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2,5-Bis(5-bromo-2-thienyl)thiophene

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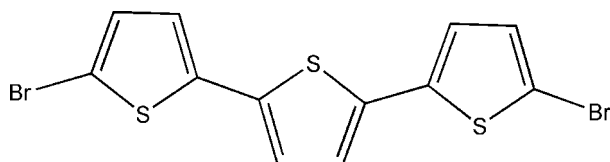
Received 25 July 2009; accepted 4 August 2009

 Key indicators: single-crystal X-ray study; $T = 173$ K; mean $\sigma(\text{C}-\text{C}) = 0.008$ Å; R factor = 0.053; wR factor = 0.114; data-to-parameter ratio = 19.6.

In the crystal structure of the title compound, $\text{C}_{12}\text{H}_6\text{Br}_2\text{S}_3$, the molecules are planar (r.m.s. deviation = 0.06 Å). Consecutive molecules do not stack in a planar fashion. There is an angle of 81.7 (12)° between the planes of the closest molecules.

Related literature

For related structures, see: Pyrka *et al.* (1988). For literature related to synthesis, see: Hoffmann & Carlsen (1999); Mei *et al.* (2009). For a recent review of oligothiophenes, see: Mishra *et al.* (2009).



Experimental

Crystal data

 $\text{C}_{12}\text{H}_6\text{Br}_2\text{S}_3$
 $M_r = 406.17$

 Orthorhombic, $Pcc2$
 $a = 7.6216$ (16) Å

 $b = 30.003$ (6) Å

 $c = 5.8841$ (13) Å

 $V = 1345.5$ (5) Å³
 $Z = 4$

 Mo $K\alpha$ radiation
 $\mu = 6.46$ mm⁻¹
 $T = 173$ K
 $0.37 \times 0.24 \times 0.10$ mm

Data collection

Siemens SMART Platform CCD diffractometer

 Absorption correction: multi-scan (SADABS; Sheldrick, 2008a)
 $T_{\min} = 0.184$, $T_{\max} = 0.524$

 9565 measured reflections
 3045 independent reflections
 2818 reflections with $I > 2\sigma(I)$
 $R_{\text{int}} = 0.035$

Refinement

 $R[F^2 > 2\sigma(F^2)] = 0.053$
 $wR(F^2) = 0.114$
 $S = 1.25$

3045 reflections

155 parameters

1 restraint

 H-atom parameters constrained
 $\Delta\rho_{\max} = 1.24$ e Å⁻³
 $\Delta\rho_{\min} = -0.62$ e Å⁻³
 Absolute structure: Flack (1983),
 1341 Friedel pairs
 Flack parameter: 0.00 (7)

Data collection: SMART (Bruker, 2001); cell refinement: SAINT (Bruker, 2001); data reduction: SAINT; program(s) used to solve structure: SHELXS97 (Sheldrick, 2008b); program(s) used to refine structure: SHELXL97 (Sheldrick, 2008b); molecular graphics: SHELXTL (Sheldrick, 2008b); software used to prepare material for publication: SHELXTL.

This work was supported in part by Research Development Grants from the Pennsylvania State University and partially by the MRSEC Program of the National Science Foundation under Award Number DMR-0819885. The author also acknowledges William W. Brennessel, Lindsay M. Hinkle, Victor G. Young Jr and the X-Ray Crystallographic Laboratory at the University of Minnesota.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: NG2619).

References

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supplementary materials

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2,5-Bis(5-bromo-2-thienyl)thiophene

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Comment

Dibromothiophenes are important building blocks in materials chemistry. They are mainly used in the preparation of various thiophene oligomers and polymers utilizing coupling reactions such as Stille and Suzuki couplings.

For literature related to the synthesis see: Hoffman & Carlsen (1999) and Mei (2009). For a recent review on synthesis and applications of oligothiophenes, see: Mishra (2009).

Experimental

Synthesis was carried out following literature procedures (Hoffman) as follows: to a solution of terthiophene dissolved in chloroform was added 2 equivalents of *N*-bromosuccinimide and the reaction mixture was stirred at room temperature for 2 h. The reaction mixture was then extracted with water and product obtained by evaporation of chloroform and recrystallized twice from hexanes. The crystals were very thin, hence the large number in the second weighting scheme.

Refinement

The structure was solved using *SHELXS97* and refined using *SHELXL97* (Sheldrick, 2008). The space group *Pcc2* was determined based on systematic absences and intensity statistics. A direct-methods solution was calculated which provided most non-hydrogen atoms from the E-map. Full-matrix least squares / difference Fourier cycles were performed which located the remaining non-hydrogen atoms. All non-hydrogen atoms were refined with anisotropic displacement parameters. All hydrogen atoms were placed in ideal positions and refined as riding atoms with relative isotropic displacement parameters. The final full matrix least squares refinement converged to $R1 = 0.0527$ and $wR2 = 0.1169$ ($F2$, all data).

Figures

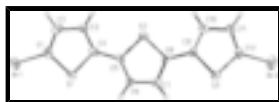


Fig. 1. 2,5-bis(5-bromothiophen-2-yl)thiophene.

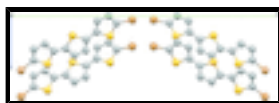


Fig. 2. Crystal packing viewed along the *a* axis.

2,5-Bis(5-bromo-2-thienyl)thiophene

Crystal data

$C_{12}H_6Br_2S_3$

$M_r = 406.17$

$F_{000} = 784$

$D_x = 2.005 \text{ Mg m}^{-3}$

supplementary materials

Orthorhombic, *Pcc2*
Hall symbol: P 2 -2c
 $a = 7.6216$ (16) Å
 $b = 30.003$ (6) Å
 $c = 5.8841$ (13) Å
 $V = 1345.5$ (5) Å³
 $Z = 4$

Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
Cell parameters from 903 reflections
 $\theta = 2.7$ – 27.5°
 $\mu = 6.46$ mm⁻¹
 $T = 173$ K
Plate, pale yellow
 $0.37 \times 0.24 \times 0.10$ mm

Data collection

Siemens SMART Platform CCD
diffractometer
Radiation source: fine-focus sealed tube
Monochromator: graphite
 $T = 173$ K
 ω scans
Absorption correction: multi-scan
(SADABS; Sheldrick, 2008a)
 $T_{\min} = 0.184$, $T_{\max} = 0.524$
9565 measured reflections

3045 independent reflections
2818 reflections with $I > 2\sigma(I)$
 $R_{\text{int}} = 0.035$
 $\theta_{\max} = 27.5^\circ$
 $\theta_{\min} = 2.7^\circ$
 $h = -9 \rightarrow 9$
 $k = -38 \rightarrow 38$
 $l = -7 \rightarrow 7$

Refinement

Refinement on F^2
Least-squares matrix: full
 $R[F^2 > 2\sigma(F^2)] = 0.053$
 $wR(F^2) = 0.114$
 $S = 1.25$
3045 reflections
155 parameters
1 restraint
Primary atom site location: structure-invariant direct
methods
Secondary atom site location: difference Fourier map

Hydrogen site location: inferred from neighbouring
sites
H-atom parameters constrained
 $w = 1/[\sigma^2(F_o^2) + (0.0403P)^2 + 2.9087P]$
where $P = (F_o^2 + 2F_c^2)/3$
 $(\Delta/\sigma)_{\max} = 0.001$
 $\Delta\rho_{\max} = 1.24$ e Å⁻³
 $\Delta\rho_{\min} = -0.62$ e Å⁻³
Extinction correction: none
Absolute structure: Flack (1983), 1341 Friedel pairs
Flack parameter: 0.00 (7)

Special details

Geometry. All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes)

are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic)

treatment of cell e.s.d.'s is used for estimating e.s.d.'s involving l.s. planes.

Refinement. Refinement of F^2 against ALL reflections. The weighted R -factor wR and goodness of fit S are based on F^2 , conventional R -factors R are based on F , with F set to zero for negative F^2 . The threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating R -factors(gt) *etc.* and is not relevant to the choice of reflections for refinement. R -factors based on F^2 are statistically about twice as large as those based on F , and R -factors based on ALL data will be even larger. The structure refined as a merohedral inversion twin, whose mass ratio converged to 61:39.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (\AA^2)

| | <i>x</i> | <i>y</i> | <i>z</i> | $U_{\text{iso}}^*/U_{\text{eq}}$ |
|-----|--------------|--------------|--------------|----------------------------------|
| Br1 | 0.69877 (9) | 0.96042 (2) | 1.02236 (11) | 0.0374 (2) |
| Br2 | 0.71126 (13) | 0.54014 (2) | 0.07093 (13) | 0.0532 (3) |
| S1 | 0.6713 (2) | 0.86007 (5) | 0.9031 (3) | 0.0271 (3) |
| S2 | 0.81817 (19) | 0.76622 (5) | 0.3646 (3) | 0.0232 (3) |
| S3 | 0.6749 (2) | 0.62433 (5) | 0.3757 (3) | 0.0279 (3) |
| C1 | 0.7418 (8) | 0.9124 (2) | 0.8288 (11) | 0.0253 (13) |
| C2 | 0.8278 (8) | 0.9124 (2) | 0.6263 (12) | 0.0287 (14) |
| H2 | 0.8761 | 0.9384 | 0.5584 | 0.034* |
| C3 | 0.8376 (7) | 0.86976 (19) | 0.5284 (11) | 0.0238 (12) |
| H3 | 0.8933 | 0.8642 | 0.3868 | 0.029* |
| C4 | 0.7597 (7) | 0.8370 (2) | 0.6553 (10) | 0.0215 (12) |
| C5 | 0.7360 (7) | 0.7908 (2) | 0.6122 (10) | 0.0172 (12) |
| C6 | 0.6539 (7) | 0.75937 (18) | 0.7416 (10) | 0.0197 (12) |
| H6 | 0.6009 | 0.7660 | 0.8838 | 0.024* |
| C7 | 0.6546 (7) | 0.71661 (19) | 0.6471 (10) | 0.0201 (12) |
| H7 | 0.6016 | 0.6916 | 0.7182 | 0.024* |
| C8 | 0.7397 (8) | 0.71439 (19) | 0.4407 (12) | 0.0190 (12) |
| C9 | 0.7621 (7) | 0.67576 (19) | 0.2972 (10) | 0.0175 (11) |
| C10 | 0.8467 (8) | 0.6726 (2) | 0.0932 (10) | 0.0233 (12) |
| H10 | 0.9036 | 0.6972 | 0.0231 | 0.028* |
| C11 | 0.8421 (8) | 0.62914 (19) | -0.0055 (11) | 0.0249 (12) |
| H11 | 0.8927 | 0.6216 | -0.1479 | 0.030* |
| C12 | 0.7553 (9) | 0.5999 (2) | 0.1323 (12) | 0.0269 (13) |

Atomic displacement parameters (\AA^2)

| | U^{11} | U^{22} | U^{33} | U^{12} | U^{13} | U^{23} |
|-----|------------|------------|------------|-------------|------------|-------------|
| Br1 | 0.0447 (4) | 0.0317 (4) | 0.0359 (4) | 0.0053 (3) | 0.0051 (4) | -0.0089 (3) |
| Br2 | 0.0814 (7) | 0.0272 (4) | 0.0512 (7) | -0.0077 (4) | 0.0045 (5) | -0.0099 (4) |
| S1 | 0.0315 (8) | 0.0282 (7) | 0.0217 (8) | -0.0025 (6) | 0.0079 (6) | -0.0021 (6) |
| S2 | 0.0252 (7) | 0.0259 (7) | 0.0185 (7) | -0.0031 (6) | 0.0045 (6) | 0.0006 (6) |
| S3 | 0.0338 (8) | 0.0234 (7) | 0.0263 (8) | -0.0046 (6) | 0.0066 (7) | 0.0012 (7) |
| C1 | 0.028 (3) | 0.025 (3) | 0.023 (3) | 0.002 (2) | -0.005 (3) | -0.003 (3) |
| C2 | 0.023 (3) | 0.029 (3) | 0.035 (3) | -0.002 (2) | -0.003 (3) | 0.009 (3) |
| C3 | 0.026 (3) | 0.024 (3) | 0.021 (3) | 0.000 (2) | 0.006 (3) | 0.004 (3) |
| C4 | 0.018 (3) | 0.030 (3) | 0.017 (3) | 0.003 (2) | 0.000 (2) | 0.000 (2) |
| C5 | 0.012 (3) | 0.026 (3) | 0.013 (3) | -0.001 (2) | -0.003 (2) | -0.004 (2) |

supplementary materials

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|-----|-----------|-----------|-----------|------------|------------|------------|
| C6 | 0.019 (3) | 0.023 (3) | 0.017 (3) | -0.001 (2) | -0.001 (2) | 0.001 (2) |
| C7 | 0.012 (3) | 0.026 (3) | 0.022 (3) | 0.000 (2) | -0.001 (2) | 0.005 (2) |
| C8 | 0.014 (2) | 0.017 (3) | 0.026 (3) | -0.002 (2) | 0.004 (2) | 0.010 (2) |
| C9 | 0.016 (3) | 0.015 (3) | 0.021 (3) | 0.002 (2) | -0.001 (2) | 0.000 (2) |
| C10 | 0.020 (3) | 0.029 (3) | 0.021 (3) | 0.002 (2) | -0.001 (2) | 0.003 (2) |
| C11 | 0.028 (3) | 0.023 (3) | 0.024 (3) | 0.005 (2) | 0.004 (3) | -0.006 (2) |
| C12 | 0.035 (3) | 0.022 (3) | 0.024 (3) | -0.004 (3) | 0.000 (3) | -0.006 (3) |

Geometric parameters (Å, °)

| | | | |
|--------------|------------|--------------|------------|
| Br1—C1 | 1.864 (6) | C4—C5 | 1.419 (8) |
| Br2—C12 | 1.858 (6) | C5—C6 | 1.365 (8) |
| S1—C1 | 1.717 (7) | C6—C7 | 1.398 (8) |
| S1—C4 | 1.749 (6) | C6—H6 | 0.9500 |
| S2—C8 | 1.725 (6) | C7—C8 | 1.379 (9) |
| S2—C5 | 1.750 (6) | C7—H7 | 0.9500 |
| S3—C12 | 1.722 (7) | C8—C9 | 1.444 (8) |
| S3—C9 | 1.742 (6) | C9—C10 | 1.366 (8) |
| C1—C2 | 1.360 (10) | C10—C11 | 1.428 (8) |
| C2—C3 | 1.404 (9) | C10—H10 | 0.9500 |
| C2—H2 | 0.9500 | C11—C12 | 1.367 (9) |
| C3—C4 | 1.370 (8) | C11—H11 | 0.9500 |
| C3—H3 | 0.9500 | | |
| C1—S1—C4 | 91.7 (3) | C7—C6—H6 | 122.9 |
| C8—S2—C5 | 92.3 (3) | C8—C7—C6 | 113.4 (5) |
| C12—S3—C9 | 91.2 (3) | C8—C7—H7 | 123.3 |
| C2—C1—S1 | 111.9 (5) | C6—C7—H7 | 123.3 |
| C2—C1—Br1 | 128.4 (5) | C7—C8—C9 | 127.6 (5) |
| S1—C1—Br1 | 119.8 (4) | C7—C8—S2 | 110.4 (5) |
| C1—C2—C3 | 112.7 (6) | C9—C8—S2 | 122.1 (5) |
| C1—C2—H2 | 123.6 | C10—C9—C8 | 128.7 (5) |
| C3—C2—H2 | 123.6 | C10—C9—S3 | 110.6 (4) |
| C4—C3—C2 | 114.0 (6) | C8—C9—S3 | 120.7 (4) |
| C4—C3—H3 | 123.0 | C9—C10—C11 | 114.2 (6) |
| C2—C3—H3 | 123.0 | C9—C10—H10 | 122.9 |
| C3—C4—C5 | 131.2 (5) | C11—C10—H10 | 122.9 |
| C3—C4—S1 | 109.7 (5) | C12—C11—C10 | 110.9 (5) |
| C5—C4—S1 | 119.1 (4) | C12—C11—H11 | 124.5 |
| C6—C5—C4 | 129.3 (5) | C10—C11—H11 | 124.5 |
| C6—C5—S2 | 109.7 (4) | C11—C12—S3 | 113.0 (5) |
| C4—C5—S2 | 121.0 (4) | C11—C12—Br2 | 126.3 (5) |
| C5—C6—C7 | 114.3 (5) | S3—C12—Br2 | 120.6 (4) |
| C5—C6—H6 | 122.9 | | |
| C4—S1—C1—C2 | 0.0 (5) | C6—C7—C8—C9 | -179.1 (6) |
| C4—S1—C1—Br1 | -179.1 (4) | C6—C7—C8—S2 | -0.3 (6) |
| S1—C1—C2—C3 | 0.1 (7) | C5—S2—C8—C7 | 0.0 (5) |
| Br1—C1—C2—C3 | 179.1 (5) | C5—S2—C8—C9 | 179.0 (5) |
| C1—C2—C3—C4 | -0.2 (8) | C7—C8—C9—C10 | -179.5 (6) |
| C2—C3—C4—C5 | 177.2 (6) | S2—C8—C9—C10 | 1.8 (9) |

supplementary materials

| | | | |
|-------------|------------|-----------------|------------|
| C2—C3—C4—S1 | 0.2 (7) | C7—C8—C9—S3 | 0.8 (9) |
| C1—S1—C4—C3 | -0.1 (5) | S2—C8—C9—S3 | -178.0 (3) |
| C1—S1—C4—C5 | -177.6 (5) | C12—S3—C9—C10 | 0.2 (5) |
| C3—C4—C5—C6 | -178.4 (7) | C12—S3—C9—C8 | 180.0 (5) |
| S1—C4—C5—C6 | -1.6 (9) | C8—C9—C10—C11 | -179.2 (6) |
| C3—C4—C5—S2 | 2.0 (9) | S3—C9—C10—C11 | 0.6 (7) |
| S1—C4—C5—S2 | 178.8 (3) | C9—C10—C11—C12 | -1.3 (8) |
| C8—S2—C5—C6 | 0.2 (5) | C10—C11—C12—S3 | 1.4 (7) |
| C8—S2—C5—C4 | 179.8 (5) | C10—C11—C12—Br2 | 178.2 (5) |
| C4—C5—C6—C7 | -180.0 (5) | C9—S3—C12—C11 | -1.0 (5) |
| S2—C5—C6—C7 | -0.4 (7) | C9—S3—C12—Br2 | -177.9 (4) |
| C5—C6—C7—C8 | 0.4 (7) | | |

Fig. 1

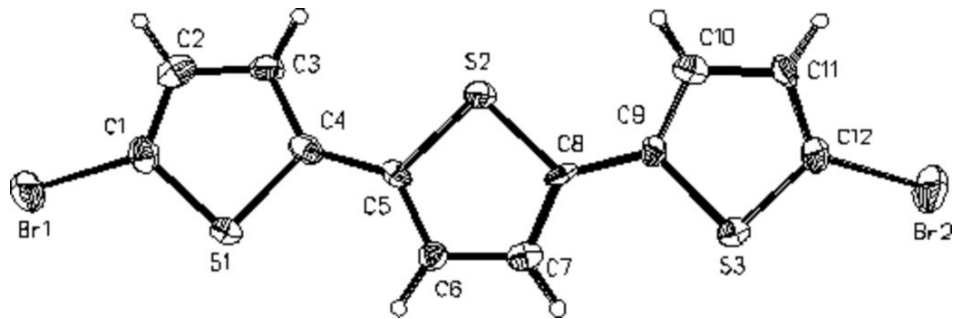


Fig. 2

