SHORT PAPER

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Stereoselective synthesis of 1,3-enynylsilanes via hydromagnesiation reaction of alkynylsilanes

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Hydromagnesiation of alkynylsilanes gives (*Z*)-α-silylvinyl Grignard reagents, which are cross-coupled with alkynyl iodides in the presence of tetrakis(triphenylphosphine)palladium(0) catalyst to afford stereoselectively 1,3-enynylsilanes in good yields.

Keywords: hydromagnesiation, alkynylsilane, 1,3-enynylsilane, palladium, cross-coupling reaction

Recently, the discovery of strong antifungal agents[1] and new powerful antitumor antibiotics[2] has stimulated intense interest in the chemistry of enynes,[3] which is at the origin of the biological properties of these substances. The conjugated enyne moiety can also be readily converted in a stereospecific manner into the corresponding diene system.[4] The synthesis of 1,3-enynes containing functional groups is of considerable interest in recent years. The stereoselective synthesis of 1,3-enynylsulfides,[5] 1,3-enynylselenides,[6] 1,3-enynyltellurides,[7] 1,3-enynylstannanes[8] has already been described in the literature. However, synthesis of 1,3-enynylsilanes has rarely been reported[9] and the synthesis of 1,3-enynylsilanes with the silyl group attached between the double and triple bonds has not been reported.

The transition metal-catalysed cross-coupling reaction is a highly versatile method for carbon–carbon bond formation and has been widely used as synthetic tool.[10] Hydromagnesiation has emerged as a unique hydrometallation with some attractive features, such as the high regioselectivity and stereoselectivity observed with alkynylsilanes.[11] In this paper, we wish to report that 1,3-enynylsilanes can be synthesised by hydromagnesiation of the alkynylsilanes, followed by treatment with alkynyl iodides via palladium-catalysed cross-coupling reaction.

Alkynylsilanes **1** and alkynyl iodides **3** were prepared according to the literature, respectively.[12,13] Hydromagnesiation of alkynylsilanes **1** at 25 °C in ether for 6 h gave (*Z*)-α-silylvinyl Grignard reagents **2**, which reacted with alkynyl iodides **3** in THF in the presence of $[Pd(PPh_3)_4]$ catalyst to afford stereoselectively (*Z*)-1,3-enynylsilanes **4**. The yields were 62–76% (Scheme 1).

Investigations of the crude products **4** by ^{1}H NMR spectroscopy (300 MHz) showed their isomeric purities of more than 96%. One olefinic proton signal of **4** splits characteristically into one triplet with coupling constant J = 7.0 Hz, which indicated that the hydromagnesiation to the alkynylsilanes had taken place with strong preference for the addition of the magnesium atom at the carbon adjacent to the silyl group. The results of the reaction are summarised in Table 1.

Table 1 Synthesis of (*Z*)-1,3-enynylsilanes

Entry	R	R^1	Product[a]	Yield[b]/%
1	*n*-C_4H_9	n-C_4H_9	**4a**	68
2	*n* -C_4H_9	Ph	**4b**	76
3	*n* -C_4H_9	CH_3OCH_2	**4c**	62
4	*i*-C_5H_{11}	n-C_4H_9	**4d**	70
5	*i*-C_5H_{11}	Ph	**4e**	73
6	*n* -C_6H_{13}	n-C_4H_9	**4f**	65
7	*n* -C_6H_{13}	Ph	**4g**	71
8	$PhCH_2$	n-C_4H_9	**4h**	64

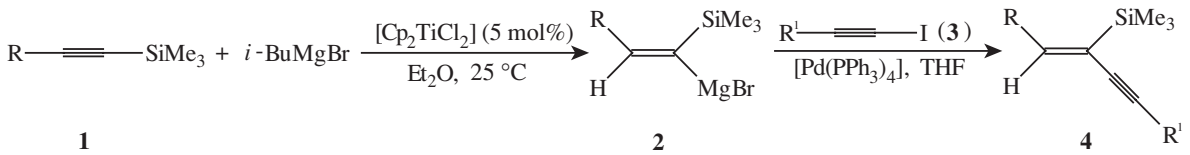
[a]All the compounds were characterised using ^{1}H NMR, IR and elemental analyses.
[b]Isolated yield based on the alkynylsilane used.

In conclusion, we have developed a novel approach to the stereoselective synthesis of 1,3-enynylsilanes by hydromagnesiation of alkynylsilanes, followed by treatment with alkynyl iodides via palladium catalysed cross-coupling reaction. The present method has the advantages of readily available starting materials, straightforward and simple procedures, mild reaction conditions and good yields.

Experimental

Tetrahydrofuran (THF) was freshly distilled from sodium-benzophenone prior to its use. ^{1}H NMR spectra were recorded on an AZ-300 MHz spectrometer with TMS as an internal standard. IR spectra were obtained on a Perkin-Elmer 683 instrument as neat films. Microanalyses were measured using a Yanaco MT-3 CHN microelemental analyser.

General procedure for the synthesis of (Z)-1,3-enynylsilanes: To a solution of isobutylmagnesium bromide (4.5 mmol) in diethyl ether (7 ml) was added $[Cp_2TiCl_2]$ (50 mg, 0.2 mmol) at 0 °C under argon, 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 ether under reduced pressure (2 h, r.t./2 Torr), the residue was dissolved in THF (6 ml), cooled to –15 °C, and $[Pd(PPh_3)_4]$ (0.232 g, 0.2 mmol) and alkynyl iodide **3** (6 mmol) was added with stirring. The reaction mixture was brought to 30 °C gradually and stirred for 4 h, quenched with sat. aq NH_4Cl (25 ml) and extracted with Et_2O (2 × 30 ml). The organic layer



Scheme 1

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† This is a Short Paper, there is therefore no corresponding material in *J Chem. Research (M).*

was washed with sat. aq NH_4Cl (20 ml) and water (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 as eluent.

(Z)-6-Trimethylsilyl-5-dodecen-7-yne (**4a**)**:** IR (film)/cm^{-1} 2958, 2874, 2176, 1583, 1466, 1379, 1249, 841; δ_H ($CDCl_3$) 0.11 (s, 9 H), 0.66─1.05 (m, 6 H), 1.07─1.68 (m, 8 H), 2.08─2.40 (m, 4 H), 6.21 (t, 1 H, *J* = 7.0 Hz); Anal. Calcd for $C_{15}H_{28}Si$: C, 76.27; H, 11.86. Found: C, 76.05; H, 11.69.

(Z)-1-Butyl-2-trimethylsilyl-4-phenyl-1-buten-3-yne (**4b**)**:** IR (film)/cm^{-1} 3056, 3031, 2957, 2872, 2188, 1598, 1489, 1465, 1249, 842, 755, 690; δ_H ($CDCl_3$) 0.16 (s, 9 H), 0.89 (t, 3 H, *J* = 5.4 Hz), 1.20─1.58 (m, 4 H), 2.25 (m, 2 H), 6.25 (t, 1 H, *J* = 7.0 Hz), 7.27─7.53 (m, 5 H); Anal. Calcd for $C_{17}H_{24}Si$: C, 79.69; H, 9.38. Found: C, 79.47; H, 9.28.

(Z)-1-Butyl-2-trimethylsilyl-5-methoxy-1-penten-3-yne (**4c**)**:** IR (film)/cm^{-1} 2958, 2874, 2197, 1583, 1465, 1376, 1249, 1187, 1099, 842; δ_H ($CDCl_3$) 0.15 (s, 9 H), 0.88 (t, 3 H, *J* = 5.4 Hz), 1.21─1.54 (m, 4 H), 2.28 (m, 2 H), 3.38 (s, 3 H), 4.17 (s, 2 H), 6.15 (t, 1 H, *J* = 7.0 Hz); Anal. Calcd for $C_{13}H_{24}OSi$: C, 69.64; H, 10.71. Found: C, 69.51; H, 10.62.

(Z)-2-Methyl-6-trimethylsilyl-5-dodecen-7-yne (**4d**)**:** IR (film)/cm^{-1} 2958, 2872, 2176, 1466, 1384, 1366, 1249, 841; δ_H ($CDCl_3$) 0.15 (s, 9 H), 0.70─1.04 (m, 9 H), 1.21─1.69 (m, 7 H), 2.26 (m, 4 H), 6.05 (t, 1 H, *J* = 7.0 Hz); Anal. Calcd for $C_{16}H_{30}Si$: C, 76.80; H, 12.00. Found: C, 76.68; H, 12.12.

(Z)-1-Isopentyl-2-trimethylsilyl-4-phenyl-1-buten-3-yne (**4e**)**:** IR (film)/cm^{-1} 3059, 3031, 2956, 2870, 2188, 1598, 1490, 1467, 1384, 1367, 1249, 841, 754, 690; δ_H ($CDCl_3$) 0.16 (s, 9 H), 0.90 (d, 6 H, *J* = 6.7 Hz), 1.19─1.70 (m, 3 H), 2.26 (m, 2 H), 6.20 (t, 1 H, *J* = 7.0 Hz), 7.22─7.56 (m, 5 H); Anal. Calcd for $C_{18}H_{26}Si$: C, 80.00; H, 9.63. Found: C, 80.13; H, 9.57.

(Z)-8-Trimethylsilyl-7-tetradecen-9-yne (**4f**)**:** IR (film)/cm^{-1} 2930, 2860, 2176, 1582, 1465, 1379, 1249, 841; δ_H ($CDCl_3$) 0.11 (s, 9 H), 0.69─1.03 (m, 6 H), 1.18─1.63 (m, 12 H), 2.18─2.43 (m, 4 H), 6.12 (t, 1 H, *J* = 7.0 Hz); Anal. Calcd for $C_{17}H_{32}Si$: C, 77.27; H, 12.12. Found: C, 77.03; H, 12.15.

(Z)-1-Hexyl-2-trimethylsilyl-4-phenyl-1-buten-3-yne (**4g**)**:** IR (film)/cm^{-1} 3057, 3031, 2956, 2857, 2171, 1597, 1488, 1443, 1249, 842, 753, 689; δ_H ($CDCl_3$) 0.15 (s, 9 H), 0.89 (t, 3 H, *J* = 5.4 Hz), 1.25─1.65 (m, 8 H), 2.20─2.48 (m, 2 H), 6.18 (t, 1 H, *J* = 7.0 Hz), 7.25─7.58 (m, 5 H); Anal. Calcd for $C_{19}H_{28}Si$: C, 80.28; H, 9.86. Found: C, 80.11; H, 9.75.

(Z)-1-Phenyl-3-trimethylsilyl-2-nonen-4-yne (**4h**)**:** IR (film)/cm^{-1} 3061, 3028, 2955, 2857, 2178, 1579, 1495, 1249, 841, 700; δ_H ($CDCl_3$) 0.16 (s, 9 H), 0.89 (t, 3 H, *J* = 5.4 Hz), 1.18─1.54 (m, 4 H), 2.28 (m, 2 H), 3.56 (d, 2 H, *J* = 7.2 Hz), 6.37 (t, 1 H, *J* = 7.0 Hz), 7.19─7.52 (m, 5 H); Anal. Calcd for $C_{18}H_{26}Si$: C, 80.00; H, 9.63. Found: C, 79.87; H, 9.49.

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