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Catalytic Asymmetric Synthesis of β-Hydroxy Ketones by Palladium-Catalyzed Asymmetric 1,4-Disilylation of α,β-Unsaturated Ketones[1]

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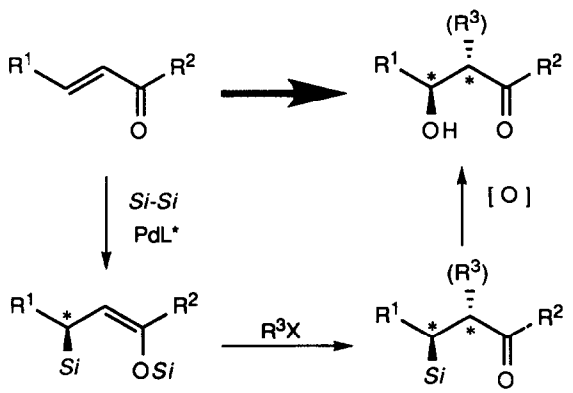
Abstract: 1,4-Disilylation of α,β-unsaturated ketones with 1,1-dichloro-1-phenyl-2,2,2-trimethyldisilane proceeded in the presence of phosphine-palladium catalysts in benzene. High enantioselectivity (up to 92%) was observed in the disilylation with dichloro[(*R*)-2,2'-bis(diphenylphosphino)-1,1'-binaphthyl]palladium(II) as a catalyst (0.5 mol %). The disilylation products, 1-(trimethylsilyloxy)-3-(dichlorophenylsilyl)propenes, were readily converted into optically active α-unsubstituted or *anti* α-substituted β-(phenyldimethylsilyl) ketones, the oxidation of which gave the corresponding optically active β-hydroxy ketones in high yields.

INTRODUCTION

Optically active β-hydroxy carbonyl compounds are important intermediates for the synthesis of a wide variety of biologically active compounds. Although they have been synthesized mainly by asymmetric aldol reactions, the reactions are not always suitable for synthesis of α-unsubstituted or *anti* α-substituted β-hydroxy ketones with high enantiomeric purity and they usually require a stoichiometric amount of chiral auxiliaries.[2] On the other hand, Fleming and co-workers have reported that conjugate addition of a silyl group to α,β-unsaturated carbonyl compounds is effected by use of silyl cuprate reagents to give selectively α-unsubstituted and *anti* α-substituted β-silyl ketones.[3,4] The β-silyl carbonyl compounds are useful synthetic intermediates convertible into β-hydroxy ketones.[5] However, the silyl-cupration seems difficult to apply to catalytic asymmetric synthesis. We have been interested in the use of chiral transition-metal complexes for catalytic

Scheme 1



asymmetric reactions, and found that a catalytic process to the β-silyl ketones is realized by the use of palladium complexes for the 1,4-addition of an unsymmetrically substituted disilane to α,β-unsaturated ketones and that high enantioselectivity is observed in the catalytic 1,4-disilylation in the presence of an optically active phosphine-palladium catalyst. We report here in detail this novel approach to optically active α-unsubstituted or *anti* α-substituted β-hydroxy ketones through the palladium-catalyzed asymmetric 1,4-disilylation of α,β-unsaturated ketones followed by oxidative cleavage of the carbon-silicon bond (Scheme 1).

RESULTS AND DISCUSSION

Palladium-Catalyzed Disilylation

In hopes of developing a new catalytic silylation of α,β-unsaturated carbonyl compounds, a variety of disilanes and catalysts were examined for the reaction of (*E*)-4-phenyl-3-buten-2-one (**1a**), and it was found that tetrakis(triphenylphosphine)palladium(0) effectively catalyzes the addition of 1,1-dichloro-1-phenyl-2,2,2-trimethyldisilane ($PhCl_2SiSiMe_3$)[6] in refluxing benzene, with phenyldichlorosilyl group and trimethylsilyl group attacking at β-carbon and carbonyl oxygen, respectively. Treatment of the disilylation product **2a** with an excess of methyllithium in ether, which should generate β-(phenyldimethylsilyl) lithium enolate **3a**, followed by hydrolysis with dilute hydrochloric acid gave 4-phenyl-4-(phenyldimethylsilyl)butan-2-one (**4a**) in 78% yield (Scheme 2) (entry 1 in Table 1).

The disilylation with $PhCl_2SiSiMe_3$ proceeded at lower temperature, though it required longer reaction time to obtain a reasonable yield (entry 2). Disilane $Cl_3SiSiMe_3$[6] could be also used for the disilylation of **1a**, which gave 39% yield (at 25 °C for 20 h) of 4-phenyl-4-(trimethylsilyl)butan-2-one after the methylation and acidic hydrolysis (entry 5). The disilylation was not observed with symmetrically substituted disilanes such as $XMe_2SiSiMe_2X$ (X = Me, Cl, F, Ph). Although $FMe_2SiSiMe_2F$ has been reported to be a good disilylation agent for methyl vinyl ketone,[7] the disilylation of **1a** did not occur under the conditions described above (entry 6). These results may indicate that unsymmetrically substituted disilanes are more active than symmetrically substituted ones, though the disilylation did not take place with other unsymmetrically substituted disilanes such as $PhF_2SiSiMe_3$, $(MeO)_3SiSiMe_3$, or $MeCl_2SiSiMe_3$.

Other palladium complexes that contain tertiary phosphine ligands were also effective giving the disilylation product in good yields (entries 7-9). Bidentate phosphine ligand, 1,1'-bis(diphenylphosphino)-ferrocene (dppf) and 1,4-bis(diphenylphosphino)butane (dppb), could be also used. But the disilylation did not occur with palladium complexes lacking phosphine ligands (entries 10 and 11) or other transition metal complexes such as $NiCl_2(PPh_3)_2$, $PtCl_2(PPh_3)_2$, $RhCl(PPh_3)_3$, and $RuCl_2(PPh_3)_3$.

Scheme 2

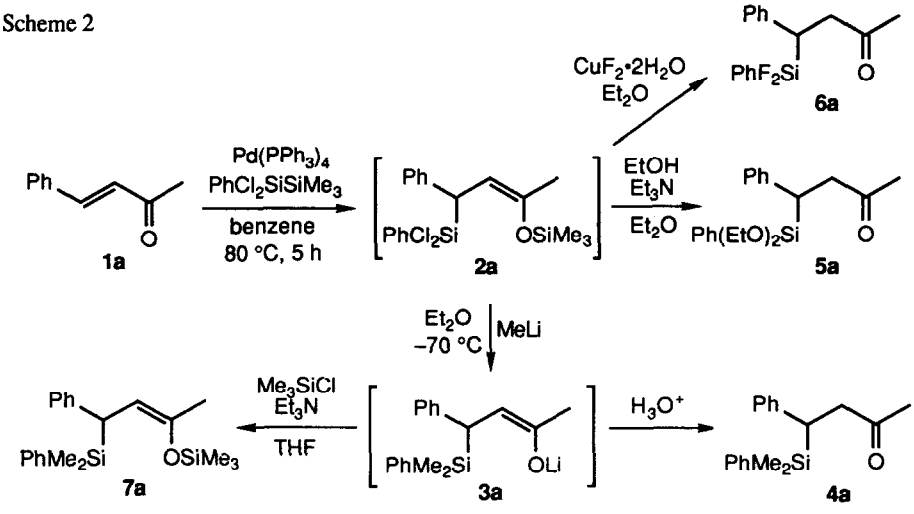


Table 1. Catalytic 1,4-Disilylation of (*E*)-4-Phenyl-3-buten-2-one (**1a**) with Disilanes in the Presence of Palladium Complexes[a]

entry	disilane	catalyst	temp (°C)	time (h)	isolation	**4a** (%)[b]
1	$PhCl_2SiSiMe_3$	$Pd(PPh_3)_4$	80	5	1.MeLi/2.H_3O^+	78
2	$PhCl_2SiSiMe_3$	$Pd(PPh_3)_4$	40	20	1.MeLi/2.H_3O^+	60
3[c]	$PhCl_2SiSiMe_3$	$Pd(PPh_3)_4$	85	4	1.MeLi/2.H_3O^+	67
4[d]	$PhCl_2SiSiMe_3$	$Pd(PPh_3)_4$	40	15	[e]	–
5	$Cl_3SiSiMe_3$	$Pd(PPh_3)_4$	25	20	1.MeLi/2.H_3O^+	39[f]
6	$FMe_2SiSiMe_2F$	$Pd(PPh_3)_4$	80	3	[e]	–
7	$PhCl_2SiSiMe_3$	$PdCl_2(PPh_3)_2$	80	29	1.MeLi/2.H_3O^+	35
8	$PhCl_2SiSiMe_3$	$[PdCl(\pi\text{-}C_3H_5)]_2$/dppf	80	2	1.MeLi/2.H_3O^+	45
9	$PhCl_2SiSiMe_3$	$[PdCl(\pi\text{-}C_3H_5)]_2$/dppb	80	4	1.MeLi/2.H_3O^+	66
10	$PhCl_2SiSiMe_3$	$[PdCl(\pi\text{-}C_3H_5)]_2$	80	6	[e]	–
11	$PhCl_2SiSiMe_3$	$Pd(OAc)_2$	80	6	[e]	–
12	$PhCl_2SiSiMe_3$	$Pd(PPh_3)_4$	80	5	EtOH/Et_3N	65[g]
13	$PhCl_2SiSiMe_3$	$Pd(PPh_3)_4$	80	5	CuF_2·$2H_2O$	54[h]

[a] All reactions were carried out in benzene unless otherwise noted. **1a**/disilane/catalyst = 1.0/1.1/0.005. See Experimental section. [b] Isolated yield. [c] In 1,2-dimethoxyethane. [d] In dichloromethane. [e] Starting enone **1a** was not consumed at all. [f] 4-Phenyl-4-(trimethylsilyl)butan-2-one. [g] **5a**. [h] **6a**.

The disilylation product **2a** formed in the reaction of **1a** with $PhCl_2SiSiMe_3$ can be also isolated as 4-phenyl-4-(phenyldiethoxysilyl)butan-2-one (**5a**) by treatment of the reaction mixture with ethanol and triethylamine (entry 12). Fluorination of **2a** by treatment with copper fluoride gave 4-phenyl-4-(phenyldifluorosilyl)butan-2-one (**6a**) (entry 13). Diethoxysilyl group and difluorosilyl group were directly substituted with hydroxy group by one step procedure (*vide infra*).[8] Attempts to isolate **2a** which is a silyl enol ether having dichlorosilyl group failed because of its lability. It was successful to isolate trimethylsilyl enol ether **7a** formed by treatment of lithium enolate **3a**, generated from **2a** with methyllithium, with trimethylchlorosilane and triethylamine in THF (Scheme 2). Silyl enol ether **7a** was found to have *Z* configuration predominantly, the ratio of *Z*/*E* being 10/1.[4a,9] This *Z* geometry indicates that the enone undergoes the disilylation in a *cisoid* conformation to generate (*Z*)-silyl enol ether **2**.

α,β-Unsaturated ketones **1b-1d**, which have an analogous structure to **1a**, underwent the 1,4-disilylation with $PhCl_2SiSiMe_3$ in the presence of $Pd(PPh_3)_4$ to give β-(phenyldimethylsilyl) ketones **4b-4d** or β-

Scheme 3

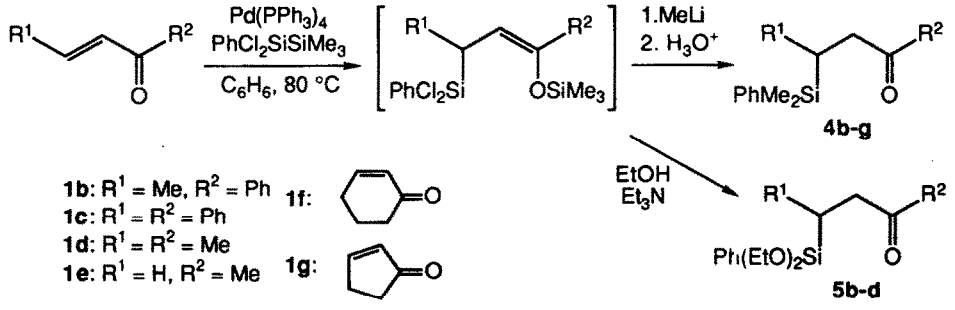


Table 2. Palladium-Catalyzed 1,4-Disilylation of α,β-Unsaturated Ketones with 1,1-Dichloro-1-phenyl-2,2,2-trimethyldisilane[a]

entry	α,β-unsaturated ketone (**1**)	reaction time (h)	isolation[b]	product	yield (%)[c]
1	R^1 = Me, R^2 = Ph (**1b**)	1.5	1.MeLi/2.H_3O^+	**4b**	68
2	**1b**	1.5	EtOH/Et_3N	**5b**	78
3	R^1 = R^2 = Ph (**1c**)	2	1.MeLi/2.H_3O^+	**4c**	80
4	**1c**	2	EtOH/Et_3N	**5c**	78
5	R^1 = R^2 = Me (**1d**)	4	1.MeLi/2.H_3O^+	**4d**	64
6	**1d**	4	EtOH/Et_3N	**5d**	64
7	R^1 = H, R^2 = Me (**1e**)	5	1.MeLi/2.H_3O^+	**4e**	48
8	2-Cyclohexenone (**1f**)	4	1.MeLi/2.H_3O^+	**4f**	43
9	2-Cyclopentenone (**1g**)	4	1.MeLi/2.H_3O^+	**4g**	41

[a] All reactions were carried out in benzene at 80 °C. **1**/disilane/$Pd(PPh_3)_4$ = 1.0/1.1/0.005. [b] The 1,4-disilylation products were isolated as **4** or **6**. See Experimental section. [c] Isolated yield.

(phenyldiethoxysilyl) ketones **5b-5d** in high yields (Scheme 3, Table 2). The disilylation was also observed with methyl vinyl ketone (**1e**), though in lower yield due to side reactions. Cyclic enones, 2-cyclohexenone (**1f**) and 2-cyclopentenone (**1g**), where the two double bonds are oriented only in transoid conformation, were also disilylated to give product **4f** and **4g** respectively, in moderate yields. On the other hand, the disilylation did not take place with β,β-disubstituted enones such as 4-phenyl-3-penten-2-one or 3-methyl-2-cyclohexen-1-one. The disilylation of methyl cinnamate or cinnamaldehyde was not successful.

Since Fleming has reported *anti* alkylation of the enolates generated by the conjugate addition of a silyl cuprate to α,β-unsaturated carbonyl compounds,[4] β-silyl lithium enolates **3**, generated by treatment of the disilylation product **2** with methyllithium, are expected to undergo the *anti*-alkylation.[4] Actually, methylation of β-silyl lithium enolate **3a** with methyl iodide in THF introduced methyl group *anti* selectively (>95/5) at α-position to give 59% yield of 4-phenyl-4-(phenyldimethylsilyl)-3-methylbutan-2-one (**8a**). *Anti* selective alkylation was also observed in the reaction of lithium enolates **3b**, **3c**, and **3d** with methyl iodide, benzyl bromide, or allyl bromide giving α-alkyl ketones **8**, **9**, or **10**, respectively (Scheme 4). These results are summarized in Table 3. The diastereoselectivity can be explained by the steric and electronic influences in the low-energy conformation **A** (Scheme 5).[4] In this conformation, the hydrogen eclipses the double bond leaving the larger groups staggered. Attack by alkyl halide then takes place *anti* to the silyl group either for electronic or

Scheme 4

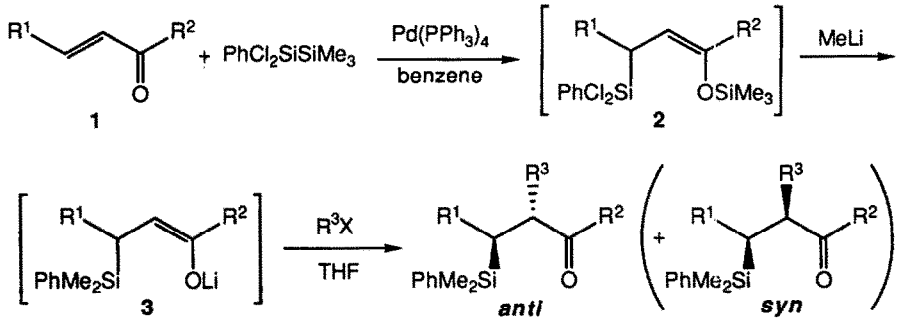


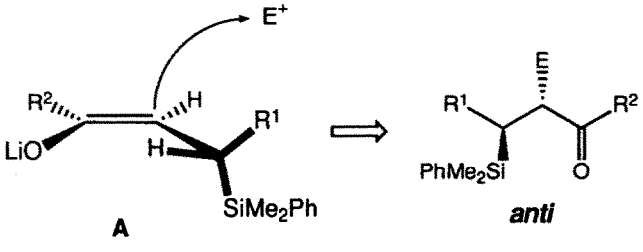
Table 3. Alkylation of β-Silyl Lithium Enolate **3**[a]

entry	α,β-unsaturated ketone **1**	reaction time (h)	alkylation[b]	product	yield (%)[c]	*anti* / *syn*[d]
1	R^1 = Ph, R^2 = Me (**1a**)	5	1.MeLi/2.MeI	**8a**	59	>95/5
2	**1a**	1.5	1.MeLi/2.$PhCH_2Br$	**9a**	26	>95/5
3	**1a**	1.5	1.MeLi/2.AllylBr	**10a**	22	>95/5
4	R^1 = Me, R^2 = Ph (**1b**)	1.5	1.MeLi/2.MeI	**8b**	42	>95/5
5	**1b**	1.5	1.MeLi/2.$PhCH_2Br$	**9b**	55	>95/5
6	R^1 = R^2 = Ph (**1c**)	2	1.MeLi/2.MeI	**8c**	49	>95/5
7	**1c**	2	1.MeLi/2.AllylBr	**10c**	38	>95/5
8	R^1 = R^2 = Me (**1d**)	4	1.MeLi/2.$PhCH_2Br$	**9d**	32	>95/5

[a] For the disilylation, see footnote *a* in Table 2. [b] The details are described in Experimental section. [c] Isolated yield. [d] The ratio was determined by ^1H NMR spectra.

steric reasons or for both combined. It is notable that the face of the double bond of the enolate attacked is the same face as that found to be attacked in allylsilanes.[10] The difference in the two series is that the electrophile settles down on C-3 of the allyl system in allylsilanes but on C-2 of the allyl system of the enolates. The sense of the electrophilic attack on the double bond **A** is essentially that predicted by Houk.[11]

Scheme 5

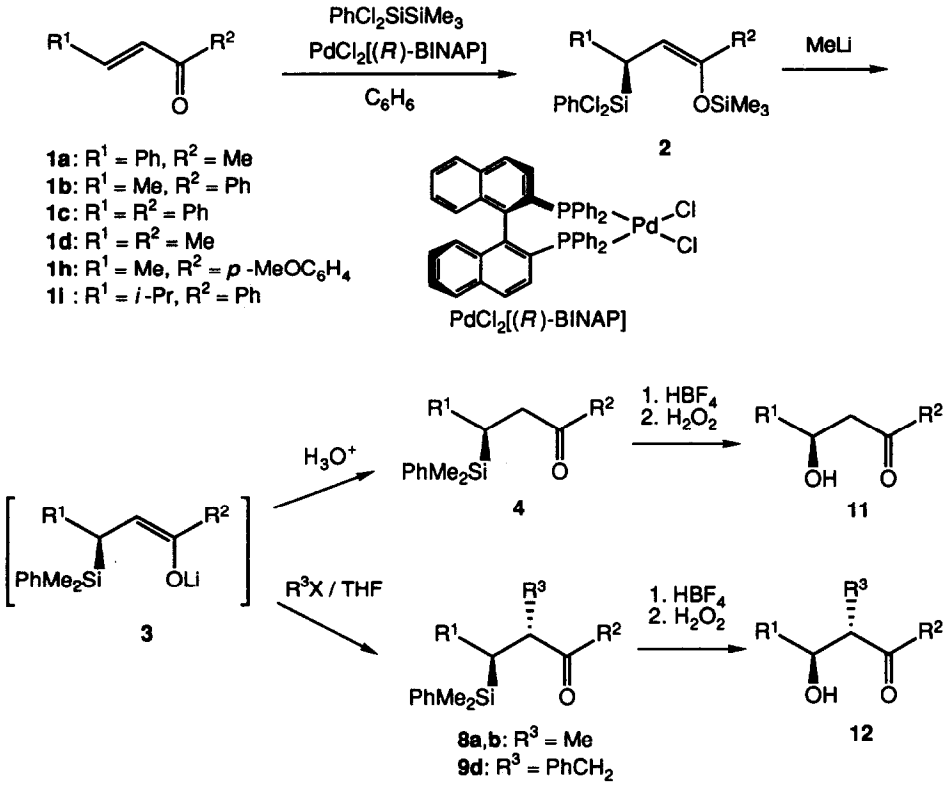


The 1,4-disilylation is considered to take place via (phenyldichlorosilyl)(trimethylsilyl)palladium(II) which is formed by oxidative addition of the disilane to a palladium(0). Coordination of the enone **1** to the disilyl palladium followed by selective migration of phenyldichlorosilyl group and trimethylsilyl group to β-position and carbonyl oxygen of the enone, respectively, will form the 1,4-disilylation product. (Z)-Configuration of the carbon-carbon double bond in silyl enol ether **2** indicates that the enone coordinates mainly in a cisoid conformation. The detailed mechanism of transfer of the two silyl groups from palladium to enone remains to be clarified.

Catalytic Asymmetric Disilylation

A variety of chiral phosphine ligands were examined for the palladium-catalyzed disilylation of (*E*)-4-phenyl-3-buten-2-one (**1a**) with 1,1-dichloro-1-phenyl-2,2,2-trimethyldisilane ($PhCl_2SiSiMe_3$). The asymmetric disilylation of **1a** was carried out at 80 °C in benzene with 1.1 equiv of $PhCl_2SiSiMe_3$ in the presence of a palladium complex generated in situ by mixing $[PdCl(\eta^3\text{-}C_3H_5)]_2$ or $Pd_2(dba)_3\cdot CHCl_3$ with a chiral phosphine ligand. The 1,4-disilylation product was isolated as 4-phenyl-3-(phenyldimethylsilyl)butan-2-one (**4a**) by treatment of the reaction mixture with methyllithium followed by acidic hydrolysis and the enantiomeric purity of **4a** was determined by HPLC analysis with chiral stationary phase column Sumichiral OA-2000 (hexane/1,2-dichloroethane/ethanol = 500/20/1) (Scheme 6). These results are shown in Table 4.

Scheme 6



(*R*)-(+)-2,2'-Bis(diphenylphosphino)-1,1'-binaphthyl ((*R*)-(+)-BINAP)[12] showed the highest enantioselectivity and other chiral ligands, DIOP,[13] chiraphos,[14] and ferrocenylphosphines,[15] were much less enantioselective (entries 1-5). It was found that the ratio of the disilane to the substrate affected the enantioselectivity, higher enantioselectivity being obtained by use of 1.8 equiv of the disilane (entry 6). Benzene was the most favorable solvent giving high enantioselectivity and other solvents such as toluene, THF, DME, and chloroform gave poor results. The enantiomeric purity and yield of **4a** were improved by use of preformed palladium catalyst $PdCl_2$[(*R*)-BINAP] (entry 7), which was prepared by the reaction of dichlorobis(acetonitrile)palladium with 1 equiv of (*R*)-BINAP in benzene. Thus, disilylation of **1a** with 1.8 equiv of $PhCl_2SiSiMe_3$ catalyzed by $PdCl_2$[(*R*)-BINAP] at 80 °C for 17 h followed by the methylation and hydrolysis gave 71% yield of optically active **4a** ($[\alpha]_D^{20}$ +9.2 (*c* 1.1, $CHCl_3$)) whose enantiomeric purity determined by the HPLC analysis was 78% ee (entry 7). The absolute configuration of **4a** was determined to be *R* after conversion into 4-phenyl-4-hydroxy-2-butanone (**11a**). The oxidative conversion was readily achieved by method developed by Tamao.[8] It has been established that the oxidation of C-Si bond into C-O bond proceeds with retention of configuration at the carbon atom. The phenyldimethylsilyl group on β-silyl ketone **4a** (78% ee) was converted into hydroxy group by fluorodephenylation (HBF_4-Et_2O/CH_2Cl_2) on the silyl group followed by oxidation of the silicon-carbon bond (H_2O_2/KF/$KHCO_3$/MeOH/THF) to give 83% yield of optically active alcohol (*R*)-**11a** ($[\alpha]_D^{25}$ +56.7 (*c* 1.1, $CHCl_3$)), whose enantiomeric purity was determined to be 78% ee by HPLC analysis with a chiral stationary phase column, Sumichiral OA-2000 (hexane/1,2-dichloroethane/ethanol = 500/20/1). These results indicate that the oxidative conversion of silyl group into hydroxy group took place without loss of the enantiomeric purity. This is the first demonstration of the complete retention of configuration at the oxidative conversion in an enantiomeric system.

Table 4. Asymmetric Disilylation of (*E*)-4-Phenyl-3-buten-2-one (**1a**) and (*E*)-1-Phenyl-2-buten-1-one (**1b**) with $PhCl_2SiSiMe_3$ Catalyzed by Palladium-Phosphine Complexes[a]

entry	substrate	ligand	disilane (equiv)	temp (°C)	time (h)	**4** (%)[b]	% ee[c] (config)[d]
1	**1a**	(+)-DIOP[e]	1.1	80	11	42	8 (*R*)
2	**1a**	(*S*,*S*)-chiraphos[e]	1.1	80	13	0	–
3	**1a**	(*R*)-(*S*)-BPPFA[e]	1.1	80	11	40	2 (*R*)
4	**1a**	(*R*)-(*S*)-PPFA[f]	1.1	80	4	42	3 (*R*)
5	**1a**	(*R*)-BINAP[e]	1.1	80	5	52	69 (*R*)
6	**1a**	(*R*)-BINAP[g]	1.8	80	5	42	73 (*R*)
7	**1a**	(*R*)-BINAP[h]	1.8	80	17	71	78 (*R*)
8	**1b**	(*R*)-BINAP[h]	1.8	80	2	72	87 (*R*)
9	**1b**	(*R*)-BINAP[h]	1.8	60	25	40	80 (*R*)
10	**1b**	(*R*)-BINAP[h]	1.8	100	2	44	87 (*R*)
11	**1b**	(*R*)-BINAP[h]	1.8	120	3	35	35 (*R*)

[a] All reactions were carried out in benzene. **1**/catalyst = 1/0.005. The 1,4-disilylation product was isolated as **4**. See Experimental section. [b] Isolated yield. [c] Determined by HPLC analysis with chiral stationary phase column Sumichiral OA-2000. [d] The configuration of **4** was determined after conversion into alcohol **11**. [e] $Pd_2(dba)_3$•$CHCl_3$ was used as a precursor of the catalyst. [f] $PdCl_2$[(*R*)-(*S*)-PPFA] was used as a catalyst. [g] $[PdCl(\eta^3\text{-}C_3H_5)]_2$ was used as a precursor of the catalyst. [h] $PdCl_2$[(*R*)-BINAP] was used as a catalyst.

In the disilylation of (*E*)-1-phenyl-2-buten-1-one (**1b**) the enantioselectivity was observed to be dependent on the reaction temperature (entries 8-11 in Table 4). The highest enantioselectivity (87% ee) was obtained at temperatures between 80 and 100 °C and the enantioselectivity decreased at the lower or higher temperature. Thus, the disilylation of **1b** with $PhCl_2SiSiMe_3$ in the presence of the $PdCl_2$[(*R*)-BINAP] catalyst at 80 °C followed by the work-up gave 72% yield of optically active 1-phenyl-3-(phenyldimethylsilyl)butan-1-one (**4b**) (entry 8). The enantiomeric purity of **4b** was determined to be 87% ee after conversion into (*S*)-1-phenyl-3-hydroxybuten-1-one (**11b**).

The asymmetric disilylation catalyzed by $PdCl_2$[(*R*)-BINAP] was employed to several α,β-unsaturated ketones **1** (Scheme 6). These results are summarized in Table 5. The highest enantioselectivity (92% ee) was obtained in the asymmetric disilylation of 1-(4-methoxyphenyl)-2-buten-1-one (**1h**) (entry 8). Other α,β-unsaturated ketones, (*E*)-3-penten-2-one (**1d**) and (*E*)-4-methyl-1-phenyl-2-penten-1-one (**1i**) also underwent the asymmetric disilylation with high enantioselectivity to give β-silyl ketones (*S*)-**4d** (74% ee) and **4i** (86% ee), respectively (entries 6 and 9). However, the asymmetric disilylation of (*E*)-1,3-diphenyl-2-propen-1-one (**1c**) slowly proceeded to give (*R*)-**4c** with moderate enantioselectivity (entry 5). The β-silyl ketones **4c,d,h,i** were converted into β-hydroxy ketones **11c,d,h,i**, respectively, with high (69-100%) yields. The absolute configurations of (*R*)-**4c** and (*S*)-**4d** were deduced from those of β-hydroxy ketones (*R*)-**11c** and (*S*)-**11d**, respectively. The asymmetric disilylation of **1c** and **1d** took place at the same face of the carbon-carbon double bond as that of α,β-unsaturated ketones **1a** and **1b**.

The β-phenyldimethylsilyl lithium enolates **3** generated by treatment of the disilylation product **2** with methyllithium underwent α-alkylation with the high diastereoselectivity. Methylation of the enolate generated from **2b** with methyl iodide in THF introduced methyl group *anti* selectively (>20/1) at α-position to give 54% yield of *anti* 2-methyl-1-phenyl-3-(phenyldimethylsilyl)-1-butanone (**8b**) ($[\alpha]_D^{20}$ +80.2 (*c* 1.1, $CHCl_3$)) (entry 4 in Table 5). The high *anti* selectivity (>20/1) was also observed in the α-methylation or α-benzylation of the enolates resulting from **2a** and **2d** to give *anti* α-methyl β-silyl ketone (2*S*,3*R*)-**8a** and *anti* α-benzyl β-silyl

Table 5. Asymmetric Disilylation of α,β-Unsaturated Ketones with $PhCl_2SiSiMe_3$ Catalyzed by $PdCl_2$[(*R*)-BINAP][a]

entry	1	time (h)	isolation	silyl ketone yield[b](%)	$[\alpha]_D^{20}$[c]	% ee[d] (config)	hydroxy ketone yield (%)	$[\alpha]_D^{20}$[e]
1	**1a**	17	1.MeLi/2.H_3O^+	**4a** (71)	+9.2	78 (*R*)[f]	**11a** (83)	+56.7[g]
2	**1a**	17	1.MeLi/2.MeI	**8a** (47)	−1.0	(78) (2*S*,3*R*)[h]	**12a** (45)	+47.9
3	**1b**	2	1.MeLi/2.H_3O^+	**4b** (72)	+11.2	87 (*S*)[f]	**11b** (90)	+59.6[i]
4	**1b**	2	1.MeLi/2.MeI	**8b** (54)	+80.2	85 (2*S*,3*S*)[h]	**12b** (70)	+62.3
5	**1c**	96	1.MeLi/2.H_3O^+	**4c** (44)	+11.4	47 (*R*)	**11c** (71)	+15.1[i,j]
6	**1d**	0.5	1.MeLi/2.H_3O^+	**4d** (65)	+21.0	(74) (*S*)[f]	**11d** (69)	+57.1[i]
7	**1d**	0.5	1.MeLi/2.$PhCH_2Br$	**9d** (42)	+120	74 (2*S*,3*S*)[h]	**12d** (66)	+68.2
8	**1h**	0.5	1.MeLi/2.H_3O^+	**4h** (64)	+12.2	92	**11h** (81)	+56.7
9	**1i**	15	1.MeLi/2.H_3O^+	**4i** (42)	+11.7	86	**11i** (100)	+64.9

[a] The reaction was carried out in benzene at 80 °C. **1**/$PhCl_2SiSiMe_3$/$PdCl_2$[(*R*)-BINAP] = 1.0/(1.8-2.0)/0.005. See Experimental section. [b] Isolated yield by preparative TLC on silica gel. [c] *c* 1.1-1.3 in chloroform. [d] Determined by HPLC analysis of **4a**, **11b**, **12b**, **4c**, **9d**, **11h**, and **4i** with chiral column Sumichiral OA-2000. The % ee values in parenthesis (entries 2 and 6) were deduced from those in entries 1 and 7, respectively. [e] *c* 0.8-1.1 in chloroform unless otherwise noted. [f] The configurations in entries 1, 3, and 7 were determined by the optical rotations of **11a**, **11b**, and **11d**, respectively. [g] At 23 °C. [h] The *anti* selectivity is >20/1. The configurations of alkylated products were deduced from the *anti* stereochemistry and the absolute configurations at 3 position of the protonated products. [i] At 25 °C. [j] In methanol.

ketone (2*S*,3*S*)-**9d**, respectively (entries 2 and 7). The enantiomeric purity of **9d** was determined to be 74% ee by the HPLC analysis. The oxidative conversions of *anti* α-alkyl β-silyl ketones **8**,**9** also took place with complete retention of configuration at both the α- and β-carbon atoms to give *anti* α-alkyl β-hydroxy ketones **12** (entries 2, 4, and 7). The oxidation of β-silyl ketone **8b** gave 70 % yield of *anti* 2-methyl-1-phenyl-3-hydroxy-1-butanone (**12b**) ($[\alpha]_D^{20}$ +62.3 (*c* 1.1, $CHCl_3$)), whose enantiomeric purity determined by the HPLC analysis was 85% ee, essentially the same as that of the protonation-oxidation product **11b**. The absolute configuration of **12b** is determined to be (2*S*,3*S*) since **12b** should have the same configuration at 3 position as **11b**.

EXPERIMENTAL

General. Optical rotations were measured with a Perkin-Elmer 241 polarimeter. ^1H NMR spectra were measured with a JEOL JNM-MH-100 (100 MHz) or Varian VXR-200 (200 MHz) spectrometer. Infrared spectra were obtained with a Hitachi 270-30 spectrometer.

Preparation of Disilanes. 1,1-Dichloro-1-phenyl-2,2,2-trimethyldisilane. A mixture of 135 g (0.458 mol) of chlorotriphenylsilane and 12.7 g (1.83 mol) of lithium shot in 1000 ml of THF was stirred at room temperature for 15 h under nitrogen. The mixture turned deep greenish color. The silyl lithium solution obtained was added dropwise under nitrogen to a solution of 87 ml (0.687 mol) of chlorotrimethylsilane in 170 ml of THF. The mixture was stirred by a mechanical stirrer at room temperature for 20 h and hydrolyzed with 200 ml of water. The mixture was extracted with ether and the organic layer was dried over magnesium sulfate. Removal of solvent followed by recrystallization from ethanol gave 117 g (77%) of 1,1,1-triphenyl-2,2,2-trimethyldisilane as white crystals. ^1H NMR ($CDCl_3$/TMS) δ 0.13 (s, 9 H), 7.0-7.4 (m, 15 H). Hydrogen chloride was bubbled through a solution of 50.1 g (0.151 mmol) of 1,1,1-triphenyl-2,2,2-trimethyldisilane in 150 ml of benzene. To the solution was added catalytic amount (about 20 mg) of aluminium trichloride which was freshly sublimed before use. The mixture was warmed, then the reaction occurred and benzene was spontaneously refluxed. The reaction mixture was stirred for 4 h under bubbling hydrogen chloride. The

progress was checked by GLC. When the second dephenylation completed, the reaction was quenched by addition of 0.5 ml of acetone. The mixture was filtered through a glass micro fiber filter and concentrated by distillation. First distillation under reduced pressure (bp 73 °C/73 mmHg) gave 3.91 g (12%, 18.8 mmol) of 1,1,1-trichloro-2,2,2-trimethyldisilane. The residue was distilled under reduced pressure (bp 92 °C/1.8 mmHg) to give 28.2 g (75%) of 1,1-dichloro-1-phenyl-2,2,2-trimethyldisilane: ^{1}H NMR ($CDCl_3$/TMS) δ 0.15 (s, 9 H), 7.4-7.55 (m, 3 H), 7.65-7.75 (m, 2 H); IR (neat) 2964, 1432, 1252, 1110, 843, 738, 694 cm^{-1}.

1,1,1-Trichloro-2,2,2-trimethyldisilane. $Cl_3SiSiMe_3$ was prepared in the same manner described above. The third dephenylation completely proceeded for a longer reaction time. The reaction mixture was worked up in the same way to give 1,1,1-trichloro-2,2,2-trimethyldisilane in 75% yield. ^{1}H NMR (CCl_4/TMS) δ 0.35 (s, 9 H); IR (neat) 2966, 1255, 846 cm^{-1}.

Palladium-Catalyzed 1,4-Disilylation of α,β-Unsaturated Ketones with 1,1-Dichloro-1-phenyl-2,2,2-trimethyldisilane. General Procedure. All reactions were carried out under argon atmospher. Reaction conditions and results are summarized in Tables 1, 2, and 3. To a mixture of 0.01 mmol of a palladium catalyst and 0.55 g (2.2 mmol) of $PhCl_2SiSiMe_3$ in 2.0 ml of benzene was added 2.0 mmol of enone **1**, and the mixture was stirred at a given temperature for a given period. The consumption of enone **1** was checked by GLC. The 1,4-disilylation product was isolated by either of the procedure, Method A, Method B, or Method C. **Method A:** The reaction mixture was cooled to room temperature, diluted with 2.0 ml of ether, and then cooled to –70 °C. To the mixture was added 6.2 ml (12 mmol) of 1.9 M methyllithium in ether. The mixture was stirred at the same temperature for 10 min and then quenched with dilute hydrochloric acid. The mixture was extracted with ether. The ether layer was washed with saturated sodium bicarbonate solution and dried over magnesium sulfate. Removal of solvent followed by preparative TLC on silica gel (hexane/ether = 2/1) gave β-(phenyldimethylsilyl) ketone **4**. **Method B:** The reaction mixture was cooled to room temperature, diluted with 20 ml of ether and then cooled to 0 °C. To the solution were added 0.76 ml (12 mmol) of ethanol and 1.86 ml (12 mmol) of triethylamine and the mixture was stirred at room temperature for 1 h. Ammonium salts were filtered off, and the filtrate was concentrated. Bulb-to-bulb distillation of the residue gave β-(phenyldiethoxysilyl) ketone **5**. **Method C.** The reaction mixture was cooled to room temperature, diluted with 2.0 ml of ether, and then cooled to 0 °C. To the solution was added 303 mg (2.2 mmol) of $CuF_2{\cdot}2H_2O$ and the mixture was stirred at the same temperature for 18 h. Pentane was added, and copper salts were filtered off. Removal of solvent followed by bulb-to-bulb distillation of the residue gave β-(phenyldifluorosilyl) ketone **6**. **4-Phenyl-4-(phenyldimethylsilyl)-2-butanone (4a)**: ^{1}H NMR (CCl_4/TMS) δ 0.20 (s, 6 H), 1.83 (s, 3 H), 2.3-3.0 (m, 3 H), 6.7-7.4 (m, 10 H); IR (neat) 1720 cm^{-1}. Anal. Calcd. for $C_{18}H_{22}OSi$: C, 76.54; H, 7.85. Found: C, 76.36; H, 7.88. **4-Phenyl-4-(trimethylsilyl)-2-butanone**: ^{1}H NMR (CCl_4/TMS) δ –0.15 (s, 9 H), 1.85 (s, 3 H), 2.4-2.7 (m, 3 H), 6.7-7.2 (m, 5 H). **1-Phenyl-3-(phenyldimethylsilyl)-1-butanone (4b)**: ^{1}H NMR (CCl_4/TMS) δ 0.33 (s, 6 H), 0.98 (d, J = 8 Hz, 3 H), 1.4-1.8 (m, 1 H), 2.56 (dd, J = 16 and 10 Hz, 1 H), 2.90 (dd, J = 16 and 4 Hz, 1 H), 7.1-7.5, 7.6-7.8 (m, 5 H); IR (neat) 1687 cm^{-1}. Anal. Calcd. for $C_{18}H_{22}OSi$: C, 76.54; H, 7.85. Found: C, 76.30; H, 7.77. **1,3-Diphenyl-3-(phenyldimethylsilyl)-1-propanone (4c)**: ^{1}H NMR (CCl_4/TMS) δ 0.22, 0.24 (a pair of s, 6 H), 2.9-3.5 (m, 3 H), 6.8-7.5, 7.6-7.8 (m, 15 H); IR (neat) 1688 cm^{-1}. Anal. Calcd. for $C_{23}H_{24}OSi$: C, 80.18; H, 7.02. Found: C, 80.29; H, 6.93. **3-(Phenyldimethylsilyl)-2-pentanone (4d)**: ^{1}H NMR (CCl_4/TMS) δ 0.29 (s, 6 H), 0.91 (d, J = 7 Hz, 3 H), 1.3-1.6 (m, 1 H), 1.96 (s, 3 H), 2.06 (dd, J = 17 and 9 Hz, 1 H), 2.35 (dd, J = 17 and 5 Hz, 1 H), 7.1-7.5 (m, 5 H); IR (neat) 1720 cm^{-1}. Anal. Calcd. for $C_{13}H_{20}OSi$: C, 70.84; H, 9.15. Found: C, 70.58; H, 9.18. **3-(Phenyldimethylsilyl)-2-butanone (4e)**: ^{1}H NMR (CCl_4/TMS) δ 0.28 (s, 6 H), 0.98 (t, J = 8 Hz, 2 H), 2.00 (s, 3 H), 2.34 (t, J = 8 Hz, 2 H), 7.25-7.6 (m, 5 H). **3-(Phenyldimethylsilyl)-cyclohexanone (4f)**: ^{1}H NMR (CCl_4/TMS) δ 0.32 (s, 6 H), 1.1-2.3 (m, 9 H), 7.1-7.5 (m, 5 H); IR (neat) 1714 cm^{-1}. **3-(Phenyldimethylsilyl)cyclopentanone (4g)**: ^{1}H NMR (CCl_4/TMS) δ 0.34 (s, 6 H), 1.4-2.2 (m, 7 H), 7.25-7.65 (m, 5 H). **4-Phenyl-4-(phenyldiethoxysilyl)-2-butanone (5a)**: ^{1}H NMR (CCl_4/TMS) δ 1.17 (t, J = 7 Hz, 6 H), 1.90 (s, 3 H), 2.7-3.1 (m, 3 H), 3.69, 3.75 (a pair of q, J = 7 Hz, 4 H), 6.9-7.5 (m, 10 H); IR (neat) 1721 cm^{-1}. Anal. Calcd. for $C_{20}H_{26}O_3Si$: C, 70.14; H, 7.65. Found: C, 70.01; H, 7.87. **1-Phenyl-3-(phenyldiethoxysilyl)-1-butanone (5b)**: ^{1}H NMR (CCl_4/TMS) δ 0.99 (d, J = 7 Hz, 3 H), 1.25 (t, J = 7 Hz, 6 H), 1.6-2.0 (m, 1 H), 2.62 (dd, J = 17 and 9 Hz, 1 H), 3.12 (dd, J = 17 and 3 Hz, 1 H), 3.85 (q, J = 7 Hz, 4 H), 7.2-7.9 (m, 10 H); IR (neat) 1690 cm^{-1}. Anal. Calcd. for $C_{20}H_{26}O_3Si$: C, 70.14; H, 7.65. Found: C, 70.25; H, 7.76. **1,3-Diphenyl-3-(phenyldiethoxysilyl)-1-propanone (5c)**: ^{1}H NMR (CCl_4/TMS) δ 1.16, 1.18 (a pair of t, J = 7 Hz, 6 H), 3.1-3.5 (m, 3 H), 3.75, 3.80 (a pair of q, J = 7 Hz, 4 H), 6.9-7.6, 7.7-7.9 (m, 15 H); IR (neat) 1691 cm^{-1}. Anal. Calcd. for $C_{25}H_{28}O_3Si$: C, 74.22; H, 6.98. Found: C, 74.51; H, 7.03. **3-(Phenyldiethoxysilyl)-2-pentanone (5d)**: ^{1}H NMR (CCl_4/TMS) δ 0.90 (d, J = 8 Hz, 3 H), 1.24 (t, J = 7 Hz, 6 H), 1.6-1.9 (m, 1 H), 2.00 (s, 3 H), 2.11 (dd, J = 16 and 10 Hz,

1 H), 2.51 (dd, J = 16 and 4 Hz, 1 H), 3.79 (q, J = 7 Hz, 4 H), 7.1-7.6 (m, 5 H); IR (neat) 1721 cm^{-1}. Anal. Calcd. for $C_{15}H_{24}O_3Si$: C, 64.24; H, 8.63. Found: C, 64.27; H, 8.91. **4-Phenyl-4-(phenyldifluorosilyl)-2-butanone (6a)**: ^1H NMR (CCl_4/TMS) δ 2.03 (s, 3 H), 2.8-3.1 (m, 3 H), 6.9-7.5 (m, 10 H); IR (neat) 1719 cm^{-1}.

Alkylation of β-Silyl Lithium Enolates 3. To the lithium enolate generated in the same procedure as method A, were added at -70 °C 10 ml of THF and 10 mmol of an alkyl halide. The mixture was slowly warmed up to room temperature and quenched with 10% hydrochloric acid. The mixture was extracted with ether. The ether layer was washed with saturated sodium bicarbonate solution and dried over magnesium sulfate. Removal of solvent followed by preparative TLC on silica gel (hexane/ether = 5/1~2/1) gave β-(phenyldimethylsilyl) α-alkyl ketone **8**, **9**, or **10**. ***anti*-3-Methyl-4-phenyl-4-(phenyldimethylsilyl)-2-butanone (8a)**: ^1H NMR (CCl_4/TMS) δ 0.07, 0.22 (a pair of s, 6 H), 0.86 (d, J = 7 Hz, 3 H), 1.75 (s, 3 H), 2.54 (d, J = 11 Hz, 1 H), 2.91 (dq, J = 11 and 7 Hz, 1 H), 6.7-7.4 (m, 10 H). ***anti*-3-Methyl-1-phenyl-3-(phenyldimethylsilyl)-1-butanone (8b)**: ^1H NMR (CCl_4/TMS) δ 0.32, 0.37 (a pair of s, 6 H), 0.88 (d, J = 7 Hz, 3 H), 1.03 (d, J = 7 Hz, 3 H), 1.1-1.5 (m, 1 H), 3.2-3.6 (m, 1 H), 7.1-7.7 (m, 10 H). Anal. Calcd. for $C_{19}H_{24}OSi$: C, 76.97; H, 8.16. Found: C, 76.78; H, 8.20. ***anti*-2-Methyl-1,3-diphenyl-3-(phenyldimethylsilyl)-1-propanone (8c)**: ^1H NMR (CCl_4/TMS) δ 0.04, 0.21 (a pair of s, 6 H), 0.97 (d, J = 7 Hz, 3 H), 2.91 (d, J = 10 Hz, 1 H), 3.86 (dq, J = 10 and 7 Hz, 1 H), 6.8-7.5, 7.6-7.9 (m, 15 H); IR (neat) 1684 cm^{-1}. ***anti*-3-Benzyl-4-phenyl-4-(phenyldimethylsilyl)-2-butanone (9a)**: ^1H NMR (CCl_4/TMS) δ 0.25, 0.31 (a pair of s, 6 H), 1.50 (s, 3 H), 2.3-3.0 (m, 3 H), 3.32 (td, J = 11 and 4 Hz, 1 H), 6.9-7.5 (m, 15 H). ***anti*-3-Benzyl-1-phenyl-3-(phenyldimethylsilyl)-1-butanone (9b)**: ^1H NMR (CCl_4/TMS) δ 0.39, 0.50 (a pair of s, 6 H), 1.01 (d, J = 7 Hz, 3 H), 1.0-1.3 (m, 1 H), 2.47 (dd, J = 13 and 2 Hz, 1 H), 3.22 (dd, J = 13 and 11 Hz, 1 H), 3.67 (dt, J = 11 and 2 Hz, 1 H), 6.8-7.6 (m, 15 H); IR (neat) 1680 cm^{-1}. Anal. Calcd. for $C_{25}H_{28}OSi$: C, 80.59; H, 7.57. Found: C, 80.51; H, 7.59. ***anti*-3-Benzyl-4-(phenyldimethylsilyl)-2-pentanone (9d)**: ^1H NMR (CCl_4/TMS) δ 0.40, 0.44 (a pair of s, 6H), 0.99 (d, J = 7 Hz, 3H), 1.27 (dq, J = 7 and 3 Hz, 1H), 1.76 (s, 3H), 2.34 (d, J = 10 Hz, 1H), 2.75 (dd, J = 10 and 3 Hz, 1H), 2.91 (t, J = 10 Hz, 1H), 6.7-7.6 (m, 10H); IR (neat) 1712 cm^{-1}. Anal. Calcd for $C_{20}H_{26}OSi$: C, 77.36; H, 8.44. Found: C, 77.21; H, 8.52. **3-Allyl-4-phenyl-4-(phenyldimethylsilyl)-2-butanone (10a)**: ^1H NMR (CCl_4/TMS) δ 0.22, 0.36 (a pair of s, 6 H), 1.84 (s, 3 H), 2.0-2.3 (m, 2 H), 2.68 (d, J = 11 Hz, 1 H), 2.9-3.2 (m, 1 H), 4.81 (broad d, J = 18 Hz, 1 H), 4.93 (broad d, J = 10 Hz, 1 H), 5.3-5.8 (m, 1 H), 6.9-7.5 (m, 10 H). **2-Allyl-1,3-diphenyl-3-(phenyldimethylsilyl)-1-propanone (10c)**: ^1H NMR (CCl_4/TMS) δ 0.25, 0.40 (a pair of s, 6 H), 2.2-2.4 (m, 2 H), 3.10 (d, J = 11 Hz, 1 H), 3.95-4.25 (m, 1 H), 4.80 (broad d, J = 17 Hz, 1 H), 4.94 (broad d, J = 12 Hz, 1 H), 5.4-5.8 (m, 1 H), 6.95-8.1 (m, 15 H).

Isolation of β-Silyl Silyl Enol Ether (7a). To the lithium enolate generated in the same procedure as method A, were added successively at –70 °C 4 ml of THF, 2.3 ml (18 mmol) of chlorotrimethylsilane, and 2.5 ml (18 mmol) of triethylamine. The mixture was allowed to warm to room temperature under stirring. The mixture was diluted with ether, washed with sodium bicarbonate solution, and dried over magnesium sulfate. Removal of solvent followed by bulb-to-bulb distillation (bath temperature 120 °C/0.8 mmHg) gave 415 mg (59%) of the silyl enol ether **7a**. The product consisted of Z and E isomers in a ratio of 10 to 1. **(*Z*)-4-Phenyl-4-(phenyldimethylsilyl)-2-trimethylsiloxy-2-butene ((*Z*)-7a)**: ^1H NMR ($CDCl_3$/$CHCl_3$) δ 0.11 (s, 9 H), 1.82 (d, J = 1.0 Hz, 3 H), 3.47 (d, J = 10.9 Hz, 1 H), 4.79 (dq, J = 10.9 and 1.0 Hz, 1 H), 6.80-7.40 (m, 10 H). **(*E*)-4-Phenyl-4-(phenyldimethylsilyl)-2-trimethylsiloxy-2-butene ((*E*)-7a)**: ^1H NMR ($CDCl_3$/$CHCl_3$) δ 0.21 (s, 9 H), 1.61 (d, J = 1.0 Hz, 3 H), 3.06 (d, J = 11.1 Hz, 1 H), 5.07 (dq, J = 11.1 and 1.0 Hz, 1 H), 6.80-7.40 (m, 10 H).

Preparation of Dichloro[(*R*)-(+)-2,2'-bis(diphenylphosphino)-1,1'-binaphthyl]palladium(II) ($PdCl_2$[(*R*)-BINAP]). A solution of 249 mg (0.400 mmol) of (*R*)-(+)-2,2'-bis(diphenylphosphino)-1,1'-binaphthyl in 4.0 ml of benzene was added under stirring to a mixture of 104 mg (0.400 mmol) of $PdCl_2(MeCN)_2$ in 4.0 ml of benzene and the mixture was stirred overnight. Yellow precipitates were collected by filtration and washed with benzene. Removal of benzene by pumping gave 316 mg (0.395 mmol) of dichloro[(*R*)-(+)-2,2'-bis(diphenylphosphino)-1,1'-binaphthyl]palladium(II) as yellow powders. The yellow powders were recrystallized from acetone and hexane to give 238 mg (75%) of $PdCl_2$[(*R*)-BINAP] as red crystals: mp 255-260 °C (dec); $[\alpha]_D^{20}$ +682 (*c* 0.5, $CHCl_3$); Anal. Calcd for $C_{44}H_{32}Cl_2P_2Pd$: C, 66.06; H, 4.03; Cl, 8.86; P, 7.74. Found: C, 65.82; H, 3.93; Cl, 8.96; P, 7.77.

Asymmetric Disilylation of α,β-Unsaturated Ketones 1. All reactions were carried out under argon atmosphere. Reaction conditions and results are summarized in Table 5. The enantiomeric purities of **4a**, **4c**, **4e**, **4f**, and **9d** were determined by HPLC analysis with chiral stationary phase column Sumichiral OA-2000 (hexane/1,2-dichloroethane/ethanol = 500/20/1). The optical rotation data and ^1H NMR spectra for the

disilylation products are shown below. **4-Phenyl-4-(phenyldimethylsilyl)-2-butanone (4a)**: 78% ee; $[\alpha]_D^{20}$ +9.2 (*c* 1.1, $CHCl_3$). **1-Phenyl-3-(phenyldimethylsilyl)-1-butanone (4b)**: $[\alpha]_D^{20}$ +11.2 (*c* 1.3, $CHCl_3$). **1,3-Diphenyl-3-(phenyldimethylsilyl)-1-propanone (4c)**: 47% ee; $[\alpha]_D^{20}$ +11.4 (*c* 1.2, $CHCl_3$). **4-(Phenyldimethylsilyl)-2-pentanone (4d)**: $[\alpha]_D^{20}$ +21.0 (*c* 1.0, $CHCl_3$). **1-(4-Methoxyphenyl)-3-(phenyldimethylsilyl)-1-butanone (4h)**: 86% ee; $[\alpha]_D^{20}$ +12.2 (*c* 1.0, $CHCl_3$); ^1H NMR (CCl_4/TMS) δ 0.31 (s, 6 H), 0.96 (d, *J* = 7 Hz, 3 H), 1.4-1.8 (m, 1 H), 1.51 (dd, *J* = 15 and 9 Hz, 1 H), 1.84 (dd, *J* = 15 and 4 Hz, 1 H), 3.79 (s, 3 H), 6.75 (d, *J* = 9 Hz, 2 H), 7.1-7.5 (m, 5 H), 7.64 (d, *J* = 9 Hz, 2 H). Anal. Calcd for $C_{19}H_{24}O_2Si$: C, 73.03; H, 7.74. Found: C, 73.10; H, 7.88. **4-Methyl-1-phenyl-3-(phenyldimethylsilyl)-1-pentanone (4i)**: 92% ee; $[\alpha]_D^{20}$ +11.7 (*c* 1.2, $CHCl_3$); ^1H NMR (CCl_4/TMS) δ 0.34, 0.37 (a pair of s, 6 H), 0.86, 0.91 (a pair of d, *J* = 7 Hz, 6 H), 1.4-2.1 (m, 2 H), 2.90 (d, *J* = 7 Hz, 2 H), 7.1-7.5, 7.6-7.8 (m, 10 H). Anal. Calcd for $C_{20}H_{26}OSi$: C, 77.36; H, 8.44. Found: C, 77.24; H, 8.52. ***anti*-3-Methyl-4-phenyl-4-(phenyldimethylsilyl)-2-butanone (8a)**: $[\alpha]_D^{20}$ −1.0 (*c* 1.0, $CHCl_3$). ***anti*-2-Methyl-1-phenyl-3-(phenyldimethylsilyl)-1-butanone (8b)**: $[\alpha]_D^{20}$ +80.2 (*c* 1.1, $CHCl_3$). ***anti*-3-Benzyl-4-(phenyldimethylsilyl)-2-pentanone (9d)**: 74% ee; $[\alpha]_D^{20}$ +120 (*c* 1.0, $CHCl_3$).

Oxidation of β-(Phenyldimethylsilyl) Ketones to β-Hydroxy Ketones. Typical Procedure. To a solution of 93 mg (0.33 mmol) of 1-phenyl-3-(phenyldimethylsilyl)-1-butanone (**4b**) ($[\alpha]_D^{20}$ +11.2° (*c* 1.3, $CHCl_3$)) in 1.0 ml of dichloromethane was added dropwise at 0 °C 127 mg (0.79 mmol) of tetrafluoroboric acid diethyl ether complex. The mixture was stirred at room temperature for 15 min and dichloromethane was removed. The residue was dissolved in 1.0 ml of methanol and 1 ml of THF and was cooled with ice bath. To the solution were added 38 mg (0.66 mmol) of potassium fluoride and 312 mg (3.1 mmol) of potassium bicarbonate. After stirring for 15 min 0.43 ml (3.9 mmol) of 30% aqueous hydrogen peroxide was added at 0 °C. The ice bath was removed after 30 min and the mixture was stirred at room temperature overnight. Sodium thiosulfate solution was added to quench excess hydrogen peroxide. The mixture was extracted with ether and the ether layer was dried over magnesium sulfate. Removal of solvent followed by preparative TLC on silica gel (hexane/ether = 1/2) gave 48 mg (90%) of 1-phenyl-3-hydroxy-1-butanone (**11b**).

The enantiomeric purities of β-hydroxy ketones **11a**, **11b**, **11c**, **11e**, **12b**, and **12d** were determined by HPLC analyses with a chiral stationary phase column. Conditions: column, Sumitomo Chemical Co., Sumichiral OA-2000; eluent, hexane/1,2-dichloroethane/ethanol = 250/20/1; Detection 254 nm light. The absolute configurations of β-hydroxy ketones **11b**, **11c**, and **11d** were determined by comparison of the rotation values reported in the literature. The absolute configurations of **11h** and **11i** were assigned to be (*S*) and (*R*) respectively, by similarity on enantioface selectivity in the disilylation reaction and on elution order in the HPLC analyses. The configurations of **12a**, **12b**, and **12d** were deduced to be (2*S*,3*R*), (2*S*,3*S*), and (2*S*,3*S*) respectively, from the *anti* stereochemistry and the absolute configurations at 3-position of the protonated products **11a**, **11b**, and **11d**. The optical rotation data for β-hydroxy ketones, and ^1H NMR spectra and analytical data for new compounds are shown below. **4-Phenyl-4-hydroxy-2-butanone (11a)**: 78% ee; $[\alpha]_D^{23}$ +56.7 (*c* 1.1, $CHCl_3$) (*lit.*[16] (+)-**11a** (50% ee) $[\alpha]_D^{23}$ +37.8 (*c* 1, $CHCl_3$)). **(*S*)-1-Phenyl-3-hydroxy-1-butanone (11b)**: 87% ee; $[\alpha]_D^{25}$ +59.6 (*c* 0.8, $CHCl_3$) (*lit.*[17] (*S*)-**11b** $[\alpha]_D^{25}$(max) +50.5 (*c* 0.12, $CHCl_3$)). **(*R*)-1,4-Diphenyl-3-hydroxy-1-propanone (11c)**: 47% ee; $[\alpha]_D^{25}$ +15.1 (*c* 1.2, methanol) (*lit.*[18] (*S*)-**11c** $[\alpha]_D^{25}$(max) −32.50 (*c* 0.4, methanol)). **(*S*)-4-Hydroxy-2-pentanone (11d)**: $[\alpha]_D^{25}$ +57.1 (*c* 1.1, $CHCl_3$) (*lit.*[19] (*S*)-**11d**: $[\alpha]_D^{25}$(max) +55 (*c* 0.05, $CHCl_3$)). **1-(4-Methoxyphenyl)-3-hydroxy-1-butanone (11h)**: 92% ee; $[\alpha]_D^{20}$ +56.7 (*c* 1.0, $CHCl_3$); mp 55.7-56.4 °C; ^1H NMR ($CDCl_3$/TMS) δ 1.31 (d, *J* = 7 Hz, 3 H), 2.9-3.2 (m, 2 H), 3.48 (broad s, 1 H), 3.87 (s, 3 H), 4.2-4.5 (m, 1 H), 6.90 (d, *J* = 10 Hz, 2 H), 7.90 (d, *J* = 10 Hz, 2 H); IR (neat) 3462, 1671 cm^{-1}. Anal. Calcd for $C_{11}H_{14}O_3$: C, 68.02; H, 7.26. Found: C, 67.88; H, 7.30. **4-Methyl-1-phenyl-3-hydroxy-1-pentanone (11i)**: $[\alpha]_D^{20}$ +64.9 (*c* 1.0, $CHCl_3$); ^1H NMR ($CDCl_3$/TMS) δ 1.02, 1.04 (a pair of d, *J* = 7 Hz, 6 H), 1.69 (sept, *J* = 7 Hz, 1 H), 2.9-3.3 (m, 3 H), 3.8-4.1 (m, 1 H), 7.3-7.6, 7.8-8.0 (m, 5 H); IR (neat) 3484, 1682 cm^{-1}. Anal. Calcd for $C_{12}H_{16}O_2$: C, 74.97; H, 8.39. Found: C, 75.08; H, 8.57. ***anti*-3-Methyl-4-phenyl-4-hydroxy-2-butanone (12a)**:[20] $[\alpha]_D^{20}$ +47.9 (*c* 1.0, $CHCl_3$). ***anti*-2-Methyl-1-phenyl-3-hydroxy-1-butanone (12b)**:[21] 85% ee; $[\alpha]_D^{20}$ +62.3 (*c* 1.1, $CHCl_3$). ***anti*-3-Benzyl-4-hydroxy-2-pentanone (12d)**: $[\alpha]_D^{20}$ −68.2 (*c* 1.0, $CHCl_3$).

Determination of the Absolute Configuration of 4-Phenyl-4-hydroxy-2-butanone (11a). To a solution of 44 mg (0.27 mmol) of 4-phenyl-4-hydroxy-2-butanone (**11a**) ($[\alpha]_D^{23}$ +40.4° (*c* 1.0, $CHCl_3$), 53% ee) in 3.0 ml of ether was added at 0 °C 0.28 ml (0.8 mmol) of methyllithium in ether. The mixture was stirred at room temperature for 16 h, then hydrolyzed by addition of dilute hydrochloric acid, and extracted with ether. The ether layer was dried over magnesium sulfate. Removal of solvent followed by preparative TLC on silica gel (hexane/ether = 1/2) gave 44 mg (91%) of (*R*)-3-methyl-1-phenyl-1,3-butandiol. The enantiomeric

purity was determined to be 53% ee by HPLC analysis with chiral column Sumichiral OA-2000: $[\alpha]_D^{13}$ +28.0 (*c* 1.1, acetone) (*lit.*[22] (*S*)-isomer $[\alpha]_D^{13}$ –57.1 (*c* 4.7, acetone)); ^{1}H NMR ($CDCl_3$/TMS) δ 1.29 (s, 3 H), 1.44. (s, 3 H), 1.5-2.2 (m, 2 H), 3.48 (broad s, 2 H), 5.03 (dd, *J* = 11 and 3 Hz, 1 H), 7.2-7.45 (m, 5 H).

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