Supporting Information
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Supporting Information

Chromium-Catalyzed, Regioselective Cross-Coupling of C–O Bonds Using Organic Bromides as Reactants

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1. Materials and Methods

**General.** All reactions dealing with air- or moisture-sensitive compounds were carried out in a flame-dried, sealed Schlenk reaction tube under an atmosphere of nitrogen. Analytical thin-layer chromatography was performed on glass plates coated with 0.25 mm 230–400 mesh silica gel containing a fluorescent indicator (Merck). Flash silica gel column chromatography was performed on silica gel 60N (spherical and neutral, 140–325 mesh) as described by Still. NMR spectra were measured on a Bruker AV-400 spectrometer and reported in parts per million. H NMR spectra were recorded at 400 MHz in CDCl₃ were referenced internally to tetramethylsilane as a standard, and C NMR spectra were recorded at 100 MHz and referenced to the solvent resonance. Analytical gas chromatography (GC) was carried out on a Thermo Trace 1300 gas chromatograph, equipped with a flame ionization detector. Mass spectra (GC-MS) were taken at Thermo Trace 1300 gas chromatograph mass spectrometer. High resolution mass spectra (HRMS) were recorded on the Exactive Mass Spectrometer (Thermo Scientific, USA) equipped with ESI ionization source. Melting points were determined with a Hanon MP-300.

**Materials.** Unless otherwise noted, materials were purchased from Tokyo Chemical Industry Co., Aldrich Inc., Alfa Aesar, and other commercial suppliers and used as received. Solvents were dried over sodium (for THF and ether) by refluxing for overnight and freshly distilled prior to use. CrCl₂ (99.99%) and CrCl₃ (99.99%) were purchased from Aldrich Inc. and used as received. CrCl₂ (97%) was purchased from Alfa Aesar and used as received. Mg (99.9%) was purchased from Acros Inc. and used as received.
2. Optimization of Reaction Conditions

Table 1. Optimization of Reaction Conditions

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<th>Entry</th>
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<th>Solvent</th>
<th>Yield (3a)(^b)</th>
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<td>nd(^c)</td>
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<td>CrCl(_2)</td>
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<td>Toluene</td>
<td>nd(^c)</td>
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</table>

\(^a\)Reaction conditions: 1a (0.2 mmol), 2a, Cr salt (10 mmol%), Mg (2.2 eq), solvent (0.1 M), 12 h. \(^b\)\(^1\)H-NMR yield using 1,3,5-methoxybenzene as internal stand. \(^c\)Not detected. \(^d\)Without metallic magnesium. \(^g\)Isolated yield in parentheses. \(^f\)CrCl\(_2\) (99.99% purity).

3. The Preparation of Substrates

General procedure for the synthesis of \(N\)-\(tert\)-butyl-substituted ortho-methoxy-bearing aromatic imines\(^1\)\(^2\)

In a 25 mL screw-capped vial with a stirring bar, the ortho-alkoxy-substituted aromatic aldehyde (5 mmol) was treated with \(tert\)-butylamine (25 mmol). The vial was then sealed and the mixture was stirred at 100 °C for overnight. After cooling to room temperature, the excess \(tert\)-butylamine was evaporated under a reduced pressure. The corresponding imine product was generally obtained in very high purity and employed without further purification after checking by \(^1\)H NMR and \(^13\)C NMR or purified by distillation if necessary.
**N-(2-methoxybenzylidene)-**tert-*butylamine (1a)**

The title compound was obtained as a colorless liquid. $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 8.70$ (s, 1H), 7.94 (dd, $J = 7.6$, 2.0 Hz, 1H), 7.32 (td, $J = 8.4$, 2.0 Hz, 1H), 6.95 (t, $J = 7.6$ Hz, 1H), 6.88 (d, $J = 8.4$ Hz, 1H), 3.86 (s, 3H), 1.29 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 158.7$, 151.4, 131.4, 127.2, 125.8, 120.9, 110.9, 57.6, 55.6, 30.0. GC-MS (EI): calcd for C$_{12}$H$_{17}$NO [M$^+$] 191.13, found 191.11.

**N-(2,3-dimethoxybenzylidene)-**tert-*butylamine (1b)**

The title compound was obtained as a slight yellow oil. $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 8.65$ (s, 1H), 7.54 (dd, $J = 8.0$, 1.2 Hz, 1H), 7.04 (t, $J = 8.0$ Hz, 1H), 6.93 (dd, $J = 8.0$, 1.2 Hz, 1H), 3.87 (s, 3H), 3.86 (s, 3H), 1.30 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 152.8$, 151.5, 149.3, 131.1, 124.3, 118.8, 113.9, 61.8, 57.7, 56.0, 29.9. GC-MS (EI): calcd for C$_{13}$H$_{19}$NO$_2$ [M$^+$] 221.14, found 221.15.

**N-(2,3,4-trimethoxybenzylidene)-**tert-*butylamine (1c)**

The title compound was obtained as a yellow oil. $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 8.54$ (s, 1H), 7.67 (d, $J = 8.8$ Hz, 1H), 6.69 (d, $J = 8.8$ Hz, 1H), 3.92 (s, 3H), 3.88 (s, 3H), 3.87 (s, 3H), 1.29 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 155.5$, 153.8, 151.0, 141.9, 124.0, 122.0, 107.9, 62.0, 61.1, 57.4, 56.2, 30.0. GC-MS (EI): calcd for C$_{14}$H$_{21}$NO$_3$ [M$^+$] 251.15, found 251.15.
The title compound was obtained as a slight yellow solid. Melting point: 72–74 °C; $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 8.38$ (s, 1H), 6.11 (s, 2H), 3.82 (s, 3H), 3.79 (s, 6H), 1.30 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 161.9, 160.3, 150.7, 109.0, 91.0, 57.8, 56.1, 55.4, 30.0$. GC-MS (EI): calcd for C$_{14}$H$_{21}$NO$_3$ [M$^+$] 251.15, found 251.15.

The title compound was obtained as a white solid. Melting point: 64–66 °C; $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 8.66$ (s, 1H), 7.52 (d, $J = 3.2$ Hz, 1H), 6.89 (dd, $J = 8.8, 3.2$ Hz, 1H), 6.82 (d, $J = 8.8$ Hz, 1H), 3.82 (s, 3H), 3.81 (s, 3H), 1.29 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 154.0, 153.4, 151.2, 126.4, 117.9, 112.7, 110.9, 57.6, 56.4, 56.0, 30.0$. GC-MS (EI): calcd for C$_{13}$H$_{19}$NO$_2$ [M$^+$] 221.14, found 221.15.

The title compound was obtained as a colorless oil. $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 8.62$ (d, $J = 2.4$ Hz, 1H), 7.67 (dd, $J = 8.8, 3.2$ Hz, 1H), 7.04–6.99 (m, 1H), 6.80 (dd, $J = 8.8, 4.0$ Hz, 1H), 3.84 (s, 3H), 1.29 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 156.3$ (d, $J = 237.0$ Hz), 155.0 (d, $J = 2.0$ Hz), 150.4 (d, $J = 2.0$ Hz), 127.1 (d, $J = 7.0$ Hz), 117.3 (d, $J = 24.0$ Hz), 113.3 (d, $J = 24.0$ Hz), 112.2 (d, $J = 8.0$ Hz), 57.8, 56.2, 29.9; $^{19}$F NMR (377 MHz, CDCl$_3$): $\delta$...
= –123.62. GC-MS (EI): calcd for C_{12}H_{16}FNO [M^+] 209.12, found 209.10.

\[ \text{N-(5-chloro-2-methoxybenzyldene)- tert-butylamine (1g)} \]

The title compound was obtained as a white solid. Melting point: 45–47 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta = 8.60 \) (s, 1H), 7.93 (d, \( J = 2.8 \) Hz, 1H), 7.26 (dd, \( J = 8.8, 2.8 \) Hz, 1H), 6.80 (d, \( J = 8.8 \) Hz, 1H), 3.84 (s, 3H), 1.29 (s, 9H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta = 157.3, 150.2, 130.8, 127.2, 126.9, 126.3, 112.4, 57.8, 55.9, 29.9. \) GC-MS (EI): calcd for C\(_{12}\)H\(_{16}\)CINO [M^+] 225.09, found 225.11.

\[ \text{N-((5-methoxynaphthalen-1-yl)methylene)- tert-butylamine (1h)} \]

The title compound was obtained as a yellow oil. \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta = 9.02 \) (d, \( J = 8.8 \) Hz, 1H), 8.93 (s, 1H), 7.83 (d, \( J = 9.2 \) Hz, 1H), 7.73 (d, \( J = 8.0 \) Hz, 1H), 7.51–7.47 (m, 1H), 7.36–7.32 (m, 1H), 7.23 (d, \( J = 9.2 \) Hz, 1H), 3.95 (s, 3H), 1.41 (s, 9H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta = 157.4, 153.5, 132.2, 131.7, 129.5, 128.1, 127.7, 125.5, 124.0, 119.0, 113.0, 58.5, 56.8, 30.1. \) GC-MS (EI): calcd for C\(_{16}\)H\(_{19}\)NO [M^+] 241.15, found 241.16.

4. General Procedure for the Chromium-Catalyzed, Regioselective Cross-Coupling of C–O Bonds Using Aryl Bromide as Reactants

In a dried Schlenk tube were placed an ortho-methoxy-bearing aromatic imine 1 (0.2
mmol), Mg (11 mg, 0.44 mmol) and CrCl₂ (3 mg, 0.02 mmol), then aryl bromide (0.4 mmol) was added by a syringe under atmosphere of nitrogen. After that, 2 ml THF was added and the mixture was stirred at room temperature for 12 h. After quenched by 3 N HCl (1 mL), the resulting mixture was further stirred at room temperature for another 0.5 h, and then extracted with ethyl acetate (3 x 10 mL). The combined organic layer was dried over anhydrous Na₂SO₄ and concentrated under vacuum. The crude product was purified by silica gel chromatography to afford the desired product 3.

Biphenyl-2-carbaldehyde (3a)

The general procedure was applied to N-(2-methoxybenzylidene)-tert-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), bromobenzene (63 mg, 0.4 mmol) and CrCl₂ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a colorless oil (28 mg, 78% yield). ¹H NMR (400 MHz, CDCl₃): δ = 9.98 (s, 1H), 8.02 (dd, J = 7.6, 0.8 Hz, 1H), 7.61 (td, J = 7.6, 1.2 Hz, 1H), 7.51–7.44 (m, 5H), 7.39–7.37 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): δ = 192.6, 146.1, 137.9, 133.9, 133.7, 130.9, 130.2, 128.6, 128.2, 127.9, 127.7. IR (neat): 3060, 2844, 1689, 1596, 1473, 1392, 1252, 1194, 1075, 1008, 919, 827 cm⁻¹. Spectroscopic data are in accordance with those described in the literature.³

4'-Phenyl-biphenyl-2-carbaldehyde (3b)

The general procedure was applied to N-(2-methoxybenzylidene)-tert-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 4-bromobiphenyl (93 mg, 0.4 mmol) and CrCl₂ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column S7
chromatography on silica gel (EtOAc/PE = 1/50) to afford the title compound as a white solid (39 mg, 75% yield). Melting point: 111–113 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta = 10.06\) (s, 1H), 8.04 (d, \(J = 8.0\) Hz, 1H), 7.71–7.65 (m, 5H), 7.53–7.45 (m, 6H), 7.37 (t, \(J = 7.2\) Hz, 1H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta = 192.6, 145.7, 141.2, 140.4, 136.8, 133.9, 133.8, 130.9, 130.7, 129.1, 128.0, 127.83, 127.82, 127.3\). IR (neat): 3025, 2961, 2876, 1680, 1594, 1471, 1389, 1250, 1070, 1006, 856, 827 cm\(^{-1}\). Spectroscopic data are in accordance with those described in the literature.

\[
\text{4'-Fluoro-biphenyl-2-carbaldehyde (3c)}
\]

The general procedure was applied to \(N\)-(2-methoxybenzylidene)-\textit{tert}-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 4-bromofluorobenzene (70 mg, 0.4 mmol) and CrCl\(_2\) (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a colorless oil (24 mg, 61% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta = 9.97\) (s, 1H), 8.01 (dd, \(J = 8.0, 1.2\) Hz, 1H), 7.62 (td, \(J = 7.6, 1.6\) Hz, 1H), 7.49 (t, \(J = 7.6\) Hz, 1H), 7.41 (dd, \(J = 7.6, 0.8\) Hz, 1H), 7.38–7.33 (m, 2H), 7.20–7.14 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta = 192.2, 161.7\) (d, \(J = 247.0\) Hz), 144.9, 133.93, 133.89 (d, \(J = 1.0\) Hz), 133.8, 131.8 (d, \(J = 8.0\) Hz), 130.9, 128.1, 127.9, 115.5 (d, \(J = 21.0\) Hz); \(^{19}\)F NMR (377 MHz, CDCl\(_3\)): \(\delta = -113.77\). IR (neat): 3064, 2847, 1694, 1598, 1513, 1475, 1394, 1228, 1160, 841 cm\(^{-1}\). Spectroscopic data are in accordance with those described in the literature.

\[
\text{4'-Chloro-biphenyl-2-carbaldehyde (3d)}
\]

The general procedure was applied to \(N\)-(2-methoxybenzylidene)-\textit{tert}-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 4-bromochlorobenzene (77 mg, 0.4 mmol) and CrCl\(_2\) (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column
chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a colorless solid (26 mg, 60% yield). Melting point: 52–54 °C; $^1$H NMR (400 MHz, CDCl$_3$): $\delta =$ 9.97 (s, 1H), 8.02 (d, $J =$ 8.0 Hz, 1H), 7.63 (td, $J =$ 7.6, 1.2 Hz, 1H), 7.50 (t, $J =$ 7.6 Hz, 1H), 7.44 (d, $J =$ 8.4 Hz, 2H), 7.40 (d, $J =$ 7.6 Hz, 1H), 7.31 (d, $J =$ 8.4 Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta =$ 192.0, 144.6, 136.4, 134.6, 133.82, 133.77, 131.4, 130.8, 128.8, 128.3, 128.0. IR (neat): 3062, 2973, 2881, 1684, 1595, 1468, 1403, 1247, 1193, 1087, 1003, 841, 825 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^3$

![4'-Methyl-biphenyl-2-carbaldehyde](image)

**4'-Methyl-biphenyl-2-carbaldehyde (3e)**

The general procedure was applied to $N$-(2-methoxybenzylidene)-*tert*-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 4-bromotoluene (68 mg, 0.4 mmol) and CrCl$_2$ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a slight yellow oil (21 mg, 54% yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta =$ 9.99 (s, 1H), 8.00 (dd, $J =$ 8.0, 1.2 Hz, 1H), 7.60 (td, $J =$ 7.2, 1.2 Hz, 1H), 7.49–7.43 (m, 2H), 7.27 (m, 4H), 2.43 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta =$ 192.7, 146.1, 138.2, 134.9, 133.9, 133.7, 130.9, 130.2, 129.3, 127.67, 127.66, 21.3. IR (neat): 3025, 2920, 2847, 1689, 1596, 1515, 1474, 1448, 1392, 1252, 1193, 1005, 822 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^5$

![4'-Methoxy-biphenyl-2-carbaldehyde](image)

**4'-Methoxy-biphenyl-2-carbaldehyde (3f)**

The general procedure was applied to $N$-(2-methoxybenzylidene)-*tert*-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 4-bromoanisole (75 mg, 0.4 mmol) and CrCl$_2$ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/50) to afford the title compound as a colorless solid (21 mg, 54% yield). Melting point: 52–54 °C; $^1$H NMR (400 MHz, CDCl$_3$): $\delta =$ 9.97 (s, 1H), 8.02 (d, $J =$ 8.0 Hz, 1H), 7.63 (td, $J =$ 7.6, 1.2 Hz, 1H), 7.50 (t, $J =$ 7.6 Hz, 1H), 7.44 (d, $J =$ 8.4 Hz, 2H), 7.40 (d, $J =$ 7.6 Hz, 1H), 7.31 (d, $J =$ 8.4 Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta =$ 192.0, 144.6, 136.4, 134.6, 133.82, 133.77, 131.4, 130.8, 128.8, 128.3, 128.0. IR (neat): 3062, 2973, 2881, 1684, 1595, 1468, 1403, 1247, 1193, 1087, 1003, 841, 825 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^3$
oil (16 mg, 37% yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ = 9.99 (s, 1H), 7.99 (dd, $J$ = 8.0, 1.2 Hz, 1H), 7.60 (td, $J$ = 7.6, 1.6 Hz, 1H), 7.49–7.42 (m, 2H), 7.29 (dt, $J$ = 8.8, 2.8 Hz, 2H), 6.99 (dt, $J$ = 8.8, 2.8 Hz, 2H), 3.87 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ = 192.7, 159.8, 145.7, 133.9, 133.6, 131.4, 130.9, 130.1, 127.7, 127.5, 114.0, 55.5. IR (neat): 2933, 2837, 1688, 1609, 1596, 1514, 1473, 1297, 1244, 1177, 1033, 833 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^5$

![Chemical structure of 3'-Methoxy-biphenyl-2-carbaldehyde (3g)](image)

3'-Methoxy-biphenyl-2-carbaldehyde (3g)

The general procedure was applied to N-(2-methoxybenzylidene)-tert-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 3-bromoanisole (75 mg, 0.4 mmol) and CrCl$_2$ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/50) to afford the title compound as a colorless oil (25 mg, 58% yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ = 10.00 (s, 1H), 8.01 (d, $J$ = 8.0 Hz, 1H), 7.61 (td, $J$ = 7.6, 1.2 Hz, 1H), 7.48 (t, $J$ = 7.2 Hz, 1H), 7.44 (d, $J$ = 7.6 Hz, 1H), 7.36 (t, $J$ = 8.0 Hz, 1H), 7.00–6.92 (m, 3H), 3.85 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ = 192.6, 159.6, 145.9, 139.3, 133.9, 133.7, 130.7, 129.5, 128.0, 127.6, 122.8, 115.8, 113.7, 55.5. IR (neat): 3062, 2959, 2836, 1689, 1595, 1472, 1284, 1040, 1018, 868, 822 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^6$

![Chemical structure of 3'-Methyl-biphenyl-2-carbaldehyde (3h)](image)

3'-Methyl-biphenyl-2-carbaldehyde (3h)

The general procedure was applied to N-(2-methoxybenzylidene)-tert-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 3-bromotoluene (68 mg, 0.4 mmol) and CrCl$_2$ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/50) to afford the title compound as a colorless oil (25 mg, 58% yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ = 10.00 (s, 1H), 8.01 (d, $J$ = 8.0 Hz, 1H), 7.61 (td, $J$ = 7.6, 1.2 Hz, 1H), 7.48 (t, $J$ = 7.2 Hz, 1H), 7.44 (d, $J$ = 7.6 Hz, 1H), 7.36 (t, $J$ = 8.0 Hz, 1H), 7.00–6.92 (m, 3H), 3.85 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ = 192.6, 159.6, 145.9, 139.3, 133.9, 133.7, 130.7, 129.5, 128.0, 127.6, 122.8, 115.8, 113.7, 55.5. IR (neat): 3062, 2959, 2836, 1689, 1595, 1472, 1284, 1040, 1018, 868, 822 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^6$
mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a colorless oil (45 mg, 38% yield). \( ^1 \text{H NMR (400 MHz, CDCl}_3\)): \( \delta = 9.99 \) (s, 1H), 8.01 (dd, \( J = 8.0, 0.8 \) Hz, 1H), 7.61 (td, \( J = 7.6, 0.8 \) Hz, 1H), 7.47 (t, \( J = 7.6 \) Hz, 1H), 7.44 (d, \( J = 7.6 \) Hz, 1H), 7.34 (t, \( J = 7.6 \) Hz, 1H), 7.28–7.25 (m, 1H), 7.20–7.17 (m, 2H), 2.43 (s, 3H); \( ^{13} \text{C NMR (100 MHz, CDCl}_3\)): \( \delta = 192.8, 146.3, 138.3, 137.8, 133.8, 133.7, 131.0, 130.9, 129.0, 128.4, 127.8, 127.6, 127.4, 21.6 \). IR (neat): 3030, 2846, 1690, 1596, 1472, 1392, 1257, 1197, 1102, 822, 791 cm\(^{-1}\). Spectroscopic data are in accordance with those described in the literature.\(^5\)

![3'-Chloro-biphenyl-2-carbaldehyde (3i)](image)

**3'-Chloro-biphenyl-2-carbaldehyde (3i)**

The general procedure was applied to \( N \)-(2-methoxybenzylidene)-\( \text{tert} \)-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 3-bromochlorobenzene (77 mg, 0.4 mmol) and \( \text{CrCl}_2 \) (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a colorless solid (19 mg, 43% yield). Melting point: 42–44 °C; \( ^1 \text{H NMR (400 MHz, CDCl}_3\)): \( \delta = 9.97 \) (s, 1H), 8.02 (d, \( J = 8.0 \) Hz, 1H), 7.63 (td, \( J = 7.6, 1.2 \) Hz, 1H), 7.50 (t, \( J = 7.6 \) Hz, 1H), 7.44–7.38 (m, 4H), 7.26–7.24 (m, 1H); \( ^{13} \text{C NMR (100 MHz, CDCl}_3\)): \( \delta = 191.9, 144.4, 139.7, 134.6, 133.8, 133.7, 130.8, 130.0, 129.7, 128.5, 128.44, 128.39, 128.0 \). IR (neat): 3068, 2843, 1686, 1593, 1558, 1461, 1396, 1279, 1195, 1024, 899, 830 cm\(^{-1}\). Spectroscopic data are in accordance with those described in the literature.\(^7\)

![2-(Naphthalen-2-yl)benzaldehyde (3j)](image)

**2-(Naphthalen-2-yl)benzaldehyde (3j)**

The general procedure was applied to \( N \)-(2-methoxybenzylidene)-\( \text{tert} \)-butylamine (38 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 2-naphthyl bromide (83 mg, 0.4 mmol) and \( \text{CrCl}_2 \) (3 mg,
0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/50) to afford the title compound as a slight yellow oil (32 mg, 69% yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 10.03$ (s, 1H), 8.06 (d, $J = 8.0$ Hz, 1H), 7.95–7.87 (m, 3H), 7.82 (s, 1H), 7.65 (td, $J = 8.4$, 1.2 Hz, 1H), 7.56–7.51 (m, 5H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 192.6, 146.0, 135.3, 134.0, 133.7, 133.1, 132.9, 131.1, 129.6, 128.30, 128.26, 128.0, 127.9, 127.8, 127.0, 126.8$. IR (neat): 3055, 2844, 1691, 1595, 1484, 1393, 1256, 1195, 900, 861, 824 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^8$

![6-Methoxy-biphenyl-2-carbaldehyde (3n)](file)

6-Methoxy-biphenyl-2-carbaldehyde (3n)

The general procedure was applied to $N$-(2,3-dimethoxybenzylidene)-$\text{-}$ tert-$\text{-}$ butylamine (44 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), bromobenzene (63 mg, 0.4 mmol) and CrCl$_2$ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/50) to afford the title compound as a white solid (25 mg, 58% yield). Melting point: 72–74 °C; $^1$H NMR (400 MHz, CDCl$_3$): $\delta = 9.73$ (s, 1H), 7.61 (d, $J = 7.6$ Hz, 1H), 7.47–7.40 (m, 4H), 7.34–7.32 (m, 2H), 7.19 (d, $J = 8.0$ Hz, 1H), 3.79 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 192.7, 157.1, 135.5, 135.0, 133.2, 131.2, 128.9, 128.11, 128.06, 119.2, 116.0, 56.2$. IR (neat): 2959, 2869, 1679, 1591, 1576, 1497, 1253, 1237, 1064, 933, 907, 792 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^9$

![5,6-Dimethoxy-biphenyl-2-carbaldehyde (3o)](file)

5,6-Dimethoxy-biphenyl-2-carbaldehyde (3o)
The general procedure was applied to \(N\)-(2,3,4-trimethoxybenzylidene)-\textit{tert}-butylamine (50 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), bromobenzene (63 mg, 0.4 mmol) and CrCl\(_2\) (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/20) to afford the title compound as a slight yellow oil (16 mg, 33% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta = 9.60\) (s, 1H), 7.83 (d, \(J = 8.8\) Hz, 1H), 7.46–7.43 (m, 3H), 7.36–7.33 (m, 2H), 7.04 (d, \(J = 8.8\) Hz, 1H), 3.99 (s, 3H), 3.55 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta = 191.3, 157.8, 146.3, 140.6, 133.2, 130.7, 128.4, 128.13, 128.10, 111.5, 60.9, 56.2\). IR (neat): 2939, 2842, 1681, 1585, 1483, 1453, 1287, 1258, 1204, 1017, 935, 815 cm\(^{-1}\). Spectroscopic data are in accordance with those described in the literature.\(^2\)

![5-Methoxy-3-phenyl-biphenyl-2-carbaldehyde (3p)](image)

### 5-Methoxy-3-phenyl-biphenyl-2-carbaldehyde (3p)

The general procedure was applied to \(N\)-(2,4,6-trimethoxybenzylidene)-\textit{tert}-butylamine (50 mg, 0.2 mmol), Mg (21 mg, 0.88 mmol), bromobenzene (126 mg, 0.8 mmol) and CrCl\(_2\) (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/50) to afford the title compound as a slight yellow oil (17 mg, 29% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta = 9.82\) (s, 1H), 7.44–7.39 (m, 6H), 7.36–7.34 (m, 4H), 6.86 (s, 2H), 3.88 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \(\delta = 191.8, 161.6, 147.7, 140.1, 129.4, 128.2, 127.8, 126.1, 116.0, 55.7\). IR (neat): 3056, 2938, 2841, 1686, 1586, 1574, 1493, 1339, 1203, 1037, 902, 842 cm\(^{-1}\). Spectroscopic data are in accordance with those described in the literature.\(^2\)

![4-Methoxy-biphenyl-2-carbaldehyde (3q)](image)

### 4-Methoxy-biphenyl-2-carbaldehyde (3q)

The general procedure was applied to \(N\)-(2,5-dimethoxybenzylidene)-\textit{tert}-butylamine (44 mg,
0.2 mmol), Mg (11 mg, 0.44 mmol), bromobenzene (63 mg, 0.4 mmol) and CrCl₂ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/50) to afford the title compound as a white solid (8 mg, 18% yield). Melting point: 80–82 °C; ¹H NMR (400 MHz, CDCl₃): δ = 9.95 (s, 1H), 7.51 (d, J = 2.8 Hz, 1H), 7.48–7.41 (m, 3H), 7.39–7.34 (m, 3H), 7.19 (dd, J = 8.4, 2.8 Hz, 1H), 3.90 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ = 192.5, 159.3, 139.3, 137.6, 134.6, 132.2, 130.4, 128.5, 127.9, 121.6, 109.9, 55.7. IR (neat): 3062, 2956, 2848, 1683, 1606, 1481, 1443, 1388, 1285, 1197, 1048, 934, 886, 826 cm⁻¹. Spectroscopic data are in accordance with those described in the literature.¹⁰

4-Fluoro-biphenyl-2-carbaldehyde (3r)

The general procedure was applied to N-(5-fluoro-2-methoxybenzylidene)-tert-butylamine (42 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), bromobenzene (63 mg, 0.4 mmol) and CrCl₂ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a colorless oil (16 mg, 39% yield). ¹H NMR (400 MHz, CDCl₃): δ = 9.91 (d, J = 3.2 Hz, 1H), 7.68 (dd, J = 8.8, 2.8 Hz, 1H), 7.50–7.43 (m, 4H), 7.36–7.32 (m, 3H); ¹³C NMR (100 MHz, CDCl₃): δ = 191.3 (d, J = 1.0 Hz), 161.1 (d, J = 248.0 Hz), 142.2 (d, J = 3.0 Hz), 136.9, 135.3 (d, J = 7.0 Hz), 132.8 (d, J = 8.0 Hz), 130.3, 128.7, 128.4, 120.8 (d, J = 22.0 Hz), 113.6 (d, J = 22.0 Hz); ¹⁹F NMR (377 MHz, CDCl₃): δ = –113.18. IR (neat): 3066, 2856, 1689, 1607, 1478, 1393, 1265, 1207, 1148, 967, 886, 833 cm⁻¹. Spectroscopic data are in accordance with those described in the literature.⁵

4-Chloro-biphenyl-2-carbaldehyde (3s)

The general procedure was applied to N-(5-chloro-2-methoxybenzylidene)-tert-butylamine
(45 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), bromobenzene (63 mg, 0.4 mmol) and CrCl₂ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a slight yellow oil (15 mg, 34% yield). ¹H NMR (400 MHz, CDCl₃): δ = 9.92 (s, 1H), 7.99 (d, J = 2.0 Hz, 1H), 7.59 (dd, J = 8.0, 2.0 Hz, 1H), 7.50–7.44 (m, 3H), 7.40 (d, J = 8.4 Hz, 1H), 7.37–7.34 (m, 2H); ¹³C NMR (100 MHz, CDCl₃): δ = 191.2, 144.3, 136.7, 134.8, 134.5, 133.6, 132.4, 130.1, 128.8, 128.6, 127.5. IR (neat): 3060, 2925, 2850, 1692, 1591, 1471, 1389, 1240, 1183, 1008, 894, 833 cm⁻¹. Spectroscopic data are in accordance with those described in the literature.

5. General Procedure for the Chromium-Catalyzed, Regioselective Cross-Coupling of C–O Bonds Using Alkyl Bromide as Reactants

In a dried Schlenk tube were placed an ortho-methoxy-bearing aromatic aldimine 1 (0.2 mmol), Mg (11 mg, 0.44 mmol) and CrCl₂ (3 mg, 0.02 mmol), then alkyl bromide (0.4 mmol) was added by a syringe under atmosphere of nitrogen. After that, 2 ml THF was added and the mixture was stirred at room temperature for 12 h. After quenched by 3 N HCl (1 mL), the resulting mixture was further stirred at room temperature for another 0.5 h, and then extracted with ethyl acetate (3 x 10 mL). The combined organic layer was dried over anhydrous Na₂SO₄ and concentrated under vacuum. The crude product was purified by silica gel chromatography to afford the desired product 3.
2-Benzyl-1-naphthaldehyde (3k)

The general procedure was applied to N-((2-methoxynaphthalen-1-yl)methylene)-tert-butylamine (48 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 1-bromotoluene (68 mg, 0.4 mmol) and CrCl$_2$ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a slight yellow oil (31 mg, 63% yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ = 10.93 (s, 1H), 8.95 (d, $J$ = 8.8 Hz, 1H), 7.97 (d, $J$ = 8.4 Hz, 1H), 7.84 (d, $J$ = 8.0 Hz, 1H), 7.61 (t, $J$ = 7.2 Hz, 1H), 7.51 (t, $J$ = 8.0 Hz, 1H), 7.37 (d, $J$ = 8.4 Hz, 1H), 7.29–7.25 (m, 2H), 7.21–7.14 (m, 3H), 4.53 (s, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ = 193.6, 144.5, 140.4, 134.7, 132.9, 131.6, 129.6, 128.99, 128.95, 128.84, 128.76, 128.6, 126.6, 126.5, 124.9, 38.6. IR (neat): 3059, 2957, 2929, 2872, 1681, 1592, 1509, 1494, 1453, 1375, 1210, 1180, 1061, 859, 838 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^2$

2-Heptyl-1-naphthaldehyde (3l)

The general procedure was applied to N-((2-methoxynaphthalen-1-yl)methylene)-tert-butylamine (48 mg, 0.2 mmol), Mg (11 mg, 0.44 mmol), 1-bromoheptane (72 mg, 0.4 mmol) and CrCl$_2$ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a slight yellow oil (28 mg, 56% yield). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ = 10.90 (s, 1H), 9.02 (d, $J$ = 8.8 Hz, 1H), 7.94 (d, $J$ = 8.4 Hz, 1H), 7.81 (d, $J$ = 8.0 Hz, 1H), 7.63–7.59 (m, 1H), 7.48 (td, $J$ = 7.2, 0.8 Hz, 1H), 7.33 (d, $J$ = 8.4 Hz, 1H), 3.08 (t, $J$ = 8.0 Hz, 2H), 1.74–1.66 (m, 2H), 1.44–1.34 (m, 2H), 1.31–1.27 (m, 6H), 0.86 (t, $J$ = 7.2 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ = 193.5, 148.2, 134.6, 132.6, 131.4, 129.2, 128.8, 128.4, 128.2, 126.2, 125.0, 33.5, 33.4, 31.9, 29.7, 29.3, 22.8, 14.2. IR (neat): 3052, 2926, 2854, 1682, 1508, 1431, 1180, 1060, 823 cm$^{-1}$. Spectroscopic data are in accordance with those described in the literature.$^2$
2-Cyclohexyl-1-naphthaldehyde (3m)

The general procedure was applied to N-((2-methoxynaphthalen-1-yl)methylene)-tert-butylamine (60 mg, 0.25 mmol), Mg (11 mg, 0.44 mmol), cyclohexyl bromide (65 mg, 0.4 mmol) and CrCl₂ (3 mg, 0.02 mmol) at room temperature for 12 h. The crude product was purified by column chromatography on silica gel (EtOAc/PE = 1/100) to afford the title compound as a slight yellow oil (9 mg, 19% yield). ¹H NMR (400 MHz, CDCl₃): δ = 11.00 (s, 1H), 8.79 (d, J = 8.4 Hz, 1H), 7.98 (d, J = 8.8 Hz, 1H), 7.82 (d, J = 8.0 Hz, 1H), 7.61–7.51 (m, 2H), 7.48 (t, J = 7.2 Hz, 1H), 3.51–3.45 (m, 1H), 1.92–1.89 (m, 4H), 1.84–1.80 (m, 1H), 1.70–1.60 (m, 2H), 1.53–1.43 (m, 2H), 1.38–1.31 (m, 1H); ¹³C NMR (100 MHz, CDCl₃): δ = 194.3, 151.0, 134.1, 132.1, 131.1, 128.6, 128.4, 126.1, 124.9, 124.4, 39.4, 34.5, 26.9, 26.2. IR (neat): 3056, 2927, 2852, 1682, 1594, 1509, 1448, 1431, 1351, 1183, 1059, 892, 863, 823 cm⁻¹. Spectroscopic data are in accordance with those described in the literature.


**Gram-Scale Reaction:** In a dried Schlenk tube were placed an N-(2-methoxybenzylidene)-tert-butylamine 1a (1.5 g, 7.8 mmol), Mg (415 mg, 17 mmol), 4-bromobiphenyl (3.66 g, 15.7 mmol) and CrCl₂ (98 mg, 0.78 mmol), then a freshly distilled THF (70 mL) was added with a syringe under atmosphere of nitrogen. The mixture was stirred at room temperature for 12 h and then quenched by the addition of 3 N HCl (20 mL). The resulting mixture was stirred at room temperature for 0.5 h, and then extracted with ethyl acetate (3 x 40 mL). The combined organic layer was dried over anhydrous Na₂SO₄ and concentrated under reduced pressure. The crude product was purified by silica gel chromatography to afford the desired product 3b (1.43 g, 71% yield).
Synthesis of 2-phenyl-9H-fluoren-9-one (4)

The mixture of 3b (77 mg, 0.3 mmol), Tetraethylammonium chloride (6 mg, 0.03 mmol), and \( \text{K}_2\text{S}_2\text{O}_8 \) (162 mg, 2.0 equiv) in DCE (1.5 mL) was heated to 120 °C for 36 h, giving the title compound 4 as an orange solid (50.7 mg, 66% yield). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta = 7.91 \) (d, \( J = 1.6 \) Hz, 1H), 7.74–7.67 (m, 2H), 7.64–7.45 (m, 7H), 7.40–7.37 (m, 1H), 7.30 (td, \( J =7.6, 1.2 \) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta = 193.8, 144.3, 143.2, 142.3, 139.8, 134.9, 134.8, 134.5, 133.2, 129.0, 128.9, 127.9, 126.8, 124.4, 123.0, 120.7, 120.4 \). Spectroscopic data are in accordance with those described in the literature.\(^{11}\)

Supplementary References

7. $^1$H, $^{13}$C and $^{19}$F NMR Spectra

$^1$H and $^{13}$C NMR spectra for compound 1a
$^1$H and $^{13}$C NMR spectra for compound 1b
$^1$H and $^{13}$C NMR spectra for compound 1c
$^{1}H$ and $^{13}C$ NMR spectra for compound 1d
$^1$H and $^{13}$C NMR spectra for compound 1e
$^1$H, $^{19}$F and $^{13}$C NMR spectra for compound 1f
$^1$H and $^{13}$C NMR spectra for compound 1g
^1H and ^13C NMR spectra for compound 1h
$^1$H and $^{13}$C NMR spectra for compound 3a
$^1$H and $^{13}$C NMR spectra for compound 3b
$^1$H, $^{19}$F and $^{13}$C NMR spectra for compound 3c
$^1$H and $^{13}$C NMR spectra for compound 3d
$^1$H and $^{13}$C NMR spectra for compound 3e
$^1$H and $^{13}$C NMR spectra for compound 3f
$^1$H and $^{13}$C NMR spectra for compound 3g
$^1$H and $^{13}$C NMR spectra for compound 3h
$^1$H and $^{13}$C NMR spectra for compound 3i
$^1$H and $^{13}$C NMR spectra for compound 3j
$^1$H and $^{13}$C NMR spectra for compound 3k
$^1$H and $^{13}$C NMR spectra for compound 3l
$^1$H and $^{13}$C NMR spectra for compound 3m
$^1$H and $^{13}$C NMR spectra for compound 3n
$^1\text{H}$, $^{19}\text{F}$ and $^{13}\text{C}$ NMR spectra for compound 3o
$^1$H and $^{13}$C NMR spectra for compound 3p
$^1$H and $^{13}$C NMR spectra for compound 3q
$^1$H and $^{13}$C NMR spectra for compound 3r
$^1$H and $^{13}$C NMR spectra for compound 3s
$^1$H and $^{13}$C NMR spectra for compound 4