Catalytic Performance of Polystyrene-Bound *ChibaG* Derivatives as Guanidine Organobases in Asymmetric *Michael* Additions

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The guanidine organocatalyst, *ChibaG*, was bound *via* an ether linkage to the phenyl group of the 2-imino substituent to *Merrifield* resin. Polystyrene-bound *ChibaG* acted as an effective catalyst in the *Michael* reaction of *tert*-butyl *N*-(diphenylmethylidene)glycinate with methyl vinyl ketone, and could be recovered and reused many times.

Introduction. – Polymer-bound and polymeric reagents and catalysts are becoming more common in organic synthesis. Compared with conventional solution reactions, polymer-bound reagents are easier to handle for large-scale reactions, they are reusable and less toxic. They play an important role in high-throughput chemistry [1] and 'green chemistry' [2]. Guanidine is a common organobase catalyst in organic synthesis [3]. We have previously reported new preparation methods for a range of chiral guanidines [4], some of which have been evaluated as homogeneous organobase catalysts for asymmetric reactions, such as the *Michael* reaction [5a–5e], kinetic silylation [5f], TMS cyanation [5g], base-catalyzed epoxidation [5h], and alkylating esterification [5i]. (4*R*,5*R*)-2-{[(*S*)-1-(Hydroxymethyl)-2-phenylethyl]imino}-1,3-dimethyl-4,5-diphenylimidazolidine ((−)-*ChibaG*; **1**) and its enantiomer [5d] afforded the addition product in intermolecular [5a–5c] and intramolecular *Michael* reactions [5d][5e] with reasonable enantioselectivity. In the intermolecular *Michael* reaction with *N*-(diphenylmethylidene)glycinate as a *Michael* donor, it has been proposed that a transition state consisting of a complex formed with *ChibaG* (**1**) is responsible for the excellent asymmetric induction.

We report herein a polystyrene (PS)-bound chiral catalyst based on *ChibaG* which exhibited satisfactory asymmetric induction in a *Michael* addition product. The *ChibaG* catalyst was bound through an ether linkage to the phenyl group of the 2-imino substituent to the *Merrifield* resin. Furthermore, the catalyst remained active after it was reused repeatedly.

Results and Discussion. – We have previously designed polymer-supported and polymeric chiral guanidines, **2** and **3**, respectively, with a (*R*)-2-{[(*S*)-1-(hydroxymethyl)-2-phenylethyl]imino}-4-phenylimidazolidine core as heterogeneous guanidine organobases and used them for the asymmetric *Michael* reaction of *tert*-butyl *N*-(diphenylmethylidene)glycinate (**4**) with methyl vinyl ketone (MVK; **5**; *Table*). However, only moderate asymmetric induction was observed in the product for

polymeric guanidine **3** [6]. Therefore, we designed PS-bound *ChibaG* derivatives **6**–**8** as alternative heterogeneous guanidine organobases (*Fig.*). Derivatives **6** and **7** incorporated *HypoGel*® and *TentaGel*® at N^1 through an oxyethyl tether, whereas **8** was bound to *Merrifield* resin through an ether linkage on the phenyl group of the 2-imino substituent.

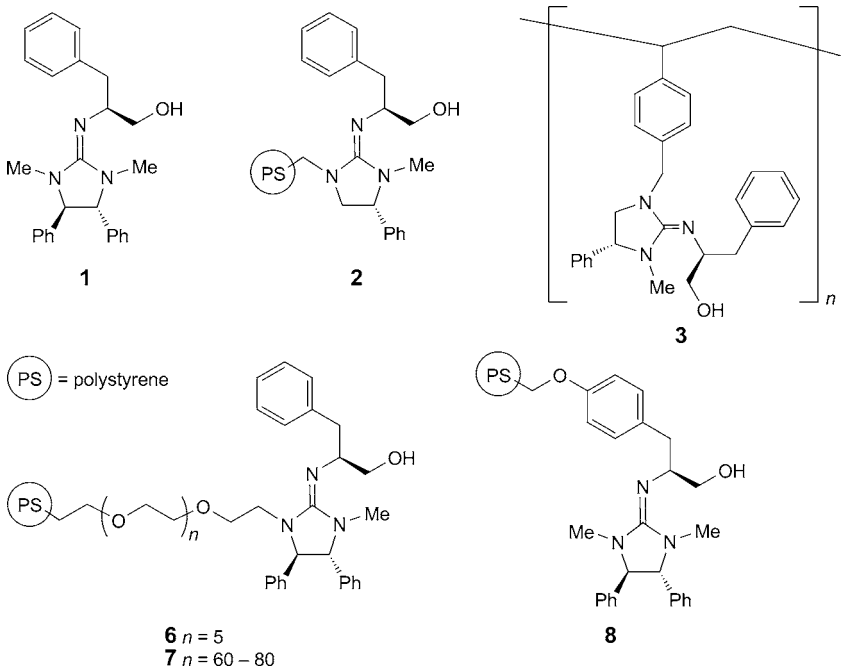
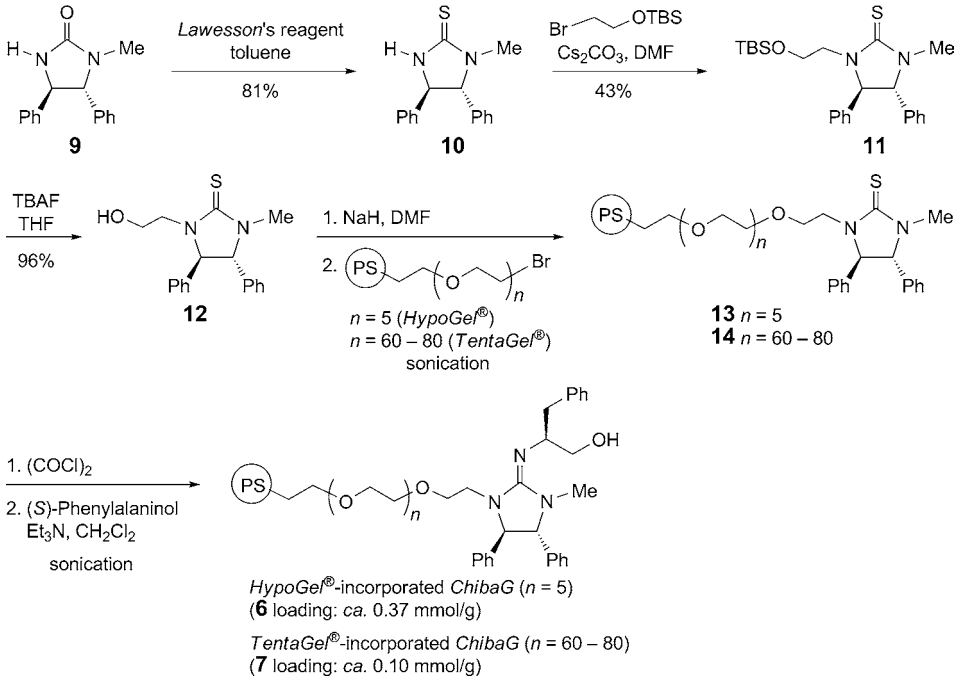


Figure. *Structures of the guanidine organobases*

The *HypoGel*® and *TentaGel*® *ChibaG* derivatives, **6** and **7**, respectively, were prepared from (4*R*,5*R*)-1-methyl-4,5-diphenylimidazolin-2-one (**9**) [7] (*Scheme 1*). Because of the low reactivity of **9**, the key 1-(2-hydroxyethyl)-3-methyl-4,5-diphenyl-imidazoline-2-thione (**12**) intermediate was synthesized by converting **9** to thiourea **10** [8] with *Lawesson*'s reagent. A 2-silyloxyethyl group was introduced at the unsubstituted N-atom of thiourea **10**, and the silyl group of **11** was removed by treatment with Bu_4NF (TBAF) to afford **12**. The *Williamson* reaction of 2-hydroxyethyl-substituted thiourea **12** with *HypoGel*® *200* bromide under sonication furnished PS-bound thiourea **13**. The latter was activated with oxalyl chloride $(COCl)_2$, and the 2-chloroamidinium chloride intermediate reacted with (*S*)-phenylalaninol, to afford the desired *HypoGel*® guanidine **6**. The loading of **6** was estimated to be *ca.* 0.37 mmol/g by elemental analysis. The reaction of **12** with *TentaGel*® *200* bromide provided an alternative thiourea **14**, which was similarly converted to *TentaGel*® guanidine **7**. The loading efficiency was *ca.* 0.10 mmol/g.

Scheme 1. *Preparation of* HypoGel® *and* TentaGel® *Guanidines,* **6** *and* **7**, *Respectively.* TBS, ^{t}BuMe$_2$Si.

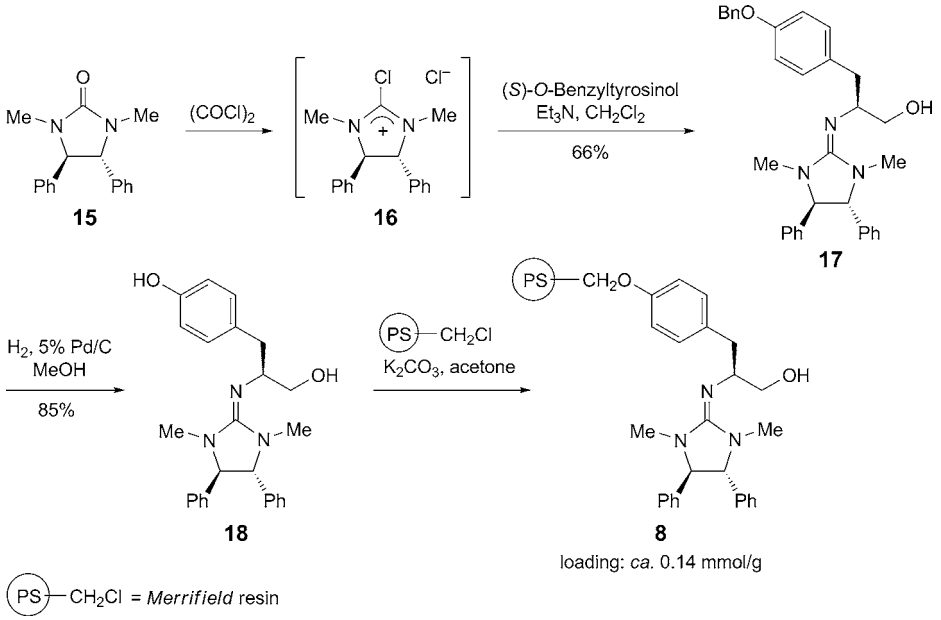


However, PS-bound guanidines **6** and **7** did not act as catalysts for the *Michael* reaction of *tert*-butyl *N*-(diphenylmethylene)glycinate (**4**) with MVK (**5**). We have already observed that replacing both Me substituents C(1) and C(3) in the *ChibaG* skeleton with Bn groups leads to low yields of the *Michael*-addition product, although it increases the enantioselectivity [5b]. The results for **6** and **7** also indicated that steric bulk around the guanidine N-core in *ChibaG* derivatives affects the *Michael* reaction, by reducing the activation of glycinate substrate **4** by the guanidine catalyst in the transition state. Therefore, we focused on tyrosinol-based *ChibaG* derivative **8** as an alternative PS-bound organobase carrying the same 2-(1-benzyl-2-hydroxyethyl)-1,3-dimethylimino moiety as *ChibaG* (**1**) (*Scheme 2*).

ChibaG derivative **8** was prepared according to our standard method for synthesizing fully-substituted monocyclic chiral guanidines [4a]. 1,3-Dimethyl-4,5-diphenylimidazolin-2-one (**15**) was treated with $(COCl)_2$, and then the crude 2-chloroamidinium chloride **16** formed was reacted with (*S*)-[4-(benzyloxy)phenyl]alaninol (*O*-benzyltyrosinol) [9] to afford guanidine **17** in 66% yield. Guanidine **17** was hydrogenated to provide tyrosinol-substituted *ChibaG* (**18**). The immobilization of **18** on *Merrifield* resin in acetone in the presence of K_2CO_3 afforded the desired PS-bound *ChibaG* derivative **8**. The loading of **8** was estimated to be *ca.* 0.14 mmol/g by elemental analysis.

Prior to the heterogeneous *Michael* reaction using immobilized *ChibaG* derivative **8**, the catalytic performance of tyrosinol-substituted guanidines **17** and **18**, and the original (–)-*ChibaG* (**1**) was examined for the previously reported homogeneous

Scheme 2. *Preparation of Tyrosinol-Based* ChibaG *Derivative* **8**

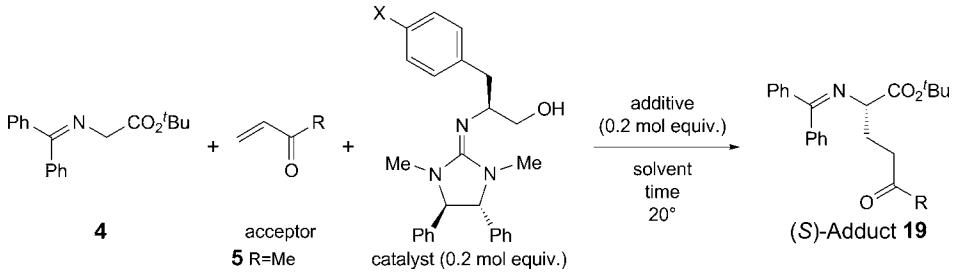


Michael reaction of **4** with MVK (**5**) [5c] (*Table*). The reaction using *O*-benzyltyrosinol-substituted *ChibaG*, **17**, afforded the (*S*)-adduct **19** (R = Me) with a similar yield and enantioselectivity as the original (–)-*ChibaG* (**1**)-catalyzed reaction (*Entries 1* and *2*). The addition of K_2CO_3 as a dehydrating agent did not affect the reaction (*Entry 3*). We have previously found that solvent-free conditions were critical for the completion of the *ChibaG* (**1**)-catalyzed *Michael* reaction with a less reactive acrylate as a *Michael* acceptor [5c]. *O*-Benzyltyrosinol-substituted *ChibaG*, **17**, also served as an effective catalyst in the solvent-free *Michael* reaction with acrylates (*Entries 4* and *5*). The addition product **19** (R = Me) was also formed, when a catalyst bearing a phenolic OH group was used, or when a H-atom source, such as an alcohol or phenol, was used (*Entries 6–9*). The catalytic activity was maintained even when an additional substituent was introduced at C(4) of the Ph group of the phenylalaninol moiety in *ChibaG*; therefore, the catalyst **8** was used in a heterogeneous *Michael* reaction.

A mixture of glycinate **4** and MVK (**5**) was stirred with PS-bound *ChibaG* derivative **8**, and the (*S*)-adduct **19** (R = Me) was obtained in reasonable yields and enantioselectivity (*Entry 10*). Furthermore, the insoluble catalyst was recovered from the reaction mixture by filtration and was reused repeatedly (*Entries 11* and *12*).

Conclusions. – The *ChibaG* organocatalyst was bound *via* an ether linkage to the phenyl group of the 2-imino substituent to *Merrifield* resin. The PS-bound catalyst acted as a reusable heterogeneous guanidine organobase catalyst in the *Michael* reaction of *tert*-butyl *N*-(diphenylmethylene)glycinate with MVK.

Table. Michael *Reactions Catalyzed by Tyrosinol-Substituted* ChibaG *Derivatives*



Entry	R	X	Solvent	Additive	Time [d]	Yield of **19** [%]	ee [%]
1	Me	H (**1**)	THF	–	4	93	85
2	Me	BnO (**17**)	THF	–	4	89	82
3	Me	BnO (**17**)	THF	K_2CO_3[a])	4	88	88
4	CO_2Me	BnO (**17**)	–	–	3	90	92
5	CO_2Et	BnO (**17**)	THF	–	7	23	86
6	Me	HO (**18**)	THF	–	2	83	83
7	Me	H (**1**)	THF	MeOH	4	87	85
8	Me	H (**1**)	THF	EtOH	4	89	93
9	Me	H (**1**)	THF	PhOH	4	90	92
10	Me	PS-CH_2O (**8**)	THF	–	2	87	85
11[b])	Me	PS-CH_2O (**8**)	THF	–	2	72	80
12[c])	Me	PS-CH_2O (**8**)	THF	–	2	70	83

[a]) 0.6 mol of K_2CO_3 was added. [b]) Recycle use of a guanidine recovered in *Entry 10* (2nd trial). [c]) Recycle use of a guanidine recovered in *Entry 11* (3rd trial).

Experimental Part

General. Anh. DMF and CH_2Cl_2 were used as purchased from *Kanto Chemical*, and anh. THF was used as purchased from *Wako Chemical*. The org. extracts were dried ($MgSO_4$), and evaporations were conducted under reduced pressure. TLC: *Merck Art 5715 DC-Fertigplatten Kieselgel 60 F_{254}* and *Fuji Silicia NH-TLC* plate. Column chromatography (CC): *Kanto Chemical* silica gel *60* (SiO_2) spherical and *Fuji Silisia NH* SiO_2 (100–200 mesh). M.p.: *Yanagimoto MPSI* melting-point apparatus; uncorrected. IR Spectra: Attenuated Total Reflectance (ATR) system on a *JASCO FT/IR-300E* spectrophotometer; $\tilde{\nu}$ in cm^{-1}. ^{1}H- and ^{13}C-NMR spectra: *JEOL JNM-ECP-400* and *-500* instruments; in $CDCl_3$; δ in ppm rel. to Me_4Si as internal standard, *J* in Hz. MS: *JEOL JNM HX-110* for FAB-MS; in *m*/*z*.

*(4*R*,5*R*)-1-Methyl-4,5-diphenylimidazolidine-2-thione* (**10**) [8]. A soln. of **9** [7] (1.03 g, 4.09 mmol) and *Lawesson*'s reagent (2.15 g, 5.28 mmol) in toluene (14 ml) was heated to reflux for 14 h, and to the resulting soln. were added MeOH (5 ml) and 10% aq. HCl (10 ml). The mixture was stirred at r.t. for 1 d, poured into H_2O, and extracted with AcOEt. The org. soln. was washed with sat. aq. $NaHCO_3$, H_2O, and brine, and dried and evaporated to give **10** (0.893 g, 81%). Colorless prisms (recrystallized from hexane/AcOEt). M.p. 177–178°. ^{1}H-NMR (400 MHz): 2.98 (*s*, 3 H); 4.52 (*d*, *J* = 7.9, 1 H); 4.70 (*d*, *J* = 7.9, 1 H); 6.56 (*s*, 1 H); 7.20–7.44 (*m*, 10 H). ^{13}C-NMR (125 MHz): 32.6; 66.5; 75.6; 126.2; 127.1; 128.6; 128.97; 129.00; 129.2; 137.6; 139.3; 183.5. FAB-MS: 269 ($[M+H]^+$). Anal. calc. for $C_{16}H_{16}N_2S$ (268.368): C 71.60, H 6.01, N 10.44; found: C 71.73, H 6.05, N 10.38.

*(4*R*,5*R*)-1-(2-{[(*tert*-Butyl)(dimethyl)silyl]oxy}ethyl)-3-methyl-4,5-diphenylimidazolidine-2-thione* (**11**). A mixture of **10** (117 mg, 0.435 mmol) and Cs_2CO_3 (282 mg, 0.866 mmol) in DMF (0.8 ml) was stirred at r.t. for 30 min, and to the resulting mixture was added (2-bromoethoxy)(*tert*-butyl)(dime-

thyl)silane (0.1 ml, 0.466 mmol). The mixture was stirred at r.t. for 16 h, poured into H_2O, and extracted with AcOEt. The org. soln. was washed with H_2O and brine, and dried and evaporated. Purification of the residue by CC (SiO_2; hexane/AcOEt 40:1 → 20:1) gave **11** (79 mg, 43%). Colorless prisms (recrystallized from hexane/Et_2O). M.p. 77–78°. ^{1}H-NMR (400 MHz): −0.04 (*s*, 6 H); 0.77 (*s*, 9 H); 3.01–3.07 (*m*, 1 H); 3.04 (*s*, 3 H); 3.63–3.67 (*m*, 1 H); 3.98–4.03 (*m*, 1 H); 4.21–4.26 (*m*, 1 H); 4.41 (*d*, *J* = 6.7, 1 H); 4.92 (*d*, *J* = 6.7, 1 H); 7.13–7.18 (*m*, 4 H); 7.34–7.39 (*m*, 6 H). ^{13}C-NMR (125 MHz): −5.6; −5.5; 18.1; 25.8; 33.3; 47.6; 61.7; 71.9; 73.2; 126.8; 127.0; 128.6; 128.7; 129.13; 129.14; 138.6; 139.0; 182.6. FAB-MS: 427 ($[M+H]^+$). Anal. calc. for $C_{24}H_{34}N_2OSSi$ (426.701): C 67.56, H 8.03, N 6.57; found: C 67.51, H 7.99, N 6.45.

*(4*R*,5*R*)-1-(2-Hydroxyethyl)-3-methyl-4,5-diphenylimidazolidine-2-thione* (**12**). A soln. of **11** (583 mg, 1.37 mmol) in THF (4 ml) was stirred with a 1.0M soln. of Bu_4NF in THF (1.5 ml, 1.50 mmol) at r.t. for 18 h, poured into 10% aq. HCl, and extracted with AcOEt. The org. soln. was washed with sat. aq. $NaHCO_3$, H_2O, and brine, and dried and evaporated. Purification of the residue by CC (SiO_2, hexane/AcOEt 20:1 → 4:1) gave **12** (409 mg, 96%). Colorless prisms (recrystallized from hexane/AcOEt). M.p. 120–121°. IR: 3352 (OH). ^{1}H-NMR (400 MHz): 2.62–2.68 (br. *s*, 1 H, exchangeable); 3.04 (*s*, 3 H); 3.29–3.34 (*m*, 1 H); 3.68–3.78 (*m*, 2 H); 4.18–4.23 (*m*, 1 H); 4.48 (*d*, *J* = 7.8, 1 H); 4.69 (*d*, *J* = 7.8, 1 H); 7.18–7.20 (*m*, 4 H); 7.36–7.41 (*m*, 6 H). ^{13}C-NMR (125 MHz): 33.4; 47.7; 61.3; 71.6; 73.4; 126.9; 127.1; 128.87; 128.93; 129.21; 129.23; 137.9; 138.0; 183.9. Anal. calc. for $C_{18}H_{20}N_2OS$ (312.437): C 69.20, H 6.45, N 8.97; found: C 69.03, H 6.45, N 8.90.

The HypoGel®-*Incorporated Thiourea* **13**. A suspension of **12** (699 mg, 2.24 mmol) and NaH (60% in mineral oil, 130 mg, 3.25 mmol) in DMF (8 ml) was stirred at r.t. for 3 h. After addition of *HypoGel® 200-Br* (807 mg; loading, 0.8 mmol of Br/g) the mixture was sonicated at r.t. for 2 d (negative for *Beilstein* test). After acidification with 10% aq. HCl, the mixture was filtered through a glass filter (*G3*), successively washed with H_2O (4×), MeOH (4×), AcOEt (4×), CH_2Cl_2 (8×), and MeOH (8×), and dried under reduced pressure to give **13** (821 mg). Yellow powder. M.p. > 300°. ^{13}C-NMR (125 MHz, C_6D_6; gel phase): 33.2; 45.1; 67.7; 69.7; 70.3; 71.7; 73.2; 86.5; 127.3; 128.6; 129.2; 139.4; 139.6; 183.7. Anal. calc. (based on the loading of *HypoGel® 200-Br*): N 1.89; found: N 1.04.

The HypoGel®-*Incorporated Guanidine* (**6**). A mixture of **13** (699 mg) and $(COCl)_2$ (0.5 ml, 5.73 mmol) was heated to reflux for 20 h. The mixture was evaporated and suspended in CH_2Cl_2 (0.5 ml). After addition of a soln. of (*S*)-phenylalaninol (130 mg, 0.858 mmol) and Et_3N (0.5 ml, 3.59 mmol) in CH_2Cl_2 (1.0 ml) at 0°, the suspension was sonicated at r.t. for 24 h. After addition of H_2O, the mixture was filtered through a glass filter (*G3*), successively washed with 10% aq. HCl (2×), 20% aq. NaOH (2×), H_2O (4×), MeOH (4×), CH_2Cl_2 (8×), and MeOH (8×), and dried under reduced pressure to give **6** (821 mg, loading, *ca.* 0.37 mmol/g). Brown powder. M.p. > 300°. IR: 3302 (OH), 1655 (C=N). ^{13}C-NMR (125 MHz, C_6D_6; gel phase): 14.4; 22.9; 37.3; 43.1; 45.9; 53.1; 53.8; 59.1; 61.7; 65.6; 68.1; 69.1; 73.2; 139.4; 157.6. Anal. calc. (based on the loading of *HypoGel® 200-Br*): N 1.49; found: N 1.86.

The TentaGel®-*Incorporated Thiourea* **14**. A soln. of **12** (0.620 g, 1.99 mmol) and NaH (60% in mineral oil, 0.150 g, 3.75 mmol) in DMF (7 ml) was stirred at r.t. for 3 h. After addition of *TentaGel® 200-Br* (1.53 g, loading: 0.125 mmol of Br/g), the mixture was sonicated at r.t. for 3 d (negative for *Beilstein* test). After acidification with 10% aq. HCl, the mixture was filtered through a glass filter (*G3*), successively washed with H_2O (4×), MeOH (4×), AcOEt (4×), CH_2Cl_2 (8×), and MeOH (8×), and dried under reduced pressure to give **14** (1.45 g). Yellow powder. M.p. > 300°. ^{13}C-NMR (125 MHz, C_6D_6; gel phase): 33.1; 40.9; 45.1; 67.7; 69.7; 71.7; 73.2; 86.5; 127.3; 128.3; 128.6; 129.2; 152.3; 183.7. Anal. calc. (based on the loading of *TentaGel® 200-Br*): N 0.34; found: N 0.28.

The TentaGel®-*Incorporated Guanidine* (**7**). A mixture of **14** (220 mg) and $(COCl)_2$ (0.8 ml, 9.17 mmol) was heated to reflux for 20 h. The mixture was evaporated and suspended in CH_2Cl_2 (1 ml). After addition of a soln. of (*S*)-phenylalaninol (85 mg, 0.56 mmol) and Et_3N (0.3 ml, 2.15 mmol) in CH_2Cl_2 (1.5 ml) at 0°, the suspension was sonicated at r.t. for 24 h. After addition of H_2O, the mixture was filtered through a glass filter (*G3*), successively washed with 10% aq. HCl (2×), 20% aq. NaOH (2×), H_2O (4×), MeOH (4×), CH_2Cl_2 (8×), and MeOH (8×), and dried under reduced pressure to give **7** (180 mg; loading, *ca.* 0.10 mmol/g). Brown powder. M.p. > 300°. IR: 1662 (C=N). ^{13}C-NMR (125 MHz, C_6D_6; gel phase): 29.8; 37.2; 40.9; 41.8; 68.1; 69.2; 73.1; 138.6; 139.0; 139.5; 146.2; 160.8. Anal. calc. (based on the loading of *TentaGel® 200-Br*): N 0.43; found: N 0.62.

(2S)-3-[4-(Benzyloxy)phenyl]-2-{[(4R,5R)-1,3-dimethyl-4,5-diphenylimidazolidin-2-ylidene]amino}propan-1-ol (**17**). A soln. of (*S*)-*O*-benzyltyrosinol [9] (495 mg, 1.54 mmol) in CH_2Cl_2 (4.5 ml) was added to an ice-cooled soln. of **16** (94% purity; 361 mg, 1.40 mM) and Et_3N (1.0 ml, 7.18 mmol) in CH_2Cl_2 (2 ml) under Ar, and the mixture was stirred at r.t. for 3 h. After acidification (pH *ca.* 3) with 10% aq. HCl (5 ml) under ice-cooling, the separated org. soln. was collected, and the aq. soln. was extracted with CH_2Cl_2. The combined org. solns. were evaporated. After addition of H_2O, the mixture was extracted with toluene. The aq. soln. was basified (pH > 11) with 20% aq. NaOH and extracted with toluene. The org. soln. was washed with H_2O and brine, and dried (K_2CO_3) and evaporated to give **17** (466 mg, 60%). A pale-yellow oil. $[\alpha]_D^{17} = -49.2$ ($c = 1.02$, $CHCl_3$). IR: 3600–3200 (br., OH), 1624 (C=N). ^{1}H-NMR (400 MHz): 2.95–3.00 (*m*, 1 H); 3.06 (*s*, 6 H); 3.33 (*dd*, $J = 9.2$, 4.0, 1 H); 3.95 (*d*, $J = 5.6$, 2 H); 4.25 (*s*, 2 H); 4.55 (br. *s*, 1 H); 5.55 (*s*, 2 H); 7.39 (*d*, $J = 8.4$, 2 H); 7.47 (*d*, $J = 7.2$, 4 H); 7.63 (*d*, $J = 8.0$, 2 H); 7.72–7.75 (*m*, 7 H); 7.80 (*t*, $J = 7.2$, 2 H); 7.88 (*d*, $J = 8.4$, 2 H). ^{13}C-NMR (100 MHz): 39.0; 57.5; 65.8; 69.9; 77.3; 114.4; 127.3; 127.4; 127.8; 128.2; 128.5; 128.6; 130.5; 132.2; 137.0; 138.1; 157.2; 157.8. HR-FAB-MS: 506.2820 ($[M+H]^+$, $C_{33}H_{36}N_3O_2^+$; calc. 506.2808).

4-[(2S)-2-{[(4R,5R)-1,3-Dimethyl-4,5-diphenylimidazolidin-2-ylidene]amino}-3-hydroxypropyl]-phenol (**18**). A mixture of **17** (1.89 g, 3.74 mmol) and 5% Pd/C (200 mg) in MeOH (55 ml) was hydrogenated at r.t. for 5 h under atmospheric pressure. After the catalyst was removed by filtration through *Celite*, the filtrate was evaporated. The residue was purified by CC (NH-SiO_2, toluene/MeOH 5:1) to afford **18** (1.31 g, 85%). A pale-yellow oil. $[\alpha]_D^{20} = -66.2$ ($c = 1.01$, $CHCl_3$). IR: 3734 (OH), 1649 (C=N). ^{1}H-NMR (400 MHz, (D_6)DMSO, 150°): 2.60 (*s*, 6 H); 2.70–2.85 (br. *s*, 2 H); 3.48 (*d*, $J = 6.0$, 2 H); 3.79 (*s*, 2 H); 4.08 (br. *s*, 1 H); 6.72 (*d*, $J = 8.0$, 2 H); 7.01–7.37 (*m*, 12 H). ^{13}C-NMR (100 MHz): 38.6; 58.6; 64.9; 77.3; 116.7; 127.0; 128.5; 128.8; 130.2; 137.1; 159.0; 159.2. HR-FAB-MS: 416.2323 ($[M+H]^+$, $C_{26}H_{30}N_3O_2^+$; calc. 416.2338).

Merrifield *Resin-Incorporated* ChibaG (**8**). After stirring a mixture of **18** (1.26 g, 3.02 mmol) and K_2CO_3 (0.884 g, 6.39 mmol) in acetone (10 ml) at r.t. for 30 min under sonication, chloromethylpolystyrene resin (1.705 g, *ca.* 1.7 mmol/g) was added. The mixture was sonicated at r.t. for 24 h (negative for *Beilstein* test). After addition of H_2O, the mixture was filtered through a glass filter (*G3*), successively washed with MeOH (4×) and Et_2O (4×), and dried under reduced pressure to give **8** (1.98 g; loading, *ca.* 0.14 mmol/g). Colorless solids. IR: 3674 (br., OH). Anal. calc. (based on the loading of *Merrifield* resin): N 4.41; found: N 0.60.

General Procedure for the Michael *Reaction of* tert-*Butyl* N-*(Diphenylmethylidene)glycinate* (**4**) *and MVK* (**5**). To a soln. of **4** (*ca.* 30 mg, *ca.* 0.10 mmol) and the guanidine catalyst (0.2 mol equiv.) in THF (0.5 ml), **5** (0.04 ml, 0.48 mmol) was slowly added at 20° under Ar either in the presence of an additive (0.2 mol equiv.) or in the absence of an additive. After stirring at r.t. for an appropriate time, the mixture was evaporated. The residue was purified by CC (SiO_2; hexane/AcOEt 3:1) to afford an adduct **19** (R = Me) [5c] as a colorless oil. The ee value was estimated by chiral HPLC (*DAICEL CHIRALCEL OD*; hexane/^{i}PrOH 100:1; flow rate, 1.0 ml/min; detection, at 254 nm): t_R 11.0 (*R*) and 15.8 (*S*) min.

Using of a heterogeneous catalyst, the reaction was carried out in suspension, and the recovered catalyst by filtration was reused for the next reaction after being successively washed with H_2O, MeOH, and Et_2O, followed by drying under reduced pressure.

We are grateful for the partial financial support from *Japan Science and Technology Cooporation* (*JST*).

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Received June 26, 2013