Supporting information for

Efficient Heterogeneous Hydroboration of Alkynes: Enhancing the Catalytic Activity by Cu(0) Incorporated CuFe$_2$O$_4$ Nanoparticles

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7. Analytic data of the obtained compounds:

**(E)-4,4,5,5-tetramethyl-2-styryl-1,3,2-dioxaborolane (2a)**\(^{[1]}\): Colorless oil, yield 95%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.477-7.496 (m, 2H), 7.470 (d, \(J = 18.8\) Hz, 1H), 7.285-7.351 (m, 3H), 6.168 (d, \(J = 18.4\) Hz, 1H), 1.312 (s, 12H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 149.50, 137.41, 128.89, 128.56, 127.04, 83.35, 24.81. GC-MS: M\(^+\) m/z 230.2.

**(E)-4,4,5,5-tetramethyl-2-(4-methylstyryl)-1,3,2-dioxaborolane (2b)**\(^{[2]}\): Colorless oil, yield 90%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.345-7.392 (m, 3H), 7.127-7.147 (m, 2H), 6.100 (d, \(J = 18.4\) Hz, 1H), 2.239 (s, 3H), 1.306 (s, 12H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 149.45, 138.96, 134.57, 129.27, 127.00, 83.27, 24.80, 21.34. GC-MS: M\(^+\) m/z 244.2.

**(E)-4,4,5,5-tetramethyl-2-(3-methylstyryl)-1,3,2-dioxaborolane (2c)**\(^{[1]}\): Colorless oil, yield 91%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.369 (d, \(J = 18.4\) Hz, 1H), 7.202-7.297 (m, 3H), 7.096-7.115 (m, 1H), 6.147 (d, \(J = 18.4\) Hz, 1H), 2.342 (s, 3H), 1.309 (s, 12H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 149.65, 138.07, 137.40, 129.70, 128.44, 127.76, 124.22, 83.30, 24.80, 21.40. GC-MS: M\(^+\) m/z 244.2.

**(E)-2-(4-ethylstyryl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2d)**\(^{[2]}\): Colorless oil, yield 90% \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.356-7.421 (m, 3H), 7.155-7.175 (m, 2H), 6.117 (d, \(J = 18.4\) Hz, 1H), 2.638 (q, \(J = 7.6\) Hz, 2H), 1.309 (s, 12H), 1.226 (t, \(J = 7.6\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 149.49, 145.30, 134.99, 128.68, 126.99, 83.26, 28.69, 24.81, 15.41. GC-MS: M\(^+\) m/z 258.2.

**(E)-4,4,5,5-tetramethyl-2-(4-propylstyryl)-1,3,2-dioxaborolane (2e)**: Colorless oil, yield 92%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.358-7.415 (m, 3H), 7.132-7.152 (m, 2H), 6.119 (d, \(J = 18.4\) Hz, 1H), 2.553-2.591 (m, 2H), 1.583-1.676 (m, 2H), 1.309 (s, 12H), 0.931 (t, \(J = 7.6\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 149.52, 143.77, 134.99, 128.68, 126.99, 83.25, 37.85, 24.80, 24.40, 13.82. GC-MS: M\(^+\) m/z 272.2.

**(E)-2-(4-butylstyryl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2f)**: Colorless oil, yield 92%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.350-7.409 (m, 3H), 7.132-7.152 (m, 2H), 6.109 (d, \(J = 18.4\) Hz, 1H), 2.594 (d, \(J = 7.6\) Hz, 2H), 1.546-1.621 (m, 2H), 1.305-1.369 (m, 14H), 0.915 (t, \(J = 7.2\) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 149.51,
GC-MS: M⁺ m/z 286.2.

(E)-2-(4-hexylstyrlyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2g)[1]: Colorless oil, yield 89%. ¹H NMR (400 MHz, CDCl₃) δ: 7.870 (d, J = 8.4 Hz, 1H), 7.352-7.409 (m, 3H), 7.249-7.269 (m, 1H), 7.130-7.150 (m, 1H), 6.110 (d, J = 18.4 Hz, 1H), 2.652 (t, J = 8.0 Hz, 1H), 2.578 (t, J = 5.6 Hz, 3H), 1.599-1.627 (m, 2H), 1.306-1.316 (m, 14H), 0.883 (dt, J = 6.8, 3.2 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ: 149.51, 148.83, 144.05, 134.94, 128.59, 128.00, 35.75, 31.48, 26.56, 24.80, 22.53, 14.03. GC-MS: M⁺ m/z 300.2.

(E)-2-(4-methoxystyrlyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2h): Colorless oil, yield 90%. ¹H NMR (400 MHz, CDCl₃) δ: 7.419-7.441 (m, 2H), 7.344 (d, J = 18.8 Hz, 2H), 6.859 (d, J = 8.8 Hz, 1H), 6.009 (d, J = 18.4 Hz, 1H), 3.806 (s, 3H), 1.301 (s, 12H); ¹³C NMR (100 MHz, CDCl₃) δ: 160.24, 149.04, 130.27, 128.45, 113.93, 83.21, 55.27, 24.80. GC-MS: M⁺ m/z 260.2.

(E)-2-(4-ethoxystyrlyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2i)[1]: Colorless oil, yield 91%. ¹H NMR (400 MHz, CDCl₃) δ: 7.398-7.427 (m, 2H), 7.341 (d, J = 19.2 Hz, 2H), 6.842 (d, J = 8.8 Hz, 1H), 5.999 (d, J = 18.4 Hz, 1H), 4.000-4.053 (m, 2H), 1.402 (d, J = 6.8 Hz, 3H), 1.300 (s, 12H); ¹³C NMR (100 MHz, CDCl₃) δ: 159.66, 149.12, 130.16, 128.45, 114.43, 83.18, 63.42, 24.80, 14.80. GC-MS: M⁺ m/z 274.2.

(E)-2-(4-chlorostyrlyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2j)[1]: white solid, yield 85%. ¹H NMR (400 MHz, CDCl₃) δ: 7.349-7.408 (m, 3H), 7.281-7.302 (m, 2H), 6.124 (d, J = 18.4 Hz, 1H), 1.302 (s, 12H); ¹³C NMR (100 MHz, CDCl₃) δ: 148.00, 135.86, 134.58, 128.77, 128.21, 83.44, 24.80. GC-MS: M⁺ m/z 264.1.

(E)-2-(4-fluorostyrlyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2k)[1]: Colorless oil, yield 92%. ¹H NMR (400 MHz, CDCl₃) δ: 7.433-7.469 (m, 2H), 7.345 (d, J = 18.4 Hz, 1H), 7.014 (d, J = 8.4 Hz, 1H), 6.066 (d, J = 18.8 Hz, 1H), 1.304 (s, 12H); ¹³C NMR (100 MHz, CDCl₃) δ: 164.34, 161.89, 148.14, 133.64, 128.73, 128.64, 115.65, 115.43, 83.38, 24.79. GC-MS: M⁺ m/z 248.1.

(E)-4-(2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)vinyl)aniline(2l): light yellow solid, yield 84%. ¹H NMR (400 MHz, CDCl₃) δ: 7.278-7.324 (m, 3H), 6.618.
(d, J = 8.4 Hz, 1H), 5.930 (d, J = 18.4 Hz, 1H), 3.806 (s, 2H), 1.294 (s, 12H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 149.56, 147.33, 128.56, 128.18, 114.82, 83.08, 24.80. GC-MS: M$^+$ m/z 245.1.

**(E)-2-(2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)vinyl)pyridine** (2m)$^{[1]}$: Colorless oil, yield 94%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.585 (d, J = 4.4 Hz, 1H), 7.617-7.659 (m, 1H), 7.374-7.460 (m, 2H), 7.145-7.176 (m, 1H), 6.613 (d, J = 18.4 Hz, 1H), 1.290 (s, 12H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 155.36, 149.66, 148.68, 136.49, 123.08, 122.23, 83.46, 24.77. GC-MS: M$^+$ m/z 231.1.

**(E)-4,4,5,5-tetramethyl-2-(2-(thiophen-2-yl)vinyl)-1,3,2-dioxaborolane** (2n): Colorless oil, yield 87%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.464 (d, J = 18.0 Hz, 1H), 7.230 (d, J = 5.2 Hz, 1H), 7.071 (d, J = 3.2 Hz, 1H), 6.975 (dd, J = 3.6, 2.4 Hz, 1H), 5.907 (d, J = 18.0 Hz, 1H), 1.290 (s, 12H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 143.89, 141.79, 127.71, 127.61, 126.29, 83.34, 24.78. GC-MS: M$^+$ m/z 236.1.

**(E)-4,4,5,5-tetramethyl-2-(2-(thiophen-3-yl)vinyl)-1,3,2-dioxaborolane** (2o)$^{[1]}$: Colorless oil, yield 90%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.373 (d, J = 18.4 Hz, 1H), 7.283-7.297 (m, 2H), 7.245-7.256 (m, 1H), 5.937 (d, J = 18.4 Hz, 1H), 1.295 (s, 12H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 143.13, 132.27, 126.11, 124.99, 124.88, 83.34, 24.79. GC-MS: M$^+$ m/z 236.1.

**(E)-1-phenyl-3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)prop-2-en-1-ol** (2p): Colorless oil, yield 92%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.540-7.558 (m, 1H), 7.373 7.269-7.388 (m, 5H), 5.937 (dd, J = 18.0, 5.2 Hz, 1H), 5.738 (dd, J = 18.0, 1.2 Hz, 1H), 5.229 (dd, J = 5.6, 1.6 Hz, 1H), 1.246 (s, 12H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 153.62, 141.90, 128.67, 128.56, 127.79, 126.59, 126.47, 83.38, 76.11, 24.77. GC-MS: M$^+$ m/z 260.2.

**(E)-2-methyl-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)but-3-en-2-ol** (2q)$^{[1]}$: Colorless oil, yield 91%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 6.706 (d, J = 18.0 Hz, 1H), 5.597 (d, J = 18.0 Hz, 1H), 1.594 (s, 1H), 1.300 (s, 6H), 1.262 (s, 12H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 159.76, 104.95, 83.28, 71.80, 29.10, 24.76. GC-MS: M$^+$ m/z 212.1.

**(E)-4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)but-3-en-1-ol** (2r)$^{[1]}$: Colorless
oil, yield 90%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.544-7.621 (m, 1H), 5.541 (dd, $J = 18.0, 1.2$ Hz, 1H), 3.705 (t, $J = 6.4$ Hz, 2H), 2.417 (q, $J = 6.4$ Hz, 2H), 1.691 (s, 1H), 1.246 (s, 12H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 150.02, 105.17, 83.19, 61.20, 39.06, 24.75. GC-MS: M$^+$/m/z 198.1.

(E)-2-(3,3-dimethylbut-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2s): Colorless oil, yield 87%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 6.625 (d, $J = 18.4$ Hz, 1H), 5.336 (d, $J = 18.8$ Hz, 1H), 1.258 (s, 12H), 1.003 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 164.40, 82.98, 35.00, 24.78. GC-MS: M$^+$/m/z 210.2.

(E)-2-(hex-1-en-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (2u): Colorless oil, yield 95%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 6.615 (dt, $J = 16.6, 6.4$ Hz, 1H), 5.404 (d, $J = 18.0$ Hz, 1H), 2.105-2.158 (m, 2H), 1.296-1.401 (m, 4H), 1.246 (s, 12H), 0.867 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 154.79, 128.64, 82.95, 35.49, 31.71, 28.91, 24.75, 22.23, 13.90. GC-MS: M$^+$/m/z 223.2.

(E)-4,4,5,5-tetramethyl-2-(oct-1-en-1-yl)-1,3,2-dioxaborolane (2v): Colorless oil, yield 94%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 6.623 (dt, $J = 18.0, 6.4$ Hz, 1H), 5.404 (d, $J = 18.0$ Hz, 1H), 2.104-2.114 (m, 4H), 1.308-1.424 (m, 4H), 1.233 (s, 12H), 0.845-0.914 (m, 6H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 145.96, 82.87, 30.54, 24.69, 23.28, 22.38, 14.08, 14.03. GC-MS: M$^+$/m/z 223.2.

(E)-4,4,5,5-tetramethyl-2-(1-phenylprop-1-en-2-yl)-1,3,2-dioxaborolane (2x): Colorless oil, yield 90%. $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.297-7.393 (m, 3H), 7.217-
7.254 (m, 2H), 7.143-7.162 (m, 1H), 1.990 (s, 3H), 1.313 (s, 12H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 142.34, 137.90, 129.39, 128.01, 127.07, 83.50, 24.84, 24.73, 15.90. GC-MS: M\(^+\) m/z 244.2.

**(E)-ethyl 3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)acrylate (2y)**: Colorless oil, yield 70%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 6.738 (d, \(J=18.0\) Hz, 1H), 6.593 (d, \(J=18.0\) Hz, 1H), 4.177 (q, \(J=7.2\) Hz, 2H), 1.251 (s, 12H), 1.192-1.210(m, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 174.88, 138.70, 125.91, 83.15, 60.56, 24.78, 24.70, 24.43, 14.15. GC-MS: M\(^+\) m/z 226.1.

**(E)-methyl 3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)acrylate (2z)**: Colorless oil, yield 75%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 6.761 (d, \(J=18.4\) Hz, 1H), 6.610 (d, \(J=18.4\) Hz, 1H), 3.744 (s, 3H), 1.269(s, 12H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 166.33, 138.70, 138.15, 84.03, 51.77, 24.71. HRMS m/z (ESI): Calcd for C\(_{10}\)H\(_{17}\)BO\(_4\)Na ([M+Na]\(^+\)): 235.1112, Found 235.1110.

**(Z)-N-methyl-N-styrylmethanesulfonamide (3a)**: White solid, yield 95% (Z:E=3:1). \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.292-7.404 (m, 5H), 6.333 (d, \(J=8.8\) Hz, 1H), 6.055 (d, \(J=8.8\) Hz, 1H), 2.932 (s, 3H), 2.892 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 134.69, 129.00, 128.33, 127.72, 126.97, 120.64, 36.59, 36.21. HRMS m/z (ESI): Calcd for C\(_{10}\)H\(_{13}\)O\(_2\)SNa ([M+Na]\(^+\)): 234.0559, Found 234.0558.

**1,3-diphenylpropan-1-one (3b)**: Colorless oil, yield 92%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.952-7.973 (m, 2H), 7.541-7.578 (m, 1H), 7.435-7.474 (m, 2H), 7.210-7.324 (m, 5H), 3.331 (t, \(J=7.6\) Hz, 2H), 3.073 (t, \(J=7.6\) Hz, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 199.23, 141.27, 136.80, 133.07, 128.60, 128.52, 128.42, 128.03, 127.16, 126.12, 40.46, 30.11. HRMS m/z (ESI): Calcd for C\(_{15}\)H\(_{14}\)O\(_2\)Na ([M+Na]\(^+\)): 233.0937, Found 233.0935.

**(5S)-2-methyl-5-(prop-1-en-2-yl)-3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)cyclohexanone (3c)**: white solid, yield 94%. Colorless oil, yield 95%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 4.644-4.699 (m, 2H), 2.532-2.592 (m, 1H), 2.408-2.423 (m, 2H), 2.374-2.389 (m, 1H), 1.952-2.216 (m, 1H), 1.664-1.791 (m, 5H), 1.158-1.204 (m, 12H), 1.029-1.046 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 212.08, 147.90, 109.43, 83.38, 46.13, 45.83, 44.36, 32.41, 24.81, 24.77, 24.57, 20.69, 13.91. HRMS m/z (ESI):
Calcd for C_{16}H_{27}O_{3}Na ([M+Na]^+): 301.1945, Found 301.1944.

**Ethyl 3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)but-3-enoate (3d):** Colorless oil, yield 95%. \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 5.882 (s, 1H), 5.672 (s, 1H), 4.112 (q, \(J=7.2\) Hz, 2H), 3.155 (s, 2H), 1.251 (s, 12H), 1.215-1.235 (m, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 172.16, 131.75, 83.67, 60.42, 40.66, 24.67, 14.21. HRMS \(m/z\) (ESI): Calcd for C_{12}H_{21}O_{4}Na ([M+Na]^+): 263.1425, Found 263.1422.

8. References


9. $^1$H-NMR and $^{13}$C-NMR spectra of the obtained compounds

2a
2q

[Chemical structure image]

[Graphical representation of a 1D NMR spectrum]
$2t$
2z