



## A novel method for the bromination of thiophenes

Pavel Arsenyan\*, Edgars Paegle, Sergey Belyakov

Latvian Institute of Organic Synthesis, Aizkraukles 21, LV-1006 Riga, Latvia

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### ABSTRACT

A novel, fast and convenient method for the bromination of thiophenes and oligothiophenes with *N*-bromosuccinimide (NBS) using ultrasonic irradiation is elaborated. The yield of bromothiophenes strongly depends on the initial thiophene structure and nature of the solvent.

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The number of  $\pi$ -conjugated oligomers and polymers as advanced materials for electronic and optical applications has increased rapidly. Thiophene-based oligomers belong to one of the most carefully studied types of materials and have received a great deal of attention for both fundamental and practical reasons. Oligothiophenes are among the most prominent organic semiconductors.<sup>1</sup> The interest in dibromobithiophene derivatives stems from the fact that they are useful synthetic intermediates for the preparation of various types of organic compounds. According to the literature data, 2,2'-bithiophene reacts with *N*-bromosuccinimide in various solvents such as DMF, or a mixture of chloroform and acetic acid, to yield 5,5'-dibromo-2,2'-bithiophene in good yield.<sup>2</sup> Typically, this reaction takes from one hour to one day. Also, dibromobithiophene can be obtained by treating the initial bithiophene with *n*-butyllithium at  $-78$  °C and then quenching with bromine.<sup>3</sup>

Our previous experience with oligothiophene derivatives<sup>4</sup> inspired us to investigate the bromination of various thiophenes with *N*-bromosuccinimide under ultrasound irradiation.

Motivated by the importance of developing fast and facile methods, we started our investigation with solvent optimization. 2,2'-Bithiophene was chosen as a model compound in the reaction with NBS (Scheme 1). Reaction of bithiophene with 2 equiv of NBS was carried out in ethyl acetate, acetone, 1,4-dioxane, toluene, dimethoxyethane (DME) and dichloromethane during 3 min of ultrasonic irradiation at rt. According to our experimental data (Table 1), the best results were obtained in ethyl acetate, 1,4-dioxane and dichloromethane. Ethyl acetate was selected as the solvent for further

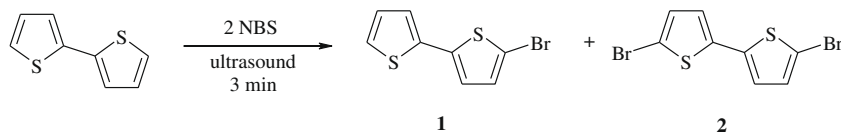
investigations, due to its lower toxicity compared with the other solvents.

Treatment of thiophene with 2 equiv of *N*-bromosuccinimide led to the formation of 2,5-dibromothiophene (**3**) in excellent yield (98%) after 3 min of ultrasonic irradiation (Table 2, entry 1). 2,5-Dibromofuran (**4**) was obtained in good yield under the same reaction conditions (entry 2, 86%). It should be noted that an alternative way to produce **4** involves the treatment of furan with bromine in dimethylformamide to afford the product in 48% yield.<sup>5a</sup> Reaction of 2-acetylthiophene with NBS gave the corresponding 5-bromo-2-acetylthiophene<sup>5b</sup> (**5**) in excellent yield (entry 3, 99%). However, treatment of 3-phenylthiophene with two equivalents of NBS led to the formation of 2-bromo-4-phenylthiophene<sup>5c</sup> (**6**) as a single product even after 15 min of irradiation (entry 4, 88%).

$\beta$ -Substituted bithiophenes have attracted significant attention as building blocks for the construction of oligothiophene chains with the aim of increasing oligomer solubility. It is especially difficult to add bromine atoms to silylthiophenes, due to the simultaneous desilylation, which usually occurs during this process.<sup>4e,6</sup> The reported procedure involves a quite complicated multi-step method, which proceeds via reaction of the initial 3-silylthiophene with butyllithium or LDA in THF at  $-30$  °C, followed by the addition of very toxic cyanogen bromide to obtain the desired 2-bromo-3-silylthiophene.<sup>7</sup> Surprisingly, using our method 4,4'-bis(trimethylsilyl)-2,2'-bithiophene reacted successfully with 2 equiv of *N*-bromosuccinimide to afford the desired 5,5'-dibromo derivative **7**<sup>8</sup> in very good yield (entry 5, 81%). The structure of **7** was confirmed unambiguously by X-ray diffraction (Fig. 1).<sup>9</sup> Crystals of 5,5'-dibromo-4,4'-bis(trimethylsilyl)-2,2'-bithiophene (**7**) suitable for X-ray analysis were obtained by slow crystallization from ethanol. The molecular structure of **7** is planar due to the extended conjugated system.

\* Corresponding author. Tel.: +371 29849464.

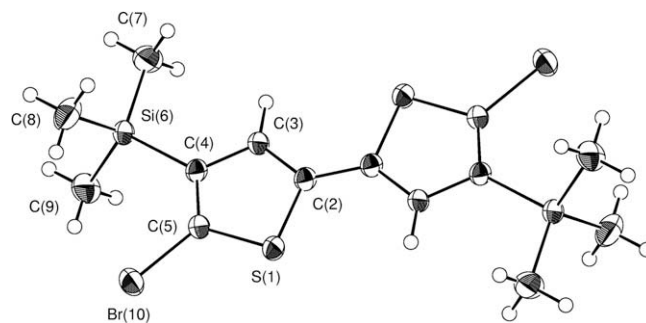
E-mail address: [pavel.arsenyan@lycos.com](mailto:pavel.arsenyan@lycos.com) (P. Arsenyan).



**Scheme 1.** Ultrasonic bromination of 2,2'-bithiophene.

**Table 1**  
Ultrasonic bromination of 2,2'-bithiophene in different solvents

Entry	Solvent	Conversion (%)	
		1	2
1	EtOAc	0	97
2	Acetone	7	93
3	1,4-Dioxane	0	97
4	Toluene	15	85
5	DME	7	93
6	CH <sub>2</sub> Cl <sub>2</sub>	0	98



**Figure 1.** ORTEP molecular structure of 5,5'-dibromo-4,4'-bis(trimethylsilyl)-2,2'-bithiophene (7).

**Table 2**  
Ultrasonic bromination of various thiophenes using NBS

Entry	Substrate	NBS (equiv)	Product	Yield (%)
1		2		98
2		2		86
3		1		99
4		2		88
5		2		81
6		2		90
7		2		88

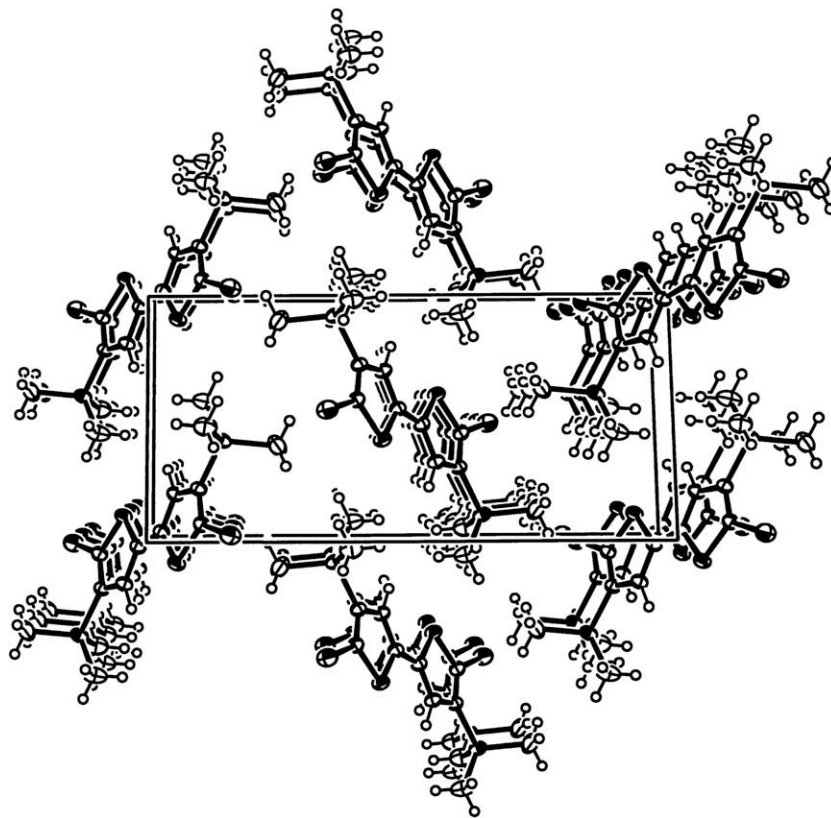


Figure 2. Molecular packing of **7** viewed along crystallographic axis *x*.

The average length of the S–C bonds is 1.730(2) Å, the valence angle C–S–C is equal to 90.9(1)°. The molecules **7** form stacks along the crystallographic axis *x* (Fig. 2). The distance between molecular planes in these stacks is 3.582 Å.

A very useful oligothiophene synthon was prepared by treatment of 4,4'-bis(trimethylsilylmethyl)-2,2'-bithiophene with NBS for 10 min under ultrasonic irradiation to yield the corresponding dibromo derivative **8**<sup>10</sup> (90%). Finally,  $\alpha$ -terthiophene was easily converted into 5,5''-dibromo-[2,2';5',2'']terthiophene (**9**)<sup>11</sup> in only 10 min in very good yield (88%).

In summary, extremely mild and convenient conditions (NBS, ethyl acetate, rt, ultrasonic irradiation) have been utilized for the bromination of thiophenes in very good to excellent yields.

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- A mixture of 4,4'-bis(trimethylsilyl)-2,2'-bithiophene (0.62 g, 2.0 mmol) and N-bromosuccinimide (0.712 g, 4.0 mmol) in EtOAc (30 mL) was subjected to ultrasonic irradiation (Grant ultrasonic bath XB2) for 10 min at rt. The organic phase was washed with brine and dried over Na<sub>2</sub>SO<sub>4</sub>. After 2 h, the organic phase was filtered through a Celite pad. The desired product **7** was obtained after solvent evaporation in good purity. 5,5'-Dibromo-4,4'-bis(trimethylsilyl)-2,2'-bithiophene (**7**): 81% yield; MS, *m/z* 468 (M<sup>+</sup>). <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>/TMS)  $\delta$  (ppm): 0.36 (s, 2Me<sub>3</sub>Si, 18H), 6.81 (s, 2CH, 2H); <sup>13</sup>C NMR (100.6 MHz, CDCl<sub>3</sub>/TMS)  $\delta$  (ppm): -0.9, 117.7, 129.6, 137.2, 142.4. Anal. Calcd for C<sub>14</sub>H<sub>20</sub>Br<sub>2</sub>S<sub>2</sub>Si<sub>2</sub>: C, 35.90; H, 4.30; S, 13.69. Found: C, 35.77; H, 4.18; S, 13.65.
- X-ray diffraction data were collected on a Nonius KappaCCD diffractometer using graphitic monochromated Mo K $\alpha$  radiation ( $\lambda = 0.71073$  Å). All non-hydrogen atoms were refined anisotropically. Crystal data for **7**: C<sub>14</sub>H<sub>20</sub>Br<sub>2</sub>S<sub>2</sub>Si<sub>2</sub>, monoclinic, *a* = 6.7327(2), *b* = 17.6191(3), *c* = 8.8717(7) Å,  $\beta = 110.700(2)^\circ$ ; *V* = 984.46(9) Å<sup>3</sup>, *Z* = 2,  $\mu = 4.44$  mm<sup>-1</sup>, *D*<sub>calcd</sub> = 1.580 g cm<sup>-3</sup>; space group is *P2<sub>1</sub>/n*. A total of 2716 independent reflection intensities ( $2\theta_{\max} = 59^\circ$ ) were collected at room temperature. For structure refinement, 2154 reflections with *I*  $\geq 3\sigma(I)$  were used. The final *R*-factor is 0.038. CCDC deposition number is 707646. The crystal structure of **7** was solved by direct methods and refined by full-matrix least squares. (a) Altomare, A.; Burla, M. C.; Camalli, M.; Casciaro, G. L.; Giacovazzo, C.; Guagliardi, A.; Moliterni, A. G. G.; Polidori, G.; Spagna, R. *J. Appl. Crystallogr.* **1999**, *32*, 115–119; (b) Maskay, S.; Gilmore, C. J.; Edwards, C.

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10. 5,5'-Dibromo-4,4'-bis(trimethylsilylmethyl)-2,2'-bithiophene (**8**): 90% yield; MS,  $m/z$  481 ( $M^+ - Me$ ).  $^1H$  NMR (400 MHz,  $CDCl_3/TMS$ )  $\delta$  (ppm): 0.06 (s, 2Me<sub>3</sub>Si, 18H), 2.03 (s, 2CH<sub>2</sub>, 4H), 6.62 (s, 2CH, 2H);  $^{13}C$  NMR (100.6 MHz,  $CDCl_3/TMS$ )  $\delta$  (ppm): -1.4, 20.7, 105.1, 124.4, 135.7, 140.5. Anal. Calcd for C<sub>16</sub>H<sub>24</sub>Br<sub>2</sub>S<sub>2</sub>Si<sub>2</sub>: C, 38.71; H, 4.87; S, 12.92. Found: C, 38.62; H, 4.74; S, 13.04.
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