

Acta Crystallographica Section E

## Structure Reports

Online

ISSN 1600-5368

## 5-Sulfanylidene-2*H*,5*H*-1,3-dithiolo-[4,5-*d*][1,3]dithiol-2-one

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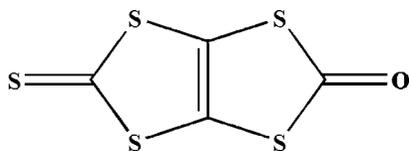
Received 7 December 2011; accepted 9 February 2012

 Key indicators: single-crystal X-ray study;  $T = 294$  K; mean  $\sigma(\text{C}-\text{C}) = 0.009$  Å;  $R$  factor = 0.044;  $wR$  factor = 0.130; data-to-parameter ratio = 18.3.

The title molecule,  $\text{C}_4\text{OS}_5$ , is essentially planar, with an r.m.s. deviation of 0.032 (3) Å. All the C—S single bonds are shorter than the standard  $\text{Csp}^3$ —S single-bond length, showing the  $\pi$ -conjugated nature of the molecule. In the crystal, molecules lie parallel to one another and pack in columns along the  $a$  axis. Short intermolecular S...S contacts [3.314 (3), 3.482 (2) and 3.501 (2) Å] are observed between the columns. The angle between the two molecular dipole moments in the unit cell is 39.3 (1)° and the macro-polarization vector is along the [1 0 - 1.41] direction. As a result of the high polarization and  $\pi$ -conjugation of the structure, the crystalline powder exhibits a second harmonic generating intensity, which is as strong as that of the urea standard powder crystals, when irradiated by a 1053 nm laser beam. The diffraction space of the crystal showed a nonmerohedral twinning.

### Related literature

For details of *GAUSSIAN03* software, see: Frisch *et al.* (2003). For the synthesis, see: Schumaker & Engler (1977); Wang *et al.* (1998).



### Experimental

#### Crystal data

$\text{C}_4\text{OS}_5$	$V = 373.11$ (4) Å <sup>3</sup>
$M_r = 224.34$	$Z = 2$
Monoclinic, $Pn$	Mo $K\alpha$ radiation
$a = 3.9638$ (2) Å	$\mu = 1.47$ mm <sup>-1</sup>
$b = 11.0211$ (8) Å	$T = 294$ K
$c = 8.7110$ (7) Å	$0.27 \times 0.07 \times 0.05$ mm
$\beta = 101.344$ (5)°	

#### Data collection

Bruker APEXII CCD diffractometer	8524 measured reflections
Absorption correction: multi-scan ( <i>TWINABS</i> ; Bruker, 2005)	1683 independent reflections
$T_{\min} = 0.697$ , $T_{\max} = 0.928$	1487 reflections with $I > 2\sigma(I)$
	$R_{\text{int}} = 0.039$

#### Refinement

$R[F^2 > 2\sigma(F^2)] = 0.044$	$\Delta\rho_{\max} = 0.41$ e Å <sup>-3</sup>
$wR(F^2) = 0.130$	$\Delta\rho_{\min} = -0.45$ e Å <sup>-3</sup>
$S = 1.12$	Absolute structure: Flack (1983),
1683 reflections	815 Friedel pairs
92 parameters	Flack parameter: 0.1 (3)
2 restraints	

Data collection: *APEX2* (Bruker, 2005); cell refinement: *SAINTE* (Bruker, 2005); data reduction: *SAINTE*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *SHELXTL* (Sheldrick, 2008); software used to prepare material for publication: *SHELXTL*.

This work was supported by the National Natural Science Foundation of China (grant Nos. 50673054 and 20972089). We thank Professor Shao-Jun Zhang for help with the second harmonic generation experiment and Professor Wen-Tao Yu for helpful advice in X-ray absorption correction.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: IS5027).

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## supporting information

*Acta Cryst.* (2012). E68, o721 [doi:10.1107/S1600536812005703]

## 5-Sulfanylidene-2*H*,5*H*-1,3-dithiolo[4,5-*d*][1,3]dithiol-2-one

Hua-Wen Wen, Li-Xia Fan, Li Liu, Ao Li and Qi Fang

### S1. Comment

Sulfur-rich compounds are well known as electronic donors in the field of organic molecular conductors, while their non-linear optical (NLO) properties are seldom reported. The synthesis of the title sulfur-rich compounds was reported by Schumaker and Engler (1977). Recently, we have re-synthesized the title compound by a new synthetic route and determined its X-ray structure.

The molecule adopts a planar conformation. All the C—S bond lengths are shorter than the length of C(*sp*<sup>3</sup>)—S single bond, showing the  $\pi$ -conjugated nature of the molecule. The molecules are parallel packed into columns along the *a* axis with a uniform spacing being 3.57 (1) Å. In addition to the above longitudinal  $\pi$ - $\pi$  interactions, there are plenty of transverse short intermolecular S...S contacts. For example, S1...S2 [1/2 + *x*, 2 - *y*, -1/2 + *z*], S1...S3 [*x*, *y*, -1 + *z*], and S4...S5 [1/2 + *x*, 1 - *y*, -1/2 + *z*] distances are 3.314 (3), 3.482 (2) and 3.501 (2) Å, respectively.

The polar molecules crystallized into polar *Pn* space group. The angle [39.3 (1)°] between the two molecular dipole moments in the unit cell is not large, meaning that the crystal is well auto-polarized. The projection of both the molecular moments on the (010) plane is along the [1 0 -1.41] direction, which is also the direction of the macro polarization vector.

By the way, the molecular dipole moment has been calculated to be 0.8862 Debye by using the Gaussian-03 programs (Frisch *et al.*, 2003), by the DFT method at the B3LYP/6-311(*d*) level. Meantime, the theoretical optimization for the molecular conformation by using the same Gaussian-03 programs indicates that the "free" molecule indeed adopts a perfect planar conformation with a strict C<sub>2v</sub> symmetry.

The highly polar structure prompted us to carry out a frequency doubling experiment. When irradiated by the 1053 nm of laser pulses, the powder sample of the title crystal can emit 526.5 nm of green light, which is as strong as that of the urea powder crystals (as reference) and therefore has a remarkable 2-nd NLO effect.

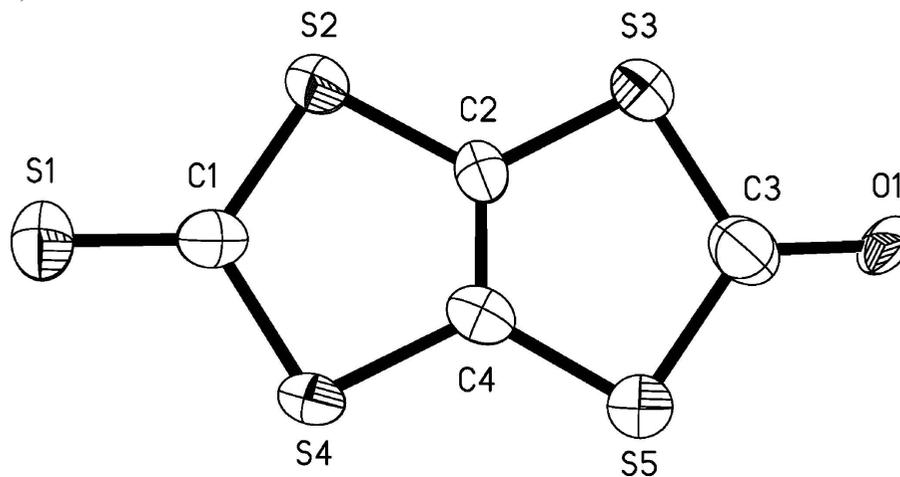
### S2. Experimental

We firstly synthesized bis(tetrabutylammonium)bis(1,3-dithiole-2-thione-4,5-dithiol) zincate precursor by the method reported by Wang *et al.* (1998). For the synthesis of the title compound, the above zincate precursor (2.3 g, 2.5 mmol) was dissolved in THF (50 ml). And then the triphosgen (1.40 g, 5.0 mmol) at 195 K was added in presence of N<sub>2</sub>. The solution was stirred overnight. An orange precipitate was obtained and dried *in vacuo*. And the final compound was purified by column chromatography using carbon disulfide as eluent, giving 0.46 g (86.7% yield) orange crystalline product. MS (EI): *m/z* 224.

### S3. Refinement

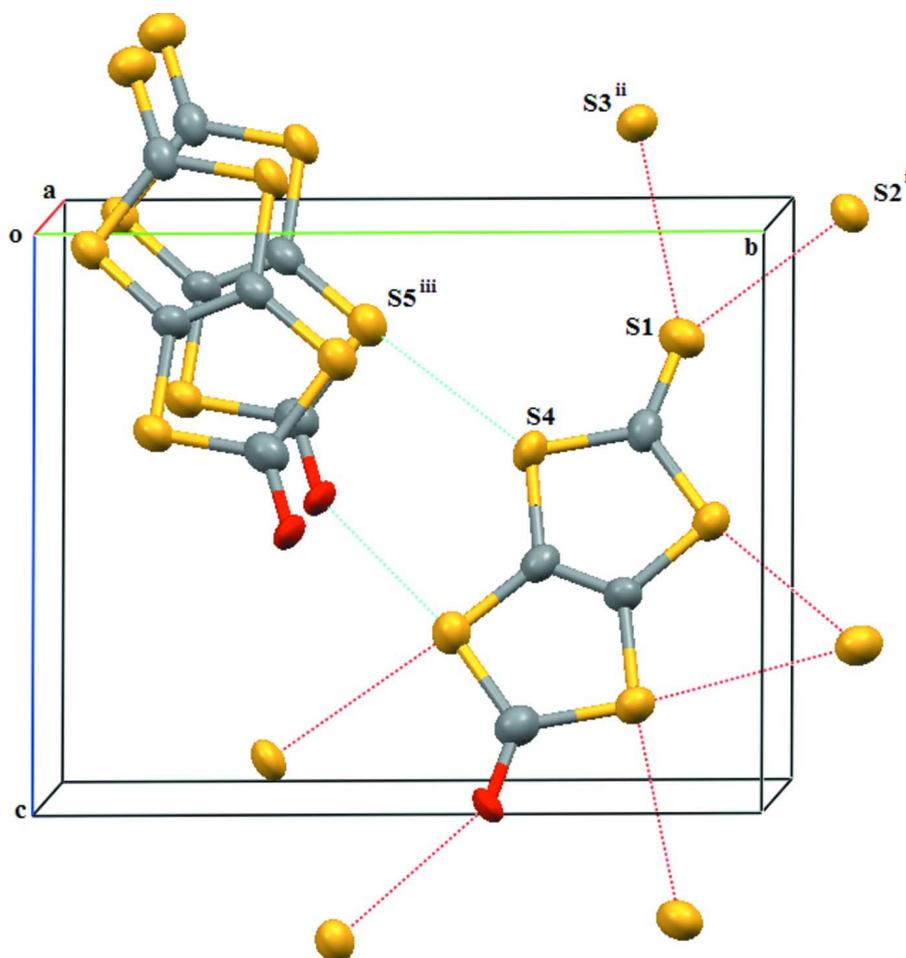
There is no hydrogen atom in this structure. The reciprocal space showed a non-merohedral twin for the crystal used. All diffraction spots, except those of (*0kl*) kind, appeared in pairs. The diffraction spots on the (*0kl*) layer were supposed to be overlapped in pairs. By using the editing tools in RLATT, two reciprocal lattices corresponding to the two domains

have been successfully separated and two P4P files been produced separately. After merging two P4P files into a new P4P file, data integration and absorption correction have been carried out. All the programs used are in the *APEX2* Software Suite (Bruker, 2005). The domain scale factor has been refined to be 0.293 for the second domain.



**Figure 1**

Molecular structure of the title compound. Displacement ellipsoids are drawn at 50% probability level.

**Figure 2**

The packing pattern of the title molecules in crystal viewed down the *a*-axis, showing S...S and other intermolecular short contacts. [Symmetry codes: (i)  $1/2 + x, -y + 2, -1/2 + z$ ; (ii)  $x, y, -1 + z$ ; (iii)  $1/2 + x, 1 - y, -1/2 + z$ ].

### 5-Sulfanylidene-2H,5H-1,3-dithiolo[4,5-*d*][1,3]dithiol-2-one

#### Crystal data

$C_4OS_5$

$M_r = 224.34$

Monoclinic, *Pn*

Hall symbol: *P* -2*yac*

$a = 3.9638$  (2) Å

$b = 11.0211$  (8) Å

$c = 8.7110$  (7) Å

$\beta = 101.344$  (5)°

$V = 373.11$  (4) Å<sup>3</sup>

$Z = 2$

$F(000) = 224$

$D_x = 1.997$  Mg m<sup>-3</sup>

Mo *K*α radiation,  $\lambda = 0.71073$  Å

Cell parameters from 1431 reflections

$\theta = 3.0$ – $26.0$ °

$\mu = 1.47$  mm<sup>-1</sup>

$T = 294$  K

Bar, orange

$0.27 \times 0.07 \times 0.05$  mm

#### Data collection

Bruker APEXII CCD

diffractometer

Radiation source: fine-focus sealed tube

Graphite monochromator

Detector resolution: 8.3 pixels mm<sup>-1</sup>

$\omega$  scans

Absorption correction: multi-scan

(*TWINABS*; Bruker, 2005)

$T_{\min} = 0.697$ ,  $T_{\max} = 0.928$   
 8524 measured reflections  
 1683 independent reflections  
 1487 reflections with  $I > 2\sigma(I)$   
 $R_{\text{int}} = 0.039$

$\theta_{\max} = 27.5^\circ$ ,  $\theta_{\min} = 1.9^\circ$   
 $h = -5 \rightarrow 5$   
 $k = -14 \rightarrow 14$   
 $l = -11 \rightarrow 11$

*Refinement*

Refinement on  $F^2$   
 Least-squares matrix: full  
 $R[F^2 > 2\sigma(F^2)] = 0.044$   
 $wR(F^2) = 0.130$   
 $S = 1.12$   
 1683 reflections  
 92 parameters  
 2 restraints  
 Primary atom site location: structure-invariant  
 direct methods

Secondary atom site location: difference Fourier  
 map  
 $w = 1/[\sigma^2(F_o^2) + (0.0831P)^2 + 0.0664P]$   
 where  $P = (F_o^2 + 2F_c^2)/3$   
 $(\Delta/\sigma)_{\max} < 0.001$   
 $\Delta\rho_{\max} = 0.41 \text{ e } \text{\AA}^{-3}$   
 $\Delta\rho_{\min} = -0.45 \text{ e } \text{\AA}^{-3}$   
 Absolute structure: Flack (1983), 815 Friedel  
 pairs  
 Absolute structure parameter: 0.1 (3)

*Special details*

**Experimental.** The twin operator is an  $180^\circ$  rotation about the  $c^*$  axis and the twin law can be recognized as  $-1 \ 0 \ 0, 0 \ -1 \ 0, 0.873 \ 0 \ 1$ . The frequency doubling experiment indicates that it is impossible for the crystal to adopt the centrosymmetric  $P2_1/c$  space group.

**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.

*Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters ( $\text{\AA}^2$ )*

	$x$	$y$	$z$	$U_{\text{iso}}^*/U_{\text{eq}}$
S1	0.5018 (5)	0.86748 (19)	0.2126 (2)	0.0551 (5)
S2	0.3162 (4)	0.91619 (15)	0.51687 (18)	0.0415 (4)
S3	0.1270 (5)	0.82054 (14)	0.8209 (2)	0.0451 (4)
S4	0.3021 (4)	0.66835 (13)	0.39376 (17)	0.0427 (4)
S5	0.1178 (5)	0.56886 (16)	0.6947 (2)	0.0471 (4)
O1	-0.0459 (13)	0.6265 (3)	0.9824 (4)	0.0394 (10)
C1	0.3780 (16)	0.8219 (6)	0.3637 (8)	0.0373 (14)
C2	0.216 (2)	0.8000 (6)	0.6361 (8)	0.0372 (13)
C3	0.055 (2)	0.6625 (7)	0.8518 (8)	0.0487 (18)
C4	0.211 (2)	0.6863 (6)	0.5810 (7)	0.0386 (14)

*Atomic displacement parameters ( $\text{\AA}^2$ )*

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
S1	0.0732 (12)	0.0538 (10)	0.0417 (8)	-0.0058 (10)	0.0194 (8)	0.0051 (9)
S2	0.0544 (9)	0.0344 (7)	0.0386 (7)	-0.0034 (7)	0.0161 (7)	-0.0067 (6)
S3	0.0617 (10)	0.0400 (9)	0.0371 (7)	0.0003 (8)	0.0186 (8)	-0.0060 (7)
S4	0.0604 (10)	0.0291 (7)	0.0427 (8)	-0.0019 (7)	0.0205 (8)	-0.0101 (7)

S5	0.0614 (11)	0.0367 (8)	0.0478 (8)	-0.0023 (8)	0.0222 (8)	-0.0025 (7)
O1	0.066 (3)	0.0233 (18)	0.031 (2)	-0.004 (2)	0.015 (2)	0.0100 (16)
C1	0.034 (3)	0.032 (3)	0.046 (3)	0.000 (2)	0.009 (3)	-0.005 (2)
C2	0.046 (3)	0.038 (3)	0.032 (3)	-0.003 (3)	0.017 (3)	-0.002 (2)
C3	0.055 (4)	0.050 (4)	0.043 (4)	0.005 (3)	0.015 (3)	-0.006 (3)
C4	0.043 (3)	0.037 (3)	0.036 (3)	0.001 (3)	0.007 (3)	-0.009 (2)

*Geometric parameters (Å, °)*

S1—C1	1.575 (7)	S4—C4	1.750 (6)
S2—C1	1.746 (6)	S5—C4	1.713 (7)
S2—C2	1.743 (6)	S5—C3	1.770 (7)
S3—C2	1.730 (7)	O1—C3	1.338 (8)
S3—C3	1.794 (8)	C2—C4	1.340 (7)
S4—C1	1.747 (7)		
C1—S2—C2	95.8 (3)	C4—C2—S2	117.6 (4)
C2—S3—C3	94.6 (3)	S3—C2—S2	124.8 (4)
C1—S4—C4	95.9 (3)	O1—C3—S5	126.6 (5)
C4—S5—C3	94.9 (3)	O1—C3—S3	119.9 (5)
S1—C1—S2	124.2 (4)	S5—C3—S3	113.5 (4)
S1—C1—S4	121.7 (4)	C2—C4—S5	119.3 (4)
S2—C1—S4	114.1 (4)	C2—C4—S4	116.6 (4)
C4—C2—S3	117.6 (4)	S5—C4—S4	124.1 (4)