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SELECTIVE HALOGEN DANCE REACTIONS AT 5,5'-DIBROMO-2,2'-BITHIOPHENE

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Abstract – Selective single and double halogen migrations were achieved at 5,5'-dibromo-2,2'-bithiophene by varying the amount of lithiation reagent, and a number of tri- and tetrasubstituted bithiophenes was obtained by quenching the lithio intermediates with various electrophiles. Some of the mono-rearranged products were subjected to a second migration in order to introduce two different substituents. Finally, the potential of the resulting compounds to undergo lithium-induced ring opening reactions was demonstrated on a few examples.

Dedicated to Prof. Ryoji Noyori on the occasion of his 70th birthday

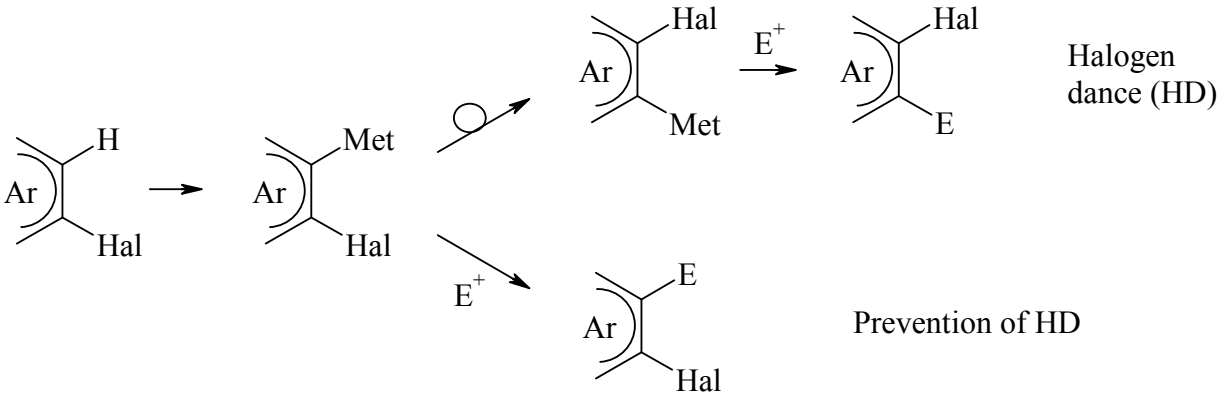
INTRODUCTION

The term "halogen dance" (HD, also known as halogen migration or scrambling) refers to a reaction of a (hetero)aromatic system, during which a halogen atom changes its position under the influence of a base. When first observed, it was regarded as an unexpected side reaction without any preparative usefulness.[1] In the meantime, its mechanism is well understood and a large number of synthetic applications has been developed, mostly using a lithium dialkylamide as base and quenching the final lithio intermediate with an electrophile in order to introduce an additional substituent.[2]

Our own work in this field started with migrations at bromothiophenes and –furans, providing access to several series of trisubstituted derivatives.[3] In the present paper we extend the HD methodology to brominated 2,2'-bithiophenes, a class of compounds with numerous potential applications, e.g. synthesis of polythiophenes and highly conjugated building blocks.

RESULTS AND DISCUSSION

In general, a halogen dance reaction may take place when a halogenated aromatic system is metalated in a way that the resulting substitution pattern is not the thermodynamically most stable one. If in such a case the metalated species and the starting material are present together in the reaction mixture, a cascade of metal-halogen exchange steps can take place leading to the final, most stable intermediate. This in turn can then be quenched by an electrophile to form the final product. In some cases the reaction can also be conducted in a way that prevents the transmetalation cascade and thus leads to a product with the original halogen pattern retained, although this course of the reaction is usually more difficult to achieve.



Scheme 1. General pathways for halogen dance and its prevention.

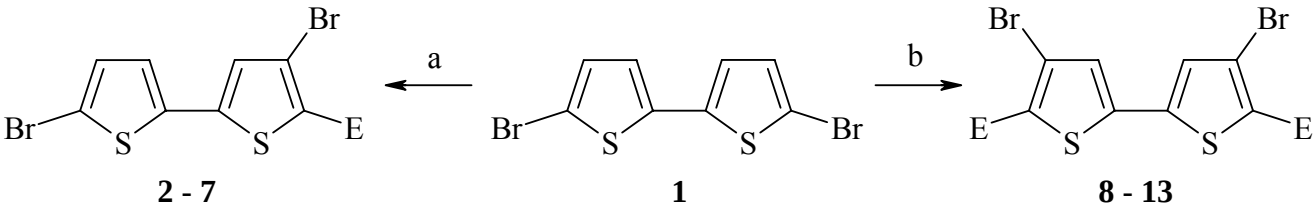
5,5'-Dibromo-2,2'-bithiophene (**1**) fulfills the above requirements in a way similar to 2,5-dibromo-thiophene, the halogen migration of which has already been studied.[4] The principal prerequisites thus being met, the crucial question for **1** to serve as a useful substrate for selective HD reactions is: to what extent does the metalation of one thiophene ring influence the reactivity of the other?

Initial experiments were carried out by rapid addition of **1** to one equivalent of LDA, a method which in many cases provides quick metalation, but also sufficient contact between the starting material and the primary lithiated species for the halogen dance to proceed smoothly. However, in this case varying mixtures of single (**3**) and double (**9**) rearrangement products together with some remaining **1** were obtained after quenching with TMSCl. Therefore we changed to a method that allows much better control of the lithiation process: the slow addition of a pre-formed LDA solution to the substrate, sometimes referred to as "inverse addition". By using 1.25 equiv. of LDA at -20 °C it was indeed possible to obtain rearrangement at only one ring almost exclusively, together with less than 5 % of the double migration product, which could easily be removed during the purification step. Using this procedure a number of trisubstituted 2,2'-bithiophene derivatives was synthesized (see Scheme 2, Table 1).

However it should be pointed out that to achieve this high level of selectivity very careful observance of the protocol is absolutely necessary. As the reaction starts with a suspension of **1** instead of a solution, it is of

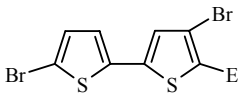
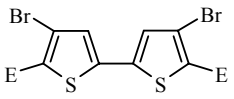
particular importance to keep the addition of LDA slow, especially from the beginning of the reaction until all of **1** has dissolved, otherwise a local excess of the metalation agent might arise and trigger the second rearrangement step. Also any excess of diisopropylamine should be avoided during the preparation of LDA, as this seriously interferes with the initial lithiation step. Finally it proved necessary to adjust the excess of LDA to the actual scale on which the reaction is performed: while the mentioned amount of 1.25 LDA was optimal for 1 g of **1** (~ 3 mmol), best results for reactions on a 5-fold scale were obtained with only 1.1 equivalents. This can be attributed to the relatively higher losses occurring when the external preparation and especially the transfer of LDA is carried out with small amounts.

As the protocol for single rearrangement also allows the gradual addition of a larger extent of LDA, we also tried to employ it for the double migration reaction by stepwise increasing the amount of the lithiation reagent. By applying 2.5 equivalents of LDA complete conversion to the double rearranged pattern was obtained, and again a number of products were synthesized by quenching with various electrophiles (see Scheme 2, Table 1). Having in hand the results for single and double migration, the initial question for the influence of the first metalation step on the bithiophene system can be answered: the presence of a lithium atom in one thiophene ring does reduce the reactivity of the second ring towards metalation considerably, otherwise a selective single rearrangement would not be possible; however the second lithiation is still possible by applying a significant excess of reagent.

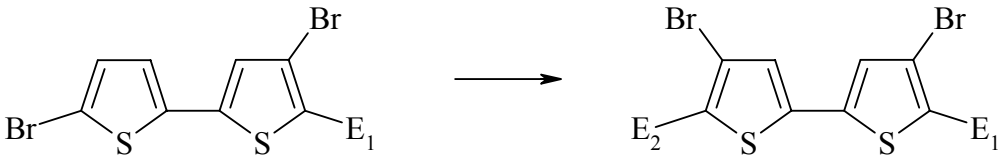


Scheme 2. Single and double halogen dance at **1**: (a) 1.25 LDA, E^+; (b) 2.5 LDA, E^+.

Table 1. Single and double rearrangement products of **1**.

Electrophile	E				
		Compd	Yield (%)	Compd	Yield (%)
MeOH	-H	**2**	68	**8**	74
TMS-Cl	-TMS	**3**	89	**9**	79
TBDMS-Cl	-TBDMS	**4**	91	**10**	71
MeI	-Me	**5**	76	**11**	83
MeSSMe	-SMe	**6**	51	**12**	61
DMF	-CHO	**7**	63	**13**	67

Having synthesized double rearrangement products with two identical substituents, our next effort was towards compounds with two different residues by subjecting some of the single-migrated substances to a second, independent migration step. As the first substituent of potential substrates for such a reaction obviously has to be inert towards lithiation conditions, our experiments started with the trimethylsilyl derivative **3**. However, the TMS group turned out to be unstable in the presence of some of the aryl lithium compounds occurring in the rearrangement reaction. Therefore its TBDMS analogue **4** was used, and by applying a similar method as above, the desired mixed-substituted bithiophenes were obtained, although in this case a more classical halogen dance protocol (rapid addition of the substrate to 0.95 equiv. of LDA, stirring for 15 minutes and completing the reaction with another 0.25 equiv. of LDA) provided better yields and purity. Despite some doubts concerning side chain metalation, we also applied the procedure to the methyl derivative **5**, and succeeded in the synthesis of another series of tetrasubstituted bithiophenes (see Scheme 3, Table 2).

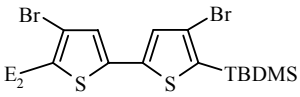
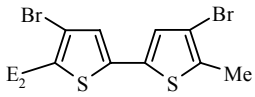


4, E_1 = TBDMS
5, E_1 = Me

14 - 17, E_1 = TBDMS
18 - 21, E_1 = Me

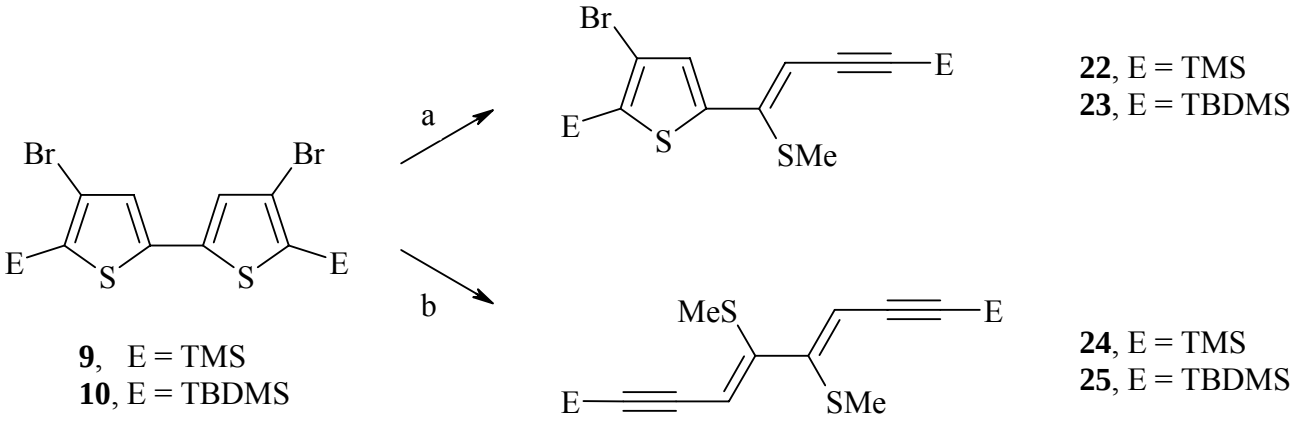
Scheme 3. Second migration reaction at **4** and **5**.

Table 2. Unsymmetrically tetrasubstituted 2,2'-bithiophenes.

Electrophile	E_2				
		Compd	Yield (%)	Compd	Yield (%)
MeOH	-H	-		**18**	81
TMS-Cl	-TMS	**14**	53	**19**	64
MeI	-Me	**15**	45	-	
MeSSMe	-SMe	**16**	80	**20**	70
DMF	-CHO	**17**	53	**21**	70

Finally, a few of the silyl-substituted bithiophenes were subjected to a lithium-induced ring opening reaction. By carefully controlling the amount of BuLi used, it was possible to obtain cleavage of one or both thiophene rings in a selective manner. Quenching the thiolate anion formed by the ring opening with

methyl iodide then provided access to compounds of potential interest as highly unsaturated building blocks (see Scheme 4).



Scheme 4. Ring opening reactions: (a) 1.0 BuLi, MeI; (b) 2.1 BuLi, MeI.

In conclusion, we have shown that selective single and double halogen dance reactions at 5,5'-dibromo-2,2'-bithiophene can be achieved using an "inverse addition" protocol by varying the amount of metalating agent. Some of the mono-rearranged products were successfully subjected to a second migration step. In total, four series of mostly novel tri- and tetrasubstituted 2,2'-bithiophene derivatives were synthesized by quenching the lithio intermediates with various electrophiles. Finally the suitability of the obtained compounds for ring-opening reactions was demonstrated on a few examples.

EXPERIMENTAL

General. Chemicals were purchased from commercial suppliers and purified before use. All solvents were distilled prior to use. Dry diethyl ether and dry tetrahydrofuran were obtained by distillation over sodium/benzophenone. All reactions were carried out under an atmosphere of dry nitrogen. Flash column chromatography was performed on silica gel 60 from Merck (40 – 63 μm). Melting points were determined using a Kofler-type Leica Galen III micro-hot-stage microscope and are uncorrected. Elemental analyses were carried out in the Microanalytical Laboratory, University of Vienna. NMR spectra were recorded from solutions in $CDCl_3$ on a Bruker AC-200 spectrometer (200 MHz for ^1H, 50 MHz for ^{13}C) and chemical shifts are reported in ppm using Me_4Si as internal standard. 5,5'-Dibromo-2,2'-bithiophene (**1**) was synthesized via Ni-catalyzed homo-coupling of 2-bromothiophene[5] and bromination of the resulting 2,2'bithiophene using NBS.[6] The synthesis of compounds **8** and **13** has previously been described by other methods.[7]

General procedure for single halogen migration. Compounds 2-7. *n*-Butyllithium (3.86 mmol) was

added to a solution of diisopropylamine (0.39 g, 3.86 mmol) in dry THF (20 mL) at -40 °C and stirred for 15 min. This solution was then slowly transferred via a Teflon cannula into another flask containing a suspension of **1** (1 g, 3.09 mmol) in dry THF (10 mL) at -20 °C over a period of 10 min and stirred for another 15 min. At the same temperature a solution of the appropriate electrophile (4 mmol) in dry THF (5 mL) was added. The mixture was allowed to reach 0 °C, poured onto water and extracted with Et_2O. The combined organic layers were washed with water, dried over Na_2SO_4 and evaporated.

4,5'-Dibromo-2,2'-bithiophene (2). Instead of an electrophile, MeOH (1 mL) was added to the reaction mixture. The crude product was triturated with dry MeOH to yield 0.68 g (68%) of **2** as yellow crystals. Mp 72-74 °C. ^{1}H-NMR: δ = 7.12 (d, 1H, J = 1.6 Hz), 7.01 (d, 1H, J = 1.6 Hz), 6.98 (d, 1H, J = 3.8 Hz), 6.91 (d, 1H, J = 3.8 Hz) ppm. ^{13}C-NMR: δ = 137.5 (s), 137.3 (s), 130.7 (d), 126.3 (d), 124.5 (d), 121.8 (d), 112.1 (s), 110.4 (s) ppm. Anal. Calcd for $C_8H_4Br_2S_2$ (324.06): C 29.65; H 1.24. Found: C 29.48; H 1.05.

4,5'-Dibromo-5-trimethylsilyl-2,2'-bithiophene (3). Chlorotrimethylsilane (0.43 g) was used as electrophile. The crude product was purified by bulb-to-bulb distillation to yield 1.09 g (89%) of **3** as yellow oil. Bp 90-95 °C / 0.02 torr. ^{1}H-NMR: δ = 7.09 (s, 1H), 6.97 (d, 1H, J = 3.8 Hz), 6.91 (d, 1H, J = 3.8 Hz), 0.42 (s, 9H) ppm. ^{13}C-NMR: δ = 141.0 (s), 137.3 (s), 134.0 (s), 130.6 (d), 128.7 (d), 124.2 (d), 117.4 (s), 111.9 (s), -0.8 (q) ppm. Anal. Calcd for $C_{11}H_{12}Br_2S_2Si$ (396.24): C 33.34; H 3.05. Found: C 33.25; H 2.95.

4,5'-Dibromo-5-((1,1-dimethylethyl)dimethylsilyl)-2,2'-bithiophene (4). Chloro-(1,1dimethylethyl)-dimethylsilane (0.6 g) was used as electrophile. The crude product was purified by bulb-to-bulb distillation to yield 1.23 g (91%) of **4** as yellow oil. Bp 110-115 °C / 0.02 torr. ^{1}H-NMR: δ = 7.09 (s, 1H), 6.97 (d, 1H, J = 3.8 Hz), 6.92 (d, 1H, J = 3.8 Hz), 0.99 (s, 9H), 0.41 (s, 6H) ppm. ^{13}C-NMR: δ = 141.4 (s), 137.3 (s), 132.2 (s), 130.7 (d), 129.1 (d), 124.3 (d), 118.0 (s), 112.0 (s), 26.8 (q), 18.2 (s), -0.4 (q) ppm. Anal. Calcd for $C_{14}H_{18}Br_2S_2Si$ (438.32): C 38.36; H 4.14. Found: C 38.63; H 3.93.

4,5'-Dibromo-5-methyl-2,2'-bithiophene (5). Methyl iodide (0.57 g) was used as electrophile. The crude product was recrystallized from dry EtOH to yield 0.79 g (76%) of **5** as yellow crystals. Mp 100-102 °C. ^{1}H-NMR: δ = 6.95 (d, 1H, J = 3.8 Hz), 6.91 (s, 1H), 6.83 (d, 1H, J = 3.8 Hz), 2.37 (s, 3H) ppm. ^{13}C-NMR: δ = 137.7 (s), 133.6 (s), 133.3 (s), 130.5 (d), 126.1 (d), 123.6 (d), 111.2 (s), 109.6 (s), 14.6 (q) ppm. Anal. Calcd for $C_9H_6Br_2S_2$ (338.09): C 31.97; H 1.79. Found: C 32.01; H 1.76.

4,5'-Dibromo-5-methylthio-2,2'-bithiophene (6). Dimethyl disulfide (0.38 g) was used as electrophile. The product was purified by flash chromatography (hexane) to yield 0.58 g (51%) of **6** as yellow oil. TLC: R_f = 0.48 (hexane). ^{1}H-NMR: δ = 6.98-6.93 (m, 2H) 6.86 (d, 1H, J = 3.8 Hz), 2.48 (s, 3H) ppm.

^{13}C-NMR: δ = 137.6 (s), 137.1 (s), 131.9 (s), 130.6 (d), 126.6 (d), 124.2 (d), 115.9 (s), 112.1 (s), 20.3 (q) ppm. Anal. Calcd for $C_9H_6Br_2S_3$ (370.15): C 29.21; H 1.63. Found: C 29.35; H 1.67.

4,5'-Dibromo-2,2'-bithiophene-5-carbaldehyde (7). Dimethyl formamide (0.29 g) was used as electrophile. The crude product was recrystallized from diisopropyl ether to yield 0.69 g (63%) of **7** as yellow crystals. Mp 141-143 °C. ^{1}H-NMR: δ = 9.92 (s, 1H), 7.13-7.07 (m, 2H), 7.05 (d, 1H, J = 3.8 Hz) ppm. ^{13}C-NMR: δ = 182.5 (d), 145.2 (s), 136.2 (s), 134.8 (s), 131.4 (d), 127.4 (d), 126.7 (d), 120.8 (s), 115.2 (s) ppm. Anal. Calcd for $C_9H_4Br_2OS_2$ (352.07): C 30.70; H 1.15. Found: C 30.73; H 0.92.

General procedure for double halogen migration. Compounds 8-13. *n*-Butyllithium (7.73 mmol) was added to a solution of diisopropylamine (0.78 g, 7.73 mmol) in dry THF (20 mL) at -40 °C and stirred for 15 min. This solution was then slowly transferred via a Teflon cannula into another flask containing a suspension of **1** (1 g, 3.09 mmol) in dry THF (10 mL) at -20 °C over a period of 10 min and stirred for another 15 min. At the same temperature a solution of the appropriate electrophile (7.8 mmol) in dry THF (5 mL) was added. The mixture was allowed to reach 0 °C, poured onto water and extracted with Et_2O. The combined organic layers were washed with water, dried over Na_2SO_4 and evaporated.

4,4'-Dibromo-2,2'-bithiophene (8). Instead of an electrophile, MeOH (1 mL) was added to the reaction mixture. The crude product was recrystallized from dry MeOH to yield 0.74 g (74%) of **8** as beige crystals. Mp 121-123 °C. ^{1}H-NMR: δ = 7.15 (d, 2H, J = 1.6 Hz), 7.08 (d, 2H, J = 1.6 Hz) ppm. ^{13}C-NMR: δ = 137.0 (s), 126.6 (d), 122.2 (d), 110.5 (s) ppm. Anal. Calcd for $C_8H_4Br_2S_2$ (324.06): C 29.65; H 1.24. Found: C 29.74; H 1.44.

4,4'-Dibromo-5,5'-bis(trimethylsilyl)-2,2'-bithiophene (9). Chlorotrimethylsilane (0.84 g) was used as electrophile. The crude product was triturated with dry MeOH to yield 1.14 g (79%) of **9** as light-yellow crystals. Mp 110-112 °C. ^{1}H-NMR: δ = 7.15 (s, 2H), 0.41 (s, 18H) ppm. ^{13}C-NMR: δ = 140.6 (s), 134.5 (s), 129.0 (d), 117.5 (s), -0.8 (q) ppm. Anal. Calcd for $C_{14}H_{20}Br_2S_2Si_2$ (468.42): C 35.90; H 4.30. Found: C 35.82; H 4.25.

4,4'-Dibromo-5,5'-bis((1,1-dimethylethyl)dimethylsilyl)-2,2'-bithiophene (10). Chloro-(1,1dimethyl-ethyl)dimethylsilane (1.18 g) was used as electrophile. The crude product was recrystallized from dry EtOH to yield 1.21 g (71%) of **10** as beige crystals. Mp 97-98 °C. ^{1}H-NMR: δ = 7.17 (s, 2H), 0.99 (s, 18H), 0.42 (s, 12H) ppm. ^{13}C-NMR: δ = 140.8 (s), 132.6 (s), 129.3 (d), 117.9 (s), 26.7 (q), 18.1 (s), -4.4 (q) ppm. Anal. Calcd for $C_{20}H_{32}Br_2S_2Si_2$ (552.58): C 43.47; H 5.84. Found: C 43.46; H 5.85.

4,4'-Dibromo-5,5'-dimethyl-2,2'-bithiophene (11). Methyl iodide (1.11 g) was used as electrophile. The crude product was recrystallized from dry MeOH to yield 0.91 g (83%) of **11** as yellow crystals. Mp

110-111 °C. ^{1}H-NMR: δ = 6.90 (s, 2H), 2.38 (s, 6H) ppm. ^{13}C-NMR: δ = 133.3 (2s), 125.7 (d), 109.5 (s), 14.6 (q) ppm. Anal. Calcd for $C_{10}H_8Br_2S_2$ (352.11): C 34.11; H 2.29. Found: C 33.92; H 2.12.

4,4'-Dibromo-5,5'-bis(methylthio)-2,2'-bithiophene (12). Dimethyl disulfide (0.73 g) was used as electrophile. The crude product was recrystallized from dry MeOH to yield 0.78 g (61%) of **12** as yellow crystals. Mp 90-92 °C. ^{1}H-NMR: δ = 7.01 (s, 2H), 2.50 (s, 6H) ppm. ^{13}C-NMR: δ = 136.8 (s), 132.8 (s), 126.8 (d), 115.6 (s), 20.2 (q) ppm. Anal. Calcd for $C_{10}H_8Br_2S_4$ (416.25): C 28.86; H 1.94. Found: C 28.71; H 1.71.

4,4'-Dibromo-2,2'-bithiophene-5,5'-dicarbaldehyde (13). DMF (0.57 g) was used as electrophile. The crude product was recrystallized from $CHCl_3$ to yield 0.78 g (67%) of **13** as yellow crystals. Mp 258-260 °C. ^{1}H-NMR: δ = 9.89 (s, 2H), 7.90 (s, 2H) ppm. ^{13}C-NMR: δ = 183.1 (d), 142.1 (s), 136.8 (s), 131.3 (d), 120.7 (s) ppm. Anal. Calcd for $C_{10}H_4Br_2O_2S_2$ (380.08): C 31.60; H 1.06. Found: C 31.54; H 0.90.

General procedure for second halogen migration at 4. Compounds 14-17. *n*-Butyllithium (2.17 mmol) was added to a solution of diisopropylamine (0.22 g, 2.17 mmol) in dry THF (20 mL) at -30 °C and stirred for 15 min. Then a solution of **4** (1 g, 2.28 mmol) in dry THF (5 mL) was added quickly and the mixture stirred for 15 min at -20 °C. Diisopropylamine (0.06 g, 0.57 mmol) dissolved in dry THF (5 mL) and *n*-butyllithium (0.57 mmol) were mixed in a dropping funnel and added to the reaction mixture within 5 min at -20 °C. After stirring for another 5 min a solution of the appropriate electrophile (3 mmol) in dry THF (5 mL) was added. The mixture was allowed to reach 0 °C, poured onto water and extracted with Et_2O. The combined organic layers were washed with water, dried over Na_2SO_4 and evaporated.

4,4'-Dibromo-5-((1,1-dimethylethyl)dimethylsilyl)-5'-trimethylsilyl-2,2'-bithiophene (14). Chlorotrimethylsilane (0.32 g) was used as electrophile. The crude product was recrystallized from dry MeOH to yield 0.61 g (53%) of **14** as white crystals. Mp 82-83 °C. ^{1}H-NMR: δ = 7.16 (s, 1H), 7.15 (s, 1H), 0.99 (s, 9H), 0.42 (s, 15H) ppm. ^{13}C-NMR: δ = 141.0 (s), 140.5 (s), 134.7 (s), 132.7 (s), 129.3 (d), 129.1 (d), 118.0 (s), 117.5 (s), 26.8 (q), 18.3 (s), -0.8 (q), -4.4 (q) ppm. Anal. Calcd for $C_{17}H_{26}Br_2S_2Si_2$ (510.50): C 40.00; H 5.13. Found: C 39.74; H 4.98.

4,4'-Dibromo-5-((1,1-dimethylethyl)dimethylsilyl)-5'-methyl-2,2'-bithiophene (15). Methyl iodide (0.42 g) was used as electrophile. The crude product was recrystallized from dry MeOH to yield 0.46 g (45%) of **15** as beige crystals. Mp 71-73 °C. ^{1}H-NMR: δ = 7.08 (s, 1H), 6.99 (s, 1H), 2.40 (s, 3H), 0.99 (s, 9H), 0.42 (s, 6H) ppm. ^{13}C-NMR: δ = 141.5 (s), 134.1 (s), 132.9 (s), 132.0 (s), 128.7 (d), 126.6 (d), 117.9 (s), 109.8 (s), 26.8 (q), 18.2 (s), 14.8 (q), -4.3 (q) ppm. Anal. Calcd for $C_{15}H_{20}Br_2S_2Si$ (452.35): C 39.83;

H 4.46. Found: C 39.86; H 4.32.

4,4'-Dibromo-5-((1,1-dimethylethyl)dimethylsilyl)-5'-methylthio-2,2'-bithiophene (16). Dimethyl disulfide (0.28 g) was used as electrophile. The product was purified by flash chromatography (light petroleum) to yield 0.83 g (80%) of **16** as yellow crystals. TLC: R_f = 0.36 (light petroleum). Mp 52-54 °C. ^{1}H-NMR: δ = 7.12 (s, 1H), 7.06 (s, 1H), 2.50 (s, 3H), 0.98 (s, 9H), 0.42 (s, 6H) ppm. ^{13}C-NMR: δ = 140.7 (s), 137.0 (s), 132.8 (s), 132.5 (s), 129.1 (d), 127.0 (d), 118.0 (s), 115.7 (s), 26.7 (q), 20.3 (q), 18.1 (s), -4.5 (q) ppm. Anal. Calcd for $C_{15}H_{20}Br_2S_3Si$ (484.42): C 37.19; H 4.16. Found: C 36.89; H 3.87.

4,4'-Dibromo-5'-((1,1-dimethylethyl)dimethylsilyl)-2,2'-bithiophene-5-carbaldehyde (17). DMF (0.22 g) was used as electrophile. The crude product was recrystallized from light petroleum to yield 0.56 g (53%) of **17** as yellow crystals. Mp 122-124 °C. ^{1}H-NMR: δ = 9.92 (s, 1H), 7.32 (s, 1H), 7.20 (s, 1H), 0.99 (s, 9H), 0.42 (s, 6H) ppm. ^{13}C-NMR: δ = 182.5 (d), 144.6 (s), 139.7 (s), 136.3 (s), 135.2 (s), 131.4 (d), 127.8 (d), 120.7 (s), 118.6 (s), 26.8 (q), 18.2 (s), -4.4 (q) ppm. Anal. Calcd for $C_{15}H_{18}Br_2OS_2Si$ (466.33): C 38.63; H 3.89. Found: C 38.33; H 3.62.

General procedure for second halogen migration at 5. Compounds 18-21. *n*-Butyllithium (3.55 mmol) was added to a solution of diisopropylamine (0.38 g, 3.73 mmol) in dry THF (25 mL) at -40 °C and stirred for 15 min. This solution was then slowly transferred via a Teflon cannula into another flask containing a solution of **5** (1 g, 2.96 mmol) in dry THF (40 mL) at -20 °C over a period of 15 min and stirred for another 15 min. At the same temperature a solution of the appropriate electrophile (3.85 mmol) in dry THF (5 mL) was added. The mixture was allowed to reach 0 °C, poured onto water and extracted with Et_2O. The combined organic layers were washed with water, dried over Na_2SO_4 and evaporated.

4,4'-Dibromo-5-methyl-2,2'-bithiophene (18). Instead of an electrophile, MeOH (1 mL) was added to the reaction mixture. The crude product was recrystallized from dry EtOH to yield 0.81 g (81%) of **18** as yellow crystals. Mp 55-57 °C. ^{1}H-NMR: δ = 7.10 (d, 1H, J = 1.6 Hz), 7.00 (d, 1H, J = 1.6 Hz), 6.98 (s, 1H), 2.40 (s, 3H) ppm. ^{13}C-NMR: δ = 137.5 (s), 134.3 (s), 133.0 (s), 126.6 (d), 125.9 (d), 121.6 (d), 110.4 (s), 109.7 (s), 14.8 (q) ppm. Anal. Calcd for $C_9H_6Br_2S_2$ (338.09): C 31.97; H 1.79. Found: C 32.22; H 1.70.

4,4'-Dibromo-5-methyl-5'-trimethylsilyl-2,2'-bithiophene (19). Chlorotrimethylsilane (0.40 g) was used as electrophile. The crude product was recrystallized from dry EtOH to yield 0.78 g (64%) of **19** as orange crystals. Mp 101-104. ^{1}H-NMR: δ = 7.08 (s, 1H), 6.98 (s, 1H), 2.40 (s, 3H), 0.40 (s, 9H) ppm. ^{13}C-NMR: δ = 141.0 (s), 134.0 (s), 133.8 (s), 132.9 (s), 128.4 (d), 126.4 (d), 117.3 (s), 109.7 (s), 14.7 (q),

-0.9 (q) ppm. Anal. Calcd for $C_{12}H_{15}Br_2S_2Si$ (410.27): C 35.13; H 3.44. Found: C 35.20; H 3.33.

4,4'-Dibromo-5-methyl-5'-methylthio-2,2'-bithiophene (20). Dimethyl disulfide (0.36 g) was used as electrophile. The crude product was recrystallized from dry EtOH to yield 0.66 g (70%) of **21** as orange crystals. Mp 67-69 °C. ^{1}H-NMR: δ = 6.97 (s, 1H), 6.93 (s, 1H), 2.50 (s, 3H), 2.40 (s, 3H) ppm. ^{13}C-NMR: δ = 137.8 (s), 134.2 (s), 132.7 (s), 131.7 (s), 126.4 (2d), 115.9 (s), 109.7 (s), 20.4 (q), 14.7 (q) ppm. Anal. Calcd for $C_{10}H_8Br_2S_3$ (384.18): C 31.26; H 2.10. Found: C 31.62; H 2.00.

4,4'-Dibromo-5'-methyl-2,2'-bithiophene-5-carbaldehyde (21). DMF (0.30 g) was used as electrophile. The crude product was recrystallized from dry EtOH to yield 0.76 g (70%) of **21** as orange crystals. Mp 160-163 °C. ^{1}H-NMR: δ = 9.90 (s, 1H), 7.16 (s, 1H), 7.11 (s, 1H), 2.40 (s, 3H) ppm. ^{13}C-NMR: δ = 182.3 (d), 145.2 (s), 137.1 (s), 134.6 (s), 131.8 (s), 128.2 (d), 127.0 (d), 120.6 (s), 110.6 (s), 14.9 (q) ppm. Anal. Calcd for $C_{10}H_6Br_2OS_2$ (366.10): C 32.81; H 1.65. Found: C 33.06; H 1.75.

General procedure for single ring opening. Compounds 22 and 23. *n*-Butyllithium (0.92 mmol) was added to a solution of **9** or **10**, resp. (0.91 mmol) in dry Et_2O (40 mL) within 1 min at -40 °C. The mixture was allowed to reach ambient temperature and a solution of methyl iodide (0.71 g, 5 mmol) in dry Et_2O (5 mL) was added. After stirring for 10 min the mixture was poured onto water and extracted with Et_2O. The combined organic layers were washed with water, dried over Na_2SO_4 and evaporated.

3-Bromo-5-(1-methylthio-4-(trimethylsilyl)but-1-en-3-ynyl)-2-(trimethylsilyl)thiophene (22). 9 (0.43 g) was used as starting material. The product was purified by flash chromatography (light petroleum) to yield 0.31 g (85%) of **22** as orange oil. TLC: R_f = 0.26 (light petroleum). ^{1}H-NMR: δ = 7.22 (s, 1H), 6.07 (s, 1H), 2.45 (s, 3H), 0.39 (s, 9H), 0.23 (s, 9H) ppm. ^{13}C-NMR: δ = 147.6 (s), 142.1 (s), 136.9 (s), 130.9 (d), 117.4 (s), 109.0 (d), 105.5 (s), 102.2 (s), 17.3 (q), -0.2 (q), -0.9 (q) ppm. Anal. Calcd for $C_{15}H_{23}BrS_2Si_2$ (403.56): C 44.64; H 5.74. Found: C 44.86; H 5.69.

3-Bromo-5-(1-methylthio-4-((1,1-dimethylethyl)dimethylsilyl)but-1-en-3-ynyl)-2-((1,1-dimethylethyl)dimethylsilyl)thiophene (23). 10 (0.50 g) was used as starting material. The product was purified by flash chromatography (light petroleum) to yield 0.33 g (75%) of **23** as yellow oil. TLC: R_f = 0.31 (light petroleum). ^{1}H-NMR: δ = 7.22 (s, 1H), 6.11 (s, 1H), 2.44 (s, 3H), 0.99 (s, 9H), 0.97 (s, 9H), 0.40 (s, 6H) 0.19 (s, 6H) ppm. ^{13}C-NMR: δ = 148.0 (s), 142.0 (s), 135.0 (s), 131.2 (d), 117.9 (s), 109.5 (d), 104.1 (s), 102.8 (s), 26.8 (q), 26.1 (q), 18.2 (s), 17.4 (q), 16.8 (s), -4.4 (q), -4.7 (q) ppm. Anal. Calcd for $C_{21}H_{35}BrS_2Si_2$ (487.72): C 51.73; H 7.23. Found: C 51.87; H 7.00.

General procedure for double ring opening. Compounds 24 and 25. *n*-Butyllithium (1.91 mmol) was added to a solution of **9** or **10**, resp. (0.91 mmol) in dry Et_2O (10 mL) within 1 min at ambient

temperature. The mixture was stirred for 30 min and a solution of methyl iodide (0.71 g, 5 mmol) in dry Et_2O (5 mL) was added. After stirring for another 15 min the mixture was poured onto water and extracted with Et_2O. The combined organic layers were washed with water, dried over Na_2SO_4 and evaporated.

4,5-Bis(methylthio)-1,8-bis(trimethylsilyl)octa-3,5-diene-1,7-diyne (24). 9 (0.43 g) was used as starting material. The crude product was triturated with dry MeOH to yield 0.16 g (52%) of **24** as beige crystals. Mp 104-106 °C. ^{1}H-NMR: δ = 5.74 (s, 2H), 2.34 (s, 6H), 0.22 (s, 18H) ppm. ^{13}C-NMR: δ = 149.4 (s), 109.1 (d), 105.1 (s), 100.9 (s), 15.3 (q), -0.2 (q) ppm. Anal. Calcd for $C_{16}H_{26}S_2Si_2$ (403.56): C 56.74; H 7.74. Found: C 56.33; H 7.57.

4,5-Bis(methylthio)-1,8-bis((1,1-dimethylethyl)dimethylsilyl)octa-3,5-diene-1,7-diyne (25). 10 (0.50 g) was used as starting material. The crude product was triturated with dry MeOH to yield 0.21 g (55%) of **25** as beige crystals. Mp 93-95 °C. ^{1}H-NMR: δ = 5.78 (s, 2H), 2.35 (s, 6H), 0.99 (s, 18H), 0.19 (s, 12H) ppm. ^{13}C-NMR: δ = 149.4 (s), 109.1 (d), 103.4 (s), 101.5 (s), 26.0 (q), 16.6 (s), 15.2 (q), -4.8 (q) ppm. Anal. Calcd for $C_{22}H_{38}S_2Si_2$ (422.85): C 62.49; H 9.06. Found: C 62.53; H 8.91.

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