Pergamon

Tetrahedron Letters 42 (2001) 581–584

TETRAHEDRON LETTERS

A new regio- and stereocontrolled access to functionalised silacyclopent-3-enes†

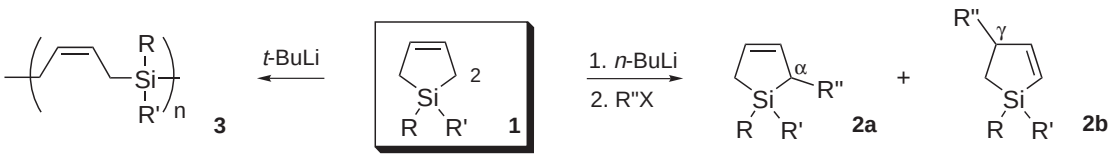
Yannick Landais* and Sheetal S. Surange

Université Bordeaux-I, Laboratoire de Chimie Organique et Organométallique, 351, Cours de la Libération, 33405 Talence Cedex, France

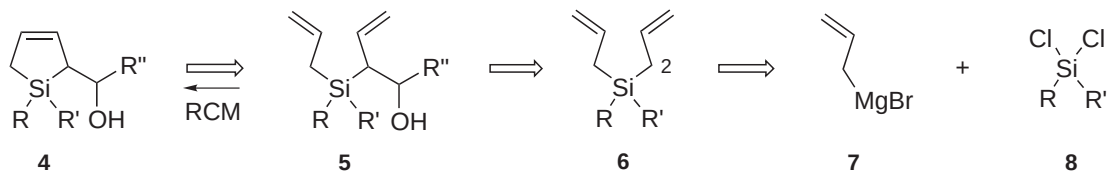
Received 18 July 2000; accepted 7 November 2000

Abstract—C-2 functionalised silacyclopent-3-enes were obtained in high yields in only two steps from diallyldiphenylsilane through hydroxy-alkylation of an allyltitanium intermediate followed by ring closure metathesis of the resulting β-hydroxysilane.

Silacyclopent-3-enes **1** widely used as polymer precursors are attractive synthons that have found little use as building blocks in organic synthesis.[1] These are most commonly accessible by a coupling reaction between dichlorosilanes and dienes in the presence of lithium or magnesium.[1e–f] This method, which affords the titled compounds in moderate to good yields, is, however, not general owing to the restricted number of substituents allowed on the ring and at the silicon centre. Moreover, the access to polysubstituted silacyclopent-3-enes through alkylation of **1** is not straightforward. For instance, the preparation of C-2 substituted silacyclopent-3-enes **2a** through metallation of **1** with a strong base (i.e. *t*-BuLi) followed by alkylation is precluded by the formation of polymeric materials **3** formed by initial nucleophilic attack on the silicon centre (Scheme 1).[2] Increasing the steric hindrance to slow down the attack of RLi on the silicon centre was shown to partially overcome this problem.[2] However, the reaction of the allylic carbanion with a range of electrophiles was found to be poorly regioselective affording inseparable mixtures of α/γ-regioisomers (i.e. **2a** and **2b**). Therefore, while few methods are available and give access to various types of silacyclopentenes,[1] a general and regioselective method of preparation of synthons such as **2a** that could also be extended into homochiral series is still lacking.



Scheme 1.



Scheme 2.

Keywords: silicon and compounds; titanium and compounds; metathesis; hydroxylation.
* Corresponding author. Fax: (33) 5 56 84 66 46; e-mail: y.landais@lcoo.u-bordeaux.fr
† Dedicated to Dr. Ian Fleming on the occasion of his 65th birthday.

0040-4039/01/$ - see front matter
PII: S0040-4039(00)02004-9

Table 1. Hydroxy-alkylation of diallyldiphenylsilane **9** (Scheme 3)

Alcohol	R	Yield (%)[a]	d.e. (%)[b]
11a	*i*-Pr	65	>98
11b	Ph	68	>98
11c	*n*-Pr	78	>98
11d	(*E*)-CH_3CH=CH	60	>98
11e	PhCH(Me)	52	>98

[a] Yield after purification.
[b] Estimated from 250 MHz ^{1}H NMR.

We wish to propose in this context an alternative and simple access to C-2 substituted silacyclopent-3-enes such as **4** starting from readily available diallylsilanes (Scheme 2). Diallylsilanes **6** are easily prepared through allylation of dichlorosilanes **8** with allylmagnesium bromide **7** (Scheme 2).[3] As the alkylation of allylsilanes is often not regioselective (vide supra),[4] we reasoned that the functionalisation at C-2 should be best carried out through hydroxy-alkylation of one or both the allylic moieties.[5] The metallation of the allylsilane fragment with a strong lithium base followed by transmetallation with titanium, boron or tin reagents and coupling of the resulting allyl-metal species with an aldehyde would then give rise to the desired β-hydroxysilane **5**. The formation of the silacyclopent-3-ene ring (i.e. **4**) could then be carried out by ring closure metathesis (RCM) using the commercially available Grubbs catalyst ($RuCl_2(PCy_3)_2CHPh$).[6] This cyclisation process should be fairly easy owing to the important length of the C–Si bond (1.9 Å), which should minimize the steric hindrance.[7] Such an approach would be relatively flexible allowing the introduction of various substituents on the silicon centre, and more importantly of two new stereogenic centres, leaving a double bond in **4** which could then be functionalised in a stereoselective manner.

Our preliminary investigations were carried out starting from diallyldiphenylsilane **9**.[3] Lithiation of **9** with *n*-BuLi followed by transmetallation with $Ti(O\text{-}i\text{-}Pr)_4$ led to the putative allyltitanium intermediate **10**[5c–e,8] which afforded, after addition of isobutyraldehyde at −78°C and acidic work-up, the β-hydroxysilane **11a** in 65% yield and more interestingly with complete diastereocontrol (Table 1, Scheme 3). X-Ray structure determination of a more functionalised intermediate (vide infra, **14a**) unambiguously showed that **11a** had the *anti* configuration. The protocol was then extended to several aldehydes providing the β-hydroxysilanes **11b–d** in good yields and in all cases as one diastereomer having the *anti* configuration.[9] When applied to the chiral racemic 2-phenylpropionaldehyde, the method afforded the alcohol **11e** as only one diastereomer having an *anti–anti* relative configuration.[10]

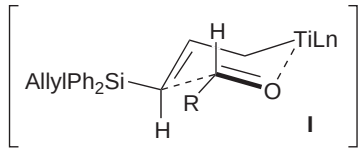


Figure 1.

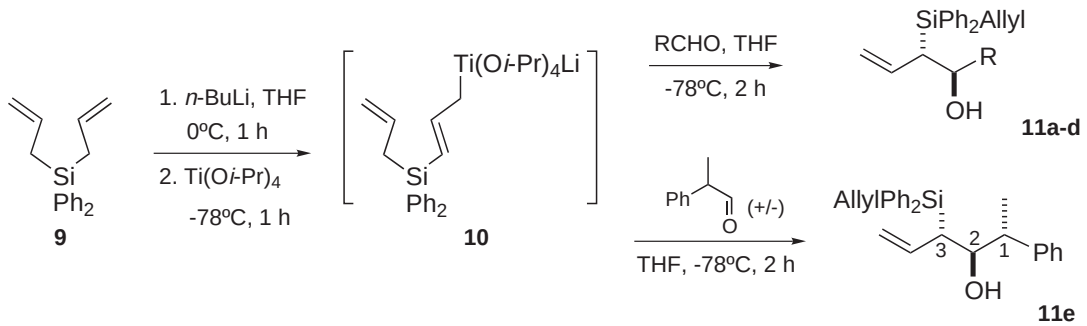
Table 2. Grubbs catalyst mediated ring closure metathesis of **11a–e** (Scheme 4)

Sila ring	R	R′	Reaction time (h)	Yield (%)[a]
12a	*i*-Pr	Ac	3	88
12b	*n*-Pr	Ac	3	95
12c	(*E*)-CH_3CH=CH	Ac	11	61
13a	*i*-Pr	H	6	93
13b	Ph	H	8	78
13c	PhCH(Me)	H	8	74
13d	(*E*)-CH_3CH=CH	H	12	57

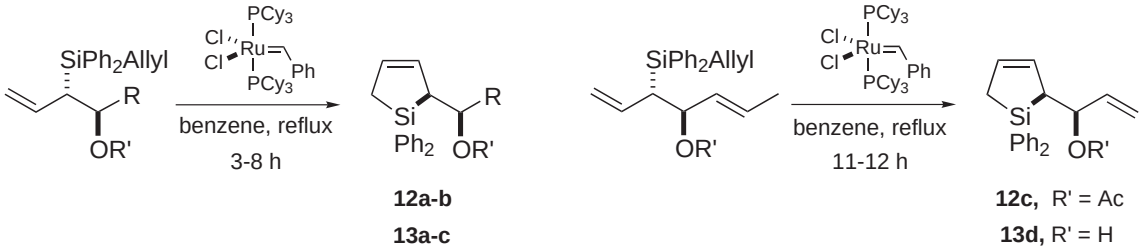
[a] Yield after purification.

The observed *anti* configuration is consistent with the chair-like transition state model **I** shown in Fig. 1. In this model, titanium of the allyltitanium species is coordinated to the aldehyde and the bulky silicon group as well as the aldehyde R substituent occupy pseudo-equatorial positions.[5]

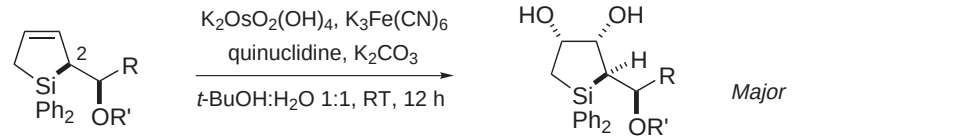
The alcohols **11a–d** were then protected as their acetates (Ac_2O, NEt_3, DMAP, RT) and subjected to the RCM process in the presence of the Grubbs catalyst (2 mol%) in benzene under reflux,[11] providing the silacyclopent-3-enes **12a–c** in excellent yield (Table 2, Scheme 4). The presence of a bulky substituent on one of the



Scheme 3.



Scheme 4.



Scheme 5.

allylic moieties had no consequence on the RCM process which is known to be affected by steric effects.[7,12] We eventually found that the reaction worked equally well on the unprotected alcohols providing the pure five-membered ring **13a–d** after a simple filtration through silica gel. It is noteworthy that the reaction on the β-hydroxysilane **11d** and its acetate led regioselectively to the silacyclopentene **13d** and **12c**, respectively, in which the crotyl methyl group had disappeared, indicating that the ring closure metathesis was followed by the metathesis of the acyclic double bond.[6,12,13]

With these silacyclopent-3-enes in hand, our efforts then focused on the electrophilic functionalisation of the cyclic double bond. It was anticipated that the stereochemical information at the C-2 stereogenic centre could be easily propagated through stereoselective processes, thus allowing for a rapid elaboration of these building blocks into useful intermediates. Earlier literature reports[1d] indicated that such double bonds reacted very much like allylsilanes, but surprisingly nothing was known about the 1,2-stereocontrol which might be exerted by a C-2 stereogenic centre. Our preliminary studies on the dihydroxylation of **13a** and **12b** showed that the expected diol **14a–b** could be obtained in high yield with somewhat moderate diastereoselectivities (Scheme 5). Fortunately, in both cases the diastereomers were easily separated over silica gel. The stereochemistry of the major isomer **14a** was established by X-ray crystallography,[14] indicating that the approach of the osmium reagent on the cyclopentene ring had taken place *anti* relative to the C-2 chain (Fig. 2).

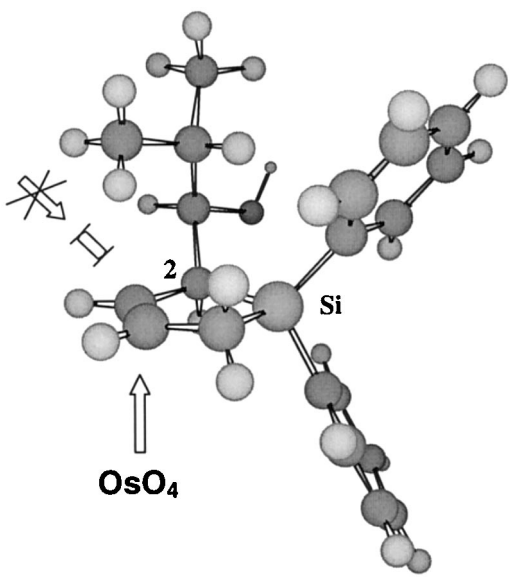


Figure 2. Chem3D® representation of the stereochemistry of the dihydroxylation process on **13a**.

In conclusion, we have presented a new regio- and stereocontrolled access to substituted silacyclopent-3-enes in two steps from diallyldiphenylsilane which is applicable to a large variety of substrates. Further studies on the asymmetric version of this strategy[10,15] and on the elaboration of these synthons into biologically active compounds are now under way.

Acknowledgements

S.S.S. thanks the MENRT for a postdoctoral grant. We gratefully acknowledge Professor K. Schenk (University of Lausanne, CH) for X-ray structure determination of **14a** and Mr. S. Bontemps for technical assistance.

References

1. (a) Mignani, S.; Damour, D.; Bastart, J.-P.; Manuel, G. *Synth. Commun.* **1995**, *25*, 3855–3862; (b) Mignani, S.; Barreau, M.; Damour, D.; Renaudon, A.; Dejean, V.;

Manuel, G. *Synth. Commun.* **1998**, *28*, 1163–1174; (c) Matsumoto, K.; Yokoo, T.; Oshima, K.; Utimoto, K.; Abd. Rahman, N. *Bull. Chem. Soc. Jpn.* **1994**, *67*, 1694–1700; (d) Manuel, G.; Mazerolles, P.; Lesbre, M.; Pradel, J.-P. *J. Organomet. Chem.* **1973**, *61*, 147–165; (e) Weyenberg, D. R.; Toporcer, L. H.; Nelson, L. E. *J. Org. Chem.* **1968**, *33*, 1975–1982; (f) Dunoguès, J.; Arréguy, B.; Biran, C.; Calas, R.; Pisciotti, F. *J. Organomet. Chem.* **1973**, *63*, 119–131.

2. Horvath, R. F.; Chan, T. H. *J. Org. Chem.* **1987**, *52*, 4489–4494 and references cited therein.
3. Compound **9** is commercially available from Aldrich. For synthesis, see: Nasiak, L. D.; Post, H. W. *J. Org. Chem.* **1959**, *24*, 489–492.
4. (a) Li, L.-H.; Wang, D.; Chan, T. H. *Tetrahedron Lett.* **1991**, *32*, 2879–2882; (b) Chan, T. H.; Labrecque, D. *Tetrahedron Lett.* **1991**, *32*, 1149–1152; (c) Muchowski, J. M.; Naef, R.; Maddox, M. L. *Tetrahedron Lett.* **1985**, *26*, 5375–5378; (d) Koumaglo, K.; Chan, T. H. *Tetrahedron Lett.* **1984**, *25*, 717–720.
5. (a) Hodgson, D. M.; Wells, C. *Tetrahedron Lett.* **1992**, *33*, 4761–4762; (b) Shimizu, N.; Shibata, F.; Tsuno, Y. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 3017–3018; (c) Ikeda, Y.; Yamamoto, H. *Bull. Chem. Soc. Jpn.* **1986**, *59*, 657–658; (d) Sato, F.; Suzuki, Y.; Sato, M. *Tetrahedron Lett.* **1982**, *23*, 4589–4592; (e) Reetz, M. T.; Wenderoth, B. *Tetrahedron Lett.* **1982**, *23*, 5259–5262.
6. (a) Grubbs, R. H.; Chang, S. *Tetrahedron* **1998**, *54*, 4413–4450; (b) Armstrong, S. K. *J. Chem. Soc., Perkin Trans. 1* **1998**, 371–388; (c) Schuster, M.; Blechert, S. *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 2036–2056; (d) Meyer, C.; Cossy, J. *Tetrahedron Lett.* **1997**, *38*, 7861–7864.
7. The synthesis of non substituted silacyclopent-3-enes through RCM using a tungsten catalyst has recently been reported. Poor to excellent results (8–90% yield) were obtained depending on the nature of the substituents at the silicon centre. See: Leconte, M.; Pagano, S.; Mutch, A.; Lefebvre, F.; Basset, J. M. *Bull. Soc. Chim. Fr.* **1995**, *132*, 1069–1071.
8. Hydroxy-alkylation of the allyl-lithium species led exclusively to the γ-product.
9. All other relative configurations in this series (**11b–d**) were assigned by analogy.
10. The *anti–anti* relative configuration of **11e** was tentatively assigned on the basis of coupling constants ($J_{1,2}=9.5$ Hz, $J_{2,3}=1.5$ Hz) which are in good agreement with those of closely related compounds, see: Hunt, J. A.; Roush, W. R. *J. Org. Chem.* **1997**, *62*, 1112–1124.
11. Much lower yields were obtained when the reaction was carried out in CH_2Cl_2 under reflux.
12. (a) Briot, A.; Bujard, M.; Gouverneur, V.; Nolan, S. P.; Mioskowski, C. *Org. Lett.* **2000**, *2*, 1517–1519; (b) Stoianova, D. S.; Hanson, P. R. *Org. Lett.* **2000**, *2*, 1769–1772; (c) Fürstner, A.; Langemann, K. *Synthesis* **1997**, 792–803.
13. It is noteworthy that the silacyclohex-3-ene could not be detected from the crude ^{1}H NMR reaction mixture.
14. The X-ray structure determination was carried out by Professor K. Schenk (University of Lausanne, CH) and will be reported elsewhere.
15. Barrett, A. G. M.; Malecha, J. W. *J. Org. Chem.* **1991**, *56*, 5243–5245.