Advanced Synthesis & Catalysis

Accepted Article

Title: A Heteroarylamine Library: Indium-Catalyzed Nucleophilic Aromatic Substitution of Alkoxyheteroarenes with Amines

Authors: Kyohei Yonekura, Yasuhiro Yoshimura, Mizuri Akehi, and Teruhisa Tsuchimoto

To be cited as: *Adv. Synth. Catal.* 10.1002/adsc.201701452

Link to VoR: http://dx.doi.org/10.1002/adsc.201701452

10.1002/adsc.201701452

FULL PAPER

DOI: 10.1002/adsc.201((will be filled in by the editorial staff))

A Heteroarylamine Library: Indium-Catalyzed Nucleophilic Aromatic Substitution of Alkoxyheteroarenes with Amines

Kyohei Yonekura,[a] Yasuhiro Yoshimura,[a] Mizuri Akehi,[a] and Teruhisa Tsuchimoto[a]*

[a] Department of Applied Chemistry, School of Science and Technology, Meiji University, 1-1-1 Higashimita, Tama-ku, Kawasaki 214-8571, Japan
Fax: (+81)-44-934-7228; e-mail: tsuchimo@meiji.ac.jp

Received: ((will be filled in by the editorial staff))

Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/adsc.201######.

Abstract. Under indium Lewis acid catalysis, electron-rich five-membered heteroaryl electrophiles fused with/without a benzene ring were found to couple with amines to produce heteroarylamines with broad structural diversity. The heteroarylamine formation proceeds through the cleavage of a heteroaryl–OMe bond by the nucleophilic attack of the amine based on the nucleophilic aromatic substitution (S_NAr). In contrast to the corresponding traditional S_NAr amination, the present S_NAr-based heteroaryl amination can be performed without relying on both heteroaryl electrophiles with electron-withdrawing groups and nucleophilicity-enhanced metal amides. High compatibility towards the functional groups such as NO_2, Br, I, CF_3, CN, CO_2Et, pyridyl, thiazolyl, C=C, and OH groups was observed, thus showing the practicality and reliability of this method. Mechanistic studies indicated that a carbon–indium bond is likely to be formed on the heteroaryl ring during the process.

Keywords: Amination; Aromatic substitution; Heterocycles; Indium; Lewis acids

Introduction

The ubiquity of amines with electron-rich heteroaryl groups in biologically active compounds and drugs[1] as well as functional materials[2] and synthetic intermediates[3] has continued to inspire chemists to develop new methods for preparing such molecules more efficiently. In fact, a variety of approaches have been reported and, among them, the nitrogen–heteroaryl bond-forming process with easily available amines as nucleophiles appears to be straightforward to address heteroarylamines. In this regard, the coupling of heteroaryl (pseudo)halides and amines with the aid of transition metals would be undoubtedly one of the reliable and powerful strategies, the origin of which dates back to the Ullmann amination with a stoichiometric amount of copper metal, first reported over 100 years ago.[4] This transition metal strategy has now been achieved as a catalytic process and still been continuing to evolve (Scheme 1, route A).[5,6] At present, the palladium-catalyzed Buchwald–Hartwig amination would be one of the representative of this category.[7] In addition to the C–X bond amination, lately, a C–H bond of heteroarenes has been reportedly used in a direct manner for the same purpose, while requiring the assistance of a directing group (DG) to guide transition metals for the site-selective amination (Scheme 1, route B).[8]

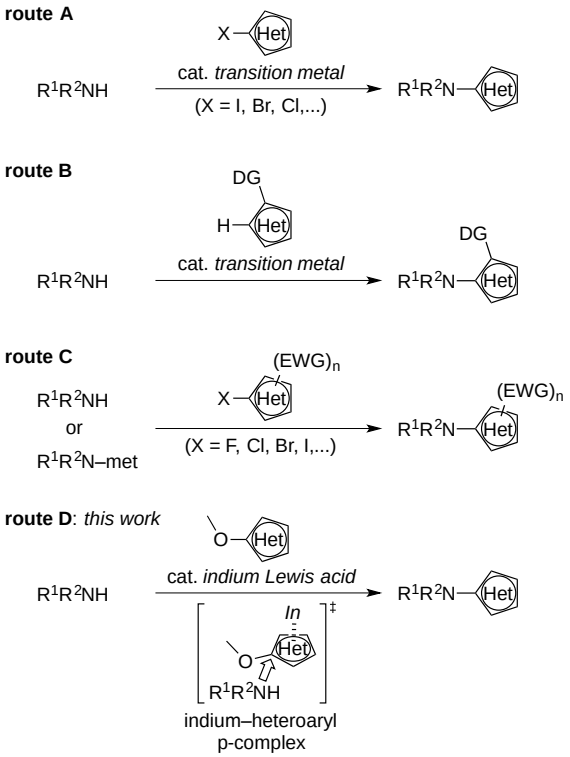
An alternative amine-based nitrogen–heteroaryl bond-forming transformation should be the utilization of nucleophilic aromatic substitution (S_NAr) reaction (Scheme 1, route C).[9] However, performing the S_NAr amination on the heteroaryl ring is not an easy task because amines and heteroaryls are intrinsically both electron-rich, and thus behave as nucleophiles in general. In order to connect each other with the same electronic requirement, heteroaryls with one or more electron-withdrawing groups (EWGs) have been used as electrophiles to accept nucleophilic attack of amines. This is also the well-known technique to attain the S_NAr process with nucleophiles other than amines.[10] For the successful S_NAr amination, further enhancing the nucleophilicity of amines by using metal amides (R^1R^2N–met) is another approach, which, however, may be often combined with the use of the X–heteroaryl–$(EWG)_n$ (see also route C).[11] These requisites seem to have limited the widespread applicability of the heteroarylamine synthesis via the S_NAr pathway.

On the other hand, we have disclosed the first example of the S_NAr-based catalytic biheteroaryl synthesis by connecting two electron-rich heteroaryl molecules.[12] The key strategic idea of the method is that an indium Lewis acid temporarily behaves as an EWG by forming an indium–heteroaryl π-complex, thus allowing to use heteroaryl electrophiles without having the EWGs as well as non-metalated heteroaryl nucleophiles, in contrast to the conventional S_NAr-based biheteroaryl synthesis. We therefore envisioned that if the indium–heteroaryl π-complex could react with amines without forming an unfavorable complex between the indium Lewis acid and the amine Lewis

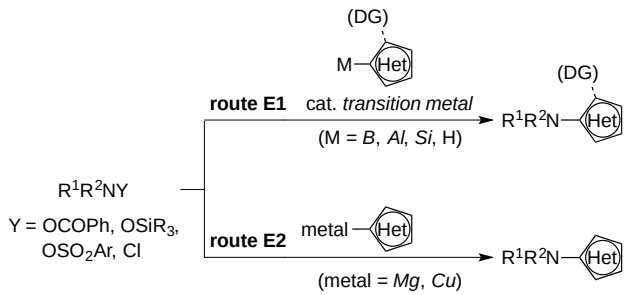
10.1002/adsc.201701452

base,[13] the catalytic heteroarylamine synthesis will be achieved without depending on both of the EWG-substituted heteroaryl electrophile and the metal amide (Scheme 1, route D: this work). During the course of our investigation on the basis of this idea,[14] very recently, triflic acid has been reported to catalyze the amination but only for 3-methoxythiophene as a heteroaryl electrophile.[15] In contrast, we herein disclose the new protocol to synthesize heteroarylamines from a variety of combinations of methoxyheteroarenes and amines.

As a remaining category, the C–N bond-forming heteroarylamine synthesis in which amines behave as electrophiles has been known as well. This group should be divided further into the transition metal catalysis (Scheme 2, route E1)[16] and non-transition-metal catalysis (Scheme 2, route E2),[17] but, herein, umpolung oxidation of amines to prepare the



Scheme 1. Synthetic methods of heteroarylamines by using amines as nucleophiles based on the C–N bond formation. *In* = an indium salt.



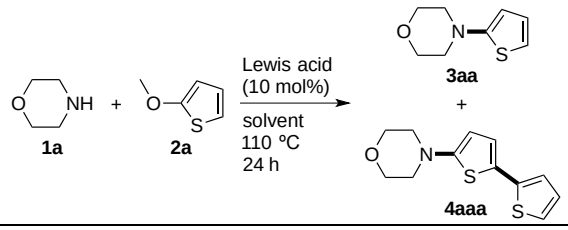
Scheme 2. Synthetic methods of heteroarylamines using amines as electrophiles based on the C–N bond formation.

electrophilic amine substrate is necessary.[18]

Results and Discussion

Initially, we examined suitable reaction conditions for the S_NAr amination of 2-methoxythiophene (**2a**) with morpholine (**1a**) (Table 1). Thus, treating **1a** and **2a** with $In(OTf)_3$ (10 mol%, Tf = SO_2CF_3) in 1,4-dioxane at 110 ºC for 24 h gave desired 2-morpholinothiophene (**3aa**), albeit only in a small amount based on the low conversion of **2a** (entry 1). Using other metal triflates based on Sc, Cu, Ag, Zn, and Bi metals lowered the reaction efficiency, and thus resulted in no improvements in the yield of **3aa** (entries 2–6). Changing the ligand of $In(OTf)_3$ to NTf_2 increased the reaction rate, while $In(ONf)_3$ (Nf = $SO_2C_4F_9$) was less effective (entries 7 and 8). A survey on the effect of solvents indicated that the choice of chlorobenzene is suitable, thereby giving **3aa** in 66% yield (entries 9–14). Increasing the molar equivalent of **1a** to **2a** from 2.5 to 3 had no positive effect on the yield of **3aa** (entries 14 and 15). Reducing the amount of **1a** to 2 molar equivalents

Table 1. Lewis acid-catalyzed S_NAr amination of 2-methoxythiophene with morpholine.[a]



Entry	Lewis acid	Solvent[b]	Conv. [%] **2a**[c]	Yield **3aa**	[%][d] **4aaa**
1	$In(OTf)_3$	Dioxane	9	7	<1
2	$Sc(OTf)_3$	Dioxane	21	6	<1
3	$Cu(OTf)_2$	Dioxane	12	<1	<1
4	AgOTf	Dioxane	7	<1	<1
5	$Zn(OTf)_2$	Dioxane	5	<1	<1
6	$Bi(OTf)_3$	Dioxane	12	3	<1
7	$In(ONf)_3$	Dioxane	22	4	<1
8	$In(NTf_2)_3$	Dioxane	43	29	<1
9	$In(NTf_2)_3$	Bu_2O	84	59	<1
10	$In(NTf_2)_3$	DEE	35	21	<1
11	$In(NTf_2)_3$	$MeNO_2$	52	26	<1
12	$In(NTf_2)_3$	PrCN	13	5	<1
13	$In(NTf_2)_3$	*p*-Xylene	78	59	<1
14	$In(NTf_2)_3$	PhCl	93	66	<1
15[e]	$In(NTf_2)_3$	PhCl	89	61	<1
16[f]	$In(NTf_2)_3$	PhCl	91	63	1
17[g]	$In(NTf_2)_3$	PhCl	98	61	5
18	none	PhCl	3	<1	<1

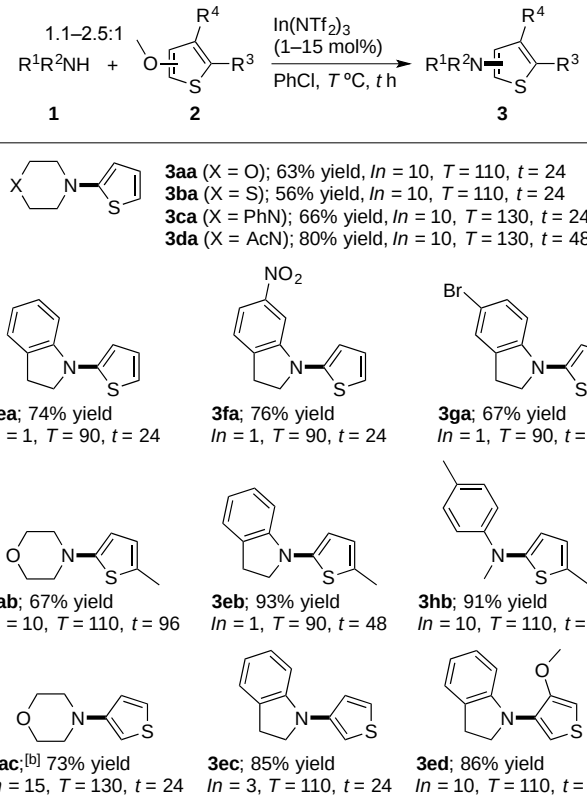
[a] Reagents (unless otherwise specified): **1a** (0.625 mmol), **2a** (0.250 mmol), Lewis acid [25.0 μmol (10 mol%)], solvent (1.0 mL). [b] Solvent abbreviations: Dioxane = 1,4-dioxane; DEE = 1,2-diethoxyethane. [c] Determined by GC using *n*-decane as an internal standard. [d] Determined by ^1H NMR using nitromethane as an internal standard. [e] Performed with **1a** (0.750 mmol). [f] Performed with **1a** (0.500 mmol). [g] Performed with **1a** (0.375 mmol).

10.1002/adsc.201701452

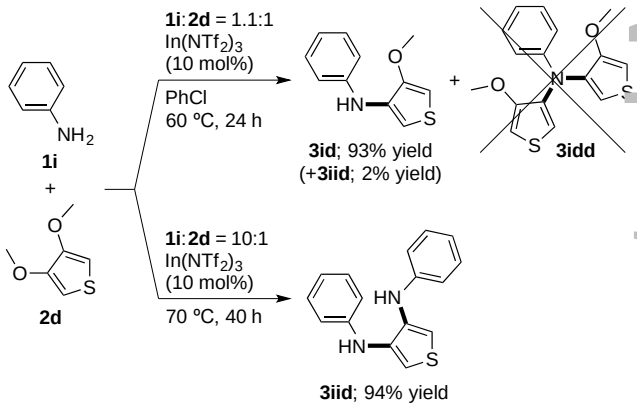
similarly provided **3aa** in a comparable yield of 63% (entry 16), but the further lower loading of **1a** (1.5 molar equivalents) slightly brought about the S_NAr biheteroaryl formation between **2a** and product **3aa** (entry 17), as in our preceding study.[12] No amination was observed in the absence of a Lewis acid catalyst (entry 18).

With the promising reaction conditions in hand, the S_NAr amination of a series of thiophene electrophiles **2** with some amine nucleophiles **1** was examined (Table 2). As similar to the nitrogen atom of morpholine (**1a**), those of cyclic dialkylamines including thiomorpholine (**1b**), *N*-phenyl- (**1c**) and *N*-acetylpiperazine (**1d**) reacted as nucleophilic sites with 2-methoxythiophene (**2a**), thus providing 2-aminothiophenes **3ba**–**3da** in moderate to high yields. The MeO group of **2a** was also readily substituted by simple and functionalized indolines of cyclic alkylarylamines, in which even **1f** with the strongly electron-withdrawing nitro group worked well as a nucleophile (**3ea**–**3ga**). Of importance to note is that the NO_2 and Br groups on the aryl unit can act as leaving groups in the general S_NAr reaction,[19] but here remained intact under the reaction conditions. The indium catalyst also connected some amines with 2-methoxy-5-methylthiophene (**2b**) to produce the corresponding aminothiophenes **3ab**–**3hb**. Besides 2-methoxythiophenes **2a** and **2b**, the C3 of 3-methoxythiophene (**2c**) accepted nucleophilic attack of **1a** and **1e** to give **3ac** and **3ec**, respectively. In the case of 3,4-dimethoxythiophene (**2d**), only the single amination proceeded, whereby mono-aminated methoxythiophene **3ed** was obtained in a high yield of 86%. In addition to this result, the selective single and double aminations of **2d** are feasible by the appropriate choice of the reaction conditions, when using aniline (**1i**) as a primary amine nucleophile (Scheme 3). Thus, the reaction carried out with a slight excess of **1i** to **2d** (1.1:1) in solvent PhCl at 60 °C led to the selective single amination (**3id**), and, on the other hand, the treatment of **2d** with a ten-fold excess of **1i** under the solvent-free conditions at 70 °C exclusively provided diaminothiophene **3iid**. Importantly, **1i** that has the two N–H bonds underwent no over-thienylation to give, for instance, dithienylaniline **3idd**, and thus favorably resulted in the exclusive mono-thienylation. This trend also holds true for other entries with a variety of primary amines, as collected in Table 3 (*vide infra*), and is in sharp contrast to the palladium-catalyzed amination of 3-bromothiophene with primary amines to generate a mixture of mono- and di-thienylated amines.[20] A further unique aspect of this method is the MeO-selective S_NAr amination to 3-bromo-4-methoxythiophene (**2e**) wherein the Br group that can also behave as a leaving group co-exists (Scheme 4). Thus, the reaction of **2e** with **1i** gave **3ie** exclusively without the formation of **3'ie**. This unusual functional

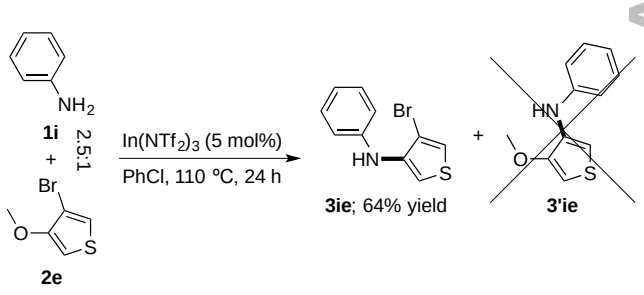
Table 2. Indium-catalyzed S_NAr amination of thiophene electrophiles with secondary amines.[a]



[a] Reagents (unless otherwise noted): **1** (0.275–0.625 mmol), **2** (0.250 mmol), $In(NTf_2)_3$ (2.50–37.5 μmol), PhCl (1.0 mL). Yields of isolated **3** based on **2** are shown here. *In*: mol% of $In(NTf_2)_3$ used. See the Experimental Section for further details. [b] Performed in PhCl (0.50 mL).



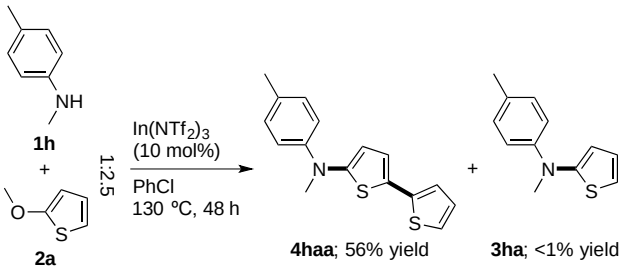
Scheme 3. Indium-catalyzed S_NAr amination of 3,4-dimethoxythiophene with aniline.



Scheme 4. Indium-catalyzed S_NAr amination of 3-bromo-4-methoxythiophene with aniline.

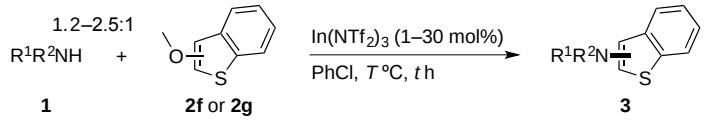
10.1002/adsc.201701452

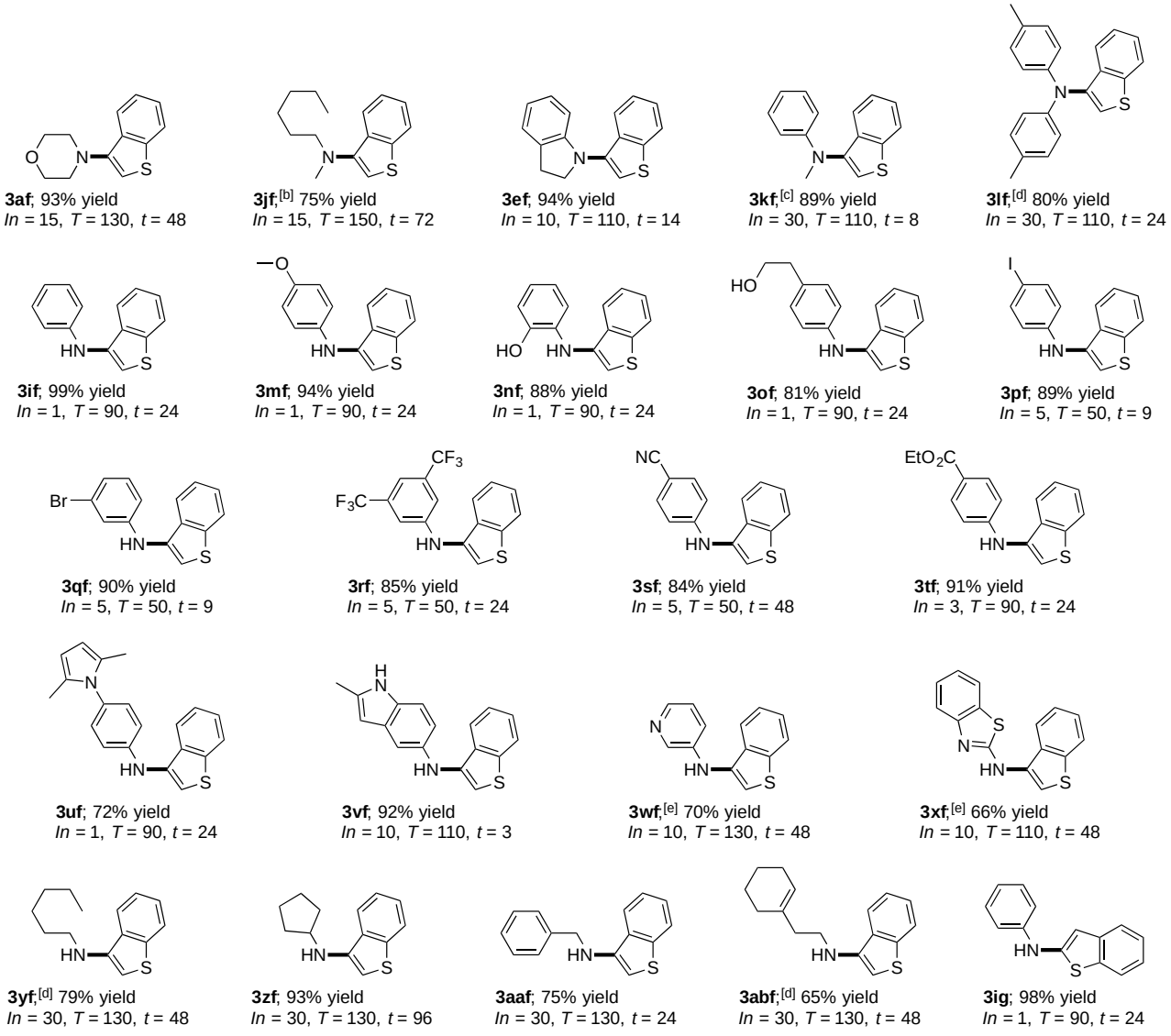
group selectivity is in sharp contrast to the transition metal catalysis[5e,j] and also other reactions.[21] As already stated, the indium salt catalyzes the S_NAr-based biheteroary synthesis.[12] By utilizing our original reaction, as shown in Scheme 5, the remaining nucleophilic α-site of the thienyl ring in **3ha** derived from the amination of **2a** with **1h** is available in situ for the tandem heteroaryl–heteroaryl bond formation. Thus, different from the standard reaction conditions with an excess amount of amine **1** to **2**, treating a 1:2.5 mixture of **1h** and **2a** at 130 ºC for 48 h provided **4haa** in 56% yield, without contamination by **3ha**.



Scheme 5. Indium-catalyzed tandem S_NAr reaction of 2-methoxythiophene with *N*-methyl-*p*-toluidine.

Table 3. Indium-catalyzed S_NAr amination of 3- and 2-methoxybenzothiophenes.[a]





[a] Reagents (unless otherwise noted): **1** (0.300–0.625 mmol), **2** (0.250 mmol), $In(NTf_2)_3$ (2.50–75.0 μmol), PhCl (1.0 mL). Yields of isolated **3** based on **2** are shown here. *In*: mol% of $In(NTf_2)_3$ used. See the Experimental Section for further details. [b] Performed with *o*-$Cl_2C_6H_4$ instead of PhCl as a solvent. [c] Performed in PhCl (0.50 mL). [d] Performed in PhCl (0.25 mL). [e] Performed with a 1:2 mixture of **1** (0.250 mmol) and **2f**.

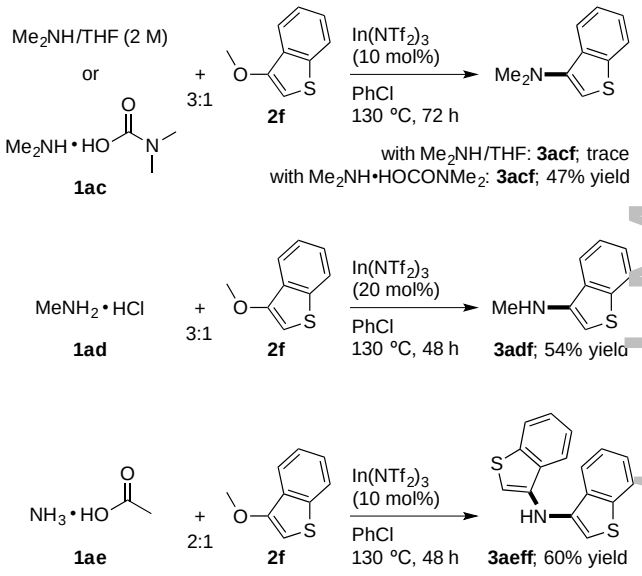
10.1002/adsc.201701452

We successively investigated the scope of the amination, and found that 3-methoxybenzothiophene (**2f**) is a good heteroaryl electrophile to accept a broad range of amines highly efficiently (Table 3). Not only the types of amines used for the reaction of 2-methoxythiophene (**2a**) (**3af**, **3ef** and **3kf**), but also other types, that is, acyclic dialkylamine **1j** and diarylamine **1l** constructed the desired N–C bonds with **2f**, giving **3jf** and **3lf**. Moreover, aniline (**1i**) and its derivatives (**1m**–**1u**) with high substitutional diversity can be also installed onto the benzothienyl ring (**3if**–**3uf**). In regard to the amination with the aniline derivatives, the present method again demonstrated favorable chemo-selectivity on the leaving group: the aryl–OMe, –I, –Br and –CN moieties that possibly undergo nucleophilic substitution were survived safely (**3mf**, **3pf**, **3qf** and **3sf**).[19] The OH groups co-existing with the NH_2 one in **1n** and **1o** did not disturb the amination process by acting as nucleophilic sites, and **3nf** and **3of** were thus obtained in high yields. The generation of **3qf**–**3tf** clearly indicates that electron-withdrawing groups do not interfere with the nucleophilic attack of the aniline substrates. Furthermore, the CO_2Et functionality has been known to react with amines to form amides in the presence of acid catalysts including an indium salt, but $In(NTf_2)_3$ catalyzed only the desired amination without the amidation (**3tf**).[22] Diheteroaylamines **3vf**–**3xf** consisting of two different heteroaryl units can be also prepared from aminoheteroarenes with, for instance, indolyl, pyridyl and benzothiazolyl structures. This protocol is applicable as well to primary alkylamines with linear and branched alkyl chaines as well as benzyl and alkenyl moieties, whereas these aminations required higher loadings of $In(NTf_2)_3$ and higher reaction temperatures (**3yf**–**3abf**). This may be due to higher nucleophilicity of the primary alkylamine that possibly impairs the catalytic activity of the indium Lewis acid. Notably, in the reaction of **1ab** to form **3abf**, the C=C bond was tolerated without suffering Lewis acid-induced hydroamination.[23] Similar to **2f**, 2-methoxybenzothiophene (**2g**) can be activated under indium catalysis, thereby reacting smoothly with **1i** to give **3ig** in 98% yield. Since both of the aminations of **2f** and **2g** with **1i** equally proceeded in a quantitative manner under the same reaction conditions (**3if** and **3ig**), a wide variety of amines other than **1i** should be expected to be applied to the amination of **2g**.

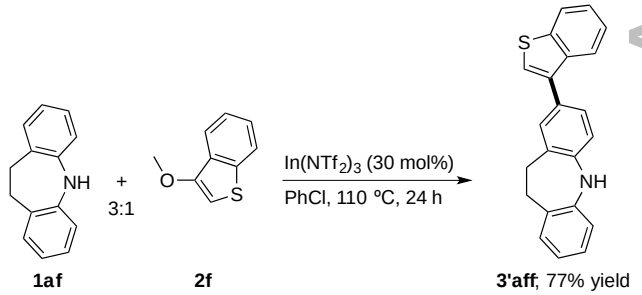
In order to broaden the scope of this reaction, we tried the use of small molecular weight amines, which are originally gaseous and thus are troublesome to handle (Scheme 6). With the 2 M THF solution of Me_2NH for easy handling, almost no nucleophilic substitution on **2f** was unfortunately observed. In marked contrast, its salt with *N*,*N*-dimethylcarbamic acid that can be also easily handled successfully reacted with **2f** to afford desired product **3acf**. Introducing the MeHN group is also possible by using the HCl salt of $MeNH_2$ (**1ad**), giving **3adf** in a moderate yield of 54%. In a similar manner with the NH_3•HOCOMe salt, the indium catalyst put NH_3 together with 2 molar equivalents of **2f** to give **3aeff** as a sole product, without the corresponding mono- and tri-benzothienylated amines being detected.

In contrast to amines so far examined, an N–H bond was found to not necessarily lead to the N–C bond formation. Thus, the C–C bond formation occurred exclusively in the reaction of **2f** with cyclic diarylamine **1af**, thereby giving **3'aff** in a good yield (Scheme 7).[24]

Besides the thienyl and benzothienyl electrophiles, oxygen- and nitrogen-based heteroaryl rings can be incorporated as a part of the product to further expand the library of this heteroarylamine synthesis (Table 4). Even though the furan ring is the least aromatic of the 5-membered 1-heteroatom-containing heteroaryl rings[25] and, in general, is not a good substrate for this type of substitution,[26] the amination of 2-methoxy-5-phenylfuran (**2h**) with indoline (**1e**) or *N*-methylaniline (**1k**) proceeded to give **3eh** or **3kh** in a moderate yield, respectively. For the coupling of 2-methoxybenzofuran (**2i**) with **1e**, 1 mol% of $In(NTf_2)_3$ is enough, leading to the isolation of **3ei** in



Scheme 6. Indium-catalyzed S_NAr amination of 3-methoxybenzothiophene with small molecular weight amines.



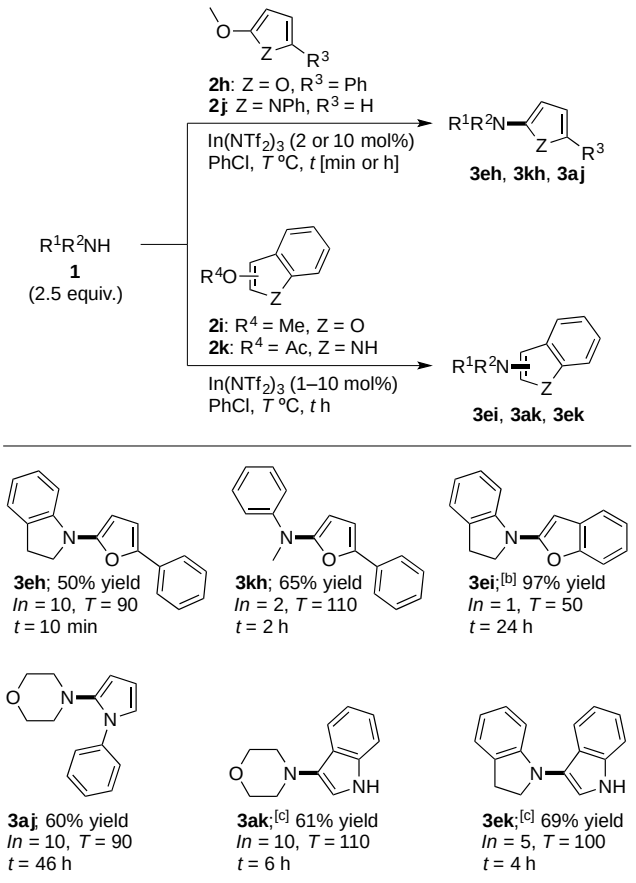
Scheme 7. Indium-catalyzed S_NAr C–C bond formation of 3-methoxybenzothiophene with cyclic diarylamine **1af**.

97% yield. In spite of the fact that pyrrole and indole rings are the most electron-rich heteroaryl molecules,[27] the indium catalyst here again successfully worked as a tentative EWG to connect pyrrole **2j** and indole **2k** with amines, thus providing **3aj**, **3ak**, and **3ek** in good yields. When synthesizing the aminoindole, commercially available 3-acetyloxyindole (**2k**) wherein not the alkoxy group but the acetyloxy (AcO) one acts as a leaving group can be used, and only the ipso substitution desirably occurred. This outcome is in sharp contrast to the preceding S_NAr-based heteroaryl–heteroaryl bond formation of **2k**, which resulted in the non-selective ipso and cine substitutions.[12]

Not only to the amination, but this system is also applicable to the alkoxylation and thiolation (Table 5).[28] For example, the MeO group of 2-methoxythiophene (**2a**) can be replaced with another alkoxy group with a longer alkyl chain with the aid of the indium catalyst. Upon treatment of a 4:1 mixture of *n*-decanol (**5a**) and **2a** with 10 mol% of $In(NTf_2)_3$ in a manner similar to the amination, 63% yield of 2-decyloxythiophene (**7aa**) was thus obtained. The introduction of the multi-oxygenated alkoxy unit is also feasible (**7ba**). As shown separately in Scheme 8, due probably to the lower nucleophilicity of phenol (**5c**), no phenoxylation of **2f** leading to **7cf** was attained, but instead, the S_NAr-based dimerization between the two molecules of **2f** selectively proceeded to afford **9** in 87% yield. The absence of **5c**, however, substantially reduced the yield of **9**. At present, while it is unclear how phenol affects to the selective dimerization, a survey to ascertain the unique behavior of phenol is ongoing. Returning to the discussion of Table 5, the progress of the thiolation of **2a** and **2d** provided us with desired alkylthiothiophenes **8aa** and **8bd** in high yields.

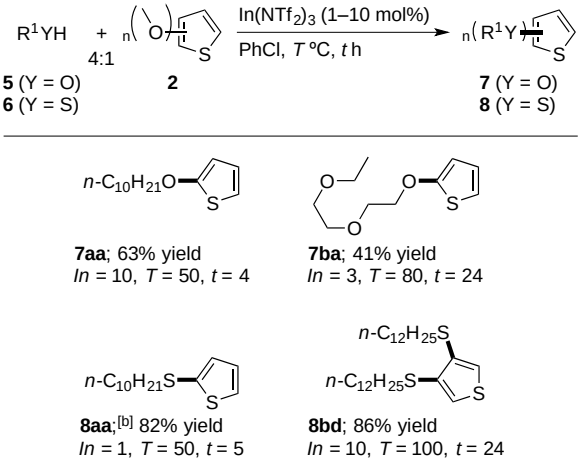
As already demonstrated in Schemes 3, 4 and 6 and Table 3, the NH_2 moiety of primary amines undergoes the mono-heteroarylation exclusively, and we naturally expected that this would be a good opportunity to evolve the remaining NH group of the product. Since a biphenyl structure sandwiched by two diarylamino groups has been attracting

Table 4. Indium-catalyzed S_NAr amination of furan, benzofuran, pyrrole, and indole electrophiles.[a]

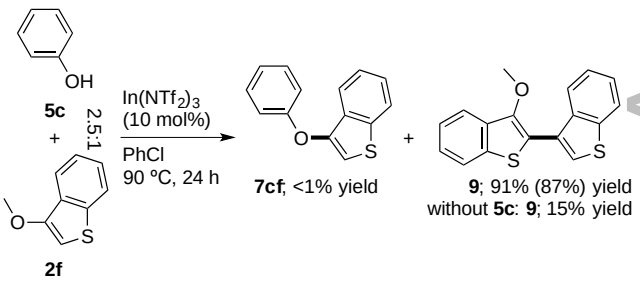


[a] Reagents (unless otherwise noted): **1** (0.625 mmol), **2** (0.250 mmol), $In(NTf_2)_3$ (2.50–25.0 μmol), PhCl (1.0 mL). Yields of isolated **3** based on **2** are shown here. *In*: mol% of $In(NTf_2)_3$ used. See the Experimental Section for further details. [b] Performed with 1.2 molar equiv. of **1e** (0.300 mmol) to **2i** (0.250 mmol). [c] Performed in PhCl (0.50 mL).

Table 5. Indium-catalyzed S_NAr alkoxylation and thiolation of thiophene electrophiles.[a]

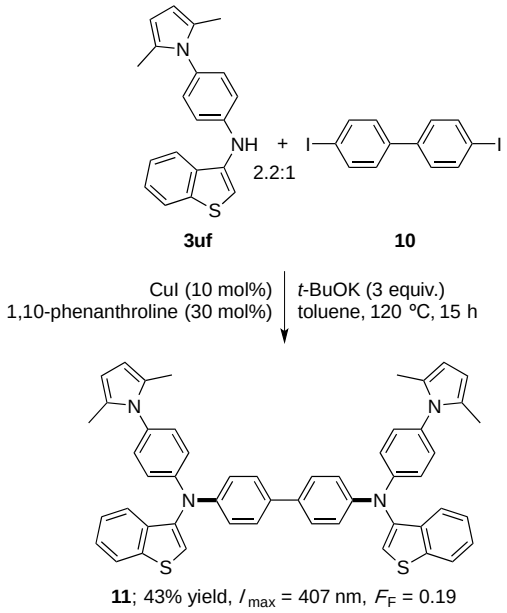


[a] Reagents (unless otherwise noted): **5** or **6** (1.00 mmol), **2** (0.250 mmol), $In(NTf_2)_3$ (2.50–25.0 μmol), PhCl (1.0 mL). Yields of isolated **7** and **8** based on **2** are shown here. *In*: mol% of $In(NTf_2)_3$ used. See the Experimental Section for further details. [b] Performed with 1.2 molar equiv. of **6a** (0.300 mmol) to **2a** (0.250 mmol).



Scheme 8. Indium-catalyzed S_NAr reaction of 3-methoxybenzothiophene in the presence of phenol. Yields of **7cf** and **9** determined by ^1H NMR using nitromethane as an internal standard are shown here. The yield of isolated **9** based on **2f** is shown in parentheses.

10.1002/adsc.201701452

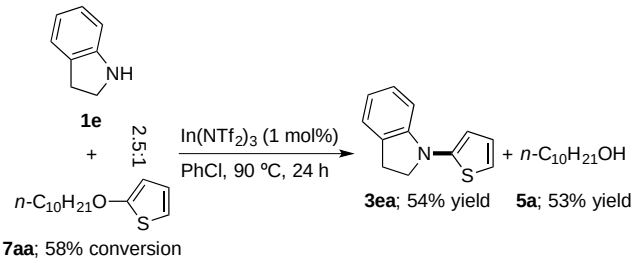


Scheme 9. Synthetic application: copper-catalyzed coupling of **3uf** with 4,4'-diiodobiphenyl. A fluorescence spectrum excited at 265 nm was measured in CH_2Cl_2 (c = 1.5 x 10^{-6} M). The quantum yield of **11** was determined with reference to that of *p*-terphenyl.

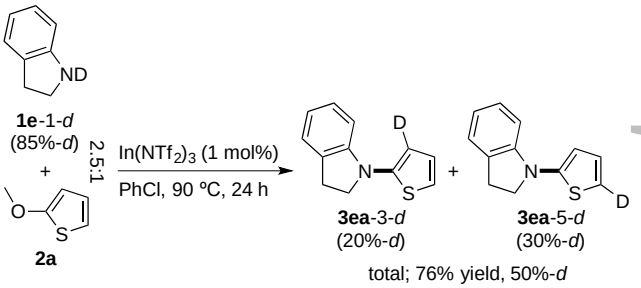
considerable attention as charge transport materials[29] found in, for instance, organic light-emitting diodes[30] and photovoltaic cells,[31] a heteroarylamine in hand was applied to construct such a related architecture but designed uniquely. Amongst a lot of candidates, we picked up **3uf**, which was then treated with 4,4'-diiodobiphenyl (**10**) under the Ullmann–Goldberg conditions,[32] thereby giving potentially useful structure **11**. It was found that **11** is a blue-violet light-emitting photoactive molecule with the emission maximum at 407 nm when excited at 265 nm in CH_2Cl_2 (Scheme 9).

Some experimental observations are available for the mechanistic studies of this reaction. We first confirmed whether the heteroarylamine formation in fact proceeds via the nucleophilic substitution on the heteroaryl ring. Thus, after the treatment of **1e** and 2-decyloxythiophene (**7aa**) with the long alkyl chain under the conditions shown in Scheme 10, *n*-decanol (**5a**) was secured in 53% yield with 58% conversion of **7aa** and with the generation of **3ea** in 54% yield, showing that the decyloxy group on the aromatic thienyl ring is replaced by the *N*-indolinyl unit, and that this reaction is thus based on the S_NAr route. In addition, the result already demonstrated in entry 18 of Table 1 reveals that the indium catalyst is indispensable and accordingly a key activator for the S_NAr process. We next carried out the reaction of a deuterium labelling experiment (Scheme 11). Under the same reaction conditions as those for the reaction of **2a** with **1e**, the replacement of the amine substrate (**1e**) with the corresponding deuterium labelled indoline (**1e**-1-*d*; 85%-*d*) led to the formation of **3ea**-3-*d* and **3ea**-5-*d* with 50% total deuterium content. This result implies that a carbon–indium bond formed in situ at the C3- or C5-position of the thienyl ring was trapped by D^+ originating in the N–D part of **1e**-1-*d*. Besides these results, the kinetic isotope effect (KIE) experiment was carried out with **1e** or **1e**-1-*d* in the reaction of **2a**, and indicated that, due to the k_H/k_D value of 1.0, the stage of the N–H bond cleavage is unlikely to be involved in the rate-determining step. (Scheme 12).

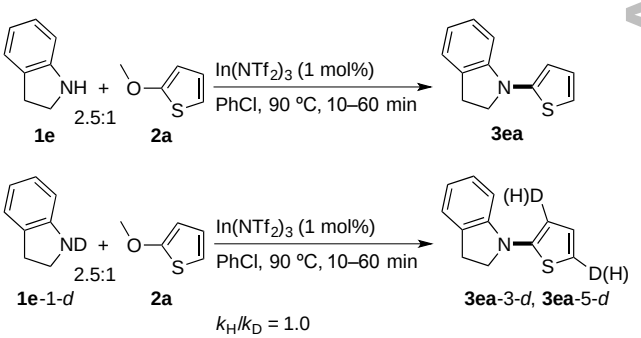
On the basis of the above experimental results and of previous findings reported by us and others, possible reaction mechanisms exemplified by the reaction of **2a** and R^1R^2ND (**1**-*d*) are proposed in Scheme 13, where path a and b leading to **3**-5-*d* and **3**-3-*d*, respectively, are depicted. First up is the coordination of **2a** to the indium Lewis acid (*In*) to form *In*–thienyl π-complex **12**,[12,33] wherein *In* withdraws the electron from **2a**, which then becomes highly electrophilic to accept amine nucleophile **1**. The attack of **1**-*d* to **12** occurs from the side opposite to the coordinated *In* to afford allylindium type intermediate **13**-*d* or **13'**-*d*,[34] which subsequently



Scheme 10. A confirmation experiment of a released alcohol.



Scheme 11. A deuterium labelling study: reaction of **1e**-1-*d* with **2a**.

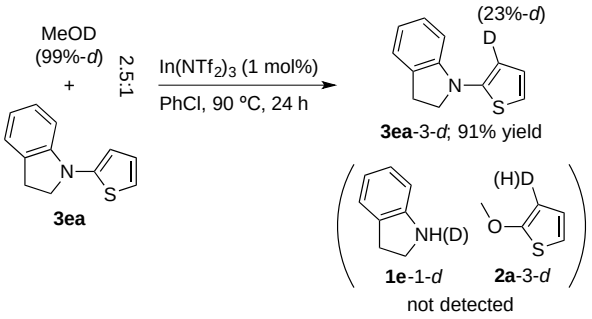


Scheme 12. Kinetic isotope effect experiments.

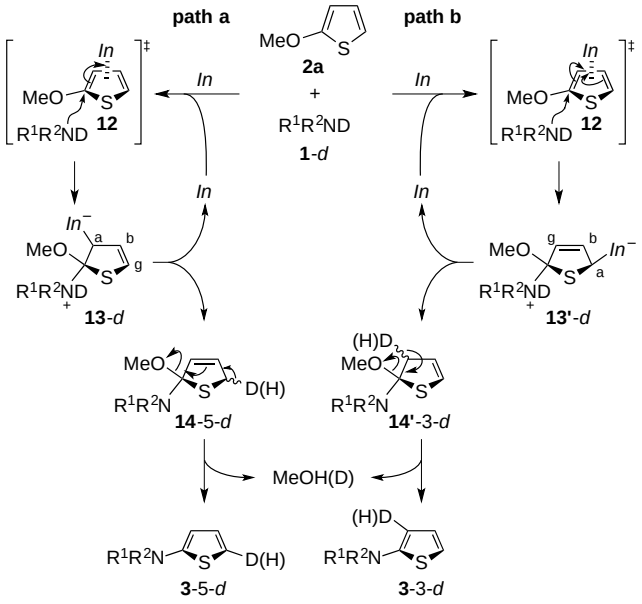
undergoes regioselective deuteration at the γ site of the allylindium unit by the migration of the D^+ from the $R^1R^2N^+D$ moiety, as previously demonstrated.[35] The elimination of MeOH(D) from **14**-5-*d* or **14'**-3-*d* for the re-aromatization provides desired product **3**-5-*d* or **3**-3-*d*, respectively. As observed in Scheme 11, the decrease of the D content from substrate **1e**-1-*d* (85%-*d*) to product **3ea**-*d* (total 50%-*d*) should be ascribed to the final step in which MeOD would be able to be eliminated.

The additional experiment shown in Scheme 14 is likely to be available for discussing which of path a or b is in operation. Thus, in the presence of MeOD instead of MeOH being the by-product in the amination, the treatment of product **3ea** under the standard reaction conditions gave only **3ea**-3-*d* deuterated at the C3-position of the thienyl ring in 91% yield with 23% deuterium incorporation. The results of Scheme 14 as well as Scheme 11 (*vide supra*) seem to provide us with important mechanistic insights. Firstly, since the deuterium content of **3ea**-3-*d* produced in the two reactions is almost equal, the C3-deuterium incorporation of **3ea** may occur not during the amination process of **2a** but after the formation of **3ea**. Next, since no **3ea**-5-*d* is produced in the reaction of Scheme 14, the C5-deuterium incorporation of **3ea** is considered to occur only during the amination process of **2a**. From these taken collectively, path a leading to the formation of **3**-5-*d* would be more plausible than path b as the route of the present amination. On the other hand, as shown also in Scheme 14, **1e**-1-*d* and **2a**-3-*d* that could be potentially formed by nucleophilic attack of MeOD to **3ea** were neither detected. This result and the result on the formation of **3ea**-3-*d*, both in Scheme 14, suggest that re-attack of by-product MeOH to product **3** is plausible under the reaction conditions, but the existence of the reverse process to go back to the starting substrate is unlikely. A possible route from **3ea** to **3ea**-3-*d* is presented in Scheme 15, and thus starts with the formation of π-complex **15**, which then accepts the nucleophilic attack of MeOD to give **16'**-*d* but not to do possible alternative **16**-*d*, due possibly to the steric repulsion between the indolinyl and *In* moieties. The γ-selective deuteration of the allylindium unit in **16'**-*d* leading to **17'**-*d*[35] followed by the elimination of MeOH(D) results in the generation of **3ea**-3-*d*. No formation of **2a**-3-*d* by the elimination of **1e**-1-*d* from **17'**-*d* should be responsible for the higher leaving ability of the methoxy group than the indolinyl one.[36] Throughout the present study, of note is that the successful S_NAr heteroaryl amination would be largely dependent on no participation of the reverse process on the basis of the lower leaving ability of the R_2N group.

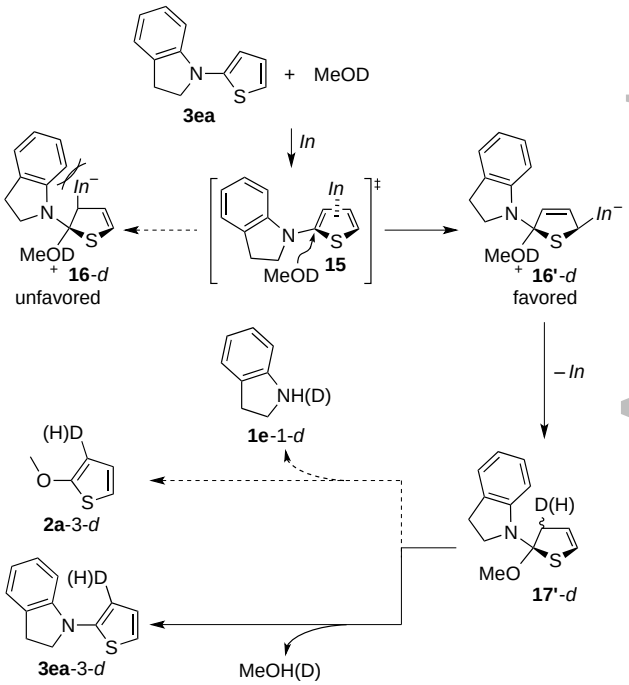
Finally, with regard to the coordination mode of **2a** to *In*, there could be four possibilities of **A**–**D** at least as shown in Figure 1. Among them, **D** may be



Scheme 14. A deuterium labelling study: reaction of MeOD with **3ea**.



Scheme 13. Proposed reaction mechanisms. *In* = an indium salt.



Scheme 15. A possible route from **3ea** to **3ea**-3-*d* in the presence of MeOD.

10.1002/adsc.201701452

excluded first from the candidate list because 3-methoxythiophene (**2c**) of which the oxygen and sulfur atoms cannot coordinate concurrently to *In* works as a substrate (see **3ac** and **3ec** in Table 2). At present, it is difficult to eliminate the possibility of **B** and **C**. However, because of the deuterium labelling studies showing the possibility of the in situ formation of the C–*In* bond, coordination mode **A** wherein the carbon atoms of the thienyl ring directly interact with *In* appears to be most likely.

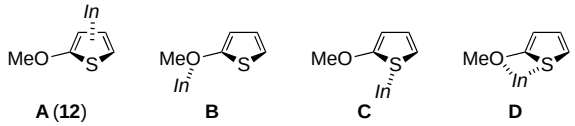


Figure 1. Possible coordination modes of 2-methoxythiophene to an indium salt.

Conclusion

We have demonstrated herein that the indium Lewis acid acts as an effective catalyst for the S_NAr-based amination of electron-rich heteroarenes. The key to the achievement would be the choice of the indium catalyst, which behaves as the tentative EWG capable of bringing the character of the electron-rich heteroaryl molecule into the electrophile. Therefore, in sharp contrast to the corresponding conventional heteroaryl amination, our system is independent of both of the EWG-substituted heteroaryl electrophile and the metal amide, and thus is applicable to a broad range of substrates with high functional group compatibility (Figure 2): for the amine nucleophile: 8 types except for cyclic diaryl amines; for the heteroaryl electrophile: all 6 types of thiophenes, furans and pyrroles fused with/without a benzene ring; for the functional group: NO_2, Br, I, CF_3, CN, CO_2Et, pyridyl, thiazolyl, C=C, and OH groups. As if to reflect these diversity, 34 structures of 49 heteroarylamines synthesized here are new compounds unreported in the literature. Moreover, our method provides at least the following three advantages, compared to the transition metal catalysis based on the C–halogen bond amination: (1) amines selectively substitute the MeO group even in the co-existence of the Br group (see Scheme 4); (2) the S_NAr-based tandem C–N and C–C bond-forming reactions are achievable in one step (see Scheme 5); (3) *N*-unsubstituted indoles can be used directly as electrophiles without the protection–deprotection treatment on the nitrogen atom (see Table 4).[37] Mechanistic studies revealed that the reaction proceeds through the S_NAr pathway including the elimination of the MeOH, that the C–In bond is formed in situ, and that the cleavage of the amine(N)–H bond is unlikely to be involved in the rate-determining step. Application of this transformation is in progress in our laboratory.

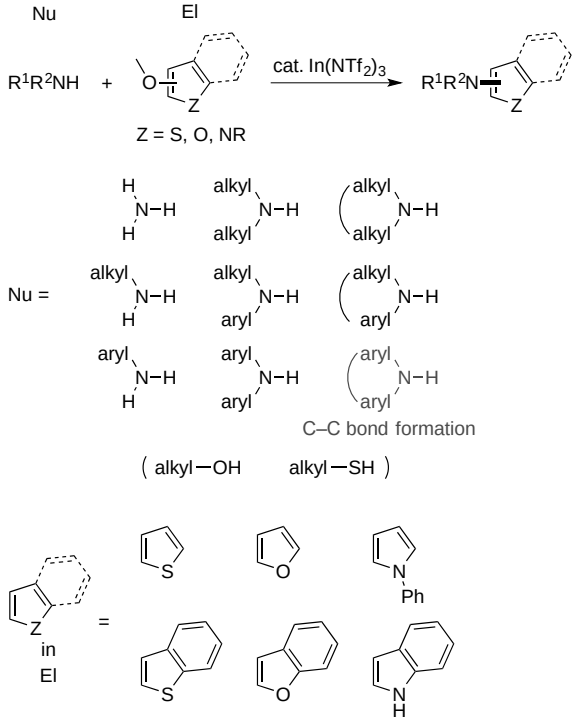


Figure 2. Outline of the indium-catalyzed S_NAr amination of methoxyheteroarenes.

Experimental Section

General Remarks

All manipulations were conducted with a standard Schlenk technique under an argon atmosphere. Nuclear magnetic resonance (NMR) spectra were taken on a JEOL JMN-ECA 400 (^{1}H, 400 MHz; ^{13}C, 100 MHz) or JEOL JMN-ECA 500 (^{1}H, 500 MHz; ^{13}C, 125 MHz) spectrometer using tetramethylsilane (^{1}H and ^{13}C) as an internal standard. Analytical gas chromatography (GC) was performed on a Shimadzu model GC-2014 instrument equipped with a capillary column of ID-BPX5 (5% phenyl-polysilphenylene-siloxane, 30 m x 0.25 mm x 0.25 μm) or InertCap 5 (5% diphenyl- and 95% dimethylpolysiloxane, 30 m x 0.25 mm x 0.25 μm) and with a FID detector, using nitrogen as carrier gas. Gas chromatography-mass spectrometry (GC-MS) analyses were performed with a Shimadzu model GCMS-QP2010 instrument equipped with a capillary column of ID-BPX5 or InertCap 5 by electron ionization at 70 eV using helium as carrier gas. Preparative recycling gel permeation chromatography (GPC) was performed with JAI LC-9105 equipped with JAIGEL-1H and JAIGEL-2H columns using chloroform as eluent. High-resolution mass spectra (HRMS) were obtained with a JEOL JMS-T100GCV spectrometer. Elemental analyses were performed on a Vario EL III elemental analysis instrument. UV-vis absorption spectra were recorded with a JASCO V-550 spectrophotometer at room temperature. Fluorescence spectra were recorded with a JASCO FP-6500 spectrofluorometer at room temperature using an excitation wavelength of 265 nm. A solution of *p*-terphenyl in cyclohexane was used as a quantum yield standard (Φ_F = 0.87 at 265 nm excitation). All melting points were measured with a Yanaco Micro Melting Point apparatus and are uncorrected. Kugelrohr bulb-to-bulb distillation was carried out with a Sibata glass tube oven GTO-250RS apparatus. 1,4-Dioxane (Dioxane) and dibutyl ether (Bu_2O) were distilled under argon from sodium just prior to use. Toluene, 1,2-diethoxyethane (DEE), nitromethane ($MeNO_2$), *p*-xylene, *o*-dichlorobenzene, substrates **1a**, **1e**, **1r**, **2a**–**2f**, **2i**, **2j**, **5**, **6**, and **7aa** were stored over molecular sieves 4Å (MS 4Å) under argon. Butyronitrile (PrCN) was distilled under argon from P_2O_5 just prior to use. Chlorobenzene (PhCl) was distilled under argon from $CaCl_2$ just prior to use. Substrates **1b**, **1h**–**1k**, **1q** and **1y**–**1ab** were stored over

KOH pellets under argon. Anhydrous dimethylacetamide (DMA) and anhydrous *N*,*N*-dimethylformamide (DMF) were commercially available and used without further purification. MeOH was stored over molecular sieves 3Å (MS 3Å) under argon. The following indium salts and substrates were synthesized according to the respective literature methods: $In(ONf)_3$,[38] $In(NTf_2)_3$,[39] 3,4-dimethoxythiophene (**2d**),[40] 3-bromo-4-methoxythiophene (**2e**),[41] 3-methoxybenzo[*b*]thiophene (**2f**),[42] 4-(2,5-dimethyl-1*H*-pyrrol-1-yl)benzenamine (**1u**),[33a] 2-bromobenzo[*b*]furan,[43] indoline-1-*d* (**1e**-1-*d*).[44] Unless otherwise noted, other substrates and reagents were commercially available and used as received without further purification.

Synthesis of Methoxyheteroarene Substrates

Substrates **2b**, **2g**, **2h**, **2i** and **2j** were synthesized based on the reported or modified literature procedures that have been used for preparing the related compounds, and were fully characterized by ^{1}H and ^{13}C NMR spectroscopy, and HRMS, unless otherwise noted.

Synthesis of 2-Methoxy-5-methylthiophene (2b)

Based on the literature procedure,[40] **2b** was synthesized using the following reagents and conditions: 2-bromo-5-methylthiophene (8.85 g, 50.0 mmol), CuBr (1.43 g, 10.0 mmol), NaOMe (4.32 g, 80.0 mmol), MeOH (10 mL), 90 ºC, 8 h, and was isolated by Kugelrohr bulb-to-bulb distillation (120 ºC/67.0 hPa) in 72% yield (4.62 g) as a colorless liquid. Compound **2b** was fully characterized by ^{1}H and ^{13}C NMR spectroscopy and HRMS, as follows: ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.34 (d, *J* = 1.4 Hz, 3 H), 3.84 (s, 3 H), 5.96 (d, *J* = 3.7 Hz, 1 H), 7.02 (dq, *J* = 3.7, 1.2 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.5, 60.2, 103.2, 121.8, 126.0, 164.0. HRMS (FI) Calcd for C_6H_8OS: M, 128.0296. Found: *m*/*z* 128.0305.

Synthesis of 2-Methoxybenzo[*b*]thiophene (2g)

Based on the literature procedure,[40] **2g** was synthesized using the following reagents and conditions: 2-bromobenzo[*b*]thiophene (1.07 g, 5.00 mmol), CuBr (143 mg, 1.00 mmol), NaOMe (459 mg, 8.50 mmol), MeOH (1.0 mL), 90 ºC, 8 h, and was isolated by Kugelrohr bulb-to-bulb distillation (120 ºC/400 Pa) in 66% yield (542 mg) as a white solid, mp 41–42 ºC. Compound **2g** has already appeared in the literature,[45] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.98 (s, 3 H), 6.34 (s, 1 H), 7.15–7.20 (m, 1 H), 7.24–7.29 (m, 1 H), 7.50–7.54 (m, 1 H), 7.58–7.62 (m, 1 H). HRMS (FD) Calcd for C_9H_8OS: M, 164.0296. Found: *m*/*z* 164.0296.

Synthesis of 2-Methoxy-5-phenylfuran (2h)

Based on the literature procedure,[46] **2h** was synthesized using the following reagents and conditions: 2-methoxyfuran (736 mg, 7.50 mmol), bromobenzene (785 mg, 5.00 mmol), $PdCl_2$ (44.3 mg, 0.250 mmol), tricyclohexyl phosphine (701 mg, 0.500 mmol, 20 wt% in toluene), tetrabutylammonium bromide (1.61 g, 5.00 mmol), KOAc (982 mg, 10.0 mmol), anhydrous DMA (15 mL), 80 ºC, 8 h, and was isolated by column chromatography on silica gel (hexane/EtOAc/Et_3N = 60/1/1) in 66% yield (575 mg) as a yellow solid, mp 44–45 ºC. Compound **2h** was fully characterized by ^{1}H and ^{13}C NMR spectroscopy and HRMS, as follows: ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.90 (s, 3 H), 5.25 (d, *J* = 3.4 Hz, 1 H), 6.53 (d, *J* = 3.2 Hz, 1 H), 7.17 (tt, *J* = 7.3, 1.4 Hz, 1 H), 7.30–7.36 (m, 2 H), 7.52–7.57 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 57.8, 81.7, 106.3, 122.5, 126.3, 128.6, 130.8, 144.1, 161.5. HRMS (FI) Calcd for $C_{11}H_{10}O_2$: M, 174.0681. Found: *m*/*z* 174.0693.

Synthesis of 2-Methoxybenzo[*b*]furan (2i)

Based on the literature procedure,[40] **2i** was synthesized using the following reagents and conditions: 2-bromobenzo[*b*]furan (1.46 g, 7.43 mmol), CuBr (212 mg, 1.48 mmol), NaOMe (638 mg, 11.8 mmol), MeOH (1.5 mL), 90 ºC, 3 h, and was isolated by Kugelrohr bulb-to-bulb distillation (80 ºC/100 Pa) in 80% yield (881 mg) as a colorless liquid. Compound **2i** was fully characterized by ^{1}H and ^{13}C NMR spectroscopy and HRMS, as follows: ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.97 (s, 3 H), 5.52 (d, *J* = 0.9 Hz, 1 H), 7.11 (td, *J* = 7.7, 1.7 Hz, 1 H), 7.15 (td, *J* = 7.6, 1.2 Hz, 1 H), 7.31 (ddd, *J* = 7.9, 1.8, 1.0 Hz, 1 H), 7.34–7.39 (m, 1 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 57.6, 75.7, 110.1, 119.1, 121.6, 122.9, 129.7, 148.9, 164.3. HRMS (FI) Calcd for $C_9H_8O_2$: M, 148.0524. Found: *m*/*z* 148.0531.

Synthesis of 2-methoxy-1-phenyl-1*H*-pyrrole (2j)

According to the modified literature procedure, **2j** was synthesized in two steps of the bromination of 1-phenyl-1*H*-pyrrole[47] followed by the methoxylation.[40]
The first step: A flame-dried 100 mL Schlenk tube was filled with argon and then charged with anhydrous DMF (40 mL), 1-phenyl-1*H*-pyrrole (1.43 g, 10.0 mmol) and *N*-bromosuccinimide (1.78 g, 10.0 mmol) at –50 ºC. After stirring at –20 ºC for 1 h, sodium sulfite (2.00 g) was added to the mixture, and stirred at room temperature for 5 min. The resulting mixture was diluted with Et_2O (100 mL), and then washed with water (100 mL x 3) and brine (20 mL). The organic layer was dried over anhydrous Na_2SO_4. Filtration and evaporation of the solvent provided a brown oil (2.08 g). The formation of 2-bromo-1-phenyl-1*H*-pyrrole was confirmed by GC-MS and ^{1}H NMR analyses, and the resulting crude product was used for the next step without purification.
The second step: A flame-dried 50 mL Schlenk tube was filled with argon and then charged with NaOMe (1.62 g, 30.0 mmol) and MeOH (3.0 mL). The mixture was stirred at room temperature until NaOMe is completely dissolved. To this were added CuBr (287 mg, 2.00 mmol) and crude 2-bromo-1-phenyl-1*H*-pyrrole (2.08 g). After stirring at 100 ºC for 3 h, the solution was filtered through a pad of Celite. The resulting filtrate was diluted with Et_2O (100 mL), and then washed with a saturated $NaHCO_3$ aqueous solution (20 mL x 2), water (20 mL) and brine (10 mL). The organic layer was dried over anhydrous sodium sulfate (Na_2SO_4). Filtration and evaporation of the solvent followed by column chromatography on silica gel (hexane/EtOAc/Et_3N = 100/2/3) gave 2-methoxy-1-phenyl-1*H*-pyrrole (**2j**) in 37% yield (641 mg) for the two steps as a colorless oil. Compound **2j** was fully characterized by ^{1}H and ^{13}C NMR spectroscopy and HRMS, as follows: ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.81 (s, 3 H), 5.38–5.44 (m, 1 H), 6.08–6.15 (m, 1 H), 6.45–6.51 (m, 1 H), 7.21–7.30 (m, 1 H), 7.36–7.45 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 57.9, 84.6, 106.6, 113.5, 124.1, 126.0, 128.9, 138.5, 147.8. HRMS (FI) Calcd for $C_{11}H_{11}NO$: M, 173.0841. Found: *m*/*z* 173.0850.

Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2

$In(NTf_2)_3$ [(2.39 mg, 2.50 μmol), (7.16 mg, 7.50 μmol), (23.9 mg, 25.0 μmol) or (35.8 mg, 37.5 μmol)] was placed in a 20 mL Schlenk tube, which was heated at 150 °C in vacuo for 2 h. The tube was cooled down to room temperature and filled with argon. PhCl (0.50 or 1.0 mL) was added to the tube, and the mixture was then stirred at room temperature for 3 min. To this were added **1** (0.275, 0.300 or 0.625 mmol) and **2** (0.250 mmol), and the resulting mixture was stirred at 90, 110 or 130 °C. After the time specified in Table 2, a saturated $NaHCO_3$ aqueous solution (0.5 mL) was added to the mixture, and the aqueous phase was extracted with EtOAc (5 mL x 3). The combined organic layer was washed with brine (1 mL) and then dried over anhydrous sodium sulfate (Na_2SO_4).

Filtration and evaporation of the solvent followed by purification gave product **3**. Unless otherwise noted, products **3** prepared in this section were fully characterized by ^{1}H and ^{13}C NMR spectroscopy, and HRMS.

4-(2-Thienyl)morpholine (3aa): The title compound was synthesized using the following reagents and conditions: **1a** (54.5 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 110 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 10/1). Compound **3aa** has already appeared in the literature,[48] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A pale yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.10–3.16 (m, 4 H), 3.82–3.87 (m, 4 H), 6.15 (dd, *J* = 3.7, 1.4 Hz, 1 H), 6.64 (dd, *J* = 5.7, 1.1 Hz, 1 H), 6.80 (dd, *J* = 5.4, 3.7 Hz, 1 H). HRMS (FI) Calcd for $C_8H_{11}NOS$: M, 169.0561. Found: *m*/*z* 169.0561.

4-(2-Thienyl)thiomorpholine (3ba): The title compound was synthesized using the following reagents and conditions: **1b** (64.5 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 110 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 20/1). A pale green oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.74–2.79 (m, 4 H), 3.45–3.50 (m, 4 H), 6.14 (dd, *J* = 3.7, 1.4 Hz, 1 H), 6.63 (dd, *J* = 5.4, 1.4 Hz, 1 H), 6.78 (dd, *J* = 5.4, 3.7 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 26.6, 54.2, 106.4, 112.9, 126.1, 159.1. HRMS (FI) Calcd for $C_8H_{11}NS_2$: M, 185.0333. Found: *m*/*z* 185.0340.

1-Phenyl-4-(2-thienyl)piperazine (3ca): The title compound was synthesized using the following reagents and conditions: **1c** (101 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 130 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 20/1). A white solid, mp 120–122 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.28–3.37 (m, 8 H), 6.20 (dd, *J* = 3.6, 1.3 Hz, 1 H), 6.66 (dd, *J* = 5.6, 1.3 Hz, 1 H), 6.81 (dd, *J* = 5.4, 3.7 Hz, 1 H), 6.90 (tt, *J* = 7.3, 1.1 Hz, 1 H), 6.95–7.01 (m, 2 H), 7.27–7.34 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 49.1, 51.9, 106.1, 112.9, 116.6, 120.3, 126.1, 129.2, 151.1, 159.1. HRMS (FI) Calcd for $C_{14}H_{16}N_2S$: M, 244.1034. Found: *m*/*z* 244.1054.

1-Acetyl-4-(2-thienyl)piperazine (3da): The title compound was synthesized using the following reagents and conditions: **1d** (80.1 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 130 °C, 48 h, and was isolated by column chromatography on silica gel (EtOAc). A pale yellow solid, mp 57–59 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.13 (s, 3 H), 3.07–3.18 (m, 4 H), 3.56–3.65 (m, 2 H), 3.71–3.81 (m, 2 H), 6.19 (dd, *J* = 3.7, 1.4 Hz, 1 H), 6.67 (dd, *J* = 5.5, 1.4 Hz, 1 H), 6.79 (dd, *J* = 5.5, 3.7 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.3, 40.9, 45.8, 51.8, 52.1, 107.0, 113.6, 126.1, 158.6, 169.0. HRMS (FI) Calcd for $C_{10}H_{14}N_2OS$: M, 210.0827. Found: *m*/*z* 210.0814.

2,3-Dihydro-1-(2-thienyl)-1*H*-indole (3ea): The title compound was synthesized using the following reagents and conditions: **1e** (74.5 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 20/1). A white solid, mp 72–74 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.16–3.23 (m, 2 H), 3.97 (t, *J* = 8.5 Hz, 2 H), 6.50 (dd, *J* = 3.7, 1.4 Hz, 1 H), 6.73–6.84 (m, 2 H), 6.92 (dd, *J* = 5.5, 3.7 Hz, 1 H), 7.12–7.18 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.2, 54.1, 108.4, 110.2, 113.6, 119.4, 124.8, 125.7, 127.4, 130.3, 147.1, 148.4. HRMS (FI) Calcd for $C_{12}H_{11}NS$: M, 201.0612. Found: *m*/*z* 201.0640.

2,3-Dihydro-6-nitro-1-(2-thienyl)-1*H*-indole (3fa): The title compound was synthesized using the following reagents and conditions: **1f** (103 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 5/1). A red solid, mp 111–112 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.23–3.30 (m, 2 H), 4.08 (t, *J* = 8.6 Hz, 2 H), 6.67 (dd, *J* = 3.7, 1.4 Hz, 1 H), 6.91 (dd, *J* = 5.7, 1.1 Hz, 1 H), 6.97 (dd, *J* = 5.4, 3.7 Hz, 1 H), 7.22 (dt, *J* = 8.0, 1.1 Hz, 1 H), 7.68 (dd, *J* = 8.0, 1.7 Hz, 1 H), 7.79 (d, *J* = 1.7 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.1, 54.9, 102.3, 113.3, 115.2, 116.2, 124.5, 126.0, 137.9, 146.6, 148.5, 148.7. HRMS (FD) Calcd for $C_{12}H_{10}N_2O_2S$: M, 246.0463. Found: *m*/*z* 246.0472.

5-Bromo-2,3-dihydro-1-(2-thienyl)-1*H*-indole (3ga): The title compound was synthesized using the following reagents and conditions: **1g** (124 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 80/1). A pale green solid, mp 48–49 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.17 (t, *J* = 8.6 Hz, 2 H), 3.97 (t, *J* = 8.6 Hz, 2 H), 6.51 (dd, *J* = 3.7, 1.4 Hz, 1 H), 6.80 (dd, *J* = 5.5, 1.4 Hz, 1 H), 6.91 (dd, *J* = 5.5, 3.7 Hz, 1 H), 6.94 (d, *J* = 8.5 Hz, 1 H), 7.18–7.25 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 27.9, 54.4, 109.6, 110.96, 111.04, 114.4, 125.7, 127.8, 130.1, 132.7, 146.4, 147.8. HRMS (FI) Calcd for $C_{12}H_{10}BrNS$: M, 278.9717. Found: *m*/*z* 278.9744.

4-(5-Methyl-2-thienyl)morpholine (3ab): The title compound was synthesized using the following reagents and conditions: **1a** (26.1 mg, 0.300 mmol), **2b** (32.0 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 110 °C, 96 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 10/1). A white solid, mp 54–56 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.37 (d, *J* = 1.1 Hz, 3 H), 3.01–3.09 (m, 4 H), 3.78–3.86 (m, 4 H), 5.95 (d, *J* = 4.0 Hz, 1 H), 6.41 (dq, *J* = 3.4, 1.1 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.3, 52.2, 66.5, 105.8, 123.3, 127.6, 157.0. HRMS (FI) Calcd for $C_9H_{13}NOS$: M, 183.0718. Found: *m*/*z* 183.0718.

2,3-Dihydro-1-(5-methyl-2-thienyl)-1*H*-indole (3eb): The title compound was synthesized using the following reagents and conditions: **1e** (35.8 mg, 0.300 mmol), **2b** (32.0 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 30/1). A white solid, mp 70–72 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.43 (d, *J* = 0.9 Hz, 3 H), 3.15 (t, *J* = 8.5 Hz, 2 H), 3.89 (t, *J* = 8.5 Hz, 2 H), 6.34 (d, *J* = 3.7 Hz, 1 H), 6.51–6.57 (m, 1 H), 6.73–6.79 (m, 1 H), 7.00–7.04 (m, 1 H), 7.07–7.16 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.4, 28.2, 54.5, 108.2, 111.8, 119.1, 123.1, 124.7, 127.4, 129.2, 130.1, 146.1, 147.9. HRMS (FD) Calcd for $C_{13}H_{13}NS$: M, 215.0769. Found: *m*/*z* 215.0769.

***N*,5-Dimethyl-*N*-(4-methylphenyl)-2-thiophenamine (3hb):** The title compound was synthesized using the following reagents and conditions: **1h** (75.7 mg, 0.625 mmol), **2b** (32.0 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 110 °C, 21 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 40/1). A brown oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.27 (s, 3 H), 2.41 (d, *J* = 1.1 Hz, 3 H), 3.25 (s, 3 H), 6.41 (d, *J* = 3.4 Hz, 1 H), 6.49–6.53 (m, 1 H), 6.82–6.87 (m, 2 H), 7.01–7.07 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.8, 20.4, 42.0, 116.2, 118.6, 123.1, 129.1, 129.4, 133.7, 147.3, 151.5. HRMS (FI) Calcd for $C_{13}H_{15}NS$: M, 217.0925. Found: *m*/*z* 217.0932.

4-(3-Thienyl)morpholine (3ac): The title compound was synthesized using the following reagents and conditions: **1a** (54.5 mg, 0.625 mmol), **2c** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (35.8 mg, 37.5 μmol), PhCl (0.50 mL), 130 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 5/1). Compound **3ac** has already appeared in the literature,[49] and its spectral and analytical

data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A white solid, mp 75–77 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.02–3.15 (m, 4 H), 3.78–3.91 (m, 4 H), 6.20 (dd, *J* = 3.2, 1.4 Hz, 1 H), 6.86 (dd, *J* = 5.3, 1.6 Hz, 1 H), 7.26 (dd, *J* = 5.3, 3.0 Hz, 1 H). HRMS (FI) Calcd for $C_8H_{11}NOS$: M, 169.0561. Found: *m*/*z* 169.0561.

2,3-Dihydro-1-(3-thienyl)-1*H*-indole (3ec): The title compound was synthesized using the following reagents and conditions: **1e** (35.8 mg, 0.300 mmol), **2c** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (7.16 mg, 7.50 μmol), PhCl (1.0 mL), 110 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 40/1). A white solid, mp 44–46 ºC. ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.14 (t, *J* = 8.3 Hz, 2 H), 3.92 (t, *J* = 8.6 Hz, 2 H), 6.63 (dd, *J* = 3.4, 1.7 Hz, 1 H), 6.74 (td, *J* = 7.4, 1.1 Hz, 1 H), 6.98–7.03 (m, 1 H), 7.09 (td, *J* = 7.7, 1.1 Hz, 1 H), 7.13–7.17 (m, 1 H), 7.18 (dd, *J* = 5.2, 1.7 Hz, 1 H), 7.32 (dd, *J* = 5.2, 3.4 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.2, 52.8, 103.7, 107.9, 118.6, 120.6, 124.9, 125.0, 127.3, 130.4, 143.4, 147.5. HRMS (FI) Calcd for $C_{12}H_{11}NS$: M, 201.0612. Found: *m*/*z* 201.0635.

2,3-Dihydro-1-(4-methoxy-3-thienyl)-1*H*-indole (3ed): The title compound was synthesized using the following reagents and conditions: **1e** (32.8 mg, 0.275 mmol), **2d** (36.0 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 110 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 40/1). A white solid, mp 96–97 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.11 (t, *J* = 8.4 Hz, 2 H), 3.86 (t, *J* = 8.5 Hz, 2 H), 3.87 (s, 3 H), 6.30 (d, *J* = 3.4 Hz, 1 H), 6.69 (d, *J* = 7.8 Hz, 1 H), 6.72 (td, *J* = 7.4, 1.0 Hz, 1 H), 6.93 (d, *J* = 3.4 Hz, 1 H), 7.00–7.06 (m, 1 H), 7.11–7.16 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.6, 53.7, 57.4, 96.8, 109.3, 110.7, 118.7, 124.6, 127.1, 130.1, 134.9, 149.4, 153.4. HRMS (FI) Calcd for $C_{13}H_{13}NOS$: M, 231.0718. Found: *m*/*z* 231.0706.

Indium-Catalyzed S_NAr Amination of 3,4-Dimethoxythiophene with Aniline (Scheme 3)

Unless otherwise noted, synthesis of **3id** and **3iid** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". As shown below, products **3id** and **3iid** were fully characterized by ^{1}H and ^{13}C NMR spectroscopy, and HRMS.

4-Methoxy-*N*-phenyl-3-thiophenamine (3id): The title compound was synthesized using the following reagents and conditions: **1i** (25.6 mg, 0.275 mmol), **2d** (36.0 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 60 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 20/1). A pale brown solid, mp 57–59 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.90 (s, 3 H), 5.97 (bs, 1 H), 6.23 (d, *J* = 3.2 Hz, 1 H), 6.65 (d, *J* = 2.7 Hz, 1 H), 6.89 (tt, *J* = 7.3, 1.1 Hz, 1 H), 7.06–7.13 (m, 2 H), 7.24–7.30 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 57.5, 95.5, 100.1, 116.0, 120.2, 129.3, 131.6, 143.2, 149.0. HRMS (FI) Calcd for $C_{11}H_{11}NOS$: M, 205.0561. Found: *m*/*z* 205.0567.

***N*^{3},*N*^{4}-Diphenyl-3,4-thiophenediamine (3iid):** A procedure for the synthesis of the title compound conducted in the absence of a solvent is as follows: $In(NTf_2)_3$ (23.9 mg, 25.0 μmol) was placed in a 20 mL Schlenk tube, which was heated at 150 °C in vacuo for 2 h. The tube was cooled down to room temperature and filled with argon. To this were added **1i** (233 mg, 2.50 mmol) and **2d** (36.0 mg, 0.250 mmol), and the resulting mixture was stirred at 70 °C for 40 h. A saturated $NaHCO_3$ aqueous solution (0.5 mL) was added to the mixture, and the aqueous phase was extracted with EtOAc (5 mL x 3). The combined organic layer was washed with brine (1 mL) and then dried over anhydrous sodium sulfate (Na_2SO_4). Filtration and evaporation of the solvent followed by column chromatography on silica gel (hexane/$CHCl_3$/Et_3N = 100/50/3) gave **3iid** in 94% yield (62.6 mg). A beige solid, mp 171–173 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.51 (bs, 2 H), 6.82–6.90 (m, 4 H), 6.90–6.98 (m, 4 H), 7.20–7.27 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 107.9, 115.6, 120.1, 129.4, 135.2, 144.5. HRMS (FI) Calcd for $C_{16}H_{14}N_2S$: M, 266.0878. Found: *m*/*z* 266.0906.

Indium-Catalyzed S_NAr Amination of 3-Bromo-4-methoxythiophene with Aniline (Scheme 4)

Synthesis of **3ie** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". As shown below, product **3ie** was fully characterized by ^{1}H and ^{13}C NMR spectroscopy, and HRMS.

4-Bromo-*N*-phenyl-3-thiophenamine (3ie): The title compound was synthesized using the following reagents and conditions: **1i** (58.2 mg, 0.625 mmol), **2e** (48.3 mg, 0.250 mmol), $In(NTf_2)_3$ (11.9 mg, 12.5 μmol), PhCl (1.0 mL), 110 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 50/1). A pale yellow solid, mp 40–41 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.86 (bs, 1 H), 6.75 (d, *J* = 3.4 Hz, 1 H), 6.94 (tt, *J* = 7.3, 1.1 Hz, 1 H), 7.08–7.14 (m, 2 H), 7.24–7.33 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 102.1, 105.4, 116.9, 121.1, 122.1, 129.4, 138.9, 143.0. HRMS (FD) Calcd for $C_{10}H_8BrNS$: M, 252.9561. Found: *m*/*z* 252.9570.

Indium-Catalyzed Tandem S_NAr Reaction of 2-Methoxythiophene with *N*-Methyl-*p*-toluidine (Scheme 5)

Synthesis of **4haa** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". As shown below, product **4haa** was fully characterized by ^{1}H and ^{13}C NMR spectroscopy, and HRMS.

***N*-Methyl-*N*-(4-methylphenyl)-[2,2'-bithiophen]-5-amine (4haa):** The title compound was synthesized using the following reagents and conditions: **1h** (30.3 mg, 0.250 mmol), **2a** (71.4 mg, 0.625 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 130 °C, 48 h, and was isolated by column chromatography on silica gel (hexane). A pale yellow solid, mp 84–85 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.31 (s, 3 H), 3.32 (s, 3 H), 6.32 (d, *J* = 3.7 Hz, 1 H), 6.91 (d, *J* = 4.1 Hz, 1 H), 6.95 (dd, *J* = 5.0, 3.7 Hz, 1 H), 6.99 (dd, *J* = 3.4, 1.1 Hz, 1 H), 7.00–7.06 (m, 2 H), 7.07–7.13 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.7, 42.1, 113.9, 119.4, 122.2, 122.5, 123.1, 127.4, 127.6, 129.7, 131.6, 138.3, 146.5, 154.2. HRMS (FD) Calcd for $C_{16}H_{15}NS_2$: M, 285.0646. Found: *m*/*z* 285.0671.

Indium-Catalyzed S_NAr Amination of 3- and 2-Methoxybenzothiophenes (Table 3)

Synthesis of **3af**–**3ig** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". Unless otherwise noted, products **3** synthesized in this section were fully characterized by ^{1}H and ^{13}C NMR spectroscopy, and HRMS.

4-Benzo[*b*]thien-3-ylmorpholine (3af): The title compound was synthesized using the following reagents and conditions: **1a** (54.5 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (35.8 mg, 37.5 μmol), PhCl (1.0 mL), 130 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 10/1). Compound **3af** has already appeared in the literature,[49] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are

omitted here. A white solid, mp 62–63 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.14 (t, *J* = 4.6 Hz, 4 H), 3.94 (t, *J* = 4.6 Hz, 4 H), 6.64 (s, 1 H), 7.31–7.40 (m, 2 H), 7.72–7.78 (m, 1 H), 7.78–7.84 (m, 1 H). HRMS (FD) Calcd for $C_{12}H_{13}NOS$: M, 219.0718. Found: *m*/*z* 219.0729.

***N*-Hexyl-*N*-methylbenzo[*b*]thiophen-3-amine (3jf):** The title compound was synthesized using the following reagents and conditions: **1j** (34.6 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (35.8 mg, 37.5 μmol), *o*-$Cl_2C_6H_4$ (1.0 mL) as a solvent, 150 °C, 72 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 30/1). A pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, *J* = 6.9 Hz, 3 H), 1.24–1.40 (m, 6 H), 1.59–1.71 (m, 2 H), 2.85 (s, 3 H), 3.05–3.14 (m, 2 H), 6.53 (s, 1 H), 7.29–7.38 (m, 2 H), 7.72–7.85 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.1, 22.7, 26.9, 27.3, 31.8, 41.1, 56.3, 106.2, 122.2, 123.2, 123.5, 124.3, 135.1, 139.3, 147.6. HRMS (FI) Calcd for $C_{15}H_{21}NS$: M, 247.1395. Found: *m*/*z* 247.1424.

1-(Benzo[*b*]thien-3-yl)-2,3-dihydro-1*H*-indole (3ef): The title compound was synthesized using the following reagents and conditions: **1e** (35.8 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 110 °C, 14 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 100/1). A white solid, mp 86–88 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.19 (t, *J* = 8.2 Hz, 2 H), 3.96 (t, *J* = 8.2 Hz, 2 H), 6.54 (d, *J* = 7.8 Hz, 1 H), 6.75 (td, *J* = 7.4, 0.8 Hz, 1 H), 7.00 (td, *J* = 7.6, 0.8 Hz, 1 H), 7.12 (s, 1 H), 7.20 (dd, *J* = 7.3, 0.7 Hz, 1 H), 7.33–7.41 (m, 2 H), 7.74–7.78 (m, 1 H), 7.84–7.87 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.9, 55.0, 109.3, 113.4, 118.8, 122.8, 123.1, 123.7, 124.7, 124.8, 127.2, 130.3, 135.4, 139.0, 139.1, 149.9. HRMS (FD) Calcd for $C_{16}H_{13}NS$: M, 251.0769. Found: *m*/*z* 251.0740.

***N*-Methyl-*N*-phenylbenzo[*b*]thiophen-3-amine (3kf):** The title compound was synthesized using the following reagents and conditions: **1k** (67.0 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (71.6 mg, 75.0 μmol), PhCl (0.50 mL), 110 °C, 8 h, and was isolated by column chromatography on silica gel (hexane). Compound **3kf** has already appeared in the literature,[50] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.39 (s, 3 H), 6.75–6.79 (m, 2 H), 6.82 (tt, *J* = 7.3, 1.1 Hz, 1 H), 7.13 (s, 1 H), 7.16–7.22 (m, 2 H), 7.22–7.27 (m, 1 H), 7.30–7.36 (m, 1 H), 7.40 (ddd, *J* = 8.0, 1.3, 0.7 Hz, 1 H), 7.83 (ddd, *J* = 8.0, 1.1, 0.7 Hz, 1 H). HRMS (FI) Calcd for $C_{15}H_{13}NS$: M, 239.0769. Found: *m*/*z* 239.0798.

***N*,*N*-Bis(4-methylphenyl)benzo[*b*]thiophen-3-amine (3lf):** The title compound was synthesized using the following reagents and conditions: **1l** (123 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (71.6 mg, 75.0 μmol), PhCl (0.25 mL), 110 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/$CHCl_3$ = 100/1). A pale yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.29 (s, 6 H), 6.90–6.98 (m, 5 H), 6.98–7.05 (m, 4 H), 7.19 (ddd, *J* = 8.1, 7.0, 1.0 Hz, 1 H), 7.30 (dt, *J* = 10.3, 3.8 Hz, 1 H), 7.35 (ddd, *J* = 8.0, 1.1, 0.7 Hz, 1 H), 7.80 (dt, *J* = 8.0, 0.8 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.7, 118.6, 122.3, 122.8, 123.1, 123.9, 124.5, 129.7, 131.7, 135.4, 139.1, 140.8, 145.4. HRMS (FI) Calcd for $C_{22}H_{19}NS$: M, 329.1238. Found: *m*/*z* 329.1259.

***N*-Phenylbenzo[*b*]thiophen-3-amine (3if):** The title compound was synthesized using the following reagents and conditions: **1i** (27.9 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 30/1). Compound **3if** has already appeared in the literature,[49] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A beige solid, mp 81–83 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.75 (bs, 1 H), 6.89 (tt, *J* = 7.3, 1.1 Hz, 1 H), 6.97–7.05 (m, 3 H), 7.22–7.30 (m, 2 H), 7.34–7.42 (m, 2 H), 7.63–7.70 (m, 1 H), 7.80–7.88 (m, 1 H). HRMS (FI) Calcd for $C_{14}H_{11}NS$: M, 225.0612. Found: *m*/*z* 225.0633.

***N*-(4-Methoxyphenyl)benzo[*b*]thiophen-3-amine (3mf):** The title compound was synthesized using the following reagents and conditions: **1m** (36.9 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 10/1). Compound **3mf** has already appeared in the literature,[51] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A beige solid, mp 100–102 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.80 (s, 3 H), 5.62 (bs, 1 H), 6.74 (s, 1 H), 6.86 (dt, *J* = 9.2, 2.7 Hz, 2 H), 7.04 (dt, *J* = 9.2, 2.7 Hz, 2 H), 7.34–7.40 (m, 2 H), 7.63–7.69 (m, 1 H), 7.79–7.85 (m, 1 H). HRMS (FI) Calcd for $C_{15}H_{13}NOS$: M, 255.0718. Found: *m*/*z* 255.0689.

2-(Benzo[*b*]thien-3-ylamino)phenol (3nf): The title compound was synthesized using the following reagents and conditions: **1n** (32.7 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 4/1). A beige solid, mp 81–83 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.43 (bs, 1 H), 5.80 (bs, 1 H), 6.58 (s, 1 H), 6.86–7.01 (m, 3 H), 7.17 (dd, *J* = 7.8, 1.4 Hz, 1 H), 7.36–7.44 (m, 2 H), 7.66–7.73 (m, 1 H), 7.79–7.87 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 105.2, 115.3, 120.1, 120.4, 121.3, 123.2, 123.4, 123.9, 124.9, 131.2, 133.7, 136.4, 139.1, 147.3. HRMS (FI) Calcd for $C_{14}H_{11}NOS$: M, 241.0561. Found: *m*/*z* 241.0550.

4-(Benzo[*b*]thien-3-ylamino)benzeneethanol (3of): The title compound was synthesized using the following reagents and conditions: **1o** (41.2 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 10/1). A beige solid, mp 65–67 ºC. ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.40 (bs, 1 H), 2.82 (t, *J* = 6.6 Hz, 2 H), 3.74–3.89 (m, 2 H), 5.74 (bs, 1 H), 6.91–7.06 (m, 3 H), 7.13 (d, *J* = 8.0 Hz, 2 H), 7.33–7.42 (m, 2 H), 7.63–7.69 (m, 1 H), 7.79–7.87 (m, 1 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 38.4, 63.8, 108.3, 116.5, 120.5, 123.2, 123.9, 124.9, 129.9, 130.0, 134.5, 135.2, 138.9, 143.2. HRMS (FD) Calcd for $C_{16}H_{15}NOS$: M, 269.0874. Found: *m*/*z* 269.0871.

***N*-(4-Iodophenyl)benzo[*b*]thiophen-3-amine (3pf):** The title compound was synthesized using the following reagents and conditions: **1p** (65.7 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (11.9 mg, 12.5 μmol), PhCl (1.0 mL), 50 °C, 9 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 10/1). A dark red solid, mp 105–107 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.72 (bs, 1 H), 6.73 (dt, *J* = 9.6, 2.5 Hz, 2 H), 7.05 (s, 1 H), 7.33–7.43 (m, 2 H), 7.50 (dt, *J* = 9.3, 2.5 Hz, 2 H), 7.57–7.66 (m, 1 H), 7.81–7.87 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 81.1, 111.4, 117.8, 120.7, 123.3, 124.1, 125.0, 134.2, 134.6, 138.0, 138.9, 144.7. HRMS (FI) Calcd for $C_{14}H_{10}INS$: M, 350.9579. Found: *m*/*z* 350.9560.

***N*-(3-Bromophenyl)benzo[*b*]thiophen-3-amine (3qf):** The title compound was synthesized using the following reagents and conditions: **1q** (51.6 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (11.9 mg, 12.5 μmol), PhCl (1.0 mL), 50 °C, 9 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 15/1). A pale pink solid, mp 73–74 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.73 (bs, 1 H), 6.85 (d, *J* = 8.2 Hz, 1 H), 6.98 (d, *J* = 7.3 Hz, 1 H), 7.04–7.14 (m, 3 H), 7.34–7.43 (m, 2 H), 7.59–7.66 (m, 1 H), 7.81–7.89 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 112.1, 114.1, 118.2, 120.7, 122.7, 123.2, 123.3, 124.1, 125.0, 130.7, 133.9, 134.6, 138.9, 146.4. HRMS

(FD) Calcd for $C_{14}H_{10}BrNS$: M, 302.9717. Found: *m*/*z* 302.9711.

***N*-[3,5-Bis(trifluoromethyl)phenyl]benzo[*b*]thiophen-3-amine (3rf):** The title compound was synthesized using the following reagents and conditions: **1r** (68.7 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (11.9 mg, 12.5 μmol), PhCl (1.0 mL), 50 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 30/1). A beige solid, mp 68–69 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 5.99 (bs, 1 H), 7.22–7.23 (m, 1 H), 7.24–7.26 (m, 2 H), 7.29–7.32 (m, 1 H), 7.37–7.46 (m, 2 H), 7.57–7.63 (m, 1 H), 7.86–7.91 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 112.6 (sept, *J* = 4.1 Hz), 114.2 (q, *J* = 3.5 Hz), 115.4, 120.6, 123.4 (q, *J* = 272.7 Hz), 123.5, 124.5, 125.4, 132.4, 132.7 (q, *J* = 32.9 Hz), 134.4, 139.0, 146.5. HRMS (FI) Calcd for $C_{16}H_9F_6NS$: M, 361.0360. Found: *m*/*z* 361.0376.

4-(Benzo[*b*]thien-3-ylamino)benzonitrile (3sf): The title compound was synthesized using the following reagents and conditions: **1s** (35.4 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (11.9 mg, 12.5 μmol), PhCl (1.0 mL), 50 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 5/1). A pale beige solid, mp 158–160 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 6.03 (bs, 1 H), 6.85 (dt, *J* = 9.2, 2.2 Hz, 2 H), 7.24 (s, 1 H), 7.35–7.44 (m, 2 H), 7.47 (dt, *J* = 9.2, 2.2 Hz, 2 H), 7.54–7.65 (m, 1 H), 7.82–7.93 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 101.2, 114.3, 116.4, 120.0, 120.9, 123.3, 124.4, 125.2, 132.2, 133.8, 134.7, 138.9, 149.2. HRMS (FI) Calcd for $C_{15}H_{10}N_2S$: M, 250.0565. Found: *m*/*z* 250.0579.

Ethyl 4-(benzo[*b*]thien-3-ylamino)benzoate (3tf): The title compound was synthesized using the following reagents and conditions: **1t** (49.6 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (7.16 mg, 7.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 6/1). A brown solid, mp 127–129 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 1.37 (t, *J* = 7.1 Hz, 3 H), 4.33 (q, *J* = 7.2 Hz, 2 H), 6.01 (bs, 1 H), 6.88 (dt, *J* = 9.3, 2.3 Hz, 2 H), 7.20 (s, 1 H), 7.34–7.44 (m, 2 H), 7.58–7.67 (m, 1 H), 7.83–7.89 (m, 1 H), 7.92 (dt, *J* = 9.2, 2.2 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.4, 60.4, 113.9, 114.2, 120.9, 121.1, 123.3, 124.2, 125.1, 131.5, 133.1, 134.7, 138.8, 149.2, 166.6. HRMS (FI) Calcd for $C_{17}H_{15}NO_2S$: M, 297.0823. Found: *m*/*z* 297.0813.

***N*-[4-(2,5-dimethyl-1*H*-pyrrol-1-yl)phenyl]benzo[*b*]thiophen-3-amine (3uf):** The title compound was synthesized using the following reagents and conditions: **1u** (55.9 mg, 0.300 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 10/1). A pink solid, mp 176–178 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 2.05 (s, 6 H), 5.85 (bs, 1 H), 5.88 (s, 2 H), 7.02 (dt, *J* = 9.0, 2.5 Hz, 2 H), 7.08 (dt, *J* = 9.0, 2.5 Hz, 2 H), 7.13 (s, 1 H), 7.41 (dt, *J* = 9.8, 3.5 Hz, 2 H), 7.65–7.73 (m, 1 H), 7.82–7.91 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.0, 105.2, 110.8, 115.7, 120.6, 123.3, 124.1, 125.0, 129.08, 129.12, 130.9, 134.4, 134.6, 138.9, 144.3. HRMS (FD) Calcd for $C_{20}H_{18}N_2S$: M, 318.1191. Found: *m*/*z* 318.1186.

***N*-(2-Methylindol-5-yl)benzo[*b*]thiophen-3-amine (3vf):** The title compound was synthesized using the following reagents and conditions: **1v** (91.4 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 110 °C, 3 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 5/1). A brown solid, mp 154–156 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 2.43 (s, 3 H), 5.70 (bs, 1 H), 6.13 (s, 1 H), 6.70 (s, 1 H), 6.95 (dd, *J* = 8.5, 2.1 Hz, 1 H), 7.22 (d, *J* = 8.5 Hz, 1 H), 7.26 (d, *J* = 2.1 Hz, 1 H), 7.33–7.40 (m, 2 H), 7.67–7.73 (m, 1 H), 7.77 (bs, 1 H), 7.79–7.86 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.8, 100.2, 102.7, 109.5, 110.8, 114.7, 120.1, 123.2, 123.6, 124.7, 129.8, 132.3, 133.9, 136.0, 136.8, 138.3, 139.1. HRMS (FD) Calcd for $C_{17}H_{14}N_2S$: M, 278.0878. Found: *m*/*z* 278.0875.

***N*-(Pyridin-3-yl)benzo[*b*]thiophen-3-amine (3wf):** The title compound was synthesized using the following reagents and conditions: **1w** (18.8 mg, 0.250 mmol), **2f** (82.1 mg, 0.500 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 130 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 1/1). Compound **3wf** has already appeared in the literature,[52] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A pale brown solid, mp 116–117 °C. ^1H NMR (500 MHz, $CDCl_3$) δ 5.91 (bs, 1 H), 7.06 (s, 1 H), 7.14 (dd, *J* = 8.2, 4.7 Hz, 1 H), 7.20–7.28 (m, 1 H), 7.34–7.44 (m, 2 H), 7.60–7.67 (m, 1 H), 7.82–7.88 (m, 1 H), 8.10–8.16 (m, 1 H), 8.36 (d, *J* = 2.9 Hz, 1 H). HRMS (FD) Calcd for $C_{13}H_{10}N_2S$: M, 226.0565. Found: *m*/*z* 226.0556.

***N*-Benzo[*b*]thien-3-yl-2-benzothiazolamine (3xf):** The title compound was synthesized using the following reagents and conditions: **1x** (37.5 mg, 0.250 mmol), **2f** (82.1 mg, 0.500 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 110 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 10/1). A brown solid, mp 202–204 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.12–7.19 (m, 1 H), 7.28–7.36 (m, 1 H), 7.38–7.47 (m, 2 H), 7.56 (ddd, *J* = 8.1, 1.0, 0.5 Hz, 1 H), 7.62 (ddd, *J* = 7.8, 1.3, 0.6 Hz, 1 H), 7.72–7.81 (m, 2 H), 7.84–7.92 (m, 1 H), 8.23 (bs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 113.7, 119.6, 119.9, 121.0, 122.6, 123.3, 124.4, 125.3, 126.2, 130.5, 131.6, 133.4, 138.6, 151.6, 164.8. HRMS (FI) Calcd for $C_{15}H_{10}N_2S_2$: M, 282.0285. Found: *m*/*z* 282.0297.

***N*-Hexylbenzo[*b*]thiophen-3-amine (3yf):** The title compound was synthesized using the following reagents and conditions: **1y** (63.2 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (71.6 mg, 75.0 μmol), PhCl (0.25 mL), 130 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 100/1). Compound **3yf** has already appeared in the literature,[53] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A pale yellow oil. ^1H NMR (400 MHz, $CDCl_3$) δ 0.91 (t, *J* = 7.0 Hz, 3 H), 1.29–1.53 (m, 6 H), 1.74 (quint, *J* = 7.3 Hz, 2 H), 3.23 (t, *J* = 7.1 Hz, 2 H), 3.82 (bs, 1 H), 6.03 (s, 1 H), 7.30–7.38 (m, 2 H), 7.54–7.59 (m, 1 H), 7.75–7.81 (m, 1 H). HRMS (FI) Calcd for $C_{14}H_{19}NS$: M, 233.1238. Found: *m*/*z* 233.1261.

***N*-Cyclopentylbenzo[*b*]thiophen-3-amine (3zf):** The title compound was synthesized using the following reagents and conditions: **1z** (53.2 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (71.6 mg, 75.0 μmol), PhCl (1.0 mL), 130 °C, 96 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 200/1). A brown oil. ^1H NMR (500 MHz, $CDCl_3$) δ 1.56–1.69 (m, 6 H), 2.03–2.14 (m, 2 H), 3.74–3.93 (m, 2 H), 6.04 (s, 1 H), 7.30–7.37 (m, 2 H), 7.51–7.57 (m, 1 H), 7.74–7.81 (m, 1 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 24.4, 33.6, 56.4, 95.2, 119.3, 123.2, 123.3, 124.6, 133.0, 139.1, 140.9. HRMS (FI) Calcd for $C_{13}H_{15}NS$: M, 217.0925. Found: *m*/*z* 217.0947.

***N*-Benzylbenzo[*b*]thiophen-3-amine (3aaf):** The title compound was synthesized using the following reagents and conditions: **1aa** (67.0 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (71.6 mg, 75.0 μmol), PhCl (1.0 mL), 130 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc/Et_3N = 100/1/5). Compound **3aaf** has already appeared in the literature,[54] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A pale blue oil. ^1H NMR (400 MHz, $CDCl_3$) δ 4.22 (bs, 1 H), 4.44 (s, 2 H), 6.07 (s, 1 H), 7.28–7.41 (m, 5 H), 7.43–7.48 (m, 2 H), 7.56–7.61 (m, 1 H),

7.76–7.82 (m, 1 H). HRMS (FD) Calcd for $C_{15}H_{13}NS$: M, 239.0769. Found: *m*/*z* 239.0790.

***N*-[2-(1-Cyclohexen-1-yl)ethyl]benzo[*b*]thiophen-3-amine (3abf):** The title compound was synthesized using the following reagents and conditions: **1ab** (78.3 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (71.6 mg, 75.0 μmol), PhCl (0.25 mL), 130 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 100/1). Compound **3abf** has already appeared in the literature,[55] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A brown oil. ^1H NMR (400 MHz, $CDCl_3$) δ 1.54–1.68 (m, 4 H), 1.95–2.09 (m, 4 H), 2.38 (t, *J* = 6.5 Hz, 2 H), 3.28 (t, *J* = 6.8 Hz, 2 H), 3.90 (bs, 1 H), 5.60 (tt, *J* = 4.9, 1.6 Hz, 1 H), 6.05 (s, 1 H), 7.31–7.37 (m, 2 H), 7.49–7.55 (m, 1 H), 7.75–7.81 (m, 1 H). HRMS (FI) Calcd for $C_{16}H_{19}NS$: M, 257.1238. Found: *m*/*z* 257.1260.

***N*-Phenylbenzo[*b*]thiophen-2-amine (3ig):** The title compound was synthesized using the following reagents and conditions: **1i** (27.9 mg, 0.300 mmol), **2g** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 30/1). A salmon pink solid, mp 133–134 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 5.93 (bs, 1 H), 6.82 (s, 1 H), 6.95 (tt, *J* = 7.3, 1.1 Hz, 1 H), 7.07–7.13 (m, 2 H), 7.17–7.24 (m, 1 H), 7.26–7.33 (m, 3 H), 7.53–7.59 (m, 1 H), 7.63–7.69 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 109.2, 116.2, 121.1, 121.9, 122.9, 124.5, 129.4, 134.4, 139.5, 143.7, 146.3 (One carbon signal is missing due to overlapping). HRMS (FD) Calcd for $C_{14}H_{11}NS$: M, 225.0612. Found: *m*/*z* 225.0615.

Indium-Catalyzed S_NAr Amination of 3-Methoxybenzothiophene with Small Molecular Weight Amines (Scheme 6)

Synthesis of **3acf–3aeff** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". As shown below, products **3acf–3aeff** were fully characterized by ^1H and ^{13}C NMR spectroscopy, and HRMS.

***N*,*N*-Dimethylbenzo[*b*]thiophen-3-amine (3acf):** The title compound was synthesized using the following reagents and conditions: **1ac** (101 mg, 0.750 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 130 °C, 72 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 15/1). A colorless oil. ^1H NMR (400 MHz, $CDCl_3$) δ 2.89 (s, 6 H), 6.54 (s, 1 H), 7.30–7.40 (m, 2 H), 7.75–7.86 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 44.4, 105.6, 122.2, 123.2, 123.6, 124.4, 134.7, 139.4, 148.0. HRMS (FD) Calcd for $C_{10}H_{11}NS$: M, 177.0612. Found: *m*/*z* 177.0604.

***N*-Methylbenzo[*b*]thiophen-3-amine (3adf):** The title compound was synthesized using the following reagents and conditions: **1ad** (50.6 mg, 0.750 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (47.8 mg, 50.0 μmol), PhCl (1.0 mL), 130 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 15/1). A pale brown oil. ^1H NMR (400 MHz, $CDCl_3$) δ 3.00 (s, 3 H), 3.90 (bs, 1 H), 6.06 (s, 1 H), 7.31–7.38 (m, 2 H), 7.52–7.57 (m, 1 H), 7.75–7.81 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 32.4, 94.6, 119.3, 123.2, 123.4, 124.7, 132.7, 139.3, 142.7. HRMS (FD) Calcd for C_9H_9NS: M, 163.0456. Found: *m*/*z* 163.0452.

***N*-Benzo[*b*]thien-3-ylbenzo[*b*]thiophen-3-amine (3aeff):** The title compound was synthesized using the following reagents and conditions: **1ae** (38.5 mg, 0.500 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 130 °C, 48 h, and was isolated by column chromatography on silica gel (hexane/$CHCl_3$ = 4/1). A pale brown solid, mp 104–106 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 6.13 (bs, 1 H), 6.80 (s, 2 H), 7.38–7.44 (m, 4 H), 7.71–7.78 (m, 2 H), 7.82–7.89 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 105.5, 120.1, 123.3, 123.9, 124.9, 133.4, 136.1, 139.0. HRMS (FD) Calcd for $C_{16}H_{11}NS_2$: M, 281.0333. Found: *m*/*z* 281.0354.

Indium-Catalyzed Reaction of 3-Methoxybenzothiophene with Cyclic Diarylamine 1af (Scheme 7)

Synthesis of **3'aff** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". As shown below, product **3'aff** was fully characterized by ^1H and ^{13}C NMR spectroscopy, and HRMS.

2-(Benzo[*b*]thien-3-yl)-10,11-dihydro-5*H*-dibenz[*b*,*f*]azepine (3'aff): The title compound was synthesized using the following reagents and conditions: **1af** (146 mg, 0.750 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (71.6 mg, 75.0 μmol), PhCl (0.25 mL), 110 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 20/1). A pale yellow solid, mp 62–64 °C. ^1H NMR (500 MHz, $CDCl_3$) δ 3.14 (s, 4 H), 6.11 (bs, 1 H), 6.75–6.85 (m, 3 H), 7.05–7.13 (m, 2 H), 7.26–7.34 (m, 3 H), 7.34–7.42 (m, 2 H), 7.87–7.98 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 34.9, 35.1, 118.0, 118.2, 119.7, 122.2, 122.9, 123.0, 124.2, 124.3, 126.9, 127.07, 127.09, 128.6, 128.8, 130.7, 130.9, 137.7, 138.1, 140.6, 141.9, 142.2. HRMS (FD) Calcd for $C_{22}H_{17}NS$: M, 327.1082. Found: *m*/*z* 327.1096.

Indium-Catalyzed S_NAr Amination of Furan, Benzofuran, Pyrrole, and Indole Electrophiles (Table 4)

Synthesis of **3eh–3ek** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". As shown below, products **3eh–3ek** were fully characterized by ^1H and ^{13}C NMR spectroscopy, and HRMS.

2,3-Dihydro-1-(5-phenyl-2-furanyl)-1*H*-indole (3eh). The title compound was synthesized using the following reagents and conditions: **1e** (74.5 mg, 0.625 mmol), **2h** (43.5 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 90 °C, 10 min, and was isolated by column chromatography on silica gel (hexane/$CHCl_3$ = 8/1). A brown oil. ^1H NMR (400 MHz, $CDCl_3$) δ 3.22 (t, *J* = 8.7 Hz, 2 H), 3.98 (t, *J* = 8.7 Hz, 2 H), 5.53 (d, *J* = 3.4 Hz, 1 H), 6.67 (d, *J* = 3.4 Hz, 1 H), 6.83 (td, *J* = 7.4, 0.8 Hz, 1 H), 7.15–7.22 (m, 3 H), 7.34–7.41 (m, 3 H), 7.57–7.64 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.1, 50.1, 88.3, 106.9, 109.7, 119.9, 122.3, 124.8, 125.9, 127.7, 128.7, 130.0, 131.1, 145.0, 145.9, 152.2. HRMS (FI) Calcd for $C_{18}H_{15}NO$: M, 261.1154. Found: *m*/*z* 261.1183.

***N*-Methyl-*N*,5-diphenyl-2-furanamine (3kh):** The title compound was synthesized using the following reagents and conditions: **1k** (67.0 mg, 0.625 mmol), **2h** (43.5 mg, 0.250 mmol), $In(NTf_2)_3$ (4.78 mg, 5.00 μmol), PhCl (1.0 mL), 110 °C, 2 h, and was isolated by column chromatography on silica gel (hexane/$CHCl_3$ = 8/1). A pale yellow solid, mp 30–31 °C. ^1H NMR (500 MHz, $CDCl_3$) δ 3.35 (s, 3 H), 5.84 (d, *J* = 3.4 Hz, 1 H), 6.63 (d, *J* = 3.4 Hz, 1 H), 6.90–6.94 (m, 1 H), 6.99–7.04 (m, 2 H), 7.19 (t, *J* = 7.4 Hz, 1 H), 7.24–7.30 (m, 2 H), 7.31–7.37 (m, 2 H), 7.57–7.61 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 38.8, 97.6, 106.4, 116.5, 120.4, 122.9, 126.6, 128.6, 129.0, 130.9, 147.1, 147.7, 154.3. HRMS (FD) Calcd for $C_{17}H_{15}NO$: M, 249.1154. Found: *m*/*z* 249.1174.

1-(Benzo[*b*]furan-2-yl)-2,3-dihydro-1*H*-indole (3ei): The title compound was synthesized using the following reagents and conditions: **1e** (35.8 mg, 0.300 mmol), **2i** (37.0 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol),

PhCl (1.0 mL), 50 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/Et_3N = 20/1). A white solid, mp 96–98 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.25 (t, *J* = 8.7 Hz, 2 H), 4.04 (td, *J* = 8.7, 0.6 Hz, 2 H), 5.72 (d, *J* = 0.9 Hz, 1 H), 6.87 (td, *J* = 7.3, 0.9 Hz, 1 H), 7.08 (td, *J* = 7.6, 1.5 Hz, 1 H), 7.13–7.24 (m, 3 H), 7.34–7.42 (m, 2 H), 7.46–7.56 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.0, 49.8, 80.9, 109.8, 110.8, 118.3, 120.5, 120.6, 123.0, 124.9, 127.7, 130.1, 130.4, 144.2, 150.6, 154.7. HRMS (FI) Calcd for $C_{16}H_{13}NO$: M, 235.0997. Found: *m*/*z* 235.0988.

4-(1-Phenylpyrrol-2-yl)morpholine (3aj): The title compound was synthesized using the following reagents and conditions: **1a** (54.5 mg, 0.625 mmol), **2j** (43.3 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 90 °C, 46 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 20/1). A white solid, mp 87–88 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.75–2.81 (m, 4 H), 3.61–3.68 (m, 4 H), 5.76 (dd, *J* = 3.5, 1.9 Hz, 1 H), 6.17 (t, *J* = 3.4 Hz, 1 H), 6.63 (dd, *J* = 3.2, 1.8 Hz, 1 H), 7.23–7.30 (m, 1 H), 7.38–7.45 (m, 2 H), 7.53–7.58 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 52.3, 66.9, 95.2, 107.3, 117.7, 124.3, 126.2, 128.9, 139.8, 142.9. HRMS (FI) Calcd for $C_{14}H_{16}N_2O$: M, 228.1263. Found: *m*/*z* 228.1287.

3-(Morpholin-4-yl)-1*H*-indole (3ak): The title compound was synthesized using the following reagents and conditions: **1a** (54.5 mg, 0.625 mmol), **2k** (43.8 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (0.50 mL), 110 °C, 6 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 2/1). A yellow-brown solid, mp 140–142 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.05–3.14 (m, 4 H), 3.89–3.99 (m, 4 H), 6.74 (d, *J* = 2.7 Hz, 1 H), 7.09 (ddd, *J* = 8.2, 6.9, 0.9 Hz, 1 H), 7.19 (ddd, *J* = 8.4, 6.8, 1.3 Hz, 1 H), 7.28–7.35 (m, 1 H), 7.60–7.66 (m, 1 H), 7.71 (bs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 53.1, 67.1, 110.2, 111.4, 119.0, 122.0, 122.4, 132.5, 135.7 (One carbon signal is missing due to overlapping). HRMS (FI) Calcd for $C_{12}H_{14}N_2O$: M, 202.1106. Found: *m*/*z* 202.1119.

2,3-Dihydro-1,3'-bi-1*H*-indole (3ek): The title compound was synthesized using the following reagents and conditions: **1e** (74.5 mg, 0.625 mmol), **2k** (43.8 mg, 0.250 mmol), $In(NTf_2)_3$ (11.9 mg, 12.5 μmol), PhCl (0.50 mL), 100 °C, 4 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 5/1). A brown solid, mp 84–86 ºC. ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.17 (t, *J* = 8.6 Hz, 2 H), 3.91 (t, *J* = 8.6 Hz, 2 H), 6.52 (d, *J* = 8.0 Hz, 1 H), 6.69 (t, *J* = 7.4 Hz, 1 H), 6.99 (t, *J* = 7.7 Hz, 1 H), 7.08 (t, *J* = 7.4 Hz, 1 H), 7.14–7.19 (m, 2 H), 7.22 (t, *J* = 7.4 Hz, 1 H), 7.37 (d, *J* = 8.6 Hz, 1 H), 7.53 (d, *J* = 8.0 Hz, 1 H), 7.90 (bs, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.9, 55.4, 108.3, 111.5, 116.9, 117.8, 119.3, 119.7, 122.4, 123.1, 123.5, 124.5, 127.3, 129.7, 135.2, 151.4. HRMS (FI) Calcd for $C_{16}H_{14}N_2$: M, 234.1157. Found: *m*/*z* 234.1139.

Indium-Catalyzed S_NAr Alkoxylation and Thiolation of (Di)methoxythiophenes (Table 5)

Synthesis of **7aa**, **7ba**, **8aa**, and **8bd** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". Unless otherwise noted, products **7** and **8** prepared in this section were fully characterized by ^{1}H and ^{13}C NMR spectroscopy, and HRMS.

2-(*n*-Decyloxy)thiophene (7aa): The title compound was synthesized using the following reagents and conditions: **5a** (158 mg, 1.00 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 50 °C, 4 h, and was isolated by column chromatography on silica gel (hexane). Compound **7aa** has already appeared in the literature,[56] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, *J* = 6.9 Hz, 3 H), 1.20–1.38 (m, 12 H), 1.38–1.48 (m, 2 H), 1.71–1.82 (m, 2 H), 4.02 (t, *J* = 6.6 Hz, 2 H), 6.19 (dd, *J* = 3.9, 1.6 Hz, 1 H), 6.53 (dd, *J* = 5.7, 1.6 Hz, 1 H), 6.71 (dd, *J* = 5.5, 3.7 Hz, 1 H). HRMS (FI) Calcd for $C_{14}H_{24}OS$: M, 240.1548. Found: *m*/*z* 240.1525.

2-[2-(2-Ethoxyethoxy)ethoxy]thiophene (7ba): The title compound was synthesized using the following reagents and conditions: **5b** (134 mg, 1.00 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (7.16 mg, 7.50 μmol), PhCl (1.0 mL), 80 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 4/1). A pale yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.22 (t, *J* = 6.9 Hz, 3 H), 3.54 (q, *J* = 6.9 Hz, 2 H), 3.62 (dd, *J* = 5.7, 4.0 Hz, 2 H), 3.71 (dd, *J* = 5.7, 4.0 Hz, 2 H), 3.85 (dd, *J* = 5.7, 4.0 Hz, 2 H), 4.20 (dd, *J* = 5.2, 4.0 Hz, 2 H), 6.23 (dd, *J* = 3.7, 1.4 Hz, 1 H), 6.55 (dd, *J* = 5.7, 1.7 Hz, 1 H), 6.70 (dd, *J* = 5.7, 3.4 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.2, 66.7, 69.4, 69.9, 70.9, 73.1, 105.1, 112.2, 124.6, 165.3. HRMS (FD) Calcd for $C_{10}H_{16}O_3S$: M, 216.0820. Found: *m*/*z* 216.0813.

2-(*n*-Decylthio)thiophene (8aa): The title compound was synthesized using the following reagents and conditions: **6a** (52.3 mg, 0.300 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 50 °C, 5 h, and was isolated by column chromatography on silica gel (hexane). A colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, *J* = 6.9 Hz, 3 H), 1.22–1.33 (m, 12 H), 1.33–1.44 (m, 2 H), 1.55–1.65 (m, 2 H), 2.79 (t, *J* = 7.6 Hz, 2 H), 6.97 (dd, *J* = 5.3, 3.4 Hz, 1 H), 7.10 (dd, *J* = 3.4, 1.1 Hz, 1 H), 7.32 (dd, *J* = 5.3, 1.1 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.1, 22.7, 28.4, 29.2, 29.3, 29.4, 29.50, 29.54, 31.9, 39.0, 127.4, 128.8, 133.2, 135.0. HRMS (FI) Calcd for $C_{14}H_{24}S_2$: M, 256.1319. Found: *m*/*z* 256.1333.

3,4-Bis(*n*-dodecylthio)thiophene (8bd): The title compound was synthesized using the following reagents and conditions: **6b** (202 mg, 1.00 mmol), **2d** (36.0 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 100 °C, 24 h, and was isolated by column chromatography on silica gel (hexane). Compound **8bd** has already appeared in the literature,[28c] and its spectral and analytical data are in good agreement with those reported. Accordingly, ^{13}C NMR data are omitted here. A colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 0.88 (t, *J* = 7.0 Hz, 6 H), 1.20–1.33 (m, 32 H), 1.41 (quint, *J* = 7.0 Hz, 4 H), 1.64 (quint, *J* = 7.6 Hz, 4 H), 2.86 (t, *J* = 7.4 Hz, 4 H), 7.08 (s, 2 H). HRMS (FD) Calcd for $C_{28}H_{52}S_3$: M, 484.3231. Found: *m*/*z* 484.3247.

Indium-Catalyzed S_NAr Reaction of 3-Methoxybenzothiophene in the Presence of Phenol (Scheme 8)

Synthesis of **9** was carried out in a similar way to the procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". As shown below, product **9** was fully characterized by ^{1}H and ^{13}C NMR spectroscopy, and HRMS.

3-Methoxy-2,3'-bibenzo[*b*]thiophene (9): The title compound was synthesized using the following reagents and conditions: **5c** (58.8 mg, 0.625 mmol), **2f** (41.1 mg, 0.250 mmol), $In(NTf_2)_3$ (23.9 mg, 25.0 μmol), PhCl (1.0 mL), 90 °C, 24 h, and was isolated by column chromatography on silica gel (hexane/EtOAc = 200/1). A pale yellow solid, mp 96–97 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.71 (s, 3 H), 7.36–7.47 (m, 4 H), 7.73 (s, 1 H), 7.76–7.80 (m, 1 H), 7.82–7.86 (m, 1 H), 7.89–7.95 (m, 1 H), 8.06–8.12 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 60.7, 117.7, 121.1, 122.5, 122.7, 123.6, 124.3, 124.7, 124.8, 125.1, 126.7, 128.1, 134.0, 136.4, 138.3, 139.8, 148.1. HRMS (FD) Calcd for $C_{17}H_{12}OS_2$: M, 296.0330. Found: *m*/*z* 296.0355.

Synthetic Application: Copper-Catalyzed Coupling of 3uf with 4,4'-Diiodobiphenyl (Scheme 9)

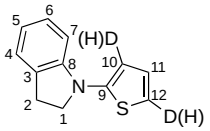
According to the reported procedure,[32] the coupling of **3uf** with 4,4'-diiodobiphenyl (**10**) was performed, as follows: A flame-dried 20 mL Schlenk tube was charged with CuI (4.76 mg, 25.0 μmol), 1,10-phenanthroline (13.5 mg, 75.0 μmol), *t*-BuOK (84.2 mg, 0.750 mmol) and toluene (1.0 mL). The resulting solution was degassed by three freeze-pump-thaw cycles, and the Schlenk tube was then filled with argon. After stirring at room temperature for 5 min, to this solution were successively added **3uf** (175 mg, 0.550 mmol) and **10** (102 mg, 0.250 mmol), and the mixture was stirred at room temperature for 20 min, and then heated at 120 ºC for 15 h. The resulting mixture was diluted with CH_2Cl_2 (5 mL). Filtration through a pad of Celite and evaporation of the solvent followed by recycling GPC after column chromatography on silica gel (hexane/CH_2Cl_2 = 1/1) gave *N,N'*-bis(benzo[*b*]thiophen-3-yl)-*N,N'*-bis[4-(2,5-dimethyl-1*H*-pyrrol-1-yl)phenyl]-[1,1'-biphenyl]-4,4'-diamine (**11**) in 43% yield (84.7 mg) as a yellow solid (mp 290–292 °C; decomp.). Compound **11** was fully characterized by ^{1}H and ^{13}C NMR spectroscopy and elemental analysis, as follows: ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.06 (s, 12 H), 5.88 (s, 4 H), 7.05 (dt, *J* = 9.4, 2.5 Hz, 4 H), 7.14 (dt, *J* = 9.3, 2.5 Hz, 4 H), 7.20 (dt, *J* = 9.2, 2.3 Hz, 4 H), 7.23 (s, 2 H), 7.23–7.28 (m, 2 H), 7.36 (ddd, *J* = 7.6, 7.1, 0.9 Hz, 2 H), 7.41 (dt, *J* = 8.0, 0.8 Hz, 2 H), 7.48 (dt, *J* = 9.2, 2.3 Hz, 4 H), 7.87 (dt, *J* = 8.1, 0.7 Hz, 2 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 13.0, 105.4, 120.8, 121.5, 122.5, 122.8, 123.3, 124.2, 124.8, 127.4, 128.8, 128.9, 132.7, 134.9, 135.3, 139.2, 139.5, 145.9, 146.8. Anal. Calcd for $C_{52}H_{42}N_4S_2$: C, 79.36; H, 5.38; N, 7.12; S, 8.15. Found: C, 78.97; H, 5.16; N, 6.86; S, 8.52.

A Confirmation Experiment of a Released Alcohol (Scheme 10)

The reaction shown in Scheme 10 was carried out similarly as the general procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". Reagents and conditions: **1e** (74.5 mg, 0.625 mmol), **7aa** (60.1 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h. Compounds **3ea** and *n*-decanol (**5a**) were isolated by column chromatography on silica gel (hexane/EtOAc = 10/1 to 5/1). Compound **3ea** has already emerged in this Experimental Section, and the spectral and analytical data are thus collected there (*vide supra*). Compound **5a** is commercially available, and spectral and analytical data of **5a** are in good agreement with those of the commercial *n*-decanol. Accordingly, only ^{1}H NMR data of **5a** are provided here. ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, *J* = 6.9 Hz, 3 H), 1.19–1.40 (m, 14 H), 1.57 (quint, *J* = 7.1 Hz, 2 H), 3.64 (t, *J* = 6.6 Hz, 2 H).

A Deuterium Labelling Study: Reaction of 1e-1-*d* with 2a (Scheme 11)

The reaction shown in Scheme 11 was carried out similarly as the general procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". Reagents and conditions: **1e**-1-*d* (75.1 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h. A mixture of products **3ea**-3-*d* and **3ea**-5-*d* was isolated by column chromatography on silica gel (hexane/EtOAc = 20/1) in 76% yield (38.4 mg) with a total deuterium content of 50%, which was determined by ^{1}H NMR. A white solid, mp 72–74 ºC. ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.20 (t, *J* = 8.6 Hz, 2 H), 3.97 (t, *J* = 8.6 Hz, 2 H), 6.47–6.55 (m, 0.80 H), 6.71–6.85 (m, 1.70 H), 6.88–6.96 (m, 1 H), 7.09–7.20 (m, 3 H);



^{13}C NMR (125 MHz, $CDCl_3$) δ 28.2 (C1), 54.1 (C2), 108.4 (C7), 110.1 (C10), 110.2 (C10), 113.5 (C12), 113.6 (C12), 119.4 (C5), 124.7 (C4), 124.8 (C4), 125.4 (C11), 125.5 (C11), 125.6 (C11), 125.7 (C11), 127.2 (C6), 127.3 (C6), 127.4 (C6), 130.4 (C3), 146.97 (C8), 147.05 (C8), 148.3 (C9), 148.4 (C9). HRMS (FI) Calcd for $C_{12}H_{10}DNS$: M, 202.0675. Found: *m*/*z* 202.0697.

Kinetic Isotope Effect Experiments (Scheme 12)

The reaction shown in Scheme 12 was carried out similarly as the general procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". The amination of 2-methoxythiophene (**2a**) with indoline (**1e**) or indoline-1-*d* (**1e**-1-*d*) was thus performed using the following reagents and conditions: **1e** or **1e**-1-*d* (74.5 or 75.1 mg, 0.625 mmol), **2a** (28.5 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 10–60 min, and the yields of product **3ea** including **3ea**-3-*d* and **3ea**-5-*d* after 10, 20, 30, 40, 50 and 60 min were determined by GC using *n*-decane as an internal standard. Compound **3ea** has already emerged in this Experimental Section, and their spectral and analytical data are thus collected there (*vide supra*). The reaction rate at the early stage of each reaction was obtained by plotting the yield of **3ea** against the reaction time. Figure ES1 indicates the result for the reaction of **1e** or **1e**-1-*d* with **2a**. The slope value of each line in Figure ES1 is 0.38 or 0.37, respectively, thus showing that the value of the k_H/k_D is approximately 1.0 (= 0.38/0.37).

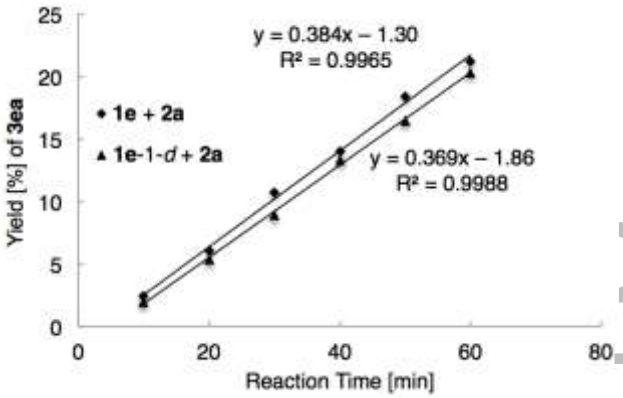
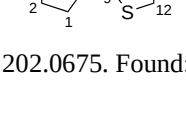


Figure ES1. Plots of the yield of **3ea** against the reaction time for the indium-catalyzed S_NAr amination of **2a** with **1e** or **1e**-1-*d*.

A Deuterium Labelling Study: Reaction of MeOD with 3ea (Scheme 14)

The reaction shown in Scheme 14 was carried out similarly as the general procedure described in "**Indium-Catalyzed S_NAr Amination of Thiophene Electrophiles with Secondary Amines: A General Procedure for Table 2**". Reagents and conditions: MeOD (20.7 mg, 0.625 mmol), **3ea** (50.3 mg, 0.250 mmol), $In(NTf_2)_3$ (2.39 mg, 2.50 μmol), PhCl (1.0 mL), 90 °C, 24 h. Product **3ea**-3-*d* was isolated by column chromatography on silica gel (hexane/EtOAc = 20/1) in 91% yield (46.1 mg) with a total deuterium content of 23%, which was determined by ^{1}H NMR. A white solid, mp 72–73 ºC. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.16–3.23 (m, 2 H), 3.96 (t, *J* = 8.6 Hz, 2 H), 6.50 (dd, *J* = 3.7, 1.4 Hz, 0.78 H), 6.74–6.83 (m, 2 H), 6.89–6.95 (m, 1 H), 7.12–7.18 (m, 3 H);



^{13}C NMR (125 MHz, $CDCl_3$) δ 28.2 (C1), 54.1 (C2), 108.4 (C7), 109.7 (C10), 109.9 (C10), 110.1 (C10), 113.5 (C12), 119.3 (C5), 124.8 (C4), 125.6 (C11), 125.7 (C11), 127.4 (C6), 130.4 (C3), 147.0 (C8), 148.3 (C9), 148.4 (C9). HRMS (FD) Calcd for $C_{12}H_{10}DNS$: M, 202.0675. Found: *m*/*z* 202.0667.

Acknowledgements

We thank Mr. Toshiyuki Katsumata for experimental assistance.

References

[1] For selected reports, see: a) K. Wakabayashi, H. Miyachi, Y. Hashimoto, A. Tanatani, *Bioorg. Med. Chem.* **2005**, *13*, 2837–2846; b) R. Romagnoli, P. G. Baraldi, T. Sarkar, M. D. Carrion, C. L. Cara, O. Cruz-Lopez, D. Preti, M. A. Tabrizi, M. Tolomeo, S. Grimaudo, A. D. Cristina, N. Zonta, J. Balzarini, A. Brancale, H.-P. Hsieh, E. Hamel, *J. Med. Chem.* **2008**, *51*, 1464–1468; c) H.-P. Fiedler, C. Bruntner, J. Riedlinger, A. T. Bull, G. Knutsen, M. Goodfellow, A. Jones, L. Maldonado, W. Pathom-aree, W. Beil, K. Schneider, S. Keller, R. D. Sussmuth, *J. Antibiot.* **2008**, *61*, 158–163; d) R. Romagnoli, P. G. Baraldi, C. L. Cara, E. Hamel, G. Basso, R. Bortolozzi, G. Viola, *Eur. J. Med. Chem.* **2010**, *45*, 5781–5791; e) E. A. Ilardi, E. Vitaku, J. T. Njardarson, *J. Med. Chem.* **2014**, *57*, 2832–2842; f) C.-Y. Chen, C.-M. Lin, H.-C. Lin, C.-F. Huang, C.-Y. Lee, T.-C. S. Tou, C.-C. Hung, C.-S. Chang, *Eur. J. Med. Chem.* **2017**, *125*, 1023–1035.

[2]For selected recent reports, see: a) H. Bürckstümmer, E. V. Tulyakova, M. Deppisch, M. R. Lenze, N. M. Kronenberg, M. Gsänger, M. Stolte, K. Meerholz, F. Würthner, *Angew. Chem.* **2011**, *123*, 11832–11836; *Angew. Chem. Int. Ed.* **2011**, *50*, 11628–11632; b) J. Kim, H. M. Ko, N. Cho, S. Paek, J. K. Lee, J. Ko, *RSC Adv.* **2012**, *2*, 2692–2695; c) A. Zitzler-Kunkel, M. R. Lenze, N. M. Kronenberg, A.-M. Krause, M. Stolte, K. Meerholz, F. Würthner, *Chem. Mater.* **2014**, *26*, 4856–4866; d) M. Kumar, L. K. Kumawat, V. K. Gupta, A. Sharma, *ChemistryOpen* **2015**, *4*, 626–632; e) H. Watanabe, M. Ono, H. Saji, *Chem. Commun.* **2015**, *51*, 17124–17127; f) T. Satoh, M. Minoura, H. Nakano, K. Furukawa, Y. Matano, *Angew. Chem.* **2016**, *128*, 2275–2278; *Angew. Chem. Int. Ed.* **2016**, *55*, 2235–2238; g) L. Zhang, J. C. Er, H. Jiang, X. Li, Z. Luo, T. Ramezani, Y. Feng, M. K. Tang, Y.-T. Chang, M. Vendrell, *Chem. Commun.* **2016**, *52*, 9093–9096.

[3] For example, see: a) J. S. Lee, K. Kim, *J. Heterocycl. Chem.* **2000**, *37*, 363–372; b) Q. Dang, J. E. Gomez-Galeno, *J. Org. Chem.* **2002**, *67*, 8703–8705; c) A. Klásek, A. Lyčka, M. Holčapek, *Tetrahedron* **2007**, *63*, 7059–7069; d) R. Medimagh, S. Marque, D. Prim, S. Chatti, H. Zarrouk, *J. Org. Chem.* **2008**, *73*, 2191–2197; e) F. R. Petronijevic, P. Wipf, *J. Am. Chem. Soc.* **2011**, *133*, 7704–7707.

[4] F. Ullmann, *Ber. Dtsch. Chem. Ges.* **1903**, *36*, 2382–2384.

[5]For selected recent reports, see: a) J. Dong, Y. Wang, Q. Xiang, X. Lv, W. Weng, Q. Zeng, *Adv. Synth. Catal.* **2013**, *355*, 692–696 (Cu); b) N. H. Park, G. Teverovskiy, S. L. Buchwald, *Org. Lett.* **2014**, *16*, 220–223 (Ni); c) I. Sokolovs, D. Lubriks, E. Suna, *J. Am. Chem. Soc.* **2014**, *136*, 6920−6928 (Cu); d) N. Liu, B. Wang, W. Chen, C. Liu, X. Wang, Y. Hu, *RSC Adv.* **2014**, *4*, 51133–51139 (Cu); e) A. T. Brusoe, J. F. Hartwig, *J. Am. Chem. Soc.* **2015**, *137*, 8460−8468 (Pd); f) S. Sharif, R. P. Rucker, N. Chandrasoma, D. Mitchell, M. J. Rodriguez, R. D. J. Froese, M. G. Organ, *Angew. Chem.* **2015**, *127*, 9643–9647; *Angew. Chem. Int. Ed.* **2015**, *54*, 9507–9511 (Pd); g) A. J. DeAngelis, P. G. Gildner, R. Chow, T. J. Colacot, *J. Org. Chem.* **2015**, *80*, 6794–6813 (Pd); h) W. Zhou, M. Fan, J. Yin, Y. Jiang, D. Ma, *J. Am. Chem. Soc.* **2015**, *137*, 11942−11945 (Cu); i) J. Shaya, M.-A. Deschamps, B. Y. Michel, A. Burger, *J. Org. Chem.* **2016**, *81*, 7566–7573 (Pd); j) W. Huang, S. L. Buchwald, *Chem. Eur. J.* **2016**, *22*, 14186–14189 (Pd); k) M. S. Oderinde, N. H. Jones, A. Juneau, M. Frenette, B. Aquila, S. Tentarelli, D. W. Robbins, J. W. Johannes, *Angew. Chem.* **2016**, *128*, 13413–13417; *Angew. Chem. Int. Ed.* **2016**, *55*, 13219–13223 (Ir/Ni).

[6] The copper-catalyzed coupling of amines with aryl boronic acids and their esters instead of aryl (pseudo)halides has been known as the Chan–Evans–Lam amination, and thus is a powerful tool to prepare arylamines, but, in contrast, its version for synthesizing heteroarylamines is rare. For a report to couple ammonia with 5-acetyl-2-thienylboronic acid: a) H. Rao, H. Fu, Y. Jiang, Y. Zhao, *Angew. Chem.* **2009**, *121*, 1134–1136; *Angew. Chem. Int. Ed.* **2009**, *48*, 1114–1116; for a report to couple 2-aminopyridine with 3-thienylboronic acid: b) D. N. Rao, S. Rasheed, S. Aravinda, R. A. Vishwakarma, P. Das, *RSC. Adv.* **2013**, *3*, 11472–11475.

[7] For the Buchwald–Hartwig amination, see: *Comprehensive Organic Name Reactions and Reagents*, *Vol. 1* (Ed.: Z. Wang), Wiley, Hoboken, **2009**, pp. 575–581.

[8] For selected examples, see: a) L. D. Tran, J. Roane, O. Daugulis, *Angew. Chem.* **2013**, *125*, 6159–6162; *Angew. Chem. Int. Ed.* **2013**, *52*, 6043–6046 (Cu/Ag); b) Á. M. Martínez, N. Rodríguez, R. G. Arrayás, J. C. Carretero, *Chem. Commun.* **2014**, *50*, 2801–2803 (Cu); c) Q. Yan, Z. Chen, W. Yu, H. Yin, Z. Liu, Y. Zhang, *Org. Lett.* **2015**, *17*, 2482–2485 (Ni); d) L.-B. Zhang, S.-K. Zhang, D. Wei, X. Zhu, X.-Q. Hao, J.-H. Su, J.-L. Niu, M.-P. Song, *Org. Lett.* **2016**, *18*, 1318–1321 (Co); e) J. Roane, O. Daugulis, *J. Am. Chem. Soc.* **2016**, *138*, 4601–4607 (Cu); f) H.-W. Wang, Y. Lu, B. Zhang, J. He, H.-J. Xu, Y.-S. Kang, W.-Y. Sun, J.-Q. Yu, *Angew. Chem.* **2017**, *129*, 7557–7561; *Angew. Chem. Int. Ed.* **2017**, *56*, 7449–7453 (Rh).

[9] For selected examples, see: a) J. Bergman, R. Carlsson, B. Sjöberg, *J. Heterocycl. Chem.* **1977**, *14*, 1123–1134; b) J. Koyanagi, M. Ogawa, K. Yamamoto, K. Nakayama, A. Tanaka, *J. Heterocycl. Chem.* **1998**, *35*, 301–305; c) D. Prim, G. Kirsch, *Tetrahedron* **1999**, *55*, 6511–6526; d) K. Burger, A. Fuchs, L. Hennig, B. Helmreich, D. Greif, *Monatsh. Chem.* **2001**, *132*, 929–945; e) A. V. Zaytsev, R. J. Anderson, O. Meth-Cohn, P. W. Groundwater, *Tetrahedron* **2005**, *61*, 5831–5836; f) S. Roy, G. W. Gribble, *Tetrahedron Lett.* **2007**, *48*, 1003–1005; g) R. Medimagh, S. Marque, D. Prim, S. Chatti, *Org. Biomol. Chem.* **2011**, *9*, 6055–6065; h) S. Lethu, J. Dubois, *Eur. J. Org. Chem.* **2011**, 3920–3931;

i) P. Sarkar, S. Maiti, K. Ghosh, S. S. Bandyopadhyay, R. J. Butcher, C. Mukhopadhyay, *Tetrahedron Lett.* **2014**, *55*, 996–1001; j) O. A. Varzatskii, I. N. Denisenko, A. S. Belov, A. V. Vologzhanina, Y. N. Bubnov, S. V. Volkov, Y. Z. Voloshin, *Inorg. Chem. Commun.* **2014**, *44*, 134–138; k) S. P. Nikumbh, A. Raghunadh, V. N. Murthy, R. Jinkala, S. C. Joseph, Y. L. N. Murthy, B. Prasad, M. Pal, *RSC Adv.* **2015**, *5*, 74570–74574.

[10] M. B. Smith, *March's Advanced Organic Chemistry—Reactions, Mechanisms, and Structure, 7th ed.*, Wiley, Hoboken, **2013**, pp. 732–802.

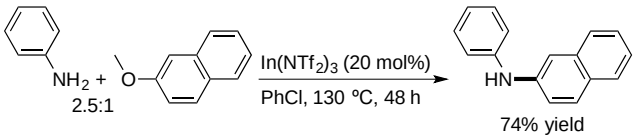
[11] a) M. G. Reinecke, H. W. Adickes, *J. Am. Chem. Soc.* **1968**, *90*, 511–513; b) P. Barraja, P. Diana, A. Carbone, G. Cirrincione, *Tetrahedron* **2008**, *64*, 11625–11631.

[12] T. Tsuchimoto, M. Iwabuchi, Y. Nagase, K. Oki, H. Takahashi, *Angew. Chem.* **2011**, *123*, 1411–1415; *Angew. Chem. Int. Ed.* **2011**, *50*, 1375–1379.

[13] For the stable complexation of a Lewis acid in the presence of an amine, see: *Friedel–Crafts and Related Reactions, Vol. 1* (Ed.: G. A. Olah), Wiley, New York, **1963**, p 100.

[14] A part of this research has been presented at the 94th annual meeting of the Chemical Society of Japan on March 29, 2014 (presentation #: 3B3-18).

[15] A. K. Mishra, A. Verma, S. Biswas, *J. Org. Chem.* **2017**, *82*, 3403–3410, which mainly focuses on the nucleophilic substitution on a naphthalene ring. Unlike this article, the S_NAr amination towards such aryl electrophiles is not subject to our work discussed hereafter, but nevertheless, we confirm that our indium system is also applicable to the amination of 2-methoxynaphthalene, as the following scheme shows:



[16] For selected recent reports, see: a) N. Matsuda, K. Hirano, T. Satoh, M. Miura, *Angew. Chem.* **2012**, *124*, 3702–3705; *Angew. Chem. Int. Ed.* **2012**, *51*, 3642–3645 (Cu); b) R. P. Rucker, A. M. Whittaker, H. Dang, G. Lalic, *Angew. Chem.* **2012**, *124*, 4019–4022; *Angew. Chem. Int. Ed.* **2012**, *51*, 3953–3956 (Cu); c) M. Shang, S.-H. Zeng, S.-Z. Sun, H.-X. Dai, J.-Q. Yu, *Org. Lett.* **2013**, *15*, 5286–5289 (Ru); d) T. Matsubara, S. Asako, L. Ilies, E. Nakamura, *J. Am. Chem. Soc.* **2014**, *136*, 646−649 (Fe); e) H. Yoon, Y. Lee, *J. Org. Chem.* **2015**, *80*, 10244−10251 (Cu); see also a review: f) X. Dong, Q. Liu, Y. Dong, H. Liu, *Chem. Eur. J.* **2017**, *23*, 2481–2511 (Cu).

[17] a) P. Bernardi, P. Dembech, G. Fabbri, A. Ricci, G. Seconi, *J. Org. Chem.* **1999**, *64*, 641–643; b) T. J. Barker, E. R. Jarvo, *Angew. Chem.* **2011**, *123*, 8475–8478; *Angew. Chem. Int. Ed.* **2011**, *50*, 8325–8328; see also a review: c) P. Dembech, G. Seconi, A. Ricci, *Chem. Eur. J.* **2000**, *6*, 1281–1286.

[18] For reports with respect to the heteroarylamine synthesis that is not classified into any of the routes A–E, see: a) E. Campaigne, P. A. Monroe, *J. Am. Chem. Soc.* **1954**, *76*, 2447–2450; b) Y.-X. Li, K.-G. Ji, H.-X. Wang, S. Ali, Y.-M. Liang, *J. Org. Chem.* **2011**, *76*, 744–747.

[19] F. Terrier, *Modern Nucleophilic Aromatic Substitution*, Wiley-VCH, Weinheim, **2013**, pp. 205–278.

[20] For example, see: K. Ogawa, K. R. Radke, S. D. Rothstein, S. C. Rasmussen, *J. Org. Chem.* **2001**, *66*, 9067–9070, and see also reference 5f.

[21] For the Br-selective amination of bromoanisoles under strong basic conditions in the absence of a transition metal catalyst, see: a) L. Shi, M. Wang, C.-A. Fan, F.-M. Zhang, Y.-Q. Tu, *Org. Lett.* **2003**, *5*, 3515–3517; b) Y. Dong, M. I. Lipschutz, T. D. Tilley, *Org. Lett.* **2016**, *18*, 1530–1533.

[22] For the amidation of esters with amines catalyzed by indium and other acids, see: a) B. C. Ranu, P. Dutta, *Synth. Commun.* **2003**, *33*, 297–301; b) H. Morimoto, R. Fujiwara, Y. Shimizu, K. Morisaki, T. Ohshima, *Org. Lett.* **2014**, *16*, 2018–2021; c) D. D. S. Sharley, J. M. J. Williams, *Chem. Commun.* **2017**, *53*, 2020–2023.

[23] For selected reports on the Lewis acid-catalyzed hydroamination of alkenes, see: a) J. Zhang, C.-G. Yang, C. He, *J. Am. Chem. Soc.* **2006**, *128*, 1798–1799; b) J. Michaux, V. Terrasson, S. Marque, J. Wehbe, D. Prim, J.-M. Campagne, *Eur. J. Org. Chem.* **2007** 2601–2603; c) X. Cheng, Y. Xia, H. Wei, B. Xu, C. Zhang, Y. Li, G. Qian, X. Zhang, K. Li, W. Li, *Eur. J. Org. Chem.* **2008**, 1929–1936.

[24] The reaction of **2f** with 9,10-dihydroacridine as another example of the cyclic diarylamine was also examined but resulted in the dehydrogenative oxidation of 9,10-dihydroacridine to give acridine preferentially and thus in no formation of the desired C–N bond.

[25] For example, see: K. E. Horner, P. B. Karadakov, *J. Org. Chem.* **2013**, *78*, 8037–8043.

[26] L. D. Quin, J. A. Tyrell, *Fundamentals of Heterocyclic Chemistry: Importance in Nature and in the Synthesis of Pharmaceuticals*, Wiley, Hoboken, **2010**, pp. 170–195.

[27] A. R. Katritzky, C. A. Ramsden, J. A. Joule, V. V. Zhdankin, *Handbook of Heterocyclic Chemistry, 3rd ed.*, Elsevier, Oxford, **2010**, pp. 87–138.

[28] For reports concerning substitution of the MeO group on the thiophene ring to the alkyloxy and alkylthio groups under the acidic conditions, see: a) P. Wegener, M. Feldhues, H. Litterer (A. G. Hoechst), *German Patent* DE 3,804,522 A1, **1989**; *Chem. Abstr.* **1990**, *114*, 98369f, and selected reports on the corresponding alkoxylation performed based on reference 28a: b) F. Goldoni, B. M. W. Langeveld-Voss, E. W. Meijer, *Synth. Commun.* **1998**, *28*, 2237–2244; c) B. M. W. Langeveld-Voss, R. A. J. Janssen, E. W. Meijer, *J. Mol. Struct.* **2000**, *521*, 285–301, and see also reference 15.

[29] For a representative review, see: Y. Shirota, H. Kageyama, *Chem. Rev.* **2007**, *107*, 953–1010.

[30] For examples of reviews, see: a) J. G. C. Veinot, T. J. Marks, *Acc. Chem. Res.* **2005**, *38*, 632–643; b) F. Huang, Y.-J. Cheng, Y. Zhang, M. S. Liu, A. K.-Y. Jen, *J. Mater. Chem.* **2008**, *18*, 4495–4509.

[31] For selected reviews, see: a) A. Mishra, P. Bäuerle, *Angew. Chem.* **2012**, *124*, 2060–2109; *Angew. Chem. Int. Ed.* **2012**, *51*, 2020–2067; b) J. Wang, K. Liu, L. Ma, X. Zhan, *Chem. Rev.* **2016**, *116*, 14675–14725.

[32] For the reaction conditions used, see: C.-K. Tseng, C.-R. Lee, M.-C. Tseng, C.-C. Han, S.-G. Shyu, *Dalton Trans.* **2014**, *43*, 7020–7027.

[33] For related our preceding reports, see: a) K. Yonekura, K. Oki, T. Tsuchimoto, *Adv. Synth. Catal.* **2016**, *358*, 2895–2902; b) S. Nomiyama, T. Ogura, H. Ishida, K. Aoki, T. Tsuchimoto, *J. Org. Chem.* **2017**, *82*, 5178–5197.

[34] For an example on the attack of a nucleophile to an indium–alkyne complex from the side opposite to the coordinated indium salt, see: Y. Nishimoto, R. Moritoh, M. Yasuda, A. Baba, *Angew. Chem.* **2009**, *121*, 4647–4650; *Angew. Chem. Int. Ed.* **2009**, *48*, 4577–4580.

[35] Cinnamylindium species have reportedly been protonated regioselectively at the γ-position by a weak proton donor such as diphenylmethanol, see: a) M. Yasuda, M. Haga, Y. Nagaoka, A. Baba, *Eur. J. Org. Chem.* **2010**, 5359–5363; for another example of the γ-selective protonation of the allylindium species, see: b) S. Araki, T. Shimizu, P. S. Johar, S.-J. Jin, Y. Butsugan, *J. Org. Chem.* **1991**, *56*, 2538–2542.

[36] For the extremely poor leaving ability of R_2N and RHN groups, and also for the higher leaving ability of an RO group than an RHN group, see: M. B. Smith, *March's Advanced Organic Chemistry—Reactions, Mechanisms, and Structure*, *7th ed.*, Wiley, Hoboken, **2013**, pp. 373–568, and references cited therein.

[37] For the transition metal-catalyzed amination of *N*-silyl-3-bromoindoles followed by the *N*-desilylation, see: J. R. Allen, A. K. Amegadzie, K. M. Gardinier, G. S. Gregory, S. A. Hitchcock, P. J. Hoogestraat, W. D. Jones Jr., D. L. Smith (Eli Lilly and Company), *WO Patent* WO 2,005,066,126 A1, **2005**; *Chem. Abstr.* **2005**, *143*, 133274.

[38] a) T. Tsuchimoto, H. Matsubayashi, M. Kaneko, E. Shirakawa, Y. Kawakami, *Angew. Chem.* **2005**, *117*, 1360–1364; *Angew. Chem. Int. Ed.* **2005**, *44*, 1336–1340; b) T. Tsuchimoto, H. Matsubayashi, M. Kaneko, Y. Nagase, T. Miyamura, E. Shirakawa, *J. Am. Chem. Soc.* **2008**, *130*, 15823–15835.

[39] a) C. G. Frost, J. P. Hartley, D. Griffin, *Tetrahedron Lett.* **2002**, *43*, 4789–4791; b) M. Nakamura, K. Endo, E. Nakamura, *Adv. Synth. Catal.* **2005**, *347*, 1681–1686. $In(NTf_2)_3$ is commercially available from, e.g., Sigma-Aldrich, where its purity by EDTA titration is exhibited to be 82.5–117.5%, but can be easily prepared in solvent H_2O in accordance with the above literature procedure. Therefore, $In(NTf_2)_3$ is stable to H_2O but highly hygroscopic, and thus is recommended to be pre-dried as shown in the Experimental Section, in which catalyst $In(NTf_2)_3$ as well as substrates and solvent PhCl are pre-dried. However, the amination of, for instance, **2f** with **1i** performed without pre-drying $In(NTf_2)_3$ or without pre-drying all of **1i**, **2f**, $In(NTf_2)_3$ and PhCl gave 93% NMR yield of **3if** in either case and thus resulted in no significant decrease of the yield, compared to the 99% yield of **3if** obtained by the reaction based on the general procedure (see Table 3). These results clearly show that the high performance of the heteroaryl amination is attributed to the anhydrous conditions but, on the other hand, that its good performance is maintained even without the precaution.

[40] M. A. Keegstra, T. H. A. Peters, L. Brandsma, *Tetrahedron* **1992**, *48*, 3633–3652.

[41] Y. Hu, K. Wang, W. Yang, J. Zhu, L. Wang (Nanjing University of Technology), *Chinese Patent* CN 102,558,139 A, **2012**; *Chem. Abstr.* **2012**, *157*, 197943.

[42] J. F. D. Chabert, L. Joucla, E. David, M. Lemaire, *Tetrahedron* **2004**, *60*, 3221–3230.

[43] S. G. Newman, V. Aureggi, C. S. Bryan, M. Lautens, *Chem. Commun.* **2009**, 5236–5238.

[44] C. S. Yi, D. W. Lee, *Organometallics* **2009**, *28*, 947–949.

[45] O. Galangau, T. Nakashima, F. Maurel, T. Kawai, *Chem. Eur. J.* **2015**, *21*, 8471–8482.

[46] J. Wysocki, N. Ortega, F. Glorius, *Angew. Chem.* **2014**, *126*, 8896–8900; *Angew. Chem. Int. Ed.* **2014**, *53*, 8751–8755.

[47] H. M. Gilow, D. E. Burton, *J. Org. Chem.* **1981**, *46*, 2221–2225.

[48] S. Zhou, Z. Yang, X. Chen, Y. Li, L. Zhang, H. Fang, W. Wang, X. Zhu, S. Wang, *J. Org. Chem.* **2015**, *80*, 6323–6328.

[49] M. D. Charles, P. Schultz, S. L. Buchwald, *Org. Lett.* **2005**, *7*, 3965–3968.

[50] For the spectral data of **3kf**, see: a) M. W. Hooper, M. Utsunomiya, J. F. Hartwig, *J. Org. Chem.* **2003**, *68*, 2861–2873; for the elemental analysis data of **3kf**, see: b) G. V. Zyl, D. C. D. Jongh, V. L. Heasley, J. W. V. Dyke, *J. Org. Chem.* **1961**, *26*, 4946–4949.

[51] M.-J. R. P. Queiroz, A. Begouin, I. C. F. R. Ferreira, G. Kirsch, R. C. Calhelha, S. Barbosa, L. M. Estevinho, *Eur. J. Org. Chem.* **2004**, 3679–3685.

[52] E. Pinto, M.-J. R. P. Queiroz, L. A. Vale-Silva, J. F. Oliveira, A. Begouin, J.-M. Begouin, G. Kirsch, *Bioorg. Med. Chem.* **2008**, *16*, 8172–8177.

[53] T. Hasegawa, M. Ashizawa, H. Matsumoto, *RSC Adv.* **2015**, *5*, 61035–61043.

[54] A. Pöllnitz, A. Silvestru, *Tetrahedron* **2015**, *71*, 2914–2921.

10.1002/adsc.201701452

[55] F. Y. Kwong, S. L. Buchwald, *Org. Lett.* **2003**, *5*, 793–796.

[56] S. Kyasa, R. N. Meier, R. A. Pardini, T. K. Truttmann, K. T. Kuwata, P. H. Dussault, *J. Org. Chem.* **2015**, *80*, 12100–12114.

10.1002/adsc.201701452

FULL PAPER

A Heteroarylamine Library: Indium-Catalyzed Nucleophilic Aromatic Substitution of Alkoxyheteroarenes with Amines

Adv. Synth. Catal. **Year**, *Volume*, Page – Page

Kyohei Yonekura, Yasuhiro Yoshimura, Mizuri Akehi, Teruhisa Tsuchimoto*