Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Organometallic Chemistry 689 (2004) 3593–3597
Journal of Organometallic Chemistry
www.elsevier.com/locate/jorganchem

A facile stereoselective synthesis of (E)-α-silylvinylstannanes via hydromagnesiation of alkynylsilanes

Mingzhong Cai [a,*], Wenyan Hao [a], Hong Zhao [b], Jun Xia [a]

[a] *Institute of Chemistry, Jiangxi Normal University, Nanchang 330027, PR China*
[b] *Department of Pharmacy, Guangdong Pharmaceutical College, Guangzhou 510240, PR China*

Received 15 March 2004; accepted 7 July 2004
Available online 11 September 2004

Abstract

(E)-α-Silylvinylstannanes have been synthesized by the hydromagnesiation reaction of alkynylsilanes, followed by the reaction with trialkylstannyl chlorides. (E)-α-Silylvinylstannanes can undergo the cross-coupling reaction with aryl iodides in the presence of a catalytic amounts of $Pd(PPh_3)_4$ and CuI to afford (Z)-1,2-disubstituted vinylsilanes in good yields.

Keywords: Hydromagnesiation; Alkynylsilane; (E)-α-Silylvinylstannane; Cross-coupling reaction; Stereoselective synthesis

1. Introduction

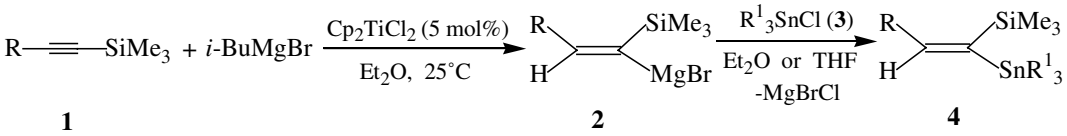
Methodologies for the stereoselective synthesis of vinylstannanes are of considerable interest because the vinylstannanes are proven synthons and very useful building blocks in synthetic organic chemistry [1]. Due to their synthetic utility, a variety of methods have been developed for their preparation including those involving carbonyl addition chemistry [2]; transmetallation of vinylmetallic species [3]; metallometallation of alkynes [4]; and the hydrostannylation of alkynes induced by either radical initiators [5] or Lewis acid [6] or transition metal catalysts [7]. Difunctional group reagents, which have two different functional groups linked to the olefinic carbon atoms, for example, Sn–Al [8], Sn–Cu [9], Sn–Mg [10], Sn–Zr [11] and Sn–Se [12] combinations, play an important role in organic synthesis, especially in developing many convenient methods for the stereoselective synthesis of substituted alkenes. These reagents and their synthetic applications have been reported. Vinylsilanes are also important synthetic intermediates [13], but the difunctional group reagent containing tin and silicon has rarely aroused extensive attention. Mitchell et al. [14] described that the alkynes underwent the regio- and stereospecific addition with (trimethylsilyl)trialkylstannanes in the presence of $Pd(PPh_3)_4$ catalyst to give (Z)-β-silylvinylstannanes. Hydromagnesiation has emerged as a unique hydrometallation with some attractive features such as the high regioselectivity and stereoselectivity observed with alkynylsilanes [15]. We now wish to report that (E)-α-silylvinylstannanes could be synthesized by hydromagnesiation of alkynylsilanes, followed by treatment with trialkylstannyl chlorides (Scheme 1).

2. Results and discussion

Alkynylsilanes **1** were prepared according to the literature procedure [16]. Hydromagnesiation of alkynylsilanes **1** at 25 °C in diethyl ether for 6 h gave (Z)-α-silylvinyl Grignard reagents **2**, which reacted with tributylstannyl chloride or trimethylstannyl chloride **3**

* Corresponding author. Fax: +86 791 8517500.
E-mail address: caimingz@tom.com (M. Cai).

0022-328X/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.jorganchem.2004.07.063



Scheme 1.

at room temperature for 4 h to afford (E)-α-silylvinylstannanes **4** in high yields. The intermediates **2** were found to possess low reactivity with triphenylstannyl chloride and the Mg/Sn metathesis reaction did not occur in diethyl ether at 30 °C. However, the Mg/Sn metathesis reaction proceeded smoothly in THF at 60 °C and the corresponding (E)-α-silylvinylstannanes **4** were obtained in good yields (Entry 3, 6, 9) after 8 h. The typical results are summarized in Table 1.

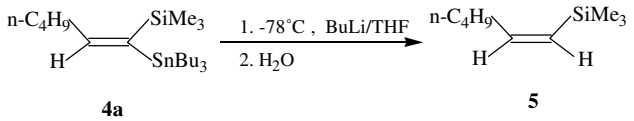
The hydromagnesiation of alkynylsilanes **1** at 25 °C in ether is almost 100% regio-and stereoselective as previously described [15]. We observed that the Mg/Sn metathesis reaction on intermediates **2** occurs with total retention of the configuration. Investigations of the crude products **4** by ^{1}H NMR spectroscopy (400 MHz) showed their isomeric purities to be more than 98%, one olefinic proton signal of **4a–j** splits characteristically into one triplet with a coupling constant of $J = 6.9$ Hz, which indicated that the hydromagnesiation of alkynylsilanes had taken place with strong preference for the addition of the magnesium atom at the carbon adjacent to the silyl group. The configuration of compound **4a** could be confirmed from compound **5** which was obtained by treatment of **4a** with *n*-butyllithium in THF followed by hydrolysis, a reaction which occurs stereoselectively (Scheme 2) [17]. The stereochemistry of compound **5** was easily established, since ^{1}H NMR spectrum (400 MHz) of **5** gives rise to a doublet at $\delta = 5.44$ with a coupling constant of 11.5 Hz, which is consistent with an Z-configuration.

We have also carried out the cross-coupling reaction of compounds **4** with aryl iodides. We observed that

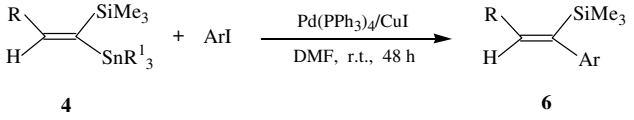
Table 1
Synthesis of (E)-α-silylvinylstannanes **4a–j**

Entry	R	R^1	Product[a]	Yield (%)[b]
1	*n*-C_4H_9	*n*-C_4H_9	**4a**	90
2	*n*-C_4H_9	CH_3	**4b**	87
3	*n*-C_4H_9	Ph	**4c**	69
4	i-C_5H_{11}	*n*-C_4H_9	**4d**	89
5	i-C_5H_{11}	CH_3	**4e**	86
6	i-C_5H_{11}	Ph	**4f**	72
7	*n*-C_6H_{13}	*n*-C_4H_9	**4g**	88
8	*n*-C_6H_{13}	CH_3	**4h**	85
9	*n*-C_6H_{13}	Ph	**4i**	70
10	$PhCH_2$	*n*-C_4H_9	**4j**	81

[a] All the compounds **4** were characterized by IR, ^{1}H NMR, ^{13}C NMR, MS and elemental analyses.
[b] Isolated yield based on the trialkylstannyl chloride used.



Scheme 2.



Scheme 3.

Table 2
Synthesis of (Z)-1,2-disubstituted vinylsilanes **6** according to Scheme 3

Entry	R	R^1	Ar	Product	Yield[a] (%)
1	*n*-C_4H_9	CH_3	Ph	**6a**	78
2	*n*-C_4H_9	CH_3	4-ClC_6H_4	**6b**	83
3	i-C_5H_{11}	*n*-C_4H_9	4-ClC_6H_4	**6c**	71
4	*n*-C_6H_{13}	CH_3	Ph	**6d**	84
5	$PhCH_2$	*n*-C_4H_9	Ph	**6e**	75

[a] Isolated yield based on the **4** used.

when (E)-α-silylvinylstannanes **4** were allowed to react with aryl iodides in the presence of a catalytic amounts of $Pd(PPh_3)_4$ and CuI in DMF at room temperature under Ar, the corresponding (Z)-1,2-disubstituted vinylsilanes **6** were obtained in good yields according to Scheme 3 and Table 2.

In summary, our results showed that the hydromagnesiation–stannylation sequence of the alkynylsilanes has the advantages of readily available starting materials, straightforward and simple procedures, mild reaction conditions and high yields. The investigation on the synthetic applications of compounds **4** is in progress.

3. Experimental

^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on a Bruker AC 400 MHz spectrometer with TMS as an internal standard. Chemical shifts are given in ppm and spin–spin coupling constants, *J*, are given in Hz. IR spectra were obtained on a Perkin–Elmer 683 instrument as neat films. Mass spectra were determined on a

Finnigan 8230 mass spectrometer. Microanalyses were measured using a Yanaco MT-3 CHN microelemental analyzer. All solvents were dried, deoxygenated and freshly distilled before use.

3.1. General procedure for the synthesis of (*E*)-α-silylvinylstannanes **4a**, **4b**, **4d**, **4e**, **4g**, **4h**, **4j**

To a solution of isobutylmagnesium bromide (4.5 mmol) in Et_2O (7 ml) was added Cp_2TiCl_2 (50 mg, 0.2 mmol) at 0 °C under Ar, and the mixture was stirred for 30 min at that temperature. To this solution was added alkynylsilane **1** (4.0 mmol), and the mixture was stirred for 6 h at 25 °C. After being cooled to 0 °C, a solution of trialkylstannyl chloride **3** (3.0 mmol) in Et_2O (2 ml) was added and the mixture was stirred at room temperature for 4 h, quenched with saturated aqueous NH_4Cl (25 ml) and extracted with Et_2O (2×40 ml). The organic layer was washed with saturated aqueous NH_4Cl (25 ml) and H_2O (3×30 ml) and dried ($MgSO_4$). Removal of solvent under reduced pressure gave an oil, which was purified by column chromatography on silica gel using light petroleum ether (bp 30–60 °C) as eluent.

3.1.1. (*E*)-1-Trimethylsilyl-1-tributylstannyl-1-hexene (**4a**)

IR (film): ν (cm^{-1}) 2955, 2926, 2871, 1567, 1464, 1376, 1246, 858, 834. ^1H NMR: δ 6.47 (t, $J = 6.9$ Hz, 1H), 2.25–2.15 (m, 2H), 1.49–1.29 (m, 16H), 0.95–0.82 (m, 18H), 0.12 (s, 9H). ^{13}C NMR: δ 159.20, 141.17, 36.37, 31.84, 29.25, 27.38, 22.53, 14.06, 13.68, 10.47, 1.53. MS: *m/z* 445 (M^+, 3.7), 73 (100). Anal. Found: C, 56.44; H, 10.15. $C_{21}H_{46}SiSn$ Calc.: C, 56.63; H, 10.34%.

3.1.2. (*E*)-1-Trimethylsilyl-1-trimethylstannyl-1-hexene (**4b**)

IR (film): ν (cm^{-1}) 2924, 2855, 1568, 1465, 1378, 1248, 839. ^1H NMR: δ 6.51 (t, $J = 6.9$ Hz, 1H), 2.26–2.19 (m, 2H), 1.45–1.29 (m, 4H), 0.93 (t, $J = 7.2$ Hz, 3H), 0.15 (s, 9H), 0.12 (s, 9H). ^{13}C NMR: δ 158.33, 141.78, 36.35, 31.73, 22.52, 14.07, 1.54, −8.01. MS: *m/z* 319 (M^+, 8.4), 73 (100). Anal. Found: C, 44.96; H, 8.62. $C_{12}H_{28}SiSn$ Calc.: C, 45.14; H, 8.78%.

3.1.3. (*E*)-1-Trimethylsilyl-1-tributylstannyl-5-methyl-1-hexene (**4d**)

IR (film): ν (cm^{-1}) 2955, 2926, 2872, 1567, 1465, 1384, 1366, 1247, 1071, 856, 834. ^1H NMR: δ 6.48 (t, $J = 6.9$ Hz, 1H), 2.25–2.16 (m, 2H), 1.61–1.27 (m, 15H), 0.95–0.83 (m, 21H), 0.13 (s, 9H). ^{13}C NMR: δ 159.11, 140.94, 38.90, 34.87, 29.20, 27.99, 27.38, 22.61, 13.69, 10.48, 1.50. MS: *m/z* 459 (M^+, 4.2), 73 (100). Anal. Found: C, 57.31; H, 10.27. $C_{22}H_{48}SiSn$ Calc.: C, 57.52; H, 10.46%.

3.1.4. (*E*)-1-Trimethylsilyl-1-trimethylstannyl-5-methyl-1-hexene (**4e**)

IR (film): ν (cm^{-1}) 2958, 2925, 2872, 1571, 1465, 1440, 1384, 1367, 856, 839. ^1H NMR: δ 6.51 (t, $J = 6.9$ Hz, 1H), 2.25–2.19 (m, 2H), 1.65–1.56 (m, 1H), 1.34–1.28 (m, 2H), 0.92 (d, $J = 6.8$ Hz, 6H), 0.21 (s, 9H), 0.16 (s, 9H). ^{13}C NMR: δ 158.43, 141.92, 38.23, 34.63, 27.88, 22.59, 1.53, −8.02. MS: *m/z* 333 (M^+, 9.8), 73 (100). Anal. Found: C, 46.62; H, 8.79. $C_{13}H_{30}SiSn$ Calc.: C, 46.85; H, 9.01%.

3.1.5. (*E*)-1-Trimethylsilyl-1-tributylstannyl-1-octene (**4g**)

IR (film): ν (cm^{-1}) 2954, 2926, 2872, 2855, 1567, 1464, 1247, 856, 835. ^1H NMR: δ 6.48 (t, $J = 6.9$ Hz, 1H), 2.25–2.16 (m, 2H), 1.52–1.29 (m, 20H), 0.95–0.82 (m, 18H), 0.13 (s, 9H). ^{13}C NMR: δ 159.10, 141.15, 36.83, 31.84, 29.62, 29.20, 29.03, 27.38, 22.62, 14.04, 13.68, 10.49, 1.50. MS: *m/z* 473 (M^+, 1.8), 73 (100). Anal. Found: C, 58.12; H, 10.41. $C_{23}H_{50}SiSn$ Calc.: C, 58.35; H, 10.57%.

3.1.6. (*E*)-1-Trimethylsilyl-1-trimethylstannyl-1-octene (**4h**)

IR (film): ν (cm^{-1}) 2924, 2856, 1567, 1462, 1376, 1248, 839. ^1H NMR: δ 6.51 (t, $J = 6.9$ Hz, 1H), 2.26–2.17 (m, 2H), 1.41–1.25 (m, 8H), 0.90 (t, $J = 6.8$ Hz, 3H), 0.15 (s, 9H), 0.12 (s, 9H). ^{13}C NMR: δ 158.39, 141.76, 36.65, 31.80, 29.56, 29.12, 22.60, 14.06, 1.54, −8.01. MS: *m/z* 347 (M^+, 8.2), 73 (100). Anal. Found: C, 48.19; H, 9.04. $C_{14}H_{32}SiSn$ Calc.: C, 48.42; H, 9.22%.

3.1.7. (*E*)-1-Trimethylsilyl-1-tributylstannyl-3-phenyl-1-propene (**4j**)

IR (film): ν (cm^{-1}) 3061, 3018, 2955, 2853, 1579, 1492, 1464, 839, 730, 690. ^1H NMR: δ 7.43–6.94 (m, 5H), 6.51 (t, $J = 6.9$ Hz, 1H), 3.56 (d, $J = 7.2$ Hz, 2H), 1.47–1.29 (m, 12 H), 0.93–0.82 (m, 15H), 0.13 (s, 9H). ^{13}C NMR: δ 159.21, 140.22, 130.17, 129.11, 128.40, 126.04, 39.55, 29.05, 27.32, 13.63, 9.87, 0.75. MS: *m/z* 479 (M^+, 1.4), 73 (100). Anal. Found: C, 59.87; H, 9.24. $C_{24}H_{44}SiSn$ Calc.: C, 60.13; H, 9.19%.

3.2. General procedure for the synthesis of (*E*)-α-silylvinylstannanes **4c**, **4f**, **4i**

To a solution of isobutylmagnesium bromide (4.5 mmol) in Et_2O (7 ml) was added Cp_2TiCl_2 (50 mg, 0.2 mmol) at 0 °C under Ar, and the mixture was stirred for 30 min at that temperature. To this solution was added alkynylsilane **1** (4.0 mmol), and the mixture was stirred for 6 h at 25 °C. After removal of the Et_2O under reduced pressure (2 h, r.t./2 Torr), the residue was dissolved in THF (6 ml), and a solution of Ph_3SnCl (3.0 mmol) in THF (4 ml) was added and the reaction mixture was stirred at 60 °C for 8 h, quenched with

saturated aqueous NH_4Cl (25 ml) at 0 °C and extracted with Et_2O (2 × 40 ml). The organic layer was washed with saturated aqueous NH_4Cl (25 ml) and H_2O (3 × 30 ml) and dried ($MgSO_4$). Removal of solvent under reduced pressure gave an oil, which was purified by column chromatography on silica gel using light petroleum ether (bp 30–60 °C) as eluent.

*3.2.1. (E)-1-Trimethylsilyl-1-triphenylstannyl-1-hexene (**4c**)*

IR (film): ν (cm^{-1}) 3064, 3015, 2954, 2871, 2858, 1639, 1568, 1480, 1428, 1247, 1073, 836, 727, 700. ^1H NMR: δ 7.53–7.24 (m, 15H), 6.60 (t, J = 6.9 Hz, 1H), 2.27–2.19 (m, 2H), 1.36–1.18 (m, 4H), 0.89 (t, J = 7.2 Hz, 3H), 0.18 (s, 9H). ^{13}C NMR: δ 164.17, 140.34, 137.43, 137.08, 128.73, 128.39, 36.87, 31.71, 22.58, 14.09, 1.70. MS: m/z 505 (M^+, 1.4), 73 (100). Anal. Found: C, 63.93; H, 6.56. $C_{27}H_{34}SiSn$ Calc.: C, 64.16; H, 6.73%.

*3.2.2. (E)-1-Trimethylsilyl-1-triphenylstannyl-5-methyl-1-hexene (**4f**)*

IR (film): ν (cm^{-1}) 3064, 3016, 2955, 2869, 1639, 1568, 1480, 1429, 1384, 1366, 1248, 838, 727, 699. ^1H NMR: δ 7.49–7.22 (m, 15H), 6.57 (t, J = 6.9 Hz, 1H), 2.29–2.18 (m, 2H), 1.50–1.36 (m, 1H), 1.20–1.13 (m, 2H), 0.87 (d, J = 6.4 Hz, 6H), 0.15 (s, 9H). ^{13}C NMR: δ 164.30, 140.35, 137.46, 137.11, 128.77, 128.44, 38.71, 35.26, 28.22, 22.67, 1.74. MS: m/z 519 (M^+, 2.2), 73 (100). Anal. Found: C, 64.51; H, 6.85. $C_{28}H_{36}SiSn$ Calc.: C, 64.74; H, 6.94%.

*3.2.3. (E)-1-Trimethylsilyl-1-triphenylstannyl-1-octene (**4i**)*

IR (film): ν (cm^{-1}) 3064, 3016, 2927, 2855, 1638, 1570, 1480, 1429, 1247, 1074, 835, 727, 700. ^1H NMR: δ 7.63–7.35 (m, 15H), 6.65 (t, J = 6.9 Hz, 1H), 2.29–2.19 (m, 2H), 1.40–1.19 (m, 8H), 0.84 (t, J = 7.2 Hz, 3H), 0.16 (s, 9H). ^{13}C NMR: δ 164.26, 140.36, 137.36, 137.11, 128.76, 128.23, 37.14, 31.63, 29.18, 28.89, 22.53, 14.09, 1.68. MS: m/z 533 (M^+, 1.7), 73 (100). Anal. Found: C, 65.04; H, 7.21. $C_{29}H_{38}SiSn$ Calc.: C, 65.29; H, 7.13%.

*3.3. General procedure for the synthesis of (Z)-1,2-disubstituted vinylsilanes (**6a–e**)*

To a solution of compound **4** (1.0 mmol), aryl iodide (1.1 mmol) and $Pd(PPh_3)_4$ (58 mg, 0.05 mmol) in DMF (5 ml) was added CuI (19 mg, 0.1 mmol) under Ar. The reaction mixture was stirred at room temperature for 48 h, treated with saturated aqueous NH_4Cl (10 ml) and extracted with CH_2Cl_2 (2 × 15 ml). The organic layer was washed with saturated aqueous NH_4Cl (2 × 10 ml), water (3 × 20 ml) and dried ($MgSO_4$). After removal of the solvent, the residue was purified by column chromatography on silica gel eluting with light petroleum (30–60 °C).

*3.3.1. (Z)-1-Trimethylsilyl-1-phenyl-1-hexene (**6a**)*

IR (film): ν (cm^{-1}) 2956, 2858, 1602, 1598, 1489, 1249, 839. ^1H NMR: δ 7.40–6.91 (m, 5H), 6.01 (t, J = 7.0 Hz, 1H), 2.35–2.17 (m, 2H), 1.49–1.23 (m, 4H), 0.91 (t, J = 7.1 Hz, 3H), 0.12 (s, 9H). Anal. Found: C, 77.31; H, 10.25. $C_{15}H_{24}Si$ Calc.: C, 77.59; H, 10.34%.

*3.3.2. (Z)-1-Trimethylsilyl-1-(4-chlorophenyl)-1-hexene (**6b**)*

IR (film): ν (cm^{-1}) 2957, 2858, 1605, 1597, 1485, 1249, 839. ^1H NMR: δ 7.08 (d, J = 8.8 Hz, 2H), 6.78 (d, J = 8.8 Hz, 2H), 5.94 (t, J = 7.0 Hz, 1H), 2.32–2.18 (m, 2H), 1.47–1.25 (m, 4H), 0.90 (t, J = 7.2 Hz, 3H), 0.15 (s, 9H). Anal. Found: C, 67.66; H, 8.56. $C_{15}H_{23}SiCl$ Calc.: C, 67.54; H, 8.63%.

*3.3.3. (Z)-1-Trimethylsilyl-1-(4-chlorophenyl)-5-methyl-1-hexene (**6c**)*

IR (film): ν (cm^{-1}) 2955, 2870, 1606, 1486, 1384, 1366, 1249, 838. ^1H NMR: δ 7.06 (d, J = 8.8 Hz, 2H), 6.74 (d, J = 8.8 Hz, 2H), 5.91 (t, J = 7.0 Hz, 1H), 2.34–2.16 (m, 2H), 1.67–1.23 (m, 3H), 0.91 (d, J = 6.4 Hz, 6H), 0.13 (s, 9H). Anal. Found: C, 68.61; H, 8.99. $C_{16}H_{25}SiCl$ Calc.: C, 68.45; H, 8.91%.

*3.3.4. (Z)-1-Trimethylsilyl-1-phenyl-1-octene (**6d**)*

IR (film): ν (cm^{-1}) 2955, 2855, 1602, 1573, 1488, 1249, 837. ^1H NMR: δ 7.36–6.97 (m, 5H), 5.98 (t, J = 7.0 Hz, 1H), 2.41–2.19 (m, 2H), 1.59–1.21 (m, 8H), 0.90 (t, J = 7.1 Hz, 3H), 0.11 (s, 9H). Anal. Found: C, 78.22; H, 10.53. $C_{17}H_{28}Si$ Calc.: C, 78.46; H, 10.77%.

*3.3.5. (Z)-1-Trimethylsilyl-1,3-diphenyl-1-propene (**6e**)*

IR (film): ν (cm^{-1}) 2958, 2860, 1605, 1596, 1490, 1249, 839. ^1H NMR: δ 7.46–6.87 (m, 10H), 5.96 (t, J = 7.0 Hz, 1H), 3.52 (d, J = 7.2 Hz, 2H), 0.12 (s, 9H). Anal. Found: C, 81.07; H, 8.11. $C_{18}H_{22}Si$ Calc.: C, 81.20; H, 8.27%.

Acknowledgements

Project 20062002 was supported by the National Nature Science Foundation of China and this work was also supported by the Nature Science Foundation of Jiangxi Province in China.

References

[1] (a) P.J. Smith (Ed.), Chemistry of Tin, Blackie, New York, 1998; (b) V. Farina, V. Krishnamurthy, W. Scott, Org. React. 50 (1997) 1.

[2] (a) J.M. Chong, S.B. Park, J. Org. Chem. 58 (1993) 523;
(b) D.J. Ager, G.E. Cooke, M.B. East, S.J. Mole, A. Rampersaud, V.J. Webb, Organometallics 5 (1986) 1906.
[3] (a) M. Havranek, D. Dvorak, Synthesis (1998) 1264;
(b) M. Hoshi, K. Takahashi, A. Arase, Tetrahedron Lett. 38 (1997) 8049;
(c) T.N. Mitchell, Synthesis (1992) 803.
[4] (a) F. Suzenet, E. Blart, J.P. Quintard, Synlett (1998) 879;
(b) M.W. Hutzinger, A.C. Oehlschlager, J. Org. Chem. 60 (1995) 4595;
(c) J.F. Betzer, A. Pancrazi, Synthesis (1999) 629;
(d) J. Thibonnet, V. Launay, M. Abarbri, A. Duchene, J.L. Parrain, Tetrahedron Lett. 39 (1998) 4277;
(e) I. Beletskaya, C. Moberg, Chem. Rev. 99 (1999) 3435.
[5] (a) K. Nozaki, K. Oshima, K. Utimoto, J. Am. Chem. Soc. 109 (1987) 2547;
(b) E. Nakamura, D. Machii, T. Inubushi, J. Am. Chem. Soc. 111 (1989) 6849;
(c) J.C. Cochran, K.M. Terrence, H.K. Phillips, Organometallics 10 (1991) 2411;
(d) R.E. Maleczka Jr., L.R. Terrell, D.H. Clark, S.L. Whitehead, W.P. Gallagher, I. Terstiege, J. Org. Chem. 64 (1999) 5958.
[6] (a) V. Gevorgyan, J.X. Liu, Y. Yamamoto, Chem. Commun. (1998) 37;
(b) N. Asao, J.X. Liu, T. Sudoh, Y. Yamamoto, J. Org. Chem. 61 (1996) 4568;
(c) N. Asao, J.X. Liu, T. Sudoh, Y. Yamamoto, J. Chem. Soc., Chem. Commun. (1995) 2405.
[7] (a) N.D. Smith, J. Mancuso, M. Lautens, Chem. Rev. 100 (2000) 3257;
(b) R. Trebbe, F. Schager, R. Goddard, K.R. Porschke, Organometallics 19 (2000) 521;
(c) F. Liron, G. LeGarrec, M. Alami, Synlett (1999) 246;
(d) M.A. Blaskovich, M. Kahn, J. Org. Chem. 63 (1998) 1119;
(e) B.M. Trost, C.J. Li, Synthesis (1994) 1267;
(f) A. Casaschi, R. Grigg, J.M. Sansano, D. Wilson, J. Redpath, Tetrahedron 56 (2000) 7541;
(g) T.N. Mitchell, S.N. Moschref, Synlett (1999) 1259;
(h) U. Kazmaier, D. Schauss, M. Pohlman, Org. Lett. 1 (1999) 1017.
[8] P.A. Magrietis, M.E. Scott, K.D. Kim, Tetrahedron Lett. 32 (1991) 6085.
[9] S. Sharma, A.C. Oehlschlager, Tetrahedron Lett. 27 (1986) 6161.
[10] J.C. Hibino, S. Matsubara, Y. Morizawa, Tetrahedron Lett. 25 (1984) 2151.
[11] (a) B.H. Lipschutz, A. Bhandari, C. Lindsley, R. Keil, M.R. Wood, Pure Appl. Chem. 66 (1994) 1493;
(b) B.H. Lipschutz, R. Keil, J.C. Barton, Tetrahedron Lett. 33 (1992) 5861.
[12] (a) X. Huang, Y. Ma, Synthesis (1997) 417;
(b) Y. Ma, X. Huang, J. Chem. Soc. Perkin Trans. 1 (1997) 2947;
(c) Y. Ma, B. Li, X. Huang, J. Organomet. Chem. 590 (1999) 234.
[13] (a) T.H. Chan, I. Fleming, Synthesis (1979) 761;
(b) E.W. Colvin, Silicon Reagents in Organic Synthesis, Academic, London, 1988.
[14] T.N. Mitchell, R. Wickenkamp, A. Amamria, U. Schneider, J. Org. Chem. 52 (1987) 4868.
[15] (a) F. Sato, H. Watanabe, Y. Tanaka, T. Yamaji, M. Sato, Tetrahedron Lett. 24 (1983) 1041;
(b) F. Sato, J. Organomet. Chem. 285 (1985) 53;
(c) F. Sato, H. Urabe, in: H.G. RicheyJr. (Ed.), Grignard Reagents – New Developments: Hydromagnesiation of Alkenes and Alkynes, Wiley, Chichester, 2000, p. 65.
[16] C. Eaborn, D.R.M. Walton, J. Organomet. Chem. 2 (1964) 95.
[17] (a) B.T. Grobel, D. Seebach, Chem. Ber. 110 (1977) 867;
(b) A. Pelter, K. Smith, D.E. Parry, K.D. Jones, Aust. J. Chem. 45 (1992) 57.