# Formation of stable enols from 1,4-dilithio-1,3-dienes and acid chlorides by a de-aromatization/Michael addition/re-aromatization domino process†

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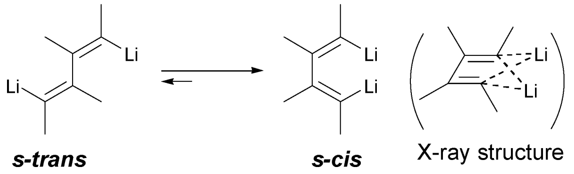
*Received 4th April 2007, Accepted 18th May 2007*
*First published as an Advance Article on the web 31st May 2007*
**DOI: 10.1039/b705110g**

Stable enols were synthesized from the reaction of (1*Z*,3*Z*)-1,4-dilithio-1,3-dienes with acid chlorides and structurally characterized by single-crystal X-ray analysis. These stable enols were formed by a novel de-aromatization/Michael addition/re-aromatization domino process.

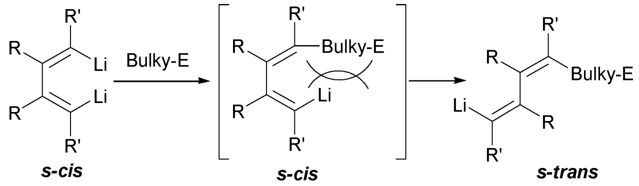
## Introduction

(1*Z*,3*Z*)-1,4-Dilithio-1,3-butadienes have been of substantial interest for decades,[1–7] especially as organobimetallic reagents for synthetic chemistry, utilizing the cooperative effect of the two alkenyllithiums in the same molecule,[1–3] and their structural properties.[4–6] The solid-state X-ray structures have generally shown an *s-cis* conformation and a double-bridged dilithium structure (Scheme 1),[6] which has also been supported by theoretical predictions.[4] As demonstrated by the work of ourselves and others,[1–3,7] these *s-cis* forms and the doubly-bridged dilithium structure contribute greatly to their interesting reaction chemistry.



Scheme 1

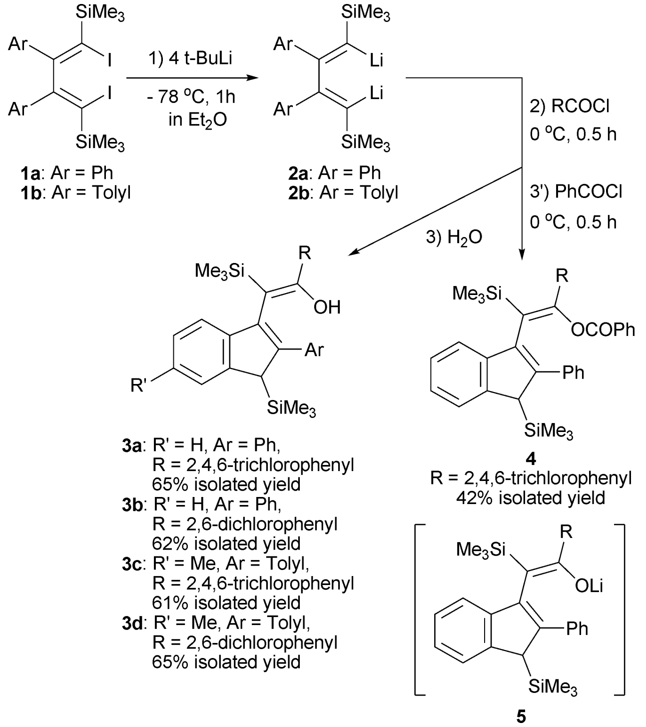
As part of our continuing research into these interesting and useful organodilithium reagents,[1,7] we envisioned that the *s-trans* form should have different reactivity from that of the *s-cis* form. In order to change the conformation of (1*Z*,3*Z*)-1,4-dilithio-1,3-butadienes from the relatively stable *s-cis* form to the relatively unstable *s-trans* form, we employed a strategy taking advantage of the steric repulsion effect forcing the equilibrium to the *s-trans* form (Scheme 2). Very interestingly, this strategy resulted in the formation and isolation of a new type of stable enol from the reaction of 1,4-dilithio-1,3-butadienes with acid chlorides. In this paper, we would like to report: (1) the formation of unexpected stable enols by a novel de-aromatization/Michael addition/re-aromatization domino process, (2) the structure and reaction chemistry of this kind of enol, and (3) mechanistic aspects.



Scheme 2

## Results and discussion

1,4-Bis(trimethylsilyl)-2,3-diaryl-1,4-dilithio-1,3-dienes **2a** (Ar = Ph) and **2b** (Ar = tolyl) could be readily generated quantitatively *in situ* by lithium–iodine exchange of the corresponding 1,4-diiodo-1,3-butadienes **1** with 4 equivalents of *t*-BuLi.[7] Addition of acid chloride to this mixture caused immediate reaction, the reaction being complete within 30 minutes, and affording enols **3a–d** in good isolated yield after quenching with water (Scheme 3).



Scheme 3

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† Electronic supplementary information (ESI) available: Copies of $^1$H and $^{13}$C NMR spectra for all new compounds; crystal data for **3a**. See DOI: 10.1039/b705110g

When the reaction was terminated using PhCOCl instead of by hydrolysis, the ester **4** was isolated in 42% yield. All these results indicated that a novel reaction was taking place, with the lithium enolate **5** as an intermediate.

The structure of enol **3a** was determined by single-crystal X-ray analysis (Fig. 1).

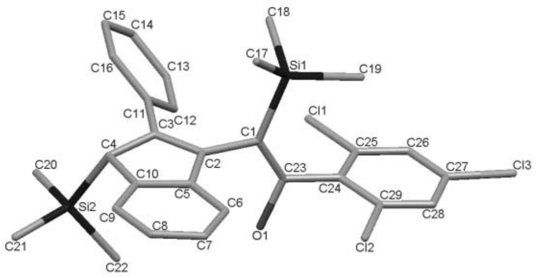
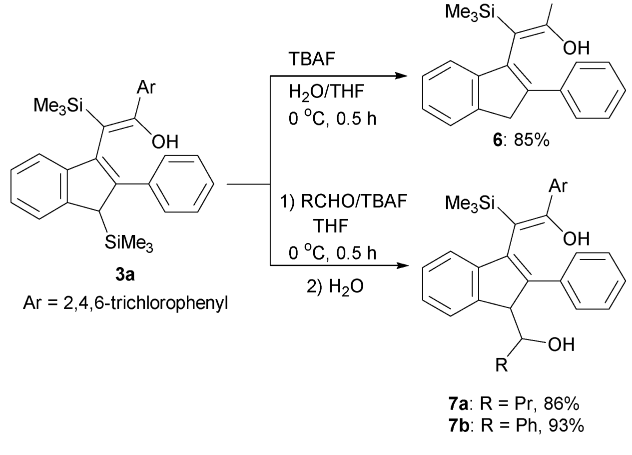


**Fig. 1** X-Ray structure of **3a**. Selected bond lengths (in Å): C23–O1 1.384(3), C1–C23 1.330(4), C1–C2 1.503(4), C2–C3 1.359(4), C2–C5 1.474(4), C3–C4 1.508(4). CCDC reference number 633783. For crystallographic data in CIF or other electronic format, see DOI: 10.1039/b705110g.

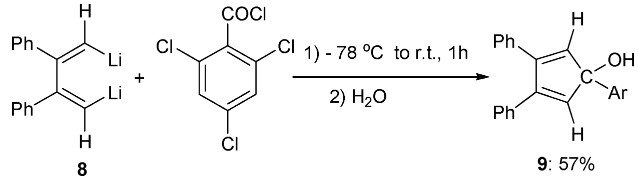
The study of the synthesis, stability and reaction chemistry of enols has been a fundamental subject in organic chemistry both from the theoretical point of view and the experimental point of view. Several excellent methods and a number of stable enols have been reported in the literature.[8–10] For example, Rappoport and co-workers have developed a series of interesting and useful synthetic methods for simple stable enols and have determined their structures by X-ray analysis.[8] The enols reported in this paper represent a new type of stable enol, and the synthetic method is unprecedented.

We tested the stability of these enols in various solvents. No tautomeric equilibrium was observed for these enols when they were dissolved in solvents such as $CDCl_3$, DMSO-$d_6$ and $C_6D_6$. In addition, they were also chemically very stable; the enol moiety did not undergo any reaction on exposure to strong conditions. However, the $SiMe_3$ group on the five-membered ring of **3a** did undergo desilylation, affording their derivatives **6** and **7** in excellent isolated yields (Scheme 4).



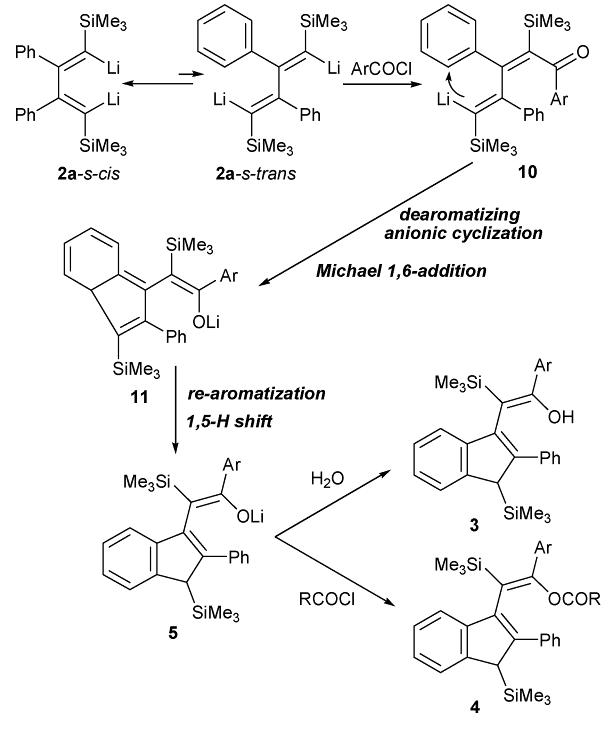
**Scheme 4**

The steric effect is generally accepted as the major factor contributing to the existence of stable enols.[8–10] To further investigate the steric effect for these stable enols, we treated 2,3-diphenyl-1,4-dilithio-1,3-diene **8** with 2,4,6-trichlorophenyl carbonyl chloride. In contrast to **2a**, this dilithio reagent **8** does not have the bulky trimethylsilyl groups at the 1- and 4-positions. Indeed, instead of an enol, cyclopentadienol **9**[7e] was obtained in 57% isolated yield (Scheme 5). This result demonstrates that the steric effect does play a crucial role for the formation of stable enols.



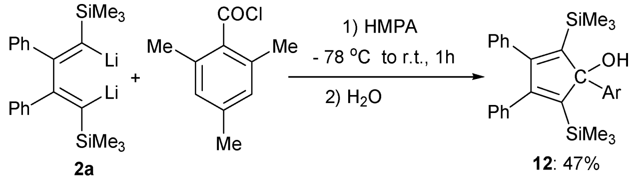
**Scheme 5**

A proposed reaction mechanism for the synthesis of the stable enols is given in Scheme 6. The steric effect is considered to be crucial for this novel reaction. Because of the steric effect, the Li atom gets close enough to the adjacent phenyl ring and undergoes immediate anionic attack, de-aromatizing the phenyl ring. This dearomatizing anionic cyclization has been well documented in the literature.[11–15] However, it is not yet clear whether the **2a**-*s-trans* conformation or the **2a**-*s-cis* conformation reacts first with the acid chloride. What is clear is that upon formation, the intermediate **10** must immediately undergo dearomatizing anionic cyclization and Michael 1,6-addition, leading to **11**. Re-aromatization of **11** by a 1,5-H shift then affords the enolate **5**.



**Scheme 6**

Although the steric effect is crucial here, further reactions suggested that the electronic effect must also play an important role. For example, as shown in Scheme 3, **2a** reacted with 2,4,6-trichlorobenzoyl chloride affording the stable enol **3a** in 65% isolated yield. However, when **2a** was treated with mesitoyl chloride without HMPA, no reaction was detected. As shown in Scheme 7, in the presence of HMPA, the reaction took place to form the cyclopentadiene derivative **12** in 47% isolated yield,[7e] with no enol being formed. This result demonstrates that the electronic effect also plays an important role for the formation of stable enols.



**Scheme 7**

## Conclusion

In conclusion, we have developed an interesting methodology involving a de-aromatization/Michael addition/re-aromatization domino process to afford a new type of stable enol. Both steric and electronic effects were found to be crucial for this reaction.

## Experimental

All reactions were conducted under a slightly positive pressure of dry, pre-purified nitrogen using standard Schlenk line techniques when appropriate. Unless otherwise noted, all starting materials were commercially available and were used without further purification. Diethyl ether and THF were refluxed and distilled from sodium–benzophenone ketyl under a nitrogen atmosphere. 1,4-Dihalo-1,3-butadienes were prepared according to literature methods.[16] $^{1}$H and $^{13}$C NMR spectra were recorded at 300 and 75.4 MHz, respectively, in $CDCl_3$ unless stated otherwise.

### Typical procedure for synthesis of enols 3 by reaction between dilithio-diene 2 and acid chlorides

To a solution of 1,4-bis(trimethylsilyl)-2,3-diary-1,4-diiodo-1,3-dienes **1** (1.0 mmol) in $Et_2O$ (10 ml) at −78 °C was added *t*-BuLi (4.0 mmol, 1.5 M in pentane). After stirring the reaction mixture at −78 °C for 1 h, acid chloride (1.2 mmol) was added, and the reaction mixture warmed up to 0 °C for 0.5 h. The mixture was then quenched with water, extracted with $Et_2O$, the extract washed with brine and dried over $MgSO_4$. The solvent was evaporated *in vacuo* and the residue purified by column chromatography (silica gel, 10 : 1 hexane–dichloromethane) to afford the products **3**.

**3a.** Colorless crystals, 65% yield (363 mg); mp 199.6–200.2 °C; $^{1}$H NMR (300 MHz, $CDCl_3$, $Me_4Si$, 25 °C): $\delta = -0.54$ (s, 9H, $CH_3$), −0.23 (s, 9H, $CH_3$), 4.21 (s, 1H, CH), 5.56 (s, 1H, OH), 7.22–7.78 (m, 11H, CH). $^{13}$C NMR (75 MHz, $CDCl_3$, $Me_4Si$, 25 °C): $\delta = -2.52$ (3 $CH_3$), −0.85 (3 $CH_3$), 48.39 (1 CH), 110.02 (1 quat C), 121.12 (1 CH), 123.08 (1 CH), 124.20 (1 CH), 125.27 (1 CH), 127.51 (1 CH), 127.96 (2 CH), 128.17 (1 CH), 128.22 (1 CH), 129.57 (2 CH), 131.74 (1 quat C), 134.26 (1 quat C), 135.39 (1 quat C), 136.77 (1 quat C), 136.92 (1 quat C), 137.65 (1 quat C), 144.57 (1 quat C), 144.74 (1 quat C), 148.14 (1 quat C), 151.40 (1 quat C). HRMS calcd. for $C_{29}H_{31}OSi_2Cl_3$: 556.0979, found 556.0984. Anal. Calcd for $C_{29}H_{31}OSi_2Cl_3$: C, 62.41%; H, 5.60%. Found: C, 62.42%, H, 5.58%.

**3b.** Colorless crystals, 62% yield (323 mg); mp 165.0–166.3 °C; $^{1}$H NMR (300 MHz, $CDCl_3$, $Me_4Si$, 25 °C): $\delta = -0.55$ (s, 9 H, $CH_3$), −0.22 (s, 9 H, $CH_3$), 4.22 (s, 1 H, CH), 5.58 (s, 1 H, OH), 7.22–7.85 (m, 12 H, CH). $^{13}$C NMR (75 MHz, $CDCl_3$, $Me_4Si$, 25 °C): $\delta = -2.50$ (3 $CH_3$), −0.91 (3 $CH_3$), 48.30 (1 CH), 109.30 (1 quat C), 121.30 (1 CH), 123.02 (1 CH), 124.12 (1 CH), 125.26 (1 CH), 127.43 (1 CH), 127.93 (2 CH), 128.11 (1 CH), 128.22 (1 CH), 129.64 (2 CH), 130.37 (1 CH), 132.01 (1 quat C), 135.50 (1 quat C), 136.21 (1 quat C), 136.32 (1 quat C), 137.72 (1 quat C), 144.73 (1 quat C), 144.78 (1 quat C), 148.03 (1 quat C), 152.33 (1 quat C). HRMS calcd. for $C_{29}H_{32}OSi_2Cl_2$: 522.1369, found 522.1358.

**3c.** Colorless crystals, 61% yield (356 mg); mp 153.9–154.8 °C; $^{1}$H NMR (300 MHz, $CDCl_3$, $Me_4Si$, 25 °C): $\delta = -0.53$ (s, 9H, $CH_3$), −0.23 (s, 9H, $CH_3$), 2.37 (s, 3H, $CH_3$), 2.45 (s, 3H, $CH_3$), 4.13 (s, 1H, CH), 5.58 (s, 1H, OH), 7.11–7.64 (m, 9H, CH). $^{13}$C NMR (75 MHz, $CDCl_3$, $Me_4Si$, 25 °C): $\delta = -2.41$ (3 $CH_3$), −0.77 (3 $CH_3$), 21.34 (1 $CH_3$), 21.77 (1 $CH_3$), 47.88 (1 CH), 110.26 (1 quat C), 120.67 (1 CH), 123.84 (1 CH), 126.25 (1 CH), 128.14 (1 CH), 128.18 (1 CH), 128.59 (2 CH), 129.38 (2 CH), 130.92 (1 quat C), 133.60 (1 quat C), 134.36 (1 quat C), 134.83 (1 quat C), 135.32 (1 quat C), 136.35 (1 quat C), 136.94 (1 quat C), 137.03 (1 quat C), 142.23 (1 quat C), 144.96 (1 quat C), 147.15 (1 quat C), 151.18 (1 quat C). HRMS calcd. for $C_{31}H_{35}OSi_2Cl_3$: 584.1292, found 584.1292. Anal. Calcd for $C_{31}H_{35}OSi_2Cl_3$: C, 63.52%; H, 6.02%. Found: C, 63.51%, H, 6.10%.

**3d.** Colorless crystals, 65% yield (360 mg); mp 153.3–154.2 °C; $^{1}$H NMR (300 MHz, $CDCl_3$, $Me_4Si$, 25 °C): $\delta = -0.54$ (s, 9H, $CH_3$), −0.22 (s, 9H, $CH_3$), 2.37 (s, 3H, $CH_3$), 2.45 (s, 3H, $CH_3$), 4.13 (s, 1H, CH), 5.59 (s, 1H, OH), 7.11–7.70 (m, 10H, CH). $^{13}$C NMR (75 MHz, $CDCl_3$, $Me_4Si$, 25 °C): $\delta = -2.39$ (3 $CH_3$), −0.83 (3 $CH_3$), 21.35 (1 $CH_3$), 21.77 (1 $CH_3$), 47.80 (1 CH), 109.54 (1 quat C), 120.84 (1 CH), 123.78 (1 CH), 126.23 (1 CH), 128.08 (1 CH), 128.18 (1 CH), 128.57 (2 CH), 129.44 (2 CH), 130.31 (1 CH), 131.17 (1 quat C), 133.51 (1 quat C), 134.90 (1 quat C), 135.58 (1 quat C), 136.29 (1 quat C), 136.35 (1 quat C), 136.93(1 quat C), 142.44 (1 quat C), 144.95 (1 quat C), 147.06 (1 quat C), 152.12(1 quat C). HRMS calcd. for $C_{31}H_{36}OSi_2Cl_2$: 550.1682, found 550.1686.

### Synthesis of enol ester 4 by reaction between dilithio-diene 2 and two different acid chlorides

To a solution of 1,4-bis(trimethylsilyl)-2,3-diphenyl-1,4-diiodo-1,3-diene **1a** (1.0 mmol) in $Et_2O$ (10 ml) at −78 °C was added *t*-BuLi (4.0 mmol, 1.5 M in pentane). After stirring the reaction mixture −78 °C for 1 h, 2,4,6-trichlorobenzoyl chloride (1.2 mmol) was added, the reaction mixture warmed up to 0 °C for 0.5 h, and benzoyl chloride (1.2 mmol) then added at the same temperature. After stirring for another 0.5 h, the mixture was quenched with water, extracted with $Et_2O$, the extract washed with brine and dried over $MgSO_4$. The solvent was evaporated *in vacuo* and the residue purified by column chromatograph (silica gel, 10 : 1 hexane–dichloromethane) to afford the enol ester **4**.

**4.** Colorless crystals, 42% yield (278 mg); mp 229.2–230.9 °C; $^1$H NMR (300 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.53$ (s, 9H, CH$_3$), −0.51 (s, 9H, CH$_3$), 4.06 (s, 1H, CH), 7.17–7.93 (m, 16H, CH). $^{13}$C NMR (75 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -2.55$ (3 CH$_3$), −0.91 (3 CH$_3$), 47.55 (1 CH), 121.37 (1 CH), 122.74 (1 CH), 123.48 (1 CH), 124.84 (1 CH), 127.27 (1 CH), 127.96 (2 CH), 128.08 (2 CH), 128.24 (1 CH), 128.64 (1 CH), 129.29 (1 quat C), 130.18 (2 CH), 130.30 (2 CH), 130.67 (1 quat C), 133.06 (1 CH), 133.50 (1 quat C), 134.52 (1 quat C), 135.51 (1 quat C), 136.75 (1 quat C), 138.22 (1 quat C), 138.71 (1 quat C), 144.22 (1 quat C), 144.57 (1 quat C), 145.14 (1 quat C), 146.68 (1 quat C), 163.74 (1 CO); IR (neat): $\nu$ (C=O) = 1729 cm$^{-1}$; HRMS calcd. for $C_{36}H_{35}O_2Si_2Cl_3$: 660.1241, found 660.1220.

### Synthesis of enol 6 by desilylation of 3a

To a solution of enol **3a** (1.0 mmol) in 1 : 1 THF–H$_2$O (10 ml) at 0 °C was added TBAF·3H$_2$O (1.0 mmol). After stirring at 0 °C for 0.5 h, water (5 ml) was added, and the mixture extracted with Et$_2$O. The extract was then washed with brine and dried over MgSO$_4$. The solvent was evaporated *in vacuo* and the residue purified by column chromatography (silica gel, 4 : 1 hexane–dichloromethane) to afford the enol **6**.

**6.** Colorless crystals, 85% yield (413 mg); mp 149.1–150.5 °C; $^1$H NMR (300 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.31$ (s, 9H, CH$_3$), 3.79–4.13 (m, 2H, CH$_2$), 5.61 (s, 1H, OH), 7.23–7.92 (m, 11H, CH). $^{13}$C NMR (75 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.54$ (3 CH$_3$), 41.02 (1 CH$_2$), 109.82 (1 quat C), 121.30 (1 CH), 123.53 (1 CH), 125.43 (1 CH), 126.75 (1 CH), 127.61 (1 CH), 128.05 (2 CH), 128.22 (3 CH), 128.29 (1 CH), 134.03 (1 quat C), 134.98 (1 quat C), 135.53 (1 quat C), 136.48 (1 quat C), 136.72 (1 quat C), 137.02 (1 quat C), 142.36 (1 quat C), 143.48 (1 quat C), 146.25 (1 quat C), 151.02 (1 quat C). HRMS calcd. for $C_{26}H_{23}OSiCl_3$: 484.0584, found 484.0578. Anal. Calcd for $C_{26}H_{23}OSiCl_3$: C, 64.27%; H, 4.77%. Found: C, 64.27%, H, 4.82%.

### Synthesis of enol 7 by reaction between 3a and an aldehyde

To a solution of enol **3a** (1.0 mmol) and an aldehyde (1.2 mmol) in THF (10 ml) at 0 °C was added TBAF (1.0 mmol, 1 M in THF). After stirrng at 0 °C for 0.5 h, water (5 ml) was added, and the mixture extracted with Et$_2$O. The extract was then washed with brine and dried over MgSO$_4$. The solvent was evaporated *in vacuo* and the residue purified by column chromatography (silica gel, 2 : 1 hexane–dichloromethane) to afford the enol **7**.

**7a.** Colorless crystals, 86% yield (480 mg); mp 122.3–123.1 °C; $^1$H NMR (300 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.41$ (s, 9H, CH$_3$), 0.93 (t, $J = 7.3$ Hz, 3H, CH$_3$), 1.40–1.51 (m, 2H, CH$_2$), 1.66–1.75 (m, 2H, CH$_2$), 3.90 (t, $J = 5.7$ Hz, 1H, CH), 4.22 (d, $J = 5.2$ Hz, 1H, CH), 6.60 (s, 1H, OH), 7.20–7.70 (m, 11H, CH). $^{13}$C NMR (75 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.82$ (3 CH$_3$), 14.01 (1 CH$_3$), 19.69 (1 CH$_2$), 38.05 (1 CH$_2$), 56.86(1 CH), 71.99 (1 CH), 108.95 (1 quat C), 121.52 (1 CH), 124.00 (1 CH), 124.95 (1 CH), 127.43 (1 CH), 127.61 (1 CH), 128.10 (1 CH), 128.18 (2 CH), 128.21 (1 CH), 129.13 (2 CH), 134.50 (1 quat C), 135.26 (1 quat C), 135.87 (1 quat C), 136.21 (1 quat C), 136.70 (1 quat C), 136.82 (1 quat C), 141.78 (1 quat C), 146.62 (1 quat C), 147.39 (1 quat C), 151.68 (1 quat C). HRMS calcd. for $C_{30}H_{31}O_2SiCl_3$: 556.1159, found 556.1184.

**7b.** Colorless crystals, 93% yield (480 mg); mp 125.3–125.8 °C; $^1$H NMR (300 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.46$ (s, 9H, CH$_3$), 1.91 (s, 1H, OH), 4.59 (d, $J = 2.9$ Hz, 1H, CH), 5.26 (d, $J = 2.8$ Hz, 1H, CH), 5.92 (s, 1H, OH), 6.73–7.78 (m, 16H, CH). $^{13}$C NMR (75 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.87$ (3 CH$_3$), 58.47 (1 CH), 74.03 (1 CH), 108.98 (1 quat C), 121.38 (1 CH), 124.18 (1 CH), 124.96 (1 CH), 125.49 (2 CH), 127.47 (1 CH), 127.53 (1 CH), 127.74 (1 CH), 127.94 (2 CH), 128.12 (1 CH), 128.17 (1 CH), 128.28 (2 CH), 129.34 (2 CH), 134.25 (1 quat C), 135.33 (1 quat C), 136.09 (1 quat C), 136.60 (1 quat C), 136.76 (1 quat C), 137.14 (1 quat C), 141.29 (1 quat C), 141.52 (1 quat C), 145.52 (1 quat C), 146.74 (1 quat C), 151.46 (quat C). HRMS calcd. for $C_{33}H_{29}O_2SiCl_3$: 590.1002, found 590.0992.

### Synthesis of cyclopentadienol 9 by reaction between dilithio-diene 8 and 2,4,6-trichlorophenyl carbonyl chloride

To a solution of 2,3-diphenyl-1,4-diiodo-1,3-diene (1.0 mmol) in Et$_2$O (10 ml) at −78 °C was added *t*-BuLi (4.0 mmol, 1.5 M in pentane). After stirring at −78 °C for 1 h, 2,4,6-trichlorophenyl carbonyl chloride (1.2 mmol) was added. The reaction mixture was then warmed up to room temperature for 0.5 h, quenched with water and extracted with Et$_2$O. The extract was then washed with brine and dried over MgSO$_4$. The solvent was evaporated *in vacuo* and the residue purified by column chromatography (silica gel, 10 : 1 hexane–dichloromethane) to afford the product **9**.

**9.** Colorless crystals, 57% yield (235 mg); mp 123.2–124.9 °C; $^1$H NMR (300 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = 3.43$ (s, 1H, OH), 6.81 (s, 2H, CH), 7.15–7.38 (m, 12H, CH). $^{13}$C NMR (75 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = 85.71$ (1 quat C), 127.75 (2 CH), 127.93 (4 CH), 128.06 (4 CH), 130.48 (2 CH), 133.51 (1 quat C), 134.82 (3 quat C), 135.57 (2 quat C), 136.22 (2 CH), 144.02 (2 quat C). HRMS calcd. for $C_{23}H_{15}OCl_3$: 412.0189, found 412.0174. Anal. Calcd for $C_{23}H_{15}OCl_3$: C, 66.77%; H, 3.65%. Found: C, 66.77%, H, 3.77%.

### Synthesis of cyclopentadienol 12 by reaction between dilithio-diene 2a and 2,4,6-trimethylphenyl carbonyl chloride

To a solution of 1,4-bis(trimethylsilyl)-2,3-diphenyl-1,4-diiodo-1,3-dienes **1a** (1.0 mmol) in Et$_2$O (10 ml) at −78 °C was added *t*-BuLi (4.0 mmol, 1.5 M in pentane). After stirring at −78 °C for 1 h, HMPA (2.2 mmol) and 2,4,6-trimethylphenyl carbonyl chloride (1.2 mmol) were added. The reaction mixture was then warmed up to room temperature for 1 h, quenched with water and extracted with Et$_2$O. The extract was then washed with brine and dried over MgSO$_4$. The solvent was evaporated *in vacuo* and the residue purified by column chromatography (silica gel, 10 : 1 hexane–dichloromethane) to afford the product **12**.

**12.** Colorless crystals, 47% yield (234 mg); mp 168.6–169.7 °C; $^1$H NMR (300 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.33$ (s, 18H, CH$_3$), 1.71 (s, 1H, OH), 2.25 (s, 3H, CH$_3$), 2.47 (s, 3H, CH$_3$), 2.80 (s, 3H, CH$_3$) 6.75–7.25 (m, 12H, CH). $^{13}$C NMR (75 MHz, CDCl$_3$, Me$_4$Si, 25 °C): $\delta = -0.27$ (6 CH$_3$), 19.89 (1 CH$_3$), 20.56 (1 CH$_3$), 26.48 (1 CH$_3$), 99.97 (1 quat C), 126.83 (2 CH), 127.33 (4 CH), 128.81 (4 CH), 130.75 (1 CH), 133.12 (1 CH), 133.70 (1 quat C), 135.39 (1 quat C), 135.47 (1 quat C), 137.68 (2 quat C), 138.42 (1 quat C), 155.47 (2 quat C), 156.53 (2 quat C). HRMS calcd. for $C_{32}H_{40}OSi_2$: 496.2618, found 496.2609.

## Acknowledgements

This work was supported by the National Natural Science Foundation of China and the Major State Basic Research Development Program (2006CB806105). The Cheung Kong Scholars Programme, Qiu Shi Science & Technologies Foundation, the Dow Corning Corporation and BASF are gratefully acknowledged.

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