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One-Pot Synthesis of 2,4-Diacyl Thiophenes from α-Oxo Ketene Dithioacetals and Propargylic Alcohols

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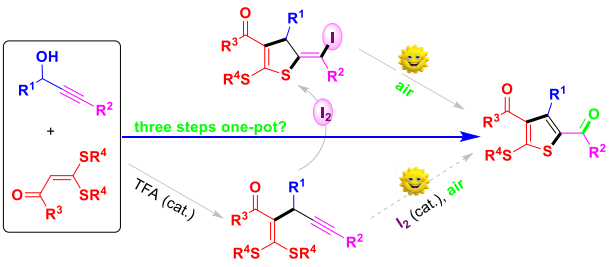


Abstract: Although thiophenes having various functionalities are the basic structural units in numerous bioactive compounds and optoelectronic materials, synthetic routes to acylated thiophenes from aliphatic sulfur-containing starting materials are still rare. In particular, there have been no reports concerning the straightforward synthesis of 2,4-diacylthiophenes from alkynes. Herein, we describe a highly efficient and metal-free three-step one-pot synthetic approach to tetrasubstituted

2,4-diacylthiophenes from propargylic alcohols and α-oxo ketene dithioacetals. This research features a relay catalysis system that integrates Brønsted acid-catalyzed propargylation, molecular iodine-mediated electrophilic cyclization and visible light-induced deiodinative oxygenation. The 2,4-diacylthiophenes serving as the key starting materials are readily synthesized, enabling facile construction of analogues of related biologically active compounds and the modular assembly of tetrasubstituted thienothiophenes.

Introduction

There are ongoing efforts to simplify synthetic methodologies for the construction of functional organic molecules, as well as to optimize reaction conditions, improve substrate accessibility and enhance atom and step economies.[1] Both relay catalysis and sequential transformations are useful approaches to these goals.[2] Relay catalysis, especially multiple relay catalysis, delivers a range of products that would not be accessible with the use of a single catalyst.[3] Sequential transformations, which are known to chemists under the term "one-pot reactions" and consist of domino reactions and consecutive reactions, are able to produce the maximum possible structural complexity using a minimum number of pots.[4] A successful sequential transformation will generate the desired organic compounds in good yields from simple starting materials in few steps and with a significant reduction in the amount of undesired by-products. Domino reactions (also described as tandem or cascade reactions) are an especially efficient type of sequential transformation that have frequently been reported to have significant usefulness.[4b] Comparatively, consecutive reactions have not been as helpful as domino reactions, because the intermediate structures in such series are often stable and

isolatable, such that subsequent reactions may not proceed in the absence of additional promoters. Therefore, the examples of consecutive reactions combined with multiple relay catalysis have drawn increasing interest, as a result of the challenges associated with the minimal compatibility of the reagents and catalysts for specific reaction conditions.[5]

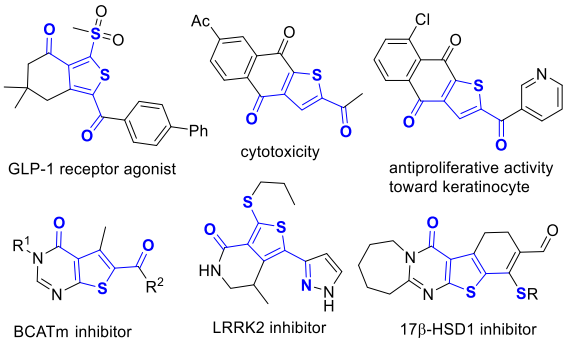
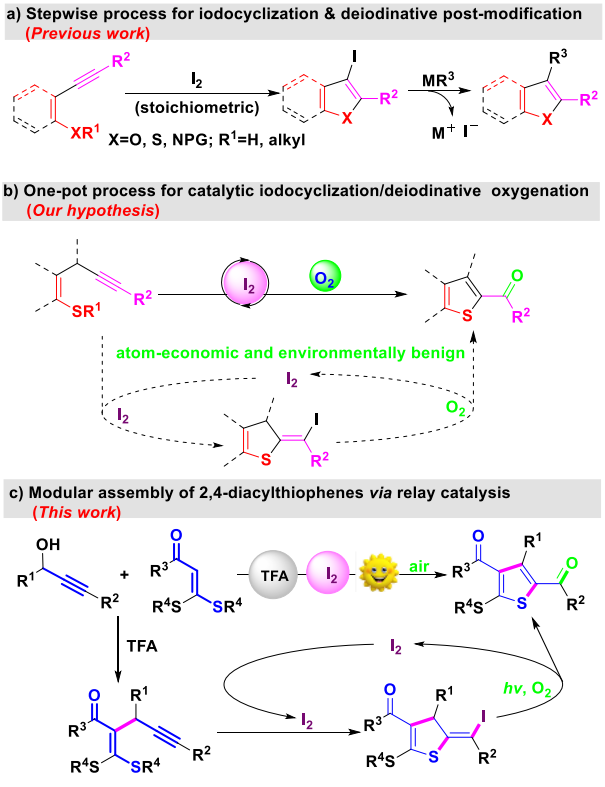


Fig. 1 Selected examples of bioactive molecules containing 2,4-diacyl thiophene scaffold.

Thiophene rings are found in numerous organic compounds, including natural products, bioactive substances, optoelectronic materials and synthetic intermediates.[6, 7] Thiophene derivatives are also widely used as conductive organic materials due to their structural rigidity and electronic properties.[8] As a result, there have been many attempts to develop reliable, high yield processes for synthesizing functionalized thiophenes.[9] Thiophenes that are acylated at the 2- and 4-positions are especially important structural motifs in numerous bioactive molecules (Figure 1).[10] The traditional approach to obtaining 2-acylthiophenes relies on late-stage modification via the Friedel-Crafts acylation of thiophenes using specific Lewis acid promotors combined with acyl anhydrides or acid chlorides, which often provides poor atom economy and/or deleterious environmental effects.[11] However, the synthesis of 2-acylthiophenes has received little attention and, to the best of our knowledge, there have been no reports to date concerning the straightforward synthesis of 2,4-diacylthiophenes from

alkynes.[12]

The intramolecular electrophilic cyclization of alkynes possessing a nucleophile in proximity to the carbon–carbon triple bond has proven to be a particularly efficient strategy for constructing functionalized heterocyclic rings (Scheme 1a).[13] Based on this approach, a number of methodologies for synthesizing fused five-membered heterocycles bearing 3-iodo substituents through the iodocyclization of *o*-alkynylized anilines, aromatic ethers and thioethers have been developed.[9a, 14] Similarly, aliphatic acetylenic analogues have been successfully employed to synthesize substituted five-membered N- and O-heterocycles.[15] However, there has been very limited success with regard to the production of thiophene counterparts using this methodology. [16]



Scheme 1. Syntheses of substituted heterocycles *via* iodocyclization. (a) Traditional strategies; (b) idea of this work; and (c) feature of this work.

Theoretically, stoichiometric iodine reagents are necessary in the iodocyclization step. Moreover, the iodocyclization products frequently need to be further converted into other functional targeted molecules via deiodinative transformations. Within a two-step operation comprising iodocyclization followed by deiodinative transformation, potentially toxic halide waste products are generated twice.[15h] We therefore envisioned that a catalytic iodocyclization/deiodinative transformation would greatly reduce the amount of iodine reagent required and thus limit the production of halide waste. This would be significantly beneficial in terms of atom economy and environmental impact (Scheme 1b). Herein, we describe a reliable one-pot catalytic protocol for the direct assembly of 2,4-diacyl thiophenes from propargyl alcohols and α-oxo ketene dithioacetals through relay catalysis, using trifluoroacetic acid (TFA), molecular iodine and visible light (Scheme 1c).

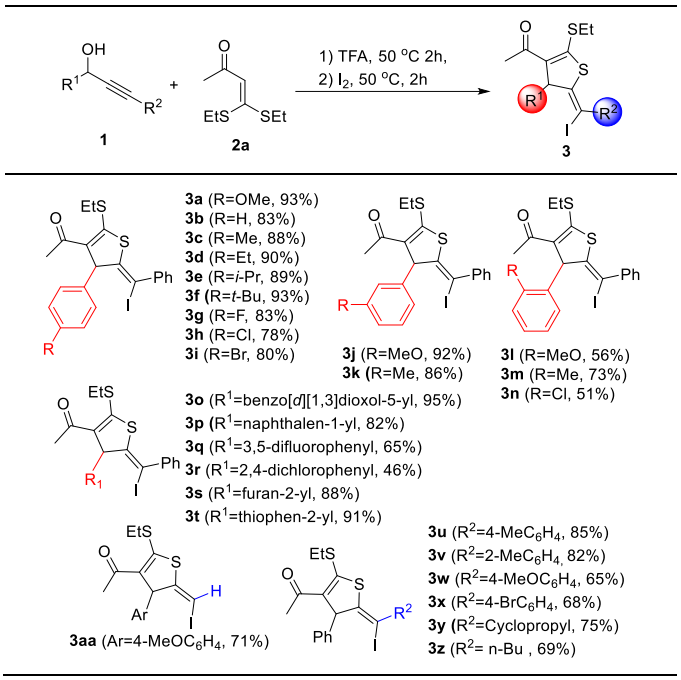
Results and discussion

α-Oxo ketene dithioacetals are versatile sulfur-containing reagents that have been widely used as 1,3-bis-electrophilic three-carbon synthons and two-carbon fragments equivalent to polarized alkenes.[17, 18] Recently, we reported that α-oxo ketene dithioacetals exhibit unique behavior as C,O-bis-nucleophilic two-carbon synthons.[19] These compounds could also serve as C,S-bis-nucleophiles in specific cascade annulations in conjunction with appropriate bis-electrophiles.[18] Thus, we examined the acid-catalyzed sequential propargylation/iodocyclization of α-oxo ketene dithioacetal **2a** using propargylic alcohol **1a** (for details of the reaction optimization process, see Table S1).[20]

The general feasibility of the propargylation/iodocyclization of α-oxo ketene dithioacetals was

assessed by examining the reactions of substrates **2**, having a variety of substituents, with a series of propargyl alcohols **1** under the optimized conditions. Propargyl alcohols containing different R^1 and R^2 substituents were initially investigated through reactions with **2a** (Table 1). The substituents at the *para*- or *meta*-positions on the α-phenyl moiety in propargyl alcohols **1a**–**1k** were found to have insignificant effects on reactivity, and the majority of the alcohols gave very good yields (**3a**–**3k**).

Table 1. Scope of propargyl alcohols for the propargylation/iodocyclization.[a]



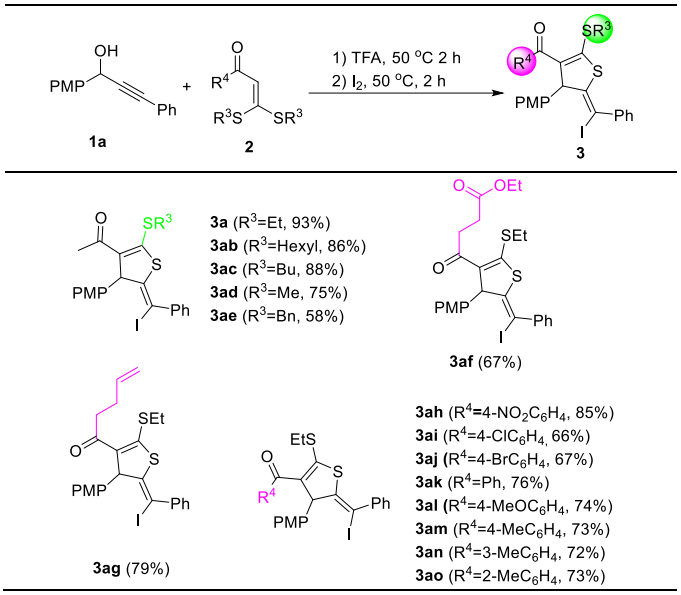
[a] *Conditions*: **1** (0.36 mmol), **2a** (0.3 mmol), TFA (0.06 mmol), and CH_3CN (1 mL) at 50 ℃ for 2 h, then I_2 (0.3 mmol) was added and further reacted for 2 h. Isolated yields are given. TFA: trifluoroacetic acid.

In contrast, the presence of *ortho*-substituents resulted in lower yields owing to the effects of steric hindrance (**3l**–**3n** vs **3a**–**3k**). A series of α-fused aryl or heteroaryl-derived propargyl alcohols was also evaluated. Those compounds having aryl groups with electron-donating substituents were determined to give better results than those with electron-withdrawing groups, because the former provided a conjugation effect in conjunction with the α-aryl moiety that stabilized the propargyl

carbocation (**3o**, **3p**, **3s**, **3r** vs **3q**−**3r**). Trials in which the distal group on the alkyne moiety in the propargyl alcohol was an alkyl-substituted aryl, such as 4-methylphenyl or 2-methylphenyl, gave the desired products in very good yields (**3u**−**3v**), while the 4-methoxyphenyl and 4-bromophenyl-substituted counterparts only led to moderate yields (**3w**−**3x**). These results imply that the conjugation effect of R^2 in these propargyl alcohols had a negative effect on the reaction. The yields obtained from propargyl alcohols bearing a distal alkyl or hydrogen of alkyne moiety were slightly inferior to those obtained from reactants with a distal phenyl group (**3y**−**3z** vs **3b**, **3aa** vs **3a**).

The use of α-oxoketene dithioacetals containing different R^3 and R^4 substituents was subsequently investigated based on reactions with **1a** (Table 2). A bis(benzylthio)-substituted dithioacetal gave the product in lower yield than the other compounds (**3ae** vs **3a**−**3ad**) due to the relatively low stability of α-oxoketene dithioacetals containing the benzylthio group in the presence of iodine. In contrast, α-oxoketene dithioacetals with small α-alkyl groups were superior to those with bulky groups (**3a** vs **3af**−**3ag**) because of the effects of steric hindrance. The yields from α-oxoketene dithioacetals containing α-aryl groups were slightly inferior to those produced from analogues containing α-alkyl moieties (**3ah**−**3ao** vs **3a**−**3ad**). This result is attributed to decreased polarization of the carbon−carbon double bond in the α-oxoketene dithioacetal because of the conjugation effect. This, in turn, reduced the nucleophilicity of the α-aryl α-oxoketene dithioacetals relative to the α-alkyl counterparts. X-ray single-crystal analysis established that the iodo carbon-carbon double bond in **3ad** had the *E* configuration (see the Supporting Information).[20, 21] The stereochemistry of each of the other compounds in series **3** was assigned by comparison with that of **3ad**.

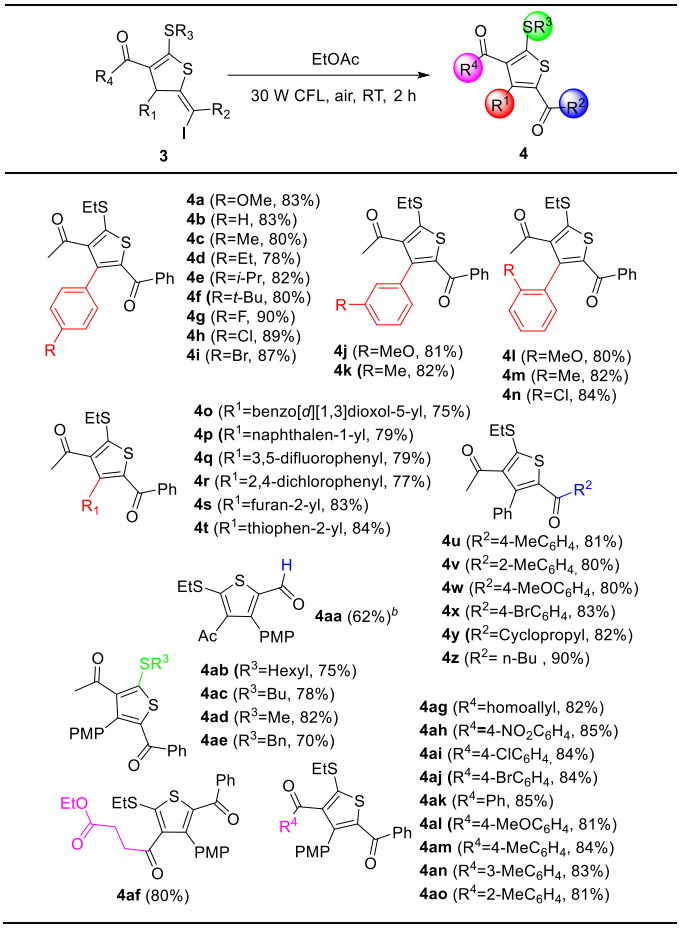
Table 2. Scope of ketene dithioacetals for the propargylation/iodocyclization.[a]



[a] *Conditions*: **1a** (0.36 mmol), **2** (0.3 mmol), TFA (0.06 mmol), and CH_3CN (1 mL) at 50 ℃ for 2 h, then I_2 (0.3 mmol) was added and further reacted for 2 h. Isolated yields are given. PMP: *para*-methoxyphenyl. TFA: trifluoroacetic acid.

When a solution of **3a** in deuterated chloroform was allowed to stand in contact with air for several days, the compound partially converted into the deiodinatively oxygenated product, whereas the same compound in its pure state was stable in air. We therefore suspected that the deiodinative oxygenation was triggered by exposure to visible light. Under optimal conditions (Table S2),[20] this same photoinduced reaction proceeded rapidly in conjunction with exposure to a 30 W household compact fluorescent lamp, using ethyl acetate as the solvent in an ambient atmosphere.[22] As shown in Table 3, all the specimens underwent the deiodinative oxygenation smoothly to give the desired diacyl thiophenes **4** in mostly good to excellent yields. There were only two exceptions (**4aa**, **4ae**) for which the isolated yields were lower than 75%, because of either the instability of formyl toward aerobic oxidations (**4aa**) or the instability of the benzylthio group in the presence of the iodine species formed *in situ* (Table 2, **3ae**).

Table 3. Reaction scope for the deiodinative oxygenations.[a]

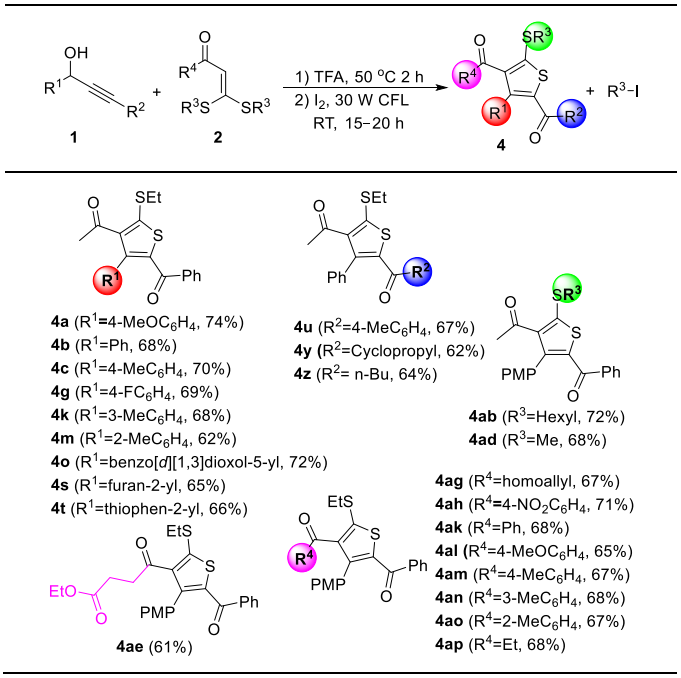


[a] *Conditions*: **3** (0.2 mmol), EtOAc (2 mL), 30 W CFL, RT for 2 h. Isolated yields are given. The reaction vessel was general heavy-wall glass flask. [b] 0.15 mmol of **3aa** was used. CFL: household compact fluorescent lamp that was a white household light bulb. PMP: *para*-methoxyphenyl.

After the optimized conditions for the propargylation, iodocyclization and photoinduced deiodinative oxygenation were established, we focused on developing a sequential relay catalysis to enable the efficient synthesis of 2,4-diacylthiophenes through a one-pot operation (Table S3).[20] It was found to be necessary to dilute the reaction mixtures in the second stage and to prolong the radiation time to 15–20 h because these mixtures became darker during the propargylation step, thereby blocking light transmission. The addition of a small amount of silica gel (such as typically used for

column chromatography) proved to be an efficient solution for preliminary decolorization. Under optimal conditions, the relay catalysis was accomplished very successfully and some representative results are summarized in Table 4. The isolated yields reached 62%–74%, which correspond to average yields of 85%–90.5% for each step of the three-step consecutive reaction process. This one-pot synthesis technique completely avoids the need to isolate and purify any intermediate products or to provide a stoichiometric amount of any additive, thereby reducing the time, resources and energy requirements.

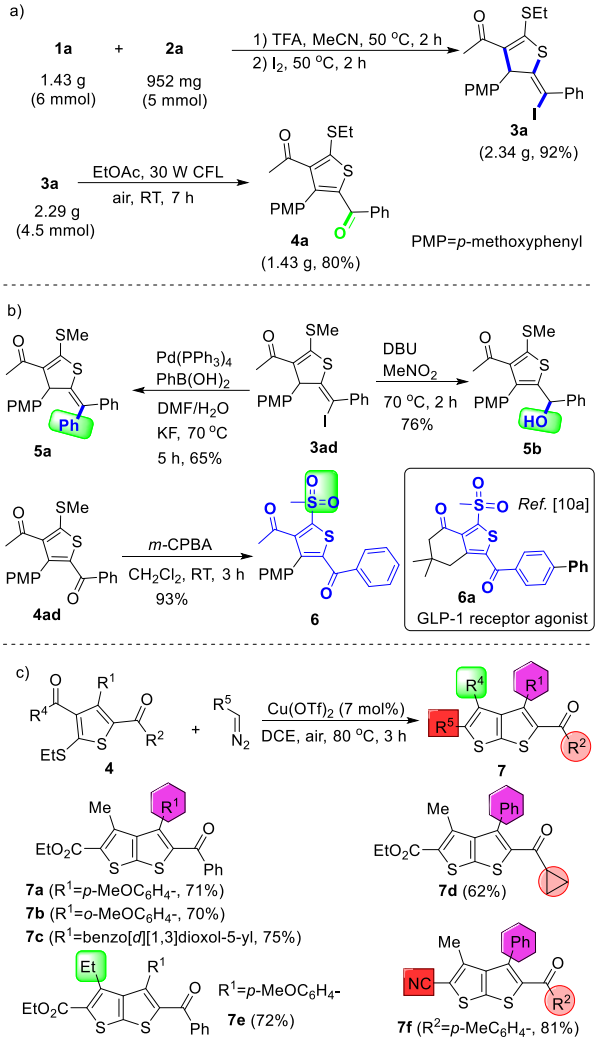
Table 4. One-pot synthesis of substituted 2,4-diacylthiophenes.[a]



[a] *Conditions*: **1** (0.36 mmol), **2** (0.3 mmol), TFA (0.06 mmol), and CH_3CN (1 mL), at 50 °C for 2h. EtOAc (10 mL), I_2 (0.18 mmol) and 350 mg of silica gel (200−300 mesh) were then added, and the reaction flask was magnetically stirred and irradiated with a 30 W CFL at RT for 15–20 h (typically, 15 h). The reaction vessel and light source were same as that shown in Table 3. Isolated yields are given. PMP: *para*-methoxyphenyl.

Gram-scale preparations of **3** and **4** were found to be feasible. Scaling the synthesis of **3a** by as

much as 20-fold and that of **4a** by 15-fold had no obvious effect on the reaction efficiency, further attesting to the robust nature of this process (Scheme 2a).



Scheme 2. Scale-up Syntheses and Transformations. (a) Scale-up syntheses of **3a** and **4a**; (b) late-stage functionalizations of **3ad** and **4ad**; and (c) modular syntheses of tetrasubstituted thieno[2,3-*b*]thiophenes.

The late-stage transformations of **3ad** and **4ad** were further explored (Scheme 2b). The Suzuki coupling of **3ad** with phenylboronic acid readily gave the tetrasubstituted dihydrothiophene derivative **5a** bearing an exocyclic double bond, while base-catalyzed deiodinative hydrolysis of **3ad** delivered

the tetrasubstituted thiophen-2-yl carbinol **5b** in good yield. The highly efficient oxidation of **4ad** with *m*-chloroperbenzoic acid (*m*-CPBA) furnished sulfone **6** containing the 3-acyl-5-aroyl-2-(methylsulfonyl)thiophene scaffold that exactly maps onto the key substructure of GLP-1 receptor agonist **6a**.[10a]

Notably, the modular synthesis of tetrasubstituted thieno[2,3-*b*]thiophenes was particularly convenient when using **4** as precursors (Scheme 2c). Thieno[2,3-*b*]thiophenes are useful building blocks for the construction of organic semiconductors possessing different conjugation lengths.[6d] Although the synthesis of thieno[2,3-*b*]thiophene and its derivatives has been previously achieved using several different protocols,[6, 23] these frequently suffer from one or more disadvantages, such as tedious multistep syntheses, harsh conditions, relatively low total yields and product mixtures containing symmetric substituents or lack of functional groups. The present protocol provides a facile modular synthetic approach to diverse functionalized thieno[2,3-*b*]thiophenes bearing four different substituents in a four-step two-pot operation under mild conditions.

Conclusion

In conclusion, we have established a versatile protocol for the synthesis of structurally diverse 2,4-diacylthiophenes through relay catalysis combining chemo- and photo-catalysis. This method provides a facile approach to structures of interest to researchers in the life sciences and materials sciences, using inexpensive reagents and easily accessible precursors together with a minimum number of pots. Under visible light irradiation, a sub-stoichiometric amount of I_2 efficiently realized the cascade iodocyclization/deiodinative transformation of alkyne thioether intermediates for the first time. The reactions were demonstrated to be extremely reliable and to give high yields while enabling

the synthesis to proceed in either a stepwise or consecutive manner under mild conditions. The products of iodocyclization could be converted to functionalized tetrasubstituted dihydrothiophene and thiophene derivatives. Our strategy of consecutive reactions permits the facile modular synthesis of diversely functionalized thieno[2,3-*b*]thiophenes, and thus opens up avenues for the development of synthetic methodologies for heterocycles from simple precursors via relay catalysis.

Experimental Section

General methods

Unless otherwise noted, commercially available reagents were used as received. Propargylic alcohols **1a**−**1z** and α-oxo ketene dithioacetals **2a**−**2o** were prepared according to literature procedures.[19, 24, 25] All solvents for chromatographic separations were distilled before use. Solvents for the water-free reactions were dried with standard procedures and stored with Schlenk flasks over molecular sieves. Column chromatography was carried out with 200−300 mesh silica gel. Thin-layer chromatography (TLC) was performed on glass-backed silica plates. UV light, I_2, and solutions of 2, 4-dinitrophenylhydrazine were used to visualize products. Concentrating a solution under reduced pressure refers to distillation using a rotary evaporator attached to a vacuum pump (3 – 10 mmHg). Products obtained as solids or high boiling oils were dried under vacuum (1 – 3 mmHg). ^{1}H and ^{13}C NMR spectra were recorded on a 600 MHz NMR spectrometer at 293 K and the chemical shifts (δ) were internally referenced by the residual solvent signals relative to tetramethylsilane ($CDCl_3$ at 7.26 ppm for ^{1}H, and at 77.00 ppm for ^{13}C). Data are reported as (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, b = broad; coupling constant(s) in Hz; integration). The yields in the text refer to isolated yields of compounds.

General procedure for the synthesis of 3

To the solutuion of **1** (0.36 mmol) and **2** (0.3 mmol) in CH_3CN (1 mL) was added trifluoroacetic acid (5 μL, 0.06 mmol) with stirring. The reaction mixture was continually stirred at 50 ℃ in an oil bath until **1** was consumed as indicated by TLC (*ca*. 2 h). Iodine (76 mg, 0.3 mmol) was added. The solution was stirred at 50 ℃ in the oil bath until the intermediate was consumed as indicated by TLC (*ca*. 2 h). The mixture was cooled to RT, diluted with a saturated aqueous solution of sodium thiosulfate (5 mL), and extracted with ethyl acetate (3 × 5 mL). The combined organic layer was washed with water and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate as eluent) to give the desired product **3**.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3a**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3a** (142 mg, 93%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.43 (d, *J* = 8.6 Hz, 2H), 7.28 – 7.24 (m, 2H), 7.23 – 7.19 (m, 3H), 6.80 (d, *J* = 8.6 Hz, 2H), 5.10 (s, 1H), 3.73 (s, 3H), 2.80 (d, *J* = 7.4 Hz, 2H), 2.00 (s, 3H), 1.23 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.3, 159.1, 156.3, 143.3, 142.8, 130.9 (CH×2), 130.0 (CH×2), 128.9 (CH×2), 128.6 (CH×2), 128.5 (CH×2), 113.9 (CH×2), 64.8, 55.2, 29.5, 28.2, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{22}IO_2S_2$ 509.0100; found 509.0094.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-phenyl-4,5-dihydrothiophen-3-yl)ethan-1-one (**3b**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3b** (119 mg, 83%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.60 (d, *J* = 7.2 Hz, 2H), 7.34 (t, *J* = 6.6 Hz, 2H), 7.32 (d, *J* = 7.9 Hz, 2H), 7.28 (m, 4H), 5.23 (s, 1H), 2.88 (q, *J* = 7.4 Hz, 2H), 2.08 (s, 3H), 1.31 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.1, 156.6, 143.3, 142.6, 138.8, 129.7, 129.0 (CH×2), 128.9, 128.64 (CH×2), 128.55 (CH×2), 128.5 (CH×2), 127.7, 87.4, 65.5, 29.6, 28.3, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{20}IOS_2$ 478.9995; found 478.9996.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(p-tolyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3c**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1,

v/v) gave **3c** (130 mg, 88%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.9 Hz, 2H), 7.35 – 7.31 (m, 2H), 7.28 (dd, *J* = 12.3, 7.1 Hz, 3H), 7.15 (d, *J* = 7.7 Hz, 2H), 5.19 (s, 1H), 2.88 (q, *J* = 7.4 Hz, 2H), 2.34 (s, 3H), 2.07 (s, 3H), 1.31 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.2, 156.4, 143.3, 142.8, 137.4, 135.8, 129.7, 129.2, 128.9 (CH×2), 128.8 (CH×2), 128.60 (CH×2), 128.55 (CH×2), 87.2, 65.2, 29.5, 28.2, 21.2, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{22}IOS_2$ 493.0151; found 493.0139.

(E)-1-(4-(4-ethylphenyl)-2-(ethylthio)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl)etha n-1-one (**3d**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3d** (137 mg, 90%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.50 (d, *J* = 8.0 Hz, 2H), 7.34 – 7.27 (m, 5H), 7.17 (d, *J* = 8.0 Hz, 2H), 5.20 (s, 1H), 2.87 (d, *J* = 7.4 Hz, 2H), 2.64 (d, *J* = 7.6 Hz, 2H), 2.07 (s, 3H), 1.30 (t, *J* = 7.4 Hz, 3H), 1.24 (t, *J* = 7.6 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.3, 156.5, 143.6, 143.3, 142.8, 135.9, 129.7, 128.9 (CH×2), 128.8 (CH×2), 128.61 (CH×2), 128.57 (CH×2), 128.0, 87.3, 65.2, 29.5, 28.5, 28.2, 15.3, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{23}H_{24}IOS_2$ 507.0308; found 507.0312.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-isopropylphenyl)-4,5-dihydrothiophen-3-yl) ethan-1-one (**3e**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3e** (139 mg, 89%) as a white solid, mp 118−120 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.50 (d, *J* = 7.9 Hz, 2H), 7.32 (m, 5H), 7.19 (d, *J* = 7.8 Hz, 2H), 5.20 (s, 1H), 2.91 – 2.85 (m, 3H), 2.07 (s, 3H), 1.30 (dd, *J* = 10.2, 4.5 Hz, 3H), 1.26 (s, 3H), 1.25 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.3, 156.5, 148.2, 143.2, 142.8, 136.0, 129.6, 128.9 (CH×4), 128.8 (CH×2), 128.6 (CH×2), 126.6 (CH×2), 87.4, 65.2, 33.8, 29.6, 28.2, 23.9, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{24}H_{26}IOS_2$ 521.0464; found 521.0459.

(E)-1-(4-(4-(tert-butyl)phenyl)-2-(ethylthio)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-y l)ethan-1-one (**3f**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3f** (149 mg, 93%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.49 (s, 2H), 7.34 (d, *J* = 8.4 Hz, 3H), 7.32 (s, 2H), 7.31 – 7.27 (m, 2H), 5.21 (s, 1H), 2.87 (q, *J* = 7.4 Hz, 2H), 2.07 (s, 3H), 1.31 (d, *J* = 6.5 Hz, 12H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.3, 150.5, 143.2, 142.7,

135.6, 129.7 (CH×2), 128.8 (CH×2), 128.61 (CH×2), 128.58 (CH×2), 128.4 (CH×2), 125.4 (CH×2), 87.4, 65.1, 34.6, 31.3 (CH_3×2), 29.6, 28.2, 14.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{25}H_{28}IOS_2$ 535.0621; found 535.0624.

(E)-1-(2-(ethylthio)-4-(4-fluorophenyl)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3g**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **3g** (124 mg, 83%) as a white solid, mp 130−132 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.57 (dd, *J* = 7.8, 5.4 Hz, 2H), 7.34 (t, *J* = 7.2 Hz, 2H), 7.30 – 7.27 (m, 3H), 7.03 (t, *J* = 8.4 Hz, 2H), 5.22 (s, 1H), 2.88 (q, *J* = 7.3 Hz, 2H), 2.09 (s, 3H), 1.31 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.9, 162.2 (d, $^1J_{CF}$ = 246 Hz), 156.6, 143.1, 142.2, 134.7 (d, $^4J_{CF}$ = 2.9 Hz), 130.5 (d, $^3J_{CF}$ = 8.0 Hz), 129.7, 129.0, 128.7 (CH×2), 128.5 (CH×2), 115.5 (d, $^2J_{CF}$ = 21.4 Hz), 87.7, 64.7, 29.7, 28.4, 14.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{19}FIOS_2$ 496.9901; found 496.9891.

(E)-1-(4-(4-chlorophenyl)-2-(ethylthio)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3h**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **3h** (120 mg, 78%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.54 (d, *J* = 8.1 Hz, 2H), 7.31 (m, 7H), 5.22 (s, 1H), 2.89 (dd, *J* = 14.7, 7.3 Hz, 2H), 2.10 (s, 3H), 1.32 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.8, 156.7, 143.1, 142.0, 137.4, 133.5, 130.2, 129.5, 129.0 (CH×2), 128.8 (CH×2), 128.7 (CH×2), 128.4 (CH×2), 87.8, 64.8, 29.7, 28.4, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{19}ClIOS_2$ 512.9605; found 512.9611.

(E)-1-(4-(4-bromophenyl)-2-(ethylthio)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3i**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **3i** (134 mg, 80%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (s, 4H), 7.35 (dd, *J* = 9.9, 4.5 Hz, 2H), 7.31 – 7.28 (m, 3H), 5.21 (s, 1H), 2.89 (q, *J* = 7.4 Hz, 2H), 2.10 (s, 3H), 1.31 (t, *J* = 7.5 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.8, 156.8, 143.1, 141.9, 137.9, 131.7, 130.6, 129.5 (CH×2), 129.0 (CH×2), 128.7 (CH×2), 128.4 (CH×2), 121.6, 87.9, 64.9, 29.7, 28.4, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{19}BrIOS_2$ 556.9100; found 556.9117.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(3-methoxyphenyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3j**). Purification by flash column chromatography eluting with petroleum ether/ethyl

acetate (20/1, v/v) gave **3j** (140 mg, 92%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.32 (s, 2H), 7.30 (d, *J* = 7.5 Hz, 4H), 7.19 (d, *J* = 12.6 Hz, 2H), 6.87 – 6.82 (m, 1H), 5.20 (s, 1H), 3.83 (s, 3H), 2.87 (d, *J* = 7.4 Hz, 2H), 2.10 (s, 3H), 1.31 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.2, 159.7, 156.9, 143.2, 142.5, 140.2, 129.5, 129.3, 128.9 (CH×2), 128.6 (CH×2), 128.5, 121.4, 115.2, 112.6, 87.5, 65.3, 55.3, 29.6, 28.3, 14.3. HRMS (ESI-TOF) calcd for $C_{22}H_{22}IO_2S_2$ $[M + H]^+$: 509.0100; found 509.0104.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(m-tolyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3k**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3k** (127 mg, 86%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.33 (d, *J* = 7.7 Hz, 1H), 7.30 (s, 1H), 7.28 – 7.24 (m, 2H), 7.24 – 7.18 (m, 3H), 7.15 (t, *J* = 7.6 Hz, 1H), 7.03 (d, *J* = 7.4 Hz, 1H), 5.11 (s, 1H), 2.81 (d, *J* = 7.4 Hz, 2H), 2.30 (s, 3H), 2.00 (s, 3H), 1.23 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.3, 155.6, 142.3, 141.7, 137.6, 137.2, 128.5 (CH×2), 128.4 (CH×2), 127.9, 127.6, 127.53, 127.50, 127.3, 125.2, 86.3, 64.4, 28.5, 27.2, 20.6, 13.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{22}IOS_2$ 493.0151; found 493.0151.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(2-methoxyphenyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3l**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3l** (85 mg, 56%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.53 (dd, *J* = 7.6, 1.2 Hz, 1H), 7.38 – 7.35 (m, 2H), 7.34 – 7.29 (m, 4H), 6.99 (s, 1H), 6.94 (d, *J* = 8.2 Hz, 1H), 5.74 (s, 1H), 3.95 (s, 3H), 2.87 (d, *J* = 7.4 Hz, 2H), 2.10 (s, 3H), 1.32 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 192.1, 156.2, 156.0, 144.9, 144.5, 129.5, 129.0, 128.70, 128.67, 128.43, 128.36, 128.0, 127.5, 121.34, 121.27, 110.8, 84.5, 57.7, 55.4, 28.7, 28.0, 14.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{22}IO_2S_2$ 509.0100; found 509.0100.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(o-tolyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3m**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3m** (108 mg, 73%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.57 – 7.53 (m, 1H), 7.36 – 7.32 (m, 2H), 7.28 (dd, *J* = 16.0, 7.3 Hz, 3H), 7.19 – 7.13 (m, 3H), 5.43 (s, 1H), 2.87 (q, *J* = 7.4 Hz, 2H), 2.73 (s, 3H), 2.14 (s, 3H), 1.30 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.6,

153.4, 144.20, 144.15, 138.2, 136.7, 132.0, 130.9, 129.5, 128.79, 128.76, 128.6, 128.3, 127.7, 127.5, 126.3, 84.8, 61.9, 30.3, 28.5, 20.9, 14.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{22}IOS_2$ 493.0151; found 493.0152.

(E)-1-(4-(2-chlorophenyl)-2-(ethylthio)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3n**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **3n** (78 mg, 51%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.56 – 7.53 (m, 1H), 7.31 – 7.27 (m, 2H), 7.23 – 7.16 (m, 6H), 5.60 (s, 1H), 2.78 (d, *J* = 7.4 Hz, 2H), 2.09 (s, 3H), 1.22 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.7, 144.1, 143.9, 137.7, 133.8, 130.4, 129.9, 129.0, 128.9 (CH×2), 128.8 (CH×2), 128.2 (CH×2), 127.8 (CH×2), 85.5, 60.5, 29.7, 28.2, 14.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{19}ClIOS_2$ 512.9605; found 512.9604.

(E)-1-(4-(benzo[d][1,3]dioxol-5-yl)-2-(ethylthio)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3o**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3o** (149 mg, 95%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39 – 7.34 (m, 2H), 7.32 (d, *J* = 7.8 Hz, 3H), 7.12 (d, *J* = 8.0 Hz, 1H), 7.08 (d, *J* = 1.2 Hz, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 6.03 – 5.97 (m, 2H), 5.17 (s, 1H), 2.89 (d, *J* = 7.4 Hz, 2H), 2.13 (s, 3H), 1.33 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.2, 156.6, 147.8, 147.1, 144.7, 143.2, 142.9, 132.3, 129.5, 128.9, 128.7, 128.5, 122.9, 108.8, 108.0, 101.2, 95.7, 87.6, 65.1, 29.6, 28.3, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{20}IO_3S_2$ 522.9893; found 522.9894.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(naphthalen-1-yl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3p**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3p** (130 mg, 82%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.64 (d, *J* = 8.2 Hz, 1H), 7.85 (dd, *J* = 7.1, 2.4 Hz, 2H), 7.81 (d, *J* = 8.0 Hz, 1H), 7.58 (t, *J* = 7.6 Hz, 1H), 7.48 (dd, *J* = 10.4, 4.9 Hz, 2H), 7.34 – 7.30 (m, 2H), 7.30 – 7.26 (m, 3H), 6.07 (s, 1H), 2.91 (q, *J* = 7.4 Hz, 2H), 2.00 (s, 3H), 1.32 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.7, 144.0, 133.7, 131.3, 129.0 (CH×2), 128.8 (CH×2), 128.72 (CH×2), 128.68 (CH×2), 128.3 (CH×2), 127.1 (CH×2), 125.9, 125.8, 125.7, 125.5, 86.2, 60.4, 30.4, 28.4, 14.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{25}H_{22}IOS_2$ 529.0151; found 529.0146.

(E)-1-(4-(3,5-difluorophenyl)-2-(ethylthio)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl) ethan-1-one (**3q**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **3q** (100 mg, 65%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.30 – 7.27 (t, *J* = 7.2 Hz, 2H), 7.25 – 7.21 (m, 3H), 7.08 (dd, *J* = 7.8, 1.8 Hz, 2H), 6.68 (tt, *J* = 8.7, 2.4 Hz, 1H), 5.17 (s, 1H), 2.83 (q, *J* = 7.4 Hz, 2H), 2.08 (s, 3H), 1.25 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.6, 163.0 (dd, J_{CF} = 249, 12.6 Hz), 157.3, 142.9, 142.6 (t, $^3J_{CF}$ = 8.3 Hz), 141.1, 129.2, 129.1, 128.7 (CH×2), 128.4 (CH×2), 111.8 (dd, J_{CF} = 20.6, 5.2 Hz), 103.3 (t, $^2J_{CF}$ = 25.4 Hz), 88.7, 64.9, 29.9, 28.6, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{18}F_2IOS_2$ 514.9806; found 514.9818.

(E)-1-(4-(2,4-dichlorophenyl)-2-(ethylthio)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl) ethan-1-one (**3r**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **3r** (76 mg, 46%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.5 Hz, 1H), 7.40 (d, *J* = 1.4 Hz, 1H), 7.36 (t, *J* = 7.3 Hz, 2H), 7.30 (t, *J* = 8.7 Hz, 3H), 7.26 (s, 1H), 5.62 (s, 1H), 2.86 (q, *J* = 7.3 Hz, 2H), 2.17 (s, 3H), 1.30 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.3, 143.9, 143.2, 136.3, 134.5, 134.0, 131.3, 129.6, 129.3, 129.0 (CH×2), 128.8 (CH×2), 128.2 (CH×2), 100.0, 86.1, 60.3, 29.9, 28.4, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{18}Cl_2IOS_2$ 546.9215; found 546.9221.

(E)-1-(2-(ethylthio)-4-(furan-2-yl)-5-(iodo(phenyl)methylene)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3s**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3s** (124 mg, 88%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.40 (s, 1H), 7.35 (br.s, 4H), 7.32 – 7.29 (br.s, 1H), 6.41 (br.s, *J* = 2.8 Hz, 1H), 6.37 (s, 1H), 5.42 (s, 1H), 2.85 (d, *J* = 7.4 Hz, 2H), 2.21 (s, 3H), 1.28 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.0, 158.5, 151.3, 142.9, 142.1, 139.9, 129.0, 128.7 (CH×2), 128.5 (CH×2), 125.2, 110.5, 108.3, 88.5, 59.8, 29.1, 28.2, 14.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{19}H_{18}IO_2S_2$ 468.9787; found 468.9796.

(E)-1-(5-(ethylthio)-2-(iodo(phenyl)methylene)-2,3-dihydro-[3,3'-bithiophen]-4-yl)ethan-1-one (**3t**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3t** (132 mg, 91%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 1.6 Hz, 1H), 7.33 (d, *J* = 7.4 Hz, 2H), 7.31 – 7.27 (m, 4H), 7.26 (s, 1H), 5.41 (s, 1H), 2.90 – 2.83 (m, 2H), 2.13 (s,

3H), 1.30 (s, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 191.1, 156.7, 142.9, 141.6, 138.7, 129.0 (CH×2), 128.6 (CH×2), 128.5 (CH×2), 127.1, 125.8, 123.6, 87.8, 61.3, 29.4, 28.3, 14.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{19}H_{18}IOS_3$ 484.9559; found 484.9555.

(E)-1-(2-(ethylthio)-5-(iodo(p-tolyl)methylene)-4-phenyl-4,5-dihydrothiophen-3-yl)ethan-1-one (**3u**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3u** (126 mg, 85%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.2 Hz, 2H), 7.27 (d, *J* = 7.6 Hz, 2H), 7.22 (s, 1H), 7.12 (d, *J* = 8.1 Hz, 2H), 7.06 (d, *J* = 8.0 Hz, 2H), 5.14 (s, 1H), 2.82 (q, *J* = 7.4 Hz, 2H), 2.28 (s, 3H), 2.00 (s, 3H), 1.24 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 191.2, 157.0, 145.3, 142.0, 141.2, 140.4, 139.7, 139.0, 138.8, 131.0, 129.4, 129.3, 128.9, 128.5, 128.4, 127.7, 87.9, 65.4, 29.5, 28.2, 21.3, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{22}IOS_2$ 493.0151; found 493.0164.

(E)-1-(2-(ethylthio)-5-(iodo(o-tolyl)methylene)-4-phenyl-4,5-dihydrothiophen-3-yl)ethan-1-one (**3v**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3v** (121 mg, 82%) as a yellow oil. NMR spectra demonstrated there were two rotamers present in a ratio of about 1:1. ^1H NMR (600 MHz, $CDCl_3$) δ 7.58 (d, *J* = 7.2 Hz, 2H), 7.54 (d, *J* = 7.1 Hz, 2H), 7.38–7.27 (m, 6H), 7.24–7.18 (m, 5H), 7.16–7.12 (m, 2H), 6.91 (d, *J* = 7.6 Hz, 1H), 5.18 (s, 1H), 5.15 (s, 1H), 2.90 – 2.80 (m, 4H), 2.30 (s, 3H), 2.09 (s, 3H), 2.08 (s, 3H), 1.93 (s, 3H), 1.295 (t, *J* = 7.4 Hz, 3H), 1.293 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 191.3, 191.2, 156.7, 156.4, 143.4, 143.2, 142.2, 142.0, 139.1, 138.8, 136.1, 134.9, 130.9, 130.8, 129.9, 129.7, 129.2, 129.1 (CH×2), 129.0, 128.9, 128.5, 128.4, 127.73, 127.68, 127.65, 126.52, 126.51, 85.9, 85.3, 64.3, 64.0, 29.49, 29.47, 28.33, 28.30, 19.5, 18.5, 14.3, 14.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{22}IOS_2$ 493.0151; found 493.0155.

(E)-1-(2-(ethylthio)-5-(iodo(4-methoxyphenyl)methylene)-4-phenyl-4,5-dihydrothiophen-3-yl)ethan-1-one (**3w**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3w** (99 mg, 65%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.59 (d, *J* = 7.4 Hz, 2H), 7.34 (t, *J* = 7.4 Hz, 2H), 7.29 (d, *J* = 7.2 Hz, 1H), 7.24 (d, *J* = 8.7 Hz, 2H), 6.84 (d, *J* = 8.6 Hz, 2H), 5.20 (s, 1H), 3.81 (s, 3H), 2.89 (q, *J* = 7.4 Hz, 2H), 2.07 (s, 3H), 1.32 (t, *J* = 7.4 Hz, 3H).

$^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 191.2, 159.8, 156.9, 141.8, 138.9, 135.8, 130.0, 129.5 (CH×2), 128.9 (CH×2), 128.5 (CH×2), 127.7, 113.9 (CH×2), 87.8, 65.3, 55.3, 29.5, 28.2, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{22}IO_2S_2$ 509.0100; found 509.0108.

(E)-1-(5-((4-bromophenyl)iodomethylene)-2-(ethylthio)-4-phenyl-4,5-dihydrothiophen-3-yl)ethan-1-one (**3x**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3x** (114 mg, 68%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.50 (d, *J* = 7.3 Hz, 2H), 7.39 (d, *J* = 8.4 Hz, 2H), 7.27 (t, *J* = 7.4 Hz, 2H), 7.23 (t, *J* = 7.2 Hz, 1H), 7.09 (d, *J* = 8.4 Hz, 2H), 5.13 (s, 1H), 2.82 (q, *J* = 7.4 Hz, 2H), 2.00 (s, 3H), 1.25 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 190.1, 155.3, 142.4, 141.1, 137.5, 130.9, 129.1, 128.6 (CH×2), 127.9 (CH×2), 127.6 (CH×2), 126.8 (CH×2), 122.0, 84.5, 64.5, 28.6, 27.3, 13.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{19}BrIOS_2$ 556.9100; found 556.9114.

(E)-1-(5-(cyclopropyliodomethylene)-2-(ethylthio)-4-phenyl-4,5-dihydrothiophen-3-yl)ethan-1-one (**3y**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3y** (96 mg, 75%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.40 (d, *J* = 7.3 Hz, 2H), 7.21 (t, *J* = 7.3 Hz, 2H), 7.17 (dd, *J* = 6.5, 1.8 Hz, 1H), 4.99 (s, 1H), 3.04 – 2.94 (m, 2H), 1.96 (d, *J* = 1.9 Hz, 3H), 1.39 – 1.33 (m, 4H), 0.82 (ddd, *J* = 13.3, 7.2, 4.7 Hz, 2H), 0.68 (dd, *J* = 4.8, 3.1 Hz, 1H), 0.56 (d, *J* = 5.0 Hz, 1H). $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 191.3, 156.0, 140.1, 138.9, 129.5, 129.0, 128.4, 127.5, 97.6, 64.8, 29.5, 28.7, 22.5, 19.9, 14.5, 11.9, 11.3, 10.9. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{18}H_{20}IOS_2$ 442.9995; found 443.0007.

(E)-1-(2-(ethylthio)-5-(1-iodopentylidene)-4-phenyl-4,5-dihydrothiophen-3-yl)ethan-1-one (**3z**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3z** (95 mg, 69%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.2 Hz, 2H), 7.31 (s, 2H), 7.29 – 7.26 (m, 1H), 5.05 (s, 1H), 3.10 – 3.01 (m, 2H), 2.50 (dd, *J* = 10.2, 7.5 Hz, 2H), 2.07 (s, 3H), 1.57 – 1.46 (m, 2H), 1.45 (t, *J* = 7.4 Hz, 3H), 1.33 – 1.26 (m, 2H), 0.92 (t, *J* = 7.3 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 191.3, 139.0, 138.5, 129.6, 128.9, 128.3, 127.5, 95.3, 64.7, 43.9, 36.4, 30.8, 29.5, 28.5, 21.7, 21.4, 16.6, 14.5, 13.9. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{19}H_{24}IOS_2$ 459.0308; found 459.0303.

(E)-1-(2-(ethylthio)-5-(iodomethylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3aa**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3aa** (92 mg, 71%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.40 (d, *J* = 8.6 Hz, 2H), 6.84 (d, *J* = 8.6 Hz, 2H), 6.21 (d, *J* = 1.5 Hz, 1H), 5.01 (d, *J* = 1.4 Hz, 1H), 3.79 (s, 3H), 3.03 – 2.94 (m, 2H), 2.02 (s, 3H), 1.41 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.3, 159.1, 157.1, 145.7, 130.2, 129.9 (CH×2), 129.4, 113.9 (CH×2), 68.0, 61.9, 55.2, 29.3, 28.6, 28.6, 14.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{16}H_{18}IO_2S_2$ 432.9787; found 432.9786.

(E)-1-(2-(hexylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3ab**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ab** (146 mg, 86%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.5 Hz, 2H), 7.35 – 7.32 (m, 2H), 7.31 – 7.27 (m, 3H), 6.87 (d, *J* = 8.6 Hz, 2H), 5.17 (s, 1H), 3.80 (s, 3H), 2.84 (d, *J* = 7.4 Hz, 2H), 2.07 (s, 3H), 1.64 (s, 2H), 1.37 (s, 2H), 1.26 (br.s, 4H), 0.86 (t, *J* = 6.9 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.3, 159.0, 143.2, 142.8, 131.0, 130.0, 129.7 (CH×2), 128.9 (CH×2), 128.62 (CH×2), 128.56 (CH×2), 113.9 (CH×2), 87.3, 64.8, 55.2, 34.1, 31.2, 29.5, 29.2, 28.3, 22.4, 14.0. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{26}H_{30}IO_2S_2$ 565.0726; found 565.0715.

(E)-1-(2-(butylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3ac**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ac** (142 mg, 88%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.6 Hz, 2H), 7.35 – 7.31 (m, 2H), 7.29 (dd, *J* = 11.8, 7.1 Hz, 3H), 6.88 (d, *J* = 8.6 Hz, 2H), 5.18 (s, 1H), 3.81 (s, 3H), 2.85 (t, *J* = 7.4 Hz, 2H), 2.08 (s, 3H), 1.63 (s, 2H), 1.41 (d, *J* = 7.4 Hz, 2H), 0.89 (t, *J* = 7.3 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.3, 159.0, 156.6, 143.2, 142.8, 131.0, 130.0, 129.7, 128.9 (CH×2), 128.61 (CH×2), 128.56 (CH×2), 113.9 (CH×2), 87.2, 64.8, 55.2, 33.7, 31.2, 29.5, 21.8, 13.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{24}H_{26}IO_2S_2$ 537.0413; found 537.0420.

(E)-1-(5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-2-(methylthio)-4,5-dihydrothiophen-3-yl)ethan-1-one (**3ad**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ad** (111 mg, 75%) as a yellow solid, mp 120−122 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.6 Hz, 2H), 7.36 – 7.32 (m, 2H), 7.31 – 7.27 (m, 3H), 6.88 (d, *J* = 8.6 Hz, 2H),

5.18 (s, 1H), 3.81 (s, 3H), 2.38 (s, 3H), 2.05 (s, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 191.3, 159.1, 143.2, 42.7, 130.8 (CH×2), 130.0 (CH×2), 128.9 (CH×2), 128.7 (CH×2), 128.5 (CH×2), 113.9 (CH×2), 87.5, 65.0, 55.3, 29.3, 17.0. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{19}O_3S_2$ 383.0770; found 383.0777.

(E)-1-(2-(benzylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl) ethan-1-one (**3ae**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ae** (99 mg, 58%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.42 (d, *J* = 8.6 Hz, 2H), 7.27 (d, *J* = 6.9 Hz, 2H), 7.23 – 7.21 (m, 6H), 7.18 (s, 2H), 6.80 (d, *J* = 8.6 Hz, 2H), 5.09 (s, 1H), 4.02 (s, 2H), 3.74 (s, 3H), 1.98 (s, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 190.3, 158.1, 154.5, 142.2, 141.8, 134.4, 129.7, 129.0 (CH×2), 129.0 (CH×2), 128.2 (CH×2), 127.9 (CH×2), 127.7 (CH×2), 127.6, 127.5 (CH×2), 126.8, 112.9 (CH×2), 86.4, 63.5, 54.2, 37.7, 28.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{24}IO_2S_2$ 571.0250; found 571.0257.

Ethyl(E)-4-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)-4-oxobutanoate (**3af**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3af** (120 mg, 67%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.6 Hz, 2H), 7.26 (d, *J* = 6.8 Hz, 2H), 7.22 (d, *J* = 7.2 Hz, 3H), 6.81 (d, *J* = 8.6 Hz, 2H), 5.17 (s, 1H), 4.02 (d, *J* = 7.1 Hz, 2H), 3.74 (s, 3H), 2.81 (d, *J* = 7.5 Hz, 3H), 2.51 (s, 1H), 2.33 (dt, *J* = 20.7, 6.1 Hz, 2H), 1.23 (t, *J* = 7.4 Hz, 3H), 1.15 (t, *J* = 7.1 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 191.3, 173.0, 159.1, 143.3, 142.8, 130.8 (CH×2), 130.0 (CH×2), 128.9 (CH×2), 128.64 (CH×2), 128.55 (CH×2), 114.0 (CH×2), 87.3, 64.1, 60.5, 55.2, 36.1, 28.2, 28.1, 14.2, 14.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{26}H_{28}IO_4S_2$ 595.0468; found 595.0458.

(E)-1-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)pent-4-en-1-one (**3ag**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ag** (130 mg, 79%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.3 Hz, 2H), 7.35 – 7.31 (m, 2H), 7.29 (d, *J* = 7.4 Hz, 3H), 6.87 (d, *J* = 8.3 Hz, 2H), 5.77 – 5.67 (br.s, 1H), 5.21 (s, 1H), 4.96 – 4.86 (m, 2H), 3.81 (s, 3H), 2.87 (d, *J* = 7.3 Hz, 2H), 2.55 (m, 7.6 Hz, 1H), 2.28 (s, 2H), 2.20 – 2.09 (m, 1H), 1.30 (t, *J* = 7.3 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz,

$CDCl_3$) δ 192.8, 159.1, 156.4, 143.2, 142.8, 137.6, 130.9, 130.0, 129.2, 128.9, 128.6 (CH×2), 128.5 (CH×2), 114.8 (CH×2), 113.9 (CH×2), 87.2, 64.3, 55.2, 40.4, 28.2, 27.7, 14.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{25}H_{26}IO_2S_2$ 549.0413; found 549.0404.

(E)-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)(4-nitrophenyl)methanone (**3ah**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ah** (157 mg, 85%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 8.20 (d, *J* = 8.6 Hz, 2H), 7.45 (d, *J* = 8.6 Hz, 2H), 7.39 – 7.29 (m, 5H), 7.11 (d, *J* = 8.5 Hz, 2H), 6.73 (d, *J* = 8.6 Hz, 2H), 5.33 (s, 1H), 3.76 (s, 3H), 2.86 (dd, *J* = 7.4, 2.4 Hz, 2H), 1.28 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 188.0, 158.9, 158.6, 157.2, 155.4, 149.0, 146.0, 143.2, 142.0, 131.1, 129.5, 129.0, 128.7 (CH×2), 128.4 (CH×2), 128.2 (CH×2), 123.6, 113.9 (CH×2), 100.0, 88.0, 65.5, 55.2, 28.8, 14.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{23}INO_4S_2$ 616.0108; found 616.0106.

(E)-(4-chlorophenyl)(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)methanone (**3ai**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ai** (120 mg, 66%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.30 (s, 3H), 7.29 – 7.26 (m, 4H), 7.25 (s, 2H), 7.11 (d, *J* = 8.6 Hz, 2H), 6.68 (d, *J* = 8.6 Hz, 2H), 5.36 (s, 1H), 3.68 (s, 3H), 2.77 – 2.66 (m, 2H), 1.16 (s, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 189.2, 158.8, 152.0, 143.4, 142.8, 138.3, 137.8, 132.2, 131.5, 130.5, 129.4, 128.9, 128.7 (CH×2), 128.6 (CH×2), 128.5, 123.0, 113.9 (CH×2), 113.2 (CH×2), 87.3, 66.4, 55.2, 28.7, 14.7. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{23}ClIO_2S_2$ 604.9867; found 604.9863.

(E)-(4-bromophenyl)(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)methanone (**3aj**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3aj** (131 mg, 67%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.42 (d, *J* = 8.3 Hz, 2H), 7.31 – 7.27 (m, 4H), 7.22 (s, 2H), 7.20 (s, 1H), 7.11 (d, *J* = 8.6 Hz, 2H), 6.68 (d, *J* = 8.6 Hz, 2H), 5.35 (s, 1H), 3.68 (s, 3H), 2.72 (m, 2H), 1.16 (s, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 189.3, 158.8, 143.4, 142.6, 138.8, 131.6 (CH×2), 131.4 (CH×2), 129.5 (CH×2), 129.4 (CH×2), 128.9 (CH×2), 128.7 (CH×2), 128.5 (CH×2), 126.2, 113.9 (CH×2), 87.3, 66.3, 55.2, 28.7,

14.7. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{23}BrIO_2S_2$ 648.9362; found 648.9355.

(E)-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)(phenyl)methanone (**3ak**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ak** (130 mg, 76%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (t, *J* = 7.2 Hz, 1H), 7.34 (d, *J* = 7.5 Hz, 2H), 7.32 – 7.25 (m, 6H), 7.22 (t, *J* = 6.9 Hz, 1H), 7.09 (d, *J* = 8.5 Hz, 2H), 6.65 (d, *J* = 8.5 Hz, 2H), 5.40 (s, 1H), 3.67 (s, 3H), 2.78 – 2.64 (m, 2H), 1.15 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.5, 158.7, 150.4, 143.5, 142.9, 140.1, 132.7, 131.6, 131.5, 129.5 (CH×2), 128.8 (CH×2), 128.7 (CH×2), 128.5 (CH×2), 128.3 (CH×2), 127.9, 113.8 (CH×2), 87.0, 66.5, 55.2, 28.6, 14.7. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{24}IO_2S_2$ 571.0257; found 571.0251.

(E)-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)(4-methoxyphenyl)methanone (**3al**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3al** (133 mg, 74%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.43 (d, *J* = 8.7 Hz, 2H), 7.33 (d, *J* = 7.2 Hz, 2H), 7.29 (t, *J* = 7.6 Hz, 2H), 7.21 (dd, *J* = 15.5, 6.9 Hz, 3H), 6.78 (d, *J* = 8.7 Hz, 2H), 6.70 (d, *J* = 8.6 Hz, 2H), 5.44 (s, 1H), 3.76 (s, 3H), 3.67 (s, 3H), 2.66 (m, 2H), 1.12 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 189.7, 162.9, 158.7, 143.6, 143.1, 132.1 (CH×2), 131.6 (CH×2), 130.9 (CH×2), 129.3 (CH×2), 128.7 (CH×2), 128.6 (CH×2), 128.5 (CH×2), 113.9, 113.6 (CH×2), 86.7, 67.1, 55.4, 55.1, 28.6, 14.9. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{28}H_{26}IO_3S_2$ 601.0363; found 601.0373.

(E)-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)(p-tolyl)methanone (**3am**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3am** (128 mg, 73%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.33 – 7.28 (m, 6H), 7.22 (t, *J* = 7.2 Hz, 1H), 7.15 (d, *J* = 8.6 Hz, 2H), 7.09 (d, *J* = 7.9 Hz, 2H), 6.67 (d, *J* = 8.6 Hz, 2H), 5.43 (s, 1H), 3.67 (s, 3H), 2.73 – 2.62 (m, 2H), 2.30 (s, 3H), 1.13 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.4, 158.7, 143.6, 143.2, 142.5, 137.1, 131.6 (CH×2), 129.4 (CH×2), 129.0 (CH×2), 128.8 (CH×2), 128.6 (CH×2), 128.5 (CH×2), 128.4 (CH×2), 113.9 (CH×2), 86.8, 66.8, 55.1, 28.6, 21.7, 14.8. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{28}H_{26}IO_2S_2$

585.0413; found 585.0423.

(E)-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)(m-tolyl)methanone (**3an**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3an** (126 mg, 72%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.30 (m, 4H), 7.23 (d, *J* = 6.9 Hz, 1H), 7.18 (d, *J* = 9.6 Hz, 2H), 7.16 – 7.13 (m, 2H), 7.11 (d, *J* = 8.6 Hz, 2H), 6.67 (d, *J* = 8.6 Hz, 2H), 5.39 (s, 1H), 3.68 (s, 3H), 2.77 – 2.64 (m, 2H), 2.27 (s, 3H), 1.15 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.7, 158.7, 143.0, 139.9, 138.0, 132.3, 131.6, 129.5 (CH×2), 128.8 (CH×2), 128.6 (CH×2), 128.53 (CH×2), 128.51 (CH×2), 128.1 (CH×2), 125.2, 113.8 (CH×2), 86.9, 66.6, 55.2, 28.6, 21.3, 14.7. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{28}H_{26}IO_2S_2$ 585.0413; found 585.0389.

(E)-(2-(ethylthio)-5-(iodo(phenyl)methylene)-4-(4-methoxyphenyl)-4,5-dihydrothiophen-3-yl)(o-tolyl)methanone (**3ao**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **3ao** (128 mg, 73%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.30 – 7.25 (m, 4H), 7.24 – 7.19 (m, 2H), 7.11 (t, *J* = 7.4 Hz, 1H), 7.00 (dd, *J* = 13.6, 7.5 Hz, 2H), 6.91 (d, *J* = 8.6 Hz, 2H), 6.62 (d, *J* = 8.6 Hz, 2H), 5.09 (s, 1H), 3.69 (s, 3H), 2.78 (m, 2H), 1.77 (s, 3H), 1.20 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 191.2, 158.7, 143.4, 142.7, 140.8, 135.8, 131.6, 130.9, 130.5, 129.8, 129.4 (CH×2), 128.9 (CH×2), 128.7 (CH×2), 128.5 (CH×2), 126.1, 125.4, 113.5 (CH×2), 87.2, 65.7, 55.2, 28.4, 18.6, 14.4. HRMS (ESI) m/z: $[M + H]^+$calcd for $C_{28}H_{26}IO_2S_2$ 585.0413; found 585.0402.

General procedure for the synthesis of 4

The solution of compound **3** (0.2 mmol) in EtOAc (2 mL) was continually stirred at RT with the irradiation of 30 W household compact fluorescent lamp (CFL) until **3** was consumed as indicated by TLC (*ca*. 2 h). It was then diluted with a saturated aqueous solution of sodium thiosulfate (5 mL) and extracted with ethyl acetate (3 ×5 mL). The combined organic layer was washed with water and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate as eluent) to give the desired product **4.**

1-(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)ethan-1-one (**4a**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4a** (66 mg, 83%) as a white solid, mp 82−84 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (d, *J* = 7.1 Hz, 2H), 7.23 (t, *J* = 7.4 Hz, 1H), 7.08 (t, *J* = 7.8 Hz, 2H), 6.95 (d, *J* = 8.6 Hz, 2H), 6.59 (d, *J* = 8.6 Hz, 2H), 3.65 (s, 3H), 3.03 (q, *J* = 7.4 Hz, 2H), 1.76 (s, 3H), 1.40 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.8, 189.3, 159.7, 145.8, 139.1, 137.8, 135.8, 131.9, 131.1 (CH×2), 129.1 (CH×2), 127.8 (CH×2), 127.1 (CH×2), 113.7 (CH×2), 55.2, 30.4, 29.9, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_3S_2$ 397.0927; found 397.0924.

1-(5-benzoyl-2-(ethylthio)-4-phenylthiophen-3-yl)ethan-1-one (**4b**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4b** (61 mg, 83%) as a white solid, mp 116−118 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.3 Hz, 2H), 7.29 (t, *J* = 7.4 Hz, 1H), 7.18 – 7.11 (m, 7H), 3.15 – 3.07 (m, 2H), 1.79 (s, 3H), 1.48 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.6, 189.2, 154.1, 145.9, 138.9, 137.7, 136.1, 135.0, 132.0, 129.8 (CH×2), 129.1 (CH×2), 128.4 (CH×2), 128.2 (CH×2), 127.8, 30.4, 30.0, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{19}O_2S_2$ 367.0821; found 367.0830.

1-(5-benzoyl-2-(ethylthio)-4-(p-tolyl)thiophen-3-yl)ethan-1-one (**4c**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4c** (61 mg, 80%) as a white solid, mp 102−104 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.8 Hz, 2H), 7.30 (s, 1H), 7.14 (t, *J* = 7.6 Hz, 2H), 7.00 (d, *J* = 7.9 Hz, 2H), 6.94 (d, *J* = 7.7 Hz, 2H), 3.10 (d, *J* = 7.4 Hz, 2H), 2.24 (s, 3H), 1.82 (s, 3H), 1.47 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.7, 189.2, 153.7, 146.2, 139.1, 138.3, 137.9, 135.9, 132.0, 131.7 (CH×2), 129.7 (CH×2), 129.1 (CH×2), 128.9 (CH×2), 127.7, 30.4, 30.0, 21.1, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_2S_2$ 381.0977; found 381.0977.

1-(5-benzoyl-4-(4-ethylphenyl)-2-(ethylthio)thiophen-3-yl)ethan-1-one (**4d**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4d** (62 mg, 78%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.34 (d, *J* = 7.2 Hz, 2H), 7.19 (d, *J* = 3.5 Hz, 1H), 7.04 (t, *J* = 7.7 Hz, 2H), 6.93 (d, *J* = 8.0 Hz, 2H), 6.87 (d, *J* = 7.9 Hz, 2H), 3.04 (d, *J* = 7.4 Hz, 2H), 2.45 (d,

J = 7.6 Hz, 2H), 1.74 (s, 3H), 1.40 (t, *J* = 7.4 Hz, 3H), 1.04 (d, *J* = 7.6 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 195.7, 188.3, 145.3, 143.7, 137.9, 136.8, 135.1, 131.1 (CH×2), 130.7 (CH×2), 128.8 (CH×2), 128.0 (CH×2), 126.7 (CH×2), 126.6, 29.4, 28.9, 27.6, 14.4, 12.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{23}H_{23}O_2S_2$ 395.1134; found 395.1131.

1-(5-benzoyl-2-(ethylthio)-4-(4-isopropylphenyl)thiophen-3-yl)ethan-1-one (**4e**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4e** (67 mg, 82%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.37 (d, *J* = 7.3 Hz, 2H), 7.23 (s, 1H), 7.08 (s, 2H), 6.99 (d, *J* = 7.8 Hz, 2H), 6.94 (d, *J* = 7.7 Hz, 2H), 3.12 (d, *J* = 7.4 Hz, 2H), 2.81 – 2.73 (m, 1H), 1.81 (s, 3H), 1.48 (s, 3H), 1.13 (d, *J* = 6.8 Hz, 6H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 196.7, 189.5, 154.4, 149.3, 146.3, 138.9, 137.8, 136.3, 132.2, 131.6 (CH×2), 129.9 (CH×2), 129.0 (CH×2), 127.6 (CH×2), 126.2 (CH×2), 33.8, 30.4, 29.9, 23.7, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{24}H_{25}O_2S_2$ 409.1290; found 409.1290.

1-(5-benzoyl-4-(4-(tert-butyl)phenyl)-2-(ethylthio)thiophen-3-yl)ethan-1-one (**4f**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4f** (68 mg, 80%) as a white solid, mp 120−122 °C. ^1H NMR (600 MHz, $CDCl_3$) δ 7.35 (s, 2H), 7.21 (d, *J* = 7.4 Hz, 1H), 7.09 (d, *J* = 8.2 Hz, 2H), 7.06 (s, 2H), 6.99 (d, *J* = 8.2 Hz, 2H), 3.12 (d, *J* = 7.4 Hz, 2H), 1.82 (s, 3H), 1.48 (t, *J* = 7.4 Hz, 3H), 1.20 (s, 9H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 196.7, 189.5, 154.3, 151.6, 146.2, 138.9, 137.8, 136.4, 131.8 (CH×2), 131.5 (CH×2), 129.7 (CH×2), 128.9 (CH×2), 127.6 (CH×2), 125.0 (CH×2), 34.5, 31.1, 30.4, 29.9, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{25}H_{27}O_2S_2$ 423.1447; found 423.1442.

1-(5-benzoyl-2-(ethylthio)-4-(4-fluorophenyl)thiophen-3-yl)ethan-1-one (**4g**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **4g** (69 mg, 90%) as a white solid, mp 110−112 °C. ^1H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.7 Hz, 2H), 7.35 (t, *J* = 7.7 Hz, 1H), 7.19 (d, *J* = 7.6 Hz, 2H), 7.10 (dd, *J* = 8.4, 5.4 Hz, 2H), 6.86 (t, *J* = 8.4 Hz 2H), 3.11 (d, *J* = 7.4 Hz, 2H), 1.83 (s, 3H), 1.48 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 196.3, 188.9, 162.7 (d, $^1J_{CF}$ = 249 Hz), 154.2, 144.7, 138.9, 137.7, 136.2, 132.2, 131.5 (d, $^3J_{CF}$ = 8.2 Hz, CH×2), 131.0 (d, $^4J_{CF}$ = 3.6 Hz), 129.1 (CH×2), 127.9 (CH×2), 115.3 (d, $^2J_{CF}$ = 21.7 Hz, CH×2), 30.5, 30.0,

13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{18}FO_2S_2$ 385.0727; found 385.0728.

1-(5-benzoyl-4-(4-chlorophenyl)-2-(ethylthio)thiophen-3-yl)ethan-1-one (**4h**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **4h** (71 mg, 89%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.40 (d, *J* = 7.3 Hz, 2H), 7.30 (d, *J* = 7.4 Hz, 1H), 7.13 (t, *J* = 7.7 Hz, 2H), 7.07 (d, *J* = 8.4 Hz, 2H), 7.00 (d, *J* = 8.4 Hz, 2H), 3.03 (q, *J* = 7.4 Hz, 2H), 1.78 (s, 3H), 1.40 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 195.1, 187.7, 153.2, 143.6, 137.8, 136.8, 135.2, 133.7, 132.5, 131.2 (CH×2), 130.0 (CH×2), 128.1 (CH×2), 127.4 (CH×2), 127.0, 29.6, 29.1, 12.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{18}ClO_2S_2$ 401.0431; found 401.0436.

1-(5-benzoyl-4-(4-bromophenyl)-2-(ethylthio)thiophen-3-yl)ethan-1-one (**4i**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **4i** (77 mg, 87%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.8 Hz, 2H), 7.39 (t, *J* = 7.0 Hz, 1H), 7.30 (d, *J* = 8.1 Hz, 2H), 7.21 (t, *J* = 7.4 Hz, 2H), 7.01 (d, *J* = 8.1 Hz, 2H), 3.10 (d, *J* = 7.4 Hz, 2H), 1.86 (s, 3H), 1.47 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.1, 188.7, 154.2, 144.6, 138.8, 137.8, 136.2, 134.0, 132.2, 131.4 (CH×2), 131.3 (CH×2), 129.1 (CH×2), 128.0 (CH×2), 122.9, 30.6, 30.1, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{18}BrO_2S_2$ 444.9926; found 444.9929.

1-(5-benzoyl-2-(ethylthio)-4-(3-methoxyphenyl)thiophen-3-yl)ethan-1-one (**4j**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4j** (64 mg, 81%) as a white solid, mp 80−82 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.48 (d, *J* = 7.3 Hz, 2H), 7.32 (t, *J* = 7.4 Hz, 1H), 7.17 (t, *J* = 7.7 Hz, 2H), 7.09 (t, *J* = 7.9 Hz, 1H), 6.75 (d, *J* = 7.5 Hz, 1H), 6.71 (dd, *J* = 8.3, 1.9 Hz, 1H), 6.64 (s, 1H), 3.67 (s, 3H), 3.13 (d, *J* = 7.4 Hz, 2H), 1.86 (s, 3H), 1.50 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.6, 189.2, 159.3, 154.1, 145.7, 138.8, 137.8, 136.2, 131.9, 129.3 (CH×2), 128.9 (CH×2), 127.7 (CH×2), 122.4, 115.4, 114.4, 55.2, 30.3, 30.0, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_3S_2$ 397.0927; found 397.0924.

1-(5-benzoyl-2-(ethylthio)-4-(m-tolyl)thiophen-3-yl)ethan-1-one (**4k**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4k** (62 mg, 82%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36 (d, *J* = 7.4 Hz, 2H), 7.21 (t, *J* = 5.7 Hz, 1H), 7.05 (t, *J* = 7.7 Hz, 2H), 6.96 (t, *J* = 7.6 Hz, 1H), 6.86 (t, *J* = 8.7 Hz, 2H), 6.81 (s, 1H), 3.04 (q, *J* = 7.4 Hz, 2H),

2.08 (s, 3H), 1.74 (s, 3H), 1.40 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 196.7, 189.4, 154.1, 146.2, 137.9, 136.1, 134.8, 131.8, 130.7 (CH×2), 129.1(CH×2), 128.9 (CH×2), 128.1 (CH×2), 127.6, 126.9, 30.4, 30.0, 21.0, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_2S_2$ 381.0977; found 381.0981.

1-(5-benzoyl-2-(ethylthio)-4-(2-methoxyphenyl)thiophen-3-yl)ethan-1-one (**4l**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4l** (63 mg, 80%) as a white solid, mp 132−134 °C. ^1H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.5 Hz, 2H), 7.27 (s, 1H), 7.14 – 7.06 (m, 3H), 6.96 (dd, *J* = 7.4, 1.4 Hz, 1H), 6.72 (t, *J* = 7.4 Hz, 1H), 6.60 (d, *J* = 8.3 Hz, 1H), 3.67 (s, 3H), 3.11 (q, *J* = 7.4 Hz, 2H), 1.84 (s, 3H), 1.48 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 195.9, 189.5, 156.2, 142.1, 137.8, 136.5, 131.8, 131.5, 130.3 (CH×2), 128.7 (CH×2), 127.5 (CH×2), 124.3 (CH×2), 120.5, 110.3, 55.0, 29.8, 29.3, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_3S_2$ 397.0927; found 397.0937.

1-(5-benzoyl-2-(ethylthio)-4-(o-tolyl)thiophen-3-yl)ethan-1-one (**4m**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4m** (62 mg, 82%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.51 (d, *J* = 7.2 Hz, 2H), 7.35 (s, 1H), 7.22 (t, *J* = 7.7 Hz, 2H), 7.16 – 7.11 (m, 1H), 7.08 – 7.03 (m, 3H), 3.13 (s, 2H), 2.14 (s, 3H), 1.72 (s, 3H), 1.51 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 195.4, 188.8, 157.3, 146.2, 138.2, 137.0, 136.3, 135.1, 131.9, 130.1, 130.0 (CH×2), 128.7 (CH×2), 128.6 (CH×2), 127.7, 125.7, 29.6, 29.6, 20.1, 13.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_2S_2$ 381.0977; found 381.0984.

1-(5-benzoyl-4-(2-chlorophenyl)-2-(ethylthio)thiophen-3-yl)ethan-1-one (**4n**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **4n** (67 mg, 84%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.4 Hz, 2H), 7.26 (t, *J* = 7.4 Hz, 1H), 7.17 (s, 1H), 7.14 (t, *J* = 7.6 Hz, 2H), 7.10 – 7.06 (m, 2H), 7.05 – 7.00 (m, 1H), 3.05 (q, *J* = 7.4 Hz, 2H), 1.78 (s, 3H), 1.42 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 193.8, 187.6, 155.5, 141.9, 137.1, 136.1, 135.2, 133.6, 132.6, 131.0, 130.8, 129.0, 128.5 (CH×2), 127.7 (CH×2), 126.8, 125.7, 28.8, 28.7, 28.4, 12.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{18}ClO_2S_2$ 401.0431; found 401.0424.

1-(4-(benzo[d][1,3]dioxol-5-yl)-5-benzoyl-2-(ethylthio)thiophen-3-yl)ethan-1-one (**4o**).

Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4o** (62 mg, 75%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (d, *J* = 7.3 Hz, 2H), 7.35 (t, *J* = 7.4 Hz, 1H), 7.21 (d, *J* = 7.6 Hz, 2H), 6.59 (s, 2H), 6.57 (s, 1H), 5.87 (s, 2H), 3.10 (d, *J* = 7.4 Hz, 2H), 1.91 (s, 3H), 1.47 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.5, 189.2, 147.8, 147.5, 145.5, 137.9, 136.1, 131.9, 130.0 (CH×2), 128.5 (CH×2), 127.8 (CH×2), 123.8, 110.3 (CH×2), 108.2, 101.2, 30.4, 30.0, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{19}O_4S_2$ 411.0719; found 411.0713.

1-(5-benzoyl-2-(ethylthio)-4-(naphthalen-1-yl)thiophen-3-yl)ethan-1-one (**4p**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4p** (66 mg, 79%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.75 – 7.69 (m, 1H), 7.65 (s, 1H), 7.63 (s, 1H), 7.48 – 7.41 (m, 2H), 7.21 (d, *J* = 9.4 Hz, 4H), 7.05 (s, 1H), 6.80 (t, *J* = 7.4 Hz, 2H), 3.18 (q, *J* = 7.3 Hz, 2H), 1.53 (t, *J* = 7.4 Hz, 3H), 1.49 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 195.4, 189.5, 157.5, 137.9, 137.8, 137.1, 133.2, 132.9, 132.6, 131.4, 129.1 (CH×2), 128.5 (CH×2), 128.3 (CH×2), 127.9, 127.1, 127.1, 126.1, 125.1, 124.9, 29.7, 29.4, 13.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{25}H_{21}O_2S_2$ 417.0977; found 417.0974.

1-(5-benzoyl-4-(3,5-difluorophenyl)-2-(ethylthio)thiophen-3-yl)ethan-1-one (**4q**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **4q** (64 mg, 79%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.3 Hz, 2H), 7.41 (t, *J* = 7.4 Hz, 1H), 7.26 (d, *J* = 7.8 Hz, 2H), 6.74 – 6.68 (m, 2H), 6.65 (tt, *J* = 8.9, 2.2 Hz, 1H), 3.10 (d, *J* = 7.4 Hz, 2H), 1.93 (s, 3H), 1.47 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 195.5, 188.4, 162.6 (dd, J_{CF} = 251, 13.1 Hz), 154.3, 143.0 (t, $^4J_{CF}$ = 5.3 Hz), 138.5, 138.2 (t, $^3J_{CF}$ = 10.0 Hz), 137.8, 136.5, 132.5, 128.9 (CH ×2), 128.0 (CH×2), 113.1 (dd, J_{CF} = 20.3, 5.8 Hz), 103.9 (t, $^2J_{CF}$ = 25.1 Hz), 30.5, 30.2, 13.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{17}F_2O_2S_2$403.0633; found 403.0634.

1-(5-benzoyl-4-(2,4-dichlorophenyl)-2-(ethylthio)thiophen-3-yl)ethan-1-one (**4r**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (40/1, v/v) gave **4r** (67 mg, 77%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.54 (d, *J* = 7.3 Hz, 2H), 7.42 (s, 1H), 7.30 – 7.25 (m, 3H), 7.13 – 7.04 (m, 2H), 3.11 (q, *J* = 7.4 Hz, 2H), 1.92 (s, 3H), 1.48 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 194.4, 188.2, 156.4, 141.9, 138.2, 137.1, 136.3, 135.3, 134.3, 133.3, 132.4,

132.1, 129.4, 128.7 (CH×2), 128.0 (CH×2), 127.01, 100.0, 30.0, 29.7, 13.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{17}Cl_2O_2S_2$ 435.0042; found 435.0038.

1-(5-benzoyl-2-(ethylthio)-4-(furan-2-yl)thiophen-3-yl)ethan-1-one (**4s**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4s** (59 mg, 83%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.56 (d, *J* = 7.5 Hz, 2H), 7.40 (s, 1H), 7.28 (d, *J* = 7.9 Hz, 3H), 6.20 (d, *J* = 3.1 Hz, 1H), 6.14 (s, 1H), 3.09 (d, *J* = 7.4 Hz, 2H), 1.99 (s, 3H), 1.46 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 194.8, 187.7, 144.23, 141.7, 136.8, 136.7, 133.0, 131.2, 127.9 (CH×2), 127.0 (CH×2), 112.4 (CH×2), 110.6 (CH×2), 29.1, 27.8, 12.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{19}H_{17}O_3S_2$ 357.0614; found 357.0613.

1-(2-benzoyl-5-(ethylthio)-[3,3'-bithiophen]-4-yl)ethan-1-one (**4t**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4t** (63 mg, 84%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.51 – 7.45 (m, 2H), 7.35 (t, *J* = 7.4 Hz, 1H), 7.20 (t, *J* = 7.7 Hz, 2H), 7.12 (dd, *J* = 4.8, 2.9 Hz, 1H), 7.01 (d, *J* = 1.6 Hz, 1H), 6.87 – 6.83 (m, 1H), 3.10 (q, *J* = 7.4 Hz, 2H), 1.89 (s, 3H), 1.47 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.6, 189.2, 153.7, 140.2, 138.9, 137.6, 136.7, 134.6, 132.0, 128.98 (CH×2), 128.95 (CH×2), 127.9, 126.0, 125.9, 30.0, 29.9, 13.6. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{19}H_{16}O_2S_3Na$ 395.0205; found 395.0201.

1-(2-(ethylthio)-5-(4-methylbenzoyl)-4-phenylthiophen-3-yl)ethan-1-one (**4u**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4u** (62 mg, 81%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.1 Hz, 2H), 7.18 (m, 3H), 7.15 – 7.12 (m, 2H), 6.96 (d, *J* = 7.9 Hz, 2H), 3.10 (q, *J* = 7.4 Hz, 2H), 2.27 (s, 3H), 1.80 (s, 3H), 1.47 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.6, 153.1, 145.6, 142.9, 139.0, 136.1, 135.1, 135.1, 129.8 (CH×2), 129.4 (CH×2), 128.5 (CH×2), 128.3 (CH×2), 128.2 (CH×2), 30.4, 30.0, 21.5, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_2S_2$ 381.0977; found 381.0987.

1-(2-(ethylthio)-5-(2-methylbenzoyl)-4-phenylthiophen-3-yl)ethan-1-one (**4v**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4v** (61 mg, 80%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.07 – 7.00 (m, 3H), 6.96 (m, 4H), 6.84 (d, *J* = 7.6 Hz, 1H), 6.79 (t, *J* = 7.5 Hz, 1H), 3.05 (q, *J* = 7.4 Hz, 2H), 2.17 (s, 3H), 1.61 (s, 3H), 1.42 (s, 3H).

$^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 195.0, 189.7, 156.4, 145.8, 137.7, 137.3, 136.6, 134.7, 133.6, 129.3, 129.0 (CH×2), 128.3 (CH×2), 127.3, 127.1, 126.9, 123.9, 29.1, 28.7, 18.6, 12.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_2S_2$ 381.0977; found 381.0974.

1-(2-(ethylthio)-5-(4-methoxybenzoyl)-4-phenylthiophen-3-yl)ethan-1-one (**4w**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4w** (63 mg, 80%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.6 Hz, 2H), 7.19 (d, *J* = 5.2 Hz, 3H), 7.16 (br.s, 2H), 6.65 (d, *J* = 8.6 Hz, 2H), 3.77 (s, 3H), 3.10 (d, *J* = 7.4 Hz, 2H), 1.82 (s, 3H), 1.47 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 196.8, 187.7, 163.0, 144.9, 136.3, 135.2, 131.8 (CH×2), 130.2 (CH×2), 129.8 (CH×2), 128.4 (CH×2), 128.3 (CH×2), 113.2 (CH×2), 100.0, 55.4, 30.4, 13.7. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{21}O_3S_2$ 397.0927; found 397.0920.

1-(5-(4-bromobenzoyl)-2-(ethylthio)-4-phenylthiophen-3-yl)ethan-1-one (**4x**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4x** (74 mg, 83%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.29 (d, *J* = 8.5 Hz, 2H), 7.26 (s, 1H), 7.25 – 7.21 (m, 2H), 7.17 (t, *J* = 7.5 Hz, 2H), 7.10 (d, *J* = 7.2 Hz, 2H), 3.12 (d, *J* = 7.4 Hz, 2H), 1.79 (s, 3H), 1.48 (s, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 196.4, 188.1, 146.2, 138.8, 136.5, 135.7, 134.8, 131.0, 130.5 (CH×2), 129.9 (CH×2), 128.6 (CH×2), 128.3 (CH×2), 126.8 (CH×2), 30.4, 30.0, 13.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{18}BrO_2S_2$ 444.9926; found 444.9923.

1-(5-(cyclopropanecarbonyl)-2-(ethylthio)-4-phenylthiophen-3-yl)ethan-1-one (**4y**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4y** (54 mg, 82%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.38 (s, 3H), 7.33 (d, *J* = 6.5 Hz, 2H), 3.02 (d, *J* = 7.3 Hz, 2H), 1.68 (s, 3H), 1.40 (t, *J* = 7.3 Hz, 3H), 1.36 – 1.31 (m, 1H), 1.00 (s, 2H), 0.56 – 0.49 (br.s, 2H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 195.5, 193.7, 157.2, 145.0, 138.7, 137.4, 136.2, 129.7 (CH×2), 129.0 (CH×2), 128.7 (CH×2), 30.2, 29.5, 19.5, 13.3, 12.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{18}H_{19}O_2S_2$ 331.0821; found 331.0818.

1-(4-acetyl-5-(ethylthio)-3-phenylthiophen-2-yl)pentan-1-one (**4z**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4z** (62 mg, 90%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.42 (s, 3H), 7.27 (d, *J* = 4.4 Hz, 2H), 3.03 (d, *J* = 7.4 Hz,

2H), 1.97 (t, *J* = 7.4 Hz, 2H), 1.65 (s, 3H), 1.41 (t, *J* = 7.4 Hz, 3H), 1.35 – 1.30 (m, 2H), 0.97 (d, *J* = 7.4 Hz, 2H), 0.64 (t, *J* = 7.3 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 195.2, 193.9, 158.3, 145.0, 138.5, 136.3, 129.3 (CH×2), 129.1 (CH×2), 128.8 (CH×2), 40.3, 30.2, 29.5, 26.4, 22.1, 13.6, 13.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{19}H_{23}O_2S_2$ 347.1134; found 347.1134.

4-acetyl-5-(ethylthio)-3-(4-methoxyphenyl)thiophene-2-carbaldehyde (**4aa**). The reaction was performed in a scale of 0.15 mmol. Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4aa** (30 mg, 62%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 9.38 (s, 1H), 7.30 (d, *J* = 8.6 Hz, 2H), 7.01 (d, *J* = 8.6 Hz, 2H), 3.88 (s, 3H), 3.11 (q, *J* = 7.4 Hz, 2H), 1.87 (s, 3H), 1.49 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 195.0, 182.8, 161.5, 160.5, 151.2, 136.8, 136.4, 131.0 (CH×2), 125.4, 114.2 (CH×2), 55.4, 30.4, 29.8, 13.1. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{16}H_{17}O_3S_2$ 321.0614; found 321.0613.

1-(5-benzoyl-2-(hexylthio)-4-(4-methoxyphenyl)thiophen-3-yl)ethan-1-one (**4ab**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ab** (68 mg, 75%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.38 (d, *J* = 7.2 Hz, 2H), 7.23 (s, 1H), 7.08 (t, *J* = 7.7 Hz, 2H), 6.94 (d, *J* = 8.6 Hz, 2H), 6.59 (d, *J* = 8.6 Hz, 2H), 3.65 (s, 3H), 3.00 (t, *J* = 7.4 Hz, 2H), 1.75 (s, 5H), 1.47 – 1.36 (m, 2H), 1.29 – 1.23 (m, 4H), 0.83 (s, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 195.8, 188.3, 158.7, 153.4, 144.8, 137.9, 136.8, 134.7, 130.8 (CH×2), 130.1 (CH×2), 128.1 (CH×2), 126.8, 126.2, 112.7 (CH×2), 54.2, 34.9, 30.3, 29.4, 27.6, 27.4, 21.5, 13.0. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{26}H_{29}O_3S_2$ 453.1553; found 453.1559.

1-(5-benzoyl-2-(butylthio)-4-(4-methoxyphenyl)thiophen-3-yl)ethan-1-one (**4ac**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ac** (66 mg, 78%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.43 (t, *J* = 14.9 Hz, 2H), 7.30 (dd, *J* = 14.8, 7.9 Hz, 1H), 7.14 (dd, *J* = 18.6, 11.1 Hz, 2H), 7.00 (dd, *J* = 22.3, 8.6 Hz, 2H), 6.65 (t, *J* = 11.1 Hz, 2H), 3.72 (s, 3H), 3.14 – 3.03 (m, 2H), 1.82 (d, *J* = 6.1 Hz, 3H), 1.81 – 1.76 (m, 2H), 1.57 – 1.45 (m, 2H), 1.04 – 0.87 (m, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 196.8, 189.3, 159.7, 154.4, 145.9, 138.9, 137.8, 135.7, 131.8, 131.1 (CH×2), 129.1 (CH×2), 127.8 (CH×2), 127.2, 113.7 (CH×2), 55.2, 35.6, 30.5, 30.4, 22.1, 13.6. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{24}H_{25}O_3S_2$ 425.1240; found 425.1235.

1-(5-benzoyl-4-(4-methoxyphenyl)-2-(methylthio)thiophen-3-yl)ethan-1-one (**4ad**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ad** (63 mg, 82%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.45 (d, *J* = 7.2 Hz, 2H), 7.31 (d, *J* = 7.4 Hz, 1H), 7.16 (t, *J* = 7.7 Hz, 2H), 7.03 (d, *J* = 8.6 Hz, 2H), 6.68 (d, *J* = 8.6 Hz, 2H), 3.73 (s, 3H), 2.64 (s, 3H), 1.81 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 196.2, 189.2, 159.8, 157.6, 146.4, 137.9, 137.5, 135.5, 131.8, 131.1, 129.1 (CH×2), 127.8, 127.3, 114.9 (CH×2), 113.7 (CH×2), 55.3, 30.2, 18.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{21}H_{19}O_3S_2$ 383.0770; found 383.0777.

1-(5-benzoyl-2-(benzylthio)-4-(4-methoxyphenyl)thiophen-3-yl)ethan-1-one (**4ae**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ae** (64 mg, 70%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (d, *J* = 7.3 Hz, 2H), 7.34 (d, *J* = 7.2 Hz, 2H), 7.26 (m, 4H), 7.09 (s, 2H), 6.94 (d, *J* = 8.5 Hz, 2H), 6.60 (d, *J* = 8.5 Hz, 2H), 4.20 (s, 2H), 3.65 (s, 3H), 1.72 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 195.9, 188.2, 158.8, 144.4, 139.1, 136.7, 135.3, 134.4, 131.0 (CH×2), 130.0 (CH×2), 128.3 (CH×2), 128.2, 127.7 (CH×2), 126.9 (CH×2), 126.8, 126.0, 112.7 (CH×2), 54.2, 39.9, 29.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{23}O_3S_2$ 459.1083; found 459.1077.

Ethyl 4-(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)-4-oxobutanoate (4af). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4af** (77 mg, 80%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.4 Hz, 2H), 7.31 (s, 1H), 7.16 (t, *J* = 7.7 Hz, 2H), 7.04 (d, *J* = 8.6 Hz, 2H), 6.67 (d, *J* = 8.6 Hz, 2H), 4.09 – 4.00 (m, 2H), 3.72 (s, 3H), 3.09 (d, *J* = 7.4 Hz, 2H), 2.44 (t, *J* = 6.5 Hz, 2H), 2.37 (t, *J* = 6.3 Hz, 2H), 1.46 (t, *J* = 7.4 Hz, 3H), 1.19 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 197.3, 189.2, 172.3, 159.7, 153.1, 145.5, 138.8, 137.8, 136.2, 131.9 (CH×2), 131.1 (CH×2), 129.1 (CH×2), 127.8, 127.0, 113.8 (CH×2), 60.4, 55.2, 37.4, 30.1, 28.5, 14.1, 13.6. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{26}H_{26}O_5S_2Na$ 505.1114; found 505.1112.

1-(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)pent-4-en-1-one (**4ag**). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ag** (69 mg, 82%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.41 – 7.37 (m, 2H), 7.23 (t, *J* = 7.4 Hz, 1H),

7.08 (t, *J* = 7.8 Hz, 2H), 6.94 (d, *J* = 8.7 Hz, 2H), 6.58 (d, *J* = 8.7 Hz, 2H), 5.53 – 5.44 (m, 1H), 4.76 – 4.67 (m, 2H), 3.65 (s, 3H), 3.02 (q, *J* = 7.4 Hz, 2H), 2.13 – 2.07 (m, 4H), 1.38 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 198.5, 188.3, 158.7, 144.2, 139.3, 136.7, 135.9, 130.9 (CH×2), 130.0 (CH×2), 128.2 (CH×2), 126.8 (CH×2), 126.0, 113.9 (CH×2), 112.8 (CH×2), 54.3, 40.8, 29.3, 27.1, 12.8. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{25}H_{24}O_3S_2Na$ 459.1059; found 459.1067.

(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)(4-nitrophenyl)methanone (4ah). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ah** (86 mg, 85%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.93 (d, *J* = 8.1 Hz, 2H), 7.57 (d, *J* = 8.1 Hz, 2H), 7.41 (d, *J* = 7.1 Hz, 2H), 7.20 (d, *J* = 8.1 Hz, 1H), 7.04 (t, *J* = 6.9 Hz, 2H), 6.74 (d, *J* = 7.9 Hz, 2H), 6.28 (d, *J* = 7.9 Hz, 2H), 3.47 (s, 3H), 3.04 (d, *J* = 7.2 Hz, 2H), 1.35 (s, 3H). $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 190.2, 188.2, 158.4, 148.8, 144.2, 140.97, 141.0, 136.1, 131.3 (CH×2), 130.3 (CH×2), 129.2 (CH×2), 128.36 (CH×2), 128.4 (CH×2), 126.8 (CH×2), 125.0, 122.2, 112.5 (CH×2), 54.1, 30.0, 13.1. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{22}NO_5S_2$ 504.0934; found 504.0932.

(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)(4-chlorophenyl)methanone (4ai). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ai** (83 mg, 84%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 8.5 Hz, 2H), 7.44 (d, *J* = 7.5 Hz, 2H), 7.21 (s, 1H), 7.14 (d, *J* = 8.5 Hz, 2H), 7.05 (t, *J* = 7.7 Hz, 2H), 6.79 (d, *J* = 8.6 Hz, 2H), 6.33 (d, *J* = 8.6 Hz, 2H), 3.51 (s, 3H), 2.96 (d, *J* = 7.4 Hz, 2H), 1.30 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 191.0, 188.3, 158.3, 144.9, 144.2, 140.3, 138.6, 136.8, 136.2, 134.4, 131.2 (CH×2), 130.1 (CH×2), 129.9 (CH×2), 128.4 (CH×2), 127.6 (CH×2), 126.8, 125.2, 112.4 (CH×2), 54.1, 30.4, 13.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{22}ClO_3S_2$ 493.0693; found 493.0700.

(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)(4-bromophenyl)methanone (4aj). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4aj** (90 mg, 84%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.44 (d, *J* = 7.4 Hz, 2H), 7.39 (d, *J* = 8.2 Hz, 2H), 7.31 (d, *J* = 8.1 Hz, 2H), 7.24 – 7.20 (m, 1H), 7.06 (s, 2H), 6.78 (d, *J* = 8.3 Hz, 2H), 6.34 (d, *J* = 8.3 Hz, 2H), 3.52 (s, 3H), 2.97 (d, *J* = 7.3 Hz, 2H), 1.30 (t, *J* = 7.3 Hz, 3H). $^{13}C\{^{1}H\}$

NMR (151 MHz, $CDCl_3$) δ 191.2, 188.3, 158.3, 145.0, 144.2, 140.2, 136.8, 136.2, 134.8, 131.2, 130.6 (CH×2), 130.1 (CH×2), 130.0 (CH×2), 128.4 (CH×2), 127.5 (CH×2), 126.8, 125.2, 112.5 (CH×2), 54.1, 30.4, 13.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{22}BrO_3S_2$ 537.0188; found 537.0180.

(5-(ethylthio)-3-(4-methoxyphenyl)thiophene-2,4-diyl)bis(phenylmethanone) (4ak). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ak** (78 mg, 85%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.54 (d, *J* = 7.3 Hz, 2H), 7.45 (d, *J* = 7.2 Hz, 2H), 7.32 (t, *J* = 7.4 Hz, 1H), 7.21 – 7.16 (m, 3H), 7.05 (t, *J* = 7.8 Hz, 2H), 6.81 (d, *J* = 8.7 Hz, 2H), 6.32 (d, *J* = 8.7 Hz, 2H), 3.49 (s, 3H), 2.95 (d, *J* = 7.4 Hz, 2H), 1.29 (s, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 193.3, 189.4, 159.2, 145.4, 145.2, 142.2, 137.9, 137.3, 137.1, 133.2, 132.1 (CH×2), 131.1 (CH×2), 129.6 (CH×2), 129.4 (CH×2), 128.3 (CH×2), 127.8, 126.4, 113.3 (CH×2), 55.1, 31.5, 14.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{23}O_3S_2$ 459.1083; found 459.1089.

(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)(4-methoxyphenyl)methanone (4al). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4al** (79 mg, 81%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.8 Hz, 2H), 7.46 (d, *J* = 7.8 Hz, 2H), 7.25 – 7.19 (m, 1H), 7.06 (s, 2H), 6.84 (d, *J* = 8.7 Hz, 2H), 6.69 (d, *J* = 8.8 Hz, 2H), 6.35 (d, *J* = 8.7 Hz, 2H), 3.72 (s, 3H), 3.51 (s, 3H), 2.93 (d, *J* = 7.4 Hz, 2H), 1.27 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 191.9, 189.5, 163.8, 159.2, 145.2, 138.1, 137.3, 132.1 (CH×2), 131.0 (CH×2), 130.1 (CH×2), 129.5 (CH×2), 127.8 (CH×2), 126.5 (CH×2), 113.7 (CH×2), 113.4 (CH×2), 55.4, 55.1, 31.6, 14.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{28}H_{25}O_4S_2$ 489.1189; found 489.1188.

(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)(p-tolyl)methanone (4am). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4am** (79 mg, 84%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.48 (d, *J* = 8.0 Hz, 2H), 7.46 (d, *J* = 7.5 Hz, 2H), 7.21 (t, *J* = 7.4 Hz, 1H), 7.06 (s, 2H), 7.02 (s, 2H), 6.83 (d, *J* = 8.5 Hz, 2H), 6.34 (d, *J* = 8.6 Hz, 2H), 3.50 (s, 3H), 2.93 (q, *J* = 7.3 Hz, 2H), 2.24 (s, 3H), 1.27 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ 193.0, 189.4, 159.2, 145.3, 144.4, 144.0, 142.8, 138.0, 137.3, 134.5, 132.1 (CH×2), 131.1 (CH×2), 129.9 (CH×2), 129.5 (CH×2), 129.1 (CH×2), 127.8, 126.5,

113.3 (CH×2), 55.1, 31.6, 21.7, 14.5. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{28}H_{25}O_3S_2$ 473.1240; found 473.1252.

(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)(m-tolyl)methanone (4an). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4an** (78 mg, 83%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.45 (d, *J* = 7.5 Hz, 2H), 7.35 (s, 2H), 7.20 (t, *J* = 7.4 Hz, 1H), 7.13 (d, *J* = 7.4 Hz, 1H), 7.05 (m, 3H), 6.81 (d, *J* = 8.6 Hz, 2H), 3.49 (s, 3H), 2.95 (d, *J* = 7.4 Hz, 2H), 2.18 (s, 3H), 1.29 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 193.4, 189.5, 159.2, 145.4, 142.3, 138.0, 137.8, 137.3, 137.0, 134.1, 132.1, 131.1, 130.1 (CH×2), 129.5 (CH×2), 128.2 (CH×2), 127.8 (CH×2), 127.1, 126.5, 113.3 (CH×2), 55.1, 31.5, 21.1, 14.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{28}H_{25}O_3S_2$ 473.1240; found 473.1241.

(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)(o-tolyl)methanone (4ao). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (20/1, v/v) gave **4ao** (77 mg, 81%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.2 Hz, 2H), 7.25 (d, *J* = 7.4 Hz, 1H), 7.14 – 7.08 (m, 4H), 6.99 (d, *J* = 7.8 Hz, 1H), 6.94 (t, *J* = 7.5 Hz, 1H), 6.80 (d, *J* = 8.7 Hz, 2H), 6.35 (d, *J* = 8.7 Hz, 2H), 3.56 (s, 3H), 3.08 (q, *J* = 7.4 Hz, 2H), 2.39 (s, 3H), 1.41 (t, *J* = 7.4 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 194.6, 189.4, 159.1, 149.2, 146.0, 141.6, 138.6, 137.6, 137.5, 131.9, 131.34, 131.25, 131.0 (CH×2), 130.6 (CH×2), 129.3 (CH×2), 127.7 (CH×2)), 126.7, 125.1, 113.1 (CH×2), 55.1, 30.8, 20.6, 14.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{28}H_{25}O_3S_2$ 473.1240; found 473.1229.

General procedure for the one-pot synthesis of 4

To the solution of **1** (0.36 mmol) and **2** (0.3 mmol) in CH_3CN (1 mL) was added TFA (5 μL, 0.06 mmol). The mixture was continually stirred at 50 ℃ in an oil bath until **1** was consumed as indicated by TLC (*ca*. 2 h). The oil bath was removed. Silica gel (350 mg), ethyl acetate (10 mL) and iodine (46 mg, 0.18 mmol) were sequentially added. The solution was continually stirred under the irradiation with a 30 W CFL at RT until the intermediate (**3**) was consumed as indicated by TLC (15–20 h). It

was then quenched with a saturated aqueous solution of sodium thiosulfate (5 mL) and extracted with ethyl acetate (3 × 5 mL). The combined organic layer was washed with water and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate as eluent) to give the desired product **4.**

1-(5-benzoyl-2-(ethylthio)-4-(4-methoxyphenyl)thiophen-3-yl)propan-1-one (4ap). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (30/1, v/v) gave **4ap** (84 mg, 68%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.6 Hz, 2H), 7.30 (t, *J* = 7.4 Hz, 1H), 7.15 (t, *J* = 7.7 Hz, 2H), 7.01 (d, *J* = 8.6 Hz, 2H), 6.65 (d, *J* = 8.6 Hz, 2H), 3.72 (s, 3H), 3.09 (q, *J* = 7.4 Hz, 2H), 2.08 (q, *J* = 7.2 Hz, 2H), 1.45 (t, *J* = 7.4 Hz, 3H), 0.89 (t, *J* = 7.3 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 201.1, 189.3, 159.6, 150.4, 145.1, 140.6, 137.7, 136.4, 131.9, 130.9, 129.2 (CH×2), 127.8 (CH×2), 127.0 (CH×2), 113.7 (CH×2), 55.2, 36.0, 30.4, 13.8, 8.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{23}H_{23}O_3S_2$ 411.1083; found 411.1083.

Scale-up synthesis of 3a

To the solution of **1a** (1.43 g, 6 mmol) and **2a** (0.95 g, 5 mmol) in CH_3CN (20 mL) was added TFA (75 μL, 1 mmol). The mixture was continually stirred at 50 ℃ in an oil bath until **1a** was consumed as indicated by TLC (*ca*. 2h). Iodine (1.27 g, 5 mmol) was added, and the mixture was stirred at 50 ℃ in the oil bath until the intermediate was consumed as indicated by TLC (*ca*. 2 h). It was then diluted with a saturated aqueous solution of sodium thiosulfate (20 mL), and extracted with ethyl acetate (3 × 20 mL). The combined organic layer was washed with water and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate as eluent, 10/1, v/v) to give the desired product **3a** (2.34 g, 92%).

Scale-up synthesis of 4a

The solution of compound **3a** (2.29 g, 4.5 mmol) in EtOAc (40 mL) was continually stirred under the irradiation with a 30 W CFL at RT until **3a** was consumed as indicated by TLC (*ca*. 2 h). The mixture was diluted with a saturated aqueous solution of sodium thiosulfate (20 mL), and extracted with ethyl acetate (3 × 40 mL). The combined organic layer was washed with water and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate as eluent, 10/1, v/v) to give the desired product **4a** (1.43 g, 80%).

Suzuki-Miyaura coupling of 3ad with phenylboronic acid

A 10 mL Schlenk tube was charged with the mixture of **3ad** (0.2 mmol), $Pd(PPh_3)_4$ (0.01 mmol), KF (0.4 mmol), DMF (0.8 mL) and H_2O (0.2 mL) under an argon atmosphere. The mixture was continually stirred at 70 ℃ in an oil bath until **3ad** was consumed as indicated by TLC (*ca.* 5 h). It was then diluted with a saturated aqueous solution of ammonium chloride (5 mL), and extracted with ethyl acetate (3 × 5 mL). The combined organic layer was washed with water and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate as eluent, 10/1, v/v) to give the desired product **5a** (58 mg, 65%) as a yellow solid, mp 118−122 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.27 (d, *J* = 6.2 Hz, 3H), 7.21 (d, *J* = 7.4 Hz, 2H), 7.17 – 7.13 (m, 1H), 7.09 (d, *J* = 7.2 Hz, 2H), 6.97 (d, *J* = 6.0 Hz, 2H), 6.55 (s, 2H), 6.51 (s, 2H), 5.33 (s, 1H), 3.66 (s, 3H), 2.41 (s, 3H), 1.76 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.5, 158.4, 157.6, 140.6, 139.5, 137.9, 135.4, 131.6, 128.4 (CH×2), 128.1 (CH×2), 127.9 (CH×2), 127.5 (CH×2), 127.4 (CH×2), 127.3 (CH×2), 126.8, 126.5, 112.7 (CH×2), 57.3, 54.2, 28.0, 16.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{27}H_{25}O_2S_2$ 445.1290; found 445.1280.

DBU-catalyzed deiodinative hydrolysis of 3ad

A 10 mL Schlenk tube was charged with the mixture of **3ad** (0.2 mmol), DBU (0.3 mmol) and CH_3NO_2 (1 mL) under an argon atmosphere. The mixture was continually stirred at 70 ℃ in an oil bath until **3ad** was consumed as indicated by TLC (*ca.* 2 h). It was then diluted with a saturated aqueous solution of sodium thiosulfate (5 mL), and extracted with ethyl acetate (3 × 5 mL). The combined organic layer was washed with water and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate as eluent, 5/1, v/v) to give the desired product **5b** (58 mg, 76%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.33 – 7.25 (m, 5H), 7.15 (d, *J* = 8.0 Hz, 2H), 6.93 (d, *J* = 8.0 Hz, 2H), 5.74 (s, 1H), 5.29 (s, 1H), 3.85 (s, 3H), 2.52 (s, 3H), 1.79 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 194.1, 158.6, 141.8, 140.5, 138.5, 135.2, 129.9 (CH×2), 127.5 (CH×2), 127.0 (CH×2), 127.0, 125.1 (CH×2), 113.2 (CH×2), 69.5, 54.3, 29.2, 17.6. HRMS (ESI) m/z: [M + Na]$^+$ calcd for $C_{21}H_{20}O_3S_2Na$ 407.0746; found 407.0737.

Oxidation of 4ad with *m*-CPBA

To a solution of **4ad** (0.2 mmol) in dichloromethane (DCM, 1 mL) was added *m*-chloroperoxybenzoic acid (*m*-CPBA, 190 mg, 0.22 mmol) with stirring. The mixture was continually stirred at ambient temperature until **4ad** was consumed as indicated by TLC (*ca.* 3 h). It was then diluted with water (5 mL) and extracted with dichloromethane (DCM, 3 × 5 mL). The combined organic layer was washed with saturated aqueous $NaHCO_3$ (3 × 5 mL), water (3 × 5 mL), and brine, dried (Na_2SO_4), and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate as eluent, 10/1, v/v) to give the desired product **6** (77 mg,

93%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.58 (d, *J* = 7.5 Hz, 2H), 7.37 (d, *J* = 7.4 Hz, 1H), 7.20 (d, *J* = 6.3 Hz, 2H), 6.98 (d, *J* = 8.6 Hz, 2H), 6.66 (d, *J* = 8.6 Hz, 2H), 3.66 (s, 3H), 3.34 (s, 3H), 1.99 (s, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 200.5, 188.7, 160.2, 147.3, 143.1, 142.5, 141.9, 136.3, 133.5, 130.6 (CH×2), 129.7 (CH×2), 128.3 (CH×2), 124.9 (CH×2), 114.3, 55.3, 46.5, 31.4. HRMS (ESI) m/z: $[M + Na]^+$ calcd for $C_{21}H_{18}O_5S_2Na$ 437.0488; found 437.0485.

General procedure for the synthesis of thieno[2,3-*b*]thiophenes 7

To a mixture of **4** (0.2 mmol) and $Cu(OTf)_2$ (7 mol%) in 1,2-dichloroethane (DCE, 1 mL) was slowly added the solution of diazo compound (N_2=CHR[5], 0.6 mmol) in DCE (1 mL) over 1 hour. The reaction mixture was continually stirred at 80 ℃ in an oil bath until **4** was consumed as indicated by TLC (*ca.* 3 h). It was then diluted with water (5 mL), and extracted with DCM (3 × 5 mL). The combined organic layer was washed with water and brine, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel (petroleum ether/ethyl acetate) to give the desired product **7**.

ethyl 5-benzoyl-4-(4-methoxyphenyl)-3-methylthieno[2,3-b]thiophene-2-carboxylate (7a). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (30/1, v/v) gave **7a** (62 mg, 71%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.5 Hz, 2H), 7.33 (t, *J* = 7.4 Hz, 1H), 7.18 (t, *J* = 7.7 Hz, 2H), 7.10 (d, *J* = 8.5 Hz, 2H), 6.70 (d, *J* = 8.5 Hz, 2H), 4.35 (q, *J* = 7.1 Hz, 2H), 3.75 (s, 3H), 2.26 (s, 3H), 1.38 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.2, 162.5, 159.5, 146.7, 145.6, 141.5, 141.3, 138.0, 131.8, 131.5 (CH×2), 130.5 (CH×2), 129.2 (CH×2), 127.8 (CH×2), 125.8, 113.3 (CH×2), 61.1, 55.2, 14.7, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{24}H_{21}O_4S_2$ 437.0876; found 437.0878.

ethyl 5-benzoyl-4-(2-methoxyphenyl)-3-methylthieno[2,3-b]thiophene-2-carboxylate (7b). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (30/1, v/v)

gave **7b** (61 mg, 70%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.53 (d, *J* = 7.3 Hz, 2H), 7.27 (s, 1H), 7.12 (t, *J* = 7.8 Hz, 3H), 6.97 (dd, *J* = 7.4, 1.4 Hz, 1H), 6.72 (s, 1H), 6.65 (d, *J* = 8.3 Hz, 1H), 4.34 (q, *J* = 7.1 Hz, 2H), 3.72 (s, 3H), 2.20 (s, 3H), 1.38 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.4, 162.6, 156.8, 146.9, 145.4, 142.3, 141.6, 138.1, 137.7, 131.9, 131.8, 130.2 (CH×2), 128.8 (CH×2), 127.5 (CH×2), 123.0, 120.2, 110.0, 61.0, 55.1, 14.4, 13.4. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{24}H_{21}O_4S_2$ 437.0876; found 437.0877.

ethyl 4-(benzo[d][1,3]dioxol-5-yl)-5-benzoyl-3-methylthieno[2,3-b]thiophene-2-carboxylate (7c). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (30/1, v/v) gave **7c** (68 mg, 75%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.54 (d, *J* = 7.3 Hz, 2H), 7.37 (t, *J* = 7.4 Hz, 1H), 7.23 (t, *J* = 7.7 Hz, 2H), 6.66 (d, *J* = 5.7 Hz, 2H), 6.62 (d, *J* = 8.3 Hz, 1H), 5.94 (s, 1H), 5.85 (s, 1H), 4.35 (q, *J* = 7.1 Hz, 2H), 2.31 (s, 3H), 1.38 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 190.1, 162.4, 147.6, 147.1, 146.5, 145.5, 141.8, 141.1, 140.9, 138.1, 131.8, 130.6 (CH×2), 129.1 (CH×2), 127.8 (CH×2), 127.1 (CH×2), 124.2 (CH×2), 61.1, 14.7, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{24}H_{19}O_5S_2$ 451.0668; found 451.0668.

ethyl 5-(cyclopropanecarbonyl)-3-methyl-4-phenylthieno[2,3-b]thiophene-2-carboxylate (7d). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (30/1, v/v) gave 7d (46 mg, 62%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 (dd, *J* = 5.1, 1.8 Hz, 3H), 7.44 – 7.41 (m, 2H), 4.33 (d, *J* = 7.1 Hz, 2H), 2.10 (s, 3H), 1.59 – 1.56 (m, 1H), 1.36 (t, *J* = 7.1 Hz, 3H), 1.09 (d, *J* = 1.0 Hz, 2H), 0.62 (dd, *J* = 7.8, 3.5 Hz, 2H). ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 194.6, 162.4, 147.3, 145.9, 145.1, 141.4, 140.3, 134.9, 130.3, 129.7 (CH×2), 128.8 (CH×2), 128.4 (CH×2), 61.1, 19.6, 14.3, 13.9, 12.1. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{20}H_{19}O_3S_2$ 371.0770; found 371.0769.

ethyl 5-benzoyl-3-ethyl-4-(4-methoxyphenyl)thieno[2,3-b]thiophene-2-carboxylate (7e). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (30/1, v/v) gave **7e** (65 mg, 72%) as a yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.53 (dd, *J* = 16.2, 8.0 Hz, 2H), 7.34 (t, *J* = 7.4 Hz, 1H), 7.20 (t, *J* = 7.7 Hz, 2H), 7.15 (d, *J* = 8.5 Hz, 2H), 6.71 (d, *J* = 8.5 Hz, 2H), 4.35 (q, *J* = 7.1 Hz, 2H), 3.75 (s, 3H), 2.80 (q, *J* = 7.4 Hz, 2H), 1.38 (t, *J* = 7.1 Hz, 3H), 0.84 (t, *J* =

7.4 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 190.2, 162.1, 159.5, 148.0, 146.0, 145.9, 141.639, 141.2, 138.2, 131.8, 131.2, 130.2, 129.2 (CH×2), 127.8 (CH×2), 126.0 (CH×2), 113.2 (CH×2), 61.1, 55.2, 20.5, 14.7, 14.3. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{25}H_{23}O_4S_2$ 451.1032; found 451.1032.

3-methyl-5-(4-methylbenzoyl)-4-phenylthieno[2,3-b]thiophene-2-carbonitrile (7f). Purification by flash column chromatography eluting with petroleum ether/ethyl acetate (30/1, v/v) gave **7f** (61 mg, 81%) as a yellow oil. ^1H NMR (600 MHz, $CDCl_3$) δ 7.48 (d, *J* = 8.0 Hz, 2H), 7.23 (dd, *J* = 14.0, 6.5 Hz, 3H), 7.20 (d, *J* = 7.2 Hz, 2H), 6.99 (d, *J* = 8.0 Hz, 2H), 2.29 (s, 3H), 2.08 (s, 3H). $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ 189.2, 145.1, 144.4, 144.3, 143.3, 142.9, 139.9, 134.8, 133.1, 130.2, 129.6 (CH×2), 128.6 (CH×2), 128.4 (CH×2), 128.0 (CH×2), 113.9, 109.0, 21.6, 15.2. HRMS (ESI) m/z: $[M + H]^+$ calcd for $C_{22}H_{16}NOS_2$ 374.0668; found 374.0663.

Supporting Information

Reaction optimizations, mechanistic investigations, the crystal data for **3ad**, ^1H NMR and ^{13}C NMR spectra for new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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