RSC Advances

ROYAL SOCIETY OF CHEMISTRY

www.rsc.org/advances

RSC Advances

Cite this: DOI: 10.1039/cOxxOOOOOx

ARTICLE TYPE

www.rsc.org/xxxxxx

Efficient construction of C-S and C-N bond *via* metal-free reductive coupling of *N*-tosylhydrazones with benzo[*d*]thiazole-2-thiol

Yuqing Lin,[a] Puying Luo,*[b] Qiang Zheng,[a] Yumei Liu,[a] Xiaoyan Sang,[a] and Qiuping Ding*[a]

Received (in XXX, XXX) Xth XXXXXXXXX 20XX, Accepted Xth XXXXXXXXX 20XX

DOI: 10.1039/b000000x

An efficient procedure for the synthesis of diverse benzo[*d*]thiazole derivatives has been developed *via* metal-free reductive coupling of *N*-tosylhydrazones with benzo[*d*]thiazole-2-thiols. 2-Thio-substituted benzothiazoles are useful synthetic intermediates and promising biologically active compounds. The present process tolerates a wide range of substrates with high efficiency and moderate selectivity.

Introduction

As a privileged fragment, the benzothiazole is found in many pharmaceuticals and agrochemicals that exhibit remarkable biological activities, such as antitumor, antimalarials, and antiviral activities.[1] Among these, 2-thio-substituted benzothiazole is an important class of benzothiazole derivatives. For instance, *N*-(2-(cyclopentylthio)benzo[d]thiazol-6-yl)benzamide (compound I) showed antituberculotic activity;[1e] Compound II exhibited dual antagonists for the human CCR1 and CCR3 receptors (Fig.1).[1c] Great efforts have been made to develop new methods for their construction.[2] In addition, thioether as an essential building block is of great significance to the pharmaceutical industry.[3] Therefore, development of efficient strategy for the construction of C-S bond has attracted much attention.[4]

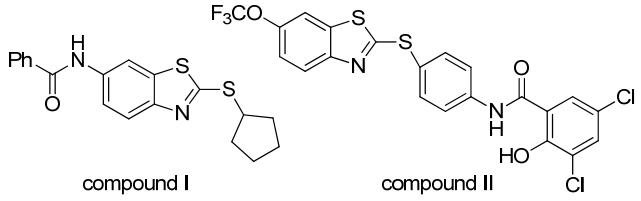
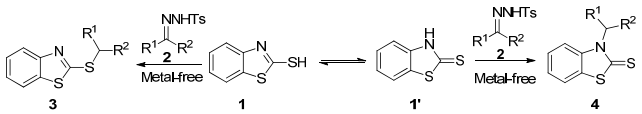


Fig. 1 Examples of bioactive 2-thio-substituted benzothiazoles.

Tosylhydrazones are useful precursors because they have shown that the *in situ* generation of carbenes and diazo compounds can also be widely applied to other reactions.[5] During the last decade, great progress has been made in the direct formation of C–C,[6] C–N,[7] and C–S[8] bond-froming reactions based on tosylhydrazones *via* metal-catalyzed progress. For example, Barluenga first described Pd-catalyzed cross-coupling reaction to polysubstituted olefins employed *N*-tosylhydrazones as the nucleophilic component.[6a] Wang reported a three-component coupling of *N*-tosylhydrazones, terminal alkynes, and aryl halides *via* a sequential palladium carbene migratory insertion and reductive elimination process.[6i] Zhou and co-workers reported the synthesis of benzofuran and indole *via* Cu(I)-catalyzed coupling of *N*-tosylhydrazone and *o*-hydroxy or *o*-amino phenylacetylene.[7b] Tosylhydrazone involved reactions are generally required transition metal (such as Pd, Cu, Co, Ni, and Rh). It is well known that transition metal-catalyzed reactions may also present problems (including high cost and disposing of some toxic metal especially in the synthesis of some pharmaceuticals). Therefore, it is desirable to develop high efficient method under metal-free condition. Rapid progress in the metal-free reactions has been made in recent years.[9] Barluenga *et al.* reported metal-free carbon–carbon bond-forming reaction between tosylhydrazones and boronic acids and C–O bond-forming reaction between tosylhydrazones and alcohols or phenols.[9a,b] Recently, Wang and co-workers reported a catalyst-free intramolecular formal σ-C–C bond based on internal *N*-tosylhydrazone produced *in situ*.[9d] We also reported the synthesis of thioethers *via* metal-free reductive coupling of tosylhydrazones with thiols.[9c]

Benzo[d]thiazole-2-thiol can potentially undergo tautomeric transformation to benzo[*d*]thiazole-2(3*H*)-thione (Scheme 1). The rate of equilibration between isomers may depend on the polarity or pH value of the solution. Therefore, it would seem to imply that the solution containing the functional group of SH and NH. Prompted by the previous results,[9c] we believe that this metal-free reaction may be applied for the selectively synthesis of thioethers **3** and thiones **4** *via* a combination of benzo[d]thiazole-2-thiol **1** and a diazo compound *in situ* generated from the *N*-tosylhydrazone **2**. This transformation provides a new approach for the synthesis of diverse benzo[d]thiazole derivatives **3** and **4** that may be useful building blocks in the design of bioactive compounds.

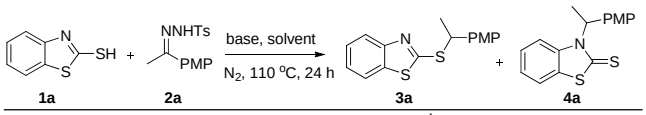


Scheme 1 Selectively C–S and C–N bond-forming reactions under metal-free conditions

Results and Discussion

To verify the practicability of the projected route, benzo[*d*]thiazole-2-thiol **1a** and *N*-tosylhydrazone **2a** were chosen as model substrates for the selectively C–S and C–N bond-forming process. The initial study was carried out based on our previous results[9c] (K_2CO_3/1,4-dioxane/110 °C for 24 h). Under such conditions, the desired products (**3a** and **4a**) were obtained in 65% yield, while the results show low selectivity (the ratio of **3a**/**4a** is 63/37 determined by isolated yield). Then different solvents, such as DMSO, DMF, toluene, and pyridine were also tried in the reaction. Only trace of product was observed in DMSO (Table 1, entry 2). Inferior results were displayed when the reaction performed in DMF and pyridine (Table 1, entries 3 and 5). Regioselective C–S bond-forming product **3a** was obtained in toluene, while only poor yield 35% (Table 1, entry 4). Further fine-tuning of the reaction conditions has revealed that K_2CO_3 is more effective than other bases, such as Na_2CO_3, ^{t}BuOK, KOH, K_3PO_4, DBU, DABCO, and Et_3N (Table 1, entries 6-13). Further studies showed that increasing the amount of base (K_2CO_3) or *N*-tosylhydrazone **2a** led to higher yield, while there were no obviously changes in selectivity (Table 1, entry 1 *vs* entry 10, and 14-17). K_2CO_3 can be recovered by filtration. Lower temperature may help to minimize the keto-enol tautomerism of the substrate, so we screened the effects of reaction temperature in order to improve the selectivity, but the inferior results were obtained (Table 1, entries 18-20), maybe because of the failed generation of intermediate diazo compound from the tosylhydrazone at low temperature.[9]

Table 1 Optimization of the reaction conditions

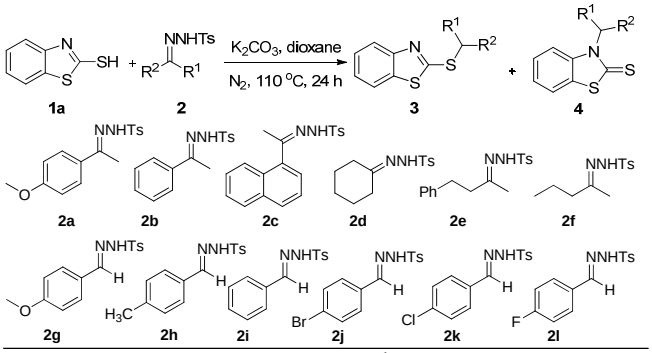


entry	base	solvent	yield (%)[a,b] **3a** + **4a**	ratio of **3a**/**4a**
1	K_2CO_3	1,4-dioxane	65	63/37
2	K_2CO_3	DMSO	trace	trace
3	K_2CO_3	DMF	54	50/50
4	K_2CO_3	Toluene	35 (**3a**)	-
5	K_2CO_3	Pyridine	60	63/37
6[c]	Na_2CO_3	1,4-dioxane	71	70/30
7[c]	^{t}BuOK	1,4-dioxane	71	70/30
8[c]	KOH	1,4-dioxane	55	63/37
9[c]	K_3PO_4	1,4-dioxane	70	64/36
10[c]	K_2CO_3	1,4-dioxane	74	69/31
11[c]	DBU	1,4-dioxane	43	65/35
12[c]	DABCO	1,4-dioxane	18 (**3a**)	-
13[c]	Et_3N	1,4-dioxane	trace	trace
14[d]	K_2CO_3	1,4-dioxane	78	70/30
15[e]	K_2CO_3	1,4-dioxane	85	68/32
16[f]	K_2CO_3	1,4-dioxane	78	70/30
17[g]	K_2CO_3	1,4-dioxane	77	70/30
18[h]	K_2CO_3	1,4-dioxane	65	65/35
19[i]	K_2CO_3	1,4-dioxane	trace	-
20[j]	K_2CO_3	1,4-dioxane	trace	-

[a] Reaction conditions: benzo[*d*]thiazole-2-thiol **1a** (0.3 mmol), *N*-tosylhydrazone **2a** (2.0 equiv, 0.6 mmol), base (3.0 equiv, 0.9 mmol), Solvent (3.0 mL), 110 °C, N_2, 24 h, PMP = 4-methoxyphenyl. [b] Yield based on **1a**. [c] **1a** : **2a** : base = 1: 3: 3.5. [d] **1a** : **2a** : base = 1: 3: 6. [e] **1a** : **2a** : base = 1: 3: 10. [f] **1a** : **2a** : base = 1: 2: 10. [g] **1a** : **2a** : base = 1: 2: 6. [h] T = 90 °C. [i] T = 60 °C. [j] T = r.t..

To demonstrate the generality of this protocol, the scope of the reaction was investigated under the optimized conditions [benzo[*d*]thiazole-2-thiol (1.0 equiv), *N*-tosylhydrazone (2.0 equiv), K_2CO_3 (6.0 equiv), 1,4-dioxane, 110 °C, N_2, 24 h]. As summarized in Table 2, the reaction activity seems to be general, as *N*-tosylhydrazones derived from aromatic or aliphatic ketones (Table 2, entries 1-6, R^1, R^2 = Aryl, alkyl) as well as aldehydes (Table 2, entries 7-12, R^1= Aryl, R^2 = H) were converted into corresponding product **3** and **4** in good to excellent yields. Moderate to satisfactory selectivities were obtained in most of cases. Tosylhydrazones with electron-rich (Table 2, entries 1, 7 and 8), electron-neutral (Table 2, entries 2 and 9) and electron-deficient groups (Table 2, entries 10-12) all gave the desired products in good yields. For instance, benzo[*d*]thiazole-2-thiol **1a** reacted with *N*-tosylhydrazone **2d** derived from aliphatic ketone, leading to thioether **3d** and thione **4d** in 63% and 26% yields respectively, with moderate selectivity (Table 2, entry 4). When electron-deficient *N*-tosylhydrazone **2j** was employed in the reaction, afforded the corresponding product **3j** and **4j** in 70% and 15% yields respectively, with better selectivity (Table 2, entry 10).

Table 2 Metal-free reductive coupling of benzo[*d*]thiazole-2-thiol **1a** with *N*-tosylhydrazones **2**



entry	*N*-tosylhydrazone **2**	yield (%)[a,b] of **3** + **4**	ratio of **3**/**4**
1	**2a**	77 (**3a** + **4a**)	70/30
2	**2b**	85 (**3b** + **4b**)	70/30
3	**2c**	50 (**3c** + **4c**)	70/30
4	**2d**	89 (**3d** + **4d**)	70/30
5	**2e**	69 (**3e** + **4e**)	83/17
6	**2f**	68 (**3f** + **4f**)	75/25
7	**2g**	77 (**3g** + **4g**)	70/30
8	**2h**	88 (**3h** + **4h**)	72/28
9	**2i**	79 (**3i** + **4i**)	81/19
10	**2j**	85 (**3j** + **4j**)	82/18
11	**2k**	75 (**3k** + **4k**)	88/12
12	**2l**	91 (**3l** + **4l**)	71/29

[a] Reaction conditions: benzo[*d*]thiazole-2-thiol **1a** (0.3 mmol), *N*-tosylhydrazone **2** (2.0 equiv, 0.6 mmol), K_2CO_3 (6.0 equiv, 1.8 mmol), 1,4-dioxane (3.0 mL), 110 °C, N_2. [b] Yield based on **1a**.

To broaden the scope of substrates, we further investigated the metal-free reductive coupling reaction of benzo[*d*]thiazole-2-thiol derivatives **1b-d** with various *N*-tosylhydrazones **2** under the same conditions (Table 3). The results showed that the additional functional groups such as methyl, chloro, and fluoro on the phenyl ring of benzo[*d*]thiazole-2-thiol did not interfere with the reaction activity.

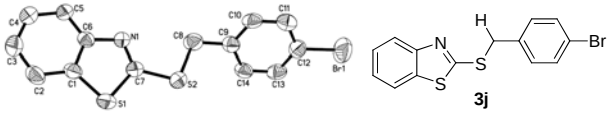


Fig. 2 ORTEP representation of the single crystal X-ray structure of **3j**

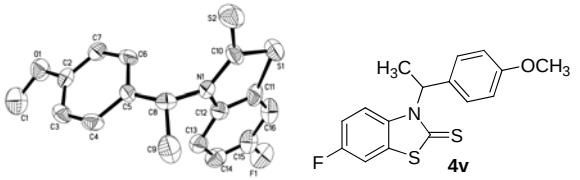
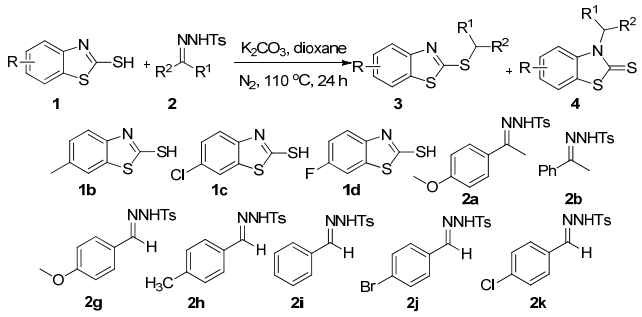


Fig. 3 ORTEP representation of the single crystal X-ray structure of **4v**

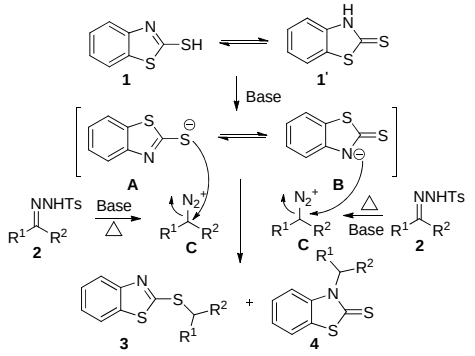
The structure of all compounds **3** and **4** were identified by NMR and HRMS. In addition, **3j** (Figure 1) and **4v** (Figure 2) were also verified by X-ray illustration.

Table 3 Metal-free reductive coupling of benzo[*d*]thiazole-2-thiol **1b-d** with *N*-tosylhydrazones **2**



Entry	Benzo[*d*]thiazole-2-thiol **1**	*N*-Tosyl-hydrazone **2**	Yield (%)[a,b] of (**3** + **4**)	Ratio of **3**/**4**
1	**1b**	**2a**	84 (**3m** + **4m**)	68/32
2	**1b**	**2b**	78 (**3n** + **4n**)	77/23
3	**1b**	**2h**	68 (**3o** + **4o**)	78/22
4	**1b**	**2i**	63 (**3p** + **4p**)	82/18
5	**1b**	**2j**	74 (**3q** + **4q**)	88/12
6	**1c**	**2a**	80 (**3r** + **4r**)	70/30
7	**1c**	**2b**	74 (**3s** + **4s**)	78/22
8	**1c**	**2g**	89 (**3t** + **4t**)	66/34
9	**1c**	**2k**	89 (**3u** + **4u**)	72/28
10	**1d**	**2a**	81 (**3v** + **4v**)	74/26
11	**1d**	**2h**	70 (**3w** + **4w**)	71/29

[a] Reaction conditions: benzo[*d*]thiazole-2-thiol **1** (0.3 mmol), *N*-tosylhydrazone **2** (2.0 equiv, 0.6 mmol), K_2CO_3 (6.0 equiv, 1.8 mmol), dioxane (3.0 mL), 110 °C, N_2. [b] Yield based on **1**.



Scheme 2 Proposed reaction mechanism

A possible mechanism for the reaction is depicted in Scheme 2.[9] Initially, benzo[*d*]thiazole-2(3*H*)-thione **1'** were formed by the tautomeric transformation of benzo[d]thiazole-2-thiol **1**, which underwent deprotonation to form corresponding intermediates **A** and **B**. Diazo compound **C** was generated *in situ* from corresponding tosylhydrazones under basic conditions at 110 °C. Then, nucleophilic attack of intermediate **A** and **B** on **C** resulted in the formation of products **3** and **4** with the loss of one molecule of N_2. Of course, we couldn't deny the selectively C–S and C–N bond-forming reactions maybe to proceed through the base-promoted decomposition of tosylhydrazones in the presence of benzo[*d*]thiazole-2-thiol and the insertion reaction of the carbene into the S-H and N-H bonds.

Conclusion

In summary, we have successfully developed a new procedure for the synthesis of diverse benzo[*d*]thiazole derivatives under transition metal-free conditions. The process proceeds with a wide range of substrates, high efficiency and moderate selectivity. Proposed mechanism for the selectively C–S and C–N bond-forming reactions of benzo[*d*]thiazole-2-thiol is depicted. This procedure represents an efficient route toward the synthesis of 2-thio-substituted benzothiazole derivatives which are useful synthetic intermediates and promising biologically active compounds. Screening for biological activity of these small molecules is under investigation in our laboratory, and the results will be reported in due course.

Experimental

General procedure for the synthesis of 2-thio-substituted benzothiazole derivatives **3** and **4** from benzo[*d*]thiazole-2-thiols **1** with tosylhydrazones **2**: a mixture of benzo[*d*]thiazole-2-thiol **1** (0.3 mmol), tosylhydrazone **2** (0.6 mmol, 2.0 equiv.) and K_2CO_3 (1.8 mmol, 6.0 equiv.) in 1,4-dioxane (3.0 mL) was stirred at 110 °C for over night under N_2. After completion of the reaction, as indicated by TLC, the mixture was cooled to room temperature. Filtered and washed with ethyl acetate (10 mL), the organic phase was washed with saturated brine, dried with $MgSO_4$ and concentrated under a vacuum. The residue was then purified by flash chromatography (EtOAc-petroleum ether, 1:50 v/v) on silica gel to afford the corresponding products **3** and **4.**

2-(1-(4-methoxyphenyl)ethylthio)benzo[*d*]thiazole (3a)[2a] White solid; mp 56-57 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.83 (d, J = 7.2 Hz, 3H), 3.78 (s, 3H), 5.12 (q, J = 7.6Hz, 1H), 6.86 (d, J = 8.8 Hz, 2H), 7.28 (t, J = 8.0 Hz, 1H), 7.39-7.43 (m, 3H), 7.72 (d, J = 8.0 Hz, 1H), 7.90 (d, J = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.7, 47.2, 55.3, 114.1, 120.9, 121.7, 124.3, 126.0, 128.6, 133.8, 135.5, 153.3, 159.1, 166.0.

3-(1-(4-methoxyphenyl)ethyl)benzo[*d*]thiazole-2(*3H*)-thione (4a) White solid; mp 97-98 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.89 (d, J = 7.2 Hz, 3H), 3.78 (s, 3H), 6.87 (d, J = 8.8 Hz, 2H), 6.91 (d, J = 8.4 Hz, 1H), 7.08 (t, J = 8.0 Hz, 1H), 7.15-7.18 (m, 2H), 7.24 (d, J = 8.8 Hz, 2H), 7.44 (d, J = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.2, 54.8, 55.3, 114.3, 114.4, 121.1, 124.2, 126.2, 127.4, 127.6, 130.0, 139.9, 159.1, 189.9; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{16}H_{16}NOS_2$: 302.0673; found: 302.0675. Elemental analysis calcd (%) for $C_{16}H_{15}NOS_2$: C 63.75, H 5.02, N 4.65; Found: C 63.79, H 5.21, N 4.70.

2-(1-phenylethylthio)benzo[*d*]thiazole (3b)[2a] Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.84 (d, J = 7.2 Hz, 3H), 5.15 (q, J = 6.8 Hz, 1H), 7.26 (d, J = 7.6 Hz, 2H), 7.33 (t, J = 7.6 Hz, 2H),

7.40 (dt, J = 2.0, 7.6 Hz 1H), 7.47 (d, J = 7.2 Hz, 2H), 7.71 (d, J = 8.0 Hz, 1H), 7.90 (d, J = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.7, 47.6, 120.9, 121.7, 124.3, 126.0, 127.4, 127.8, 128.7, 135.5, 141.9, 153.3, 165.8.

3-(1-phenylethyl)benzo[d]thiazole-2(*3H*)-thione (4b) Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.92 (d, J = 7.2 Hz, 3H), 6.86 (d, J = 8.4 Hz, 1H), 7.05-7.09 (m, 1H), 7.15-7.25 (m, 2H), 7.27-7.37 (m, 4H), 7.44 (d, J = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.1, 55.1, 114.4, 121.2, 124.3, 126.2, 126.4, 127.4, 127.8, 128.9, 138.0, 139.9, 190.0; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{14}NS_2$: 272.0568; found: 272.0575. Elemental analysis calcd (%) for $C_{15}H_{13}NS_2$: C 66.38, H 4.83, N 5.16; Found: C 66.41, H 4.90, N 5.08.

2-(1-(naphthalen-1-yl)ethylthio)benzo[*d*]thiazole (3c) Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.05 (d, J = 7.2 Hz, 3H), 6.04 (q, J = 7.2 Hz, 1H), 7.28 (dt, J =1.2, 8.4 Hz, 1H), 7.40-7.58 (m, 4H), 7.72 (d, J = 7.6 Hz, 2H), 7.80 (d, J = 8.4 Hz, 1H), 7.87 (d, J = 8.0 Hz, 1H), 7.94 (d, J = 8.4 Hz, 1H), 8.29 (d, J = 8.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.1, 43.1, 121.0, 121.7, 123.2, 124.3, 124.6, 125.4, 125.9, 126.1, 126.6, 128.7, 129.1, 130.9, 133.9, 135.4, 136.6, 153.2, 166.4; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{19}H_{16}NS_2$: 322.0724; found: 22.0727. Elemental analysis calcd (%) for $C_{19}H_{15}NS_2$: C 70.99, H 4.70, N 4.36; Found: C 71.08, H 4.75, N 4.35.

3-(1-(naphthalen-1-yl)ethyl)benzo[*d*]thiazole-2(*3H*)-thione (4c) White solid; mp 198-199 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.03 (d, J = 5.6 Hz, 3H), 6.91 (t, J = 7.6 Hz, 1H), 7.02-7.04 (m, 2H), 7.32 (d, J = 8.0 Hz, 1H), 7.42 (t, J = 8.0 Hz, 2H), 7.52 (d, J = 7.2 Hz, 1H), 7.59 (t, J = 7.6 Hz, 1H), 7.80 (d, J = 7.2 Hz, 1H), 7.88 (d, J = 8.4 Hz, 1H), 7.94 (d, J = 7.2 Hz, 1H), 7.99 (d, J = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.9, 54.9, 113.6, 121.1, 123.9, 124.0, 124.6, 125.8, 126.1, 126.2, 127.2, 127.3, 128.7, 129.7, 131.8, 133.9, 134.0, 140.6, 189.0; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{19}H_{16}NS_2$: 322.0724; found: 322.0720. Elemental analysis calcd (%) for $C_{19}H_{15}NS_2$: C 70.99, H 4.70, N 4.36; Found: C 70.88, H 4.65, N 4.38.

2-(cycloheximide)benzo[*d*]thiazole (3d)[2d,2e] Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.28-1.36 (m, 1H), 1.42-1.51 (m, 2H), 1.54-1.65 (m, 3H), 1.77-1.81 (m, 2H), 2.17-2.20 (m, 2H), 3.87-3.92 (m, 1H), 7.27 (t, J = 8.0 Hz, 1H), 7.39 (t, J = 8.0 Hz, 1H), 7.73 (d, J = 8.0 Hz, 1H), 7.87 (d, J = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 25.6, 25.9, 33.3, 47.4, 120.9, 121.6, 124.2, 125.9, 135.3, 153.4, 166.5.

3-cyclohexylamine[*d*]thiazole-2(*3H*)-thione (4d)[1d] Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.30-1.36 (m, 1H), 1.52-1.62 (m, 2H), 1.81-1.98 (m, 5H), 2.19-2.28 (m, 2H), 5.72-5.78 (m, 1H), 7.26 (t, J = 8.0 Hz, 1H), 7.35 (t, J = 8.0 Hz, 1H), 7.45 (d, J = 7.6 Hz, 1H), 7.68 (d, J = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 25.4, 26.0, 28.6, 58.5, 114.0, 121.3, 124.0, 126.1, 127.4, 140.7, 189.3.

2-(4-phenylalanine-2-thiophil)benzo[*d*]thiazole (3e)[2j] Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.53 (d, J = 6.8 Hz, 3H), 1.98-2.04 (m, 1H), 2.09-2.15 (m, 1H), 2.80 (t, J = 8.0 Hz, 2H), 3.98 (m, 1H), 7.15-7.19 (m, 3H), 7.24-7.28 (m, 3H), 7.38 (t, J = 8.0 Hz, 1H), 7.70 (d, J = 8.0 Hz, 1H), 7.86 (d, J = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.6, 33.3, 38.5, 44.0, 121.0, 121.7, 124.3, 126.0, 126.1, 128.4, 128.5, 135.4, 141.3, 153.5, 166.3.

3-(4-phenylalanine-2-yl)benzo[*d*]thiazole-2(*3H*)-thione (4e) Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.61 (d, J = 6.8 Hz, 3H), 2.24-2.28 (m, 1H), 2.43-2.53 (m, 2H), 2.73-2.79 (m, 1H), 6.09 (m, 1H), 7.09 (d, J = 7.2 Hz, 2H), 7.13 (d, J = 6.8 Hz, 1H), 7.18-7.22 (m, 2H), 7.26 (t, J = 7.6 Hz, 1H), 7.34 (t, J = 7.6 Hz, 1H), 7.45 (d, J = 7.6 Hz, 1H) ,7.55 (d, J = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.7, 33.0, 35.6, 54.6, 113.4, 121.5, 124.3, 126.1, 126.4, 127.3, 128.2, 128.4, 140.3, 140.8, 189.9; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{17}H_{18}NS_2$: 300.0881; found: 300.0882. Elemental analysis calcd (%) for $C_{17}H_{17}NS_2$: C 68.18, H 5.72, N 4.68; Found: C 68.23, H 5.79, N 4.70.

2-(Pentax-2-thiophil)benzo[*d*]thiazole (3f) Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.28-1.51 (m, 3H), 1.54-1.65 (m, 3H), 1.77-1.81 (m, 2H), 2.17-2.20 (m, 2H), 3.87-3.92 (m, 1H), 7.27 (t, J = 8.0 Hz, 1H), 7.40 (t, J = 8.0 Hz, 1H), 7.43 (d, J = 8.0 Hz, 1H), 7.87 (d, J = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 25.6, 25.9, 33.3, 47.3, 120.9, 121.6, 124.2, 125.9, 135.3, 153.4, 166.5; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{12}H_{16}NS_2$: 238.0724; found: 238.0725. Elemental analysis calcd (%) for $C_{12}H_{15}NS_2$: C 60.72, H 6.37, N 5.90; Found: C 60.65, H 6.42, N 5.95.

3-(Pentax-2-yl)benzo[d]thiazole-2(3H)-thione (4f) Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.30-1.36 (m, 1H), 1.55-1.61 (m, 2H), 1.81-1.85 (m, 2H), 1.89-1.99 (m, 3H), 2.20-2.28 (m, 2H), 5.72-5.79 (m, 1H), 7.26 (t, J = 7.6 Hz, 1H), 7.35 (t, J = 8.0 Hz, 1H), 7.47 (d, J = 7.6 Hz, 1H), 7.68 (d, J = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 25.4, 26.0, 28.6, 58.5, 114.1, 121.3, 124.0, 126.1, 127.5, 140.8, 189.3; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{12}H_{16}NS_2$: 238.0724; found: 238.0719. Elemental analysis calcd (%) for $C_{12}H_{15}NS_2$: C 60.72, H 6.37, N 5.90; Found: C 60.65, H 6.48, N 5.80.

2-(4-methylbenzene)benzo[*d*]thiazole (3g)[2b] White solid; mp 63-64 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.77 (s, 3H), 4.55 (s, 2H), 6.84 (d, J = 7.2 Hz, 2H), 7.27 (dt, J = 1.2, 7.6 Hz, 1H), 7.36 (d, J = 7.2 Hz, 2H), 7.40 (dt, J = 1.2, 7.6 Hz, 1H), 7.72 (d, J = 8.0 Hz, 1H), 7.89 (d, J = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 37.4, 55.3, 114.2, 121.0, 121.6, 124.3, 126.1, 128.1, 130.4, 135.4, 153.2, 159.2, 166.6.

3-(4-methoxide)benzo[*d*]thiazole-2(*3H*)-thione (4g) White solid; mp 104-105℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.76 (s, 3H), 5.63 (s, 2H), 6.84 (d, J = 8.8 Hz, 2H), 7.15 (d, J = 7.6 Hz, 1H), 7.23-7.32 (m, 4H), 7.47 (d, J = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 49.1, 55.3, 113.1, 114.3, 121.3, 124.8, 126.5, 126.9, 127.7, 128.7, 141.5, 159.4, 190.1; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{14}NOS_2$: 288.0517; found: 288.0518. Elemental analysis calcd (%) for $C_{15}H_{13}NOS_2$: C 62.69, H 4.56, N 4.87; Found: C 62.72, H 4.59, N 4.85.

2-(4-ethylbenzene)benzo[*d*]thiazole (3h)[2b] White solid; mp 52-53℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.29 (s, 3H), 4.53 (s, 2H), 7.10 (d, J = 8.0 Hz, 2H), 7.25 (t, J = 7.6 Hz, 1H), 7.31 (d, J = 7.6 Hz, 2H), 7.38 (t, J = 7.2 Hz, 1H), 7.69 (d, J = 7.6 Hz, 1H), 7.88 (d, J = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.2, 37.6, 121.1, 121.6, 124.3, 126.1, 129.1, 129.5, 133.0, 135.3, 137.6, 153.2, 166.7.

3-(4-ethylbenzene)benzo[*d*]thiazole-2(*3H*)-thione (4h) White solid; mp 129-130℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.29 (s, 3H), 5.65 (s, 2H), 7.10-7.13 (m, 3H), 7.20 (d, J = 7.6 Hz, 2H), 7.24-7.30 (m, 2H), 7.46 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.1, 49.3, 113.1, 121.3, 124.8, 126.9, 127.1, 127.6, 129.6, 131.3, 137.7, 141.5, 190.1; HRMS (ESI): *m/z* $[M+H]^+$

calcd for $C_{15}H_{14}NS_2$: 272.0568; found: 272.0573. Elemental analysis calcd (%) for $C_{15}H_{13}NS_2$: C 66.38, H 4.83, N 5.16; Found: C 66.45, H 4.90, N 5.20.

2-(benzyl thio)benzo[*d*]thiazole (3i)[2d] Yellow solid; mp 46-47℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.59 (s, 2H), 7.24-7.33 (m, 4H), 7.38-7.45 (m, 3H), 7.72 (d, *J* = 8.0 Hz, 1H), 7.89 (d, *J* = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 37.7, 121.0, 121.6, 124.3, 126.1, 127.8, 128.7, 129.2, 135.4, 136.2, 153.2, 166.4.

3-benzal[*d*]thiazole-2(*3H*)-thione (4i)[1d] Yellow solid; mp 149-150℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.71 (s, 2H), 7.11 (d, *J* = 7.2 Hz, 1H), 7.24-7.33 (m, 7H), 7.49 (d, *J* = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 49.5, 113.0, 121.3, 124.8, 126.9, 127.1, 127.6, 127.9, 128.9, 134.4, 141.5, 190.3.

2-(4-tribromoethanol)benzo[*d*]thiazole (3j) Yellow solid; mp 80-81℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.44 (s, 2H), 7.20 (t, *J* = 7.6 Hz, 1H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.30-7.35 (m, 3H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 36.9, 121.1, 121.6, 121.7, 124.5, 126.2, 130.8, 131.8, 135.4, 135.6, 153.1, 165.8; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{14}H_{11}BrNS_2$: 335.9516; found: 335.9513. Elemental analysis calcd (%) for $C_{14}H_{10}BrNS_2$: C 50.00, H 3.00, N 4.17; Found: C 49.95, H 3.09, N 4.25. Crystal data and structure refinement for **3j** (CCDC: 956820): Empirical formula: $C_{14}H_{10}BrNS_2$ (Formula weight: 336.26); Temperature: 298(2) K; Wavelength: 0.71073 A; Crystal system, space group Orthorhombic, P b c n; Unit cell dimensions: a = 15.095(3) A, α = 90°, b = 5.7769(10) A, β = 90°, c = 31.466(5) A, γ = 90°, Volume: 2743.9(8)A^3; Z = 8, Calculated density: 1.628Mg/m^3; Absorption coefficient: 3.280 mm^{-1}; F(000): 1344; Crystal size: 0.32 x 0.25 x 0.21 mm; Theta range for data collection: 1.87 to 25.50 deg.; Limiting indices: -8<=h<=18, -6<=k<=6, -38<=l<=34; Reflections collected /unique: 11396/2489 [R(int) = 0.0279]; Completeness to theta = 25.50: 97.8 %; Absorption correction: Semi-empirical from equivalents; Max. and min. transmission: 0.5458 and 0.4200. Refinement method: Full-matrix least-squares on F^2. Data / restraints / parameters: 2489 / 0 / 163; Goodness-of-fit on F^2: 1.059, Final *R* indices [*I*>2σ (I)]: *R1* = 0.0894, *ωR2* = 0.1886. *R* indices (all data): *R1* = 0.0978, *ωR2* = 0.1916. Largest diff. peak and hole: 0.454 and -0.588 e.A^{-3}

3-(4-bromobenzyl)benzo[*d*]thiazole-2(*3H*)-thione (4j) Yellow solid; mp 130-131℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.64 (s, 2H), 7.06 (d, *J* = 7.6 Hz, 1H), 7.19 (d, *J* = 8.0 Hz, 2H), 7.26-7.31 (m, 2H), 7.44 (d, *J* = 8.0 Hz, 2H), 7.49 (d, *J* = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 48.9, 112.8, 121.5, 122.0, 125.0, 127.1, 127.6, 128.9, 132.1, 133.4, 141.3, 190.3; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{14}H_{11}BrNS_2$: 335.9516; found: 335.9512. Elemental analysis calcd (%) for $C_{14}H_{10}BrNS_2$: C 50.00, H 3.00, N 4.17; Found: C 49.93, H 3.05, N 4.10.

2-(4-chlorobenzylthio)benzo[*d*]thiazole (3k)[2f] Yellow solid; mp 81-82℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.53 (s, 2H), 7.22-7.29 (m, 3H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.40 (t, *J* = 7.2 Hz, 1H), 7.71 (d, *J* = 8.0 Hz, 1H), 7.88 (d, *J* = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 36.9, 121.1, 121.6, 124.5, 126.2, 128.9, 130.5, 133.6, 135.0, 135.4, 153.1, 165.8.

3-(4-chlorobenzyl)benzo[*d*]thiazole-2(*3H*)-thione (4k) Yellow solid; mp 111-112℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.66 (s, 2H), 7.07 (d, *J* = 7.6 Hz, 1H), 7.26-7.31 (m, 6H), 7.50 (d, *J* = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 48.2, 112.8, 121.5, 125.0, 127.0, 127.6, 128.6, 129.2, 132.9, 133.9, 141.3, 190.3; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{14}H_{11}ClNS_2$: 292.0021; found: 292.0019. Elemental analysis calcd (%) for $C_{14}H_{11}ClNS_2$: C 57.62, H 3.45, N 4.80; Found: C 57.69, H 3.49, N 4.86.

2-(4-fluorobenzylthio)benzo[*d*]thiazole (3l)[1a] Yellow solid; mp 80-81℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.54 (s, 2H), 6.98 (t, *J* = 8.4 Hz, 2H), 7.27 (d, *J* = 7.6 Hz, 1H), 7.36-7.42 (m, 3H), 7.71 (d, *J* = 8.0 Hz, 1H), 7.89 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 36.9, 115.6 (d, $^2J_{C\text{-}F}$ = 21 Hz), 121.1, 121.6, 124.4, 126.1, 130.8 (d, $^3J_{C\text{-}F}$ = 8 Hz), 132.2, 135.4, 153.2, 162.3 (d, $^1J_{C\text{-}F}$ = 245 Hz), 166.0.

3-(4-fluorobenzyl)benzo[*d*]thiazole-2(*3H*)-thione (4l) Yellow solid; mp 130-131℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.66 (s, 2H), 7.01 (t, *J* = 8.4 Hz, 2H), 7.10 (d, *J* = 7.6 Hz, 1H), 7.25-7.33 (m, 4H), 7.49 (d, *J* = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 48.8, 112.9, 115.9 (d, $^2J_{C\text{-}F}$ = 21 Hz), 121.4, 124.9, 127.0, 127.6, 129.1 (d, $^3J_{C\text{-}F}$ = 8 Hz), 130.2, 141.3, 162.4 (d, $^1J_{C\text{-}F}$ = 245 Hz), 190.2; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{14}H_{11}FNS_2$: 276.0317; found: 276.0315. Elemental analysis calcd (%) for $C_{14}H_{11}FNS_2$: C 61.06, H 3.66, N 5.09; Found: C 60.98, H 3.59, N 4.96.

2-(1-(4-methoxyphenyl)ethylthio)-6-methylbenzo[*d*]thiazole (3m) White solid; mp 81-82 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.81 (d, *J* = 6.8 Hz, 3H), 2.44 (s, 3H), 3.78 (s, 3H), 5.07 (q, *J* = 7.2 Hz, 1H), 6.85 (d, *J* = 8.8 Hz, 2H), 7.21 (d, *J* = 8.0 Hz, 1H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.51 (s, 1H), 7.78 (d, *J* = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.4, 22.7, 47.3, 55.3, 114.1, 120.8, 121.3, 127.5, 128.6, 133.9, 134.4, 135.8, 151.5, 159.1, 164.6; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{17}H_{18}NOS_2$: 316.0830; found: 316.0826. Elemental analysis calcd (%) for $C_{17}H_{17}NOS_2$: C 64.73, H 5.43, N 4.44; Found: C 64.92, H 5.49, N 4.35.

3-(1-(4-methoxyphenyl)ethyl)-6-methylbenzo[*d*]thiazole-2(*3H*)-thione (4m) Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.88 (d, *J* = 7.2 Hz, 3H), 2.31 (s, 3H), 3.78 (s, 3H), 6.79 (d, *J* = 8.4 Hz, 1H), 6.85-6.90 (m, 3H), 7.13 (q, *J* = 7.2 Hz, 1H), 7.20-7.26 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.3, 20.9, 54.8, 55.3, 113.6, 114.1, 114.2, 121.2, 127.3, 127.5, 127.6, 130.1, 134.3, 137.9, 159.1, 189.3. HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{17}H_{18}NOS_2$: 316.0830; found: 316.0829. Elemental analysis calcd (%) for $C_{17}H_{17}NOS_2$: C 64.73, H 5.43, N 4.44; Found: C 64.89, H 5.47, N 4.39.

6-methyl-2-(1-phenylethylthio)benzo[*d*]thiazole (3n) Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.82 (d, *J* = 7.2 Hz, 3H), 2.41 (s, 3H), 5.11 (q, *J* = 7.2 Hz, 1H), 7.19-7.24 (m, 2H), 7.29-7.33 (m, 2H), 7.44 (s, 1H), 7.47 (d, *J* = 7.2 Hz, 2H), 7.77 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.5, 22.7, 47.7, 120.9, 121.3, 127.4, 127.5, 127.8, 128.7, 134.5, 135.8, 141.9, 151.4, 164.4; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{16}H_{16}NS_2$: 286.0724; found: 286.0720. Elemental analysis calcd (%) for $C_{16}H_{15}NS_2$: C 67.33, H 5.30, N 4.91; Found: C 67.43, H 5.45, N 4.87.

6-methyl-3-(1-phenylethyl)benzo[*d*]thiazole-2(*3H*)-thione (4n) Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.91 (d, *J* = 7.2 Hz, 3H), 2.31 (s, 3H), 6.74 (d, *J* = 8.4 Hz, 1H), 6.88 (d, *J* = 8.4 Hz, 1H), 7.19 (d, *J* = 7.2 Hz, 1H), 7.26 (s, 1H), 7.28-7.35 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.1, 20.9, 55.1, 114.1, 121.3, 126.4, 127.3, 127.5, 127.7, 128.9, 134.4, 137.8, 138.2, 189.5. HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{16}H_{16}NS_2$: 286.0724; found: 286.0735. Elemental analysis calcd (%) for $C_{16}H_{15}NS_2$: C 67.33,

H 5.30, N 4.91; Found: C 67.48, H 5.43, N 4.85.

2-(4-ethylbenzene)-6-methylbenzo[*d*]thiazole (3o) White solid, mp 86-87℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.31 (s, 3H), 2.42 (s, 3H), 4.53 (s, 2H), 7.11 (d, *J* = 8.0 Hz, 2H), 7.20 (d, *J* = 8.4 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.49 (s, 1H), 7.76 (d, *J* = 8.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.2, 21.4, 37.6, 120.9, 121.0, 127.5, 129.1, 129.4, 133.0, 134.4, 135.5, 137.5, 151.3, 165.3; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{16}H_{16}NS_2$: 286.0724; found: 286.0733. Elemental analysis calcd (%) for $C_{16}H_{15}NS_2$: C 67.33, H 5.30, N 4.91; Found: C 67.38, H 5.35, N 4.89.

3-(4-ethylbenzene)-6-methylbenzo[*d*]thiazole-2(*3H*)-thione (4o)[1g] White solid, mp 133-134℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.29 (s, 3H), 2.36 (s, 3H), 5.62 (s, 2H), 6.99 (d, *J* = 8.0 Hz, 1H), 7.06-7.11 (m, 3H), 7.19 (d, *J* = 8.0 Hz, 2H), 7.27 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.5, 20.6, 48.8, 112.3, 120.9, 126.6, 127.1, 127.5, 129.1, 130.9, 134.5, 137.2, 139.0, 189.0.

2-(benzyl thio)-6-methylbenzo[*d*]thiazole (3p)[2l] Yellow solid; mp 54-55℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.42 (s, 3H), 4.56 (s, 2H), 7.20 (d, *J* = 8.4 Hz, 1H), 7.25-7.32 (m, 3H), 7.42 (d, *J* = 7.6 Hz, 2H), 7.50 (s, 1H), 7.76 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.4, 37.8, 120.9, 121.1, 127.5, 127.7, 128.7, 129.1, 134.4, 135.6, 136.3, 151.4, 165.0.

3-benzyl-6-methylbenzo[*d*]thiazole-2(*3H*)-thione (4p)[1g] Yellow solid; mp 154-155℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.37 (s, 3H), 5.68 (s, 2H), 6.98 (d, *J* = 8.4 Hz, 1H), 7.08 (d, *J* = 8.4 Hz, 1H), 7.26-7.31 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.0, 49.5, 112.7, 121.4, 127.1, 127.7, 127.9, 128.0, 128.9, 134.5, 135.0, 139.5, 189.7.

2-(4-tribromoethanol)-6-methylbenzo[*d*]thiazole (3q) Yellow solid; mp 83-84℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.41 (s, 3H), 4.48 (s, 2H), 7.20 (d, *J* = 8.4 Hz, 1H), 7.28 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.4 Hz, 2H), 7.49 (s, 1H), 7.75 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.5, 37.0, 120.9, 121.2, 121.7, 127.6, 130.8, 131.8, 134.6, 135.6, 135.7, 151.3, 164.4; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{13}BrNS_2$: 349.9673; found: 349.9669. Elemental analysis calcd (%) for $C_{15}H_{12}BrNS_2$: C 51.43, H 3.45, N 4.00; Found: C 51.48, H 3.49, N 3.95.

3-(4-bromobenzyl)-6-methylbenzo[*d*]thiazole-2(*3H*)-thione (4q) Yellow solid, mp 146-147℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.38 (s, 3H), 5.62 (s, 2H), 6.95 (d, *J* = 8.4 Hz, 1H), 7.10 (d, *J* = 8.4 Hz, 1H), 7.18 (d, *J* = 8.4 Hz, 2H), 7.30 (s, 1H), 7.44 (d, *J* = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.1, 48.9, 112.4, 121.6, 121.9, 127.6, 128.1, 128.9, 132.1, 133.5, 135.2, 139.2, 189.7; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{13}BrNS_2$: 349.9673; found: 349.9675. Elemental analysis calcd (%) for $C_{15}H_{12}BrNS_2$: C 51.43, H 3.45, N 4.00; Found: C 51.38, H 3.35, N 4.05.

6-chloro-2-(1-(4-methoxyphenyl)ethylthio)benzo[*d*]thiazole (3r) White solid; mp 76-77℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.75 (d, *J* = 6.8 Hz, 3H), 3.71 (s, 3H), 5.02 (q, *J* = 7.2 Hz, 1H), 6.78 (d, *J* = 8.4 Hz, 2H), 7.27-7.32 (m, 3H), 7.61 (s, 1H), 7.71 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.6, 46.4, 54.3, 113.1, 119.6, 121.3, 125.7, 127.6, 129.2, 132.6, 135.6, 150.3, 158.2, 165.7; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{16}H_{15}ClNOS_2$: 336.0284; found: 336.0290. Elemental analysis calcd (%) for $C_{16}H_{14}ClNOS_2$: C 57.22, H 4.20, N 4.17; Found: C 57.35, H 4.33, N 4.06.

6-chloro-3-(1-(4-methoxyphenyl)ethyl)benzo[*d*]thiazole-2(*3H*)-thione (4r) Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.80 (d, *J* = 7.2 Hz, 3H), 3.72 (s, 3H), 6.72 (d, *J* = 9.2 Hz, 1H), 6.80 (d, *J* = 8.8 Hz, 2H), 6.97 (dd, *J* = 2.0, 8.8 Hz, 1H), 7.03 (q, *J* = 6.8 Hz, 1H), 7.14 (d, *J* = 8.4 Hz, 2H), 7.34 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.2, 54.9, 55.3, 114.4, 114.9, 120.8, 126.5, 127.6, 128.8, 129.6, 130.4, 138.6, 159.2, 189.7; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{16}H_{15}ClNOS_2$: 336.0284; found: 336.0279. Elemental analysis calcd (%) for $C_{16}H_{14}ClNOS_2$: C 57.22, H 4.20, N 4.17; Found: C 57.38, H 4.35, N 4.08.

6-chloro-2-(1-phenylethylthio)benzo*[d]*thiazole (3s) Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.74 (d, *J* = 6.8 Hz, 3H), 5.03 (q, *J* = 7.2 Hz, 1H), 7.16 (d, *J* = 6.8 Hz, 1H), 7.21-7.25 (m, 3H), 7.36 (d, *J* = 7.6 Hz, 2H), 7.54 (s, 1H), 7.67 (d, *J* = 8.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.7, 47.7, 120.6, 122.3, 126.7, 127.4, 127.9, 128.8, 130.2, 136.6, 141.7, 151.8, 166.6; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{13}ClNS_2$: 306.0178; found: 306.0181. Elemental analysis calcd (%) for $C_{15}H_{12}ClNS_2$: C 58.91, H 3.95, N 4.58; Found: C 58.95, H 4.08, N 4.45.

6-chloro-3-(1-phenylethyl)benzo[*d*]thiazole-2(*3H*)-thione (4s) Colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.90 (d, *J* =7.2 Hz, 3H), 6.75 (d, *J* = 8.8 Hz, 1H), 7.04 (dd, *J* = 2.0, 8.8 Hz, 1H), 7.16 (q, *J* = 7.2 Hz, 1H), 7.26-7.32 (m, 2H), 7.35-7.38 (m, 2H), 7.43 (d, *J* = 2.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.1, 55.2, 114.8, 120.9, 126.3, 126.6, 127.9, 128.7, 129.1, 130.4, 137.6, 138.5, 189.8; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{13}ClNS_2$: 306.0178; found: 306.0183. Elemental analysis calcd (%) for $C_{15}H_{12}ClNS_2$: C 58.91, H 3.95, N 4.58; Found: C 58.99, H 4.05, N 4.47.

2-(4-methylbenzene)-6-chlorobenzo[*d*]thiazole (3t) White solid; mp 99-101℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.76 (s, 3H), 4.52 (s, 2H), 6.83 (d, *J* = 8.8 Hz, 2H), 7.33-7.36 (m, 3H), 7.66 (d, *J* = 2.0 Hz, 1H), 7.76 (d, *J* = 8.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 37.4, 55.3, 114.2, 120.7, 122.1, 126.7, 127.8, 130.1, 130.4, 136.5, 151.8, 159.3, 167.3; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{13}ClNOS_2$: 322.0127; found: 322.0131. Elemental analysis calcd (%) for $C_{15}H_{12}ClNOS_2$: C 55.98, H 3.76, N 4.35; Found: C 56.12, H 3.83, N 4.28.

3-(4-methoxide)-6-chlorobenzo[*d*]thiazole-2(*3H*)-thione (4t) White solid; mp 152-153℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.76 (s, 3H), 5.58 (s, 2H), 6.84 (d, *J* = 8.4 Hz, 2H), 7.03 (d, *J* = 8.8 Hz, 1H), 7.20-7.25 (m, 3H), 7.43 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 49.1, 55.3, 113.6, 114.4, 121.0, 126.0, 127.2, 128.6, 128.9, 130.8, 140.1, 159.4, 189.8; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{13}ClNOS_2$: 322.0127; found: 322.0129. Elemental analysis calcd (%) for $C_{15}H_{12}ClNOS_2$: C 55.98, H 3.76, N 4.35; Found: C 55.89, H 3.85, N 4.40.

2-(4-chlorobenzylthio)-6-chlorobenzo[*d*]thiazole (3u) Yellow solid; mp 82-83℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 4.52 (s, 2H), 7.26 (d, *J* = 8.4 Hz, 2H), 7.34-7.37 (m, 3H), 7.67 (d, *J* = 1.2 Hz, 1H), 7.76 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 36.9, 120.7, 122.2, 126.8, 128.9, 130.3, 130.5, 133.7, 134.7, 136.5, 151.6, 166.5; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{14}H_{10}Cl_2NS_2$: 325.9632; found: 325.9629. Elemental analysis calcd (%) for $C_{14}H_9Cl_2NS_2$: C 51.54, H 2.78, N 4.29; Found: C 51.39, H 2.82, N 4.25.

3-(4-chlorobenzyl)-6-chlorobenzo[*d*]thiazole-2(*3H*)-thione (4u) Yellow solid; mp 162-163℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.62 (s, 2H), 6.97 (d, *J* = 8.8 Hz, 1H), 7.22 (d, *J* = 8.4 Hz, 2H), 7.26-

7.31 (m, 3H), 7.48 (d, J = 2.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 48.9, 113.3, 121.2, 127.4, 128.5, 128.8, 129.3, 131.0, 132.5, 134.1, 139.8, 189.9; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{14}H_{10}Cl_2NS_2$: 325.9632; found: 325.9630. Elemental analysis calcd (%) for $C_{14}H_9Cl_2NS_2$: C 51.35, H 2.88, N 4.21; Found: C 51.39, H 2.82, N 4.25.

6-fluoro-2-(1-(4-methoxyphenyl)ethylthio)benzo[*d*]thiazole (3v) White solid; mp 68-69℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.81 (d, J = 6.8 Hz, 3H), 3.77 (s, 3H), 5.09 (q, J = 6.8 Hz, 1H), 6.85 (d, J = 8.8 Hz, 2H), 7.12 (dt, J = 2.0, 8.8 Hz, 1H), 7.37-7.39 (m, 3H), 7.81 (dd, J = 4.8, J = 8.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 22.7, 47.4, 55.3, 107.4 (d, $^2J_{C\text{-}F}$ = 27 Hz), 114.1, 114.3 (d, $^2J_{C\text{-}F}$ = 24 Hz), 122.4 (d, $^3J_{C\text{-}F}$ = 9 Hz), 128.6, 133.6, 136.5 (d, $^3J_{C\text{-}F}$ = 11 Hz), 149.9, 159.2, 159.9 (d, $^1J_{C\text{-}F}$ = 243 Hz), 165.5; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{16}H_{15}FNOS_2$: 320.0579; found: 320.0583. Elemental analysis calcd (%) for $C_{16}H_{14}FNOS_2$: C 60.16, H 4.42, N 4.39; Found: C 60.25, H 4.45, N 4.43.

6-fluoro-3-(1-(4-methoxyphenyl)ethyl)benzo[*d*]thiazole-2(*3H*)-thione (4v) White solid; mp 120-121℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.87 (d, J = 7.2 Hz, 3H), 3.79 (s, 3H), 6.80-6.85 (m, 2H), 6.87 (d, J = 8.4 Hz, 2H), 7.11 (q, J = 7.2 Hz, 1H), 7.16 (d, J = 7.2 Hz, 1H), 7.22 (d, J = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.7, 54.5, 54.8, 107.7 (d, $^2J_{C\text{-}F}$ = 27 Hz), 113.3 (d, $^2J_{C\text{-}F}$ = 24 Hz), 113.9, 114.5 (d, $^3J_{C\text{-}F}$ = 9 Hz), 127.1, 128.2 (d, $^3J_{C\text{-}F}$ = 10 Hz), 129.2, 135.9, 158.7, 159.2 (d, $^1J_{C\text{-}F}$ = 245Hz), 189.1; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{16}H_{15}FNOS_2$: 320.0579; found: 320.0580. Elemental analysis calcd (%) for $C_{16}H_{14}FNOS_2$: C 60.16, H 4.42, N 4.39; Found: C 60.20, H 4.38, N 4.45. Crystal data and structure refinement for **4v** (CCDC: 956821): Empirical formula: $C_{16}H_{14}FNOS_2$ (Formula weight: 319.40); Temperature: 298(2) K; Wavelength: 0.71073 A; Crystal system, space group Monoclinic, P 21/c; Unit cell dimensions: a = 7.698(3) A, α = 90°, b = 8.149(4) A, β = 92.030(8)°, c = 23.607(10) A, γ = 90°, Volume: 1480.0(11)A^3; Z = 4, Calculated density: 1.433Mg/m^3; Absorption coefficient: 0.368 mm^{-1}; F(000): 664; Crystal size: 0.23 x 0.21 x 0.15 mm; Theta range for data collection: 1.73 to 25.10 deg.; Limiting indices: -9<=h<=9, -8<=k<=9, -28<=l<=27; Reflections collected /unique: 6527/2586 [R(int) = 0.0404]; Completeness to theta = 25.10: 97.9 %; Absorption correction: Semi-empirical from equivalents; Max. and min. transmission: 0.9469 and 0.9202. Refinement method: Full-matrix least-squares on F^2. Data / restraints / parameters: 2586 / 0 / 193; Goodness-of-fit on F^2: 1.092, Final R indices [I>2σ (I)]: *R1* = 0.1140, *ωR2* = 0.2717. R indices (all data): *R1* = 0.1202, *ωR2* = 0.2753. Extinction coefficient 0.016(5) .Largest diff. peak and hole: 0.493 and -0.472 e.A^{-3}

2-(4-ethylbenzene)-6-fluorobenzo[*d*]thiazole (3w) White solid; mp 102-103℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.31 (s, 3H), 4.52 (s, 2H), 7.09-7.14 (m, 3H), 7.30 (d, J = 7.2 Hz, 2H), 7.38 (d, J = 8.0 Hz, 1H), 7.79 (dd, J = 4.4, 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.1, 37.6, 107.5 (d, $^2J_{C\text{-}F}$ = 27 Hz), 114.4 (d, $^2J_{C\text{-}F}$ = 24 Hz), 122.2 (d, $^3J_{C\text{-}F}$ = 9 Hz), 129.1, 129.5, 132.9, 136.2 (d, $^3J_{C\text{-}F}$ = 11 Hz), 137.6, 149.8, 159.8 (d, $^1J_{C\text{-}F}$ = 243 Hz), 166.1; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{13}FNS_2$: 290.0473; found: 290.0479. Elemental analysis calcd (%) for $C_{15}H_{12}FNS_2$: C 62.26, H 4.18, N 4.84; Found: C 62.41, H 4.10, N 4.79.

3-(4-ethylbenzene)-6-fluorobenzo[*d*]thiazole-2(*3H*)-thione (4w) White solid; mp 164-165℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.30 (s, 3H), 5.62 (s, 2H), 6.99-7.04 (m, 2H), 7.12 (d, J = 7.6 Hz, 2H), 7.17-7.21 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.1, 49.5, 108.4 (d, $^2J_{C\text{-}F}$ = 26 Hz), 113.6 (d, $^3J_{C\text{-}F}$ = 8 Hz), 114.5 (d, $^2J_{C\text{-}F}$ = 24 Hz), 127.1, 128.7 (d, $^3J_{C\text{-}F}$ = 7 Hz), 128.8, 129.7, 131.0, 137.9, 160.2 (d, $^1J_{C\text{-}F}$ = 244 Hz), 189.8; HRMS (ESI): *m/z* $[M+H]^+$ calcd for $C_{15}H_{13}FNS_2$: 290.0473; found: 290.0477. Elemental analysis calcd (%) for $C_{15}H_{12}FNS_2$: C 62.26, H 4.18, N 4.84; Found: C 62.36, H 4.15, N 4.88.

Acknowledgments

Financial Supported from National Natural Science Foundation of China (21002042), Jiangxi Educational Committee (GJJ12169), and the Project of Jiangxi Youth Scientist (20122BCB23012) is gratefully acknowledged.

† Electronic Supplementary Information (ESI) available: CIF files for compound **3j** and **4v**. See DOI: 10.1039/b000000x/

Notes and references

[a] *Key Laboratory of Functional Small Organic Molecules, Ministry of Education and College of Chemistry & Chemical Engineering, Jiangxi Normal University, Nanchang, Jiangxi 330022, P. R. China*

[b] *Department of Obstetrics and Gynecology, Jiangxi Provincial people's Hospital, Nanchang, Jiangxi 330006, P. R. China*

1 (a) K. Vera, K. Jan, P. Karel, S. Jirina, D. Hans-Martin and M. Ute, *Med. Chem.,* 2012, **8**, 281; (b) I. Hutchinson, S. A. Jennings, B. R. Vishnuvajjala, A. D. Westwell and M. F. G. Stevens, *J. Med. Chem.,* 2002, **45**, 744; (c) Naya, A.; Kobayashi, K.; Ishikawa, M.; Ohwaki, K.; Saeki, T.; Noguchi, K. and Ohtake, N. *Bioorg. Med. Chem. Lett.,* 2001, **11**, 1219; (d) G. Anton, H. Richard and K, Pavol, *Toxicol. Environ. Chem.,* 1997, **64**, 155; (e) K. Waisser, E. Sidoova, Z. Odlerova, W. Goeckeritz and J. Drsata, *Pharmazie,* 1987, **42**, 536; (f) W. A. Skinner, F. Gualtiere, G. Brody, A. H. Fieldsteel, *J. Med. Chem.*, 1971, **14**, 546; (g) D. L. Garmaise, G. Y. Paris, J. Komlossy, C. H. Chambers and R. C. McCrae, *J. Med. Chem.,* 1969, **12**, 30; (h) A. Burger and S. N. Sawhney, *J. Med. Chem.*, 1968, **11**, 270.

2 (a) M. A. Savolainen and J. Wu. *Org. Lett.* 2013, **15***,* 3802; (b) X.-Q. Chu, R. Jiang, Y. Fang, Z.-Y. Gu, H, Meng, S.-Y. Wang and S.-J. Ji, *Tetrahedron*, 2013, **69**, 1166; (c) H. Wang, L. Wang, J. Shang, X. Li, H. Wang, J. Gui and A. W. Lei, *Chem. Commun.,* 2012, **48**, 76; (d) C. Dai, Z. Xu, F. Huang, Z. Yu and Y.-F. Gao, *J. Org. Chem.,* 2012, **77**, 4414; (e) S. Ranjit, R. Lee, D. Heryadi, C. Shen, J. Wu, P. Zhang, K.-W. Huang and X. Liu. *J. Org. Chem.,* 2011, **76**, 8999; (f) L. Shi, X. Liu, H. Zhang, Y. Jiang and D. Ma, *J. Org. Chem.,* 2011, **76**, 4200; (g) F. Chen, C. Shen and D. Yang, *Tetrahedron Lett.,* 2011, **52**, 2128; (h) Y. Riadi, R. Azzalou, S. Lazar, R. Mamouni, M. Haddad, S. Routier and G. Guillaumet, *Tetrahedron Lett.,* 2011, **52**, 3492; (i) D. S. Bose and M. Idrees, *Synthesis,* 2010, 398; (j) M. Teruaki, K. Kiichi and M. Yuji, *Heterocycles*, 2010, **80**, 63; (k) P. Saha, T. Ramana, N. Purkait, M. Ali, R. Paul and T. Punniyamurthy, *J. Org. Chem.,* 2009, **74**, 8719; (l) X. Fei, Y. Gu, Y. Ban, Z. Liu and B. Zhang, *Bioorg. Med. Chem.,* 2009, 17, 585; (m) T. Itoh. and T. Mase, *Org. Lett.* 2007, **9**, 3687; (n) G. Evindar and R. A. Batey, *J. Org. Chem.,* 2006, **71**, 1802.

3 (a) S. Oae, *Organic Sulfur Chemistry: Structure and Mechanism*, CRC Press, Boca Raton, Fl, 1991; (b) R. J. Cremlyn, *An Introduction to Organo-Sulfur Chemistry*, Wiley & Sons, New York, 1996; (c) J. F. Hartwig, *Angew. Chem. Int. Ed.,* 1998, **37**, 2046; (d) J. P. Wolfe, S. Wagaw, J.-F. Marcoux and S. L.Buchwald, *Acc. Chem. Res.,* 1998, **31**, 805; (e) J. Hassan, M. Sévignon, C. Gozzi, E. Schulz and M. Lemaire, *Chem. Rev*., 2002, **102**, 1359.

4 (a) M. A. Fernández-Rodríguez, Q. Shen and J. F. Hartwig, *J. Am. Chem. Soc.,* 2006, **128**, 2180; (b) Y.-C. Wong, T. T. Jayanth and C.-H. Cheng, *Org. Lett.,* 2006, **8**, 5613; (c) A. Correa, M. Carril and C. Bolm, *Angew. Chem. Int. Ed.,* 2008, **47**, 2880; (d) B. Basu, B. Mandal, S. Das and S. Kundu, *Tetrahedron Lett.,* 2009, **50**, 5523; (e) S. Murru, H. Ghosh, S. K. Sahoo and B. K. Patel, *Org. Lett.,* 2009, **11**, 4254; (f) B. Basu, S. Paul and A. K. Nanda, *Green Chem.,* 2010, **12**, 767.

5 J. Barluenga and C. Valdés, *Angew. Chem., Int. Ed.,* 2011, **50**, 7486.

6 (a) J. Barluenga, P. Moriel, C. Valdés and F. Aznar, *Angew. Chem., Int. Ed.* 2007, **46**, 5587; (b) J. Barluenga, M. Tomas-Gamasa, P. Moriel, F. Aznar and C. Valdés, *Chem.–Eur. J.,* 2008, **14**, 4792; (c) W.-Y. Yu, Y.-T. Tsoi, Z. Zhou and A. S. C. Chan, *Org. Lett.,* 2008, **11**, 469; (d) Q. Xiao, J. Ma, Y. Yang, Y. Zhang and J. Wang, *Org. Lett.,* 2009, **11**, 4732; (e) J. Barluenga, M. Escribano, P. Moriel, F. Aznar and C. Valdes, *Chem.–Eur. J.,* 2009, **15**, 13291; (f) J. Barluenga, M. Tomas-Gamasa, F. Aznar, C. Valdés, *Chem.–Eur. J.,* 2010, **16**, 12801; (g) X. Zhao, J. Jing, K. Lu, Y. Zhang and J. Wang, *Chem. Commun.,* 2010, **46**, 1724; (h) X. Zhao, G. Wu, C. Yan, K. Lu, H. Li, Y. Zhang and J. Wang, *Org. Lett.,* 2010, **12**, 5580; (i) L. Zhou, F. Ye, Y. Zhang and J. Wang, *J. Am. Chem. Soc.,* 2010, **132**, 13590; (j) J. Barluenga, L. Florentino, F. Aznar and C. Valdes, *Org. Lett.,* 2011, **13**, 510; (k) X. Zhao, G.Wu, Y. Zhang, J. Wang, *J. Am. Chem. Soc.,* 2011, **133**, 3296; (l) L. Zhou, F. Ye, J. Ma, Y. Zhang and J. Wang, *Angew. Chem., Int. Ed.* 2011, **50**, 3510; (m) W. Shi, C. Liu and A. Lei, Chem. *Soc. Rev.* 2011, **40**, 2761; (n) X. Li, Y. Feng, L. Lin and G. Zou, *J. Org. Chem.,* 2012, **77**, 10991; (o) F. Ye, X. Ma, Q. Xiao, H. Li, Y. Zhang and J. Wang, *J. Am. Chem. Soc.,* 2012, **134**, 5742; (p) L. Zhou, F. Ye, Y. Zhang and J. Wang, *Org. Lett.,* 2012, **14**, 922.

7 (a) A. Hamze, B. Tréguier, J.-D. Brion and M. Alami, *Org. Biomol. Chem.,* 2011, **9**, 6200; (b) T. Xiao, X. Dong and L. Zhou, *Org. Biomol. Chem.,* 2013, **11**, 1490.

8 (a) X.-W. Feng, J. Wang, J. Zhang, J. Yang, N. Wang and X.-Q. Yu, *Org. Lett.,* 2010, **12**, 4408; (b) J. Barluenga, M. Tomás-Gamasa, F. Aznar and C. Valdés, *Eur. J. Org. Chem.,* 2011, 1520.

9 (a) J. Barluenga, M. Tomás-Gamasa, F. Aznar and C. Valdés, *Nat. Chem.,* 2009, **1**, 433; (b) J. Barluenga, M. Tomás-Gamasa, F. Aznar and C. Valdés, *Angew. Chem. Int. Ed.,* 2010, **49**, 4993; (c) Q. Ding, B. Cao, J. Yuan, X. Liu and Y. Peng, *Org. Biomol. Chem.,* 2011, **9**, 748; (d) Y. Xia, P. Qu, Z. Liu, R. Ge, Q. Xiao, Y. Zhang and J. Wang, *Angew. Chem. Int. Ed.,* 2013, **52**, 2543; (e) J.-B. Liu, H. Yan and G. Lu, *Tetrahedron Lett.* 2013, **54**, 891; (f) Q. Sha and Y.-Y. Wei, *Org. Biomol. Chem.,* 2013, **11**, 5615.

Efficient construction of C-S and C-N bond *via* metal-free reductive coupling of *N*-tosylhydrazones with benzo[*d*]thiazole-2-thiol

Yuqing Lin,[a] Puying Luo,*[b] Qiang Zheng,[a] Yumei Liu,[a] Xiaoyan Sang,[a] and Qiuping Ding*[a]

Abstract: An efficient procedure for the synthesis of diverse benzo[*d*]thiazole derivatives has been developed *via* metal-free reductive coupling of *N*-tosylhydrazones with benzo[*d*]thiazole-2-thiol. 2-Thio-substituted benzothiazoles are useful synthetic intermediates and promising biologically active compounds. The present process tolerates a wide range of substrates with high efficiency and moderate selectivity.

Graphical Abstract: