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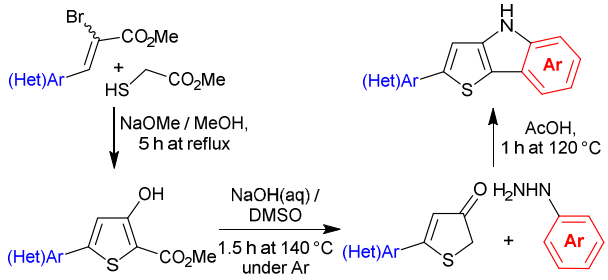
Graphical abstract

A new convenient synthetic route towards 2-(hetero)aryl-substituted thieno[3,2-*b*]indoles using the Fischer indolization

Roman A. Irgashev,* Alexander S. Steparuk, Gennady L. Rusinov



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A new convenient synthetic route towards 2-(hetero)aryl-substituted thieno[3,2-*b*]indoles using the Fischer indolization

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Keywords: Thieno[3,2-*b*]indole; Thiophen-3(2*H*)-one; Arylhydrazines; π-Conjugated molecules; the Fischer indole synthesis; the Fiesselmann thiophene synthesis

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A number of 2-(hetero)aryl-substituted thieno[3,2-*b*]indoles has been successfully prepared using an efficient transition-metal-free strategy, involved the Fiesselmann synthesis of methyl 5-(hetero)aryl-3-hydroxythiophene-2-carboxylates from 2-bromo-3-(hetero)arylacrylates and methyl thioglycolate, and transformation of the synthesized 3-hydroxyesters into corresponding thiophen-3(2*H*)-ones, followed by their treatment with arylhydrazines to directly form the targeted structures via the Fischer indolization. At the same time, structural variety of the obtained thieno[3,2-*b*]indoles has been achieved due to a wide range of available starting materials, both 2-bromo-3-(hetero)arylacrylates and arylhydrazines. In addition, two π-extended molecules, namely 1,4-bis(4*H*-thieno[3,2-*b*]indol-2-yl)benzene and 2,5-bis(4*H*-thieno[3,2-*b*]indol-2-yl)thiophene, have been synthesized in line with the current approach towards 2-(hetero)arylated thieno[3,2-*b*]indoles.

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Introduction

Indole ring system as well as its [*b*]-annelated analogues is a basic structural motif of a large number of naturally occurring and synthetic substances, which have been found to be useful for modern pharmacology, agriculture and materials science.[1–3] Thus, it is not surprising, that today various classes of indole-based compounds attract considerable attention of researchers in terms of elaborating new sustainable methods for their synthesis and their properties study.[4–7] In this context, thieno[3,2-*b*]indoles (TIs) represent an important family of fused N,S-containing heterocycles, since some TI species have exhibited promising biological properties, such as anti-osteoarthritis,[8] antitumor,[9] antitubercular[10] and antibacterial[9,11] activities. Besides, over the past decade thieno[3,2-*b*]indole has been widely and successfully utilized as electron-rich heteroaromatic subunits for engineering of various linear π-conjugated and fused molecules for organic electronics applications. Indeed, a number of organic dyes, both small molecules[12–16] and polymers,[17–19] *e.g.*, **MKZ 39-41** and **PTITBT** in Figure 1, bearing thieno[3,2-*b*]indole moiety as electron-donating part of their push-pull structures, have been regarded as light-harvesting materials for high performance organic photovoltaics (OVPs). Additionally, it has recently been reported an interesting application of near-infrared dyes, bearing thieno[3,2-*b*]indole and diketopyrrolopyrrole (DPP) scaffolds, *e.g.,* **DPP-r-TI** in Figure 1, as effective photosensitizes for both photodynamic and photothermal therapies.[20]

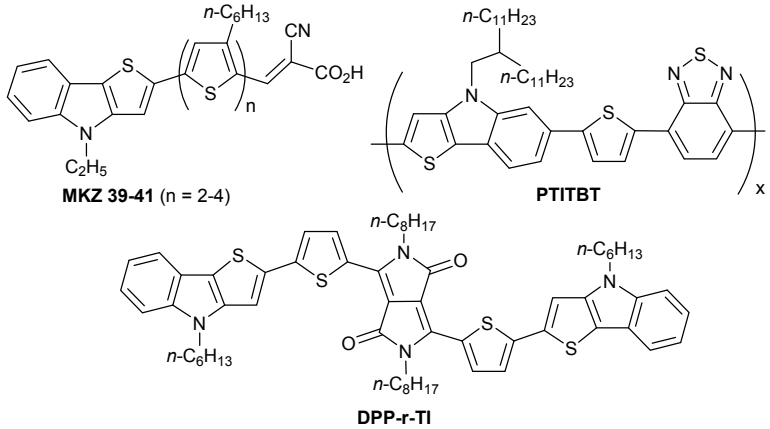

Figure 1. Thieno[3,2-*b*]indole-containing push-pull chromophores

It is important to note, that synthetic approaches towards these π-extended TI-based molecules are included (hetero)aryl-linked thieno[3,2-*b*]indoles as the key intermediates, which, in their turn, are obtained via Pd-catalyzed processes, such as the Suzuki-Miyaura or the Stille cross-coupling reactions. Therefore, the elaboration of convenient and robust synthetic approaches, that ensure an easy access to (hetero)arylated thieno[3,2-*b*]indoles, is an important challenge, since such compounds are in-demand as building blocks for optoelectronic materials engineering. Herewith, the

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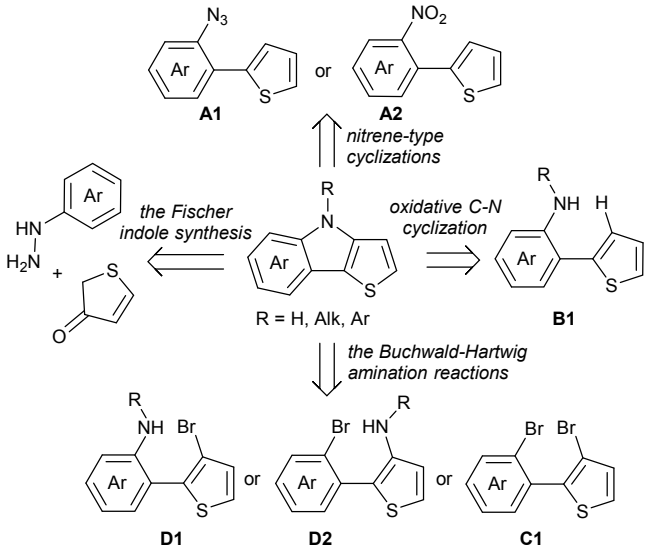
published methods for the construction of TI framework include both thermal and catalytic cyclization of 2-(2-azidoaryl)thiophenes **A1**,[21–24] the Cadogan reductive cyclization of 2-(2-nitroaryl)thiophenes **A2**,[25,26] Cu-catalyzed C-H / N-H oxidative cyclization of 2-(2-aminoaryl)thiophenes **B1**,[27] as well as the Buchwald-Hartwig amination of 2-(2-bromoaryl)-3-bromothiophenes **C1**,[28–30] and intramolecular amination of 2-(2-aminoaryl)-3-bromothiophenes **D1**[31] or isomeric molecules **D2**[32,33] (Scheme 1). Nevertheless, the application of above mentioned routes for synthesis of (hetero)aryl-substituted TIs requires additional steps, mostly Pd-catalyzed cross-coupling reactions, to prepare the functionalized in appropriate manner intermediates **A-D**. As compared with these methods, the Fischer indole synthesis[34–36] seems to be more attractive and convenient chemical tool for construction of thieno[3,2-*b*]indole ring system, including its (hetero)arylated derivatives. Indeed, in the frame of this strategy, the desired thieno[3,2-*b*]indoles can be easy obtained from corresponding thiophen-3(2*H*)-ones and arylhydrazines,[10] since such transformation of thiophen-3(2*H*)-one fragment into thieno[3,2-*b*]indole ring system proceeds smoothly and without isolation of the intermediate arylhydrazones. In particular, we have recently communicated a convenient approach towards N,S-heteroacenes, namely 6*H*-benzo[4',5']thieno[2',3':4,5]thieno[3,2-*b*]indoles, using the Fischer indole synthesis as the key reaction.[37] Continuing our research, we wish to report herein an efficient and convenient method for synthesis of 2-(hetero)arylated thieno[3,2-*b*]indoles in line with the Fischer indolization strategy.



Scheme 1. Retrosynthetic map of thieno[3,2-*b*]indole framework construction

Results and discussion

The purpose of our investigation has been to elaborate synthetic approach towards 2-(hetero)aryl-linked thieno[3,2-*b*]indoles using the Fischer indolization as the key step, to provide structural

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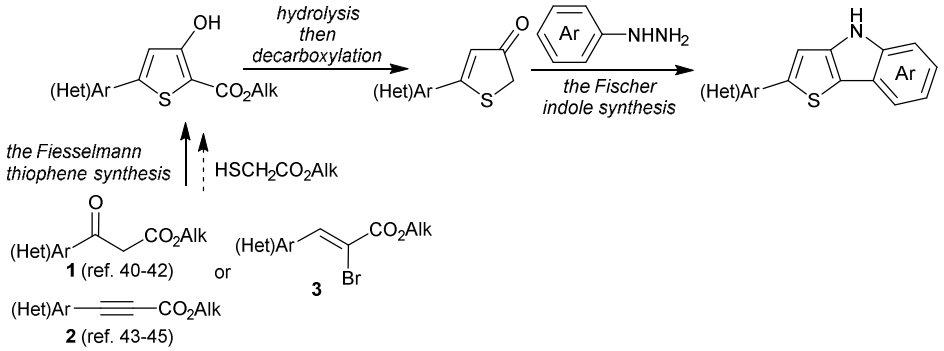
variety of these compounds. Therefore, we have focused on the 5-(hetero)arylthiophen-3(2*H*)-ones, the main precursors of the TIs, to find optimal way for their preparation based on available (hetero)aromatic sources. Generally, 2-unsubstituted thiophen-3(2*H*)-ones can be easily obtained by the ester hydrolysis and the *in situ* decarboxylation of alkyl 3-hydroxythiophene-2-carboxylates (2-thenoates). In its turn, a convenient method for preparation of the latter 2-thenoates is the Fiesselmann thiophene synthesis, which represents a reaction of 1,3-C,C-dielectrophilic substrates with alkyl thioglycolates under basic conditions.[38,39] To this way, few 5-(hetero)aryl-3-hydroxy-substituted 2-thenoates have previously been synthesized either in two steps from 2-(hetero)aroylacetates **1**[40–42] or directly from 3-(hetero)arylpropiolates **2**,[43–45] in accordance with the Fiesselmann method (Scheme 2).



Scheme 2. The selected route to 2-(hetero)aryl-substituted thieno[3,2-*b*]indoles, based on the Fischer and the Fiesselmann methods

At the same time, 2-bromo-3-(hetero)arylacrylates **3** (α-bromocinnamates or their hetero analogues), being easily obtainable chemicals, are also attractive as 1,3-dielectrophilic three-carbon units for the Fiesselmann thiophene synthesis (Scheme 2), since these compounds can be considered as synthetic equivalents of 3-(hetero)arylpropiolates **2** in a context of their reactivity as the Michael acceptors for nucleophilic addition.[46,47] For this reason, we have selected the former substrates for the preparation of 3-hydroxy-2-thenoates, bearing (hetero)aromatic fragments at C-5. To this end, methyl α-bromocinnamates **3a-k** (mixtures of Z-E stereoisomers) have readily been obtained in 87-98% yields, using the one-pot procedure for bromination/dehydrobromination of methyl cinnamates (for more experimental details see ESI). Next, species **3a-k** have successfully been involved in the reaction with methyl thioglycolate (2 equiv.) in the presence of NaOMe (4 equiv.) in a methanol solution to form methyl 5-aryl-3-hydroxythiophene-2-carboxylates **4a-k** in 29-84% yields (Scheme 3, Table 1). In regard to practical aspects of this procedure, the best results have been achieved, when substrate **3**, together with methyl thioglycolate, has gradually been added to NaOMe in dry MeOH, followed by reflux of a reaction mixture for 5 h. However, 2-thenoates **4h-k** have been

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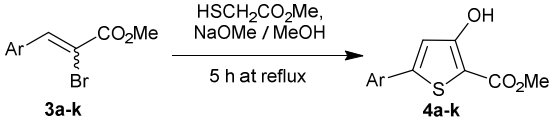
obtained in moderate yields. This fact can probably be explained by steric hindrances for *S*-nucleophile addition to activated C=C double bond of α-bromocinnamates **3h-k**, having bulky *o*-substituted aryls (Table 1, entries 8-11). At the same time, due to the rather small radius (1.47 Å)[48] of fluorine atom, 2-fluorophenyl-containing substrate **3g** (Table 1, entry 7) has given corresponding 2-thenoate **4g** in 60% yield, which is comparable with 62% yield of 2-thenoate **4a**, having a simple phenyl substituent at C-5 (Table 1, entry 1).

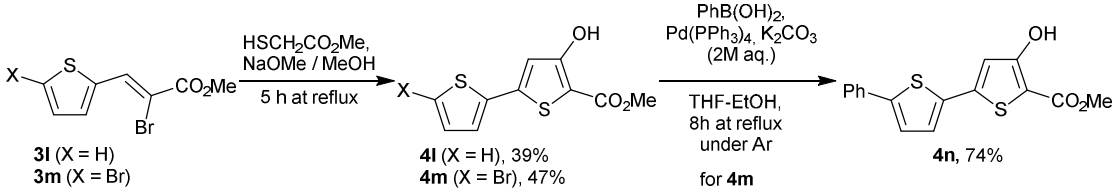


Scheme 3. Synthesis of methyl 5-aryl-3-hydroxythiophene-2-carboxylates **4**

Table 1. Substrate scope of methyl 5-aryl-3-hydroxythiophene-2-carboxylates **4**

entry	methyl α-bromocinnamate **3** (Ar)	**4** (yield %)
1	**3a** (phenyl)	**4a** (62)
2	**3b** (4-fluorophenyl)	**4b** (84)
3	**3c** (4-bromophenyl)	**4c** (75)
4	**3d** (4-methoxyphenyl)	**4d** (72)
5	**3e** (4-hexyloxyphenyl)	**4e** (65)
6	**3f** (3,4,5-trimethoxyphenyl)	**4f** (79)
7	**3g** (2-fluorophenyl)	**4g** (60)
8	**3h** (2-chlorophenyl)	**4h** (31)
9	**3i** (2-bromophenyl)	**4i** (29)
10	**3j** (2-methoxyphenyl)	**4j** (35)
11	**3k** (1-naphthyl)	**4k** (43)

Besides, to build thien-2-yl-linked thieno[3,2-*b*]indoles, methyl [2,2'-bithiophene]-5-carboxylates **4l,m** have been prepared from methyl 2-bromo-3-(thien-2-yl)acrylates **3l,m**, which obtained by esterification of corresponding 2-bromoacrylic acids[49] (for more experimental details see ESI). To show compatibility of the current strategy with others synthetic techniques, Br-containing ester **4m** has been converted into corresponding 5-phenylthien-2-yl-linked derivatives **4n** using the Suzuki-Miyaura cross-coupling reaction (Scheme 4). Importantly, the main 5-(hetero)aryl-3-hydroxy-substituted 2-thenoates **4a-m** have been produced in gram scales, thanks to easy procedure of their preparation and high availability of source compounds **3**.



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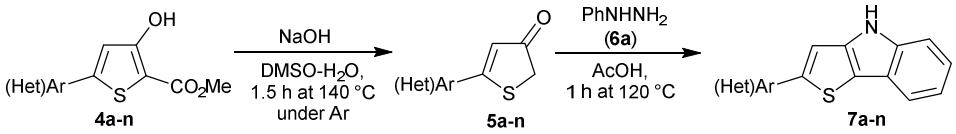
Scheme 4. Synthesis of methyl [2,2'-bithiophene]-5-carboxylates **4l,m** and **4n**

Construction of the target TI frameworks has been carried out by the next two steps. Saponification of the synthesized esters **4** has been performed by their treatment with excess of NaOH in aqueous DMSO solution at 140 °C for 1.5 h under an argon atmosphere, followed by acidic workup of the reaction mixtures to obtain thiophen-3(2*H*)-ones **5** in 88-95% yields (Scheme 5, Table 2). Along with good results in this synthetic step, saponification of ester **4m** has totally failed under these alkali reaction conditions, apparently due to a cleavage of 5-bromothien-2-yl part (Table 2, entry 13). Clearly, the preliminary replacement of bromine atom in substrate **4m**, before its conversion to thiophen-3(2*H*)-one, is more preferable way to perform the necessary modifications. Nevertheless, the treatment of ester **4m** with a mixture of trifluoroacetic and methanesulfonic acids at 80 °C for 2 h has allowed us to receive crude ketone **5m** in 29% yield, that has been used in the next step without purification. Unsubstituted at benzene ring thieno[3,2-*b*]indoles **7a-n**, bearing (hetero)aromatic moieties at C-2, have been obtained in 38-72% yields by reaction of thiophen-3(2*H*)-ones **5a-n** with phenylhydrazine **6a** (1.5 equiv.) in the solution of glacial acetic acid at 120 °C for 1 h (Scheme 5, Table 2). At the same time, the use of phenylhydrazine hydrochloride instead of its base form **6a** in the reaction with ketone **5a** under the same conditions has reduced the yield of thieno[3,2-*b*]indole **7a** to 28% because of significantly increased decomposition of starting substrate **5a**.



Scheme 5. Synthetic route to 2-(hetero)aryl-substituted thieno[3,2-*b*]indoles **7a-n**

Table 2. Substrate scope of (het)arylated thiophen-3(2*H*)-ones **5** and thieno[3,2-*b*]indoles **7**

entry	2-thenoate **4** (Ar or Het)	**5** (yield %)	**7** (yield %)
1	**4a** (phenyl)	**5a** (95)	**7a** (58 / 28[b])
2	**4b** (4-fluorophenyl)	**5b** (92)	**7b** (65)
3	**4c** (4-bromophenyl)	**5c** (95)	**7c** (61)
4	**4d** (4-methoxyphenyl)	**5d** (88)	**7d** (70)
5	**4e** (4-hexyloxyphenyl)	**5e** (95)	**7e** (70)
6	**4f** (3,4,5-trimethoxyphenyl)	**5f** (90)	**7f** (41)
7	**4g** (2-fluorophenyl)	**5g** (91)	**7g** (53)
8	**4h** (2-chlorophenyl)	**5h** (95)	**7h** (56)
9	**4i** (2-bromophenyl)	**5i** (89)	**7i** (38)
10	**4j** (2-methoxyphenyl)	**5j** (95)	**7j** (66)
11	**4k** (1-naphthyl)	**5k** (88)	**7k** (44)

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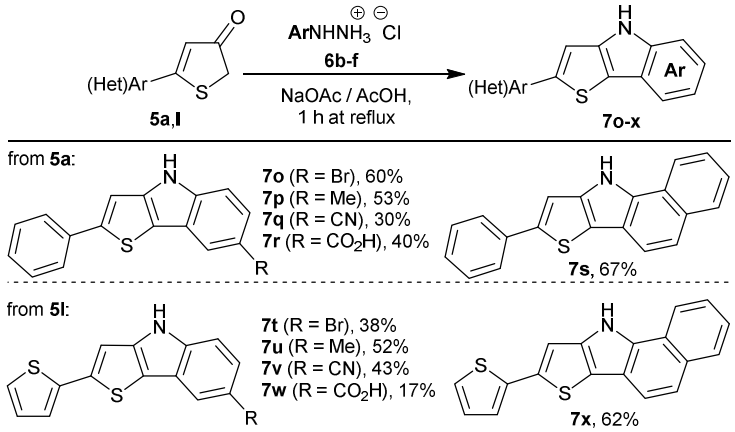
12	**4l** (thien-2-yl)	**5l** (90)	**7l** (72)
13	**4m** (5-bromothien-2-yl)	**5m** (0 / 29[a])	**7m** (61)
14	**4n** (5-phenylthien-2-yl)	**5n** (95)	**7n** (66)

[a] A mixture of CF_3CO_2H and $MeSO_3H$ (v/v, 3:1) has been used in this case.
[b] In the case of the use of $PhNHNH_2 \cdot HCl$.

During this study, thieno[3,2-*b*]indoles, functionalized at both thiophene and benzene rings of their framework, have also been obtained in the same manner using the Fischer indolization process. Two thiophen-3(2*H*)-ones **5a** and **5l**, bearing phenyl and thien-2-yl at C-5, have been treated with 4-bromo-, 4-methyl-, 4-cyano-, and 4-carboxyphenylhydrazine **6b-e** or 1-naphtylhydrazine **6f** hydrochlorides (1.5 equiv.) and NaOAc (1.5 equiv.), added to neutralize hydrochloric acid, under the similar reaction conditions, to afford 2,7-disubstituted thieno[3,2-*b*]indoles **7o-r** and **7t-w** or 8-substituted benzo[*g*]thieno[3,2-*b*]indoles **7s** and **7x**, respectively (Scheme 6).



Scheme 6. Synthesis of thiophene-benzene-functionalized TIs **7o-x**, substrate scope and yields

Thus, formation of the desired thieno[3,2-*b*]indoles has been reached in all studied by us reactions of thiophene-3(2*H*)-ones **5** with arylhydrazines **6**, that provides access to a wide range of new TI compounds **7**. However, derivatives **7f,i,k** (Scheme 5, Table 2) and **7q,r,t,v,w** (Scheme 6) have been isolated in 38-44% and 17-43% yields, respectively, although we have observed full consumption of source materials **5** in these experiments. It can be assumed, that a decrease in the yield of these products is caused by undesirable transformations of the reaction intermediates, such as N-N bond cleavage in the ene-hydrazines, that leads to side processes.[50,51] Moreover, the indolization slows down when using arylhydrazines, bearing electron-withdrawing groups,[52] which explains poor yields of compounds **7q**,**v** and **7r**,**w**, obtained from 4-cyano- and 4-carboxy-substituted phenylhydrazines **6d** and **6e**, respectively.

Furthermore, the application of the present synthetic strategy to the construction of some more π-extended thieno[3,2-*b*]indole-based molecules has been also investigated. To this end, diethyl bis(2-

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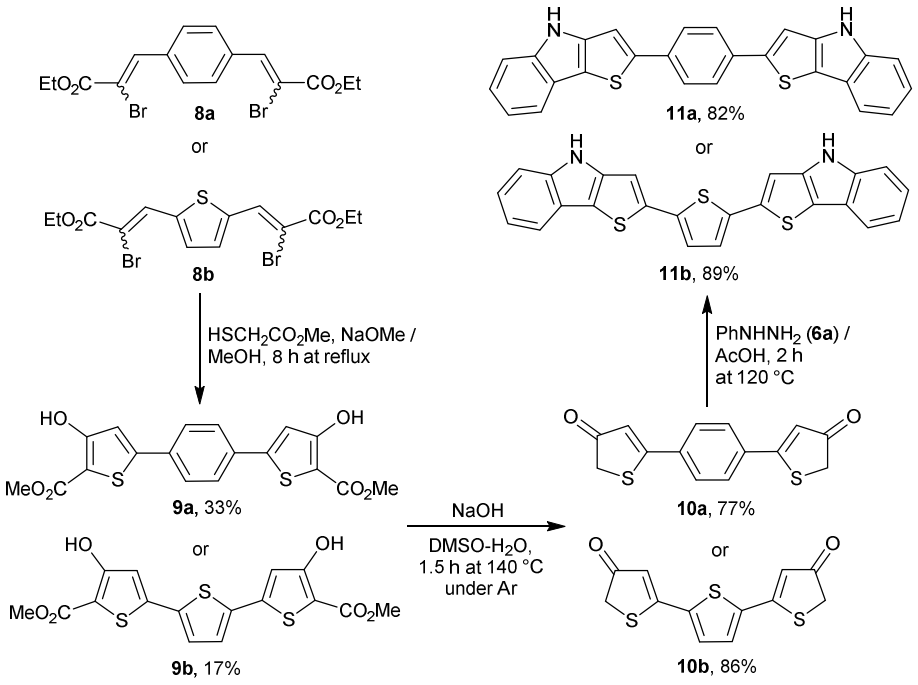
bromoacrylates) **8a** and **8b** have been synthesized starting from the corresponding bis(acrylates), by analogy with the synthesis of α-bromocinnamates **3** from cinnamates (for more experimental details see ESI). Substrates **8** have been used as ethyl diester forms to provide their sufficient solubility in the next step. Dimethyl bis(3-hydroxy-2-thenoates) **9a** and **9b** have been obtained in 33% and 17% yield, respectively, by condensation of bis(2-bromoacrylates) **8a,b** with methyl thioglycolate (4 equiv.) in the presence of NaOMe (8 equiv.) in a methanol solution. Note that the low yields of derivatives **9** can be explained by a successive transformation of 2-bromoacrylate units of starting molecules **8** into thiophene moieties during the reaction. In this context, average yields per the formation of one thiophene ring of **9a** and **9b** are respectively 57% and 41%, which is comparable with the yields of similar 2-thenoates **4a** (62%, Table 1, entry 1) and **4l** (38%, Scheme 4). Further cleavage of diesters **9a,b** under the same reaction conditions as for esters **4** has readily given the key precursors **10a,b**, that have been successfully converted into the target twin TI derivatives **11a,b** according to the Fischer indolization procedure (Scheme 7). In this case, analytically pure forms of products **11** have been obtained by their sublimation at high temperature under reduced pressure (280 °C / 3 mbar), due to low solubility of these bulky TI molecules in the majority of organic solvents. It should be also noted, that an appreciable tendency to sublimation at close to the melting point temperature, even under atmospheric pressure, has been observed for most of the synthesized thieno[3,2-*b*]indoles.



Scheme 7. Synthesis of π-extended thieno[3,2-*b*]indole-based molecules **11**

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Conclusion

In summary, we have successfully applied the Fischer indolization process to the construction of thieno[3,2-*b*]indole frameworks, having aromatic or heteroaromatic units at C-2. The necessary 5-(hetero)arylthiophen-3(2*H*)-ones have been obtained by two-step route included condensation of easily accessible α-bromocinnamates or their heteroanalogues with methyl thioglycolate according to the Fiesselmann method and alkali treatment of the afforded 5-(hetero)aryl-3-hydroxy-substituted 2-thenoates. The advantages of present methodology are available starting substrates and convenient reactions based on transition metal-free processes, thereby it provides an easy access to a variety of (hetero)aryl-linked thieno[3,2-*b*]indoles, with optional functions at benzene ring of their system. In this context, the current approach has a high synthetic utility for further engineering of new thieno[3,2-*b*]indole-based both (photo)electronic materials and pharmaceuticals.

Experimental

General information. Analytical studies were carried out using equipment of the Center for Joint Use "Spectroscopy and Analysis of Organic Compounds" at Postovsky Institute of Organic Synthesis (Ural Division, RAS). ^{1}H, ^{13}C and ^{19}F NMR spectra were obtained on a Bruker DRX-400 and AVANCE-500 spectrometers with Me_4Si as an internal standard for ^{1}H and ^{13}C NMR or C_6F_6 as an internal standard for ^{19}F NMR. ^{13}C NMR spectra of compounds **11a,b** were not recorded because of poor solubility of these substances in a majority of deuterated solvents. Elemental analysis was carried on a Eurovector EA 3000 automated analyzer. High-resolution mass spectrometry was performed using a Bruker maXis Impact HD spectrometer. Melting points were determined on Boetius combined heating stages and were not corrected. Silica gel 0.040–0.063 mm (230–400 mesh) was used to purify compounds. All used solvents were dried and distilled per standard procedures.

General procedure for synthesis of methyl 5-(hetero)aryl-3-hydroxythiophene-2-carboxylates (4a-m). A mixture of appropriate methyl 2-bromoacrylate **3** (50 mmol) and methyl thioglycolate (9.15 ml, 100 mmol) in dry MeOH (30 ml) (dry THF (30 ml) was used in the case of substrate **3m**) was added dropwise to a stirred solution of NaOMe, prepared from sodium (4.6 g, 200 mmol) and dry MeOH (70 ml), at 0 °C during 20 min and the formed suspension was vigorously stirred and heated at reflux for 5 h. Then, the reaction mixture was poured into ice-cold water (100 ml) and the obtained turbid pale-green solution was immediately acidified with conc. HCl (13 ml) to form precipitate of the product. The obtained solid was collected by filtration, washed with water (5×30

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ml), MeOH (15 ml) and dried at room temperature. Crude products **4a**,**b**,**l** were purified by crystallization from 50% aqueous EtOH (50 ml), while other crude materials **4** were crystallized from a mixture of toluene and MeOH (60 ml, v/v 1:3), to afford the analytically pure forms.

Methyl 3-hydroxy-5-phenylthiophene-2-carboxylate (4a). White needles, m.p. 97-98 °C (from 50% aqueous EtOH); yield 7.26 g (62%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.42 (s, 1H), 7.74 – 7.66 (m, 2H), 7.52 – 7.38 (m, 3H), 7.19 (s, 1H), 3.78 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.9, 161.5, 147.1, 132.5, 129.3, 129.2, 125.5, 116.7, 104.0, 51.5. Anal. Calcd for $C_{12}H_{10}O_3S$: C, 61.52; H, 4.30. Found: C, 61.63; H, 4.22.

Methyl 5-(4-fluorophenyl)-3-hydroxythiophene-2-carboxylate (4b). White fleecy crystals, m.p. 156-157 °C (from 50% aqueous EtOH); yield 10.59 g (84%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.42 (s, 1H), 7.79 – 7.72 (m, 2H), 7.34 – 7.25 (m, 2H), 7.17 (s, 1H), 3.78 (s, 3H). ^{19}F NMR (471 MHz, DMSO-d_6) δ 50.75 – 50.68 (m). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.9, 162.6 (d, J_{CF} = 247.4 Hz), 161.5, 145.9, 129.1 (d, J_{CF} = 3.1 Hz), 127.7 (d, J_{CF} = 8.5 Hz), 116.9, 116.2 (d, J_{CF} = 21.9 Hz), 104.0, 51.5. Anal. Calcd for $C_{12}H_9FO_3S$: C, 57.14; H, 3.60. Found: C, 57.03; H, 3.61.

Methyl 5-(4-bromophenyl)-3-hydroxythiophene-2-carboxylate (4c). Pink powder, m.p. 147-148 °C (from toluene-MeOH, v/v 1:3); yield 11.74 g (75%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.46 (s, 1H), 7.67 – 7.63 (m, 4H), 7.22 (s, 1H), 3.79 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.7, 161.3, 145.5, 132.1, 131.7, 127.4, 122.5, 117.3, 104.5, 51.5. Anal. Calcd for $C_{12}H_9BrO_3$: C, 46.02; H, 2.90. Found: C, 45.92; H, 2.79.

Methyl 3-hydroxy-5-(4-methoxyphenyl)thiophene-2-carboxylate (4d). White needles, m.p. 138-139 °C (from toluene-MeOH, v/v 1:3); yield 9.51 g (72%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.32 (s, 1H), 7.77 – 7.47 (m, 2H), 7.08 (s, 1H), 7.04 – 6.98 (m, 2H), 3.80 (s, 3H), 3.78 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 163.0, 161.7, 160.2, 147.4, 127.0, 125.1, 115.4, 114.6, 102.8, 55.3, 51.4. Anal. Calcd for $C_{13}H_{12}O_4S$: C, 59.08; H, 4.58. Found: C, 59.15; H, 4.50.

Methyl 5-[4-(hexyloxy)phenyl]-3-hydroxythiophene-2-carboxylate (4e). Pale pink powder, m.p. 96-97 °C (from toluene-MeOH, v/v 1:3); yield 10.87 g (65%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.32 (s, 1H), 7.61 (d, J = 8.8 Hz, 2H), 7.07 (s, 1H), 6.99 (d, J = 8.8 Hz, 2H), 4.00 (t, J = 6.5 Hz, 2H), 3.77 (s, 3H), 1.75 – 1.66 (m, 2H), 1.45 – 1.37 (m, 2H), 1.34 – 1.27 (m, 4H), 0.88 (t, J = 7.0 Hz, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ163.0, 161.7, 159.7, 147.4, 126.9, 124.9, 115.3, 115.0,

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102.7, 67.6, 51.4, 31.0, 28.5, 25.1, 22.0, 13.9. Anal. Calcd for $C_{18}H_{22}O_4S$: C, 64.65; H, 6.63. Found: C, 64.78; H, 6.67.

Methyl 3-hydroxy-5-(3,4,5-trimethoxyphenyl)thiophene-2-carboxylate (4f). Beige powder, m.p. 152-153 °C (from toluene-MeOH, v/v 1:3); yield 12.81 g (79%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.29 (s, 1H), 7.21 (s, 1H), 6.94 (s, 2H), 3.85 (s, 6H), 3.78 (s, 3H), 3.69 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ163.0, 161.5, 153.3, 147.4, 138.6, 128.2, 116.8, 103.7, 103.2, 60.1, 56.1, 51.5. Anal. Calcd for $C_{15}H_{16}O_6S$: C, 55.55; H, 4.97. Found: C, 55.54; H, 4.93.

Methyl 5-(2-fluorophenyl)-3-hydroxythiophene-2-carboxylate (4g). White powder, m.p. 139-140 °C (from toluene-MeOH, v/v 1:3); yield 7.57 g (60%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.51 (s, 1H), 7.81 (td, J = 8.0, 1.6 Hz, 1H), 7.51 – 7.44 (m, 1H), 7.41 – 7.35 (m, 1H), 7.34 – 7.27 (m, 1H), 7.24 (d, J = 0.5 Hz, 1H), 3.79 (s, 3H). ^{19}F NMR (471 MHz, DMSO-d_6) δ 49.34 – 49.25 (m). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.6, 160.7, 158.7 (d, J_{CF} = 250.2 Hz), 139.8 (d, J_{CF} = 3.1 Hz), 131.0 (d, J_{CF} = 8.7 Hz), 128.5 (d, J_{CF} = 2.6 Hz), 125.3 (d, J_{CF} = 3.2 Hz), 120.1 (d, J_{CF} = 11.7 Hz), 119.4 (d, J_{CF} = 5.4 Hz), 116.6 (d, J_{CF} = 22.0 Hz), 105.1 (d, J_{CF} = 5.4 Hz), 51.5. Anal. Calcd for $C_{12}H_9FO_3S$: C, 57.14; H, 3.60. Found:C, 57.20; H, 3.57.

Methyl 5-(2-chlorophenyl)-3-hydroxythiophene-2-carboxylate (4h). Beige needles, m.p. 136-137 °C (from toluene-MeOH, v/v 1:3); yield 4.17 g (31%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.54 (s, 1H), 7.68 – 7.64 (m, 1H), 7.63 – 7.59 (m, 1H), 7.49 – 7.42 (m, 2H), 7.12 (s, 1H), 3.78 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.5, 160.2, 143, 131.2, 131.04, 131.00, 130.7, 130.6, 127.9, 121.2, 105.8, 51.5. Anal. Calcd for $C_{12}H_9ClO_3S$: C, 53.64; H, 3.38. Found: C, 53.53; H, 3.51.

Methyl 5-(2-bromophenyl)-3-hydroxythiophene-2-carboxylate (4i). Pale orange needles, m.p. 118-119 °C (from toluene-MeOH, v/v 1:3); yield 4.54 g (29%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.55 (s, 1H), 7.78 (dd, J = 8.0, 1.0 Hz, 1H), 7.59 (dd, J = 7.7, 1.7 Hz, 1H), 7.49 (td, J = 7.6, 1.1 Hz, 1H), 7.38 (td, J = 7.7, 1.7 Hz, 1H), 7.04 (s, 1H), 3.79 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.5, 160.1, 144.9, 133.8, 133.4, 131.5, 130.8, 128.3, 121.5, 121.4, 105.7, 51.5. Anal. Calcd for $C_{12}H_9BrO_3S$: C, 46.02; H, 2.90. Found: C, 46.03; H, 2.77.

Methyl 3-hydroxy-5-(2-methoxyphenyl)thiophene-2-carboxylate (4j). Yellowish needles, m.p. 104-105 °C (from toluene-MeOH, v/v 1:3); yield 4.63 g (35%); ^{1}H NMR (400 MHz, DMSO-d_6) δ

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10.18 (s, 1H), 7.77 (dd, *J* = 7.8, 1.6 Hz, 1H), 7.40 (ddd, *J* = 8.6, 7.4, 1.6 Hz, 1H), 7.29 (s, 1H), 7.22 – 7.13 (m, 1H), 7.05 (td, *J* = 7.8, 1.0 Hz, 1H), 3.94 (s, 3H), 3.78 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 163.4, 160.8, 155.9, 142.9, 130.4, 127.7, 121.0, 120.7, 117.5, 112.4, 104.3, 55.7, 51.4. Anal. Calcd for $C_{13}H_{12}O_4S$: C, 59.08; H, 4.58. Found: C, 59.07; H, 4.65.

Methyl 3-hydroxy-5-(naphthalen-1-yl)thiophene-2-carboxylate (4k). Cream needles, m.p. 133-134 °C (from toluene-MeOH, v/v 1:3); yield 6.11 g (43%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.58 (s, 1H), 8.19 – 8.13 (m, 1H), 8.08 – 8.00 (m, 2H), 7.67 – 7.55 (m, 4H), 7.03 (s, 1H), 3.81 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.7, 160.6, 145.3, 133.4, 130.7, 130.3, 129.5, 128.6, 127.7, 127.3, 126.5, 125.5, 124.5, 121.1, 105.2, 51.5. Anal. Calcd for $C_{16}H_{12}O_3S$: C, 67.59; H, 4.25. Found: C, 67.42; H, 4.08.

Methyl 4-hydroxy-[2,2'-bithiophene]-5-carboxylate (4l). Cream crystals, m.p. 70-71 °C (from 50% aqueous EtOH); yield 4.69 g (39%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.54 (s, 1H), 7.65 (dd, *J* = 5.1, 1.0 Hz, 1H), 7.48 (dd, *J* = 3.6, 1.1 Hz, 1H), 7.14 (dd, *J* = 5.0, 3.7 Hz, 1H), 6.97 (s, 1H), 3.77 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.5, 161.0, 140.4, 135.4, 128.7, 127.6, 126.0, 116.4, 103.2, 51.5. Anal. Calcd for $C_{10}H_8O_3S_2$: C, 49.98; H, 3.36. Found: C, 49.73; H, 3.13.

Methyl 5'-bromo-4-hydroxy-[2,2'-bithiophene]-5-carboxylate (4m). Yellow needles, m.p. 138-139 °C (from toluene-MeOH, v/v 1:3); yield 7.50 g (47%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.58 (s, 1H), 7.34 (d, *J* = 3.9 Hz, 1H), 7.28 (d, *J* = 3.9 Hz, 1H), 6.96 (s, 1H), 3.76 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.4, 160.8, 138.8, 137.0, 131.9, 126.6, 117.0, 112.6, 103.8, 51.5. Anal. Calcd for $C_{10}H_7BrO_3S_2$: C, 37.63; H, 2.21. Found: C, 37.54; H, 2.20.

Procedure for synthesis of methyl 4-hydroxy-5'-phenyl-[2,2'-bithiophene]-5-carboxylate (4n). Methyl 5'-bromo-4-hydroxy-[2,2'-bithiophene]-5-carboxylate **4m** (640 mg, 2 mmol), phenylboronic acid (488 mg, 4 mmol), $Pd(PPh_3)_4$ (116 mg, 0.1 mmol) together with 2M aqueous K_2CO_3 solution (3 ml), THF (12 ml) and EtOH (8 ml) were placed in a 50 ml Schlenk tube, equipped with a magnetic stir bar and reflux condenser. The resulting mixture was deoxygenated by several cycles (4 – 5 times) of vacuum pumping and flushing with argon at room temperature, and then it was stirred and heated at reflux for 7 h under an argon atmosphere. After this time, the reaction mixture was treated with AcOH (4 ml) and evaporated to dryness under reduced pressure. The obtained residue was extracted with warm $CHCl_3$ (3×20 ml) and the resulting $CHCl_3$ solution was eluted through a short

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silica gel plug (1 cm×1.5 cm) with $CHCl_3$ (15 ml). The filtrate was concentrated in vacuum to afford the crude product, which was purified by crystallization from a mixture of toluene and MeOH (10 ml, v/v 1:1) to obtain analytically pure compound **4n**.

Methyl 4-hydroxy-5'-phenyl-[2,2'-bithiophene]-5-carboxylate (4n). Pale yellow powder, m.p. 121-122 °C; yield 468 mg (74%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.57 (s, 1H), 7.70 (d, J = 7.4 Hz, 2H), 7.56 (d, J = 3.9 Hz, 1H), 7.52 (d, J = 3.8 Hz, 1H), 7.45 (t, J = 7.6 Hz, 2H), 7.36 (t, J = 7.4 Hz, 1H), 7.00 (s, 1H), 3.77 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 162.5, 161.1, 144.3, 140.0, 134.5, 132.8, 129.2, 128.3, 127.2, 125.4, 125.0, 116.4, 103.3, 51.5. Anal. Calcd for $C_{16}H_{12}O_3S_2$: C, 60.74; H, 3.82. Found: C, 60.70; H, 3.87.

General procedure for synthesis of 5-(hetero)arylthiophen-3(2*H*)-ones (5a-l,n). NaOH (5.04 g, 126 mmol) in water (24 ml) was added in one portion to appropriate methyl 2-thenoate **4** (6.3 mmol) in DMSO (15 ml) and the obtained solution was flushed with argon, then it was stirred and heated at 140 °C for 1.5 h under an argon atmosphere. The reaction mixture was cooled to room temperature, poured into water (75 ml) with conc. HCl (12 ml) and extracted with benzene (50 ml). The benzene extract was washed with saturated aqueous $NaHCO_3$ solution (15 ml), water (2×25 ml) and dried with Na_2SO_4. The solvent was removed under reduced pressure and the residue was purified by crystallization from 50% aqueous EtOH (25 ml). Crude substances **5g-k** were purified as follows: the residue obtained after evaporation of benzene extract was dissolved in $CHCl_3$ (30 ml) and eluted through a short silica gel plug (2 cm×1.5 cm) with $CHCl_3$ (10 ml). The filtrate was concentrated in vacuum to afford analytically pure product.

To obtain single-valued ^{1}H and ^{13}C spectra of products **5g-k**, the NMR measurements were carried out in DMSO-d_6 solution, where the exclusively enol (3-hydroxythiohene) form of these compounds was detected, since a tautomeric mixture, both thiophen-3(2*H*)-one and 3-hydroxythiophene forms, were observed for their ^{1}H NMR spectra recorded in $CDCl_3$ solution.

5-Phenylthiophen-3(2*H*)-one (5a). Beige powder, m.p. 74-75 °C (from 50% aqueous EtOH); yield 1.06 g (95%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 – 7.62 (m, 2H), 7.55 – 7.40 (m, 3H), 6.56 (s, 1H), 3.80 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 202.2, 178.5, 132.6, 132.1, 128.9, 126.5, 118.4, 40.6. Anal. Calcd for $C_{10}H_8OS$: C, 68.15; H, 4.58. Found: C, 67.98; H, 4.59.

5-(4-Fluorophenyl)thiophen-3(2*H*)-one (5b). Beige powder, m.p. 112-113 °C (from 50% aqueous EtOH); yield 1.13 g (92%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 – 7.62 (m, 2H), 7.55 – 7.40 (m, 3H), 6.56 (s, 1H), 3.80 (s, 2H). ^{19}F NMR (471 MHz, $CDCl_3$) δ 55.30 (s). ^{13}C NMR (126 MHz, $CDCl_3$) δ

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201.9, 176.9, 164.9 (d, J_{CF} = 255.6 Hz), 129.0), 128.7 (d, J_{CF} = 8.2 Hz), 118.3, 116.2 (d, J_{CF} = 22.1 Hz), 40.7. Anal. Calcd for $C_{10}H_7FOS$: C, 61.84; H, 3.63. Found: C, 61.60; H, 3.55. HRMS (APCI) *m/z* calcd for $C_{10}H_8FOS$ $[M+H]^+$: 195.0274, found: 195.0273.

5-(4-Bromophenyl)thiophen-3(2*H*)-one (5c). Pale brown powder, m.p. 127-128 °C (from 50% aqueous EtOH); yield 1.53 g (95%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.61 (d, *J* = 8.3 Hz, 2H), 7.55 (d, *J* = 8.3 Hz, 2H), 6.55 (s, 1H), 3.82 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 202.0, 176.9, 132.3, 131.7, 128.0, 126.8, 118.9, 40.8. Anal. Calcd for $C_{10}H_7BrOS$: C, 47.08; H, 2.77. Found: C, 46.89; H, 2.67.

5-(4-Methoxyphenyl)thiophen-3(2*H*)-one (5d). Pale brown powder, m.p. 123-124 °C (from 50% aqueous EtOH); yield 1.15 g (88%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.8 Hz, 2H), 6.97 (d, *J* = 8.9 Hz, 2H), 6.49 (s, 1H), 3.88 (s, 3H), 3.80 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 202.0, 177.9, 162.8, 128.3, 125.2, 116.6, 114.3, 55.5, 40.5. Anal. Calcd for $C_{11}H_{10}O_2S$: C, 64.05; H, 4.89. Found: C, 63.81; H, 4.84.

5-[4-(Hexyloxy)phenyl]thiophen-3(2*H*)-one (5e). Pink powder, m.p. 92-93 °C (from 50% aqueous EtOH); yield 1.65 g (95%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 – 7.60 (m, 2H), 6.98 – 6.92 (m, 2H), 6.49 (s, 1H), 4.02 (t, *J* = 6.6 Hz, 2H), 3.80 (s, 2H), 1.86 – 1.75 (m, 2H), 1.52 – 1.42 (m, 2H), 1.40 – 1.30 (m, 4H), 0.91 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.9, 177.9, 162.4, 128.3, 124.9, 116.4, 114.7, 68.2, 40.4, 31.4, 28.9, 25.5, 22.5, 13.9. Anal. Calcd for $C_{16}H_{20}O_2S$: C, 69.53; H, 7.29. Found: C, 69.21; H, 7.61.

5-(3,4,5-Trimethoxyphenyl)thiophen-3(2*H*)-one (5f). Reddish needles, m.p. 128-129 °C (from 50% aqueous EtOH); yield 1.51 g (90%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.90 (s, 2H), 6.50 (s, 1H), 3.92 (s, 6H), 3.92 (s, 3H), 3.83 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.8, 178.3, 153.3, 141.4, 128.2, 118.1, 103.9, 60. 9, 56.2, 40.7. Anal. Calcd for $C_{13}H_{14}O_4S$: C, 58.63; H, 5.30. Found: C, 58.51; H, 5.25.

5-(2-Fluorophenyl)thiophen-3(2*H*)-one (5g). Pale brown powder, m.p. 66-67 °C; yield 1.11 g (91%); for enol form: ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.70 (s, 1H), 7.71 (td, *J* = 8.0, 1.6 Hz, 1H), 7.37 – 7.28 (m, 2H), 7.27 – 7.23 (m, 1H), 7.20 – 7.15 (m, 1H), 6.43 (d, *J* = 1.6 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 158.3 (d, J_{CF} = 248.3 Hz), 155.2, 133.9 (d, J_{CF} = 3.2 Hz), 129.1 (d, J_{CF} =

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8.6 Hz), 127.9 (d, J_{CF} = 3.2 Hz), 125.0 (d, J_{CF} = 3.3 Hz), 121.6 (d, J_{CF} = 12.0 Hz), 119.2 (d, J_{CF} = 5.8 Hz), 116.3 (d, J_{CF} = 22.0 Hz), 99.7 (d, J_{CF} = 5.0 Hz). Anal. Calcd for $C_{10}H_7FOS$: C, 61.84; H, 3.63. Found: C, 61.70; H, 3.71.

5-(2-Chlorophenyl)thiophen-3(2*H*)-one (5h). Beige needles, m.p. 80-81 °C; yield 1.26 g (95%); for enol form: ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.65 (s, 1H), 7.57 (dd, J = 7.7, 1.8 Hz, 1H), 7.54 (dd, J = 7.8, 1.5 Hz, 1H), 7.38 (td, J = 7.8, 1.5 Hz, 1H), 7.34 (td, J = 7.7, 1.8 Hz, 1H), 7.04 (d, J = 1.7 Hz, 1H), 6.42 (d, J = 1.7 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 154.7, 137.0, 132.6, 130.7, 130.7, 130.5, 129.1, 127.6, 120.7, 100.1. Anal. Calcd for $C_{10}H_7ClOS$: C, 57.01; H, 3.35. Found: C, 56.98; H, 3.57.

5-(2-Bromophenyl)thiophen-3(2*H*)-one (5i). Beige powder, m.p. 64-65 °C; yield 1.43 g (89%); for enol form: ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.67 (s, 1H), 7.73 (dd, J = 7.8, 1.2 Hz, 1H), 7.52 (dd, J = 7.7, 1.7 Hz, 1H), 7.43 (td, J = 7.8, 1.2 Hz, 1H), 7.28 (td, J = 7.7, 1.7 Hz, 1H), 6.99 (d, J = 1.7 Hz, 1H), 6.43 (d, J = 1.7 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 154.5, 138.7, 134.7, 133.7, 131.3, 129.5, 128.1, 121.4, 120.8, 99.8. Anal. Calcd for $C_{10}H_7BrOS$: C, 47.08; H, 2.77. Found: C, 47.21; H, 2.75.

5-(2-Methoxyphenyl)thiophen-3(2*H*)-one (5j). Beige powder, m.p. 89-90 °C (from 50% aqueous EtOH); yield 1.23 g (95%); for enol form: ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.47 (s, 1H), 7.61 (dd, J = 7.8, 1.6 Hz, 1H), 7.29 – 7.24 (m, 1H), 7.17 (d, J = 1.7 Hz, 1H), 7.11 – 7.08 (m, 1H), 6.99 (td, J = 7.6, 1.0 Hz, 1H), 6.29 (d, J = 1.7 Hz, 1H), 3.88 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 155.3, 154.6, 136.7, 128.5, 127.2, 122.4, 120.9, 118.2, 112.2, 98.9, 55.6. Anal. Calcd for $C_{11}H_{10}O_2S$: C, 64.05; H, 4.89. Found: C, 64.08; H, 4.71.

5-(Naphthalen-1-yl)thiophen-3(2*H*)-one (5k). Beige powder, m.p. 88-89 °C (from 50% aqueous EtOH); yield 1.25 g (88%); for enol form: ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.76 (s, 1H), 8.29 – 8.25 (m, 1H), 8.02 – 7.98 (m, 1H), 7.97 – 7.93 (m, 1H), 7.61 – 7.53 (m, 4H), 6.98 (d, J = 1.7 Hz, 1H), 6.50 (d, J = 1.7 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 154.8, 138.9, 133.5, 132.3, 130.7, 128.4, 128.3, 127.4, 126.8, 126.2, 125.5, 125.0, 120.6, 99.1. Anal. Calcd for $C_{14}H_{10}OS$: C, 74.31; H, 4.45. Found: C, 74.30; H, 4.46.

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[2,2'-Bithiophen]-4(5*H*)-one (5l). Pale brown powder, m.p. 117-118 °C (from 50% aqueous EtOH); yield 1.03 g (90%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.63 – 7.50 (m, 2H), 7.19 – 7.09 (m, 1H), 6.41 (s, 1H), 3.82 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.2, 169.8, 136.1, 130.9, 129.1, 128.4, 117.2, 40.5. Anal. Calcd for $C_8H_6OS_2$: C, 52.72; H, 3.32. Found: C, 52.82; H, 3.24.

5'-Bromo-[2,2'-bithiophen]-4(5*H*)-one (5m). Compound **5m** was prepared as follows: ester **4m** (480 mg, 1.5 mmol) was added to a mixture of CF_3CO_2H (4.5 ml) and $MeSO_3H$ (1.5 ml) at room temperature. The resulting mixture was stirred and heated at 80 °C for 2 h, then it was poured into water (50 ml) and neutralized by addition of $NaHCO_3$ (6 g). The obtained suspension was treated with $CHCl_3$ (30 ml), intensively shacked and filtered to remove insoluble black gum. The $CHCl_3$ layer was separated, washed with water (2×25 ml) and dried with Na_2SO_4. Solvent was evaporated in vacuum to yield crude product **5m** (yield 115 mg, about 29%) as greenish-black solid, which was used in the next step without purification. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 (d, J = 4.0 Hz, 1H), 7.11 (d, J = 4.0 Hz, 1H), 6.33 (s, 1H), 3.80 (s, 2H).

5'-Phenyl-[2,2'-bithiophen]-4(5*H*)-one (5n). Brown powder, m.p. 127-128 °C (from 50% aqueous EtOH); yield 245 mg (95%) was obtained from **4n** (316 mg, 1 mmol); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.61 (m, 2H), 7.53 (d, J = 4.0 Hz, 1H), 7.46 – 7.40 (m, 2H), 7.40 – 7.35 (m, 1H), 7.34 (d, J = 4.0 Hz, 1H), 6.42 (s, 1H), 3.83 (s, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 201.1, 169.5, 150.3, 134.8, 132.9, 130.3, 129.1, 129.0, 126.1, 124.2, 116.7, 40.5. HRMS (ESI) *m/z* calcd for $C_{14}H_{11}OS_2$ $[M+H]^+$: 259.0246, found: 259.0248.

General procedure for synthesis of 2-(hetero)arylthieno[3,2-*b*]indoles (7a-n) from thiophen-3(2*H*)-ones (5a-n) and phenylhydrazine (6a). Phenylhydrazine (0.15 ml, 1.5 mmol) was added to a stirred solution of appropriate thiophen-3(2*H*)-one **5** (1 mmol) in AcOH (7 ml). The reaction mixture was stirred and heated at 120 °C for 1 h, then it was cooled to room temperature and diluted with MeOH (7 ml). The precipitate was filtered, washed with MeOH (3×4 ml) and dried at 120 °C to afford product **7**. Compounds **7a-n** were obtained in analytically pure form without additional purification.

2-Phenyl-4*H*-thieno[3,2-*b*]indole (7a). White plates, m.p. 320-321 °C (sub.); yield 145 mg (58%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.48 (s, 1H), 7.76 (d, J = 7.4 Hz, 2H), 7.72 (d, J = 7.8 Hz, 1H), 7.65 (s, 1H), 7.51 – 7.41 (m, 3H), 7.32 (t, J = 7.4 Hz, 1H), 7.24 – 7.19 (m, 1H), 7.10 (t, J = 7.4 Hz,

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1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 144.3, 143.9, 140.9, 134.9, 129.1, 127.6, 125.1, 122.5, 121.2, 119.1, 118.3, 114.8, 112.3, 108.7. Anal. Calcd for $C_{16}H_{11}NS$: C, 77.07; H, 4.45; N, 5.62. Found: C, 77.05; H, 4.34; N, 5.76.

2-(4-Fluorophenyl)-4*H*-thieno[3,2-*b*]indole (7b). Pink plates, m.p. 330-331 °C (sub.); yield 174 mg (65%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.48 (s, 1H), 7.79 (dd, J = 8.7, 5.4 Hz, 2H), 7.71 (d, J = 7.8 Hz, 1H), 7.62 (s, 1H), 7.48 (d, J = 8.2 Hz, 1H), 7.28 (t, J = 8.8 Hz, 2H), 7.21 (t, J = 7.3 Hz, 1H), 7.09 (t, J = 7.5 Hz, 1H). ^{19}F NMR (471 MHz, DMSO-d_6) δ 48.82 – 47.46 (m). ^{13}C NMR (126 MHz, DMSO-d_6) δ 161.6 (d, J_{CF} = 245.1 Hz), 143.9, 143.1, 140.9, 131.5 (d, J_{CF} = 3.1 Hz), 127.1 (d, J_{CF} = 8.0 Hz), 122.5, 121.2, 119.1, 118.27, 116.1 (d, J_{CF} = 21.7 Hz), 114.7, 112.3, 108.9. Anal. Calcd for $C_{16}H_{10}FNS$: C, 71.89; H, 3.77; N, 5.24. Found: C, 71.63; H, 3.60; N, 5.42.

2-(4-Bromophenyl)-4*H*-thieno[3,2-*b*]indole (7c). Beige powder, m.p. 339-340 °C (sub.); yield 200 mg (61%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.52 (s, 1H), 7.75 – 7.68 (m, 4H), 7.66 – 7.60 (m, 2H), 7.48 (d, J = 8.1 Hz, 1H), 7.25 – 7.20 (m, 1H), 7.13 – 7.07 (m, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 143.9, 142.7, 141.0, 134.1, 132.0, 127.0, 122.7, 121.1, 120.3, 119.1, 118.4, 115.2, 112.3, 109.4. HRMS (APCI) *m/z* calcd for $C_{16}H_{11}BrNS$ $[M+H]^+$: 327.9790, found: 327.9789.

2-(4-Methoxyphenyl)-4*H*-thieno[3,2-*b*]indole (7d). Pale yellow crystals, m.p. 336-337 °C (sub.); yield 196 mg (70%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.43 (s, 1H), 7.68 (d, J = 8.8 Hz, 3H), 7.50 (s, 1H), 7.46 (d, J = 8.1 Hz, 1H), 7.22 – 7.15 (m, 1H), 7.12 – 7.05 (m, 1H), 7.04 – 6.99 (m, 2H), 3.80 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 158.93, 144.5, 144.0, 140.7, 127.6, 126.5, 122.1, 121.3, 119.0, 118.0, 114.5, 113.8, 112.2, 107.5, 55.2. Anal. Calcd for $C_{17}H_{13}NOS$: C, 73.09; H, 4.69; N, 5.01. Found: C, 72.97; H, 4.79; N, 5.24.

2-[4-(Hexyloxy)phenyl]-4*H*-thieno[3,2-*b*]indole (7e). Beige plates, m.p. 318-319 °C; yield 245 mg (70%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.41 (s, 1H), 7.70 – 7.64 (m, 3H), 7.49 (s, 1H), 7.46 (d, J = 8.1 Hz, 1H), 7.21 – 7.16 (m, 1H), 7.11 – 7.05 (m, 1H), 7.02 – 6.97 (m, 2H), 4.00 (t, J = 6.5 Hz, 2H), 1.77 – 1.69 (m, 2H), 1.47 – 1.39 (m, 2H), 1.36 – 1.28 (m, 4H), 0.89 (t, J = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 158.4, 144.5, 144.0, 140.7, 127.4, 126.5, 122.1, 121.3, 119.0, 118.0, 115.0, 113.8, 112.1, 107.4, 67.6, 31.0, 28.6, 25.2, 22.1, 13.9. Anal. Calcd for $C_{22}H_{23}NOS$: C, 75.61; H, 6.63; N, 4.01. Found: C, 75.50; H, 6.71; N, 4.14.

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2-(3,4,5-Trimethoxyphenyl)-4*H*-thieno[3,2-*b*]indole (7f). Pink powder, m.p. 200-201 °C; yield 140 mg (41%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.45 (s, 1H), 7.69 (d, J = 7.8 Hz, 1H), 7.65 (s, 1H), 7.48 (d, J = 8.2 Hz, 1H), 7.24 – 7.18 (m, 1H), 7.12 – 7.07 (m, 1H), 7.01 (s, 2H), 3.88 (s, 6H), 3.70 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 153.3, 144.5, 143.8, 140.9, 137.3, 130.7, 122.4, 121.3, 119.0, 118.2, 114.5, 112.2, 108.9, 102.8, 60.1, 56.0. Anal. Calcd for $C_{19}H_{17}NO_3S$: C, 67.24; H, 5.05; N, 4.13. Found: C, 67.14; H, 4.84; N, 4.10.

2-(2-Fluorophenyl)-4*H*-thieno[3,2-*b*]indole (7g). Pink powder, m.p. 206-207 °C; yield 142 mg (53%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.48 (s, 1H), 7.79 – 7.71 (m, 2H), 7.62 (d, J = 7.9 Hz, 1H), 7.56 (s, 1H), 7.51 (d, J = 8.2 Hz, 1H), 7.46 (t, J = 7.1 Hz, 1H), 7.40 (td, J = 7.7, 1.5 Hz, 1H), 7.24 (t, J = 7.6 Hz, 1H), 7.11 (t, J = 7.5 Hz, 1H). ^{19}F NMR (471 MHz, DMSO-d_6) δ 48.44 – 48.30 (m). ^{13}C NMR (126 MHz, DMSO-d_6) δ 158.2 (d, J_{CF} = 248.4 Hz), 143.5, 141.1, 136.8 (d, J_{CF} = 3.8 Hz), 129.1 (d, J_{CF} = 8.5 Hz), 128.3 (d, J_{CF} = 3.1 Hz), 125.2 (d, J_{CF} = 3.0 Hz), 122.8, 122.4 (d, J_{CF} = 12.1 Hz), 121.0, 119.1 (s), 118.6, 116.5 (d, J_{CF} = 22.3 Hz), 116.1 (d, J_{CF} = 5.2 Hz), 112.3, 111.4 (d, J_{CF} = 6.5 Hz). HRMS (APCI) *m/z* calcd for $C_{16}H_{10}FNS$ $[M]^+$: 267.0512, found: 267.0513.

2-(2-Chlorophenyl)-4*H*-thieno[3,2-*b*]indole (7h). Beige powder, m.p. 159-160 °C; yield 160 mg (56%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.48 (s, 1H), 7.88 (t, J = 7.5 Hz, 1H), 7.76 (d, J = 7.9 Hz, 1H), 7.68 (s, 1H), 7.51 (d, J = 8.2 Hz, 1H), 7.40 – 7.28 (m, 3H), 7.26 – 7.22 (m, 1H), 7.11 (t, J = 7.4 Hz, 1H). ^{13}C NMR (126 MHz, DMSO) δ 143.1, 140.9, 139.7, 133.2, 131.4, 130.9, 130.6, 129.2, 127.8, 122.8, 121.0, 119.0, 118.5, 116.4, 113.0, 112.3. HRMS (APCI) *m/z* calcd for $C_{16}H_{10}ClNS$ $[M]^+$: 283.0217, found: 283.0216.

2-(2-Bromophenyl)-4*H*-thieno[3,2-*b*]indole (7i). Cream powder, m.p. 152-153 °C; yield 125 mg (38%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.49 (s, 1H), 7.84 – 7.73 (m, 2H), 7.66 (dd, J = 7.7, 1.5 Hz, 1H), 7.56 – 7.45 (m, 3H), 7.33 (td, J = 7.8, 1.6 Hz, 1H), 7.28 – 7.20 (m, 1H), 7.11 (t, J = 7.2 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 143.0, 141.5, 140.8, 135.3, 133.7, 132.1, 129.7, 128.1, 122.7, 121.8, 121.0, 119.1, 118.5, 116.3, 113.1, 112.3. Anal. Calcd for $C_{16}H_{10}BrNS$: C, 58.55; H, 3.07; N, 4.27. Found: C, 58.35; H, 3.01; N, 4.23.

2-(2-Methoxyphenyl)-4*H*-thieno[3,2-*b*]indole (7j). White powder, m.p. 178-179 °C; yield 184 mg (66%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.36 (s, 1H), 7.80 (dd, J = 7.7, 1.6 Hz, 1H), 7.71 (d, J = 7.9 Hz, 1H), 7.68 (s, 1H), 7.47 (d, J = 8.1 Hz, 1H), 7.34 – 7.29 (m, 1H), 7.22 – 7.15 (m, 2H), 7.11 –

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7.03 (m, 2H), 3.96 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 155.3, 143.4, 141.0, 140.1, 128.5, 127.7, 123.3, 122.3, 121.3, 121.0, 118.9, 118.3, 116.0, 112.3, 112.1, 110.3, 55.7. Anal. Calcd for $C_{17}H_{13}NOS$: C, 73.09; H, 4.69; N, 5.01. Found: C, 73.11; H, 4.80; N, 4.71. HRMS (ESI) *m/z* calcd for $C_{17}H_{14}NOS$ $[M+H]^+$: 280.0791, found: 280.0786.

2-(Naphthalen-1-yl)-4*H*-thieno[3,2-*b*]indole (7k). Cream powder, m.p. 199-200 °C (sub.); yield 132 mg (44%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.51 (s, 1H), 8.38 – 8.32 (m, 1H), 8.08 – 7.98 (m, 2H), 7.77 (d, J = 7.8 Hz, 1H), 7.70 (d, J = 7.0 Hz, 1H), 7.61 (dd, J = 10.6, 4.9 Hz, 3H), 7.54 (d, J = 8.2 Hz, 1H), 7.45 (s, 1H), 7.25 (t, J = 7.6 Hz, 1H), 7.13 (t, J = 7.5 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 143.5, 141.7, 140.7, 133.6, 132.7, 130.9, 128.5, 128.1, 126.9, 126.3, 125.5, 125.1, 122.5, 121.2, 119.0, 118.4, 115.7, 112.9, 112.3. Anal. Calcd for $C_{20}H_{13}NS$: C, 80.23; H, 4.38; N, 4.68. Found: C, 80.37; H, 4.34; N, 4.93.

2-(Thiophen-2-yl)-4*H*-thieno[3,2-*b*]indole (7l). Beige crystals, m.p. 275-276 °C (sub.); yield 185 mg (72%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.46 (s, 1H), 7.70 (d, J = 7.8 Hz, 1H), 7.53 (d, J = 5.1 Hz, 1H), 7.48 (d, J = 8.2 Hz, 1H), 7.44 – 7.38 (m, 2H), 7.21 (t, J = 7.6 Hz, 1H), 7.16 – 7.06 (m, 2H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 143.4, 140.9, 137.9, 137.3, 128.4, 125.3, 123.7, 122.5, 121.1, 119.1, 118.3, 114.3, 112.3, 108.8. Anal. Calcd for $C_{14}H_9NS_2$: C, 65.85; H, 3.55; N, 5.49. Found: C, 65.91; H, 3.45; N, 5.55.

2-(5-Bromothiophen-2-yl)-4*H*-thieno[3,2-*b*]indole (7m). Brown crystals, m.p. 219-220 °C (dec.); yield 82 mg (61%) was obtained from **5m** (105 mg, 0.4 mmol); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.50 (s, 1H), 7.71 (d, J = 7.9 Hz, 1H), 7.48 (d, J = 8.2 Hz, 1H), 7.43 (s, 1H), 7.27 – 7.20 (m, 3H), 7.09 (t, J = 7.5 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 143.3, 141.1, 139.6, 135.8, 131.6, 124.2, 122.8, 121.0, 119.2, 118.4, 114.7, 112.3, 109.9, 109.4. HRMS (APCI) *m/z* calcd for $C_{14}H_8BrNS_2$ $[M]^+$: 332.9276, found: 332.9277.

2-(5-Phenylthiophen-2-yl)-4*H*-thieno[3,2-*b*]indole (7n). Dark-yellow crystals, m.p. 318-319 °C (sub.); yield 88 mg (66%) was obtained from **5n** (103 mg, 0.4 mmol); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.50 (s, 1H), 7.71 (t, J = 8.1 Hz, 3H), 7.54 (d, J = 3.8 Hz, 1H), 7.51 – 7.40 (m, 5H), 7.36 – 7.30 (m, 1H), 7.24 – 7.19 (m, 1H), 7.13 – 7.07 (m, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 143.5, 141.9, 141.0, 137.2, 137.0, 133.2, 129.2, 127.8, 125.1, 124.8, 122.6, 121.1, 119.2, 118.3, 114.5,

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112.3, 108.8. Anal. Calcd for $C_{20}H_{13}NS_2$: C, 72.48; H, 3.95; N, 4.23. Found: C, 72.28; H, 3.86; N, 4.54.

General procedure for synthesis of 2-(hetero)arylthieno[3,2-*b*]indoles (7o-x) from thiophen-3(2*H*)-ones (5a,l) and arylhydrazines hydrochlorides (6b-f). Anhydrous NaOAc (120 mg, 1.5 mmol) and appropriate arylhydrazine hydrochloride **6** (1.5 mmol) were added to a stirred solution of thiophen-3(2*H*)-one **5a** (176 mg, 1 mmol) or **5b** (182 mg, 1 mmol) in AcOH (7 ml). The reaction mixture was stirred and heated at 120 °C for 1 h, then it was cooled to room temperature and the formed precipitate was filtered, washed with warm water (10 ml), MeOH (3×4 ml) and dried at 120 °C to afford product **7**. Compounds **7o-x** were obtained in analytically pure form without additional purification.

7-Bromo-2-phenyl-4*H*-thieno[3,2-*b*]indole (7o). White crystals, m.p. 276-277 °C (sub.); yield 197 mg (60%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.69 (s, 1H), 7.98 (d, J = 1.6 Hz, 1H), 7.76 (d, J = 7.9 Hz, 2H), 7.66 (s, 1H), 7.46 (t, J = 7.9 Hz, 3H), 7.37 – 7.29 (m, 2H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 145.7, 145.0, 139.6, 134.6, 129.1, 127.8, 125.3, 124.8, 122.9, 120.6, 114.1, 114.0, 111.3, 108.6. Anal. Calcd for $C_{16}H_{10}BrNS$: C, 58.55; H, 3.07; N, 4.27. Found: C, 58.39; H, 2.92; N, 4.42.

7-Methyl-2-phenyl-4*H*-thieno[3,2-*b*]indole (7p). Beige powder, m.p. 273-274 °C (sub.); yield 140 mg (53%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.33 (s, 1H), 7.75 (dd, J = 8.3, 0.9 Hz, 2H), 7.62 (s, 1H), 7.49 (s, 1H), 7.44 (t, J = 7.7 Hz, 2H), 7.36 (d, J = 8.3 Hz, 1H), 7.31 (t, J = 7.4 Hz, 1H), 7.03 (dd, J = 8.3, 1.0 Hz, 1H), 2.42 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 144.1, 144.0, 139.2, 134.9, 129.1, 127.7, 127.5, 125.1, 123.9, 121.4, 118.0, 114.4, 112.0, 108.7, 21.1. Anal. Calcd for $C_{17}H_{13}NS$: C, 77.53; H, 4.98; N, 5.32. Found: C, 77.43; H, 4.88; N, 5.40.

2-Phenyl-4*H*-thieno[3,2-*b*]indole-7-carbonitrile (7q). Beige powder, m.p. 265-266 °C; yield 82 mg (30%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.11 (s, 1H), 8.36 (d, J = 0.7 Hz, 1H), 7.79 (d, J = 7.6 Hz, 2H), 7.72 (s, 1H), 7.64 (d, J = 8.5 Hz, 1H), 7.57 (dd, J = 8.5, 1.6 Hz, 1H), 7.47 (t, J = 7.7 Hz, 2H), 7.36 (t, J = 7.4 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 146.7, 145.5, 142.7, 134.4, 129.2, 128.1, 125.4, 125.2, 123.7, 121.1, 120.5, 114.92, 113.2, 108.7, 100.9. Anal. Calcd for $C_{17}H_{10}N_2S$: C, 74.43; H, 3.67; N, 10.21. Found: C, 74.42; H, 3.65; N, 10.19.

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2-Phenyl-4*H*-thieno[3,2-*b*]indole-7-carboxylic acid (7r). White powder, m.p. 334-335 °C; yield 117 mg (40%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.56 (s, 1H), 11.90 (s, 1H), 8.39 (d, J = 0.5 Hz, 1H), 7.84 (dd, J = 8.6, 1.5 Hz, 1H), 7.78 (d, J = 7.4 Hz, 2H), 7.70 (s, 1H), 7.54 (d, J = 8.6 Hz, 1H), 7.46 (t, J = 7.7 Hz, 2H), 7.34 (t, J = 7.4 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 168.0, 145.5, 145.0, 143.5, 134.6, 129.2, 127.8, 125.3, 123.7, 121.5, 120.8, 120.6, 115.5, 111.9, 108.8. Anal. Calcd for $C_{17}H_{11}NO_2S$: C, 69.61; H, 3.78; N, 4.78. Found: C, 69.76; H, 3.85; N, 4.89.

8-Phenyl-10*H*-benzo[*g*]thieno[3,2-*b*]indole (7s). Pale yellow powder, m.p. 308-309 °C (sub.); yield 200 mg (67%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 12.48 (s, 1H), 8.47 (d, J = 8.2 Hz, 1H), 7.98 (d, J = 8.0 Hz, 1H), 7.86 (d, J = 8.6 Hz, 1H), 7.80 (d, J = 7.8 Hz, 2H), 7.75 (s, 1H), 7.63 – 7.56 (m, 2H), 7.51 – 7.43 (m, 3H), 7.33 (t, J = 7.4 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 143.4, 142. 6, 135.5, 135.0, 130.1, 129.1, 128.5, 127.4, 125.6, 125.1, 124.2, 122.3, 121.1, 119.9, 118.6, 116.8, 116.6, 108.7. Anal. Calcd for $C_{20}H_{13}NS$: C, 80.24; H, 4.38; N, 4.68. Found: C, 80.39; H, 4.52; N, 4.45. HRMS (ESI) *m/z* calcd for $C_{20}H_{14}NS$ $[M+H]^+$: 300.0841, found: 300.0838.

7-Bromo-2-(thiophen-2-yl)-4*H*-thieno[3,2-*b*]indole (7t). Beige crystals, m.p. 259-260 °C (sub.); yield 127 mg (38%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.65 (s, 1H), 7.97 (d, J = 1.9 Hz, 1H), 7.55 (dd, J = 5.1, 1.0 Hz, 1H), 7.46 – 7.41 (m, 3H), 7.31 (dd, J = 8.7, 2.0 Hz, 1H), 7.13 (dd, J = 5.1, 3.6 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 144.5, 139.6, 138.7, 137.6, 128.4, 125.6, 124.8, 124.1, 122.8, 120.6, 114.1, 113.5, 111.4, 108.6. Anal. Calcd for $C_{14}H_8BrNS_2$: C, 50.31; H, 2.41; N, 4.19; Found: C, 50.38; H, 2.44; N, 4.26.

7-Methyl-2-(thiophen-2-yl)-4*H*-thieno[3,2-*b*]indole (7u). Beige powder, m.p. 243-244 °C (sub.); yield 140 mg (52%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 11.30 (s, 1H), 7.52 (dd, J = 5.1, 1.0 Hz, 1H), 7.47 (s, 1H), 7.39 – 7.34 (m, 3H), 7.11 (dd, J = 5.1, 3.6 Hz, 1H), 7.03 (dd, J = 8.3, 1.3 Hz, 1H), 2.41 (s, 3H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 143.5, 139.3, 137.9, 137.1, 128.3, 127.8, 125.1, 124.0, 123.6, 121.3, 117.9, 113.9, 112.0, 108.8, 21.1. HRMS (ESI) *m/z* calcd for $C_{15}H_{12}NS_2$ $[M+H]^+$: 270.0406, found: 270.0404.

2-(Thiophen-2-yl)-4*H*-thieno[3,2-*b*]indole-7-carbonitrile (7v). Brown powder, m.p. 233-234 °C (dec.); yield 121 mg (43%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 12.08 (s, 1H), 8.34 (d, J = 0.6 Hz, 1H), 7.63 (d, J = 8.5 Hz, 1H), 7.57 (ddd, J = 10.1, 6.8, 1.2 Hz, 2H), 7.49 (s, 1H), 7.46 (dd, J = 3.5, 0.9 Hz, 1H), 7.15 (dd, J = 5.0, 3.7 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 145.0, 142.7, 139.7,

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137.3, 128.5, 126.0, 125.2, 124.4, 123.6, 121.0, 120.5, 114.4, 113.3, 108.7, 101.0. HRMS (ESI) *m/z* calcd for $C_{15}H_9N_2S_2$ $[M+H]^+$: 281.0202, found: 281.0199.

2-(Thiophen-2-yl)-4*H*-thieno[3,2-*b*]indole-7-carboxylic acid (7w). Greenish powder, m.p. 313-314 °C; yield 51 mg (17%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 12.55 (s, 1H), 11.86 (s, 1H), 8.41 – 8.34 (m, 1H), 7.83 (dd, J = 8.6, 1.6 Hz, 1H), 7.58 – 7.51 (m, 2H), 7.46 (s, 1H), 7.44 (dd, J = 3.6, 1.1 Hz, 1H), 7.14 (dd, J = 5.1, 3.6 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 168.0, 144.5, 143.5, 138.5, 137.6, 128.4, 125.6, 124.1, 123.7, 121.6, 120.7, 120.6, 115.1, 111.9, 108.8. Anal. Calcd for $C_{15}H_9NO_2S_2$: C, 60.18; H, 3.03; N, 4.68. Found: C, 59.91; H, 3.07; N, 4.48.

8-(Thiophen-2-yl)-10*H*-benzo[*g*]thieno[3,2-*b*]indole (7x). Cream powder, m.p. 256-257 °C (sub.); yield 189 mg (62%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 12.45 (s, 1H), 8.44 (d, J = 8.2 Hz, 1H), 7.98 (d, J = 8.1 Hz, 1H), 7.85 (d, J = 8.6 Hz, 1H), 7.62 – 7.56 (m, 2H), 7.53 (dd, J = 5.1, 1.0 Hz, 1H), 7.51 (s, 1H), 7.49 – 7.45 (m, 1H), 7.43 (dd, J = 3.6, 1.0 Hz, 1H), 7.14 (dd, J = 5.0, 3.6 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 142.0, 138.0, 136.5, 135.5, 130.1, 128.6, 128.3, 125.6, 125.1, 124.3, 123.7, 122.3, 121.0, 120.0, 118.6, 116.7, 116.2, 108.7. HRMS (ESI) *m/z* calcd for $C_{18}H_{12}NS_2$ $[M+H]^+$: 306.0406, found: 306.0402.

General procedure for synthesis of 5,5'-bis(3-hydroxythiophene-2-carboxylate) compounds (9a,b). A mixture of bis(2-bromoacrylate) **8a** (6.48 g, 15 mmol) or **8b** (6.57 g, 15 mmol) and methyl thioglycolate (5.5 ml, 60 mmol) in dry MeOH (35 ml) was added dropwise to a solution of NaOMe, prepared from sodium (2.8 g, 122 mmol) and dry MeOH (35 ml), at 0 °C during 20 min with continuous stirring and the formed suspension was stirred and heated at reflux for 8 h. The reaction mixture was poured into ice-cold water (70 ml) and acidified with conc. HCl (8 ml). The formed precipitate was filtered, washed with water (3×10 ml), MeOH (10 ml), dried at room temperature and purified by crystallization from a mixture of MeOH and DMF (15 ml, v/v 1:14) to yield analytically pure product **9a** or **9b**, respectively.

Dimethyl 5,5'-(1,4-phenylene)bis(3-hydroxythiophene-2-carboxylate) (9a). Brownish needles, m.p. 287-288 °C; yield 1.93 g (33%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.46 (s, 2H), 7.77 (s, 4H), 7.26 (s, 2H), 3.79 (s, 6H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 162.9, 161.5, 146.0, 133.1, 126.2, 117.2, 104.6, 51.5. Anal. Calcd for $C_{18}H_{14}O_6S_2$: C, 55.38; H, 3.61. Found: C, 55.27; H, 3.88.

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Dimethyl 4,4''-dihydroxy-[2,2':5',2''-terthiophene]-5,5''-dicarboxylate (9b). Brownish fleecy crystals, m.p. 231-232 °C; yield 1.02 g (17%); ^{1}H NMR (500 MHz, DMSO-d_6) δ 10.61 (s, 2H), 7.51 (s, 2H), 7.03 (s, 2H), 3.77 (s, 6H). ^{13}C NMR (101 MHz, DMSO-d_6) δ 162.6, 161.1, 139.2, 136.1, 127.1, 117.1, 104.1, 51.5. Anal. Calcd for $C_{16}H_{12}O_6S_3$: C, 48.47; H, 3.05. Found: C, 48.36; H, 2.95.

General procedure for synthesis of 5,5'-bis(thiophen-3(2*H*)-one) compounds (10a,b). NaOH (1.2 g, 30 mmol) in water (5 ml) was added in one portion to diester **9a** (391 mg, 1 mmol) or **9b** (400 mg, 1 mmol) in DMSO (10 ml), the obtained solution was flushed with argon, then it was stirred and heated at 140 °C for 1.5 h under an argon atmosphere. The reaction mixture was cooled to room temperature and poured into water (20 ml) with conc. HCl (2.6 ml). The precipitate was filtered, washed with water (4×5 ml) and dried at room temperature. The obtained solid was extracted with hot EtOAc (5×15 ml), every time at triturating and heating. The EtOAc extract was eluted through a short silica gel plug (1 cm×4 cm) with hot EtOAc (15 ml). The filtrate was concentrated under reduced pressure to afford analytically pure product **10a** or **10b**, respectively.

5,5'-(1,4-Phenylene)bis(thiophen-3(2*H*)-one) (10a). Brownish powder, m.p. 256-257 °C (dec.); yield 212 mg (77%); for enol form: ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.63 (s, 1H), 7.59 (s, 2H), 7.09 (d, J = 1.6 Hz, 1H), 6.29 (d, J = 1.6 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 155.6, 140.4, 133.0,

[2,2':5',2''-Terthiophene]-4,4''(5*H*,5''*H*)-dione (10b). Brownish powder, m.p. 196-197 °C (dec.); yield 243 mg (86%); for enol form: ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.70 (s, 1H), 7.18 (s, 1H), 6.88 (d, J = 1.6 Hz, 1H), 6.26 (d, J = 1.6 Hz, 1H). ^{13}C NMR (126 MHz, DMSO-d_6) δ 155.2, 135.6, 133.9, 124.2, 116.7, 98.1. HRMS (ESI) *m/z* calcd for $C_{12}H_9O_2S_3$ $[M+H]^+$: 280.9759, found: 280.9761.

General procedure for synthesis of thieno[3,2-*b*]indole twin derivatives (11a,b). Bis(thiophen-3(2*H*)-one) **10a** (137 mg, 0.5 mmol) or **10b** (140 mg, 0.5 mmol) was dissolved in AcOH (10 ml) and phenylhydrazine (0.15 ml, 1.5 mmol) was added to this solution. The reaction mixture was stirred and heated at 120 °C for 2 h, then it was cooled to room temperature and the formed precipitate was filtered, washed with MeOH (3×4 ml) and dried at 120 °C. This crude substance was purified by sublimation at 280 °C in vacuum (3 mbar) to afford analytically pure product **11a** or **11b**, respectively.

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1,4-Bis(4*H*-thieno[3,2-*b*]indol-2-yl)benzene (11a). Pale yellow powder, m.p. >360 °C; yield 172 mg (82%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.39 (s, 2H), 7.82 (s, 4H), 7.73 (d, J = 7.8 Hz, 2H), 7.68 (s, 2H), 7.50 (d, J = 8.1 Hz, 2H), 7.26 – 7.20 (m, 2H), 7.16 – 7.09 (m, 2H). Anal. Calcd for $C_{26}H_{16}N_2S_2$: C, 74.26; H, 3.83; N, 6.66. Found: C, 74.57; H, 3.91; N, 6.56.

2,5-Bis(4*H*-thieno[3,2-*b*]indol-2-yl)thiophene (11b). Orange microcrystals, m.p. >360 °C; yield 190 mg (89%); ^{1}H NMR (400 MHz, DMSO-d_6) δ 11.39 (s, 2H), 7.72 (d, J = 7.8 Hz, 2H), 7.50 (d, J = 8.1 Hz, 2H), 7.45 (s, 2H), 7.39 (s, 2H), 7.27 – 7.19 (m, 2H), 7.15 – 7.07 (m, 2H). Anal. Calcd for $C_{24}H_{14}N_2S_3$: C, 67.58; H, 3.31; N, 6.57. Found: C, 67.52; H, 3.25; N, 6.44.

Conflicts of interest

There are no conflicts to declare

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Supporting Information

Electronic supplementary information (ESI) available: Procedures for preparation of starting materials **3a-m** and **8a,b**, copies of ^{1}H, ^{19}F and ^{13}C NMR spectra of new compounds (PDF).

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