

3i: White solid (18.4 mg, 40%). Mp 52-53 oC; 1H NMR (CDCl3, 500 MHz): δ 7.43 (1 H, d, J = 8.0 Hz), 7.36 (1 H, d, J = 5.0 Hz), 7.27 (2 H, m), 7.23 (1 H, dd, J = 7.0 Hz and 2.0 Hz), 7.21 (1 H, s); 13C NMR (CDCl3, 125 MHz): δ 145.1, 139.3, 136.3, 134.4, 131.2, 130.8, 130.6, 128.2, 126.4, 125.9, 119.4, 118.6, 21.1.

3j: White solid (31.8 mg, 35%). Mp 147-148 oC; 1H NMR (500 MHz, CDCl3): δ 7.73 (1 H, s), 7.47 (1 H, d, J = 5.5 Hz), 7.30 (1 H, d, J = 5.0 Hz).

3k: Pale yellow solid (37 mg, 71%). Mp 122-123 oC; 1H NMR (500 MHz, CDCl3): δ 8.46 (1 H, m), 8.13 (1 H, dq, J = 8.5 Hz and 1.5 Hz), 7.91 (1 H, dq, J = 8.0 Hz and 1.0 Hz), 7.62 (1 H, s), 7.56 (1 H, t, J = 8.0 Hz), 7.44 (1 H, d, J = 5.5 Hz), 7.28 (1 H, d, J = 5.0 Hz); 13C NMR (125 MHz, CDCl3): δ 148.8, 143.0, 140.1, 139.5, 136.5, 131.3, 129.9, 128.3, 122.1, 120.3, 119.6, 117.1; HRMS-ESI: m/z calcd for C12H7NO2S2Na [M+Na]+ 283.9816, found 283.9832.

3l[40]: White solid (31.2 mg, 55%). Mp 136-137 oC; 1H NMR (500 MHz, CDCl3): δ 7.71 (2 H, d, J = 8.5 Hz), 7.64 (2 H, d, J = 8.5 Hz), 7.56 (1 H, s), 7.41 (1 H, d, J = 5.5 Hz), 7.26 (1 H, d, J = 5.0 Hz); 13C NMR (125 MHz, CDCl3): δ 144.3, 140.1, 139.4, 138.2, 129.4 (q, J = 32.6 Hz, C-CF3), 127.9, 126.0 (q, J = 3.3 Hz, C-C-CF3), 125.9, 124.1 (q, J = 270.5 Hz, CF3), 119.6, 116.7.

3m: Yellow solid (45.6 mg, 67%). Mp 184-185 oC; 1H NMR (500 MHz, CDCl3): δ 8.54 (1 H, d, J = 9.0 Hz), 8.09 (8 H, m), 7.52 (1 H, s), 7.43 (1 H, d, J = 5.0 Hz), 7.35 (1 H, d, J = 5.0 Hz).

3n: Yellow solid (36.2 mg, 70%). Mp 116-117 oC; 1H NMR (500 MHz, CDCl3): δ 7.98 (2 H, d, J = 8.0 Hz), 7.72 (2 H, d, J = 8.5 Hz), 7.63 (1 H, s), 7.43 (1 H, d, J = 5.0 Hz), 7.28 (1 H, d, J = 5.0 Hz), 2.62 (3 H, s); 13C NMR (125 MHz, CDCl3): δ 197.2, 144.7, 140.2, 139.6, 139.2, 136.0, 129.2, 128.1, 125.6, 119.6, 116.8, 26.5.

3o: White solid (20.5 mg, 35%). Mp 65-66 oC; 1H NMR (500 MHz, CDCl3): δ 7.67 (2 H, d, J = 8.0 Hz), 7.60 (4 H, m), 7.51 (1 H, s), 7.42 (2 H, t, J = 7.5 Hz), 7.34 (2 H, d, J = 5.0 Hz), 7.24 (1 H, d, J = 5.5 Hz).

3p: Yellow solid (35.8 mg, 35%). Mp 142-143 °C; ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.38 (1 H, s), 7.36 (1 H, d, *J* = 5.5 Hz), 7.23 (1 H d, *J* = 5.0 Hz).

General procedure for the synthesis of 2,5-diarylthieno[3,2-*b*]thiophene 4a-e: Procedure for the synthesis of 2,5-diarylthieno[3,2-*b*]thiophenes **4a-e** was similar to that of 2-arylthieno[3,2-*b*]thiophenes **3**: from thieno[3,2-*b*]thiophene **1** (1.0 equiv), an aryl bromide **2** (3.0 equiv), $Pd(OAc)_2$ (0.02 equiv), and KOAc (4.0 equiv), or from a 2-arylthieno[3,2-*b*]thiophene **3** (1.0 equiv), an aryl bromide **2** (1.1 equiv), $Pd(OAc)_2$ (0.01 equiv), and KOAc (1.0 equiv).

2-(Anthracene-9-yl)-5-(4-nitrophenyl)thieno[3,2-b]thiophene ***4e*****:** From 2-(anthracene-9-yl)thieno[3,2-*b*]thiophene **3f** (31.6 mg, 0.10 mmol, 1.0 equiv), 1-bromo-4-nitrobenzene **2h** (22.1 mg, 0.11 mmol, 1.1 equiv), and $Pd(OAc)_2$ (2.2 mg, 0.01 mmol, 0.01 equiv), **4e** was isolated as an orange solid (26 mg, 60%). Mp 178-180 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.58 (1 H, s), 8.29 (2 H, d, *J* = 8.5 Hz), 8.06 (2 H, d, *J* = 8.0 Hz), 7.95 (2 H, d, *J* = 8.5 Hz), 7.83 (2 H, d, *J* = 9.0 Hz), 7.77 (1 H, s), 7.49 (2 H, t, *J* = 7.5 Hz), 7.44 (2 H, t, *J* = 7.5 Hz), 7.38 (1 H, s); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 146.6, 142.8, 142.4, 141.3, 140.9, 140.2, 131.6, 131.0, 128.6, 128.3, 127.6, 126.2, 126.1, 125.8, 125.3, 124.4, 121.2, 118.0; HRMS-ESI: *m/z* calcd for $C_{26}H_{15}NO_2S_2Na$ $[M+Na]^+$ 460.0442, found 460.0438.

4a: White solid (23 mg, 52%). Mp 184-185 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.56 (1 H, s), 8.14 (1 H, s), 8.05 (2 H, d, *J* = 8.5 Hz), 8.01 (2 H, d, *J* = 8.5 Hz), 7.90 (2 H, d, *J* = 8.5 Hz), 7.83 (2 H, t, *J* = 8.0 Hz), 7.72 (1 H, s), 7.45 (6 H, m), 7.37 (1 H, s); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 145.9, 141.3, 140.8, 138.6, 133.7, 132.9, 132.3, 131.9, 131.2, 128.7, 128.5, 128.4, 128.5, 127.8, 126.7, 126.5, 126.2, 126.1, 125.3, 124.3, 124.2, 121.9, 115.8 Missing

4b: Orange solid (24 mg, 55%). Mp 154-155 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.57 (1 H, s), 8.54 (1 H, d, *J* = 2.0 Hz), 8.16 (1 H, dt, *J* = 8.0 Hz and 1.0 Hz), 8.06 (2 H, d, *J* = 8.5 Hz), 8.00 (1 H, dt, *J* = 7.5 Hz and 1.0 Hz), 7.95 (2 H, d, *J* = 8.0 Hz), 7.74 (1 H, s), 7.62 (1 H, t, *J* = 8.0 Hz), 7.49 (2 H, t, *J* = 8.0 Hz), 7.44 (2 H, t, *J* = 7.5 Hz), 7.38 (1 H, s); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 167.8, 148.9, 142.4, 142.2, 141.2, 139.3, 136.5, 137.1, 131.3, 131.1, 130.8, 130.0, 128.7, 128.6, 128.3, 127.8, 126.3, 126.2, 126.0, 125.3, 122.1. 121.7, 120.3, 117.2.

4c: Orange solid (17.7 mg, 45%). Mp 142-143 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.98 (1 H, s), 8.56 (2 H, m), 8.04 (2 H, d, *J* = 8.5 Hz), 7.96 (2 H, d, *J* = 8.5 Hz), 7.92 (2 H, dt, *J* = 8.0 Hz and 1.5 Hz), 7.62 (1 H, s), 7.49 (2 H, t, *J* = 7.0 Hz), 7.44 (2 H, t, *J* = 6.5 Hz), 7.35 (2 H, m); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 148.7, 146.9, 141.7, 141.5, 141.2, 139.1, 132.9, 131.8, 131.1, 130.9, 128.6, 128.4, 128.0, 126.4, 126.2, 125.4, 123.8, 121.8, 116.6.

4d: White solid (18.9 mg, 41%). Mp 166-167 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.57 (1 H, s), 8.05 (2 H, d, *J* = 8.0 Hz), 7.97 (2 H, d, *J* = 8.5 Hz), 7.79 (2 H, d, *J* = 8.0 Hz), 7.68 (2 H, m), 7.62 (1 H, s), 7.49 (2 H, t, *J* = 8.0 Hz), 7.43 (2 H, t, *J* = 8.0 Hz), 7.36 (1 H, s); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 143.7, 141.9, 141.2, 139.3, 138.2, 131.8, 131.2, 129.5 (q, *J* = 35.7 Hz, C-CF_3), 128.6, 128.3, 126.4, 126.2, 126.0 (q, *J* = 35.7 Hz, C-C-CF_3), 125.9, 125.4, 121.8, 116.9.

General procedure for the synthesis of 2,3-diarylthieno[3,2-*b*]thiophene 5a-d: Procedure for the synthesis of 2,3-diarylthieno[3,2-*b*]thiophenes **5a-d** was similar to that of 2-arylthieno[3,2-*b*]thiophenes **3**: from thieno[3,2-*b*]thiophene **1** (1.0 equiv), a 4-EWG-aryl bromide **2** (3.0 equiv), [PdCl(C_3H_5)dppb] (0.01 equiv), and KOAc (4.0 equiv), or from a 2-(4-EWG)-arylthieno[3,2-*b*]thiophene **3** (1.0 equiv), an aryl bromide **2** (1.1 equiv), $Pd(OAc)_2$ (0.01 equiv), and KOAc (2.0 equiv).

2-(4-Nitrophenyl)-3-(4-cyanophenyl)thieno[3,2-b]thiophene ***5b***: From 2-(4-nitrophenyl)thieno[3,2-*b*]thiophene **3h** (52.2 mg, 0.20 mmol, 1.0 equiv) and 1-bromo-4-cyanobenzene **2e** (40 mg, 0.22 mmol, 1.1 equiv), **5b** was isolated as a white solid (32.5 mg, 45%). Mp 187-189 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.16 (2 H, d, *J* = 9.0 Hz), 7.70 (2 H, d, *J* = 8.5 Hz), 7.54 (2 H, d, *J* = 8.0 Hz), 7.49 (1 H, d, *J* = 5.0 Hz), 7.45 (2 H, d, *J* = 9.0 Hz), 7.35 (2 H, d, *J* = 5.0 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 147.2, 140.6, 139.4, 138.8, 138.4, 132.9, 132.6, 130.4, 129.9, 129.8, 129.7, 128.3, 128.1, 124.4, 124.1, 119.9, 118.3, 112.1; HRMS-ESI: *m/z* calcd for $C_{19}H_{10}N_2O_2S_2Na$ $[M+Na]^+$ 385.0081, found 385.0095.

2,5-Di(4-acetylphenyl)thieno[3,2-b]thiophene ***5d***: From thieno[3,2-*b*]thiophene **1** (70.0 mg, 0.5 mmol, 1.0 equiv), 4-bromoacetophenone **2n** (297 mg, 1.5 mmol, 3.0 equiv), and [PdCl(C_3H_5)dppb] (3 mg, 0.05 mmol, 0.01 equiv), **5d** was isolated as a pale yellow solid (65.8 mg, 35%). Mp 166-168 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 7.97 (2 H, d, *J* = 8.5 Hz), 7.88 (2 H, d, *J* = 8.0 Hz), 7.54 (2 H, d, *J* = 8.0 Hz), 7.45 (1 H, d, *J* = 5.0 Hz), 7.41 (2 H, d, *J* = 8.5 Hz), 7.34 (1 H, d, *J* = 5.0 Hz), 2.63 (3 H, s), 2.59 (3 H, s); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 197.6, 197.5, 139.9, 139.1, 137.7, 136.3, 136.1, 130.6, 130.4, 129.4, 129.2, 129.0, 128.7, 127.5, 119.9, 26.7, 26.5; HRMS-ESI: *m/z* calcd for $C_{22}H_{17}O_2S_2$ $[M+H]^+$ 377.0670, found 377.0668.

5a: White solid (28.7 mg, 42%). Mp 134-135 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 7.69 (2 H, d, *J* = 8.5 Hz), 7.58 (2 H, d, *J* = 8.5 Hz), 7.53 (2 H, d, *J* = 8.5 Hz), 7.46 (1 H, d, *J* = 5.5 Hz), 7.38 (2 H, d, *J* = 8.5 Hz), 7.34 (1 H, d, *J* = 5.5 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 145.1, 145.9, 141.3, 139.3, 138.6, 138.2, 132.9, 132.6, 129.8, 129.7, 128.0, 119.9, 118.4, 111.9, 111.7; HRMS-ESI: *m/z* calcd for $C_{20}H_{10}N_2S_2Na$ $[M+Na]^+$ 365.0183, found 365.0198.

5c: Yellow solid (30.6 mg, 40%). Mp 192-193 oC; 1H NMR (CDCl3, 500 MHz): δ 8.27 (2 H, d, J = 9.0 Hz), 8.17 (2 H, d, J = 9.0 Hz), 7.60 (2 H, d, J = 9.0 Hz), 7.50 (1 H, d, J = 5.0 Hz), 7.45 (2 H, d, J = 9.0 Hz), 7.37 (1 H, d, J = 5.0 Hz); 13C NMR (CDCl3, 125 MHz): δ 147.3, 138.5, 130.0, 129.9, 129.8, 128.4, 124.5, 124.2, 120.0.

General procedure for the synthesis of 2,3,5-triarylthieno[3,2-*b*]thiophene 6a-d: Procedure for the synthesis of 2,3,5-triarylthieno[3,2-*b*]thiophenes **6a-d** was similar to that of 2-arylthieno[3,2-*b*]thiophenes **3**: from thieno[3,2-*b*]thiophene **1** (1.0 equiv), an aryl bromide **2** (4.5 equiv), [PdCl(C_3H_5)dppb] (0.02 equiv), and KOAc (6.0 equiv), or from a 2-arylthieno[3,2-*b*]thiophene **3** (1.0 equiv), an aryl bromide **2** (3.0 equiv), $Pd(OAc)_2$ (0.02 equiv), and KOAc (4.0 equiv).

2-(Anthracene-9-yl)-5,6-di(4-nitrophenyl)thieno[3,2-b]thiophene ***6a***: From 2-(anthracene-9-yl)thieno[3,2-*b*]thiophene **3f** (63.2 mg, 0.20 mmol, 1.0 equiv), 1-bromo-4-nitrobenzene **2h** (120.5 mg, 0.60 mmol, 3.0 equiv), and $Pd(OAc)_2$ (0.9 mg, 0.004 mmol, 0.02 equiv), **6a** was obtained as a pale yellow solid (22.3 mg, 20%). Mp 195-196 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.59 (1 H, s), 8.25 (2 H, d, *J* = 9.0 Hz), 8.22 (2 H, d, *J* = 8.5 Hz), 8.07 (2 H, d, *J* = 8.0 Hz), 7.94 (2 H, d, *J* = 8.5 Hz), 7.68 (2 H, d, *J* = 9.0 Hz), 7.54 (2 H, d, *J* = 9.0 Hz), 7.50 (2 H, t, *J* = 7.0 Hz), 7.45 (1 H, s), 7.43 (2 H, t, *J* = 7.0 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 147.4, 147.3, 142.5, 142.3, 141.3, 140.5, 138.6, 138.4, 134.3, 131.7, 131.1, 130.2, 130.0, 129.9, 129.5, 128.9, 128.5, 127.3, 126.4, 126.1, 125.4, 124.5, 124.3, 122.1, 114.1; HRMS-ESI: *m/z* calcd for $C_{32}H_{18}N_2O_4S_2Na$ $[M+Na]^+$ 581.0600, found 581.1100.

2,3,5-Tri(4-acetylphenyl)thieno[3,2-b]thiophene ***6d***: From thieno[3,2-*b*]thiophene **1** (70.0 mg, 0.5 mmol, 1.0 equiv), 4-bromoacetophenone **2n** (445.5 mg, 2.25 mmol, 4.5 equiv), [PdCl(C_3H_5)dppb] (6.1 mg, 0.01 mmol, 0.02 equiv), **6d** was obtained as a pale yellow solid (113.6 mg, 46%). Mp 178-180 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.00 (4 H, d, *J* = 8.5 Hz), 7.88 (2 H, d, *J* = 8.5 Hz), 7.72 (2 H, d, *J* = 8.0 Hz), 7.67 (1 H, s), 7.56 (2 H, d, *J* = 8.0 Hz), 7.42 (2 H, d, *J* = 8.5 Hz), 2.64 (3 H, s), 2.63 (3 H, s), 2.60 (3 H, s); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 197.4, 197.3, 197.1, 144.6, 141.7, 140.5, 139.5, 138.6, 138.5, 136.6, 136.3, 129.4, 129.3, 129.2, 129.1, 128.8, 125.6, 117.1, 26.6, 26.5 (br); HRMS-ESI: *m/z* calcd for $C_{30}H_{23}O_3S_2$ $[M+H]^+$ 495.1089, found 495.1053.

6b: Pale yellow solid (35.5 mg, 32%). Mp 184-185 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.10 (1 H, s), 7.91 (1 H, d, *J* = 9.0 Hz), 7.87 (2 H, t, *J* = 6.5 Hz), 7.79 (1 H, dd, *J* = 8.5 Hz and 2.0 Hz), 7.71

(2 H, m), 7.62 (2 H, d, *J* = 8.5 Hz), 7.59 (2 H, d, *J* = 8.5 Hz), 7.53 (1 H, d, *J* = 9.0 Hz), 7.51 (1 H, d, *J* = 9.0 Hz), 7.47 (2 H, d, *J* = 8.5 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 146.4, 140.6, 138.9, 138.5, 133.5, 133.0, 131.6, 130.1, 129.5, 129.3, 128.8, 128.1, 127.8, 126.9, 126.4, 126.0 (q, *J* = 3.75 Hz, C-C-CF_3), 125.7 (q, *J* = 3.75 Hz, C-C-CF_3), 124.4, 123.8, 115.9.

6c: **P**ale yellow solid (125.8 mg, 46%). Mp 201-202 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.49 (1 H, d, *J* = 1.5 Hz), 8.34 (1 H, s), 8.25 (1 H, d, *J* = 9.0 Hz), 8.21 (1 H, s), 8.18 (2 H, d, *J* = 8.5 Hz), 7.94 (1 H, d, *J* = 8.0 Hz), 7.74 (1 H, d, *J* = 7.5 Hz), 7.71 (1 H, s), 7.61 (3 H, m), 7.50 (1 H, t, *J* = 8.0 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 148.9, 148.8, 148.6, 143.6, 141.0, 139.3, 138.6, 135.8, 135.2, 135.0, 134.9, 131.4, 130.3, 130.2, 130.0, 129.4, 124.0, 123.7, 123.3, 123.1, 122.7, 120.5, 117.4.

Procedure for the synthesis of 2,3,5,6-tetra(4-acetylphenyl)thieno[3,2-*b*]thiophene 7: Thieno[3,2-*b*]thiophene **1** (70.0 mg, 0.5 mmol, 1.0 equiv), KOAc (294 mg, 3.0 mmol, 6.0 equiv), and 4-bromoacetophenone **2n** (495 mg, 2.5 mmol, 5.0 equiv) were dissolved in DMAc (5.0 mL) which was saturated with argon. To the resulting solution was added $PdCl(C_3H_5)$(dppb) (6.1 mg, 0.01 mmol, 0.02 equiv). The reaction mixture was heated at 140 °C under argon atmosphere until TLC (*n*-hexane/ethyl acetate, 95:5 v/v) showed the nearly complete consumption of the starting material (32 h). The reaction mixture was cooled to room temperature and filtered to remove insoluble impurities. The filtrate was diluted with ethyl acetate, washed with water (3 times), dried over Na_2SO_4 and concentrated under reduced pressure by rotary evaporation. The residue was purified by SiO_2-column chromatography (*n*-hexane/ethyl acetate, 98:2 v/v) to give **7** as a pale yellow solid (76.5 mg, 25%). Mp 221-223 °C; ^{1}H NMR ($CDCl_3$, 500 MHz): *δ* 8.00 (2 H, d, *J* = 8.0 Hz), 7.88 (2 H, d, *J* = 8.5 Hz), 7.56 (2 H, d, *J* = 8.0 Hz), 7.41 (2 H, d, *J* = 8.0 Hz), 2.64 (3 H, s), 2.59 (3 H, s); ^{13}C NMR ($CDCl_3$, 125 MHz): *δ* 197.4, 197.3, 139.8, 139.6, 139.2, 138.5, 136.6, 136.4, 130.8, 129.3, 129.2, 129.1, 128.8, 26.7, 26.6; HRMS-ESI: *m/z* calcd for $C_{38}H_{29}O_4S_2$ $[M+H]^+$ 613.1507, found 613.1547.

Compound **7** can also be synthesized from 2,3,5-tri(4-acetylphenyl)thieno[3,2-*b*]thiophene ***6d*** and 4-bromoacetophenone **2n** with comparable yield based on the same procedure as for 2-arylthieno[3,2-b]thiophenes **3**.

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ACKNOWLEDGMENT

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(38) These crystal structures was deposed at the Cambridge Crystallographic Data Centre and have been assigned to the deposition number (CCDC 1508675 : **4a**, CCDC 1508674 : **5c**, CCDC 1519729 : **6a**). They can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif.
(40) For further arylations, these compounds were synthesized with high scale and obtained similar yield as small scale. Particularly, scale of **3e** is 0.28 g, **3g** is 0.3 g, **3l** is 0.45 mg, and **3f** is 0.5 mg.

Keywords: Pd catalyst • C-H Functionalization • thieno[3,2-*b*]thiophenes • Site-selective • CMD

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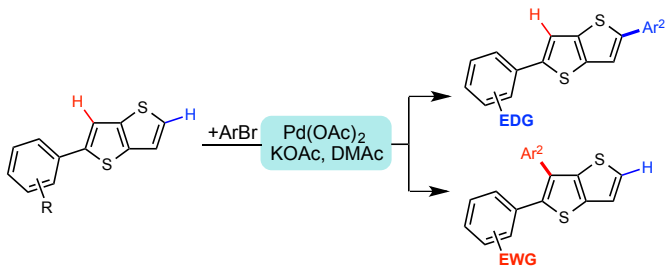

T. M. Ha Vuong, Didier Villemin, Hung-Huy Nguyen, Tin Thanh Le, Tung T. Dang, Hien Nguyen**

Page No. – Page No.

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