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Direct heteroarylation of 5-bromothiophen-2-ylpyridine and of 8-bromoquinoline *via* palladium-catalysed C–H bond activation: simpler access to heteroarylated nitrogen-based derivatives†

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The palladium-catalysed direct heteroarylation of the pyridyl-containing substrates, 2-(5-bromothiophen-2-yl)-pyridine and 8-bromoquinoline, proceeds in moderate to high yields with a variety of heteroarenes in the presence of 1–2 mol% of a palladium catalyst. This approach allows the access to polyheteroaromatics which are interesting building blocks as (*N*^*C*)-chelate ligands. The reaction proceeds regioselectively at the C5 position of thiophenes, thiazoles, furans or pyrroles and tolerates various substituents such as formyl, acetyl, ester, nitrile or chloro on the heteroarene. Therefore, this method allows a straightforward modulation of the electron density distribution on such derivatives.

Introduction

Recently, the palladium-catalysed direct arylation of heteroaromatics has emerged as a very powerful method for the synthesis of (hetero)arylated heteroaromatics.[1–4] However, there are still limitations for these reactions in terms of substrate scope. For example, the coupling of substrates incorporating a pyridine ring or its derivatives such as quinolines *via* C–H bond functionalization has attracted less attention due to the possible poisoning of palladium by coordination of the nitrogen atom.[1]

Nitrogen-based compounds containing heterocycles, such as heteroaryl-thienylpyridine or -quinoline (heteroaryl = thiophene, imidazole, indole…), have attracted increased interest due to their coordination and/or physical properties[5] making them important building blocks for the preparation of opto-electronic devices (Fig. 1).[6–8] For example, (oligo)thienylpyridine has been used to prepare single dye SAMs with multicolour fluorescence.[7d] Coordination of 2-pyridyl(oligo)thiophenes to platinum(II) or iridium(III) centres led to complexes displaying both phosphorescence and fluorescence properties.[7e] *N*,*N*-Quinoline-based boron complexes have been used to prepare electroluminescent devices.[8a] Cyclopentyldithiophene substituted by a quinoline moiety has been incorporated in dye-sensitized solar cells.[8g]

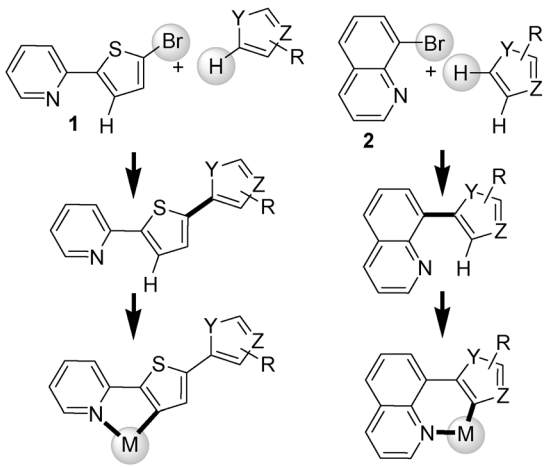

Fig. 1 A simpler access to nitrogen-based ligands.

Up to now, the introduction of various heteroaryl groups into these nitrogen-containing compounds has been achieved using Stille, Suzuki or Negishi type couplings.[7,8] To our knowledge, the synthesis of such compounds using palladium-catalysed coupling of **1** or **2** (Fig. 1) with heteroarenes *via* C–H bond functionalization has not been reported so far.

The palladium-catalysed direct heteroarylation of **1** or **2** would open the access to a variety of (*N*,*C*)-chelate ligands (precursors of five- and six-membered ring metal complexes, see Fig. 1) or extended conjugated systems. This method would present considerable advantages: (i) it would allow us to reduce

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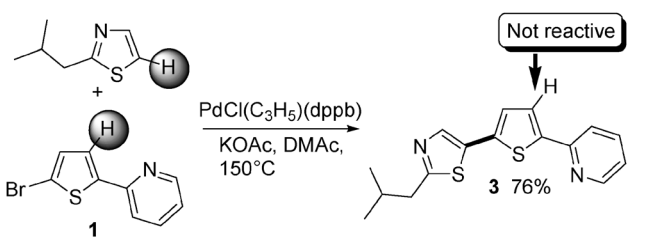
the number of steps and (ii) lower the amount of wastes produced. In addition, such coupling reactions are expected to present a better functional group tolerance, which would allow a straightforward modification of the heteroarene substituents.

Results and discussion

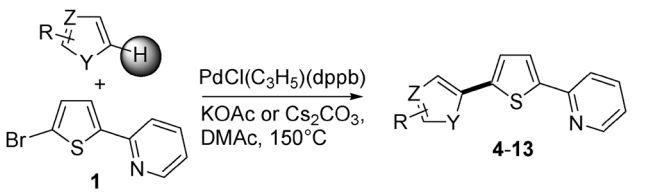
We now report (i) conditions for the palladium-catalysed direct regioselective arylation of 2-(5-bromothiophen-2-yl)pyridine **1** with a set of heteroarenes using a cheap base and an air stable catalyst, (ii) the reactivity of 2-thiophen-2-ylpyridine for direct arylation with aryl bromides, (iii) the coupling of 8-bromoquinoline **2** with a wide variety of heteroarenes.

We started our investigation on the C–H functionalization of 2-(5-bromothiophen-2-yl)pyridine **1** using 2-i-butylthiazole as the coupling partner as such heteroarenes had been previously found to be very reactive for palladium-catalysed direct arylation.[9] Since thiophenes are electron-rich heterocycles, the oxidative addition of bromothiophenes to the palladium centre often requires the use of phosphine ligands. The reaction using 1 mol% $PdCl(C_3H_5)(dppb)$ as the catalyst at 150 °C proceeded towards completion in 24 h affording **3** in 76% yield (Scheme 1). In the course of this coupling reaction, no side-products arising upon the activation of the C–H bond at the C3 position of the thiophene ring of **1**, *via* coordination of the pyridine ring, were detected. This reaction performed at 120 °C under similar reaction conditions gave **3** in only 15% yield due to a low conversion of **1**.

Then, we studied the scope of this reaction with various heteroarenes (Scheme 2 and Table 1). Good yields of **4**, **5** and **7** were also obtained for the coupling of **1** with thiophene-2-carbonitrile, 2-methyl-2(thiophen-2-yl)-1,3-dioxolane and 2-acetyl-4-chlorothiophene (Table 1, entries 1, 2 and 4). Lower yields of the desired coupling products **6** and **8** were obtained using 2-chlorothiophene and 1,2-dimethylimidazole (Table 1, entries 3 and 5). To enlarge the scope of the reaction, we also performed the 5-arylation of a pyrrole and a furan derivative. In the presence of 1-methyl-1*H*-pyrrole-2-carbaldehyde, the coupling product **9** was obtained in a moderate yield of 56% (Table 1, entry 6). The direct use of furan derivatives is an important field for research in green chemistry, since some of them can be obtained from agricultural wastes rich in pentosan polymers.

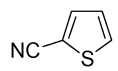
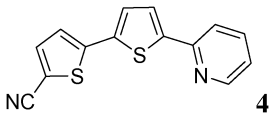
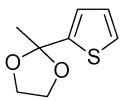
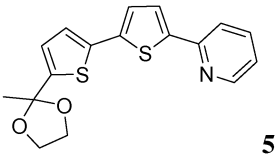
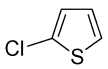
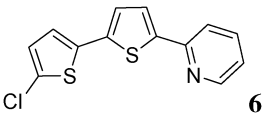
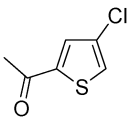
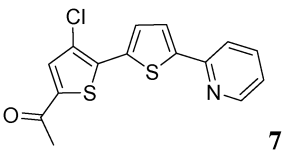
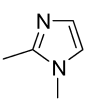
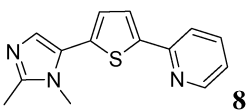
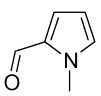
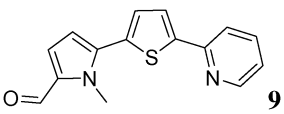
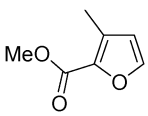
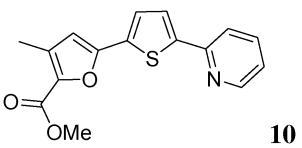
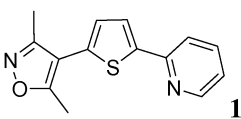
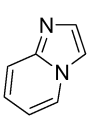
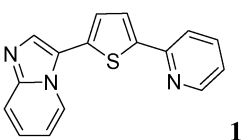
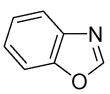
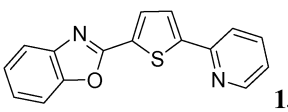


Scheme 1



Scheme 2

Table 1 Palladium-catalysed direct heteroarylations of 2-(5-bromothiophen-2-yl)-pyridine 1 (Scheme 2)

Entry	Heteroarene	Product	Yield (%)
1		 **4**	71[a]
2		 **5**	75
3		 **6**	62[a]
4		 **7**	70
5		 **8**	62[a]
6		 **9**	56
7		 **10**	26[a]
8		 **11**	29[a]
9		 **12**	88
10		 **13**	55[b]

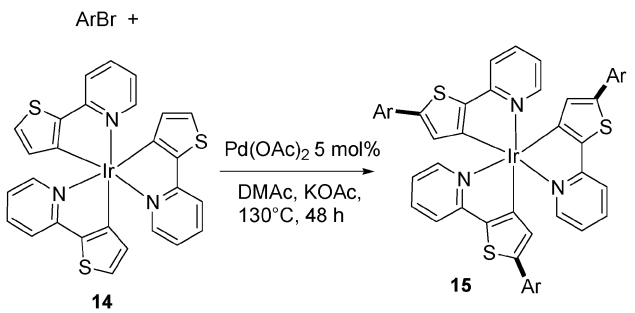
Conditions: $PdCl(C_3H_5)(dppb)$ (0.01 equiv.), 2-(5-bromothiophen-2-yl)-pyridine **1** (1 equiv.), heteroarene (2 equiv.), KOAc (2 equiv.), DMAc, 24 h, 150 °C.[a] $PdCl(C_3H_5)(dppb)$ (0.02 equiv.). [b] Cs_2CO_3 (2 equiv.) as base.

However, a low yield of **10** was obtained using methyl 2-methylfuran-3-carboxylate as a substrate (Table 1, entry 7). Furan derivatives are known to be quite unreactive heteroarenes.[9] The same trend was observed in the presence of 3,5-dimethylisoxazole. The coupling product **11** was obtained in only 29% yield (Table 1, entry 8).

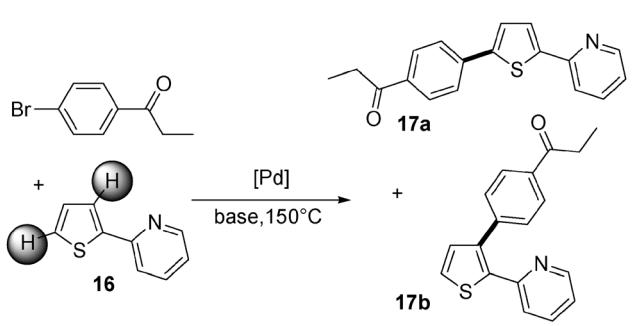
With the two latter heteroarenes, a dehalogenation side-reaction of **1** occurred affording 2-thienylpyridine in good amount. On the other hand, the reaction proceeded nicely in the presence of imidazo[1,2-*a*]pyridine, leading to the desired coupling product **12** in a high 88% yield (Table 1, entry 9). Finally, we investigated the C2 arylation of benzoxazole using the same catalyst, but in the presence of stronger base, Cs_2CO_3, which promotes the deprotonation of benzoxazole at the C2 position.[10] The coupling product **13** was successfully formed in 55% yield (Table 1, entry 10).

We have recently reported that the iridium-coordinated 2-thiophen-2-ylpyridines of complex **14** can be directly arylated with a variety of aryl bromides using 5 mol% $Pd(OAc)_2$ catalyst to give **15** (Scheme 3). Arylation occurs regioselectively at the thienyl-C5 position of the cyclometallated ligands.[11] Based on these results, we have examined the reactivity of 2-thiophen-2-ylpyridine **16** towards aryl bromides using various catalytic conditions (Scheme 4). This approach would also provide a simple access to the family of the polyheteroaromatics described above.

We studied the coupling of 2-thienylpyridine **16** with 4-bromopropiophenone (Scheme 4, Table 2). The results show that the reaction is not regioselective, as both the C3 and C5 positions of 2-thiophen-2-ylpyridine **16** were arylated. The two regioisomers, **17a** and **17b**, were produced in a 6 : 5 ratio, whatever the reaction conditions employed. The formation of the C5-arylated product



Scheme 3



Scheme 4

Table 2 Influence of the reaction conditions for the direct arylation of 2-thiophen-2-ylpyridine 16 with 4-bromopropiophenone (Scheme 4)

Entry	Catalyst	Base	Solvent	Yield of **17a** (%)
1	$PdCl(C_3H_5)(dppb)$	KOAc	DMAc	23
2	$PdCl(C_3H_5)(dppb)$	Cs_2CO_3	Xylene	25
3	$Pd(OAc)_2$	Cs_2CO_3	DMAc	24
4	$Pd(OAc)_2$	KOAc	DMAc	22
5	$Pd(OAc)_2$	KOAc	Xylene	23

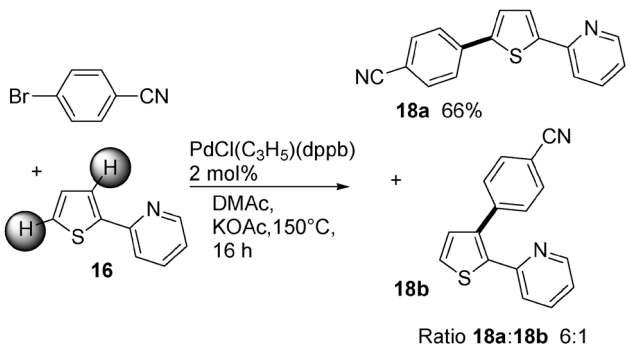
Conditions: [Pd] (0.02 equiv.), 2-thiophen-2-ylpyridine **16** (2 equiv.), 4-bromopropiophenone (1 equiv.), base (2 equiv.), 24 h, 150 °C. In all cases, a ratio **17a** : **17b** of 6 : 5 was obtained.

17a is assumed to involve a concerted metallation deprotonation mechanism;[12] whereas, the formation of **17b** likely arises from a coordination assisted mechanism as a result of coordination of the nitrogen atom of the pyridine ring to the palladium center. Such a coordination assisted mechanism has been proposed to explain the arylation at the C3 position of thiophene-2-carboxamides.[13] It should be noted that this mechanism is inhibited for cyclometallated thienylpyridine ligands in complex **14**. Even when the reaction proceeds towards completion in 36 h, it affords **17a** in only 22–25% yields using various reaction conditions (Table 2).

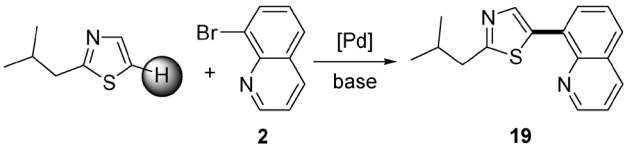
Then, we have investigated the influence of the nature of the aryl bromide on the regioselectivity of the arylation reaction (Scheme 5). Similarly, the reaction of **16** with 4-bromobenzonitrile led to a mixture of the C3 and C5 arylated products **18a** and **18b**. However, the regioselectivity was enhanced, as the desired C5 arylation product **18a** was obtained in 86% selectivity and in 66% yield.

Finally, we investigated the direct coupling of 8-bromoquinoline **2** with heteroarenes, as such reactions would provide a simple access to extended conjugated systems (Fig. 1; right).[8a,g]

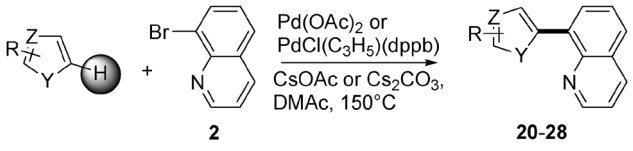
We first determined the influence of the reaction conditions for palladium-catalysed coupling of 2-isobutylthiazole with 8-bromoquinoline **2** (Scheme 6 and Table 3). When the reaction was performed with 2 mol% of $PdCl(C_3H_5)(dppb)$ in DMAc with KOAc at 150 °C for 24 h, the expected coupling product **19** was obtained in a low yield of 28% (Table 3, entry 1); while the use of CsOAc as the base afforded an improved yield in **19** of 43% (Table 3, entry 2). The nature of the solvent often modifies the catalytic activity in cross-coupling reactions; thus, we changed the solvent to DMF which is also known to be a good solvent for



Scheme 5



Scheme 6



Scheme 7

palladium C–H activation/functionalization. A relatively good yield in **19** (Table 3, entry 3) was obtained; however, we did not select this solvent due to the formation of several unidentified side-products, which were not observed in DMAc. An increase of the catalyst loading to 5 mol% afforded an higher yield of **19** (72%) (Table 3, entry 4). However, in the course of this reaction, a partial homo-coupling side-reaction of 8-bromoquinoline to form [8,8′]biquinolinyl took place. Then, we examined the efficiency of ligand free palladium catalyst $Pd(OAc)_2$, which is also known to be a very good catalyst system for the C–H activation of heteroarenes.[11] In order to avoid the formation of the homo-coupling side-product, we added to the reaction mixture Bu_4NBr which can act as a stabilizing agent for palladium catalysts, preventing them from fast aggregation. The presence of Bu_4NBr improved the yield of **19** to 78% when 5 mol% of $Pd(OAc)_2$ catalyst loading was used (Table 3, entries 5 and 6). On the other hand, when 2 mol% $Pd(OAc)_2$ was employed with or without additives, the reaction proceeded towards completion in 24 h affording quite similar yields of **19** (Table 3, entries 7 and 8). It should be noted that a lower reaction temperature of 120 °C gave a poor yield of **19** due to a low conversion of **2** (Table 3, entry 9). Therefore, we employed 2 mol% $Pd(OAc)_2$ or $PdCl(C_3H_5)(dppb)$ as a catalyst without additives in DMAc at 150 °C for the substrate scope investigation.

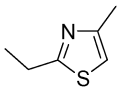
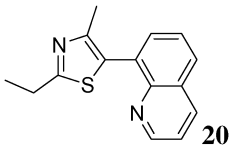
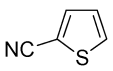
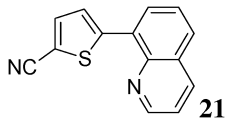
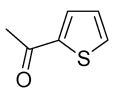
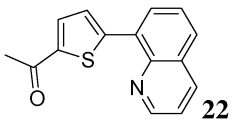
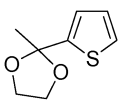
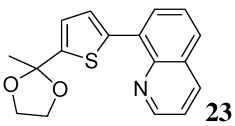
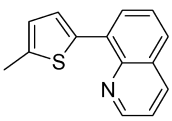
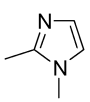
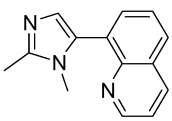
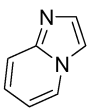
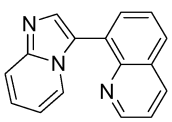
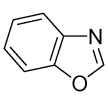
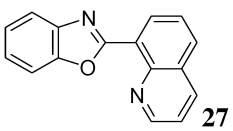
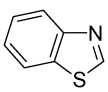
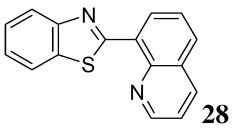
We examined the scope of the heteroarylation of 8-bromoquinoline **2** using a set of heteroarenes (Scheme 7 and Table 4). With 2-ethyl-4-methylthiazole, thiophene-2-carbonitrile or 2-acetylthiophene and 2 mol% $Pd(OAc)_2$, CsOAc as the base in DMAc at 150 °C, the coupling products **20**, **21** and **22** were obtained in moderate to high yields of 58%, 81% and 53%, respectively (Table 4, entries 1–3). The use of an acetyl functional group protected as an acetal gave a slightly higher yield of the product **23** (Table 4, entry 4). On the other hand, in the presence of 2-methylthiophene, and 2 mol% $Pd(OAc)_2$, a very low yield in **24** was obtained. Using 5 mol% of more stable $PdCl(C_3H_5)(dppb)$ catalyst, the product **24** was obtained in 35% yield due to a

Table 3 Influence of the reaction conditions for the direct arylation of 2-i-butylthiazole with 8-bromoquinoline **2** (Scheme 6)

Entry	Catalyst (mol%)	Solvent	Base	Additive	Yield in **19** (%)
1	$PdCl(C_3H_5)(dppb)$ (2)	DMAc	KOAc	—	28
2	$PdCl(C_3H_5)(dppb)$ (2)	DMAc	CsOAc	—	43
3	$PdCl(C_3H_5)(dppb)$ (2)	DMF	CsOAc	—	47
4	$PdCl(C_3H_5)(dppb)$ (5)	DMAc	CsOAc		72
5	$Pd(OAc)_2$ (5)	DMAc	CsOAc	—	17
6	$Pd(OAc)_2$ (5)	DMAc	CsOAc	Bu_4NBr	78
7	$Pd(OAc)_2$ (2)	DMAc	CsOAc	Bu_4NBr	84
8	$Pd(OAc)_2$ (2)	DMAc	CsOAc	—	76
9	$Pd(OAc)_2$ (2)	DMAc	CsOAc	—	17[a]

Conditions: 8-bromoquinoline **2** (1 equiv.), 2-i-butylthiazole (2 equiv.), base (2 equiv.), 24 h, 150 °C.[a] 120 °C.

Table 4 Palladium-catalysed direct arylation of heteroarenes with 8-bromoquinoline **2** (Scheme 7)

Entry	Heteroarene	Product	Yield (%)
1		 **20**	58
2		 **21**	81
3		 **22**	53
4		 **23**	58
5		 **24**	35[a]
6		 **25**	73
7		 **26**	81
8		 **27**	88[b]
9		 **28**	61[b]

Conditions: $Pd(OAc)_2$ (0.02 equiv.), 8-bromoquinoline **2** (1 equiv.), heteroarenes (2 equiv.), CsOAc (2 equiv.), DMAc, 24–27 h, 150 °C. [a] $PdCl(C_3H_5)(dppb)$ (0.05 equiv.). [b] Cs_2CO_3 (2 equiv.) as base, $PdCl(C_3H_5)(dppb)$ (0.035 equiv.).

partial conversion of the 8-bromoquinoline (Table 4, entry 5). It should be noted that such 8-thienyl-substituted quinolines have been employed for the synthesis of cyclometallated platinum complexes.[14] We also studied the reactivity of some imidazole derivatives such as 1,2-dimethylimidazole and imidazo[1,2-*a*]-pyridine. In both cases, the reaction proceeds nicely to give the target products **25** and **26** in high yields of 73% and 81%, respectively (Table 4, entries 6 and 7). The C2 arylation of benzoxazole and benzothiazole with 8-bromoquinoline was also examined using again the stronger base Cs_2CO_3.[10] When benzoxazole was used in the presence of 3.5 mol% $PdCl(C_3H_5)$-(dppb) catalyst, the reaction proceeded nicely to give the desired coupling product **27** in high isolated yield (Table 4, entry 8). The reaction with benzothiazole, using the same reaction conditions, led to the coupling product **28** in a lower yield of 61% (Table 4, entry 9). In the course of this reaction, side-reactions to form quinoline and [8,8′]biquinolinyl were also observed.

Conclusion

In summary, we have demonstrated that the palladium-catalysed direct heteroarylation of 2-(5-bromothiophen-2-yl)pyridine **1** and 8-bromoquinoline **2** proceeds with a variety of heteroarenes. It should be noted that this protocol, which employs a moderate loading of air stable catalysts, is applicable to a wide range of heteroarenes. This procedure allowed us to synthesize in one step new heteroarylated-(thienyl)pyridine and -quinoline derivatives. Moreover, we found that this method tolerates several functional groups on the incorporated heteroaryl group. In addition, the major by-products of these couplings are KBr or CsBr/AcOH instead of metallic salts obtained using more classical coupling procedures, making this process economically viable and environmentally attractive. Therefore, this method will open up new perspectives for the design of nitrogen-based building blocks, which are useful due to their potential coordination and photophysical properties.

Experimental section

General remarks

All the reactions were performed under argon using a Schlenk tube apparatus and pre-dried glassware. All chemical reactants were obtained from commercial sources and used without further purification. DMAc of analytical grade (99%) was not distilled before use. KOAc 99+, CsOAc 99+ and Cs_2CO_3 99% were used. Flash chromatography was performed on silica gel (230–400 mesh). Thin-layer chromatography was carried out using Merck silica gel GF_{254} plates. Chromatograms were recorded using a SHIMADZU GCMS-GP2010S gas chromatograph mass spectrometer. ^{1}H NMR and ^{13}C NMR were recorded on Bruker Avance-300, -400, -500. The chemical shifts are reported in ppm (δ) relative to $CDCl_3$ (^{1}H: 7.26 and ^{13}C: 77.0).

Representative procedure for the heteroarylation of 2-(5-bromothiophen-2-yl)pyridine 1

As a typical experiment, 2-(5-bromothiophen-2-yl)pyridine **1** (1 mmol), heteroaryl partner (2 mmol), KOAc or Cs_2CO_3 (see Table 1) (2 mmol) in the presence of $PdCl(C_3H_5)$(dppb) (6.1 mg, 0.01 mmol or 12.2 mg, 0.02 mmol) (see Table 1) were dissolved in DMAc (4 mL) under an argon atmosphere. The reaction mixture was stirred in a pre-heated oil bath at 150 °C for 24 h. After allowing the reaction mixture to cool down to room temperature, the coupling product was obtained after evaporation of the solvent and filtration on silica gel.

2-[5-(2-Isobutylthiazol-5-yl)-thiophen-2-yl]-pyridine (3). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), 2-isobutylthiazole (0.282 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (6.1 mg, 0.01 mmol) in DMAc for 24 h affords the product **3** in 76% (0.228 g) yield as a yellow solid (mp 94–97 °C). Purification was performed using diethylether–pentane (3/7) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.55 (d, J = 4.8 Hz, 1H), 7.78 (s, 1H), 7.65 (m, 2H), 7.46 (d, J = 3.8 Hz, 1H), 7.12 (m, 2H), 2.86 (d, J = 7.1 Hz, 2H), 2.14 (m, 1H), 1.02 (d, J = 6.6 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.2, 151.8, 149.4, 143.9, 138.0, 136.4, 135.2, 131.5, 125.6, 124.7, 121.8, 118.2, 42.2, 29.5, 22.0. Elemental analysis calcd (%) for $C_{16}H_{16}N_2S_2$ (300.44): C, 63.96; H, 5.37%; found: C, 64.11; H, 5.48%.

5′-Pyridin-2-yl-[2,2′]bithiophenyl-5-carbonitrile (4). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), thiophene-2-carbonitrile (0.218 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (12.2 mg, 0.02 mmol) in DMAc for 24 h affords the product **4** in 71% (0.190 g) yield as a bright yellow solid (mp 186–189 °C). Purification was performed using diethylether–pentane (3/7) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.59 (d, J = 4.5 Hz, 1H), 7.70 (m, 2H), 7.54 (d, J = 3.9 Hz, 1H), 7.50 (d, J = 3.9 Hz, 1H), 7.28 (d, J = 3.9 Hz, 1H), 7.20 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 151.6, 149.7, 146.3, 144.6, 138.3, 136.8, 136.4, 126.7, 125.1, 123.6, 122.5, 118.7, 114.1, 107.7. Elemental analysis calcd (%) for $C_{14}H_8N_2S_2$ (268.36): C, 62.66; H, 3.00%; found: C, 62.78; H, 3.14%.

2-[5′-(2-Methyl-[1,3]dioxolan-2-yl)-[2,2′]bithiophenyl-5-yl]-pyridine (5). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), 2-methyl-2-thiophen-2-yl-[1,3]dioxolane (0.340 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (6.1 mg, 0.01 mmol) in DMAc for 24 h affords the product **5** in 75% (0.247 g) yield as a light green solid (mp 118–121 °C). Purification was performed using diethylether–pentane (1/4) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.54 (d, J = 4.6 Hz, 1H), 7.63 (m, 2H), 7.46 (d, J = 3.7 Hz, 1H), 7.14 (m, 2H), 7.09 (d, J = 3.7 Hz, 1H), 6.96 (d, J = 3.7 Hz, 1H), 4.03 (m, 4H), 1.79 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.2, 149.5, 146.7, 143.3, 139.2, 136.9, 136.5, 125.0, 124.9, 124.3, 123.7, 121.8, 118.4, 107.0, 65.0, 27.4. Elemental analysis calcd (%) for $C_{17}H_{15}NO_2S_2$ (329.44): C, 61.98; H, 4.59%; found: C, 61.99; H, 4.44%.

2-(5′-Chloro-[2,2′]bithiophenyl-5-yl)-pyridine (6). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), 2-chlorothiophene (0.237 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (12.2 mg, 0.02 mmol) in DMAc for 24 h affords the product **6** in 62% (0.172 g) yield as a light green solid (mp 133–136 °C). Purification was performed using diethylether–pentane (1/49) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.57 (d, J = 4.6 Hz, 1H), 7.69 (m, 2H), 7.45 (d, J = 3.8 Hz, 1H), 7.16 (t, J = 4.6 Hz, 1H),

7.10 (d, J = 3.8 Hz, 1H), 7.01 (d, J = 3.8 Hz, 1H), 6.86 (d, J = 3.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.1, 149.6, 143.8, 138.3, 136.6, 136.1, 129.1, 127.0, 125.0, 124.5, 123.1, 122.0, 118.5. Elemental analysis calcd (%) for $C_{13}H_8ClNS_2$ (277.79): C, 56.21; H, 2.90%; found: C, 56.10; H, 2.98%.

1-(3-Chloro-5′-pyridin-2-yl-[2,2′]bithiophenyl-5-yl)-ethanone (7). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), 1-(4-chloro-thiophen-2-yl)-ethanone (0.321 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (6.1 mg, 0.01 mmol) in DMAc for 24 h affords the product **7** in 70% (0.223 g) yield as an orange solid (mp 163–166 °C). Purification was performed using diethylether–pentane (1/4) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.59 (d, J = 4.6 Hz, 1H), 7.66 (m, 2H), 7.55 (m, 3H), 7.18 (t, J = 6.5 Hz, 1H), 2.53 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.4, 151.8, 149.7, 146.9, 139.6, 138.8, 136.7, 134.7, 133.8, 128.6, 124.6, 122.5, 121.8, 118.9, 26.2. Elemental analysis calcd (%) for $C_{15}H_{10}ClNOS_2$ (319.83): C, 56.33; H, 3.15%; found: C, 56.47; H, 3.04%.

2-[5-(2,3-Dimethylimidazol-4-yl)-thiophen-2-yl]-pyridine (8). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), 1,2-dimethylimidazole (0.192 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (12.2 mg, 0.02 mmol) in DMAc for 24 h affords the product **8** in 62% (0.158 g) yield as a brown solid (mp 120–123 °C). Purification was performed using methanol–dichloromethane (1/49) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.56 (d, J = 4.8 Hz, 1H), 7.67 (m, 2H), 7.54 (d, J = 3.8 Hz, 1H), 7.15 (t, J = 4.8 Hz, 1H), 7.12 (s, 1H), 7.04 (d, J = 3.8 Hz, 1H), 3.65 (s, 3H), 2.44 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.2, 149.5, 146.7, 144.5, 136.6, 133.5, 127.4, 126.7, 126.5, 124.7, 121.9, 118.4, 31.5, 13.7. Elemental analysis calcd (%) for $C_{14}H_{13}N_3S$ (255.34): C, 65.85; H, 5.13%; found: C, 65.74; H, 5.12%.

1-Methyl-5-(5-pyridin-2-ylthiophen-2-yl)-pyrrole-2-carbaldehyde (9). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), 1-methylpyrrole-2-carbaldehyde (0.218 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (6.1 mg, 0.01 mmol) in DMAc for 24 h affords the product **9** in 56% (0.150 g) yield as a brown solid (mp 113–116 °C). Purification was performed using diethylether–pentane (1/4) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.57 (s, 1H), 8.59 (d, J = 4.6 Hz, 1H), 7.72 (m, 3H), 7.58 (d, J = 3.8 Hz, 1H) 7.23 (d, J = 3.8 Hz, 1H), 6.96 (d, J = 4.1 Hz, 1H), 6.50 (d, J = 4.1 Hz, 1H), 4.15 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 179.5, 151.9, 149.5, 146.1, 137.1, 136.6, 134.0, 133.4, 128.0, 124.6, 124.3, 122.2, 118.5, 111.3, 34.4. Elemental analysis calcd (%) for $C_{15}H_{12}N_2OS$ (268.33): C, 67.14; H, 4.51%; found: C, 67.20; H, 4.45%.

Methyl 2-methyl-5-(5-pyridin-2-yl-thiophen-2-yl)-furan-3-carboxylate (10). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), methyl 2-methylfuran-3-carboxylate (0.280 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (12.2 mg, 0.02 mmol) in DMAc for 24 h affords the product **10** in 26% (0.078 g) yield as brown oil. Purification was performed using diethylether–pentane (3/7) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.57 (d, J = 4.5 Hz, 1H), 7.66 (m, 2H), 7.50 (d, J = 3.8 Hz, 1H), 7.24 (d, J = 3.8 Hz, 1H), 7.14 (t, J = 5.7 Hz, 1H), 6.78 (s, 1H), 3.85 (s, 3H), 2.64 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.2, 158.8, 152.2, 149.6, 147.2, 143.6, 136.6, 134.4, 125.0, 123.6, 122.0, 118.6, 115.2, 106.0, 51.4, 13.8. Elemental analysis calcd (%) for $C_{16}H_{13}NO_3S$ (299.35): C, 64.20; H, 4.38%; found: C, 64.17; H, 4.30%.

2-[5-(3,5-Dimethylisoxazol-4-yl)-thiophen-2-yl]-pyridine (11). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), 3,5-dimethylisoxazole (0.194 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (12.2 mg, 0.02 mmol) in DMAc for 24 h affords the product **11** in 29% (0.074 g) yield as a light green solid (mp 122–125 °C). Purification was performed using diethylether–pentane (1/4) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.58 (d, J = 4.5 Hz, 1H), 7.69 (m, 2H), 7.56 (d, J = 3.8 Hz, 1H), 7.17 (t, J = 5.1 Hz, 1H), 7.03 (d, J = 3.8 Hz, 1H), 2.56 (s, 3H), 2.41 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.9, 158.5, 152.2, 149.6, 144.6, 136.7, 133.5, 126.9, 124.7, 122.1, 118.5, 110.7, 12.2, 11.3. Elemental analysis calcd (%) for $C_{14}H_{12}N_2OS$ (256.32): C, 65.60; H, 4.72%; found: C, 65.41; H, 4.66%.

3-(5-Pyridin-2-ylthiophen-2-yl)-imidazo[1,2-*a*]pyridine (12). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), imidazo[1,2-*a*]pyridine (0.236 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (6.1 mg, 0.01 mmol) in DMAc for 24 h affords the product **12** in 88% (0.244 g) yield as a brown solid (mp 95–98 °C). Purification was performed using methanol–dichloromethane (1/99) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.57 (m, 2H), 7.86 (s, 1H), 7.72 (m, 3H), 7.64 (d, J = 3.8 Hz, 1H), 7.31 (d, J = 3.8 Hz, 1H), 7.19 (m, 2H), 6.91 (t, J = 6.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.1, 149.7, 146.6, 144.5, 136.7, 133.7, 132.1, 126.2, 124.9, 124.6, 124.2, 122.2, 119.7, 118.6, 118.3, 113.1. Elemental analysis calcd (%) for $C_{16}H_{11}N_3S$ (277.34): C, 69.29; H, 4.00%; found: C, 69.42; H, 3.88%.

2-(5-Pyridin-2-ylthiophen-2-yl)-benzoxazole (13). The reaction of 2-(5-bromothiophen-2-yl)-pyridine **1** (0.240 g, 1 mmol), benzoxazole (0.238 g, 2 mmol), Cs_2CO_3 (0.652 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (6.1 mg, 0.01 mmol) in DMAc for 24 h affords the product **13** in 55% (0.153 g) yield as an orange solid (mp 182–185 °C). Purification was performed using diethylether–pentane (3/7) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.62 (d, J = 4.6 Hz, 1H), 7.91 (d, J = 3.9 Hz, 1H), 7.71 (m, 3H), 7.63 (d, J = 3.9 Hz, 1H), 7.55 (m, 1H), 7.35 (m, 2H), 7.21 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.9, 151.6, 150.5, 149.8, 149.4, 142.1, 136.8, 130.7, 130.6, 125.3, 125.2, 124.7, 122.8, 119.9, 119.1, 110.4. Elemental analysis calcd (%) for $C_{16}H_{10}N_2OS$ (278.33): C, 69.04; H, 3.62%; found: C, 69.18; H, 3.45%.

Representative procedure for the arylation of 2-(thiophen-2-yl)-pyridine 16

As a typical experiment, the aryl bromide (1 mmol), 2-(thiophen-2-yl)pyridine **16** (2 mmol), and KOAc (2 mmol) in the presence of $PdCl(C_3H_5)$(dppb) (0.02 mmol) were dissolved in DMAc (4 mL) under an argon atmosphere. The reaction mixture was stirred in an oil bath pre-heated at 150 °C for 16 or 24 h. After allowing the reaction mixture to cool down to room temperature, the coupling product was obtained after evaporation of the solvent and filtration on silica gel.

1-[4-(5-Pyridin-2-ylthiophen-2-yl)-phenyl]-propan-1-one (17a) and 1-[4-(2-pyridin-2-ylthiophen-3-yl)-phenyl]-propan-1-one (17b). The reaction of 4-bromopropiophenone (0.212 g, 1 mmol), 2-(thiophen-2-yl)pyridine 16 (0.322 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)(dppb)$ (12.2 mg, 0.02 mmol) in DMAc for 24 h affords the products **17a** and **17b** in a 6 : 5 (**17a** : **17b**) ratio and in 23% (0.067 g) and 14% (0.041 g) isolated yields as light yellow solids (mp 80–83 °C and 138–141 °C, respectively). Purification was performed using diethylether–pentane (1/4) as the eluent. **17a**: ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.58 (d, J = 4.6 Hz, 1H), 7.99 (d, J = 7.9 Hz, 2H), 7.74 (d, J = 7.9 Hz, 2H), 7.70 (m, 2H), 7.56 (d, J = 3.5 Hz, 1H), 7.42 (d, J = 3.5 Hz, 1H), 7.16 (t, J = 5.5 Hz, 1H), 3.01 (q, J = 7.1 Hz, 2H), 1.23 (t, J = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 199.9, 152.1, 149.6, 145.4, 144.5, 138.3, 136.6, 135.7, 128.7, 125.5, 125.4, 125.3, 122.1, 118.6, 31.7, 8.2. Elemental analysis calcd (%) for $C_{18}H_{15}NOS$ (293.38): C, 73.69; H, 5.15%; found: C, 73.79; H, 5.24%. **17b**: ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.59 (d, J = 4.6 Hz, 1H), 7.97 (d, J = 7.5 Hz, 2H), 7.46 (d, J = 7.5 Hz, 2H), 7.44–7.40 (m, 2H), 7.12–7.08 (m, 2H), 6.99 (d, J = 8.0 Hz, 1H), 3.01 (q, J = 7.5 Hz, 2H), 1.24 (t, J = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 200.4, 152.6, 149.7, 141.5, 140.1, 138.6, 136.0, 135.8, 130.7, 129.3, 128.4, 126.9, 122.2, 122.0, 31.8, 8.2.

4-(5-(Pyridin-2-yl)thiophen-2yl)benzonitrile (18a). The reaction of 4-bromobenzonitrile (0.182 g, 1 mmol), 2-(thiophen-2-yl)-pyridine **16** (0.322 g, 2 mmol), KOAc (0.196 g, 2 mmol) and $PdCl(C_3H_5)(dppb)$ (12.2 mg, 0.02 mmol) in DMAc for 16 h affords the product **18a** in 66% (0.173 g) isolated yield as a yellow solid (mp 195–198 °C). Purification was performed using diethylether–pentane (1/4) as the eluent. ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.60 (d, J = 4.5 Hz, 1H), 7.75 (d, J = 8.5 Hz, 2H), 7.71 (d, J = 7.2 Hz, 1H), 7.70–7.65 (m, 3H), 7.58 (d, J = 3.9 Hz, 1H), 7.42 (d, J = 3.9 Hz, 1H), 7.19 (t, J = 5.5 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 151.9, 149.7, 146.3, 143.4, 138.5, 136.8, 132.8, 126.0, 125.9, 125.5, 122.4, 118.8, 118.7, 110.8. Elemental analysis calcd (%) for $C_{16}H_{10}N_2S$ (262.33): C, 73.26; H, 3.84%; found: C, 73.36; H, 3.89%.

Representative procedure for the heteroarylation of 8-bromoquinoline 2

As a typical experiment, 8-bromoquinoline **2** (1 mmol), heteroaryl partner (2 mmol), CsOAc (2 mmol) in the presence of $Pd(OAc)_2$ or $PdCl(C_3H_5)(dppb)$ were dissolved in DMAc (4 mL) under an argon atmosphere. The reaction mixture was stirred in an oil bath pre-heated at 150 °C for 24–27 h. After allowing the reaction mixture to cool down to room temperature, the coupling product was obtained after evaporation of the solvent and filtration on silica gel.

8-(2-Isobutylthiazol-5-yl)-quinoline (19). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), 2-isobutylthiazole (0.282 g, 2 mmol), CsOAc (0.384 g, 2 mmol) and $Pd(OAc)_2$ (4.5 mg, 0.02 mmol) in DMAc for 24 h affords the product **19** in 76% (0.204 g) yield as a yellow oil. Purification was performed using diethylether–pentane (2/3) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.01 (d, J = 3.8 Hz, 1H), 8.31 (s, 1H), 8.19 (d, J = 8.0 Hz, 1H), 8.10 (d, J = 7.3 Hz, 1H), 7.78 (d, J = 8.0 Hz, 1H), 7.59 (t, J = 8.0 Hz, 1H), 7.47 (dd, J = 8.0, 3.8 Hz, 1H), 2.95 (d, J = 7.1 Hz, 2H), 2.23 (m, 1H), 1.06 (d, J = 6.6 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 172.9, 149.4, 144.1, 140.6, 136.4, 133.2, 130.8, 128.7, 127.6, 127.4, 126.4, 121.4, 42.3, 29.8, 22.5. Elemental analysis calcd (%) for $C_{16}H_{16}N_2S$ (268.38): C, 71.60; H, 6.01%; found: C, 71.78; H, 5.89%.

8-(2-Ethyl-4-methylthiazol-5-yl)-quinoline (20). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), 2-ethyl-4-methylthiazole (0.254 g, 2 mmol), CsOAc (0.384 g, 2 mmol) and $Pd(OAc)_2$ (4.5 mg, 0.02 mmol) in DMAc for 24 h affords the product **20** in 58% (0.193 g) yield as a brown oil. Purification was performed using diethylether only as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.91 (d, J = 4.1 Hz, 1H), 8.14 (d, J = 8.2 Hz, 1H), 7.79 (d, J = 8.1 Hz, 1H), 7.69 (d, J = 7.3 Hz, 1H), 7.53 (t, J = 7.6 Hz, 1H), 7.39 (dd, J = 8.2, 4.1 Hz, 1H), 3.01 (q, J = 7.6 Hz, 2H), 2.34 (s, 3H), 1.40 (t, J = 7.6 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.4, 150.5, 149.7, 146.6, 136.7, 132.1, 129.0, 128.6, 127.2, 126.4, 121.6, 27.2, 16.9, 14.5. Elemental analysis calcd (%) for $C_{15}H_{14}N_2S$ (254.35): C, 70.83; H, 5.55%; found: C, 70.70; H, 5.42%.

5-Quinolin-8-ylthiophene-2-carbonitrile (21). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), thiophene-2-carbonitrile (0.218 g, 2 mmol), CsOAc (0.384 g, 2 mmol) and $Pd(OAc)_2$ (4.5 mg, 0.02 mmol) in DMAc for 26 h affords the product **21** in 81% (0.191 g) yield as a bright yellow solid (mp 131–134 °C). Purification was done using dichloromethane–pentane (8/2) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.01 (d, J = 4.1 Hz, 1H), 8.22 (d, J = 8.2 Hz, 1H), 8.17 (d, J = 7.4 Hz, 1H), 7.83 (d, J = 8.1 Hz, 1H), 7.70 (d, J = 4.1 Hz, 1H), 7.62 (m, 2H), 7.51 (dd, J = 8.2, 4.1 Hz, 1H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 149.4, 146.0, 143.7, 136.7, 136.0, 130.6, 128.8, 128.7, 127.5, 126.5, 124.9, 121.8, 115.4, 112.2. Elemental analysis calcd (%) for $C_{14}H_8N_2S$ (236.29): C, 71.16; H, 3.41%; found: C, 71.14; H, 3.49%.

1-(5-Quinolin-8-ylthiophen-2-yl)-ethanone (22). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), 2-acetylthiophene (0.252 g, 2 mmol), CsOAc (0.384 g, 2 mmol) and $Pd(OAc)_2$ (4.5 mg, 0.02 mmol) in DMAc for 26 h affords the product **22** in 53% (0.134 g) yield as a white solid (mp 132–135 °C). Purification was performed using diethylether–pentane (1/4) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.04 (d, J = 4.1 Hz, 1H), 8.21 (d, J = 8.2 Hz, 1H), 8.14 (d, J = 7.5 Hz, 1H), 7.83 (d, J = 8.1 Hz, 1H), 7.77 (d, J = 4.1 Hz, 1H), 7.75 (d, J = 4.1 Hz, 1H), 7.60 (t, J = 7.5 Hz, 1H), 7.49 (dd, J = 8.2, 4.1 Hz, 1H), 2.62 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 191.3, 149.8, 147.8, 145.3, 144.5, 136.4, 131.9, 131.8, 128.7, 128.6, 128.3, 127.1, 126.3, 121.5, 20.7. Elemental analysis calcd (%) for $C_{15}H_{11}NOS$ (253.32): C, 71.12; H, 4.38%; found: C, 71.05; H, 4.48%.

8-[5-(2-Methyl-[1,3]dioxolan-2-yl)-thiophen-2-yl]-quinoline (23). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), 2-methyl-2-thiophen-2-yl-[1,3]dioxolane (0.340 g, 2 mmol), CsOAc (0.384 g, 2 mmol) and $Pd(OAc)_2$ (4.5 mg, 0.02 mmol) in DMAc for 26 h affords the product **23** in 58% (0.172 g) yield as a light brown solid (mp 101–104 °C). Purification was performed using diethylether–pentane (1/4) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.02 (d, J = 4.1 Hz, 1H), 8.17 (d, J = 8.2 Hz, 1H), 8.05 (d, J = 7.4 Hz, 1H), 7.73 (d, J = 8.1 Hz, 1H), 7.68 (d, J = 4.1 Hz, 1H),

7.55 (t, J = 7.5 Hz, 1H), 7.43 (dd, J = 8.2, 4.1 Hz, 1H), 7.10 (d, J = 4.1 Hz, 1H), 4.08 (m, 4H), 1.87 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 149.5, 149.4, 144.5, 139.3, 136.3, 132.9, 128.7, 127.6, 127.1, 126.4, 123.8, 121.2, 107.5, 65.0, 27.8. Elemental analysis calcd (%) for $C_{17}H_{15}NO_2S$ (297.37): C, 68.66; H, 5.08%; found: C, 68.79; H, 5.30%.

8-(5-Methylthiophen-2-yl)-quinoline (24). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), 2-methylthiophene (0.196 g, 2 mmol), CsOAc (0.384 g, 2 mmol) and $PdCl(C_3H_5)$-(dppb) (30.6 mg, 0.05 mmol) in DMAc for 22 h affords the product **24** in 35% (0.079 g) yield as a brown oil. Purification was performed using diethylether–pentane (1/99) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.01 (d, J = 4.1 Hz, 1H), 8.17 (d, J = 8.2 Hz, 1H), 8.02 (d, J = 7.3 Hz, 1H), 7.72 (d, J = 8.1 Hz, 1H), 7.57 (t, J = 3.5 Hz, 1H), 7.54 (d, J = 8.1 Hz, 1H), 7.44 (dd, J = 8.2, 4.1 Hz, 1H), 6.83 (d, J = 3.5 Hz, 1H), 2.58 (s, 3H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 149.4, 144.7, 142.6, 137.4, 136.4, 133.4, 128.8, 127.5, 126.7, 126.5, 125.0, 121.1, 15.4. Elemental analysis calcd (%) for $C_{14}H_{11}NS$ (225.31): C, 74.63; H, 4.92%; found: C, 74.78; H, 5.08%.

8-(2,3-Dimethylimidazol-4-yl)-quinoline (25). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), 1,2-dimethylimidazole (0.192 g, 2 mmol), CsOAc (0.384 g, 2 mmol) and $Pd(OAc)_2$ (4.5 mg, 0.02 mmol) in DMAc for 26 h affords the product **25** in 73% (0.163 g) yield as a brown oil. Purification was performed using methanol–dichloromethane (1/99) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.94 (d, J = 4.1 Hz, 1H), 8.21 (d, J = 8.2 Hz, 1H), 7.89 (d, J = 8.2 Hz, 1H), 7.71 (d, J = 8.2 Hz, 1H), 7.58 (t, J = 7.1 Hz 1H), 7.44 (dd, J = 8.2, 4.1 Hz, 1H), 7.06 (s, 1H), 3.36 (s, 3H), 2.50 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 150.4, 146.6, 145.9, 136.3, 132.2, 131.7, 130.0, 128.8, 128.6, 126.9, 126.3, 121.3, 32.0, 13.7. Elemental analysis calcd (%) for $C_{14}H_{13}N_3$ (223.27): C, 75.31; H, 5.87%; found: C, 75.50; H, 6.04%.

8-Imidazo[1,2-*a*]pyridin-3-ylquinoline (26). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), imidazo[1,2-*a*]pyridine (0.236 g, 2 mmol), CsOAc (0.384 g, 2 mmol) and $Pd(OAc)_2$ (4.5 mg, 0.02 mmol) in DMAc for 26 h affords the product **26** in 81% (0.198 g) yield as a brown oil. Purification was performed using methanol–dichloromethane (1/19) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.86 (m, 1H), 8.23 (d, J = 8.2 Hz, 1H), 7.93 (d, J = 8.2 Hz, 1H), 7.86 (m, 2H), 7.83 (d, J = 6.8 Hz, 1H), 7.68 (m, 2H), 7.46 (dd, J = 8.2, 4.1 Hz, 1H), 7.20 (t, J = 6.8 Hz, 1H), 6.69 (t, J = 6.8 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 150.3, 146.4, 146.0, 136.5, 134.2, 131.8, 128.9, 128.8, 128.7, 126.6, 125.7, 124.2, 124.1, 121.5, 117.8, 111.3. Elemental analysis calcd (%) for $C_{16}H_{11}N_3$ (245.28): C, 78.35; H, 4.52%; found: C, 78.40; H, 4.67%.

8-Benzoxazol-2-ylquinoline (27). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), benzoxazole (0.238 g, 2 mmol), Cs_2CO_3 (0.652 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (21.4 mg, 0.035 mmol) in DMAc for 27 h affords the product **27** in 88% (0.217 g) yield as a brown solid (mp 118–121 °C). Purification was performed using diethylether–pentane (1/1) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.16 (d, J = 4.1 Hz, 1H), 8.50 (d, J = 7.3 Hz, 1H), 8.23 (d, J = 8.2 Hz, 1H), 7.99 (d, J = 8.2 Hz, 1H), 7.92 (m, 1H), 7.67 (m, 2H), 7.49 (dd, J = 8.2, 4.1 Hz, 1H), 7.4 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.2, 151.8, 150.9, 145.8, 142.2, 136.5, 132.6, 131.6, 128.7, 126.3, 125.9, 125.3, 124.3, 121.6, 120.7, 110.7. Elemental analysis calcd (%) for $C_{16}H_{10}N_2O$ (246.26): C, 78.03; H, 4.09%; found: C, 78.10; H, 4.14%.

8-Benzothiazol-2-ylquinoline (28). The reaction of 8-bromoquinoline **2** (0.208 g, 1 mmol), benzothiazole (0.270 g, 2 mmol), Cs_2CO_3 (0.652 g, 2 mmol) and $PdCl(C_3H_5)$(dppb) (21.4 mg, 0.035 mmol) in DMAc for 24 h affords the product **28** in 61% (0.160 g) yield as a light green solid (mp 150–153 °C). Purification was performed using ethylacetate–pentane (1/4) as the eluent. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.09 (m, 2H), 8.27 (d, J = 8.2 Hz, 1H), 8.15 (d, J = 8.2 Hz, 1H), 8.01 (d, J = 7.7 Hz, 1H), 7.97 (d, J = 7.3 Hz, 1H), 7.73 (t, J = 7.7 Hz, 1H), 7.52 (m, 2H), 7.40 (t, J = 7.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.8, 152.4, 149.8, 145.1, 138.4, 137.0, 131.5, 130.7, 130.4, 128.7, 126.9, 126.2, 125.1, 123.3, 121.8, 121.7. Elemental analysis calcd (%) for $C_{16}H_{10}N_2S$ (262.33): C, 73.26; H, 3.84%; found: C, 73.18; H, 3.71%.

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