Facile Synthetic Approach to Functionalized 4,5-Disubstituted Norbornene Monomers

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Manipulation of a single Diels-Alder adduct employing a Ritter-type reaction affords a variety of diamido norbornene monomers. These monomers serve as excellent substrates for ring opening metathesis polymerization to afford functionalized polymers. Subsequent reduction of the amide monomers readily affords the corresponding diaminomethyl norbornenes. The functionalities reported were selected to afford maximum coordination ability, thereby facilitating the incorporation of metallic species and allowing for control of solubility by varying the *N*-alkyl pendant groups.

Monomers, such as the norbornene derivatives illustrated in Figure 1, are known to possess extreme utility in the formation of novel functional materials.[1] This popularity arises from its ability to effectively chelate numerous metals through the heteroatoms as well as the susceptibility toward ring opening metathesis polymerizations (ROMP).[1,2] Previously reported synthetic routes to similar molecules make use of a multi-step synthesis, proceed in low to moderate overall yields or occur at elevated pressure, thereby requiring specialty reaction vessels and multiple purifications.[3] Clearly there is a need for a simple high-yielding synthetic approach to a variety of *N*-alkyldiamido and diaminomethyl norbornene derivatives that would allow maximum metal loading through chelation to the heteroatoms present; thus affording control of solubility by altering pendant groups and be polymerized utilizing existing ROMP techniques.

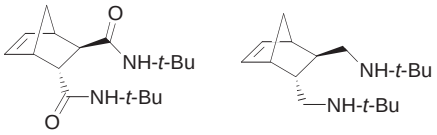
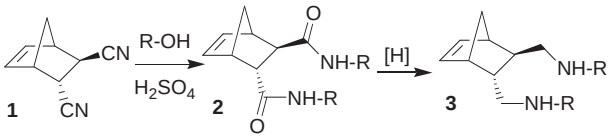


Figure 1. Structures of functionalized 4,5-disubstituted norbornene monomers.

We sought to develop a simple efficient synthetic approach to an array of norbornene derivatives with varied pendant groups starting from compound **1** (Figure 2). Compound **1** was synthesized from freshly cracked cyclopentadiene and fumaronitrile in quantitative yields according to a previous report.[4] Subsequent treatment of **1** with a variety of alcohols under acidic conditions afforded the respective diamido species, **2a–e**, in good yields.[5] This transformation makes use of a Ritter-type reaction[6] employing the corresponding alcohol in concentrated sulfuric acid and glacial acetic acid as solvent. Substitution of concentrated hydrochloric acid for sulfuric acid afforded significantly lower yields. Tertiary alcohols resulted in excellent yields with secondary alcohols slightly lower. Primary alcohols were unreactive due to their inability to form stable intermediates, unless first converted to the corresponding triflate. Reaction temperatures for this transformation must remain below 30 °C in



2 R=

a) -$C(CH_3)_3$ (99%)	**3a**) (81%)
b) -$CH(CH_3)_2CH_2CH_3$ (97%)	**3b**) (85%)
c) -$CH(CH_3)$Ph (84%)	**3c**) (87%)
d) -CH_2Ph (64%)	**3d**) (61%)
e) -*c*C_6H_{11}(53%)	**3e**) (79%)

Figure 2. Synthetic scheme.

efforts of avoiding undesirable ester formation, as observed when allowed to react at elevated temperatures.

Reduction of *N*-alkylamides to the corresponding amines has been reported utilizing a variety of reagents.[7–9] However, upon examination of a variety of methods and reagents, lithium aluminum hydride[8] and the Meerwein–Ponndorf–Verley-type[9] reductions afforded the corresponding amines in highest yields. Synthetic utility, simplicity, ease in purification and high conversion rate were all factors of this synthetic scheme. Subsequent reduction of compounds **2a–e** ensued, affording **3a–e**.[10]

This efficient facile synthetic approach allows for the synthesis of an unlimited array of monomers. These molecules may then be subjected to a variety of metathesis polymerizations and chelated to a variety of metals. This route eliminates the need for specialized synthetic schemes, elevated temperatures and pressures; thereby facilitating the formation of novel functional materials, which can easily be tuned for desired solubility and phase separation if so desired. Moreover, utilizing this novel synthetic approach eliminates the need for the previously employed lengthy, low yielding, multi-step synthetic schemes.

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References and Notes

1 V. Sankaran, J. Yue, R. E. Cohen, R. R. Schrock, and R. J. Silbey, *Chem. Mater.*, **5**, 1133 (1993); V. Sankaran, R. E. Cohen, C. C. Cummins, and R. R. Schrock, *Macromolecules*, **24**, 6664 (1991).
2 M. R. Buchmeiser, *Chem. Rev.*, **100**, 1565 (2000); H. D. Maynard and R. H. Grubbs, *Macromolecules*, **32**, 6917 (1999).
3 C. C. Cummins, M. D. Beachy, R. R. Schrock, M. G. Vale, V. Sankaran, and R. E. Cohen, *Chem. Mater.*, **3**, 1153 (1991).
4 N. D. Havis, D. R. Walters, F. M. Cook, and D. J. Robins, *J. Agric. Food Chem.*, **45**, 2341 (1997).
5 General Procedure for Preparation of **2** from **1**: In a 50 mL Erlenmeyer flask equipped with magnetic stir bar and cooled

to 0 °C in an ice bath, was added glacial acetic acid (8 mL), alcohol (15.48 mmol), dinitrile (**1**) (7.74 mmol), and concentrated H_2SO_4 (1.55 g). In some cases, it became necessary to add 20 mL of CH_2Cl_2 to facilitate stirring due to the viscosity of the reaction mixture. The resulting solution was allowed to stir for 12 h. The solution was diluted with 30 mL H_2O, and neutralized with carbonate, resulting in formation of an insoluble oil or white solid which was isolated via vacuum filtration or extracted with CH_2Cl_2 (3 × 25 mL), washed with cold H_2O (3 × 15 mL). The desired product (**2**) was afforded in suitable purity to be used in subsequent reactions without purification. Characterization: Compound **2a**: IR (neat): 3303, 3199, 3079, 2960, 2864, 2756, 1624, 1539, 1447, 1358, 1262, 1358, 1262, 1208, 1046, 1008, 900, 792 cm^{-1}. ^1H NMR (THF-d_8) δ: 6.13 (bs, 1H), 5.78 (bs, 1H), 5.46 (dd, 1H), 5.27 (dd, 1H), 2.94 (d, 2H), 2.36 (d, 2H), 2.14 (d, 1H), 1.73 (d, 1H), 0.64 (s, 9H), 0.62 (s, 9H). ^{13}C NMR (THF-d_8) δ: 174.5, 172.9, 138.1, 135.3, 51.2, 50.2, 49.3, 48.8, 48.4, 47.1, 29.2. *Anal. calcd for* $C_{17}H_{28}N_2O_2$; C, 69.83; H, 9.65; N, 9.58; Found C, 69.46.; H, 9.71; N, 9.25. Compound **2b**: IR (neat): 3314, 3026, 2958, 2866, 1665, 1542, 1463, 1364, 1169, 1035, 888 cm^{-1}. ^1H NMR ($CDCl_3$-*d*) δ: 5.78 (bs, 1H), 5.29 (d, 2H), 4.83 (bs, 1H), 2.94 (d, 1H), 2.86 (d, 1H), 2.63–2.56 (m, 2H), 1.73 (d, 2H), 1.48 (s, 6H), 1.43 (s, 6H), 1.39 (q, 4H), 0.89 (t, 6H). ^{13}C NMR ($CDCl_3$-*d*) δ: 173.6, 172.1, 137.8, 137.0, 53.4, 50.7, 47.9, 45.5, 42.9, 41.5, 36.3, 35.8, 30.2, 29.4, 25.8, 22.8, 20.7, 8.5, 7.3. *Anal. calcd for* $C_{19}H_{32}N_2O_2$; C, 71.21; H, 10.06; N, 8.74; Found C, 70.89; H, 9.69; N, 9.05. Compound **2c**: IR (neat): 3294, 3061, 3020, 2969, 2866, 1637, 1535, 1443, 1332, 1213, 1019, 908 cm^{-1}. ^1H NMR ($CDCl_3$-*d*) δ: 7.23 (s, 10H), 6.21 (bs, 2H), 6.01-5.96 (m, 2H) 4.96, (q, 1H), 3.97 (q, 1H), 3.35 (d, 1H), 2.94 (d, 1H) 2.37 (t, 2H), 1.61 (d, 2H), 1.38 (d, 3H), 1.17 (d, 3H). ^{13}C NMR ($CDCl_3$-*d*) δ: 173.7, 172.6, 138.7, 138.1, 137.9, 136.1, 135.9, 134.2, 133.9, 130.9, 129.7, 128.6, 127.3, 127.2, 126.0, 125.8, 62.7, 50.6, 48.7, 48.6, 46.7, 45.9, 44.9, 22.5, 22.0. *Anal. calcd for* $C_{25}H_{28}N_2O_2$; C, 77.29; H, 7.26; N, 7.21; Found C, 76.91; H, 7.62; N, 6.87. Compound **2d**: IR (neat): 3318, 3060, 3028, 2930, 1649, 1539, 1490, 1447, 1261, 1197, 1071, 1019, 805 cm^{-1}. ^1H NMR ($CDCl_3$-*d*) δ: 7.38 (s, 10H), 6.39 (s, 1H), 4.96 (bs, 4H), 4.62 (s, 1H), 3.86 (bs, 2H), 3.41 (d, 1H), 3.17 (d, 1H), 2.56 (d, 2H), 1.79–1.66 (m, 2H). ^{13}C NMR ($CDCl_3$-*d*) δ: 175.6, 173.8, 141.8, 140.4, 135.9, 135.7, 128.5 (overlapping peaks), 127.4, 127.9. 125.7, 49.1, 48.3, 44.2, 37.1, 36.8, 35.4, 34.8. *Anal. calcd for* $C_{23}H_{24}N_2O_2$; C, 76.64; H, 6.71; N, 8.88; Found C, 76.27; H, 6.34; N, 8.54. Compound **2e**: IR (neat): 3306, 3023, 2929, 2854, 1764, 1701, 1538, 1447, 999, 729 cm^{-1}. ^1H NMR ($CDCl_3$-*d*) δ: 6.53 (bs, 2H), 5.67 (dd, 1H), 5.46, (dd, 1H), 4.63 (dt, 2H), 3.62 (t, 1H), 3.35 (t, 1H), 3.04 (d, 1H), 2.53 (d, 1H), 1.81 (t, 2H). ^{13}C NMR ($CDCl_3$-*d*) δ: 179.1, 171.7, 173.4, 166.7, 56.3, 53.7, 48.2, 44.7, 43.9, 404.2, 37.0, 35.4, 33.6, 32.7, 31.5, 30.9, 25.6, 25.1, 24.8, 24.2, 23.4. *Anal. calcd for* $C_{22}H_{32}N_2O_2$; C, 73.22; H, 9.36; N, 8.13; Found C, 72.95; H, 9.71; N, 7.84.

6 J. J. Ritter and P. P. Minieri, *J. Am. Chem. Soc.*, **70**, 4045 (1948); For reviews, see: L. I. Krimen and D. J. Cota, *Org. React.*, **17**, 213 (1969); F. Johnson and R. Madroñero, *Adv. Heterocycl. Chem.*, **6**, 95 (1966); E. C. Tongco, G. K. S. Prakash, and G. A. Olah, *Synlett*, **1997**, 1193.

7 S. Akabori and Y. Takanohashi, *Chem. Lett.*, **1990**, 251; S. B. Mandal, V. S. Giri, and S. C. Pakrashi, *Synthesis*, **1987**, 1128; M. E. Kuehne and P. J. Shannon, *J. Org. Chem.*, **42**, 2082 (1977); T. Satoh, S. Suzuki, Y. Suzuki, and Z. Imai, *Tetrahedron Lett.*, **1969**, 4555; M. T. Rahman and A. F. M. Salahuddin, *Tetrahedron Lett.*, **1976**, 219; A. S. B. Prasad and J. V. B. Kanth, *Tetrahedron*, **48**, 4623 (1992); K. Bhandari, *Chem. Ind. (London)*, **1990**, 547.

8 Y. Nagata, J. Tsurugi, and T. Dohmaru, *Chem. Lett.*, **1972**, 989; R. A. Benkeser, G. S. Li, and E. C. Mozdzen, *Organomet. Chem.*, **178**, 21 (1979).

9 K. Bhandari, *Chem. Ind. (London)*, **1990**, 547.

10 General Procedure for Preparation of **3a** from **2a** according to a modified literature procedure[8]: Into a 100 mL round bottomed flask equipped with condenser and addition funnel was placed a suspension of $LiAlH_4$ (0.52 g, 13.68 mmol) in 15 mL dioxane. The solution was chilled in an ice bath and the dropwise addition of compound **2**, (2.00 g, 6.84 mmol) in 20 mL dioxane. Upon completion of the addition, the ice bath was replaced with a heating mantle and heated to reflux for 48 h. Afterwards, the solution was cooled to 0 °C and the addition of 10 mL of H_2O was made with vigorous stirring for 30 min, followed by the addition of NaOH (3.20 g, in 8 mL H_2O). The resulting solution was allowed to stir for 1 h, then neutralized with 5 M HCl. The solution was extracted in CH_2Cl_2, washed with H_2O (2 × 15 mL). The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting yellow oil was after elution through a 4-inch plug of silica gel with a hexane : ether (1 : 1) solvent system. Characterization: Compound **3a**: IR (neat): 3263, 3061, 2961, 2902, 2862, 2810, 1479, 1384, 1359, 1332, 1229, 1717, 1095 and 1019 cm^{-1}. ^1H NMR ($CDCl_3$) δ: 6.18 (dd, 1H), 5.99 (dd, 1H), 5.65 (bs, 1H), 2.98 (bs, 1H), 2.91 (dd, 4H), 2.29 (dd, 2H), 1.76 (d, 2H), 1.45 (dt, 2H), 1.12 (s, 9H), 1.09 (s, 9H). ^{13}C NMR ($CDCl_3$) δ: 137.71, 133.37, 65.79, 50.09, 48.07, 47.15, 46.73, 45.48, 45.13, 28.95 and 15.20.