Synthesis of 2,3-Disubstituted Benzo[*b*]thiophenes via Palladium-Catalyzed Coupling and Electrophilic Cyclization of Terminal Acetylenes

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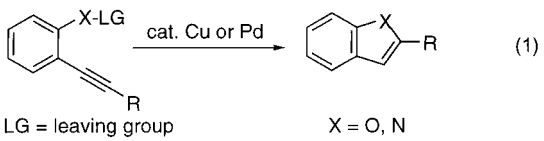
2,3-Disubstituted benzo[*b*]thiophenes have been prepared in excellent yields via coupling of terminal acetylenes with commercially available *o*-iodothioanisole in the presence of a palladium catalyst and subsequent electrophilic cyclization of the resulting *o*-(1-alkynyl)thioanisole derivatives. I_2, Br_2, NBS, *p*-$O_2NC_6H_4SCl$, and PhSeCl have been utilized as electrophiles. Aryl-, vinyl-, and alkyl-substituted terminal acetylenes undergo this coupling and cyclization to produce excellent yields of benzo[*b*]thiophenes. (Trimethylsilyl)acetylene also undergoes this coupling/cyclization process with I_2, NBS, and the sulfur and selenium electrophiles to afford the corresponding 2-(trimethylsilyl)-benzo[*b*]thiophenes. However, cyclization of the silyl-containing thioanisole using Br_2 affords 2,3-dibromobenzo[*b*]thiophene.

Introduction

The transition-metal-catalyzed cyclization of disubstituted alkynes possessing a nucleophile in proximity to the triple bond by either copper or palladium reagents has been shown to be extremely effective for the synthesis of a wide variety of carbo- and heterocycles (eq 1).[1]



(1)

Generally, this methodology requires a good leaving group on the nucleophile. However, due to sulfur's affinity for transition metals, sulfur-containing heterocycles, such as benzo[*b*]thiophenes, have never been synthesized using this strategy.

Benzo[*b*]thiophenes are of interest, because of their frequent occurrence in nature and their wide range of biological and physiological effects.[2] Benzo[*b*]thiophene derivatives, which are antimitotic agents,[3] estrogen receptor antagonists, and antitumor, antiinflammation, and antifungal agents,[4] are currently in pharmaceutical use or development. Diaminobenzothiophene derivatives

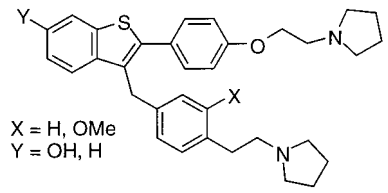


Figure 1. Diaminobenzothiophene.

such as **1** have been identified as active site directed thrombin inhibitors.[5] Thus, research directed toward concise, new syntheses of 2,3-disubstituted benzo[*b*]-thiophenes has been actively pursued in recent years.[1,6]

The electrophilic cyclization of unsaturated compounds has proven to be an efficient method for constructing heterocycles.[7] These reactions are generally viewed as proceeding through an intramolecular, stepwise electrophilic addition and dealkylation mechanism involving a

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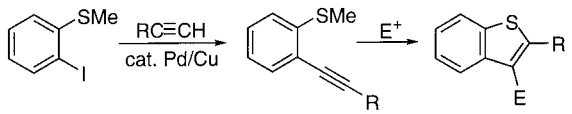
Scheme 1[a]



[a] $E^+ = I_2$, Br_2, NBS, *p*-$O_2NC_6H_4SCl$, PhSeCl.

cationic intermediate. Taniguchi and co-workers have explored the cyclization of vinylic cations as a route to heterocycles but found significant limitations in generating the vinylic cations.[8] Although mechanistic and synthetic work on the preparation of benzofuran and indole derivatives have been carried out by Cacchi and co-workers[9] and ourselves,[10] the synthesis of benzo[*b*]thiophenes by this approach remains relatively unexplored.

Recently, Flynn and co-workers treated *o*-(1-alkynyl)-phenyl benzyl sulfides with iodine to obtain 3-iodobenzo-[*b*]thiophene derivatives through a 5-endo-dig iodocyclization.[4c] The limited availability of the.requisite starting sulfides, the low yields obtained in their preparation, the incompatibility of functional groups with this methodology, and the failure to demonstrate the scope of this methodology have encouraged us to report our related studies.[11] Herein, we report the successful application of this electrophilic cyclization strategy as a convenient and general synthetic methodology for the synthesis of 2,3-disubstituted benzo[*b*]thiophenes.

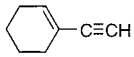
Results and Discussion

A two-step approach to benzo[*b*]thiophenes has been examined involving (i) the Sonagashira coupling of commercially available *o*-iodothioanisole with terminal alkynes and (ii) electrophilic cyclization (Scheme 1).

To assess the generality of this approach, the scope of the Sonagashira coupling of *o*-iodothioanisole has been studied. Treatment of *o*-iodothioanisole with a variety of terminal alkynes under standard Sonagashira coupling conditions (5 mmol of *o*-iodothioanisole, 1.2 equiv of terminal alkyne, 2 mol % of $PdCl_2(PPh_3)_2$, 1 mol % of CuI, and 12.5 mL of Et_3N at room temperature for 3−5 h) affords almost quantitative yields of the coupling products (Table 1).

o-Iodothioanisole shows high reactivity toward the Sonagashira coupling, and this allows the preparation of a wide variety of functionally substituted *o*-(1-alkynyl)-thioanisoles. This high reactivity may be attributed to the coordination of sulfur to palladium in the presumed intermediate (**2**) (Figure 2), which stabilizes the arylpalladium intermediate and reduces its tendency to undergo homocoupling. Alkynes with all sorts of substituents, including phenyl, trimethylsilyl, vinyl, bulky alkyl, and alkyl groups bearing functional groups, such as hydroxy and cyano groups, have been successfully employed in the Sonagashira coupling of *o*-iodothioanisole. Almost quantitative yields were obtained in all cases (Table 1).

Table 1. Sonogashira Coupling of *o*-Iodothioanisole and Terminal Acetylenes (Scheme 1)[a]

entry	terminal acetylene	arylalkyne product (R =)	reaction time (h)	% isolated yield
1	PhC≡CH	Ph (**3**)	3	100
2	*n*-C_8H_{17}C≡CH	*n*-C_8H_{17} (**4**)	3	93
3		R =  (**5**)	3	100
4	$NC(CH_2)_3C{\equiv}CH$	$NC(CH_2)_3$ (**6**)	5	99
5	$Me_3SiC{\equiv}CH$	TMS (**7**)	3	97
6	*t*-BuC≡CH	*t*-Bu (**8**)	3	99
7	$HO(CH_2)_9C{\equiv}CH$	$HO(CH_2)_9$ (**9**)	5	99

[a] All reactions were run with 5 mmol of *o*-iodothioanisole, 1.2 equiv of the terminal acetylene, 2 mol **%** of $PdCl_2(PPh_3)_2$, 1 mol % of CuI, and 12.5 mL of Et_3N at reaction temperature.

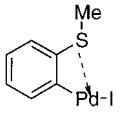


Figure 2. Sulfur-stabilized arylpalladium intermediate.

We have found that *o*-(phenylethynyl)thioanisole (**3**), when treated with **12** in CH_2Cl_2, undergoes smooth iodocyclization at room temperature and affords a nearly quantitative yield of the corresponding 2,3-disubstituted benzo[*b*]thiophene (**10**) (Scheme 1; Table 2, entry 1). The mild reaction conditions, as well as the high yield of this reaction, encouraged us to extend this methodology to a range of *o*-(1-alkynyl)thioanisoles (Table 2; entries 5, 9, 14, 18, 23, and 28). The yields in all cases are essentially quantitative. It makes little difference if the substituent on the other end of the alkyne is aryl, vinyl, alkyl, functionally substituted alkyl, or silyl. Even hindered trimethylsilyl- (**7**) or *tert*-butyl-substituted alkynes (**8**) react rapidly and quantitatively.

The sulfur moiety in this approach to benzo[*b*]-thiophenes comes from commercially available *o*-iodothioanisole. The approach used by Flynn and co-workers[4c] introduces the sulfur through a series of steps starting with 2-iodoaniline or 2-bromo-1-iodobenzene and is thus less practical. We were pleased to find that the methyl group on the sulfur is easily removed during the cyclization step, which makes introduction of the benzyl sulfide group of Flynn and co-workers unnecessary.[4c] This represents the first general route to 2,3-disubstituted benzo[*b*]thiophenes by an electrophilic cyclization strategy.

To explore the scope of this electrophilic cyclization strategy, four other electrophiles, Br_2, NBS, *p*-$O_2NC_6H_4$-SCl, and PhSeCl, have been employed. The reactions have all been monitored by thin-layer chromatography, and most of the reactions were complete within $^1/_2$ h. In virtually all cases examined, excellent yields of benzo-[*b*]thiophene of around 90% have been obtained. The results are summarized in Table 2.

The nature of the electrophile plays an important role in these cyclization reactions. The iodocyclization reactions are most efficient and general. All functional groups that we have studied tolerate the reaction conditions, and yields above 97% were obtained in all cases (Table 2, entries 1, 5, 9, 14, 18, 23, and 28). Aryl- (entry 1) and long-chain-alkyl-substituted alkynes (entry 5) are readily accommodated, and the presence of an olefin (entry 9), a nitrile (entry 14), or an alcohol (entry 28) group presents

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Table 2. Electrophilic Cyclization of *o*-(1-Alkynyl)thioanisoles to 2,3-Disubstituted Benzo[*b*]thiophenes (Scheme 1)[a]

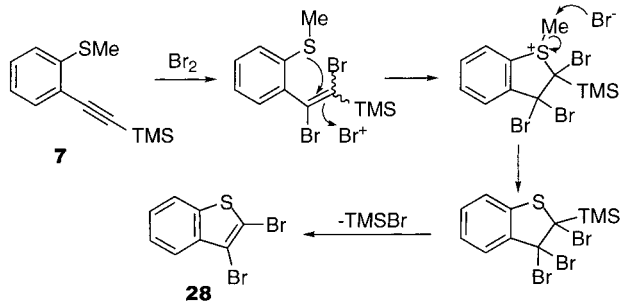
entry	*o*-(1-alkynyl)thioanisole	electrophile	time	E (product)	isolated yield (%)
1	**3**	I_2	10 min	I (**10**)	100
2		Br_2	10 min	Br (**11**)	92
3		*p*-$O_2NC_6H_4SCl$	10 min	*p*-$O_2NC_6H_4S$ (**12**)	97
4		PhSeCl	10 min	PhSe (**13**)	100
5	**4**	I_2	10 min	I (**14**)	100
6		Br_2	10 min	Br (**15**)	91
7		*p*-$O_2NC_6H_4SCl$	10 min	*p*-$O_2NC_6H_4S$ (**16**)	70
8		PhSeCl	10 min	PhSe (**17**)	91
9	**5**	I_2	10 min	I (**18**)	97
10		Br_2	10 min	Br (**19**)	–
11		NBS	2 days	Br (**19**)	74[b]
12		*p*-$O_2NC_6H_4SCl$	10 min	*p*-$O_2NC_6H_4S$ (**20**)	95
13		PhSeCl	10 min	PhSe (**21**)	97
14	**6**	I_2	10 min	I (**22**)	98
15		Br_2	10 min	Br (**23**)	79
16		*p*-$O_2NC_6H_4SCl$	10 min	*p*-$O_2NC_6H_4S$ (**24**)	25[c]
17		PhSeCl	10 min	PhSe (**25**)	78
18	**7**	I_2	10 min	I (**26**)	100
19		Br_2	60 min	Br (**27**)	95[d]
20		NBS	2 days	Br (**28**)	65
21		*p*-$O_2NC_6H_4SCl$	10 min	*p*-$O_2NC_6H_4S$ (**29**)	100
22		PhSeCl	10 min	PhSe (**30**)	100
23	**8**	I^2	20 min	I (**31**)	98
24		Br_2	30 min	Br (**32**)	67
25		NBS	6 h	Br (**32**)	52
26		*p*-$O_2NC_6H_4SCl$	20 min	*p*-$O_2C_6H_4S$ (**33**)	80
27		PhSeCl	20 min	PhSe (**34**)	82
28	**9**	I_2	30 min	I (**35**)	98
29		Br_2	30 min	Br (**36**)	70
30		*p*-$O_2NC_6H_4SCl$	30 min	*p*-$O_2NC_6H_4S$ (**37**)	60
31		PhSeCl	30 min	PhSe (**38**)	95

[a] All reactions were run with 0.25 mmol of the *o*-(1-alkynyl)thioanisole and 1.5 equiv of electrophile in 5 mL of CH_2Cl_2 at 25 °C unless otherwise indicated. All NBS reactions were run using 1.2 equiv of NBS in 10 mL of CH_2Cl_2. [b] 1.2 equiv of NBS at 25 °C for 2 days. [c] The desired benzo[*b*]thiophene **24** was obtained as an inseparable 1:3 mixture of **24** and the product of addition of the (*p*-nitrophenyl)sulfenyl chloride to the alkyne triple bond. The yield was determined by ^1H NMR spectroscopy. [d] 1 equiv of Br_2 gave the product of bromine addition to the triple bond; 1.5 equiv of NBS gave a mixture of the simple alkyne addition product and 2,3-dibromobenzo[*b*]thiophene, and 2 equiv of Br_2 gave 2,3-dibromobenzo[*b*]thiophene. The yield here is of 2,3-dibromobenzo[*b*]thiophene.

no difficulties. *o*-((Trimethylsilyl)ethynyl)thioanisole (entry 18) undergoes iodocyclization smoothly without desilylation, which provides an efficient method for the preparation of 3-iodo-2-silylbenzo[*b*]thiophenes. Even an alkyne with a bulky *tert*-butyl group (entry 23) gave almost a quantitative isolated yield (98%) of the cyclization product in only 10 min reaction time. The success of this reaction is presumably due to the highly nucleophilic nature of the iodide ion formed after the cyclization, which facilitates methyl group removal from the sulfonium intermediate presumably generated upon cyclization.

The reactions with Br_2 gave results somewhat different from those of I_2. While most alkynes reacted fairly cleanly with Br_2 to afford good to excellent yields of 3-bromobenzo[*b*]thiophenes (entries 2, 6, 15, 24, and 29), there were also complications not encountered previously using I_2. The carbon−carbon double bond present in alkyne 5 was found to be more reactive toward Br_2 than the triple bond, and only a trace of the desired bromobenzo[*b*]thiophene product was detected (entry 10). However, when the electrophile was changed from Br_2 to NBS, the desired cyclization product **19** was obtained in 74% yield (entry 11). The reaction of silyl alkyne **7** with Br_2 led to a mixture of 2,3-dibromobenzo[*b*]thiophene (**27**) and products of simple addition of the Br_2 to the carbon−carbon triple bond. The formation of **27** can be explained by either bromocyclization in the desired manner, followed by more rapid bromodesilylation, or by the mechanism described in Scheme 2, where the bromine first adds to the triple bond to form the simple addition product.

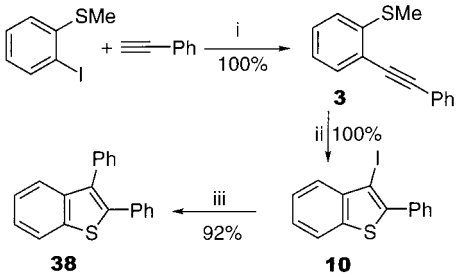
Scheme 2



Attack of another 1 equiv of Br_2 on the simple addition product might then lead to cyclization and formation of a 2,3-dihydrobenzo[*b*]thiophene bearing bromine atoms and a silyl group. Elimination of trimethylsilyl bromide would afford **27**. When the electrophile was changed from Br_2 to NBS, the desired cyclization product 3-bromo-2-silylbenzo[*b*]thiophene (**28**) was obtained in 65% yield. The bromocyclization reaction times of NBS and *o*-(l-alkynyl)thioanisoles (entries 11, 200, and 25) are generally longer than the bromocyclization reaction times employing Br_2, and the yields are generally lower.

The commercially available reagents *p*-$O_2NC_6H_4SCl$ and PhSeCl are generally good electrophiles in this cyclization reaction, when there is no nucleophilic functionality present in the *o*-(1-alkynyl)thioanisoles. *o*-(1-Alkynyl)thioanisoles **3**−**5**, **7**, and **8** all give decent yields of the desired disubstituted benzo[*b*]thiophene products. However, the yields from *p*-$O_2NC_6H_4SCl$ cyclizations are generally lower than those of the PhSeCl cyclizations,

Scheme 3[a]



[a] Reagents and reaction conditions: (i) 2 mol % $PdCl_2(PPh_3)_2$, 1 mol % CuI, Et_3N, 25 °C for 6 h; (ii) I_2, CH_2Cl_2, 25 °C for 10 min; (iii) 5 mol % $Pd(OAc)_2$, $NaBPh_4$, 1:1 DMF/H_2O, 1 equiv of Na_2CO_3, 100 °C for 12 h.

which are in turn lower than those of the iodocyclization reactions. The reason for this is not clear at this time, but factors to be considered include the electrophilicity and hardness of the electrophiles.

Substituents on the triple bond of the *o*-(1-alkynyl)-thioanisoles also affect the yields of the cyclization reactions. Substrates with substituents which are in conjugation with the triple bond, such as the phenyl group in alkyne **3** and the vinylic group in alkyne **5**, appear to cyclize more rapidly and generally produce higher yields of products. Bulky substrates, such as the *tert*-butyl group in alkyne **6**, tend to hinder cyclization. Longer reaction times are often needed, and lower yields often result. However, no products involving simple addition of the electrophile to the alkyne triple bond are observed with this alkyne.

Long alkyl chains also play a role in the cyclization. The presence of an *n*-octyl group on the triple bond, as in alkyne **2**, lowered the yields of the (*p*-nitrophenyl)-sulfenyl and phenylselenyl cyclization reactions (entries 7 and 8), relative to the halocyclization processes (entries 5 and 6). Some product of the simple addition of *p*-$O_2NC_6H_4SCl$ to the carbon−carbon triple bond of the *o*-(1-alkynyl)thioanisole **2** was observed (entry 7).

Due apparently to the electron-withdrawing effect of the cyano group on the alkyl chain, the reactions of 5-(2-(methylmercapto)phenyl)-5-hexynenitrile (**6**) with the sulfur and selenium electrophiles (entries 16 and 17) gave lower yields than the simple alkyl-substituted alkyne **2**. In fact, *p*-$O_2NC_6H_4SCl$ gave mainly the product of simple addition of the electrophile to the carbon−carbon triple bond and only a 25% yield of the desired product was obtained (entry 16). The cyano group here could serve as a nucleophile, which possibly interacts with the sulfur and selenium electrophiles and lowers the yields of the cyclization reactions.

An alcohol group can also interfere in the cyclization process. While the yield for the iodocyclization of the *o*-(1-alkynyl)thioanisole **9** with a hydroxyl group on the end of the long alkyl chain of the alkyne is still high, the Br_2 and *p*-$O_2NC_6H_4SCl$ cyclizations give much lower yields (entries 29 and 30). The hydroxyl group of alkyne **7** may be reacting directly with the *p*-$O_2NC_6H_4SCl$, generating HCl and a ((*p*-nitrophenyl)sulfenyl)oxy group on the end of the alkyl chain. The 3-substituted benzo[*b*]thiophenes produced by this new chemistry should be very useful for the synthesis of additional benzo[*b*]thiophenes. For example, the 3-iodobenzo[*b*]thiophenes produced by this strategy can be further functionalized by applying palladium-mediated coupling techniques. This methodology has been successfully employed by Flynn and co-workers in the synthesis of tubulin binding agents.[4c] We have found that 2,3-diphenylbenzo[*b*]thiophene can be obtained in a 92% overall yield from *o*-iodothioanisole and phenylacetylene by our two-step coupling/cyclization process, followed by Suzuki cross-coupling of the intermediate 3-iodo-2-phenylbenzo[*b*]thiophene with $NaBPh_4$ (Scheme 3). One should be able to prepare many other 2,3-disubstituted benzo[*b*]thiophenes using these iodo substrates and known palladium methodology.

Conclusions

A very efficient synthesis of 2,3-disubstituted benzo-[*b*]thiophenes has been developed by a two-step approach involving the Sonagashira cross-coupling of terminal alkynes and commercially available *o*-iodothioanisole, followed by electrophilic cyclization using **12**, Br_2, NBS, and sulfur and selenium electrophiles. All electrophiles give benzo[*b*]thiophenes in good to excellent yields. A wide variety of thioanisole-containing acetylenes with various functional groups undergo this overall process in good to excellent yields. The steric and electronic effects of the substituents on the carbon−carbon triple bond of the alkynylthioanisole intermediates have been studied.

Experimental Section

General Considerations. All ^1H and ^{13}C NMR spectra were recorded at 300 and 75.5 MHz or 400 and 100 MHz. Thin-layer chromatography was performed using commercially prepared 60 mesh silica gel plates (Whatman K6F), and visualization was effected with short-wavelength UV light (254 nm). All melting points are uncorrected. High-resolution mass spectra were recorded on a Kratos MS50TC double-focusing magnetic sector mass spectrometer using EI at a voltage of 70 eV. All reagents were used directly as obtained commercially, unless otherwise noted. Anhydrous forms of ethyl ether, hexanes, ethyl acetate, methylene chloride, and DMF were purchased from Fisher Scientific Co. 2-Iodothioanisole, phenylacetylene, 1-decyne, 1-cyclohexenylacetylene, 11-undecyn-1-ol, *tert*-butylacetylene, (trimethylsilyl)acetylene, 5-hexynenitrile, and Et_3N were purchased from Aldrich Chemical Co., Inc. The palladium salts were donated by Johnson Matthey Inc. and Kawaken Fine Chemicals Co. Ltd.

General Procedure for the Palladium-Catalyzed Formation of *o*-(1-Alkynyl)thioanisoles. To a solution of Et_3N (12.5 mL), $PdCl_2(PPh_3)_2$ (0.070 g, 2 mol %), 5 mmol of *o*-iodothioanisole, and 6 mmol of terminal acetylene (stirring for 5 min beforehand) was added CuI (0.010 g, 1 mol %), and stirring was continued for another 2 min before flushing with Ar; the flask was then sealed. The mixture was stirred at room temperature for 3−6 h, and the resulting solution was filtered, washed with a satuated aqueous NaCl solution, and extracted with diethyl ether (2 × 10 mL). The combined ether fractions were dried over Na_2SO_4 and concentrated under vacuum to yield the crude product. The crude product was purified by flash chromatography on silica gel using ethyl acetate/hexane as the eluent.

***o*-(Phenylethynyl)thioanisole (3).** The product was obtained as a yellow oil. The ^1H and ^{13}C NMR spectral data were in good agreement with the literature data.[12]

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Characterization data for all other *o*-(1-alkynyl)thioanisoles prepared in this study can be found in the Supporting Information.

General Procedure for the Iodo- and Bromocyclizations. To a solution of 0.25 mmol of the *o*-(1-alkynyl)-thioanisole and 3 mL of CH_2Cl_2 was added gradually 2 equiv of I_2 or Br_2 dissolved in 2 mL of CH_2Cl_2. The reaction mixture was flushed with Ar and stirred at room temperature for 30 min. The excess I_2 or Br_2 was removed by washing with a saturated aqueous solution of $Na_2S_2O_3$. The aqueous solution was then extracted by diethyl ether (2 × 10 mL). The combined ether layers were dried over anhydrous Na_2SO_4 and concentrated under vacuum to yield the crude product, which was purified by flash chromatography on silica gel using ethyl acetate/hexanes as the eluent.

3-Iodo-2-phenylbenzo[*b*]thiophene (10). Theproduct was obtained as a yellow oil. The ^1H and ^{13}C NMR spectral data were in good agreement with the literature data.[12]

Characterization data for all other 3-halobenzo[*b*]thiophenes prepared in this study can be found in the Supporting Information.

General Procedure for the *p*-$O_2NC_6H_4SCl$ and PhSeCl Cyclizations. To a solution of 0.25 mmol of the *o*-(1-alkynyl)-thioanisole and CH_2Cl_2 (3 mL) was added a solution of 0.375 mmol of *p*-$O_2NC_6H_4SCl$ and PhSeCl and CH_2Cl_2 (2 mL). The mixture was stirred for 2 min, the flask was flushed with Ar, and the mixture was then stirred at the designated temperature for 30 min. The reaction mixture was washed with 20 mL of water and extracted with diethyl ether. The combined ether layers were dried over anhydrous Na_2SO_4 and concentrated under vacuum to yield the crude product, which was further purified by flash chromatography on silica gel using ethyl acetate/hexanes as the eluent.

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3-((*p*-Nitrophenyl)sulfenyl)-2-phenylbenzo[*b*]thiophene (12). The product was obtained as a yellow oil. ^1H NMR (400 MHz, $CDCl_3$): δ 7.10−7.13 (d, J = 8.8 Hz, 2H), 7.42−7.46 (m, 5H), 7.65−7.67 (m, 2H), 7.74−7.76 (d, J = 8.8 Hz, 1H), 7.92−7.94 (d, J = 8.4 Hz, 1H), 8.01−8.04 (d, J = 9.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 115.8, 122.6, 123.4, 124.1, 124.2, 125.6, 125.8, 128.8, 129.5, 129.7, 132.9, 138.6, 140.3, 145.3, 147.8, 151.3. IR (neat, cm^{-1}): 3061, 2918, 2849, 1577, 1512, 1337, 753. HRMS: *m*/*z* calcd for $C_{20}H_{13}NO_2S_2$ 363.038 77, found 363.039 43.

Characterization data for all other 3-thio- and 3-selenobenzo[*b*]thiophenes prepared in this study can be found in the Supporting Information.

2,3-Diphenylbenzo[*b*]thiophene (39). Details of the preparation of 2,3-diphenylbenzo[*b*]thiophene by the Suzuki cross-coupling of 3-iodo-2-phenylbenzo[*b*]thiophene and $NaBPh_4$ can be found in the Supporting Information.

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Supporting Information Available: Characterization data for *o*-(1-alkynyl)thioanisoles (**3**−**9**), 3-halobenzo[*b*]-thiophenes (**10, 11, 14, 15, 18, 19, 22, 23, 26**−**28, 31, 32, 35,** and **36**), 3-thio and 3-selenobenzo[*b*]thiophenes (**12, 13, 16, 17, 20, 21, 24, 25, 29, 30, 33, 34, 37,** and **38**), and 2,3-diphenylbenzo[*b*]thiophenes (**39**) and figures giving ^1H and ^{13}C NMR spectra for compounds **3**−**39**. This material is available free of charge via the Internet at http://pubs.acs.org.

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