JOC*Note*

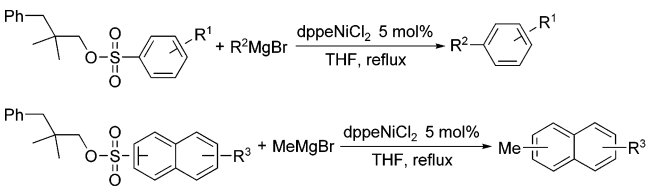
Nickel-Catalyzed Cross-Coupling of Neopentyl Arenesulfonates with Methyl and Primary Alkylmagnesium Bromides

Chul-Hee Cho, Myungchul Sun, Yong-Seok Seo, Chul-Bae Kim, and Kwangyong Park*

Department of Chemical Engineering, Chung-Ang University, Heukseok-dong 221, Dongjak-gu, Seoul 156-756, South Korea

kypark@cau.ac.kr

Received October 1, 2004



R^1 : 4-^{t}Bu, 4-Ph, 4-Tolyl, 4-^{t}BuPh, 4-MeOPh, 4-BiPh.
R^2 : Me, Neopentyl, 2-Me-2-PhPr, Bn.
R^3 : H, NMe_2.

Neopentyl arenesulfonates were reacted with methyl and primary alkylmagnesium bromides in the presence of dppeNiCl$_2$, via the nucleophilic aromatic substitution of neopentyloxysulfonyl groups by the primary alkyl nucleophiles, to produce the corresponding alkylarenes in good yields. This result shows that the alkyloxysulfonyl group might be a suitable alternative to halides and triflate in some circumstances.

Transition-metal-catalyzed coupling reactions are among the most powerful synthetic tools for the construction of carbon−carbon bonds.[1] In particular, the nickel- and palladium-catalyzed coupling reactions of organic electrophiles with organoboronic acids,[2] organostannanes,[3] organozincs,[4] alkenes,[5] and aryl Grignard reagents[6] have emerged as extremely powerful methods during the past few decades. However, the electrophilic components of these reactions have been limited to organic halides and triflates in most reports, despite the enormous effort that has been made to diversify the leaving groups of the electrophiles.

We recently reported that neopentyloxysulfonyl groups, directly attached onto arenes, could act as excellent leaving groups in the nickel-catalyzed reactions with arylmagnesium bromides.[7] Surprisingly, neopentyl arenesulfonates did not undergo the famous coupling reaction with arylmagnesium bromides via the displacement of the arenesulfonates under the standard reaction condition.[8] On the basis of this result, it was anticipated that alkyloxysulfonyl groups would act as chemoselective leaving groups in the presence of a nickel catalyst, because they are not reactive toward palladium catalysts at all. Indeed, the stepwise palladium- and nickel-catalyzed reaction of bromobenzenesulfonates has been successfully demonstrated to be a promising and conceptually straightforward route for preparing unsymmetrical terphenyls.[9] However, in previous reports, the nucleophilic substrates that could be used were restricted to arylmagnesium bromides.

Although aryl nucleophiles have been thoroughly investigated in most transition-metal-catalyzed couplings and applied to a wide array of endeavors, the use of unactivated alkyl nucleophiles has been less explored.[10] Only a limited number of methyl and primary alkyl Grignard reagents have been reported to react with aryl or vinyl halides in the presence of a Ni(0) catalyst to give the corresponding coupling products in moderate yields.[11] Moreover, the reactions of secondary or tertiary alkylmagnesium halides have usually resulted in disappointing yields as a result of the isomerization of the alkyl groups.[12] Therefore, the development of a general coup-

(1) (a) *Handbook of Organopalladium Chemistry for Organic Synthesis*; Negihsi, E., de Meijere, A., Bäckvall, J. E., Cacchi, S., Hayashi, T., Ito, Y., Kosugi, M., Murahashi, S. I., Oshima, K., Yamamoto, Y., Eds.; Wiley-Interscience: New York, 2002. (b) Hassan, J.; Sevignon, M.; Gozzi, C.; Schulz, E. Lemaire, M. *Chem. Rev*. **2002**, *102*, 1359−1469. (c) Littke, A. F.; Fu, G. C. *Angew. Chem., Int. Ed*. **2002**, *41*, 4176−4211. (d) Stanforth, S. P. *Tetrahedron* **1998**, *54*, 263−303.

(2) (a) Kotha, S.; Lahiri, K.; Kashinath, D. *Tetrahedron* **2002**, *58*, 9633−9695. (b) Suzuki, A. *J. Organomet. Chem*. **1999**, *576*, 147−168. (c) Miyaura, N.; Suzuki, A. *Chem. Rev*. **1995**, *95*, 2457−2483.

(3) (a) Farina, V.; Krishnamurthy, V.; Scott, W. J. *The Stille Reaction*; John Wiley & Sons: New York, 1998. (b) Farina, V.; Krishnamurthy, V.; Scott, W. J. *Org. React*. **1997**, *50*, 1−652. (c) Stille, J. K. *Angew. Chem., Int. Ed. Engl*. **1986**, *25*, 508−524.

(4) (a) Negishi, E. In *Organozinc Reagents: A Practical Approach*; Knochel, P., Jones, P., Eds.; Oxford University Press: Oxford, 1999; Chapter 11, pp 213−243. (b) Knochel, P.; Almena Perea, J. J.; Jones, P. *Tetrahedron* **1998**, *54*, 8275−8319. (c) Erdik, E. In *Organozinc Reagents in Organic Synthesis*; CRC Press: Boca Raton, 1996; Chapter 7, pp 271−343. (d) Negishi, E. *Acc. Chem. Res*. **1982**, *15*, 340−348.

(5) (a) Whitcombe, N. J.; Hii, K. K.; Gibson, S. E. *Tetrahedron* **2001**, *57*, 7449−7476. (b) Biffis, A.; Zecca, M.; Basato, M. *J. Mol. Catal. A: Chem*. **2001**, *173*, 249−274. (c) Shibasaki, M.; Boden, C. D. J.; Kojima, A. *Tetrahedron* **1997**, *53*, 7371−7395.

(6) (a) Karlsträm, A.; Sofia, E.; Itami, K.; Bäckvall, J.-E. *J. Org. Chem*. **1999**, *64*, 1745−1749. (b) Busacca, C. A.; Eriksson, M. C.; Fiaschi, R. *Tetrahedron Lett*. **1999**, *40*, 3101−3104. (c) Miller, J. A.; Farrell, R. P. *Tetrahedron Lett*. **1998**, *39*, 7275−7278. (d) Tamao, K.; Kumada, M. In *The Chemistry of the Metal−Carbon Bond*; Hartley, F. R., Ed.; Wiley: New York, 1987; Vol. 4; p 820. (e) Kumada, M. *Pure Appl. Chem*. **1980**, *52*, 669−679. (f) Tamao, K.; Sumitani, K.; Kiso, Y.; Zembayashi, M.; Fujioka, A.; Kodama, S.; Nakajima, I.; Minato, A.; Kumada, M. *Bull. Chem. Soc. Jpn*. **1976**, *49*, 1958−1969.

(7) Cho, C.-H.; Yun, H.-S.; Park, K. *J. Org. Chem*. **2003**, *68*, 3017−3025.

(8) For the transition-metal-catalyzed coupling reaction of organic tosylates via the displacement of tosylates, see: (a) Zim, D.; Lando, V. R.; Dupont, J.; Monteiro, A. L. *Org. Lett*. **2001**, *3*, 3049−3051. (b) Nagatsugi, F.; Uemura, K.; Nakashima, S.; Maeda, M.; Sasaki, S. *Tetrahedron* **1997**, *53*, 3035−3044. (c) Nagatsugi, F.; Uemura, K.; Nakashima, S.; Maeda, M.; Sasaki, S. *Tetrahedron Lett.* **1995**, *36*, 421−424. (d) Burns, D. H.; Miller, J. D.; Chan, H.-K.; Delaney, M. O. *J. Am. Chem. Soc*. **1997**, *119*, 2125−2133.

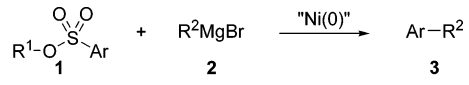
(9) Cho, C.-H.; Kim, I.-S.; Park, K. *Tetrahedron* **2004**, *60*, 4589−4599.

(10) (a) Jensen, A. E.; Knochel, P. *J. Org. Chem*. **2002**, *67*, 79−85. (b) Kirchhoff, J. H.; Dai, C.; Fu, G. C. *Angew. Chem., Int. Ed*. **2002**, *41*, 1945−1947. (c) Dübner, F.; Knochel, P. *Tetrahedron Lett.* **2000**, *41*, 9233−9237. (d) Littke, A. F.; Fu, G. C. *Angew. Chem., Int. Ed*. **1999**, *38*, 2411−2413.

(11) (a) Terao, J.; Watanabe, H.; Ikumi, A.; Kuniyasu, H.; Kambe, N. *J. Am. Chem. Soc*. **2002**, *124*, 4222−4223. (b) Seo, Y.-S.; Yun, H.-S.; Park, K. *Bull. Korean Chem. Soc*. **1999**, *20*, 1345−1347. (c) Kumada, M.; Tamao, K.; Sumitani, K. *Organic Syntheses*; Wiley: New York, 1988; Collect. Vol. VI, pp 407−411. (d) Morrell, D. G.; Kochi, J. K. *J. Am. Chem. Soc*. **1975**, *97*, 7262−7270. (e) Tamao, K.; Kiso, Y.; Sumitani, K.; Kumada, M. *J. Am. Chem. Soc*. **1972**, *94*, 4374−4376.

10.1021/jo048300c CCC: $30.25
Published on Web 01/14/2005

SCHEME 1



R^1 : 2,2-dimethyl-3-phenyl-1-propyl, 2,2-dimethylpropyl
R^2 : methyl (**2a**), neopentyl (**2b**),
2-methyl-2-phenylpropyl (**2c**), benzyl (**2d**)
Ar : benzenes, naphthalenes, biphenyls, terphenyl

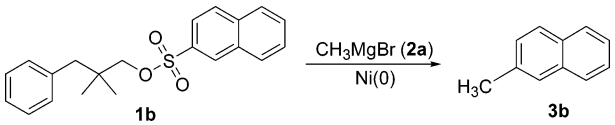
ling procedure utilizing unactivated sp^3 nucleophiles represents an interesting challenge in the field of organic synthesis.

We recently found that neopentyl arenesulfonates undergo nickel-catalyzed reactions with methyl and primary alkylmagnesium bromides to produce the corresponding alkylarenes in good yields (Scheme 1). This was particularly noteworthy, because neopentyl iodides are known to react with methylmagnesium bromide[13] and dimethylzinc[14] to give neopentylmethanes via the displacement of iodide in the presence of the same nickel catalyst. The preliminary results of this new coupling reaction between alkyloxysulfonylarenes and primary alkylmagnesium bromides are presented and discussed below.

In this study, the alkyl arenesulfonates **1a**−**d** are prepared by employing a previously reported procedure.[7] Two types of neopentyl moieties, 2,2-dimethyl-3-phenyl-1-propyl and neopentyl, were selected as the alkyl groups for the sulfonates, to avoid the competitive substitution and elimination of arenesulfonate anions in the reaction with these alkyl nucleophiles. The alkyl biphenylsulfonates **1e**−**i** and terphenylsulfonate **1j** were prepared by the palladium-catalyzed coupling reaction of 2,2-dimethyl-3-phenyl-1-propyl 4-bromobenzenesulfonate with the corresponding arylboronic acids in good yields.[9,15] The displacement of the arenesulfonates and neopentyloxysulfonyl groups was not observed under the standard Suzuki−Miyaura reaction conditions.

The cross-coupling reactions of **1b** with methylmagnesium bromide, **2a**, were preliminarily investigated in order to determine the optimum reaction conditions (Table 1). The addition of the Grignard reagent was carried out in two steps, 3 equiv initially and then 2 equiv after 6 h, and the reaction mixture was heated for 12 h overall at reflux. The naphthalenesulfonate **1b** reacted with **2a** in the presence of [1,1′-bis(diphenylphosphino)-ferrocene]dichloronickel(II) (dppfNiCl_2), which gave the best result for the reactions of the arylmagnesium bromides,[7] in good yields (entries 1 and 2). However, 1,2-[bis(diphenylphosphino)ethane]dichloronickel(II) (dppeNiCl_2) proved to be the best catalyst in the reaction of **2a** (entries 3−5). A brief solvent survey indicated that the reaction efficiencies were generally highest when THF was used as the solvent (entries 2, 4, 7, and 9). In summary, these optimization studies demonstrated that

TABLE 1. Effect of Catalyst and Solvent on the Reaction of 1b with 2a[a]



entry	solvent	catalyst	yield (%)[b]
1	Et_2O	dppfNiCl_2	65
2	THF	dppfNiCl_2	89
3	Et_2O	dppeNiCl_2	55
4	THF	dppeNiCl_2	96
5	DME	dppeNiCl_2	87
6	Et_2O	dpppNiCl_2	62
7	THF	dpppNiCl_2	74
8	Et_2O	$(PPh_3)_2$NiCl_2	55
9	THF	$(PPh_3)_2$NiCl_2	35

[a] Reactions of **1b** (0.30 mmol) with **2a** (1.5 mmol) were carried out at the refluxing temperature of the indicated solvent (10 mL) by using the indicated catalyst (0.015 mmol). [b] GC yield based on **1b**.

the highest yields were obtained when using dppeNiCl_2 as the catalyst in refluxing THF.

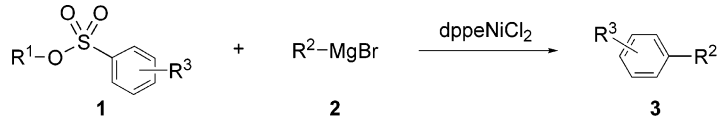
The results of the cross-coupling reactions between the various arenesulfonates **1** and the primary alkylmagnesium bromides **2**, performed in the presence of 5 mol % of dppeNiCl_2 in refluxing THF, are summarized in Table 2. Most of the arenesulfonates reacted with **2a** within 24 h to give the corresponding methylarenes **3a**−**i** in high yields (entries 1−10). 4,4′-Biphenyldisulfonate **1d** reacted with 2 equiv of **2a** to generate 4,4′-dimethylbiphenyl **3d** with a good yield (entry 4). Methoxybiphenylsulfonate **1h** also gave a competitive yield without undergoing any secondary cross-coupling reaction with excess Grignard reagents via the cleavage of the carbon−oxygen bonds (entry 8). Only vinylbiphenylsulfonate **1i** failed to undergo the coupling reaction with **2a** (entry 9). The reactivity of terphenylsulfonate **1j** toward **2a** was even higher, being completely consumed within 15 h (entry 10). The faster reaction of the more conjugated arenesulfonates has been consistently observed in their reactions with aryl nucleophiles.[7,9]

Primary alkylmagnesium bromides, not possessing a β-hydrogen to magnesium, were adopted for the reactions with **1**. Two neopentylmagnesium bromides, **2b** and **2c**, showed high reactivity toward the arenesulfonates. The reactions of **2b** with **1e** and **1f** and the reactions of 2-methyl-2-phenylpropylmagnesium bromide, **2c**, with **1b**, **1e**, and **1h** produced the corresponding neopentylarenes **3j**−**n** in good yields under the standard reaction conditions (entries 11−15). However, the reaction of benzylmagnesium bromide, **2d**, with **1b** afforded the desired product, **3o**, in reduced yield (entry 16).

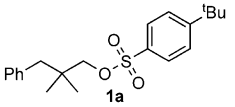
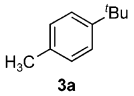
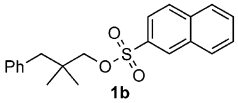
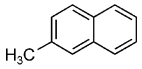
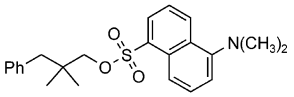
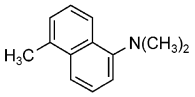
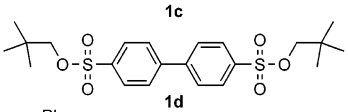
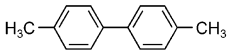
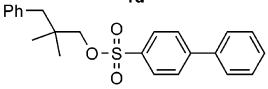
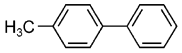
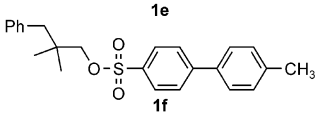
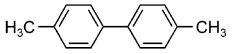
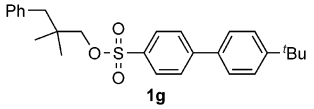
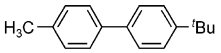
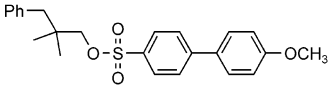
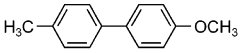
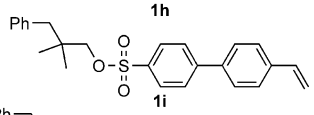
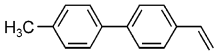
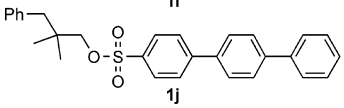
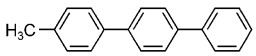
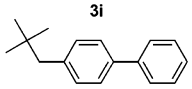
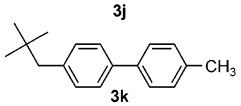
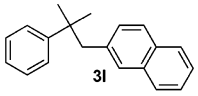
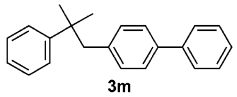
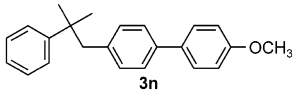
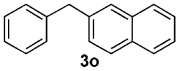
It is noteworthy that the purification of the products **3** can be easily performed by chromatography, because the amount of byproduct originating from the excess alkyl nucleophiles is relatively small after the standard work-up. In the reactions of the arylmagnesium bromides, the large amount of biphenyls produced by the dimerization of the aryl groups made the purification of the desired cross-coupling products difficult in most cases.[7] The availability of a convenient method of purification would allow this reaction to be useful, when a clean and

(12) (a) Consiglio, G.; Morandini, F.; Piccolo, O. *Tetrahedron* **1983**, *39*, 2699−2707. (b) Hayashi, T.; Konishi, M.; Kumada, M. *Tetrahedron Lett.* **1979**, *21*, 1871−1874. (c) Tamao, K.; Kiso, Y.; Sumitani, K.; Kumada, M. *J. Am. Chem. Soc.* **1972**, *94*, 9268−9269.
(13) Yuan, K.; Scott, W. J. *Tetrahedron Lett.* **1991**, *32*, 189−192.
(14) Park, K.; Yuan, K.; Scott, W. J. *J. Org. Chem.* **1993**, *58*, 4866−4870.
(15) Cho, C.-H.; Kim, C.-B.; Sun, M.; Park, K. *Bull. Korean Chem. Soc.* **2003**, *24*, 1632−1636.

TABLE 2. Coupling Reactions of 1 with 2[a]



1 **2** **3**

entry	sulfonate **1**	Grignard reagent **2**	product **3**	yield (%)[b]
1	 **1a**	**2a**	 **3a**	93[c]
2	 **1b**	**2a**	 **3b**	96[c]
3	 **1c**	**2a**	 **3c**	79
4	 **1d**	**2a**	 **3d**	84
5	 **1e**	**2a**	 **3e**	84
6	 **1f**	**2a**	 **3d**	83
7	 **1g**	**2a**	 **3f**	84
8	 **1h**	**2a**	 **3g**	80
9	 **1i**	**2a**	 **3h**	-
10	 **1j**	**2a**	 **3i**	86
11	**1e**	**2b**	 **3j**	73
12	**1f**	**2b**	 **3k**	78
13	**1b**	**2c**	 **3l**	75
14	**1e**	**2c**	 **3m**	61
15	**1h**	**2c**	 **3n**	66
16	**1b**	**2d**	 **3o**	35

[a] Reactions of sulfonates **1** (0.30 mmol) with **2** (1.5 mmol) were carried out at the refluxing temperature of THF (10 mL) by using dppeNiCl$_2$ (0.015 mmol). [b] Yields of chromatographically isolated products based on **1**. [c] GC yield based on **1**.

versatile means of cleaving the carbon−sulfur bond is required, such as in the cleavage of polymer-bound substrates in solid-phase organic synthesis (SPOS).

In summary, various neopentyl arenesulfonates were reacted with methyl and primary alkylmagnesium bromides in the presence of dppeNiCl$_2$ to give the corresponding alkylarenes in good yields. This reaction represents a novel method allowing the efficient and creative substitution of sulfur-containing groups in aromatic compounds. It also shows that the alkyloxysulfonyl group might be a suitable alternative to halides and triflate in some circumstances, especially when a chemoselective leaving group, which is inert toward palladium catalysts but reactive with nickel catalysts, is desirable. The reactions of arenesulfonates with various alkylmagnesium halides are currently under investigation and will be reported in due course.

Experimental Section

General Procedure for Preparation of Arenesulfonates (1). To 2,2-dimethyl-3-phenyl-1-propanol (5.52 mmol) in chloroform (12 mL) at 0 °C were added pyridine (0.85 mL, 10.5 mmol) dropwise over a period of 20 min and sulfonyl chloride (5.25 mmol) in small portions. The reaction mixture was stirred at room temperature for 12 h and diluted with Et$_2$O. The organic layer was washed with 0.1% aqueous HCl, water, and brine; dried over MgSO$_4$; and concentrated in vacuo. The crude sulfonates **1** were purified by either column chromatography or recrystallization.

Dineopentyl 4,4′-biphenyldisulfonate (1d) was prepared by the reaction of neopentyl alcohol (0.63 g, 7.13 mmol) with sulfonyl chloride (1.0 g, 2.85 mmol). The crude compound was purified by recrystallization from *n*-hexane to give **1d** (1.08 g, 83%) as a white solid: TLC R_f 0.74 (EtOAc); mp 193−194 °C (uncorrected); ^{1}H NMR (300 MHz, CDCl$_3$) δ 0.93 (s, 18H), 3.75 (s, 4H), 7.79 (d, J = 8.56 Hz, 4H), 8.03 (d, J = 8.56 Hz, 4H); ^{13}C NMR (75 MHz, CDCl$_3$) δ 26.1 (×6), 31.8 (×2), 80.1 (×2), 128.4 (×4), 128.9 (×4), 136.3 (×2), 144.6 (×2); HRMS (EI, 70 eV) calcd for $C_{22}H_{30}O_6S_2$ (M^+) 454.1484, found 454.1480. Anal. Calcd for $C_{22}H_{16}O_6S_2$: C, 58.12; H, 6.65; S, 14.11. Found: C, 58.16; H, 6.32; S, 14.03.

General Procedure for the Cross-Coupling Reactions of 1 with 2. To a stirred solution of sulfonate **1** (0.30 mmol) and dppeNiCl$_2$ (0.015 mmol) in THF (10 mL) was slowly added Grignard reagents **2** (0.90 mmol) at room temperature. The reaction mixture was heated at reflux for 6 h and cooled to room temperature, and an additional 0.60 mmol of **2** was added to the solution. The resulting mixture was heated at reflux for 6 h, cooled to room temperature, and diluted with Et$_2$O. The organic layer was washed with 1% aqueous HCl, water, and brine; dried over MgSO$_4$; and concentrated in vacuo.

***N,N*-Dimethyl-5-methyl-1-naphthalenamine (3c)** was prepared by the reaction of **1c** (119 mg, 0.30 mmol) with methylmagnesium bromide **2a** (3.0 M in Et$_2$O, 0.30 mL, 0.90 mmol + 0.20 mL, 0.60 mmol) in the presence of dppeNiCl$_2$. The crude compound was purified by column chromatography (ethyl acetate: *n*-hexane = 1:10) to give **3c** (43.9 mg, 79%) as a yellow oil: TLC R_f 0.53 (Et$_2$O/*n*-hexane = 1:4); ^{1}H NMR (300 MHz, CDCl$_3$) δ 2.68 (s, 3H), 2.89 (s, 6H), 7.10 (d, J = 7.22 Hz, 1H), 7.28−7.45 (m, 3H), 7.69 (d, J = 8.39 Hz, 1H), 8.14 (d, J = 8.39 Hz, 1H); ^{13}C NMR (75 MHz, CDCl$_3$) δ 19.9, 45.4 (×2), 114.1, 119.3, 122.7, 125.0, 125.8, 126.8, 129.2, 134.2, 134.8, 151.6; HRMS (EI, 70 eV) calcd for $C_{13}H_{15}N$ (M^+), 185.1204, found 185.1286.

4-Methyl-4′-neopentylbiphenyl (3k) was prepared by the reaction of **1f** (136 mg, 0.30 mmol) with neopentylmagnesium bromide **2b** (0.5 M in THF, 1.80 mL, 0.90 mmol + 1.20 mL, 0.60 mmol) in the presence of dppeNiCl$_2$. The crude compound was purified by column chromatography (EtOAc/*n*-hexane = 1:10) to give **3k** (55.78 mg, 78%) as a white solid: TLC R_f 0.74 (EtOAc/*n*-hexane = 1:4); mp 69−70 °C (uncorrected); ^{1}H NMR (300 MHz, CDCl$_3$) δ 0.94 (s, 9H), 2.39 (s, 3H), 2.53 (s, 2H), 7.18 (d, J = 8.1 Hz, 2H), 7.24 (d, J = 8.1 Hz, 2H), 7.48 (d, J = 8.3 Hz, 2H), 7.50 (d, J = 8.3 Hz, 2H); ^{13}C NMR (75 MHz, CDCl$_3$) δ 21.1, 29.4 (×3), 31.8, 49.8, 126.1 (×2), 126.8 (×3), 129.4 (×2), 130.8 (×2), 136.7, 138.5, 138.6. Anal. Calcd for $C_{18}H_{22}$: C, 90.70; H, 9.30. Found: C, 90.53; H, 9.21.

2-(2-Methyl-2-phenylpropyl)naphthalene (3l) was prepared by the reaction of **1b** (106 mg, 0.30 mmol) with 2-methyl-2-phenylpropylmagnesium chloride **2c** (0.5 M in Et$_2$O, 1.8 mL, 0.90 mmol + 1.2 mL, 0.60 mmol) in the presence of dppeNiCl$_2$. The crude compound was purified by preparative TLC in *n*-hexane to afford **3l** (58.58 mg, 75%) as a white solid: TLC R_f 0.72 (EtOAc/*n*-hexane = 1:4); mp 68−69 °C (uncorrected); ^{1}H NMR (500 MHz, CDCl$_3$) δ 1.37 (s, 6H), 3.03 (s, 2H), 6.88 (dd, J = 8.40, 1.61 Hz, 1H), 7.18−7.23 (m, 1H), 7.27−7.34 (m, 5H), 7.37−7.43 (m, 2H), 7.58 (d, J = 8.40 Hz, 1H), 7.66 (dd, J = 6.66, 2.42 Hz, 1H), 7.75 (dd, J = 6.66, 2.42 Hz, 1H); ^{13}C NMR (75 MHz, CDCl$_3$) δ 28.4 (×2), 39.1, 51.4, 125.4, 125.8, 126.0, 126.5, 126.9 (×2), 127.7, 127.8, 128.2 (×2), 129.1, 129.4, 132.3, 133.4, 136.8, 149.2; HRMS (EI, 70 eV) calcd for $C_{20}H_{20}$ (M^+) 260.1565, found 260.1554. Anal. Calcd for $C_{20}H_{20}$: C, 92.26; H, 7.74. Found: C, 91.98; H, 7.72.

4-(2-Methyl-2-phenylpropyl)biphenyl (3m) was prepared by the reaction of **1e** (114 mg, 0.30 mmol) with 2-methyl-2-phenylpropylmagnesium chloride **2c** (0.5 M in Et$_2$O, 1.8 mL, 0.90 mmol + 1.2 mL, 0.60 mmol) in the presence of dppeNiCl$_2$. The crude compound was purified by recrystallization in ethanol to afford **3m** (52.41 mg, 61%) as a white solid: TLC R_f 0.72 (EtOAc/*n*-hexane = 1:4); mp 94−95 °C (uncorrected); ^{1}H NMR (500 MHz, CDCl$_3$) δ 1.35 (s, 6H), 2.91 (s, 2H), 6.87 (d, J = 8.11 Hz, 2H), 7.18−7.22 (m, 1H), 7.28−7.34 (m, 5H), 7.36−7.42 (m, 4H), 7.55 (d, J = 7.24 Hz, 2H); ^{13}C NMR (75 MHz, CDCl$_3$) δ 28.4 (×2), 39.0 (×2), 50.9, 125.9, 126.4 (×2), 126.5 (×2), 127.2 (×2), 127.2, 128.2 (×2), 129.0 (×2), 131.1 (×2), 138.3, 139.0, 141.3, 149.3; HRMS (EI, 70 eV) calcd for $C_{22}H_{22}$ (M^+) 286.1721, found 286.1726. Anal. Calcd for $C_{22}H_{22}$: C, 92.26; H, 7.74. Found: C, 92.18; H, 7.65.

4-Methoxy-4′-(2-methyl-2-phenylpropyl)biphenyl (3n) was prepared by the reaction of **1h** (123 mg, 0.30 mmol) with 2-methyl-2-phenylpropylmagnesium chloride **2c** (0.5 M in Et$_2$O, 1.8 mL, 0.90 mmol + 1.2 mL, 0.60 mmol) in the presence of dppeNiCl$_2$. The crude compound was purified by recrystallization in ethanol to afford **3n** (62.66 mg, 66%) as a white solid: TLC R_f 0.54 (EtOAc/*n*-hexane = 1:4); mp 112−113 °C (uncorrected); ^{1}H NMR (500 MHz, CDCl$_3$) δ 1.35 (s, 6H), 2.90 (s, 2H), 3.84 (s, 3H), 6.85 (d, J = 8.16 Hz, 2H), 6.94 (d, J = 8.77 Hz, 2H), 7.18−7.22 (m, 1H), 7.28−7.34 (m, 6H), 7.48 (d, J = 8.77 Hz, 2H); ^{13}C NMR (75 MHz, CDCl$_3$) δ 28.3 (×2), 39.0 (×2), 50.9, 55.5, 114.4 (×2), 125.9, 125.7 (×2), 126.5 (×2), 128.2 (×2), 128.2 (×2), 131.1 (×2), 133.9, 137.7, 138.6, 149.3, 159.3; HRMS (EI, 70 eV) calcd for $C_{23}H_{24}O$ (M^+): 316.1827. found 316.1811. Anal. Calcd for $C_{23}H_{24}O$: C, 87.30; H, 7.64. Found: C, 86.94; H, 7.52.

Supporting Information Available: Detailed experimental procedures and spectroscopic data for **1a**−**1j** and **3c**, **3f**, **3g**, and **3i**−**3o**. This material is available free of charge via the Internet at http://pubs.acs.org.

JO048300C