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1,1,3,3-Tetra-*tert*-butyl-2,2-diisopropyl-4,4-diphenylcyclotetrasilane

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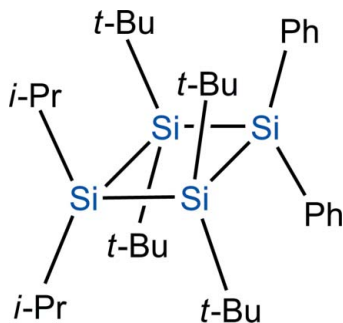
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 Key indicators: single-crystal X-ray study; $T = 173$ K; mean $\sigma(\text{C}-\text{C}) = 0.004$ Å; R factor = 0.048; wR factor = 0.095; data-to-parameter ratio = 16.1.

The molecule in the structure of the title compound, $\text{C}_{34}\text{H}_{60}\text{Si}_4$, lies on a twofold rotation axis that passes through the two Si atoms, resulting in a planar cyclotetrasilane ring. The dihedral angle between the cyclotetrasilane ring and the phenyl ring is $68.20(5)^\circ$. The Si—Si bonds [2.4404 (8) and 2.4576 (8) Å] are longer than a standard Si—Si bond (2.34 Å) and the C—Si—C bond angle [$97.07(14)^\circ$] of the phenyl-substituted Si atom is smaller than the tetrahedral bond angle (109.5°). These long bonds and small bond angle are favorable for reducing the steric hindrance among the bulky substituents.

Related literature

For background to and applications of phenyl-substituted oligosilanes, see: Hinch & Krc (1957); Matsumoto & Tanaka (2008). For a related structure of a cyclotetrasilane without phenyl groups, see: Kyushin *et al.* (1995).



Experimental

Crystal data

$\text{C}_{34}\text{H}_{60}\text{Si}_4$	$V = 3474.0(4) \text{ \AA}^3$
$M_r = 581.18$	$Z = 4$
Monoclinic, $C2/c$	Mo $K\alpha$ radiation
$a = 11.9477(9) \text{ \AA}$	$\mu = 0.19 \text{ mm}^{-1}$
$b = 17.6585(12) \text{ \AA}$	$T = 173 \text{ K}$
$c = 17.0422(13) \text{ \AA}$	$0.50 \times 0.40 \times 0.20 \text{ mm}$
$\beta = 104.9394(8)^\circ$	

Data collection

Rigaku R-Axis IV imaging plate diffractometer	8534 measured reflections
Absorption correction: multi-scan (REQAB; Jacobson, 1998)	2917 independent reflections
$T_{\min} = 0.910$, $T_{\max} = 0.963$	2899 reflections with $I > 2\sigma(I)$
	$R_{\text{int}} = 0.025$

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.048$	181 parameters
$wR(F^2) = 0.095$	H-atom parameters constrained
$S = 1.24$	$\Delta\rho_{\text{max}} = 0.24 \text{ e \AA}^{-3}$
2917 reflections	$\Delta\rho_{\text{min}} = -0.20 \text{ e \AA}^{-3}$

Data collection: *CrystalClear* (Rigaku, 2003); cell refinement: *CrystalClear*; data reduction: *CrystalClear*; program(s) used to solve structure: *SIR2004* (Burla *et al.*, 2005); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *ORTEP-3* (Farrugia, 2012); software used to prepare material for publication: *SHELXL97* and *Yadokari-XG 2009* (Kabuto *et al.*, 2009).

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Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: IS5224).

References

- Burla, M. C., Caliandro, R., Camalli, M., Carrozzini, B., Cascarano, G. L., De Caro, L., Giacovazzo, C., Polidori, G. & Spagna, R. (2005). *J. Appl. Cryst.* **38**, 381–388.
- Farrugia, L. J. (2012). *J. Appl. Cryst.* **45**, 849–854.
- Hinch, R. J. & Krc, J. Jr (1957). *Anal. Chem.* **29**, 1550–1551.
- Jacobson, R. (1998). *REQAB*. Private communication to the Rigaku Corporation, Tokyo, Japan.
- Kabuto, C., Akine, S., Nemoto, T. & Kwon, E. (2009). *J. Crystallogr. Soc. Jpn.* **51**, 218–224.
- Kyushin, S., Sakurai, H. & Matsumoto, H. (1995). *J. Organomet. Chem.* **499**, 235–240.
- Matsumoto, H. & Tanaka, R. (2008). Jpn Kokai Tokkyo Koho JP4132933. Rigaku (2003). *CrystalClear*. Rigaku Corporation, Tokyo, Japan.
- Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.

supporting information

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1,1,3,3-Tetra-*tert*-butyl-2,2-diisopropyl-4,4-diphenylcyclotetrasilane

Takayoshi Kuribara and Soichiro Kyushin

S1. Comment

Birefringent materials have a wide range of optical applications. Single crystals of calcium carbonate and barium borate have been well known as inorganic birefringent materials. Organic single crystals such as urea have also been known to show birefringence. Since birefringence is related to crystal structures, studies on molecular structures and packing in a crystal are important. In 1957, birefringence of tetrakis(4-phenylphenyl)silane was reported (Hinch & Krc, 1957). Recently, birefringence of single crystals of phenyl-substituted linear oligosilanes and their application to polarizers have been reported (Matsumoto & Tanaka, 2008). From these results, crystals of phenyl-substituted silicon compounds seem interesting as potential optical materials. We report herein the synthesis and X-ray crystal analysis of a phenyl-substituted cyclotetrasilane.

The coupling of 1,3-dibromo-1,1,3,3-tetra-*tert*-butyl-2,2-diphenyltrisilane and dichlorodiisopropylsilane with lithium in tetrahydrofuran (THF) gave 1,1,3,3-tetra-*tert*-butyl-2,2-diisopropyl-4,4-diphenylcyclotetrasilane (**1**) in 21% yield (Fig. 1). The molecular structure of **1** is shown in Fig. 2. Compound **1** has the crystallographic C_2 symmetry, and therefore the cyclotetrasilane ring has a completely planar structure. The silicon–silicon bonds [2.4404 (8) and 2.4576 (8) Å] are longer than the standard silicon–silicon bond (2.34 Å). The C1—Si1—C1ⁱ bond angle [97.07 (14)°] is smaller than the tetrahedral bond angle (109.5°), while the C7—Si2—C11 [111.39 (10)°] and C15—Si3—C15ⁱ [106.97 (15)°] bond angles are within normal values. The long silicon–silicon bonds and the small carbon–silicon–carbon bond angle are favorable for reducing the steric hindrance among bulky substituents.

Packing diagram of **1** is shown in Fig. 3. Four molecules are present in a unit cell. All cyclotetrasilane rings are oriented toward the same direction with the line through the Si1 and Si3 atoms parallel to the *b* axis. There is no intermolecular π – π interaction among phenyl groups.

S2. Experimental

A mixture of 1,3-dibromo-1,1,3,3-tetra-*tert*-butyl-2,2-diphenyltrisilane (5.00 g, 7.98 mmol), dichlorodiisopropylsilane (2.24 g, 12.1 mmol) and lithium (0.28 g, 40 mmol) in THF (50 ml) was stirred at room temperature for 1 day. The solvent was removed under reduced pressure. The residue was dissolved in hexane and passed through a short column of silica gel. After the silica gel was washed with hexane, the eluent was changed to diethyl ether. The diethyl ether eluate was evaporated. Recrystallization of the residue from methanol–THF (*ca* 1:1) gave **1** (0.956 g, 21%) as colorless crystals. Single crystals were obtained from methanol–THF (*ca* 1:1) by slow evaporation.

M.p.: 210–211 °C. ¹H NMR (400 MHz, CDCl₃): δ 1.21 (s, 36H), 1.46 (d, 12H, $J = 7.4$ Hz), 1.94 (sept, 2H, $J = 7.4$ Hz), 7.14–7.18 (m, 6H), 7.68–7.70 (m, 4H). ¹³C NMR (76 MHz, CDCl₃): δ 17.5, 24.7, 25.4, 32.8, 127.1, 127.4, 138.6, 142.1. ²⁹Si NMR (119 MHz, CDCl₃): δ -6.2, 14.0, 20.4. IR (KBr): 3050, 2950, 2920, 2850, 1470, 1420, 1390, 1360, 810, 730, 700 cm⁻¹. MS (EI, 70 eV): m/z 580 (M^+ , 17), 360 (100).

S3. Refinement

All hydrogen atoms were generated at calculated positions and refined as riding atoms, with C—H = 0.95 (phenyl), 0.98 (methyl) or 1.00 (methine) Å, and with $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{phenyl C})$, $1.5U_{\text{eq}}(\text{methyl C})$ or $1.2U_{\text{eq}}(\text{methine C})$.

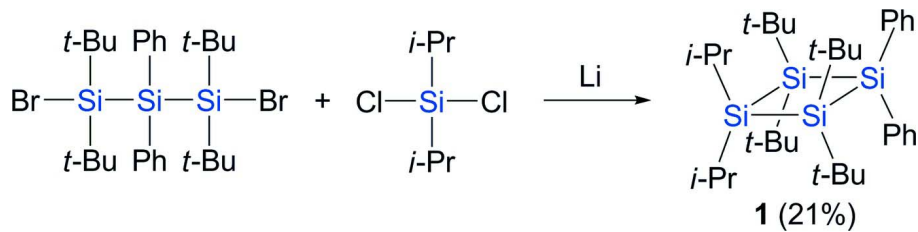


Figure 1
Synthesis of **1**.

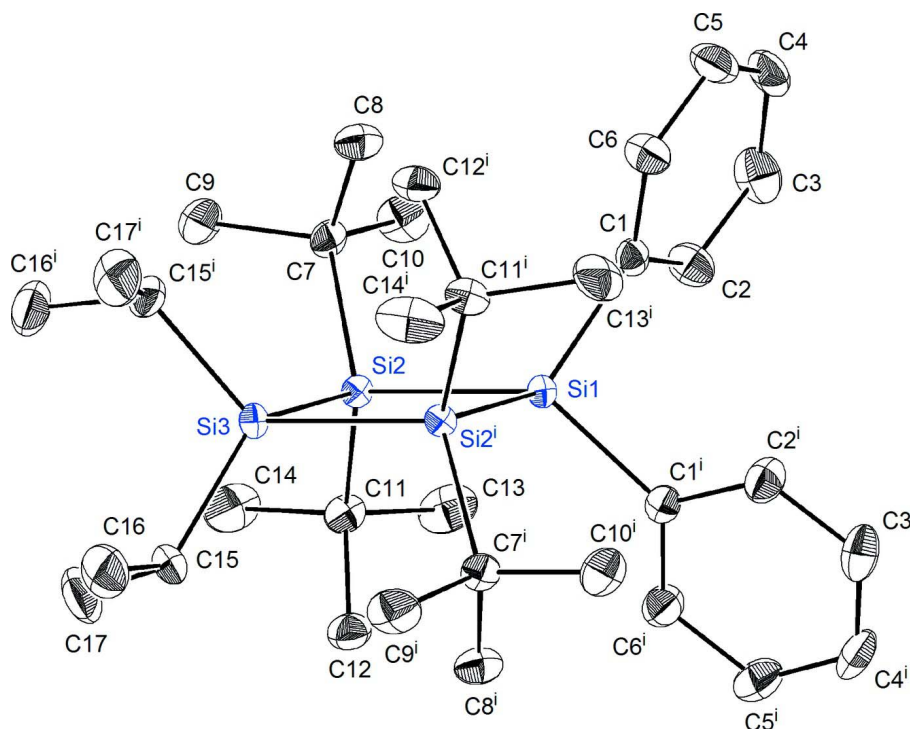


Figure 2
The molecular structure of **1**, showing 50% probability displacement ellipsoids. [Symmetry code: (i) $-x, y, -z + 3/2$.]

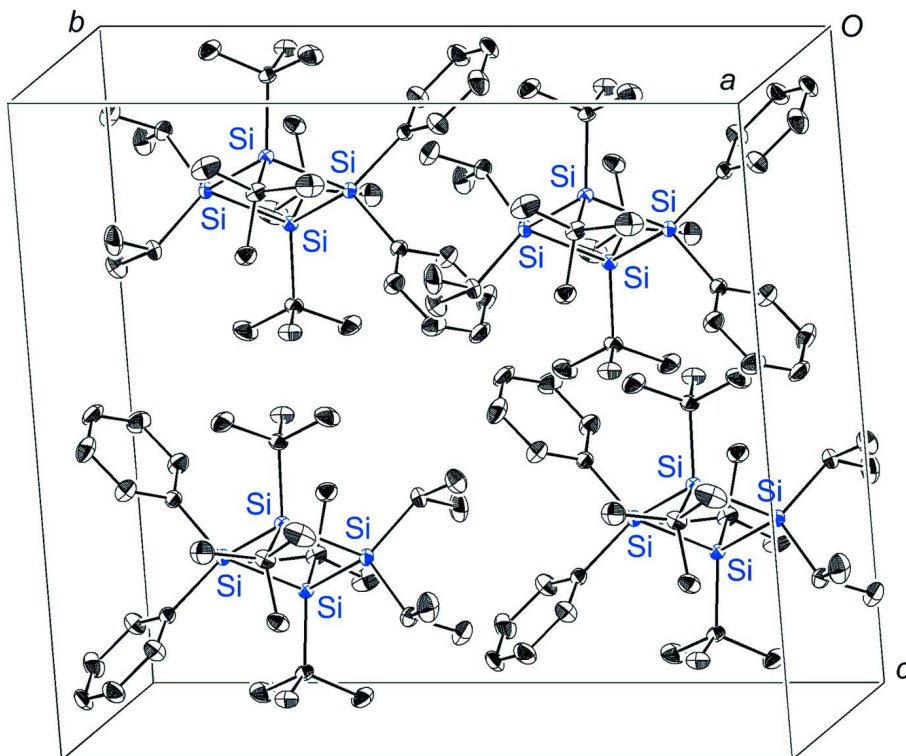


Figure 3
Packing diagram of **1**, showing 50% probability displacement ellipsoids.

1,1,3,3-Tetra-*tert*-butyl-2,2-diisopropyl-4,4-diphenylcyclotetrasilane

Crystal data

$C_{34}H_{60}Si_4$

$M_r = 581.18$

Monoclinic, $C2/c$

Hall symbol: $-C\ 2yc$

$a = 11.9477\ (9)\ \text{\AA}$

$b = 17.6585\ (12)\ \text{\AA}$

$c = 17.0422\ (13)\ \text{\AA}$

$\beta = 104.9394\ (8)^\circ$

$V = 3474.0\ (4)\ \text{\AA}^3$

$Z = 4$

$F(000) = 1280$

$D_x = 1.111\ \text{Mg m}^{-3}$

Melting point = 483–484 K

Mo $K\alpha$ radiation, $\lambda = 0.71073\ \text{\AA}$

Cell parameters from 7676 reflections

$\theta = 1.2\text{--}28.3^\circ$

$\mu = 0.19\ \text{mm}^{-1}$

$T = 173\ \text{K}$

Prism, colourless

$0.50 \times 0.40 \times 0.20\ \text{mm}$

Data collection

Rigaku R-AXISIV imaging plate
diffractometer

Radiation source: rotating anode
Graphite monochromator

Detector resolution: $10.00\ \text{pixels mm}^{-1}$

ω scans

Absorption correction: multi-scan
(*REQAB*; Jacobson, 1998)

$T_{\min} = 0.910$, $T_{\max} = 0.963$

8534 measured reflections

2917 independent reflections

2899 reflections with $I > 2\sigma(I)$

$R_{\text{int}} = 0.025$

$\theta_{\max} = 25.0^\circ$, $\theta_{\min} = 2.1^\circ$

$h = -14 \rightarrow 14$

$k = -18 \rightarrow 20$

$l = -20 \rightarrow 20$

*Refinement*Refinement on F^2

Least-squares matrix: full

 $R[F^2 > 2\sigma(F^2)] = 0.048$ $wR(F^2) = 0.095$ $S = 1.24$

2917 reflections

181 parameters

0 restraints

Primary atom site location: structure-invariant
direct methodsSecondary atom site location: difference Fourier
mapHydrogen site location: inferred from
neighbouring sites

H-atom parameters constrained

 $w = 1/[\sigma^2(F_o^2) + (0.0127P)^2 + 7.2943P]$ where $P = (F_o^2 + 2F_c^2)/3$ $(\Delta/\sigma)_{\max} = 0.001$ $\Delta\rho_{\max} = 0.24 \text{ e } \text{\AA}^{-3}$ $\Delta\rho_{\min} = -0.20 \text{ e } \text{\AA}^{-3}$ *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 $F^2 > 2\sigma(F^2)$ 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 (\AA^2)

	x	y	z	$U_{\text{iso}}^*/U_{\text{eq}}$
Si1	0.0000	0.32355 (5)	0.7500	0.01350 (19)
Si2	0.09403 (5)	0.22594 (3)	0.68813 (3)	0.01324 (15)
Si3	0.0000	0.12695 (5)	0.7500	0.01475 (19)
C1	-0.07934 (19)	0.39557 (13)	0.67052 (13)	0.0179 (5)
C2	-0.0078 (2)	0.45046 (14)	0.64962 (15)	0.0269 (6)
H1	0.0725	0.4498	0.6763	0.032*
C3	-0.0487 (2)	0.50564 (15)	0.59179 (17)	0.0330 (6)
H2	0.0031	0.5416	0.5791	0.040*
C4	-0.1657 (2)	0.50818 (15)	0.55245 (15)	0.0307 (6)
H3	-0.1947	0.5455	0.5122	0.037*
C5	-0.2392 (2)	0.45599 (15)	0.57252 (16)	0.0313 (6)
H4	-0.3196	0.4576	0.5462	0.038*
C6	-0.1968 (2)	0.40088 (14)	0.63102 (15)	0.0262 (5)
H5	-0.2494	0.3659	0.6444	0.031*
C7	0.03683 (19)	0.22973 (13)	0.56985 (13)	0.0191 (5)
C8	-0.0961 (2)	0.23931 (15)	0.54491 (14)	0.0259 (5)
H6	-0.1243	0.2356	0.4857	0.039*
H7	-0.1165	0.2890	0.5629	0.039*
H8	-0.1318	0.1994	0.5703	0.039*
C9	0.0639 (2)	0.15671 (16)	0.52878 (15)	0.0331 (6)
H9	0.0373	0.1622	0.4697	0.050*
H10	0.0240	0.1139	0.5462	0.050*
H11	0.1476	0.1476	0.5444	0.050*
C10	0.0887 (2)	0.29704 (15)	0.53389 (15)	0.0307 (6)
H12	0.1716	0.2884	0.5404	0.046*

H13	0.0779	0.3436	0.5623	0.046*
H14	0.0497	0.3020	0.4760	0.046*
C11	0.26218 (18)	0.23095 (14)	0.72206 (14)	0.0204 (5)
C12	0.3017 (2)	0.21501 (14)	0.81400 (14)	0.0253 (5)
H15	0.2866	0.1618	0.8242	0.038*
H16	0.2587	0.2477	0.8425	0.038*
H17	0.3848	0.2254	0.8338	0.038*
C13	0.3052 (2)	0.31047 (16)	0.70706 (17)	0.0347 (6)
H18	0.3880	0.3148	0.7340	0.052*
H19	0.2621	0.3486	0.7291	0.052*
H20	0.2929	0.3186	0.6486	0.052*
C14	0.3208 (2)	0.17278 (18)	0.67839 (17)	0.0379 (7)
H21	0.3064	0.1865	0.6209	0.057*
H22	0.2889	0.1223	0.6830	0.057*
H23	0.4044	0.1724	0.7034	0.057*
C15	0.0992 (2)	0.06194 (13)	0.82929 (15)	0.0241 (5)
H24	0.1364	0.0948	0.8766	0.029*
C16	0.0306 (3)	0.00034 (16)	0.86183 (17)	0.0387 (7)
H25	0.0068	-0.0395	0.8209	0.058*
H26	-0.0382	0.0231	0.8734	0.058*
H27	0.0798	-0.0215	0.9118	0.058*
C17	0.1985 (2)	0.02186 (16)	0.80303 (19)	0.0387 (7)
H28	0.2509	-0.0020	0.8504	0.058*
H29	0.2414	0.0591	0.7796	0.058*
H30	0.1662	-0.0170	0.7624	0.058*

Atomic displacement parameters (\AA^2)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
Si1	0.0139 (4)	0.0121 (4)	0.0151 (4)	0.000	0.0047 (3)	0.000
Si2	0.0127 (3)	0.0149 (3)	0.0133 (3)	-0.0005 (2)	0.0055 (2)	-0.0008 (2)
Si3	0.0165 (4)	0.0118 (4)	0.0169 (4)	0.000	0.0061 (4)	0.000
C1	0.0219 (11)	0.0167 (12)	0.0162 (11)	0.0022 (9)	0.0072 (10)	-0.0007 (9)
C2	0.0260 (12)	0.0273 (14)	0.0279 (14)	0.0013 (10)	0.0081 (11)	0.0074 (10)
C3	0.0415 (15)	0.0258 (14)	0.0367 (15)	-0.0008 (11)	0.0189 (13)	0.0106 (11)
C4	0.0465 (16)	0.0230 (14)	0.0230 (13)	0.0109 (11)	0.0101 (12)	0.0100 (10)
C5	0.0273 (13)	0.0336 (15)	0.0298 (14)	0.0095 (11)	0.0012 (12)	0.0062 (11)
C6	0.0227 (12)	0.0271 (14)	0.0276 (13)	0.0002 (10)	0.0044 (11)	0.0060 (10)
C7	0.0236 (12)	0.0209 (12)	0.0143 (11)	0.0012 (9)	0.0078 (10)	-0.0023 (9)
C8	0.0242 (12)	0.0346 (15)	0.0179 (12)	0.0005 (10)	0.0033 (10)	0.0002 (10)
C9	0.0410 (15)	0.0343 (16)	0.0232 (13)	0.0076 (12)	0.0070 (12)	-0.0095 (11)
C10	0.0375 (14)	0.0359 (16)	0.0219 (13)	-0.0041 (11)	0.0135 (12)	0.0068 (11)
C11	0.0144 (10)	0.0271 (13)	0.0210 (12)	-0.0006 (9)	0.0068 (10)	-0.0040 (9)
C12	0.0192 (11)	0.0299 (14)	0.0240 (13)	0.0013 (10)	0.0005 (10)	-0.0042 (10)
C13	0.0288 (13)	0.0431 (17)	0.0327 (15)	-0.0176 (12)	0.0086 (12)	0.0011 (12)
C14	0.0210 (13)	0.058 (2)	0.0355 (16)	0.0079 (12)	0.0092 (12)	-0.0157 (14)
C15	0.0289 (12)	0.0170 (12)	0.0243 (13)	0.0059 (10)	0.0029 (11)	0.0024 (9)
C16	0.0570 (18)	0.0254 (15)	0.0335 (15)	-0.0005 (13)	0.0113 (14)	0.0090 (12)

C17	0.0319 (14)	0.0246 (15)	0.058 (2)	0.0119 (11)	0.0084 (14)	0.0004 (13)
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Geometric parameters (Å, °)

Si1—C1	1.921 (2)	C9—H11	0.9800
Si1—Si2	2.4404 (8)	C10—H12	0.9800
Si2—C11	1.944 (2)	C10—H13	0.9800
Si2—C7	1.956 (2)	C10—H14	0.9800
Si2—Si3	2.4576 (8)	C11—C14	1.539 (3)
Si3—C15	1.929 (2)	C11—C13	1.539 (3)
C1—C6	1.394 (3)	C11—C12	1.541 (3)
C1—C2	1.398 (3)	C12—H15	0.9800
C2—C3	1.382 (3)	C12—H16	0.9800
C2—H1	0.9500	C12—H17	0.9800
C3—C4	1.386 (4)	C13—H18	0.9800
C3—H2	0.9500	C13—H19	0.9800
C4—C5	1.376 (4)	C13—H20	0.9800
C4—H3	0.9500	C14—H21	0.9800
C5—C6	1.392 (3)	C14—H22	0.9800
C5—H4	0.9500	C14—H23	0.9800
C6—H5	0.9500	C15—C17	1.543 (3)
C7—C10	1.539 (3)	C15—C16	1.548 (3)
C7—C9	1.541 (3)	C15—H24	1.0000
C7—C8	1.544 (3)	C16—H25	0.9800
C8—H6	0.9800	C16—H26	0.9800
C8—H7	0.9800	C16—H27	0.9800
C8—H8	0.9800	C17—H28	0.9800
C9—H9	0.9800	C17—H29	0.9800
C9—H10	0.9800	C17—H30	0.9800
C1 ⁱ —Si1—C1	97.07 (14)	H10—C9—H11	109.5
C1 ⁱ —Si1—Si2	125.03 (7)	C7—C10—H12	109.5
C1—Si1—Si2	111.19 (6)	C7—C10—H13	109.5
Si2 ⁱ —Si1—Si2	90.13 (4)	H12—C10—H13	109.5
C11—Si2—C7	111.39 (10)	C7—C10—H14	109.5
C11—Si2—Si1	113.26 (7)	H12—C10—H14	109.5
C7—Si2—Si1	110.10 (7)	H13—C10—H14	109.5
C11—Si2—Si3	117.16 (8)	C14—C11—C13	108.4 (2)
C7—Si2—Si3	112.93 (7)	C14—C11—C12	108.2 (2)
Si1—Si2—Si3	90.27 (3)	C13—C11—C12	107.92 (19)
C15 ⁱ —Si3—C15	106.97 (15)	C14—C11—Si2	112.95 (16)
C15 ⁱ —Si3—Si2	112.89 (7)	C13—C11—Si2	110.84 (17)
C15—Si3—Si2	117.23 (7)	C12—C11—Si2	108.42 (14)
Si2 ⁱ —Si3—Si2	89.33 (4)	C11—C12—H15	109.5
C6—C1—C2	115.8 (2)	C11—C12—H16	109.5
C6—C1—Si1	129.59 (18)	H15—C12—H16	109.5
C2—C1—Si1	114.57 (17)	C11—C12—H17	109.5
C3—C2—C1	122.9 (2)	H15—C12—H17	109.5

C3—C2—H1	118.6	H16—C12—H17	109.5
C1—C2—H1	118.6	C11—C13—H18	109.5
C2—C3—C4	119.7 (2)	C11—C13—H19	109.5
C2—C3—H2	120.2	H18—C13—H19	109.5
C4—C3—H2	120.2	C11—C13—H20	109.5
C5—C4—C3	119.1 (2)	H18—C13—H20	109.5
C5—C4—H3	120.4	H19—C13—H20	109.5
C3—C4—H3	120.4	C11—C14—H21	109.5
C4—C5—C6	120.6 (2)	C11—C14—H22	109.5
C4—C5—H4	119.7	H21—C14—H22	109.5
C6—C5—H4	119.7	C11—C14—H23	109.5
C5—C6—C1	121.9 (2)	H21—C14—H23	109.5
C5—C6—H5	119.1	H22—C14—H23	109.5
C1—C6—H5	119.1	C17—C15—C16	107.4 (2)
C10—C7—C9	108.18 (19)	C17—C15—Si3	116.68 (18)
C10—C7—C8	107.3 (2)	C16—C15—Si3	112.50 (17)
C9—C7—C8	106.7 (2)	C17—C15—H24	106.6
C10—C7—Si2	111.55 (16)	C16—C15—H24	106.6
C9—C7—Si2	112.41 (16)	Si3—C15—H24	106.6
C8—C7—Si2	110.42 (14)	C15—C16—H25	109.5
C7—C8—H6	109.5	C15—C16—H26	109.5
C7—C8—H7	109.5	H25—C16—H26	109.5
H6—C8—H7	109.5	C15—C16—H27	109.5
C7—C8—H8	109.5	H25—C16—H27	109.5
H6—C8—H8	109.5	H26—C16—H27	109.5
H7—C8—H8	109.5	C15—C17—H28	109.5
C7—C9—H9	109.5	C15—C17—H29	109.5
C7—C9—H10	109.5	H28—C17—H29	109.5
H9—C9—H10	109.5	C15—C17—H30	109.5
C7—C9—H11	109.5	H28—C17—H30	109.5
H9—C9—H11	109.5	H29—C17—H30	109.5
C1 ⁱ —Si1—Si2—C11	-3.63 (12)	C3—C4—C5—C6	-0.6 (4)
C1—Si1—Si2—C11	112.02 (11)	C4—C5—C6—C1	-0.9 (4)
Si2 ⁱ —Si1—Si2—C11	-119.92 (8)	C2—C1—C6—C5	2.0 (4)
C1 ⁱ —Si1—Si2—C7	-129.08 (11)	Si1—C1—C6—C5	-177.9 (2)
C1—Si1—Si2—C7	-13.43 (11)	C11—Si2—C7—C10	-51.24 (19)
Si2 ⁱ —Si1—Si2—C7	114.63 (8)	Si1—Si2—C7—C10	75.27 (16)
C1 ⁱ —Si1—Si2—Si3	116.29 (8)	Si3—Si2—C7—C10	174.50 (14)
C1—Si1—Si2—Si3	-128.06 (7)	C11—Si2—C7—C9	70.49 (19)
Si2 ⁱ —Si1—Si2—Si3	0.0	Si1—Si2—C7—C9	-163.01 (15)
C11—Si2—Si3—C15 ⁱ	-124.05 (11)	Si3—Si2—C7—C9	-63.78 (18)
C7—Si2—Si3—C15 ⁱ	7.41 (11)	C11—Si2—C7—C8	-170.44 (16)
Si1—Si2—Si3—C15 ⁱ	119.45 (8)	Si1—Si2—C7—C8	-43.93 (18)
C11—Si2—Si3—C15	0.95 (12)	Si3—Si2—C7—C8	55.30 (18)
C7—Si2—Si3—C15	132.41 (11)	C7—Si2—C11—C14	-51.3 (2)
Si1—Si2—Si3—C15	-115.55 (9)	Si1—Si2—C11—C14	-176.05 (16)
C11—Si2—Si3—Si2 ⁱ	116.50 (8)	Si3—Si2—C11—C14	80.87 (19)

C7—Si2—Si3—Si2 ⁱ	-112.04 (8)	C7—Si2—C11—C13	70.59 (18)
Si1—Si2—Si3—Si2 ⁱ	0.0	Si1—Si2—C11—C13	-54.17 (17)
C1 ⁱ —Si1—C1—C6	-127.9 (2)	Si3—Si2—C11—C13	-157.25 (14)
Si2 ⁱ —Si1—C1—C6	-5.8 (3)	C7—Si2—C11—C12	-171.14 (15)
Si2—Si1—C1—C6	100.2 (2)	Si1—Si2—C11—C12	64.11 (17)
C1 ⁱ —Si1—C1—C2	52.17 (16)	Si3—Si2—C11—C12	-38.97 (18)
Si2 ⁱ —Si1—C1—C2	174.29 (14)	C15 ⁱ —Si3—C15—C17	74.54 (19)
Si2—Si1—C1—C2	-79.77 (18)	Si2 ⁱ —Si3—C15—C17	-155.06 (17)
C6—C1—C2—C3	-1.9 (4)	Si2—Si3—C15—C17	-53.4 (2)
Si1—C1—C2—C3	178.1 (2)	C15 ⁱ —Si3—C15—C16	-50.24 (16)
C1—C2—C3—C4	0.5 (4)	Si2 ⁱ —Si3—C15—C16	80.16 (18)
C2—C3—C4—C5	0.7 (4)	Si2—Si3—C15—C16	-178.14 (15)

Symmetry code: (i) $-x, y, -z+3/2$.