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Studies on chalcogen-containing heterocycles. Part 38: Regio- and stereoselective tandem addition–iodocyclization of 2-ethynylphenyl isothiocyanates with N- and O-nucleophiles affording 4-(iodoalkylidene)benzo[*d*][1,3]thiazines[†]

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ABSTRACT

The treatment of the *o*-ethynylphenyl isothiocyanates with primary and secondary amines in 1,2-DCE, followed by the addition of I_2 and then heating resulted in the regio- and stereoselective tandem addition–iodocyclization to give the (4*E*)-2-amino-4-(1-iodomethylidene)benzo[*d*][1,3]thiazine derivatives as the sole product in high yields via the 6-*exo*-*dig* mode cyclization. The 2-alkoxy-1,3-benzothiazines were similarly produced from the *o*-ethynylphenyl isothiocyanates and the corresponding sodium alkoxides.

1. Introduction

The preparation of benzo[*d*][1,3]thiazine derivatives is of continuing interest in the field of synthetic organic chemistry because of their biological and pharmaceutical activities.[2] There are many efficient synthetic methods for the benzo[*d*][1,3]thiazines[3] involving the classical method, which is the condensation of 2-aminobenzyl chloride with thioamides or thioureas. Recently, a 2-amino(imino)-4-methylidene-4*H*-benzo[*d*][1,3]thiazine synthesis protocol, which is the tandem 6-*exo*-*dig* mode addition-cyclization reactions of the 2-ethynylanilines with the isothiocyanates and related compounds, has attracted considerable attention; these reactions are often promoted by a silver catalyst,[4] DMAP[5a] or silica gel.[5b] The 2-thioformylaminodiphenylacetylenes were cyclized by DBU to give the 2-unsubstituted 3,1-benzothiazines.[6]

Electrophilic cyclization involving the iodocyclization[7] approach with the heteroatom-containing arylalkynes for preparing the heterocyclic compounds is a very important methodology because the starting material, i.e., alkynes, are easily obtained from commercially available compounds via the Sonogashira palladium coupling. Furthermore, the obtained iodoheterocycles can be the starting materials for the preparation of the more functionalized heterocyclic compounds through the C–C bond formation by a cross-coupling reaction, such as the Sonogashira or Suzuki reactions.

While iodocyclization of the 2-ethynyl-phenol, -aniline or -thiol derivatives has been utilized for the synthetic approach to five-membered heterocycles, such as the benzo[*b*]furans,[8] indoles,[9] and benzo[*b*]thiophenes,[10] there are only a few studies concerning the synthesis of six-membered heterocycles[11] except for the isocoumarins[12] by the 6-*endo*-*dig* type cyclization of the *o*-ethynylbenzoate ester derivatives and seven-membered heterocycles.[13] Recently, the 3-iodoselenophenes[14] and 3-iodobenzoseleno phenes[15] were also prepared by a similar protocol. These products were transformed into the 2,3-disubstituted benzo[*b*]heteroles involving valuable biologically active compounds. The accomplishment of these iodocyclizations is dependent on the nature of the substituent directly linked to the heteroatoms; a substituent, such as the methyl, benzyl or acetyl group, is needed as the leaving group in most cases. Very recently, we described the tandem

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addition–iodocyclization of *o*-ethynylphenyllithiums with isoselenocyanates, followed by treatment with I_2 to give the (*E*)-1-(iodomethylidene)benzo[*c*]selenophenes in one pot.[16] Two independent groups[17] have already studied the 6-*exo*-*trig* mode iodocyclization of the *N*-homoallyl thioureas and thioamides leading to the monocyclic 1,3-thiazine derivatives. There have been no studies on the synthesis of the 3,1-benzothiazines via the 6-*exo*-*dig* mode iodocyclization.

In this study, as a part of our continuing studies,[16,18,19] we describe the first examples of the one-pot preparation of the (4*E*)-4-(1-iodomethylidene)benzo-1,3-thiazines by addition of the *o*-ethynylphenyl isothiocyanates with N- and O-nucleophiles, followed by iodocyclization of the thiourea or thiourethane adducts. While the silver-catalyzed tandem addition-cyclization of the *o*-ethynylphenyl isothiocyanates with the secondary amines proceeded in both the 6-*exo*-*dig* and 5-*endo*-*dig* mode cyclizations as reported in a previous study,[20] in this iodocyclization, using both the primary and secondary amines afforded only the 6-*exo*-*dig* mode products, i.e., the (4*E*)-2-amino-4-(1-iodomethylidene)-4*H*-benzo[*d*][1,3]thiazines in high yields. The isothiocyanates also reacted with the alkoxides to give the corresponding benzo[*d*][1,3]thiazines having an oxygen-functional group at the 2-position. Iodocyclization using the isothiocyanates requires no leaving groups on the sulfur element in this case and has the advantage of a high atom-economy.

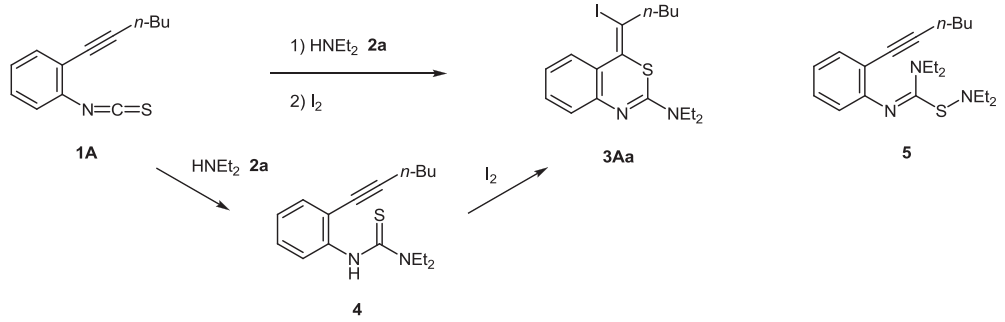
2. Results and discussion

2.1. Reaction of 2-ethynylphenyl isothiocyanate with diethylamine and I_2: optimization of reaction conditions

The treatment of the *o*-ethynylphenyl isothiocyanate **1A** with diethylamine **2a**, followed by the addition of I_2 resulted in the tandem addition-6-*exo*-*dig* mode cyclization to give the (4*E*)-2-amino-4-(1-iodomethylidene)-4*H*-benzo[*d*][1,3]thiazine **3Aa** as the sole product in one pot. This tandem addition–iodocyclization reaction was conducted to examine the optimal reaction conditions; these results are shown in Table 1.

The adduct, *N*-(2-ethynylphenyl)thiourea **4** generated from the isothiocyanate **1A** and diethylamine **2a**, was regio- and stereoselectively iodocyclized to the 1,3-thiazine **3Aa** in 51% yield in the presence of Cs_2CO_3 as a base in CH_2Cl_2 at room temperature (entry 1). When **1A** was similarly treated with **2a** and Cs_2CO_3 in the absence of I_2, the thiourea **4** was isolated in 91% yield (entry 2), then converted into the thiazine **3Aa** in high yield using I_2 in CH_2Cl_2. The 1,3-thiazine **3Aa** was produced in 60% yield with the use of refluxing CH_2Cl_2 (entry 3). However, **3Aa** was produced without the use of an inorganic base in only 5% yield together with **4** in 16% yield (entry 4). Similar results were obtained using an excess of **2a** (entry 5). Thus, the use of an inorganic base is essential, while an organic base was not effective. The 1,3-thiazine **3Aa** was produced by the reaction in the presence of K_2CO_3 and Na_2CO_3 instead of Cs_2CO_3 in 30% and 21% yields, respectively (entries 6, 7). The 1,3-thiazine **3Aa** was found to be obtained in the highest yields, of 83% in 1,2-dichloroethane (DCE) at 65 °C (entry 8). On the other hand, the use of dry THF as the solvent at room temperature gave a complex mixture involving the thiourea **4**; the desired iodothiazine **3Aa** was not obtained (entry 9). The reaction at 60 °C in THF gave **3Aa** in only 21% yield (entry 10). The isothiocyanate **1A** was reacted with 1.1 mmol of diethylamine **2a**, followed by treatment with I_2 in CH_3CN to give the bis-diethylamino derivative **5** in 50% yield through the 1:2 addition in one pot together with the thiourea **4** (entry 11). Using 2.2 mmol of diethylamine **2a** gave **5** in 86% yield as the sole product (entry 12). Generally, the use of a more polar solvent, such as CH_3CN, is favored for the iodocyclization concerning the triple bond due to the solubility of I_2 and inorganic bases, such as $NaHCO_3$, K_2CO_3, and Cs_2CO_3.[7] However, this theory did not agree with the present experimental facts; the use of a less polar solvent (1,2-DCE) gave the best result. The solvent effects on the iodocyclization are quite drastic, but cannot be clearly explained at the present.

Table 1
Reaction of 2-ethynylphenyl isothiocyanate **1A** with diethylamine **2a** and I_2



Entry	Diethylamine **2a**	I_2	Base	Solvent	Temp	Product[a,b] (%)
1	1.1 mmol	1.3 mmol	Cs_2CO_3, 1.5 mmol	CH_2Cl_2	rt	**3Aa** (51%)
2	0.1 mmol	None	Cs_2CO_3, 1.5 mmol	CH_2Cl_2	rt	**4** (91%)
3	1.1 mmol	1.3 mmol	Cs_2CO_3, 1.5 mmol	CH_2Cl_2	Reflux	**3Aa** (60%)
4	1.1 mmol	1.3 mmol	None	CH_2Cl_2	Reflux	**3Aa** (5%), **4** (16%)
5	4.0 mmol	1.3 mmol	None	CH_2Cl_2	Reflux	**3Aa** (7%), **4** (20%)
6	1.1 mmol	1.3 mmol	K_2CO_3, 1.5 mmol	CH_2Cl_2	Reflux	**3Aa** (30%)
7	1.1 mmol	1.3 mmol	Na_2CO_3, 1.5 mmol	CH_2Cl_2	Reflux	**3Aa** (21%)
8	**1.1** mmol	**1.3** mmol	**Cs_2CO_3, 1.5** mmol	**1,2-DCE**	**65** °C	**3Aa** (83%)
9	1.1 mmol	1.3 mmol	Cs_2CO_3, 1.5 mmol	THF	rt	**4** (30%)
10	1.1 mmol	1.3 mmol	Cs_2CO_3, 1.5 mmol	THF	60 °C	**3Aa** (21%)
11	1.1 mmol	1.3 mmol	Cs_2CO_3, 1.5 mmol	CH_3CN	rt	**5** (50%)
12	2.2 mmol	1.3 mmol	Cs_2CO_3, 1.5 mmol	CH_3CN	rt	**5** (86%)

[a] Isolated yield.
[b] The reaction was carried out for 3–5 h.

2.2. Reaction of 2-ethynylphenyl isothiocyanates with secondary amines and I_2: formation of (4*E*)-2-amino-4-(1-iodo methylidene)benzo[*d*][1,3]thiazines

The generality of this tandem addition–iodocyclization of *o*-ethynylphenyl isothiocyanates **1A** with other secondary amines involving the aliphatic cyclic and aromatic amines, and the substrates having an alkyl and phenyl group at the triple bond, was also performed (Table 2). The treatment of **1A** with secondary cyclic amines, such as piperidine **2b**, pyrrolidine **2c**, and morpholine **2d**, followed by the addition of I_2 gave the corresponding (4*E*)-2-amino-4-(1-iodomethylidene)-4*H*-benzo[*d*][1,3]thiazines **3Ab**, **3Ac**, and **3Ad** in 89, 88, and 95% yields, respectively (entries 1–3). This tandem reaction proceeded with the aromatic amine, *N*-methylaniline **2e**, to afford the 2-anilino derivative **3Ae** in 91% yield (entry 4). In order to demonstrate the efficiency of this tandem addition–iodocyclization, the generality was explored by extending the substrates to the *o*-ethynylphenyl isothiocyanates **1B** and **1C** having a bulky alkyl or TMS group at the sp-carbon atom of the ethynyl moiety with diethylamine **2a**. The reaction of 2-(3,3-dimethylbut-1-ynyl)phenyl isothiocyanate **1B** with diethylamine **2a**, followed by the addition of I_2 gave the (4*E*)-2-amino-4-(1-iodomethylidene)-4*H*-benzo[*d*][1,3]thiazine **3Ba** in 90% yield (entry 5).

On the contrary, neither the TMS **3Ca** nor the desilylated derivative **3Ca′** was obtained. The iodocyclized product **3Ca** from the reaction of **1C** with **2a** might be too unstable to isolate (entry 6).

2.3. Reaction of 2-ethynylphenyl isothiocyanates with primary amines and I_2: formation of (4*E*)-2-imono-4-(1-iodome thylidene) benzo[*d*][1,3]thiazines

Next, the *o*-ethynylphenyl isothiocyanates **1** and the prim ary amines **6** were also found to regio- and stereoselectively

Table 2
(4*E*)-2-Amino-**3** and (4*E*)-2-imino-4-(1-iodomethylidene)benzo[*d*][1,3]thiazines **7**[a]

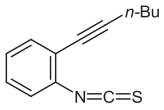
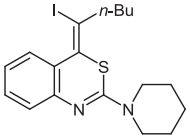
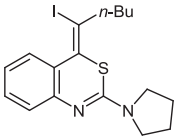
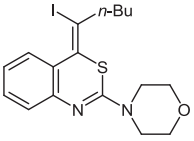
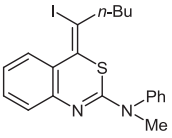
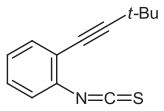
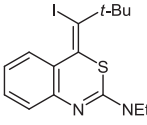
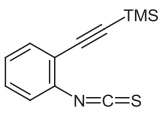
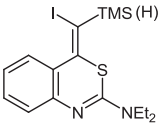
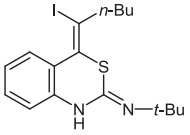
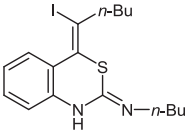
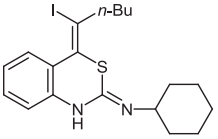
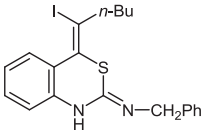
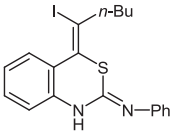
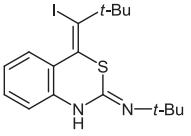
Entry	Isocyante	Amine	Reaction time (h)	Product	Yield[b] (%)
1	 **1A**	Piperidine **2b**	2.5	 **3Ab**	89
2	**1A**	Pyrrolidine **2c**	3	 **3Ac**	88
3	**1A**	Morpholine **2d**	3	 **3Ad**	95
4	**1A**	*N*-Methylaniline **2e**	3.5	 **3Ae**	91
5	 **1B**	Diethylamine **2a**	3.5	 **3Ba**	90
6	 **1C**	**2a**	7	 **3Ca (3Ca')**	00[c]
7	**1A**	*tert*-Butylamine **6a**	7	 **7Aa**	78
8	**1A**	*n*-Butylamine **6b**	4	 **7Ab**	66

Table 2 (*continued*)

Entry	Isocyante	Amine	Reaction time (h)	Product	Yield[b] (%)
9	**1A**	Cyclohexylamine **6c**	6	 **7Ac**	81
10	**1A**	Benzylamine **6d**	5	 **7Ad**	81
11	**1A**	Aniline **6e**	7	 **7Ae**	84
12	**1B**	**6a**	4	 **7Ba**	52

[a] Standard reactions conditions: **1** (1 mmol), **2** (1.1 mmol), I_2 (1.3 mmol), Cs_2CO_3 (1.5 mmol), dry DCE (2.0 mL), 65 °C.
[b] Isolated yield.
[c] Decomposed.

proceed, affording the corresponding (4*E*)-2-imino-4-(1-iodometh ylidene)-4*H*-1,2-dihydrobenzo[*d*][1,3]thiazines **7** as shown in Table 2. The *o*-ethynylphenyl isothiocyanate **1A** was similarly treated with *tert*-butylamine **6a**, followed by iodination with I_2 in DCE at 65 °C, giving the desired (4*E*)-2-imino-4*H*-1,2-dihydro benzo[*d*][1,3]thiazine **7Aa** in one pot in 78% yield (entry 7). Compound **1A** reacted with the other aliphatic amines, such as *n*-butylamine **6b**, cyclohexylamine **6c**, and benzylamine **6d**, to give the corresponding (4*E*)-1,3-thiazines **7Ab**, **7Ac**, **7Ad** in 66, 81, and 81% yields, respectively (entries 8–10). The aromatic amine, aniline **6e**, also reacted with the isothiocyanate **1A** to give the phenylimino derivative **7Ae** in 84% yield (entry 11). The *o*-(*tert*-butylethynyl)phenyl isothiocyanate **1B** also reacted with *tert*-butylamine **6a** to afford the neopentylidene **7Ba** in 52% yield (entry 12). The addition reaction of the primary amines **6** with the isothiocyanate **1** required a relatively long reaction time due to the lower nucleophilicity of the primary amines than that of the secondary amines.

2.4. Reaction of 2-(phenylethynyl)phenyl isothiocyanate with amines and I_2

Interestingly, the reaction of 2-(phenylethynyl)phenyl isothiocyanate **1D** with the secondary amine, diethylamine **2a**, under the daylight conditions, which were previously used for the preparation of (4*E*)-4-(1-iodomethylidene)benzo[*d*][1,3]-thiazines **3Aa**–**e**, **3Ba**, **7Aa**–**e**, and **7Ba**, produced the stereoisomer, the (*Z*)-iodomethylidene derivative **3Da-*Z***, in 77% yield as the sole product; no normal desired (*E*)-derivative **3Da-*E*** was obtained. Thus, this tandem reaction was performed under dark conditions (reaction and other operations including the purification) using **1D** and **2a**; the (*E*)-derivative **3Da-*E*** was isolated in 90% yield. These results for the formation of the (*E*)-**3Da-*E*** and (*Z*)-derivatives **3Da-*Z*** clearly indicated the following: the isomerization from **3Da-*E*** into **3Da-*Z*** is effective by direct light absorption due to having a typical photosensitive *trans*-styrene moiety. Furthermore, the (*E*)/(*Z*) isomerization of the isolated products under daylight was observed; The ^{1}H NMR analysis showed that **3Da-*E*** easily isomerized into **3Da-*Z*** in $CDCl_3$ at room temperature within 30 min in excellent yield. The double-doublets signal at 8.01 ppm that was assigned to the 5-H proton on the benzene-ring of **3Da-*E*** disappeared, and finally obtained a ^{1}H NMR signal that was in good agreement with that of **3Da-*Z***.

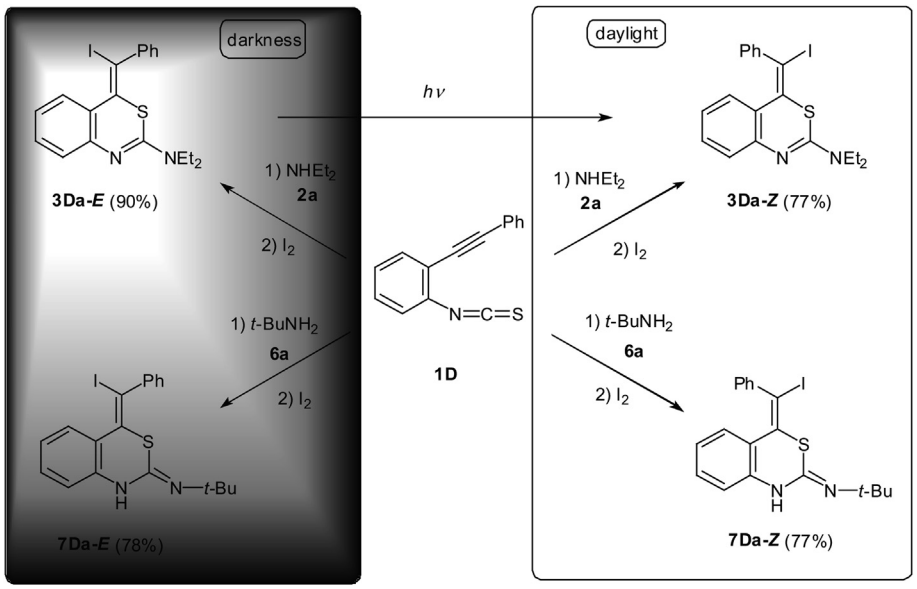
This stereospecific iodocyclization of the isocyanate **1D** with the primary amine, *tert*-butylamine **6a**, similarly proceeded to give the *tert*-butyl derivatives **7Da-*E*** and **7Da-*Z*** under the dark and daylight conditions in 78 and 77% yields, respectively (Scheme 1).

2.5. Structure of (4*E*)-4-(1-iodomethylidene)benzo-1,3-th iazines

The structures of these 3,1-thiazines **3** and **7** were mainly determined by their MS, ^{1}H, and ^{13}C NMR spectra and elemental analyses, and finally, the cyclization mode and olefin geometry were established by single-crystal X-ray studies using **7Ae** and **3Da-*Z***, which were obtained in the crystalline states. The ORTEP drawings are shown in Figs. 1 and 2, respectively.[21]

2.6. Reaction of 2-hexynylphenyl isothiocyanate with O-nu cleophiles

The similar regio- and stereoselective tandem addition–iodocyclization is also applicable to the *o*-ethynylphenyl isothiocyanate with O-nucleophiles, with the results being summarized in Scheme 2. In this case, the adducts from the *o*-ethynylphenyl isothiocyanate **1A** and the alkoxides **8** were isolated. The reaction of the *o*-ethynylphenyl isothiocyanate **1A** with sodium methoxide **8a** afforded the methyl thiocarbamate **9a** in 96% yield. Not only the primary alkoxide, ethyl **8b** and benzyl alkoxide **8c**, but also a secondary alkoxide, *iso*-propoxide **8d**, reacted with the *o*-ethynylphenyl isothiocyanate **1A** to afford the corresponding



Scheme 1. .

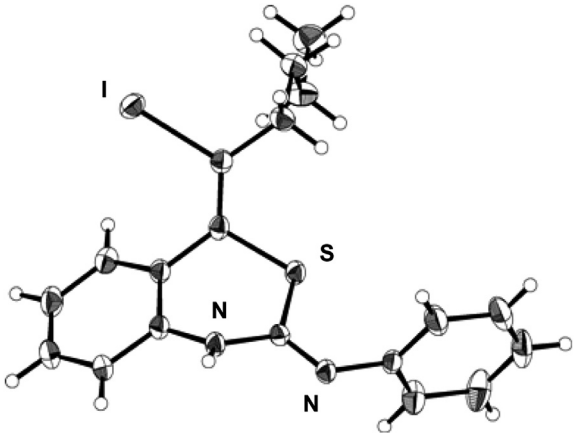


Fig. 1. An ORTEP drawing of **7Ae** with thermal ellipsoid plot (50% probability).

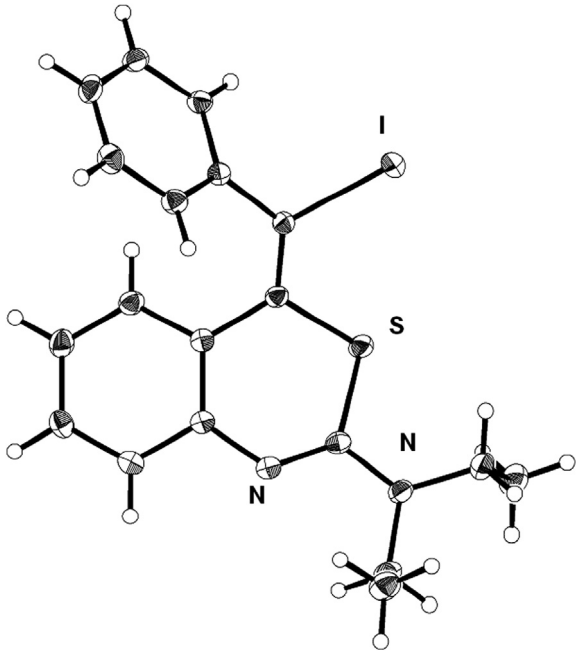


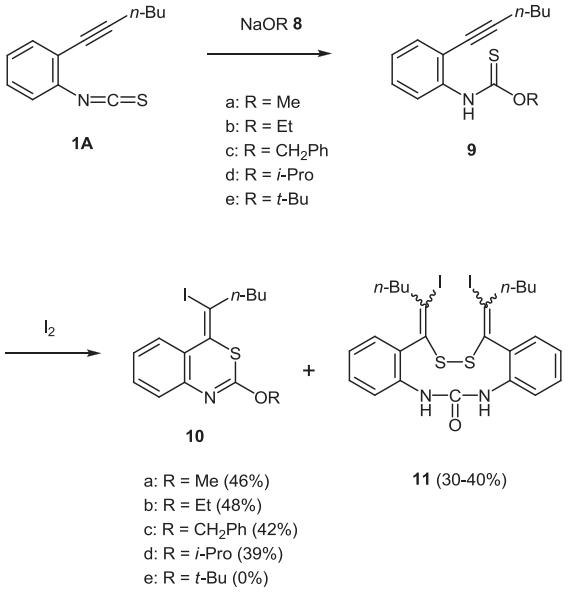
Fig. 2. An ORTEP drawing of **3Da-*Z***.

thiourethanes **9** in high yields. In contrast, the *tert*-butyl thiourethane derivative **9e** could not be obtained in a stable state from **1A** and the tertiary alkoxide **8e** under the same conditions. It is too unstable to be isolated, and decomposed during the purification. Furthermore, the isothiocyanate **1A** did not react with sodium phenoxide, and the starting material **1A** was recovered.

The treatment of the isolated thiourethanes **9a** with 1.3 mol equiv of iodine in the presence of Cs_2CO_3 in dry DCE resulted in the 6-*exo*-*dig* mode ring-closure to give the desired product, (*E*)-2-methoxybenzo[*d*][1,3]thiazine **10a**, in 46% yield. In this iodocyclization, no 7-*endo*-*dig* mode cyclization reaction products were obtained; the 11-membered disulfide **11** was also produced in 36% yield. The use of other thiourethanes **9** was also performed. The reaction of ethyl thiourethane **9b** with I_2 under similar conditions gave the (*E*)-3,1-thiazines **10b** and the disulfide **11** in 48 and 39% yields, respectively. Both the 2-benzyloxy **10c** and 2-*iso*-propyloxy-3,1-thiazines **10d** were also isolated in moderate yields by the reaction of the corresponding thiourethanes **9** with I_2 via the 6-*exo*-*dig* mode cyclization, together with the disulfide **11** in yields ranging from 30 to 40%. Regrettably, the treatment of the obtained crude *tert*-butyl thiourethane derivative **9e** with I_2 under the same conditions gave a complex mixture without any characterized product, even the disulfide **11**. The formation of the disulfide **11** may be explained by the hydrolysis and self-condensation of the cyclization products **10** including the oxidation of the thiol moiety. Both the adducts **9** and cyclization products **10** were relatively unstable, and gradually decomposed at room temperature.

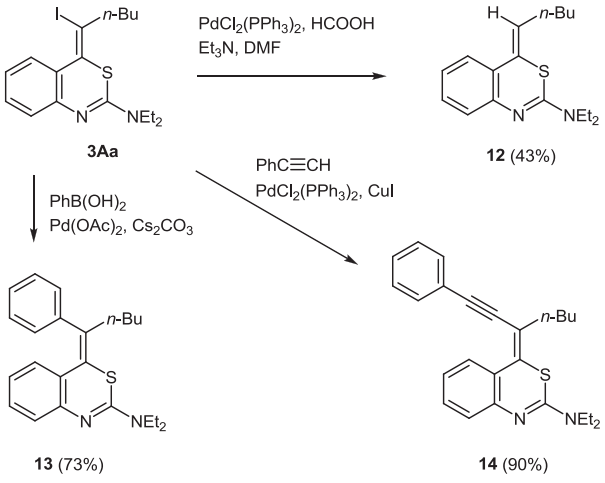
2.7. Cross-coupling reaction of (4*E*)-4-(1-iodomethylidene)benzo[*d*][1,3]thiazines

The iodomethylidenebenzothiazine **3Aa** can be deiodinated to give **12** by treatment with HCOOH/Et_3N in the presence of $PdCl_2(PPh_3)_2$; compound **12** has been previously synthesized.[20] The **3Aa** was transformed into the phenylated 4-(methylidene)benzothiazine **13** by the palladium-catalyzed Suzuki coupling reaction with phenylboronic acid through the C–C bond formation in 73%



Scheme 2.

yield. The Sonogashira reaction with phenylacetylene also proceeded to give the alkynylated benzothiazine **14** in 90% yield (Scheme 3).



Scheme 3.

3. Conclusion

The one-pot tandem addition–iodocyclization of the *o*-ethynylphenyl isothiocyanates with both secondary and primary amines for the efficient preparation of the 4-(1-iodomethylidene) benzothiazines via the 6-*exo*-*dig* mode ring-closure reaction smoothly proceeded; the intermediates, thioureas, could be isolated and transformed into the benzothiazines. The obtained benzothiazines were converted to the more functionalized derivatives via the palladium cross-coupling reactions.

4. Experimental section

4.1. General

Melting points were measured on a Yanagimoto micro melting point hot stage apparatus and are uncorrected. IR spectra were recorded on a Horiba FT-720 spectrophotometer. MS and HRMS spectra were recorded on a JEOL JMS-DX300 instrument. ^{1}H NMR spectra were recorded on a JEOL ECP-500 (500 MHz) spectrometer using TMS as internal standard in $CDCl_3$ and *J* values are given in hertz. ^{13}C NMR spectra were recorded on a JEOL ECP-500 (125 Hz) spectrometer in $CDCl_3$.

4.2. Starting materials

The starting materials, *o*-ethynylphenyl isothiocyanates **1A**, **1B**, **1C**, and **1D** were prepared by the literature method.[22]

4.3. Reaction of 2-ethynylphenyl isothiocyanate with diethylamine and I_2

A mixture of 2-ethynylphenyl isothiocyanate **1A** (215 mg, 1 mmol) and diethylamine **2a** (80 mg, 1.1 mmol) in dry DCE (2 mL) was stirred at room temperature under argon atmosphere for 10 min, and then I_2 (330 mg, 1.3 mmol) and Cs_2CO_3 (489 mg, 1.5 mmol) were added. The mixture was heated at 65 °C with stirring for 3–4 h, and then diluted with $CHCl_3$ (10 mL). The organic layer was washed with 2% $Na_2S_2O_3$ aq (15 mL×3), water (15 mL×2), dried over anhydrous Na_2SO_4, and evaporated in vacuo. The obtained residue was chromatographed on silica gel using hexane/$CHCl_3$ (1:1) as an eluent to give pure (4*E*)-4-(iodomethylidene)-1,3-benzothiazine.

*4.3.1. (4E)-2-(N,N-Diethylamino)-4-(1-iodopentylidene)-4H-benzo[d][1,3]thiazine **3Aa**.* Yield: 343 mg (83%). Yellow oil. IR (KBr, neat): 1556 (C=N) cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$) δ=0.97, 1.36–1.45, 1.57–1.66, 3.05 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.4 Hz, *n*-Bu), 1.22, 3.60 (6H, t, *J*=7.1 Hz, 4H, q, *J*=7.1 Hz, NEt_2), 7.02, 7.09, 7.27, 7.77 (1H, ddd, *J*=7.7, 7.6, 1.0 Hz, 1H, dd, *J*=7.8, 1.0 Hz, 1H, ddd, *J*=7.8, 7.6, 1.5 Hz, 1H, dd, *J*=7.7, 1.5 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.02 (q), 14.04 (q), 21.7 (t), 31.3 (t), 43.7 (t), 44.0 (t), 104.3 (s), 121.5 (d), 124.3 (s), 124.5 (d), 125.0 (s), 127.9 (d), 129.2 (d), 147.4 (s), 153.6 (s). MS (EI): *m*/*z* (relative intensity, %) 414 (M^+, 100), 385 (26), 318 (24), 287 (72), 245 (44), 135 (48). HRMS (EI) *m*/*z* M^+ calcd for $C_{17}H_{23}N_2IS$: 414.0627; found: 414.0622.

*4.3.2. 1,1-Diethyl-3-[2-(hex-1-ynyl)phenyl]thiourea **4**.* *o*-Ethynylphenyl isothiocyanate **1A** was treated with diethylamine **2a** in dry CH_2Cl_2 instead of dry DCE without I_2 and worked up as described for the preparation of **3Aa** to give **4**. Yield: 262 mg (91%). Yellow oil. IR (KBr, neat): 3363 (NH), 2224 (C≡C), 1583 (C=S) cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$) δ=0.94, 1.41–1.52, 1.55–1.64, 2.44 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.1 Hz, *n*-Bu), 1.35, 3.80 (6H, t, *J*=7.1 Hz, 4H, q, *J*=7.1 Hz, NEt_2), 7.02, 7.27, 7.37, 8.43 (1H, ddd, *J*=7.7, 7.5, 1.0 Hz, 1H, ddd, *J*=8.3, 7.5, 1.6 Hz, 1H, dd, *J*=7.7, 1.6 Hz, 1H, dd, *J*=8.3, 1.0 Hz, Ph–H), 7.72–7.83 (1H, br, NH). ^{13}C NMR (125 MHz, $CDCl_3$) δ=12.6 (q), 13.6 (q), 19.4 (t), 22.0 (t), 30.8 (t), 45.5 (t), 76.7 (s), 97.3 (s), 115.4 (s), 122.7 (d), 123.5 (d), 127.7 (d), 131.8 (d), 140.7 (s), 179.0 (s). MS (EI): *m*/*z* (relative intensity, %) 288 (M^+, 100), 213 (36), 186 (21), 116 (49), 88 (17). HRMS (EI) *m*/*z* M^+ calcd for $C_{17}H_{24}N_2S$: 288.1660; found: 288.1664.

*4.3.3. N-[(Diethylamino)(diethylaminothio)methylidene]-2-(hex-1-ynyl)aniline **5**.* *o*-Ethynylphenyl isocyanate **1A** was treated with diethylamine **2a** (2.2 mmol) in dry CH_3CN instead of dry DCE and worked up as described for the preparation of **3Aa** to give **5**. Yield: 310 mg (86%). Yellow oil. IR (KBr, neat): 2027 (C≡C), 1610 (C=N) cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$) δ=0.87–0.94, 1.21, 1.41–1.49, 1.49–1.58, 2.37, 2.56, 3.48 (9H, m, 6H, t, *J*=7.0 Hz, 2H, m, 2H, m, 2H, t, *J*=7.0 Hz, 4H, q, *J*=7.0 Hz, 4H, q, *J*=7.0 Hz, *n*-Bu, NEt_2×2), 6.71–6.77, 7.08, 7.28 (2H, m, 1H, ddd, *J*=7.9, 7.6, 1.5 Hz, 1H, dd, *J*=7.9, 1.3 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=13.4 (q), 13.71 (q), 13.74 (q), 19.5 (t), 22.0 (t), 31.1 (t), 43.8 (t), 51.0 (t), 80.0 (s), 92.4 (s), 114.9 (s), 120.0 (d), 120.8 (d), 127.6 (d), 132.2 (d), 152.6 (s),

156.5 (s). MS (FAB): *m*/*z* (relative intensity, %) 360 (MH^+, 5), 289 (45), 255 (100), 135 (51), 116 (46), 88 (21). HRMS (FAB) *m*/*z* MH^+ calcd for $C_{21}H_{34}N_3S$: 360.24730; found: 360.2586.

4.4. Typical procedure for preparation of (4*E*)-2-amino-4-(1-iodomethylidene)benzo[*d*][1,3]thiazines

o-Ethynylphenyl isothiocyanate **1** was treated with the appropriate secondary amine **2** and worked up as described for the preparation of **3Aa** to give **3**.

4.4.1. (4E)-4-(1-Iodopentylidene)-2-(piperidin-1-yl)-4H-benzo[d][1,3]thiazine ***3Ab***. Yield: 379 mg (89%). Yellow oil. IR (KBr, neat): 1549 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.97, 1.36–1.45, 1.57–1.72, 3.04, 3.71–3.79 (3H, t, *J*=7.3 Hz, 2H, m, 4H, m, 2H, t, *J*=7.4 Hz, 4H, m, *n*-Bu, piperidine–H), 7.04, 7.10, 7.27, 7.77 (1H, ddd, *J*=7.8, 7.2, 1.2 Hz, 1H, dd, *J*=8.0, 1.2 Hz, 1H, ddd, *J*=8.0, 7.2, 1.5 Hz, 1H, dd, *J*=7.8, 1.5 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.1 (q), 21.7 (t), 24.9 (t), 25.9 (t), 31.2 (t), 44.0 (t), 48.1 (t), 104.6 (s), 122.0 (d), 124.57 (s), 124.58 (d), 125.0 (s), 127.9 (d), 129.2 (d), 147.1 (s), 154.8 (s). MS (EI): *m*/*z* (relative intensity, %) 426 (M^+, 100), 383 (13), 299 (20), 216 (30). HRMS (EI) *m*/*z* M^+ calcd for $C_{18}H_{23}N_2IS$: 426.0627; found: 426.0627.

4.4.2. (4E)-4-(1-Iodopentylidene)-2-(pyrrolidin-1-yl)-4H-benzo[d][1,3]thiazine ***3Ac***. Yield: 363 mg (88%). Yellow oil. IR (KBr, neat): 1560 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.98, 1.35–1.45, 1.57–1.65, 3.04 (3H, q, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.4 Hz, *n*-Bu), 1.90–2.01, 3.57–3.70 (4H, m, 4H, m, pyrrolidine–H), 7.01, 7.10, 7.27, 7.76 (1H, dd, *J*=7.8, 7.3 Hz, 1H, d, *J*=8.1, 7.3 Hz, 1H, ddd, *J*=8.1, 7.3, 1.2 Hz, 1H, dd, *J*=7.8, 1.2 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.1 (q), 21.7 (t), 25.0 (t), 31.3 (t), 44.1 (t), 48.1 (t), 103.6 (s), 121.5 (d), 124.0 (s), 124.5 (d), 124.8 (s), 128.2 (d), 129.4 (d), 147.4 (s), 152.5 (s). MS (EI): *m*/*z* (relative intensity, %) 412 (M^+, 100), 369 (23), 285 (24), 242 (32), 216 (12). HRMS (EI) *m*/*z* M^+ calcd for $C_{17}H_{21}N_2IS$: 412.0470; found: 412.0472.

4.4.3. (4E)-4-(1-Iodopentylidene)-2-morpholinyl-4H-benzo[d][1,3]thiazine ***3Ad***. Yield: 407 mg (95%). Yellow oil. IR (KBr, neat): 1552 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.97, 1.35–1.46, 1.57–1.65, 3.03 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.4 Hz, *n*-Bu), 3.72–3.79 (8H, br, morpholine–H), 7.09, 7.11, 7.30, 7.79 (1H, ddd, *J*=7.8, 7.4, 1.3 Hz, 1H, dd, *J*=8.0, 1.3 Hz, 1H, ddd, *J*=8.0, 7.4, 1.5 Hz, 1H, dd, *J*=7.8, 1.5 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.1 (q), 21.7 (t), 31.3 (t), 40.0 (t), 47.4 (t), 66.6 (t), 105.2 (s), 122.7 (d), 124.1 (s), 124.6 (s), 124.7 (d), 128.1 (d), 129.4 (d), 146.4 (s), 155.2 (s). MS (EI): *m*/*z* (relative intensity, %) 428 (M^+, 100), 385 (32), 301 (41), 258 (28). HRMS (EI) *m*/*z* M^+ calcd for $C_{17}H_{21}ON_2IS$: 428.0419; found: 428.0418.

4.4.4. (4E)-4-(1-Iodopentylidene)-2-(N-methyl-N-phenylamino)-4H-benzo[d][1,3]thiazine ***3Ae***. Yield: 408 mg (91%). Yellow oil. IR (KBr, neat): 1548 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.85, 1.18–1.28, 1.43–1.51, 2.77 (3H, t, *J*=7.4 Hz, 2H, m, 2H, m, 2H, t, *J*=7.5 Hz, *n*-Bu), 3.54 (3H, s, NMe), 7.08, 7.19–7.27, 7.29–7.36, 7.37–7.43, 7.77 (1H, ddd, *J*=7.7, 7.5, 1.2 Hz, 3H, m, 2H, m, 2H, m, 1H, dd, *J*=7.7, 1.4 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=13.9 (q), 21.5 (t), 30.9 (t), 39.9 (q), 43.6 (t), 104.5 (s), 122.5 (d), 124.8 (s), 124.8 (d), 125.5 (s), 127.5 (d), 127.7 (d), 128.0 (d), 129.3 (d), 144.5 (s), 146.7 (s), 154.5 (s). MS (EI): *m*/*z* (relative intensity, %) 448 (M^+, 100), 405 (27), 321 (34), 278 (45), 106 (23), 83 (15). HRMS (EI) *m*/*z* M^+ calcd for $C_{20}H_{21}N_2IS$: 448.0470; found: 448.0471.

4.4.5. (4E)-2-(N,N-Diethylamino)-4-(1-iodo-2,2-dimethylpropylidene)-4H-benzo[d][1,3]thiazine ***3Ba***. Yield: 373 mg (90%). Yellow oil. IR (KBr, neat): 15,681 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=1.22, 3.62 (6H, t, *J*=7.1 Hz, 4H, q, *J*=7.1 Hz, NEt_2), 1.55 (9H, s, *t*-Bu), 6.99, 7.07, 7.24, 7.58 (1H, ddd, *J*=7.7, 7.4, 1.3 Hz, 1H, dd, *J*=8.0, 1.3 Hz, 1H, ddd, *J*=8.0, 7.4, 1.5 Hz, 1H, dd, *J*=7.7, 1.5 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.2 (q), 33.2 (q), 41.7 (s), 43.8 (t), 121.6 (s), 121.7 (d), 124.2 (d), 125.1 (s), 128.6 (s), 129.0 (d), 129.6 (d), 147.2 (s), 153.9 (s). MS (EI): *m*/*z* (relative intensity, %) 414 (M^+, 100), 399 (73), 287 (18), 83 (31). HRMS (EI) *m*/*z* M^+ calcd for $C_{17}H_{23}N_2IS$: 414.0627; found: 414.0610.

4.5. Typical procedure for preparation of (4*E*)-2-imino-4-(1-iodomethylidene)benzo[*d*][1,3]thiazines

o-Ethynylphenyl isocyanate **1** was treated with the appropriate primary amine **6** and worked up as described for the preparation of **3Aa** to give **7**.

4.5.1. (2Z,4E)-2-tert-Butylimino-4-(1-iodopentylidene)-4H-1,2-dihydrobenzo[d][1,3]thiazine ***7Aa***. Yield: 323 mg (78%). Colorless oil. IR (KBr, neat): 3400 (NH), 1615 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.97, 1.34–1.43, 1.55–1.63, 2.98 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.5 Hz, *n*-Bu), 1.48 (9H, s, *t*-Bu), 4.25–4.53 (1H, br, NH), 7.07, 7.15, 7.29, 7.79 (1H, ddd, *J*=7.8, 7.3, 1.0 Hz, 1H, dd, *J*=8.0, 1.0 Hz, 1H, ddd, *J*=8.0, 7.3, 1.3 Hz, 1H, dd, *J*=7.8, 1.3 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.0 (q), 21.6 (t), 29.4 (q), 31.2 (t), 44.0 (t), 53.9 (s), 103.9 (s), 122.3 (d), 124.6 (s), 124.8 (d), 125.4 (s), 128.1 (d), 129.2 (d), 146.9 (s), 150.0 (s). MS (EI): *m*/*z* (relative intensity, %) 414 (M^+, 50), 325 (91), 299 (100), 2561 (73), 224 (76). HRMS (EI) *m*/*z* M^+ calcd for $C_{17}H_{23}N_2IS$: 414.0627; found: 414.0628.

4.5.2. (2Z,4E)-2-n-Butylimino-4-(1-iodopentylidene)-4H-1,2-dihydrobenzo[d][1,3]thiazine ***7Ab***. Yield: 273 mg (66%). Yellow oil. IR (KBr, neat): 3406 (NH), 1610 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.95, 0.97, 1.32–1.49, 1.53–1.64, 2.98, 3.51 (3H, t, *J*=7.2 Hz, 3H, t, *J*=7.2 Hz, 4H, m, 4H, m, 2H, t, *J*=7.5 Hz, 2H, t, *J*=7.2 Hz, *n*-Bu×2), 4.34–4.84 (1H, br, NH), 7.07, 7.13, 7.30, 7.78 (1H, ddd, *J*=7.7, 7.3, 1.3 Hz, 1H, dd, *J*=8.0, 1.3 Hz, 1H, ddd, *J*=8.0, 7.3, 1.4 Hz, 1H, dd, *J*=7.7, 1.4 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=13.8 (q), 14.0 (q), 20.1 (t), 21.6 (t), 31.3 (t), 31.7 (t), 42.5 (t), 44.0 (t), 104.2 (s), 122.3 (d), 124.67 (d), 124.72 (s), 124.9 (d), 128.3 (d), 129.4 (s), 146.8 (s), 152.8 (s). MS (EI): *m*/*z* (relative intensity, %) 414 (M^+, 100), 371 (15), 287 (84), 201 (14), 115 (6). HRMS (EI) *m*/*z* M^+ calcd for $C_{17}H_{23}N_2IS$: 414.0627; found: 414.0625.

4.5.3. (2Z,4E)-2-Cyclohexylimino-4-(1-iodopentylidene)-4H-1,2-dihydrobenzo[d][1,3]thiazine ***7Ac***. Yield: 356 mg (81%). Yellow oil. IR (KBr, neat): 3435 (NH), 1606 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.97, 1.12–1.26, 1.35–1.46, 1.54–1.66, 1.68–1.77, 2.02–2.11, 2.99, 3.93–4.03 (3H, t, *J*=7.3 Hz, 3H, m, 4H, m, 3H, m, 2H, m, 2H, m, 2H, t, *J*=7.4 Hz, 1H, m, *n*-Bu, cyclohexyl–H), 4.42–4.67 (1H, br, NH), 7.06, 7.12, 7.28, 7.78 (1H, ddd, *J*=8.0, 7.3, 1.3 Hz, 1H, dd, *J*=8.0, 1.0 Hz, 1H, ddd, *J*=7.8, 7.3, 1.0 Hz, 1H, dd, *J*=7.8, 1.3 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.0 (q), 21.6 (t), 24.8 (t), 25.6 (t), 31.3 (t), 33.4 (t), 44.0 (t), 51.3 (d), 104.1 (s), 122.2 (d), 124.7 (d), 124.9 (s), 128.2 (d), 129.3 (d), 140.8 (s), 146.9 (s), 151.8 (s). MS (EI): *m*/*z* (relative intensity, %) 440 (M^+, 89), 358 (17), 313 (100), 231 (74), 188 (22). HRMS (EI) *m*/*z* M^+ calcd for $C_{19}H_{25}N_2IS$: 440.0783; found: 440.0782.

4.5.4. (2Z,4E)-2-Benzylimino-4-(1-iodopentylidene)-4H-1,2-dihydrobenzo[d][1,3]thiazine ***7Ad***. Yield: 363 mg (81%). Yellow oil. IR (KBr, neat): 3498 (NH), 1610 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.95, 1.33–1.42, 1.54–1.62, 2.96 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.5 Hz, *n*-Bu), 4.43–5.17 (1H, br, NH), 4.69 (2H, s, NCH_2), 7.09, 7.16, 7.26–7.39, 7.81 (1H, ddd, *J*=7.8, 7.4, 1.3 Hz, 1H, dd, *J*=8.0, 1.0 Hz, 6H, m, 1H, dd, *J*=7.8, 1.3 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.0 (q), 21.6 (t), 31.2 (t), 44.0 (t), 46.8 (t), 104.5 (s), 122.6 (d), 124.5 (s), 124.8 (d), 125.0 (s), 127.7 (d), 128.1 (d), 128.4 (d), 128.7 (d), 129.4 (d),

138.1 (s), 146.6 (s), 152.5 (s). MS (EI): *m/z* (relative intensity, %) 448 (M^+, 100), 405 (10), 321 (8), 216 (14), 91 (23). HRMS (EI) *m/z* M^+ calcd for $C_{20}H_{21}N_2IS$: 448.0470; found: 448.0463.

4.5.5. (2Z,4E)-4-(1-Iodopentylidene)-2-phenylimino-4H-1,2-dihydrobenzo[d][1,3]thiazine ***7Ae***. Yield: 361 mg (84%). Reddish prisms, mp 145–146 °C (from benzene/hexane). IR (KBr, tab): 3437 (NH), 1630 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.95, 1.32–1.42, 1.55–1.63, 2.96 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.5 Hz, *n*-Bu), 7.04–7.14, 7.26–7.36, 7.38–7.46, 7.80 (3H, m, 4H, m, 1H, m, 1H, dd, *J*=7.8 Hz, Ph–H), 7.38–7.46 (1H, br, NH). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.0 (q), 21.6 (t), 31.2 (t), 44.1 (t), 105.9 (s), 121.0 (d), 122.8 (d), 122.9 (d), 123.8 (s), 123.9 (d), 125.1 (s), 128.5 (d), 129.0 (d), 129.5 (d), 141.8 (s), 143.8 (s), 150.6 (s). MS (EI): *m/z* (relative intensity, %) 434 (M^+, 100), 391 (13), 307 (43), 264 (24), 231 (16), 162 (16). HRMS (EI) *m/z* M^+ calcd for $C_{19}H_{19}N_2IS$: 434.0314; found: 434.0312. Anal. Calcd for $C_{19}H_{19}N_2IS$: C, 52.53; H, 4.38; N, 6.45. Found: C, 52.68; H, 4.37; N, 6.43.

4.5.6. (2Z,4E)-2-tert-Butylimino-4-(1-iodo-2,2-dimethylpropylidene)-4H-1,2-dihydrobenzo[d][1,3]thiazine ***7Ba***. Yield: 215 mg (52%). Yellow oil. IR (KBr, neat): 3396 (NH), 1612 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=1.48 (9H, s, *t*-Bu), 1.51 (9H, s, *t*-Bu), 4.34–4.47 (1H, br, NH), 7.04, 7.12, 7.25, 7.59 (1H, ddd, *J*=7.8, 7.3, 1.4 Hz, 1H, dd, *J*=7.8, 1.2 Hz, 1H, ddd, *J*=7.9, 7.3, 1.2 Hz, 1H, dd, *J*=7.9, 1.4 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=29.5 (q), 32.9 (q), 41.8 (s), 54.0 (s), 121.0 (s), 122.4 (d), 124.5 (d), 125.5 (s), 128.8 (s), 128.9 (d), 129.9 (d), 146.9 (s), 150.1 (s). MS (EI): *m/z* (relative intensity, %) 414 (M^+, 100), 399 (54), 287 (19), 231 (40), 57 (11). HRMS (EI) *m/z* M^+ calcd for $C_{17}H_{23}N_2IS$: 414.0627; found: 414.0626.

4.6. Reaction of 2-(phenylethynyl)phenyl isothiocyanate with amine and I_2

o-(Phenylethynyl)phenyl isothiocyanate **1D** was treated with diethylamine **2a** or *tert*-butylamine **6a** and worked up as described for the preparation of **3Aa** to give **3Da** or **7Da**. All operations (reaction and purification) for **3Da-*E*** and **7Da-*E*** were performed in a dark room.

4.6.1. (4E)-2-(N,N-Diethylamino)-4-(1-iodobenzylidene)-4H-benzo[d][1,3]thiazine ***3Da-E***. Yield: 391 mg (90%). Pale yellow prisms, mp 185–186 °C (from $CHCl_3$/hexane). IR (KBr, tab): 1545 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=1.09, 3.42 (6H, t, *J*=7.0 Hz, 4H, q, *J*=7.0 Hz, NEt_2), 7.09, 7.13, 7.29–7.35, 7.36–7.41, 8.01 (1H, ddd, *J*=7.6, 7.4, 1.2 Hz, 1H, dd, *J*=8.1, 1.0 Hz, 4H, m, 2H, m, 1H, dd, *J*=7.8, 1.1 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=13.7 (q), 43.6 (t), 94.2 (s), 121.7 (d), 123.3 (s), 124.9 (d), 127.5 (d), 128.3 (d), 128.5 (d), 128.8 (s), 129.1 (d), 129.9 (d), 144.4 (s), 147.7 (s), 153.4 (s). MS (EI): *m/z* (relative intensity, %) 434 (M^+, 100), 405 (10), 307 (26), 236 (20), 72 (14). HRMS (EI) *m/z* M^+ calcd for $C_{19}H_{19}N_2IS$: 434.0314; found: 434.0306.

4.6.2. (4E)-2-(N,N-Diethylamino)-4-(1-iodobenzylidene)-4H-benzo[d][1,3]thiazine ***3Da-Z***. Yield: 334 mg (77%). Pale yellow prisms, mp 206–208 °C (from $CHCl_3$/hexane). IR (KBr, tab): 1566, 1549 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=1.29, 3.68 (6H, t, *J*=7.1 Hz, 4H, q, *J*=7.1 Hz, NEt_2), 6.51–6.57, 6.61, 7.10, 7.17–7.26 (1H, m, 1H, dd, *J*=7.8, 0.9 Hz, 2H, d, *J*=3.7 Hz, 5H, m, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=14.0 (q), 43.7 (t), 102.9 (s), 120.9 (s), 121.7 (d), 125.2 (d), 128.2 (d), 128.3 (d, two carbon), 129.2 (d), 130.2 (d), 133.8 (s), 143.9 (s), 148.3 (s), 154.0 (s). MS (EI): *m/z* (relative intensity, %) 434 (M^+, 100), 405 (9), 307 (24), 263 (10), 236 (15). HRMS (EI) *m/z* M^+ calcd for $C_{19}H_{19}N_2IS$: 434.0314; found: 434.0316.

4.6.3. (2Z,4E)-2-(N-tert-Butylimino)-4-(1-iodobenzylidene)-4H-1,2-dihydrobenzo[d][1,3]thiazine ***7Da-E***. Yield: 339 mg (78%). Pale yellow prisms, mp 139–140 °C (from $CHCl_3$/hexane). IR (KBr, tab): 3413 (NH), 1614 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=1.41 (9H, s, *t*-Bu), 4.20 (1H, br s, NH), 7.13, 7.19, 7.32–7.42, 8.03 (1H, ddd, *J*=7.8, 7.2, 1.4 Hz, 1H, dd, *J*=8.0, 1.4 Hz, 6H, m, 1H, dd, *J*=7.8, 1.5 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=29.3 (q), 53.9 (s), 93.7 (s), 122.5 (d), 123.6 (s), 125.4 (d), 127.9 (d), 128.3 (d), 128.7 (d), 129.3 (s), 129.4 (d), 129.9 (d), 144.1 (s), 147.2 (s), 149.7 (s). MS (EI): *m/z* (relative intensity, %) 434 (M^+, 100), 378 (9), 344 (15), 307 (30), 251 (83), 218 (42), 190 (15). HRMS (EI) *m/z* M^+ calcd for $C_{19}H_{19}N_2IS$: 434.0314; found: 434.0306.

4.6.4. (2Z,4E)-2-(N-tert-Butylimino)-4-(iodobenzylidene)-4H-1,2-dihydrobenzo[d][1,3]thiazine ***7Da-Z***. Yield: 334 mg (77%). Colorless prisms, mp 177–179 °C (from $CHCl_3$/hexane). IR (KBr, tab): 3394 (NH), 1616 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=1.53 (9H, s, *t*-Bu), 4.32–4.82 (1H, br, NH), 6.60, 6.63, 7.13, 7.15–7.23, 7.23–7.27 (1H, ddd, *J*=7.8, 6.8, 1.4 Hz, 1H, dd, *J*=7.8, 1.7 Hz, 1H, ddd, *J*=7.8, 6.8, 1.7 Hz, 4H, m, 2H, m, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=29.5 (q), 54.2 (s), 103.4 (s), 121.4 (s), 122.6 (d), 125.4 (d), 128.2 (d), 128.3 (d), 128.6 (d), 129.2 (d), 130.2 (d), 133.9 (s), 143.5 (s), 147.7 (s), 150.5 (s). MS (EI): *m/z* (relative intensity, %) 434 (M^+, 100), 378 (9), 307 (31), 251 (82), 218 (41), 190 (12), 57 (8). HRMS (EI) *m/z* M^+ calcd for $C_{19}H_{19}N_2IS$: 434.0314; found: 434.0310.

4.7. Typical procedure for addition of 2-ethynylphenyl isothiocyanate with the alkoxide: formation of thiourethane

To a solution of alkoxide (1.5 mmol), freshly prepared from alcohol (5 mmol) and 60% NaH (60 mg, 1.5 mmol) in dry THF (2 mL), was slowly added to a solution of *o*-ethynylphenyl isothiocyanate **3Aa** (215 mg, 1 mmol) in dry THF (2 mL) under an argon atmosphere. The reaction mixture was stirred at room temperature for 1 h, and then quenched by the addition of brine (50 mL). The resulting mixture was extracted with benzene (50 mL×3). The organic layer was washed with brine (10 mL×2), dried (Na_2SO_4), and evaporated in vacuo. The obtained residue was chromatographed on silica gel using hexane/$CHCl_3$ (1:2) as an eluent to give pure thiourethane.

4.7.1. Methyl 2-(hex-1-ynyl)phenylcarbamothioate ***9a***. Yield: 237 mg (96%). Yellow oil. IR (KBr, neat): 3361 (NH), 2224 (C≡C) cm^{-1}. ^1H NMR (500 MHz) δ=0.97, 1.47–1.56, 1.60–1.68, 2.50 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.0 Hz, *n*-Bu), 4.14 (3H, br s, OMe), 7.05, 7.26, 7.37, 7.45–8.05 (1H, dd, *J*=7.7, 7.5 Hz, 1H, dd, *J*=8.0, 7.7 Hz, 1H, dd, *J*=8.0, 1.4 Hz, 1H, m, Ph–H), 8.60–9.10 (1H, br, NH). ^{13}C NMR (125 MHz) δ=13.6 (q), 19.3 (t), 22.1 (t), 30.7 (t), 57.2 (q), 75.6 (s), 98.7 (s), 114.6 (s), 120.4 (d), 124.2 (d), 128.3 (d), 131.8 (d), 138.2 (s), 189.2 (s). MS *m/z* (relative intensity, %): 247 (M^+, 42), 205 (56), 190 (100), 172 (84), 130 (71), 75 (65). HRMS *m/z* calcd for $C_{14}H_{17}NOS$: 247.1031; found: 247.1031.

4.7.2. Ethyl 2-(hex-1-ynyl)phenylcarbamothioate ***9b***. Yield: 243 mg (93%). Yellow oil. IR (KBr, neat): 3360 (NH), 2224 (C≡C) cm^{-1}. ^1H NMR (500 MHz) δ=0.97, 1.48–1.55, 1.60–1.68, 2.50 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.0 Hz, *n*-Bu), 1.44, 4.57–4.71 (3H, t, *J*=7.0 Hz, 2H, m, OEt), 7.04, 7.26, 7.38, 7.65–8.00 (1H, dd, *J*=7.7, 7.4 Hz, 1H, dd, *J*=7.4, 6.8 Hz, 1H, dd, *J*=7.7, 1.4 Hz, 1H, m, Ph–H), 8.75–9.05 (1H, br, NH). ^{13}C NMR (125 MHz) δ=13.6 (q), 14.1 (t), 22.1 (t), 30.7 (t), 68.8 (t), 75.7 (s), 98.7 (s), 114.4 (s), 120.4 (d), 124.1 (d), 128.3 (d), 131.8 (d), 138.3 (s), 188.0 (s). MS *m/z* (relative intensity, %): 261 (M^+, 24), 232 (80), 219 (21), 190 (100), 172 (63), 130 (77), 128 (38). HRMS *m/z* calcd for $C_{15}H_{19}NOS$: 261.1187; found: 261.1194.

4.7.3. Benzyl 2-(hex-1-ynyl)phenylcarbamothioate ***9c***. Yield: 304 mg (94%). Yellow oil. IR (KBr, neat): 3356 (NH), 2225 (C≡C) cm^{-1}. ^1H NMR (500 MHz) δ=0.84–1.02, 1.43–1.68, 2.48 (3H, br, 4H, br, 2H, t, *J*=6.9 Hz, *n*-Bu), 5.55–5.70 (2H, br, CH_2Ph), 6.97–7.08, 7.10–7.30,

7.33–7.46, 7.48–7.90 (1H, br, 1H, br, 6H, m, 1H, m, Ph–H), 8.50–9.13 (1H, br, NH). ^{13}C NMR (125 MHz) δ=13.6 (q), 19.3 (t), 22.1 (t), 30.6 (t), 60.7 (t), 75.6 (s), 98.8 (s), 120.5 (d), 124.2 (d), 128.2 (d), 128.4 (d), 128.5 (d), 128.6 (d), 131.8 (d), 135.1 (s), 135.3 (s), 138.2 (s), 187.9 (s). MS *m*/*z* (relative intensity, %): 323 (M^+, 38), 232 (38), 199 (74), 156 (58), 130 (69), 91 (100). HRMS *m*/*z* calcd for $C_{20}H_{21}NOS$: 323.1344; found: 323.1343.

4.7.4. iso-Propyl 2-(hex-1-ynyl)phenylcarbamothioate ***9d***. Yield: 23 9 mg (87%). Yellow oil. IR (KBr): 3361 (NH), 2145 (C≡C) cm^{-1}. ^{1}H NMR (500 MHz) δ=0.97, 1.47–1.57, 1.62–1.68, 2.51 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.1 Hz, *n*-Bu), 1.44, 5.63–5.73 (6H, d, *J*=6.1 Hz, 1H, m, O*i*-Pro), 7.03, 7.26, 7.37, 7.55–8.05 (1H, dd, *J*=7.7, 7.6 Hz, 1H, dd, *J*=7.6, 6.1 Hz, 1H, dd, *J*=7.7, 1.4 Hz, 1H, m, Ph–H), 8.55–9.05 (1H, br, NH). ^{13}C NMR (125 MHz) δ=13.6 (q), 19.3 (t), 21.7 (q), 22.1 (t), 30.7 (t), 75.7 (s), 77.3 (d), 98.7 (s), 114.3 (s), 120.4 (d), 123.9 (d), 128.3 (d), 131.8 (d), 138.4 (s), 187.3 (s). MS *m*/*z* (relative intensity, %): 275 (M^+, 8), 232 (58), 172 (46), 130 (100), 128 (36), 102 (23), 77 (14). HRMS *m*/*z* calcd for $C_{16}H_{21}NOS$: 275.1344; found: 275.1339.

4.8. Typical procedure for iodocyclization of 2-(hex-1-ynyl) phenylcarbamothioate: formation of 2-alkoxy-4*H*-benzo[*d*] [1,3]thiazine

To a solution of the thiourethane **9** (1 mmol) in dry CH_2Cl_2 (2 mL) were added I_2 (330 mg, 1.3 mmol) and Cs_2CO_3 (489 mg, 1.5 mmol), and then the reaction mixture was stirred at room temperature for 24 h. The mixture was diluted with $CHCl_3$ (30 mL). The organic layer was washed with 2% $Na_2S_2O_3$ aq (15 mL×3), water (15 mL×2), dried over anhydrous Na_2SO_4, and evaporated in vacuo. The obtained residue was chromatographed on silica gel using hexane/$CHCl_3$ (1:5) as an eluent to give pure (4*E*)-4-(iodomethylidene)-3,1-benzothiazine **10** and **11**.

4.8.1. (4E)-4-(1-Iodopentylidene)-2-methoxy-4H-benzo[d][1,3]thiazine ***10a***. Yield: 172 mg (46%). Yellow oil. IR (KBr, neat): 1618 (C=N) cm^{-1}. ^{1}H NMR (500 MHz) δ=0.97, 1.35–1.44, 1.56–1.63, 3.00 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.6 Hz, *n*-Bu), 4.02 (3H, s, OMe), 7.19, 7.21, 7.34, 7.87 (1H, ddd, *J*=7.7, 7.5, 1.2 Hz, 1H, dd, *J*=8.0, 1.2 Hz, 1H, ddd, *J*=8.0, 7.5, 1.5 Hz, 1H, dd, *J*=7.7, 1.5 Hz, Ph–H). ^{13}C NMR (125 MHz) δ=14.0 (q), 21.6 (t), 31.2 (t), 44.1 (t), 55.7 (q), 104.4 (s), 124.0 (s), 124.5 (d), 124.6 (s), 125.4 (d), 128.8 (d), 129.5 (d), 144.4 (s), 160.3 (s). MS *m*/*z* (relative intensity, %): 373 (M^+, 100), 330 (35), 246 (20), 203 (75). HRMS *m*/*z* calcd for $C_{14}H_{16}NOIS$: 372.9997; found: 372.9997.

4.8.2. (4E)-2-Ethoxy-4-(1-iodopentylidene)-4H-benzo[d][1,3]thiazine ***10b***. Yield: 186 mg (48%). Yellow oil. IR (KBr, neat): 1618 (C=N) cm^{-1}. ^{1}H NMR (500 MHz) δ=0.97, 1.34–1.46, 1.56–1.64, 3.01 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.4 Hz, *n*-Bu), 1.38, 4.50 (3H, t, *J*=7.1 Hz, 2H, q, *J*=7.1 Hz, OEt), 7.16–7.22, 7.33, 7.87 (2H, m, 1H, ddd, *J*=7.6, 7.2, 1.4 Hz, 1H, dd, *J*=8.3, 1.6 Hz, Ph–H). ^{13}C NMR (125 MHz) δ=14.0 (q), 14.4 (q), 21.6 (t), 31.2 (t), 44.1 (t), 64.9 (t), 104.2 (s), 124.2 (s), 124.4 (d), 124.6 (s), 125.4 (d), 128.7 (d), 129.4 (d), 144.5 (s), 159.7 (s). MS *m*/*z* (relative intensity, %): 387 (M^+, 100), 344 (32), 260 (16), 217 (43), 189 (22), 156 (16). HRMS *m*/*z* calcd for $C_{15}H_{18}NOIS$: 387.0154; found: 387.0152.

4.8.3. (4E)-2-Benzyloxy-4-(1-iodopentylidene)-4H-benzo[d][1,3] thiazine ***10c***. Yield: 189 mg (42%). Yellow oil. IR (KBr, neat): 1618 (C=N) cm^{-1}. ^{1}H NMR (500 MHz) δ=0.96, 1.34–1.44, 1.56–1.63, 3.01 (3H, t, *J*=7.3 Hz, 2H, m, 2H, m, 2H, t, *J*=7.4 Hz, *n*-Bu), 5.47 (2H, s, OCH_2), 7.18–7.25, 7.32–7.41, 7.42–7.47, 7.88 (2H, m, 4H, m, 2H, m, 1H, dd, *J*=7.7, 1.2 Hz, Ph–H). ^{13}C NMR (125 MHz) δ=14.0 (q), 21.6 (t), 31.2 (t), 44.1 (t), 70.4 (t), 104.5 (s), 124.0 (s), 124.6 (d), 124.7 (s), 125.4 (d), 128.4 (d), 128.55 (d), 128.63 (d), 128.8 (d), 129.5 (d), 135.7 (s), 144.3 (s), 159.7 (s). MS *m*/*z* (relative intensity, %): 449 (M^+, 52), 322 (19), 266 (44), 161 (13), 91 (100). HRMS *m*/*z* calcd for $C_{20}H_{20}NOIS$: 449.0310; found: 449.0314.

4.8.4. (4E)-4-(1-Iodopentylidene)-2-iso-propoxy-4H-benzo[d][1,3]thiazine ***10d***. Yield: 156 mg (39%). Yellow oil. IR (KBr): 1614 (C=N) cm^{-1}. ^{1}H NMR (500 MHz) δ=0.97, 1.34–1.44, 1.55–1.64, 3.01 (3H, t, *J*=7.2 Hz, 2H, m, 2H, m, 2H, t, *J*=7.4 Hz, *n*-Bu), 1.37, 5.42–5.52 (6H, d, *J*=6.2 Hz, 1H, m, *i*-Pro), 7.13–7.21, 7.33, 7.87 (2H, m, 1H, ddd, *J*=8.0, 7.8, 1.6 Hz, 1H, dd, *J*=8.3, 1.7 Hz, Ph–H). ^{13}C NMR (125 MHz) δ=14.0 (q), 21.6 (t), 21.9 (q), 31.2 (t), 44.1 (t), 72.4 (d), 104.0 (s), 124.2 (d), 124.5 (s), 124.6 (s), 125.3 (d), 128.7 (d), 129.4 (d), 144.7 (s), 159.2 (s). MS *m*/*z* (relative intensity, %): 401 (M^+, 100), 359 (15), 316 (25), 232 (36), 190 (69), 156 (30), 130 (13). HRMS *m*/*z* calcd for $C_{16}H_{20}NOIS$: 401.0310; found: 401.0311.

4.8.5. 12,15-Bis(1-iodopentylidene)-12,15-dihydro-5H-dibenzo[d,i] [1,2,6,8]dithiadiazacycloundecin-6(7H)-one ***11***. Pale yellow oil. IR (KBr, neat): 3394 (NH), 1687 (C=O) cm^{-1}. ^{1}H NMR (500 MHz) δ=0.93, 1.23–1.41, 1.44–1.63, 2.55–2.73, 2.82–2.94 (6H, t, *J*=7.3 Hz, 4H, m, 4H, m, 2H, m, 2H, m, *n*-Bu×2), 4.10–4.50 (2H, br, NH×2), 6.93, 6.97, 7.08, 7.11, 7.18–7.25, 7.29–7.36 (1.2H, dd, *J*=7.7, 1.5 Hz, 0.8H, dd, *J*=7.7, 1.5 Hz, 0.8H, dd, *J*=7.9, 1.2 Hz, 1.2H, dd, *J*=7.9, 1.2 Hz, 2H, m, 2H, m, Ph–H). ^{13}C NMR (125 MHz) δ=13.86 and 13.88 (each q), 21.9 (t), 31.53 and 31.55 (each t), 42.3 and 42.4 (each t), 112.9 (s), 124.8 and 125.1 (each d), 125.3 and 125.6 (each d), 129.6 (d), 131.36 (s), 131.43 (d), 131.5 (s), 134.7 and 134.9 (each s), 138.2 and 138.3 (each s). MS *m*/*z* (relative intensity, %): 690 (M^+, 60), 563 (45), 499 (49), 204 (78), 191 (60), 173 (93), 161 (90), 130 (100). HRMS *m*/*z* calcd for $C_{25}H_{28}N_2OI_2S_2$: 689.9733; found: 689.9730.

4.9. (4*Z*)-2-(*N*,*N*-Diethylamino)-4-pentylidene-4*H*-benzo[*d*] [1,3]thiazine 12

To a solution of iodomethylidene-3,1-benzothiazine **3Aa** (50 mg, 0.12 mmol), formic acid (22 mg), and Et_3N (34 mg) in dry DMF (1 mL) was added $PdCl_2(PPh_3)_2$ (5 mg). The mixture was stirred at room temperature for 3days, and then diluted with $CHCl_3$ (30 mL). The organic layer was washed with satd $NaHCO_3$ aq (15 mL), water (15 mL×3), dried over anhydrous Na_2SO_4, and evaporated in vacuo. The obtained residue was chromatographed on silica gel using hexane/Et_2O (1:10) as an eluent to give pure dehalogenated compound. This compound was identical with the authentic sample prepared in the previous paper.[20] Yield: 15 mg (43%). Yellow oil.

4.10. (4*E*)-4-(1-Butylbenzylidene)-2(*N*,*N*-diethylamino)-4*H*-benzo[*d*][1,3]thiazine 13

To a solution of iodomethylidene-3,1-benzothiazine **3Aa** (443 mg, 1.07 mmol), phenylboronic acid (261 mg, 2.14 mmol), and Cs_2CO_3 (697 mg) in toluene (6 mL) was added $Pd(OAc)_2$ (150 mg), and then the reaction mixture was stirred at 100 °C under argon atmosphere for 2 days. After the reaction was over, the resulting solution was diluted with benzene (30 mL). The organic layer was washed with water (10 mL×3), dried over anhydrous Na_2SO_4, and evaporated in vacuo. The obtained residue was chromatographed on silica gel using hexane/$CHCl_3$ (1:2) as an eluent to give **13**. Yield: 284 mg (73%). Orange oil. IR (KBr, neat): 1601 (C=N) cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$) δ=0.89, 1.32–1.42, 2.74–2.81 (3H, t, *J*=7.0 Hz, 4H, m, 2H, *n*-Bu), 1.26, 3.66 (6H, t, *J*=7.1 Hz, 4H, q, *J*=7.1 Hz, NEt_2), 6.48, 6.53, 7.02–7.10, 7.17–7.22 (1H, d, *J*=7.6 Hz, 1H, ddd, *J*=8.1, 5.9, 2.5 Hz, 4H, m, 3H, m, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=13.95 (q), 14.01 (q), 22.5 (t), 29.8 (t), 35.9 (t), 43.5 (t), 121.45 (s), 121.50 (d), 122.3 (s), 124.7 (d), 126.9 (d), 127.9 (d), 128.1 (d), 128.5 (d), 129.4 (d), 141.4 (s), 142.5 (s), 147.7 (s), 154.5 (s). MS (EI): *m*/*z* (relative

intensity, %) 364 (M^+, 100), 335 (29), 321 (93), 307 (12), 250 (11). HRMS (EI) m/z M^+ calcd for $C_{23}H_{28}N_2S$: 364.1973; found: 364.1971.

4.11. (4*E*)-2(*N*,*N*-Diethylamino)-4-[(1-phenylethynyl)pentylidene]-4*H*-benzo[*d*][1,3]thiazine 14

To a solution of iodomethylidene-3,1-benzothiazine **3Aa** (550 mg, 1.33 mmol), phenylacetylene (163 mg, 1.6 mmol), and Et_3N (1 mL) in benzene (3 mL) were added $PdCl_2(PPh_3)_2$ (20 mg) and CuI (15 mg). The reaction mixture was stirred at room temperature for 2 days, and diluted with benzene (50 mL). The organic layer was washed with water (10 mL×2), dried over anhydrous Na_2SO_4, and evaporated in vacuo. The obtained residue was chromatographed on silica gel using hexane/AcOEt (5:1) as an eluent to give **14**. Yield: 464 mg (90%). Orange oil. IR (KBr, neat): 2185 (C≡C), 1601 (C=N) cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$) δ=0.99, 1.42–1.51, 1.66–1.73, 2.63 (3H, t, J=7.3 Hz, 2H, m, 2H, m, 2H, t, J=7.6 Hz, *n*-Bu), 1.22, 3.59 (6H, t, J=7.4 Hz, 4H, q, J=7.4 Hz, NEt_2), 7.05, 7.14, 7.24–7.31, 7.38, 8.28 (1H, ddd, J=8.0, 7.8, 1.4 Hz, 1H, dd, J=8.0, 1.1 Hz, 4H, m, 2H, dd, J=8.0, 1.7 Hz, 1H, dd, J=7.9, 1.4 Hz, Ph–H). ^{13}C NMR (125 MHz, $CDCl_3$) δ=13.9 (q), 14.0 (q), 22.3 (t), 30.6 (t), 34.5 (t), 43.5 (t), 90.7 (s), 93.7 (s), 104.2 (s), 120.9 (s), 121.2 (s), 121.7 (d), 123.7 (s), 125.2 (d), 127.0 (d), 128.0 (d), 128.3 (d), 129.4 (d), 131.2 (d), 146.6 (s), 152.6 (s). MS (EI): m/z (relative intensity, %) 388 (M^+, 100), 359 (12), 345 (25), 317 (14), 287 (42), 275 (25). HRMS (EI) m/z M^+ calcd for $C_{25}H_{28}N_2S$: 388.1973; found: 388.1975.

4.12. X-ray structure determination

Single crystals of **7Ae** were obtained from solutions of CH_2Cl_2/hexane after slow evaporation of the solvents at room temperature. The structure analysis is based on 2511 observed reflections with $I>2.00\sigma(I)$ and 139 variable parameters; red prisms, $C_{19}H_{19}N_2SI$, FW=432.4, 233 K, *triclinic*, space group $P\bar{1}$, a=9.3417(6) Å, b=10.9081(7) Å, c=10.9435(7) Å, α=69.699(1)°, β=69.552(1)°, γ=64.961(1)°, V=917.6(1) $Å^3$, Z=2, R=0.0272, R_w=0.0709, GOF=1.077.

Single crystals of **3Da-*Z*** were obtained from solutions of $CHCl_3$/hexane after slow evaporation of the solvents at room temperature. The structure analysis is based on 3950 observed reflections with $I>2.00\sigma(I)$ and 210 variable parameters; yellow prisms, $C_{19}H_{19}N_2SI$, FW=432.4, 230 K, *monoclinic*, space group $P2_1/n$, a=13.079(3) Å, b=10.595(3) Å, c=14.231(4) Å, β=116.121(3)°, V=1770.6(8) $Å^3$, Z=4, R=0.0445, R_w=0.1029, GOF=1.038.

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References and notes

1. This paper constitutes Part 38 in the series 'Studies on Chalcogen-containing Heterocycles', For Part 37: *m*CPBA oxidation of isotellurochromenes and isoselenochromenes Sashida, H.; Kaname, M.; Ohyanagi, K.; Minoura, M. *Tetrahedron* **2012**, *68*, 10502–10509 Special Issue of Progress in Organoselenium and Organotellurium Chemistry.
2. (a) Morgenstern, O.; Schuster, R.; Finke, M.; Richter, P. H. *Pharmazie* **1996**, *51*, 458–467; (b) Matysiak, J. *Bioorg. Med. Chem.* **2006**, *14*, 2613–2619.
3. (a) Beilenson, B.; Hamer, F. M. *J. Chem. Soc.* **1942**, 98–102; (b) Dean, W. D.; Papadopoulos, E. P. *J. Heterocycl. Chem.* **1982**, *198*, 1117–1124; (c) Looney-Dean, V.; Lindamood, B. S.; Papadopoulos, E. P. *Synthesis* **1984**, 68–71; (d) Nishio, T. *Tetrahedron Lett.* **1995**, *36*, 6113–6116; (e) Nishio, T. *J. Org. Chem.* **1997**, *62*, 1106–1111; (f) Butin, A. V.; Abaev, V. T.; Stroganova, T. A.; Gutnov, A. V. *Molecules* **1997**, *2*, 62–68; (g) El-Desoky, S. I.; Kandeel, E. M.; Abd-el-Raman, A. H.; Schmidt, R. R. *J. Heterocycl. Chem.* **1999**, *36*, 153–160; (h) Hari, A.; Miller, B. L. *Org. Lett.* **2000**, *2*, 3667–3670; (i) Tárraga, A.; Molina, P.; López, J. L. *Tetrahedron Lett.* **2000**, *41*, 4895–4899; (j) Deck, L. M.; Turner, S. D.; Deck, J. A.; Papadopoulos, E. P. *J. Heterocycl. Chem.* **2001**, *38*, 343–347; (k) Abaev, V. T.; Tsiunchik, F. A.; Gutnov, A. V.; Butin, A. V. *Tetrahedron Lett.* **2006**, *47*, 4029–4032; (l) Csomós, P.; Fodor, L.; Bernáth, G.; Sinkkonen, J.; Salminen, J.; Wiinamäki, K.; Pihlaja, K. *Tetrahedron* **2008**, *64*, 1002–1011; (m) Abaev, V. T.; Tsiunchik, F. A.; Gutnov, A. V.; Butin, A. V. *J. Heterocycl. Chem.* **2008**, *45*, 475–481; (n) Butin, A. V.; Tsiunchik, F. A.; Avaev, V. T.; Gutnov, A. V.; Cheshkov, D. A. *Synthesis* **2009**, 2616–2626; (o) Gimbert, C.; Vallribera, A. *Org. Lett.* **2009**, *11*, 269–271; (p) Fukamachi, S.; Konishi, H.; Kobayashi, K. *Synthesis* **2010**, 1593–1598; (q) Okuma, K.; Ozaki, S.; Nagahora, N.; Shioji, K. *Heterocycles* **2011**, *83*, 1303–1313; (r) Qiu, G.; Hu, Y.; Ding, Q.; Peng, Y.; Hu, X.; Wu, J. *Chem. Commun.* **2011**, 9708–9710; (s) Ding, Q.; Liu, X.; Yu, J.; Zhang, Q.; Wang, D.; Cao, B.; Peng, Y. *Tetrahedron* **2012**, *68*, 3937–3941.
4. (a) Ding, Q.; Wu, J. *J. Comb. Chem.* **2008**, *10*, 541–545; (b) Tang, R.-Y.; Luo, P.-S.; Zhang, X.-G.; Zhong, P.; Li, J.-H. *Synlett* **2010**, 1345–1350.
5. (a) Schmittel, M.; Mahajan, A.; Steffen, J.-P. *Synthesis* **2004**, 415–418; (b) Ding, Q.; Cao, B.; Zong, Z.; Peng, Y. *J. Comb. Chem.* **2010**, *12*, 370–373.
6. Fernandes, M. A.; Reid, D. H. *Synlett* **2003**, 2231–2233.
7. Iodocyclization: (a) Vaino, A. R.; Szarek, W. A. *Adv. Carbohydr. Chem. Biochem.* **2001**, *56*, 9–63; (b) Togo, H.; Iida, S. *Synlett* **2006**, 2159–2175; (c) Mphahlele, M. J. *Molecules* **2009**, *14*, 4814–4837; (d) Banerjee, A. K.; Laya, M. S.; Cabrera, E. V. *Curr. Org. Chem.* **2011**, *15*, 1058–1080; (e) Godoi, B.; Schumacher, R. F.; Zeni, G. *Chem. Rev.* **2011**, *111*, 2937–2980.
8. Furans: (a) Arcadi, A.; Cacchi, S.; Fabrizi, G.; Marinelli, F.; Moro, L. *Synlett* **1999**, 1432–1434; (b) Arcadi, A.; Cacchi, S.; Giuseppe, S.; Fabrizi, G.; Marinelli, F. *Org. Lett.* **2002**, *4*, 2409–2412; (c) Yue, D.; Yao, T.; Larock, R. C. *J. Org. Chem.* **2006**, *71*, 62–69; (d) Chen, Z.; Huang, G.; Jiang, H.; Huang, H.; Pan, X. *J. Org. Chem.* **2011**, *76*, 1134–1139; (e) Xu, M.; Zhang, X.-H.; Zhong, P. *Tetrahedron Lett.* **2011**, *52*, 6800–6804.
9. Indoles: (a) Barluenga, J.; Trincado, M.; Rubio, E.; Gonzalez, J. M. *Angew. Chem., Int. Ed.* **2003**, *42*, 2406–2409; (b) Yue, D.; Yao, T.; Larock, R. C. *J. Org. Chem.* **2005**, *70*, 10292–10296.
10. Thiophenes: (a) Flynn, B. L.; Verdier-Pinard, P.; Hamel, E. *Org. Lett.* **2001**, *3*, 651–654; (b) Larock, R. C.; Yue, D. *Tetrahedron Lett.* **2001**, *42*, 6011–6013; Yue, D.; Larock, R. C. *J. Org. Chem.* **2002**, *67*, 1905–1909; (d) Hessian, K. O.; Flynn, B. L. *Org. Lett.* **2003**, *5*, 4377–4380; (e) Cho, C.-H.; Jung, D.-I.; Larock, R. C. *Tetrahedron Lett.* **2010**, *51*, 6485–6488.
11. Six-membered heterocycles: (a) Barange, D. K.; Batchu, V. R.; Gorja, D.; Pattabiraman, V. R.; Tatini, L. K.; Babu, J. M.; Pal, M. *Tetrahedron* **2007**, *63*, 1775–1789; (b) Likhar, P. R.; Subhas, M. S.; Roy, M.; Roy, S.; Kantam, M. L. *Helv. Chim. Acta* **2008**, *91*, 259–264; (c) Schneider, C. C.; Bortolatto, C.; Back, D. F.; Menezes, P. H.; Zeni, G. *Synthesis* **2011**, 413–418.
12. *o*-(Ethynyl)benzoic acid derivatives: (a) Yao, T.; Larock, R. C. *Tetrahedron Lett.* **2002**, *43*, 7401–7404; (b) Rossi, R.; Carpita, A.; Bellina, F.; Stabile, P.; Mannina, L. *Tetrahedron* **2003**, *59*, 2067–2081; (c) Yao, T.; Larock, R. C. *J. Org. Chem.* **2003**, *68*, 5936–5942.
13. Seven-membered heterocycles Jiang, T.-S.; Zhang, X.-G.; Li, J.-H. *Synthesis* **2009**, 3029–3038.
14. Selenophenes: (a) Alves, D.; Luchese, C.; Nogueira, C. W.; Zeni, G. *J. Org. Chem.* **2007**, *72*, 6726–6734; (b) Speranca, A.; Godoi, B.; Costa, M. D.; Menezes, P. H.; Zeni, G. *Tetrahedron Lett.* **2011**, *52*, 388–391.
15. 3-Iodobenzoselenophenes: Kesharwani, T.; Worlikar, S. A.; Larock, R. C. *J. Org. Chem.* **2006**, *71*, 2307–2312.
16. Kaname, M.; Sashida, H. *Tetrahedron Lett.* **2011**, *52*, 3279–3282.
17. (a) Creeke, P. I.; Mellor, J. M. *Tetrahedron Lett.* **1989**, *30*, 4435–4438; (b) Murai, T.; Niwa, H.; Kimura, T.; Shibahara, F. *Chem. Lett.* **2004**, *33*, 508–509.
18. Reviews: (a) Sashida, H. *Rev. Heteroat. Chem.* **2000**, *22*, 59–78; (b) Sashida, H. *J. Synth. Org. Chem., Jpn.* **2001**, *59*, 355–362; (c) Sashida, H. *Mini-Rev. Org. Chem.* **2007**, *4*, 105–114; (d) Sashida, H.; Minoura, M. *J. Synth. Org. Chem., Jpn.* **2009**, *67*, 714–723; (e) Sashida, H. *Heterocycles* **2011**, *83*, 2223–2254.
19. Recent works: (a) Sashida, H.; Nakayama, A.; Kaname, M. *Synthesis* **2008**, 3229–3236; (b) Sashida, H.; Nakabayashi, S.; Kaname, M.; Minoura, M. *Heterocycles* **2010**, *80*, 1339–1352; (c) Sashida, H.; Satoh, H.; Ohyanagi, K.; Kaname, M. *Molecules* **2010**, *15*, 1466–1472; (d) Sashida, H.; Kaname, M.; Ohyanagi, K. *Heterocycles* **2010**, *82*, 441–447; (e) Sashida, H.; Kaname, M.; Nakayama, A.; Suzuki, H.; Minoura, M. *Tetrahedron* **2010**, *66*, 5149–5157; (f) Sashida, H.; Nakabayashi, S.; Suzuki, H.; Kaname, M.; Minoura, M. *Tetrahedron Lett.* **2010**, *51*, 5395–5398; (g) Sashida, H.; Pan, C.; Kaname, M.; Minoura, M. *Synthesis* **2010**, 3091–3096; (h) Kaname, M.; Minoura, M.; Sashida, H. *Tetrahedron Lett.* **2011**, *52*, 505–508; (i) Sashida, H.; Kaname, M. *Heterocycles* **2012**, *84*, 669–682.
20. Kaname, M.; Sashida, H. *Tetrahedron Lett.* **2012**, *53*, 748–751.
21. Diffraction data were collected on a Bruker Apex-II CCD diffractometer equipped with a graphite monochromated Mo Kα radiation source (λ=0.71073 Å). The structures were solved by direct methods (SHELXS-97), and refined by full-matrix least-square methods on F^2 for all reflections (SHELXL-97) with all non-hydrogen atoms anisotropic and all hydrogen atoms isotropic. CCDC-907305 (for **3Da-*Z***) and 885264 (for **7Ae**) contain the supplementary crystallographic data for this paper. The data can be obtained free of charge from the Cambridge Crystallographic Data Centre via http://www.ccdc.cam.ac.uk/products/csd/request/.
22. (a) Benati, L.; Calestani, G.; Leadini, R.; Minozzi, M.; Nanni, D.; Spagnolo, P.; Strazzari, S.; Zanardi, G. *J. Org. Chem.* **2003**, *68*, 3454–3464; (b) Saito, T.; Nihei, H.; Otani, T.; Suyama, T.; Furukawa, N.; Saito, M. *Chem. Commun.* **2008**, 172–174.