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Tandem Synthesis of 2-Carboxybenzofurans *via* Sequential Cu-Catalyzed C-O Coupling and $Mo(CO)_6$-Mediated Carbonylation reactions

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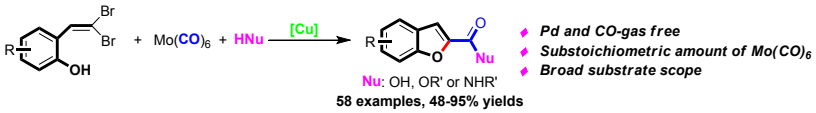
Supporting Information Placeholder



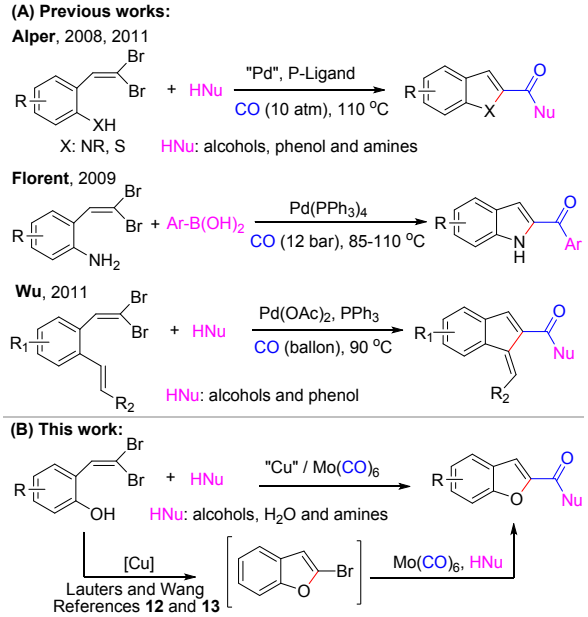
ABSTRACT: A modular tandem synthesis of 2-carboxybenzofurans from 2-*gem*-dibromovinylphenols has been established, based on a sequence of Cu-catalyzed intramolecular *C-O* coupling and $Mo(CO)_6$-mediated intermolecular carbonylation reactions. This protocol allowed one-step access to a broad variety of functionalized benzofuran-2-carboxylic acids, esters, and amides in good to excellent yields under Pd- and CO- gas free conditions.

INTRODUCTION

2-Carboxybenzofurans are an important class of carbonyl-containing heterocyclic compounds featuring an acid, ester or amide group at 2-position of benzofuran ring. These compounds have extensive utilization in medicinal chemistry for the achievement of bioactive molecules.[1] For example, Vilazodone, a derivative of benzofuran-2-carboxamide, is an important antidepressant drug launched in 2011 for the treatment of major depressive disorder.[2] Moreover, they can also serve as building blocks in the construction of liquid crystal molecules.[3] Currently, there are several approaches available to access 2-carboxybenzofurans, including intramolecular Knoevenagel condensation of 2-formylphenoxyacetates,[4] Perkin rearrangement of 3-halocoumarins,[5] carbonylation of 2-metalated benzofurans[6] or intramolecular cyclization of 3-aryloxy-4-dimethylamino-3-buten-2-ones.[7] All of these methods are incapable to concurrently construct benzofuran-2-carboxylic acids, esters and amides in one-step, thus leading to inefficiency. Therefore, development of a novel direct and modular protocol for 2-carboxybenzofurans synthesis from easily available reagents is highly desirable.

gem-Dihaloolefins are valuable synthons in synthetic chemistry owing to their high reactivity and easy availability from inexpensive aldehydes by Ramirez-Corey olefination reaction.[8] In particularly, the two halo functional groups of *gem*-dihaloolefins have different reactivity allowing them to undergo potentially selective di-functionalization. Over the past years, the research groups of Alper,[9] Florent[10] and Wu[11] have independently reported efficient protocols for the synthesis of 2-carbonyl functionalized indoles, benzothiophenes and indenes from corresponding

Scheme 1. Tandem synthesis of 2-carbonyl functionalized heterocycles and carboncycles from *gem*-dihaloolefins



gem-dihaloolefins (Scheme 1, A). These reactions involved two orthogonal reactions: a) Pd-catalyzed *C-N*, *C-S* or *C-C* coupling to form the 2-bomo-functionalized heterocycles or carboncycles; b) Pd-catalyzed carbonylation reactions. These nice achievements inspired us to extend this orthogonal tandem strategy for the synthesis of 2-carboxybenzofurans from 2-*gem*-dibromovinylphenols. Previously, Eustache,[12] Lauterns,[13] and others groups[14] developed a series of elegant 2-

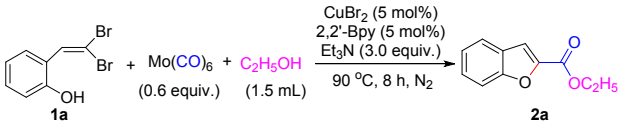
substituted benzofunans syntheses from 2-*gem*-dibromovinylphenols based on Cu- or Pd-catalyzed tandem *C-O* and *C-C*/*C-X*/*C-H* doubling couplings. Lautens[15] and Wang[16] also successively disclosed that copper can efficiently catalyze 2-*gem*-dibromovinylphenols to form 2-bromobenzofurans. Therefore, we reckon that the exploration of a carbonylation process, which can be compatible with this Cu-catalyzed intramolecular *C-O* coupling reaction (Ullman reaction), is crucial for this novel protocol. In recent years, the idea of combing two different metal catalysts in a single vessel to promote tandem reactions has been received much attentions.[17] $Mo(CO)_6$ is an intriguing solid carbonyl source with wide applications in palladium and non-palladium-catalyzed carbonyl reactions.[18] More recently, we found that $Mo(CO)_6$ can act as efficient and easy-to-handling carbonyl source for Pd-catalyzed carbonylative Suzuki coupling reaction.[19] As a continuation, we herein reported a Cu-catalyzed and $Mo(CO)_6$-mediated carbonylative tandem protocol for the synthesis of 2-carboxybenzofurans under Pd- and CO-gas free conditions (Scheme 1, B).

RESULTS AND DISCUSSION

We began our study by choosing the reaction of 2-(2,2-dibromovinyl)phenol (**1a**) and $Mo(CO)_6$ (0.6 equiv. as solid CO source) in ethanol (both as external *O*-nucleophile and solvent) as a template reaction to investigate the viability of the strategy. Table 1 summarized the results of partial optimization experiments. These results showed that the reaction can efficiently proceed under Pd-free conditions. When the reaction was carried out in the presence of 5 mol% $CuBr_2$ as catalyst, 5 mol% 2, 2'-Bpy as ligand and 3.0 equiv. of Et_3N as base at 90 °C for 8 hours, the desired product ethyl benzofuran-2-carboxylate (**2a**) can be isolated in 85% yield (entry 1, Table 1). Copper catalyst, ligand and base were essential for the reaction (entries 2-4, Table 1). Other copper salts, such as $CuCl_2$, $Cu(OTf)_2$, $CuSO_4$ or CuI, were also reactive on this transformation and afforded **2a** in comparable yields (entries 5-8, Table 1). By changing 2,2'-Bpy with 1,10-Phen, good yield (83%) of **2a** can still be obtained (entry 9, Table 1). However, other types of ligands such as *L*-proline and PPh_3 were innocent in this transformation (entries 10 and 11, Table 1). In addition, base also played a crucial role on the transformation. Similar yield can be obtained with organic DIPEA as base, while with Na_2CO_3 and K_3PO_4 as base, only 16% and 21% yields of **2a** were resulted, respectively (en-tries 12-14, Table 1). Noteworthy, in these two cases, a large amount of 2-bromobenzofuran were observed by GC-MS analyses. Varying the amount of $Mo(CO)_6$, $CuBr_2$ and 2,2'-Bpy as well as the reaction temperatures cannot further improve the yield (See supporting information, Table S1). Finally, a comparative experiment showed that Pd catalyst was much less efficient in this transformation (entries 15, Table 1).

With the optimal reaction conditions in hand, the generality of the newly developed carbonylative tandem synthesis was explored and the results were summarized in Scheme 2. First, the activities of alcohols were investigated. Under the identified reaction conditions, the reactions of 2-(2,2-dibromovinyl)phenol (**1a**) with methanol, *n*-propanol, or *n*-butanol generated the corresponding benzofuran-2-carboxylates **2b**, **2c** and **2d** in 81%, 85% and 87% yields. The sterically hindered secondary alcohol (*iso*-propanol) and tertiary alcohol (*tert*-butanol) was less active. Nevertheless, after increasing the reaction temperature to 130 °C, their corresponding esters **2e** and **2f** can also be obtained in 82% and 48% yields, respectively. Interestingly, when ethylene glycol was employed, only mono-alkoxycarbonylative product **2g** was exclusively generated. Then, the reaction activities of various substituted 2-*gem*-dibromovinylphenols were investigated. The results showed that neither the electron character nor the position of the substituents attached on the phenyl ring had obvious effect on the reactivity. Under the identified reaction conditions, most of the tested substrates worked well and gave the desirable products **2h-2s** in good to excellent yields. A number of functional groups such as Me, OMe, *t*-Bu, Ph, F, Cl, Br and $COOCH_3$ on the phenyl ring were well tolerated, and some of them could be utilized for further derivatization. Unfortunately, the reaction of 4-nitro-2-*gem*-dibromovinylphenol could not generate its corresponding ester. Some complex reductive by-products was observed by GC-MS. This phenomenon was similar to that in Pd-catalyzed $Mo(CO)_6$-mediated carbonylative reactions.[20] In addition, 1-(*gem*-dibromovinyl)-2-naphthalenol can also undergo this tandem transformation to afford corresponding ester **2t** in excellent yields (88%). To our delight, the developed catalytic system can be directly applied for the synthesis of benzofuran-2-carboxylic acids in aqueous *t*-butanol solution (1:5).[21] Under the same reaction conditions, a number of functionalized

Table 1. Optimization of the reaction conditions[a]

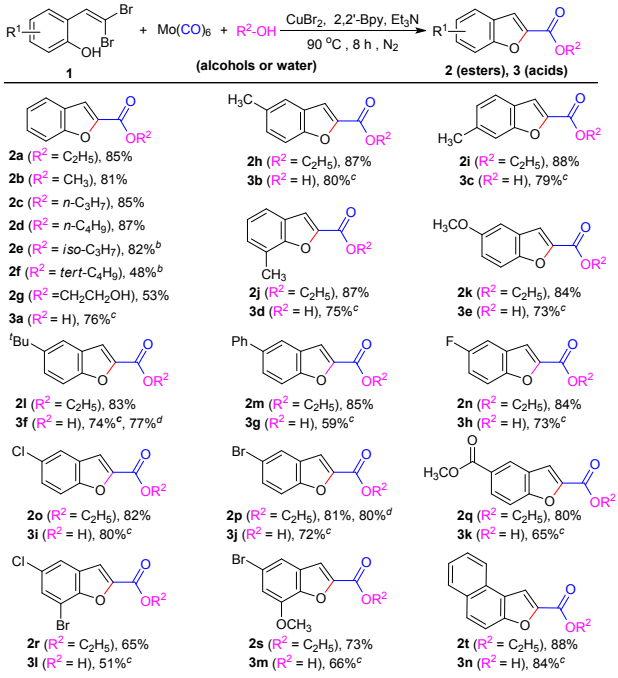


entry	variations from the standard conditions	Yield (%)[b]
1	none	89(85)
2	Without $CuBr_2$	22
3	Without 2,2'-Bpy	12
4	Without Et_3N	9
5	$CuCl_2$ instead of $CuBr_2$	87
6	$Cu(OTf)_2$ instead of $CuBr_2$	86
7	$CuSO_4$ instead of $CuBr_2$	82
8	CuI instead of $CuBr_2$	88
9	1,10-Phen instead of 2,2'-Bpy	83
10	L-Proline instead of 2,2'-Bpy	16
11	PPh_3 instead of 2,2'-Bpy	7
12	DIPEA instead of Et_3N	87
13	Na_2CO_3 instead of Et_3N	16
14	K_3PO_4 instead of Et_3N	21
15	$Pd_2(dba)_3$ instead of $CuBr_2$	15

[a] Reaction conditions: **1a** (0.5 mmol), $Mo(CO)_6$ (0.6 equiv.), catalyst (5 mol%), ligand (5 mol%), base (3.0 equiv.), C_2H_5OH (1.5 mL), 90 °C, purged with N_2 and 8 h. 2,2'-Bpy = 2,2'-bipyridine, 1,10-Phen =1,10-phenanthroline, DIPEA = *N*,*N*-Diisopropylethylamine. [b] Yields were determined by GC analysis. with diphenyl as internal standard and the datum in parentheses was isolated yield.

benzofuran-2-carboxylic acids **3a-3n** were obtained in moderate to good yields. Noteworthy, 5-(methoxycarbonyl)benzofuran-2-carboxylic acid **3k** was a key intermediate for a patented cysteine protease inhibitor.[22] In the patent, it required 4 reaction steps for its synthesis starting from 5-formylsalicylaldehyde with a 12% overall yield. However, in this work, only 2 reaction steps was needed from much cheaper 5-methoxycarbonylformylsalicylaldehyde and the overall yield of **3k** was reached to about 40% (based on 5-methoxycarbonylformylsalicylaldehyde and without optimization).

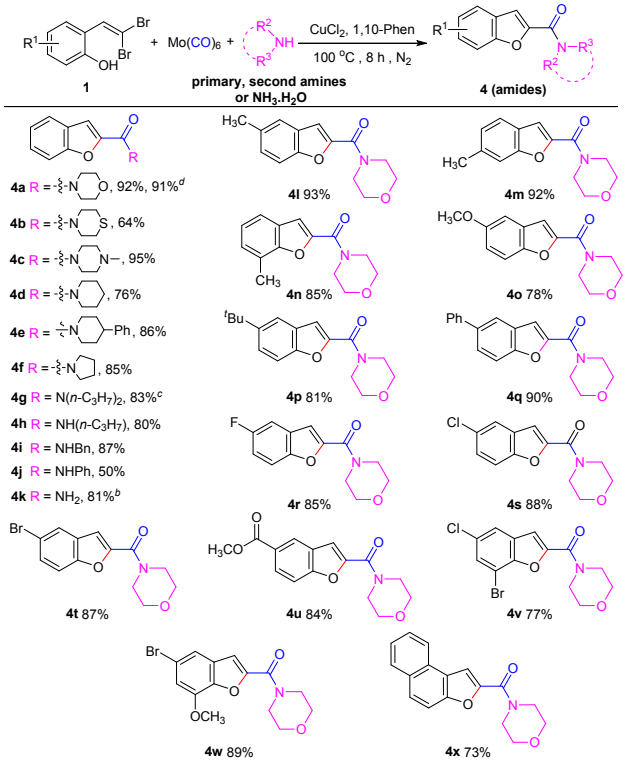
Scheme 2. Synthesis of benzofuan-2-carboxylic acids and esters from 2-(*gem*-dibromovinyl)phenols[a]



[a] Reaction conditions: **1** (0.5 mmol), alcohols (1.5 mL), $CuBr_2$ (5 mol %), 2,2'-Bpy (5 mol %), $Mo(CO)_6$ (0.6 equiv.), Et_3N (3.0 equiv.), 90 °C, purged with N_2 and 8 h, isolated yields. [b] 90 °C for 4 h and then 130 °C for 4 h. [c] water (0.25 mL), *t*-BuOH (1.25 mL). [d] 5 mmol scale.

Having successfully developed a novel procedure for the synthesis of benzofuran-2-carboxylic acids and esters, this method was extended to the synthesis of benzofuran-2-carboxylic amides. Initial study using 2-(2,2-dibromovinyl)phenol **1a** and morpholine as reaction partners showed that the same catalytic system only afforded the desired benzofuran-2-yl(morpholino)methanone (**4a**) in 33% yield. After re-optimizing the reaction conditions, it was delighted that a high isolated yield (92%) of **4a** can be obtained by using 10 mol% $CuCl_2$, 10 mol% 1,10-phenanthroline, 0.6 equiv. $Mo(CO)_6$, 4.0 equiv. morpholine, and in *n*-PrOH at 100 °C for 8 h.[23] Also, the scope of this catalytic system for benzofuran-2-carboxylic amides synthesis was explored and the results were illustrated in Scheme 3. Under the identified reaction conditions, 2-(2,2-dibromovinyl)phenol (**1a**) could smoothly react with a wide range of primary and secondary amines, including thiomorpholine, 1-methylpiperazine, piperidine, 4-phenylpiperidine, pyrrolidine, di(*n*-propyl)amine, *n*-propylamine, and benzylamine, to provide the corresponding amides **4b-4i** in good to excellent yields. For the reaction of **1a** and aniline, *N*-phenylbenzofuran-2-carboxamide **4j** was obtained in relative lower yield (50%), which maybe ascribe to its weaker nucleophilicity. Other than organic amines, ammonia (25-28%) could be also employed as external *N*-nucleophile, and primary amide **4k** was obtained in good yield (81%). Similar to the esters and acids, a wide range of functionalized groups, such as Me, OMe, *t*-Bu, Ph, F, Cl, Br and $COOCH_3$, can tolerate, and the electron character and position of these substituents attached on the phenyl ring had no obvious effect on the outcome of the reaction. A number of functionalized benzofuran-2-carboxylic amides **4l-4w** were obtained in good to excellent yields (73-93%). 1-(*gem*-dibromovinyl)-2-naphthalenol can also provide the corresponding amide **4x** in 73% yield. To further demonstrate the practical utility of our newly developed method, selected carbonylative tandem syntheses were carried out on gram-scale (5 mmol of substrates). Delightedly, equivalent results were obtained (**2p**, **3f**, and **4a**).

Scheme 3. Synthesis of benzofuan-2-carboxylic amides from 2-*gem*-dibromovinylphenols[a]

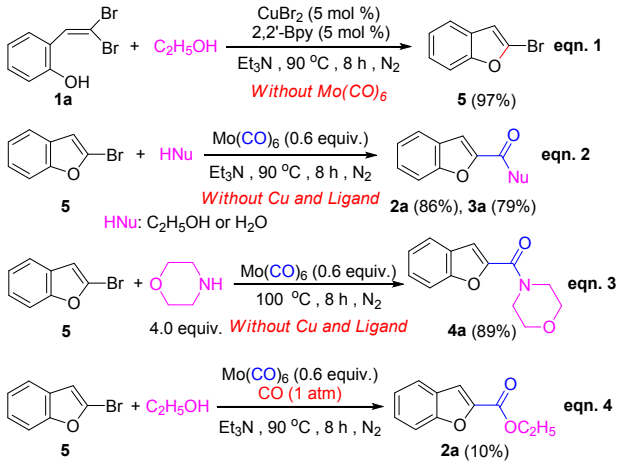


[a] Reaction conditions: **1** (0.5 mmol), amine (4.0 equiv.), $CuCl_2$ (10 mol %), 1,10-Phen (10 mol %), $Mo(CO)_6$ (0.6 equiv.), *n*-PrOH (1.5 mL), 100 °C, purged with N_2 and 8 h, isolated yields. [b] 25%-28% aqueous $NH_3 \cdot H_2O$ was used. [c] in *t*-BuOH. [d] 5 mmol scale.

To further explore the detailed reaction pathway for this tandem reaction, a few control experiments were designed (eqns. 1-4, Scheme 4). Firstly, in absence of $Mo(CO)_6$ and under the identified reaction conditions (5 mol% of $CuBr_2$, 5

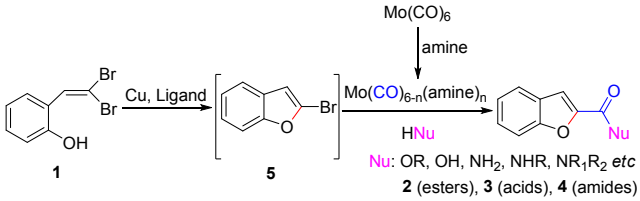
mol% of 2, 2'-Bpy, 3.0 equiv. of Et_3N, and in ethanol at 90 °C for 8h), the reaction of **1a** provided 2-bromobenzofuran (**5**) in nearly quantitative yield (eqn. 1 Scheme 4). This result proved an efficient copper-catalyzed intramolecular cyclization of 2-*gem*-dibromovinylthiophenol, which was consistent with the reports of Lautens[12] and Wang[13]. To probe the feasibility that the reaction proceeded with 2-bromobenzofuran as intermediate, the isolated **5** was then subjected to the carbonylative transformations in the presence of $Mo(CO)_6$. Without Cu catalyst and ligand, the carbonylation products **2a**, **3a**, and **4a** were obtained in 86%, 79% and 89% yields, respectively (eqns. 2 and 3, Scheme 4). Furthermore, it was found that gaseous CO greatly restrained this carbonylative transformation. When the $Mo(CO)_6$-mediated alkoxycarbonylation of 2-bromobenzofuran was performed in an CO atmosphere (1 atm in autoclave), the yield of **2a** was dramatically dropped to 10% (eqn. 4, Scheme 4). Recently, similar "Pd-free" carbonylation of (hetero)aryl halides by $Mo(CO)_6$ to form organic carboxylic acids and derivatives have been also described in several reports.[24] Although the actual mechanism was unclear, it was generally suggested that in the presence of a suitable exchange ligand $Mo(CO)_6$ can *in situ* transform to Mo complex ($Mo(CO)_{6-n}L_n$), which acted not only as the carbonyl donor, but also as the catalyst for the carbonylative transformation. In current carbonylation of 2-bromobenzofuran, such ligand was postulated as Et_3N or morpholine. Since the activation of $Mo(CO)_6$ by exchanging ligand is crucial, it could be also understandable that gaseous CO has a detrimental effect on this carbonylative transformation.

Scheme 4. Control experiments



Based on above experimental results and pervious reports, a two-step mechanistic pathway for this carbonylative tandem synthesis of 2-carboxybenzofurans from 2-*gem*-dibromovinylphenols was proposed (Scheme 5). 2-*gem*-dibromovinylphenols were firstly converted to 2-bromobenzofuran intermediates through a copper-catalyzed intramolecular Ullman cross-coupling, which then underwent a carbonylative transformation by $Mo(CO)_6$. Prior to the carbonylations, $Mo(CO)_6$ was *in situ* activated by amines (Et_3N, morpholine, or other amines) to form Mo complex [$Mo(CO)_{6-n}$(amine)$_n$] which acted as both carbonyl donor and catalyst. Depending on the external nucleophiles (alcohols, water or amines), benzofuran-2-carboxylic esters **2**, acids **3** or amides **4** were finally obtained as the desired products, respectively.

Scheme 5. Plausible reaction pathway for 2-carboxybenzofurans formation



CONCLUSIONS

In summary, we have successfully developed a novel versatile and modular carbonylative tandem protocol for the synthesis of 2-carboxybenzofurans from 2-*gem*-dibromovinylphenols *via* a sequential Cu-catalyzed intramolecular C-O coupling and $Mo(CO)_6$-mediated carbonylation reactions. With water, alcohols or amines as simple external nucleophiles and 0.6 equiv. of $Mo(CO)_6$ as carbonyl source and under the catalysis of copper salts, a wide range of functionalized bezofuran-2-carboxylic acids, esters and amides can be conveniently obtained in good to excellent yields. In addition, the reaction avoided the use of precious Pd-catalyst as well as took place under true CO-gas free conditions. Therefore, the newly developed methodology was safe and easy-to-operate, which will be attractive to organic and medicinal chemists.

EXPERIMENTAL SECTION

All chemicals and organic solvents were commercially available and directly used without further purification. De-ionized water was used in the synthesis of benzofuran-2-carboxylic acids. All proton and ^{13}C nuclear magnetic resonance (NMR) spectra were recorded on a Bruker AVANCE III 500 MHz or a Bruker Magnet System 400/600 MHz spectrometer in deuterated solvents with tetramethylsilane (TMS) as internal standard. GC-MS analyses were performed on a Thermo Scientific TRACE GC Ultra gas chromatograph using a SHIMADZU SH-Rtx-5MS (30 m x 0.25 mm ID, 0.25 μm) coupled with a Thermo Scientific ISQ single quadrupole mass spectrometer in EI mode (70 eV). High resolution mass spectra were recorded in the EI mode on Waters GCT Premier TOF mass spectrometer with an Agilent 6890 gas chromatography using a DB-XLB column (30 m x 0.25 mm (i.d.), 0.25 μ) or ESI mode on an Agilent 6210 LC/TOF mass spectrometer. Melting points (uncorrected) were determined on a BUCHI M-565 apparatus. Gas chromatography (GC) analyses were performed on Shimadzu GC-2010 Plus instrument with FID detector using a Shimadzu SH-Rtx-5 capillary column (30 m x 0.32 mm (i.d.), 0.25 μm). Flash column chromatography was performed on silica gel (200-300 mesh) with petroleum ether/ethyl acetate as eluent. The substrates 2-*gem*-dibromovinylphenols **1** were synthesized from corresponding salicylaldehydes according to the literature procedure.[25]

1. General procedure for the synthesis of benzofuran-2-carboxylic esters (2a-2t) and analytic data

To a 15 mL of Young tube, 2-*gem*-dibromovinylphenols (0.5 mmol, 1.0 equiv.), $CuBr_2$ (0.025 mmol, 5 mol%), 2,2'-Bpy (0.025 mmol, 5 mol%), $Mo(CO)_6$ (0.3 mmol, 0.6 equiv.), NEt_3 (1.5 mmol, 3.0 equiv.), alcohols (1.5 mL) were successively added. Then the tube was purged with N_2, capped and stirred at 90 °C (oil bath) for 8 h. After the reaction finished, the reaction mixture was concentrated under vacuum. The resulted residual was purified by chromatography on silica gel eluting with petroleum ether/ethyl acetate to afford the desired esters.

Ethyl benzofuran-2-carboxylate 2a (CAS No.: 3199-61-9): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (80.6 mg, 85% yield). M.p.: 30 °C (lit.[26] m.p.: 30 °C); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.66 (d, *J* = 7.9 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 1H), 7.52 (s, 1H), 7.45-7.40 (m, 1H), 7.29 (t, *J* = 7.9 Hz, 1H), 4.43 (q, *J* = 7.2 Hz, 2H), 1.42 (t, *J* = 7.2 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 159.8, 155.9, 145.9, 127.7, 127.1, 123.9, 122.9, 113.9, 112.5, 61.7, 14.5; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{11}H_{10}O_3$ 190.0630, found 190.0638.

Methyl benzofuran-2-carboxylate 2b (CAS No.: 1646-27-1): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a light yellow oil (71.4 mg, 81% yield); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.67 (d, *J* = 7.9 Hz, 1H), 7.58 (d, *J* = 8.5 Hz, 1H), 7.52 (s, 1H), 7.46-7.42 (m, 1H), 7.30 (t, *J* = 7.9 Hz, 1H), 3.97 (s, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 160.0, 155.7, 145.4, 127.6, 126.9, 123.8, 122.8, 114.0, 112.3, 52.3; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{10}H_8O_3$ 176.0473, found 176.0474.

Propyl benzofuran-2-carboxylate 2c (CAS No.: 91963-00-7): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (86.7 mg, 85% yield). M.p.: 37 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.66 (d, *J* = 7.8 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 1H), 7.52 (s, 1H), 7.45-7.40 (m, 1H), 7.29 (t, *J* = 7.8 Hz, 1H), 4.34 (t, *J* = 6.8 Hz, 2H), 1.86-1.77 (m, 2H), 1.03 (t, *J* = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 159.7, 155.7, 145.7, 127.5, 127.0, 123.7, 122.7, 113.7, 112.3, 67.0, 22.1, 10.3; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{12}H_{12}O_3$ 204.0786, found 204.0789.

Butyl benzofuran-2-carboxylate 2d (CAS No.: 1025760-20-6): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a light yellow oil (94.8 mg, 87% yield); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.66 (d, *J* = 7.9 Hz, 1H), 7.57 (d, *J* = 8.5 Hz, 1H), 7.50 (s, 1H), 7.45-7.40 (m, 1H), 7.28 (t, *J* = 7.9 Hz, 1H), 4.37 (t, *J* = 6.7 Hz, 2H), 1.80-1.73 (m, 2H), 1.51-1.43 (m, 2H), 0.97 (t, *J* = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 159.7, 155.7, 145.7, 127.5, 127.0, 123.7, 122.8, 113.7, 112.4, 65.3, 30.7, 19.1, 13.7; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{13}H_{14}O_3$ 218.0943, found 218.0939.

iso-Propyl benzofuran-2-carboxylate 2e (CAS No.: 13257-16-4): The title compound was purified by flash chromatography (PE/EA = 40/1) to afford the product as a light yellow oil (83.9 mg, 82% yield); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.68 (d, *J* = 7.9 Hz, 1H), 7.61 (d, *J* = 8.4 Hz, 1H), 7.52 (s, 1H), 7.45 (t, *J* = 8.4 Hz, 1H), 7.31 (t, *J* = 7.9 Hz, 1H), 5.38-5.29 (m, 1H), 1.42 (d, *J* = 6.3 Hz, 6H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 159.4, 155.8, 146.2, 127.6, 127.2, 123.8, 122.9, 113.7, 112.5, 69.4, 22.0; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{12}H_{12}O_3$ 204.0786, found 204.0790.

tert-Butyl benzofuran-2-carboxylate 2f (CAS No.: 1447608-46-9): The title compound was purified by flash chromatography (PE/EA = 50/1) to afford the product as a light yellow oil (52.2 mg, 48% yield); ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.65 (d, *J* = 7.9 Hz, 1H), 7.57 (d, *J* = 8.3 Hz, 1H), 7.46-7.38 (m, 2H), 7.28 (t, *J* = 7.6 Hz, 1H), 1.63 (s, 9H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$): δ 159.0, 155.7, 147.0, 127.3, 127.2, 123.7, 122.8, 113.1, 112.4, 82.7, 28.4; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{13}H_{14}O_3$ 218.0943, found 218.0942.

2-Hydroxyethyl benzofuran-2-carboxylate 2g: The title compound was purified by flash chromatography (PE/EA = 50/1) to afford the product as a white solid (54.6 mg, 53% yield), M.p.: 69 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.68 (d, *J* = 7.6 Hz, 1H), 7.62-7.55 (m, 2H), 7.46 (t, *J* = 7.9 Hz, 1H), 7.31 (t, *J* = 7.5 Hz, 1H), 4.54-4.50 (m, 2H), 3.99 (t, *J* = 4.6 Hz, 2H), 2.26-2.05 (m, 1H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 159.9, 156.0, 145.3, 128.0, 127.0, 124.0, 123.0, 114.6, 112.5, 67.1, 61.3; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{11}H_{10}O_4$ 206.0579, found 206.0581.

Ethyl 5-methylbenzofuran-2-carboxylate 2h (CAS No.: 53715-88-1): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (88.8 mg, 87% yield). M.p.: 40 °C (lit.[27] m.p.: 41-42 °C); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.49-7.40 (m, 3H), 7.24 (d, *J* = 8.5 Hz, 1H), 4.43 (q, *J* = 7.2 Hz, 2H), 2.44 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 159.8, 154.3, 145.9, 133.5, 129.2, 127.2, 122.4, 113.7, 112.0, 61.5, 21.4, 14.4; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{12}H_{12}O_3$ 204.0786, found 204.0792.

Ethyl 6-methylbenzofuran-2-carboxylate 2i (CAS No.: 53715-89-2): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (89.7 mg, 88% yield). M.p.: 44 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.53 (d, *J* = 8.1 Hz, 1H), 7.48 (s, 1H), 7.37 (s, 1H), 7.53 (d, *J* = 7.4 Hz, 1H), 4.44 (q, *J* = 7.2 Hz, 2H), 2.49 (s, 3H), 1.42 (t, *J* = 7.2 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 159.9, 156.4, 145.3, 138.5, 125.6, 124.6, 122.3, 113.9, 112.5, 61.5, 22.1, 14.5; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{12}H_{12}O_3$ 204.0786, found 204.0787.

Ethyl 7-methylbenzofuran-2-carboxylate 2j (CAS No.: 53715-90-5): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a yellow oil (88.7 mg, 87% yield); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.53-7.46 (m, 2H), 7.25-7.17 (m, 2H), 4.44 (q, *J* = 7.2 Hz, 2H), 2.58 (s, 3H), 1.43 (t, *J* = 7.2 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 159.9, 155.1, 145.7, 128.4, 126.7, 123.9, 122.8, 120.3, 114.2, 61.5, 15.3, 14.5; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{12}H_{12}O_3$ 204.0786, found 204.0791.

Ethyl 5-methoxybenzofuran-2-carboxylate 2k (CAS No.: 50551-56-9): The title compound was purified by flash chromatography (PE/EA = 20/1) to afford the product as a white solid (92.2 mg, 84% yield). M.p.: 56 °C (lit.[28] m.p.: 62 °C); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.52-7.42 (m, 2H), 7.10-7.03 (m, 2H), 4.44 (q, *J* = 7.2 Hz, 2H), 3.85 (s, 3H), 1.42 (t, *J*

= 7.2 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 159.7, 156.7, 151.0, 146.5, 127.6, 117.6, 114.0, 113.1, 103.9, 61.6, 56.0, 14.5; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{12}H_{12}O_4$ 220.0736, found 220.0746.

Ethyl 5-(tert-butyl)benzofuran-2-carboxylate 2l (CAS No.: 2097262-18-3): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a light yellow oil (102.1 mg, 83% yield); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.64 (s, 1H), 7.54-7.44 (m, 3H), 4.44 (q, *J* = 7.2 Hz, 2H), 1.42 (t, *J* = 7.2 Hz, 3H), 1.37 (s, 9H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 159.8, 154.2, 147.0, 145.9, 126.8, 126.0, 118.7, 114.2, 111.8, 61.5, 34.9, 31.8, 14.4; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{15}H_{18}O_3$ 246.1256, found 246.1248.

Ethyl 5-phenylbenzofuran-2-carboxylate 2m (CAS No.: 59962-90-2): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (113.1 mg, 85% yield). M.p.: 78.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.85 (s, 1H), 7.70-7.63 (m, 2H), 7.61 (d, *J* = 7.1 Hz, 2H), 7.57 (s, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.37 (t, *J* = 7.4 Hz, 1H), 4.47 (q, *J* = 7.2 Hz, 2H), 1.45 (t, *J* = 7.1 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 159.7, 155.4, 146.5, 141.1, 137.7, 129.0, 128.9, 127.7, 127.6, 127.4, 121.2, 114.1, 112.7, 66.7, 14.5; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{17}H_{14}O_3$ 266.0943, found 266.0937.

Ethyl 5-fluorobenzofuran-2-carboxylate 2n (CAS No.: 93849-31-1): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (87.4 mg, 84% yield). M.p.: 59 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.55-7.50 (m, 1H), 7.48 (s, 1H), 7.34-7.29 (m, 1H), 7.20-7.12 (m, 1H), 4.44 (q, *J* = 7.2 Hz, 2H), 1.42 (t, *J* = 7.2 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 159.5 (d, *J* = 239.1 Hz), 159.3, 151.9, 147.3, 127.7 (d, *J* = 10.9 Hz), 115.8 (d, *J* = 26.6 Hz), 113.6 (d, *J* = 4.5 Hz), 113.3 (d, *J* = 9.6 Hz), 107.8 (d, *J* = 24.7 Hz), 61.7, 14.3; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{11}H_9FO_3$ 208.0536, found 208.0540.

Ethyl 5-chlorobenzofuran-2-carboxylate 2o (CAS No.: 59962-89-9): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (92.0 mg, 82% yield). M.p.: 49 °C (lit.[29] m.p.: 49.5 °C); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.65 (d, *J* = 2.1 Hz, 1H), 7.51 (d, *J* = 8.9 Hz, 1H), 7.45 (s, 1H), 7.39 (d, *J* = 8.9 Hz, 1H), 4.44 (q, *J* = 7.2 Hz, 2H), 1.42 (t, *J* = 7.2 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 159.3, 154.1, 147.1, 129.6, 128.4, 128.0, 122.3, 113.6, 113.1, 61.9, 14.4; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{11}H_9ClO_3$ 224.0240, found 224.0244.

Ethyl 5-bromobenzofuran-2-carboxylate 2p (CAS No.: 84102-69-2): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a light yellow solid (108.9 mg, 81% yield). M.p.: 58 °C (lit.[30] m.p.: 60-62 °C); ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.81 (s, 1H), 7.55-7.42 (m, 3H), 4.44 (q, *J* = 7.2 Hz, 2H), 1.42 (t, *J* = 7.2 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 159.3, 154.5, 147.0, 130.7, 129.0, 125.5, 117.0, 114.0, 113.0, 61.9, 14.4; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{11}H_9BrO_3$ 267.9735, found 267.9742.

2-Ethyl 5-methyl benzofuran-2,5-dicarboxylate 2q (CAS No.: 1652570-59-6): The title compound was purified by flash chromatography (PE/EA = 20/1) to afford the product as a white solid (99.2 mg, 80% yield). M.p.: 93.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.43 (s, 1H), 8.15 (d, *J* = 8.8 Hz, 1H), 7.62 (d, *J* = 8.8 Hz, 1H), 7.58 (s, 1H), 4.45 (q, *J* = 7.2 Hz, 2H), 3.95 (s, 3H), 1.43 (t, *J* = 7.2 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$): δ 166.8, 159.3, 158.1, 147.2, 129.1, 127.1, 126.4, 125.6, 114.1, 112.4, 61.9, 52.5, 14.5; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{13}H_{12}O_5$ 248.0685, found 248.0692.

Ethyl 7-bromo-5-chlorobenzofuran-2-carboxylate 2r (CAS No.: 1823331-46-9): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (98.4 mg, 65% yield). M.p.: 110.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.61 (s, 2H), 7.50 (s, 1H), 4.45 (q, *J* = 7.2 Hz, 2H), 1.43 (t, *J* = 7.2 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 158.8, 151.7, 147.8, 130.5, 130.0, 128.9, 121.5, 113.7, 105.6, 62.1, 14.4; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{11}H_8BrClO_3$ 301.9345, found 301.9352.

Ethyl 5-bromo-7-methoxybenzofuran-2-carboxylate 2s (CAS No.: 150612-67-2): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a white solid (109.1 mg, 73% yield). M.p.: 93 °C; ^{1}H NMR (600 MHz, $CDCl_3$): δ 7.44 (s, 1H), 7.40 (s, 1H), 7.02 (s, 1H), 4.44 (q, *J* = 7.1 Hz, 2H), 4.00 (s, 3H), 1.41 (t, *J* = 7.1 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$): δ 159.1, 147.0, 146.4, 144.4, 129.8, 117.2, 117.0, 113.3, 112.7, 61.8, 56.5, 14.5; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{12}H_{11}BrO_4$ 297.9841, found 297.9837.

Ethyl naphtho[2,1-b]furan-2-carboxylate 2t (CAS No.: 32730-03-3): The title compound was purified by flash chromatography (PE/EA = 30/1) to afford the product as a yellow solid (105.4 mg, 88% yield). M.p.: 96.5 °C (lit.[31] m.p.: 84-86 °C); ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.17 (d, *J* = 8.1 Hz, 1H), 8.02 (s, 1H), 7.96 (d, *J* = 8.1 Hz, 1H), 7.87 (d, *J* = 9.0 Hz, 1H), 7.71 (d, *J* = 9.0 Hz, 1H), 7.68-7.62 (m, 1H), 7.58-7.52 (m, 1H), 4.49 (q, *J* = 7.2 Hz, 2H), 1.47 (t, *J* = 7.2 Hz, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 159.7, 154.1, 145.2, 130.6, 129.2, 129.1, 128.2, 127.4, 125.5, 123.5, 122.9, 112.9, 61.6, 14.6; HRMS(EI-TOF) *m/z*: [M^+] calculated for $C_{15}H_{12}O_3$ 240.0786, found 240.0791.

2. General procedure for the synthesis of benzofuran-2-carboxylic acids (3a-3n) and analytic data

To a 15 mL of Young tube, 2-*gem*-dibromovinylphenols (0.5 mmol, 1.0 equiv.), $CuBr_2$ (0.025 mmol, 5 mol%), 2,2'-Bpy (0.025 mmol, 5 mol%), $Mo(CO)_6$ (0.3 mmol, 0.6 equiv.), NEt_3 (1.5 mmol, 3.0 equiv.), H_2O (0.25 mL), *t*-BuOH (1.25 mL) were successively added. Then the tube was purged with N_2, capped and stirred at 90 °C (oil bath) for 8 h. After the reaction finished, the reaction mixture was poured over water, acidified with HCl (1 mol/L) and then extracted with ethyl acetate (5 mL × 3). The extractions were combined, dried over anhydrous Na_2SO_4, filtrated and concentrated under vacuum. The resulted residual was purified by chromatography on silica gel eluenting with petroleum ether/ethyl acetate to afford the desired acids.

Benzofuran-2-carboxylic acid 3a (CAS No.: 496-41-3): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (61.2 mg, 76% yield). M.p.: 192 °C (lit.[27] m.p.: 193.0-193.5 °C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 13.90-13.10 (br, 1H), 7.79 (d,

J = 7.8 Hz, 1H), 7.73-7.64 (m, 2H), 7.50 (t, *J* = 7.8 Hz, 1H), 7.35 (t, *J* = 7.5 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (125 MHz, DMSO-d_6): δ 160.1, 155.0, 146.2, 127.6, 126.9, 123.8, 123.1, 113.5, 112.1; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_9H_5O_3^-$ 161.0244, found 161.0247.

5-Methylbenzofuran-2-carboxylic acid 3b (CAS No.: 10242-09-8): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (70.0 mg, 80% yield). M.p.: 239 °C (lit.[24] m.p.: 237-238 °C); ^1H NMR (500 MHz, DMSO-d_6): δ 14.19-12.70 (br, 1H), 7.62-7.52 (m, 3H), 7.31 (d, *J* = 8.7 Hz, 1H), 2.41 (s, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, DMSO-d_6): δ 160.1, 153.5, 146.2, 132.9, 128.9, 126.9, 122.4, 113.2, 111.6, 20.8; HRMS (ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{10}H_7O_3^-$ 175.0401, found 175.0405.

6-Methylbenzofuran-2-carboxylic acid 3c (CAS No.: 50779-65-2): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (69.3 mg, 79% yield). m.p.: 202 °C; ^1H NMR (600 MHz, DMSO-d_6): δ 14.03-12.67 (br, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.60 (s, 1H), 7.50 (s, 1H), 7.18 (d, *J* = 8.0 Hz, 1H), 2.45 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, DMSO-d_6): δ 160.2, 155.5, 145.7, 137.9, 125.4, 124.4, 122.5, 113.5, 111.9, 21.4; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{10}H_7O_3^-$ 175.0401, found 175.0404.

7-Methylbenzofuran-2-carboxylic acid 3d (CAS No.: 17349-64-3): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (66.1 mg, 75% yield). M.p.: 217 °C; ^1H NMR (500 MHz, DMSO-d_6): δ 14.76-12.16 (br, 1H), 7.65 (s, 1H), 7.60 (d, *J* = 7.8 Hz, 1H), 7.31 (d, *J* = 7.2 Hz, 1H), 7.25 (t, *J* = 7.5 Hz, 1H), 2.50 (s, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, DMSO-d_6): δ 160.2, 154.1, 145.9, 128.1, 126.4, 123.8, 121.8, 120.5, 113.8, 14.7; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{10}H_7O_3^-$ 175.0401, found 175.0403.

5-Methoxybenzofuran-2-carboxylic acid 3e (CAS No.: 10242-08-7): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (70.3 mg, 73% yield). M.p.: 214 °C (lit.[32] m.p.: 215-217 °C); ^1H NMR (500 MHz, DMSO-d_6): δ 13.76-13.16 (br, 1H), 7.64-7.56 (m, 2H), 7.25 (s, 1H), 7.09 (d, *J* = 9.0 Hz, 1H), 3.80 (s, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, DMSO-d_6): δ 160.0, 156.1, 150.0, 146.7, 127.5, 117.2, 113.6, 112.8, 104.2, 55.6; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{10}H_7O_4^-$ 191.0350, found 191.0353.

5-(tert-Butyl)benzofuran-2-carboxylic acid 3f (CAS No.: 1210226-98-4): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a light yellow solid (81.1 mg, 74% yield). M.p.: 175 °C; ^1H NMR (500 MHz, DMSO-d_6): δ 13.77-13.20 (br, 1H), 7.74 (s, 1H), 7.64-7.55 (m, 3H), 1.33 (s, 9H); $^{13}C\{^{1}H\}$ NMR (125 MHz, DMSO-d_6): δ 160.2, 153.3, 146.4, 146.3, 126.6, 125.7, 118.7, 113.8, 111.4, 34.5, 31.4; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{13}H_{13}O_3^-$ 217.0870, found 217.0878.

5-Phenylbenzofuran-2-carboxylic acid 3g (CAS No.: 59962-93-5): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (70.7 mg, 59% yield). M.p.: 221 °C; ^1H NMR (600 MHz, DMSO-d_6): δ 14.00-12.80 (br, 1H), 8.04 (s, 1H), 7.79 (s, 1H), 7.72-7.68 (m, 3H), 7.49 (t, *J* = 7.7 Hz, 2H), 7.39 (t, *J* = 7.4 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (150 MHz, DMSO-d_6): δ 156.0, 154.6, 146.8, 140.0, 136.4, 128.9, 127.5, 127.3, 127.0, 126.8, 120.9, 113.7, 112.4; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{15}H_9O_3^-$ 237.0557, found 237.0558.

5-Fluorobenzofuran-2-carboxylic acid 3h (CAS No.: 89197-62-6): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (65.4 mg, 73% yield). M.p.: 255 °C; ^1H NMR (500 MHz, DMSO-d_6): δ 14.20-13.30 (br, 1H), 7.78-7.73 (m, 1H), 7.64 (s, 1H), 7.62-7.55 (m, 1H), 7.40-7.33 (m, 1H); $^{13}C\{^{1}H\}$ NMR (125 MHz, DMSO-d_6): δ 159.8, 158.8 (d, *J* = 236.1Hz), 151.4, 147.9, 127.8 (d, *J* = 11.3 Hz), 115.6 (d, *J* = 26.6 Hz), 113.55 (d, *J* = 7.7 Hz), 113.50 (d, *J* = 2.2 Hz), 108.2 (d, *J* = 24.9 Hz); HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_9H_4FO_3^-$ 179.0150, found 179.0153.

5-Chlorobenzofuran-2-carboxylic acid 3i (CAS No.: 10242-10-1): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a light yellow solid (79.9 mg, 80% yield). M.p.: 258 °C (lit.[33] m.p.: 259-262 °C); ^1H NMR (400 MHz, DMSO-d_6): δ 14.03-13.46 (br, 1H), 7.87 (s, 1H), 7.76 (d, *J* = 8.9 Hz, 1H), 7.63 (s, 1H), 7.53 (d, *J* = 8.9 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (100 MHz, DMSO-d_6): δ 159.8, 153.5, 147.6, 128.5, 128.2, 127.6, 122.4, 113.9, 113.0; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_9H_4ClO_3^-$ 194.9854, found 194.9859.

5-Bromobenzofuran-2-carboxylic acid 3j (CAS No.: 10242-11-2): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a light yellow solid (86.0 mg, 72% yield). M.p.: 258 °C; ^1H NMR (400 MHz, DMSO-d_6): δ 14.12-13.40 (br, 1H), 8.01 (d, *J* = 1.9 Hz, 1H), 7.71 (d, *J* = 8.9 Hz, 1H), 7.67-7.59 (m, 2H); $^{13}C\{^{1}H\}$ NMR (100 MHz, DMSO-d_6): δ 159.8, 153.5, 147.6, 128.5, 128.2, 127.6, 122.4, 113.9, 113.0; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_9H_4BrO_3^-$ 238.9349, found 238.9348.

5-(Methoxycarbonyl)benzofuran-2-carboxylic acid 3k (CAS No.: 251457-26-8): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (71.2 mg, 65% yield). M.p.: 209 °C; ^1H NMR (500 MHz, DMSO-d_6): δ 14.05-13.45 (br, 1H), 8.46 (s, 1H), 8.08 (d, *J* = 8.8 Hz, 1H), 7.86-7.75 (m, 2H), 3.89 (s, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, DMSO-d_6): δ 166.0, 159.7, 157.3, 147.6, 128.3, 127.2, 125.6, 125.3, 114.0, 112.5, 52.3; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{11}H_7O_5^-$ 219.0299, found 219.0303.

7-Bromo-5-chlorobenzofuran-2-carboxylic acid 3l (CAS No.: 190775-65-6): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a white solid (69.7 mg, 51% yield). M.p.: 259 °C; ^1H NMR (600 MHz, DMSO-d_6): δ 14.92-12.49 (br, 1H), 7.90 (s, 1H), 7.87 (s, 1H), 7.72 (s, 1H); $^{13}C\{^{1}H\}$ NMR (150 MHz, DMSO-d_6): δ 159.4, 150.8, 148.2, 129.5, 129.1, 128.7, 122.1, 113.6, 114.0, 104.7; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_9H_3BrClO_3^-$ 272.8960, found 272.8967.

5-Bromo-7-methoxybenzofuran-2-carboxylic acid 3m (CAS No.: 20037-37-0): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a yellow solid (88.8 mg, 66% yield). M.p.: 246 °C; ^{1}H NMR (600 MHz, DMSO-d_6): δ 14.35-12.86 (br, 1H), 7.59 (s, 1H), 7.54 (s, 1H), 7.24 (s, 1H), 3.98 (s, 3H); ^{13}C{^{1}H} NMR (150 MHz, DMSO-d_6): δ 159.6, 147.1, 145.9, 143.5, 129.7, 117.0, 116.2, 113.0, 112.3, 56.4; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{10}H_6BrO_4^-$ 268.9455, found 268.9461.

Naphtho[2,1-b]furan-2-carboxylic acid 3n (CAS No.: 5656-67-7): The title compound was purified by flash chromatography (PE/EA = 5/1, 5‰ AcOH) to afford the product as a brown solid (88.9 mg, 84% yield). M.p.: 195 °C (lit.[34] m.p.: 197-199 °C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 13.86-13.05 (br, 1H), 8.44 (d, *J* = 8.2 Hz, 1H), 8.37 (s, 1H), 8.08 (d, *J* = 8.2 Hz, 1H), 8.02 (d, *J* = 9.1 Hz, 1H), 7.86 (d, *J* = 9.1 Hz, 1H), 7.69 (t, *J* = 7.5 Hz, 1H), 7.59 (t, *J* = 7.5 Hz, 1H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 160.0, 153.1, 145.5, 130.1, 128.9, 128.8, 127.6, 127.3, 125.5, 123.8, 122.5, 113.0, 112.7; HRMS(ESI$^-$-TOF) *m/z*: [M-H]$^-$ calculated for $C_{13}H_7O_3^-$ 211.0401 , found 211.0404.

3. General procedure for the synthesis of benzofuran-2-carboxylic amides (4a-4x) and analytic data

To a 15 mL of Young tube, 2-*gem*-dibromovinylphenols (0.5 mmol, 1.0 equiv.), $CuCl_2$ (0.05 mmol, 10 mol%), 1,10-Phen (0.05 mmol, 10 mol%), $Mo(CO)_6$ (0.3 mmol, 0.6 equiv.), amines (2.0 mmol, 4.0 equiv.), *n*-PrOH (1.5 mL) were successively added. Then the tube was purged with N_2, capped and stirred for at 100 °C (oil bath) for 8 h. After the reaction finished, the reaction mixture was concentrated under vacuum. The resulted residual was purified by chromatography on silica gel eluting with petroleum ether/ethyl acetate to afford the desired amides.

Benzofuran-2-yl(morpholino)methanone 4a (CAS No.: 77509-76-3): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (106.7 mg, 92% yield). M.p.: 97 °C (lit.[35] m.p.: 95 °C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.74 (d, *J* = 7.8 Hz, 1H), 7.66 (d, *J* = 8.4 Hz, 1H), 7.47-7.40 (m, 2H), 7.33 (t, *J* = 7.5 Hz, 1H), 3.85-3.60 (m, 8H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 158.9, 153.9, 148.1, 126.7, 126.5, 123.7, 122.4, 111.8, 111.0, 66.2, 47.3, 42.8; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{13}H_{13}NO_3$ 231.0895 , found 231.0903.

Benzofuran-2-yl(thiomorpholino)methanone 4b (CAS No.: 2327350-36-5): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (79.1 mg, 64% yield). M.p.: 74 °C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.74 (d, *J* = 7.5 Hz, 1H), 7.66 (d, *J* = 8.4 Hz, 1H), 7.47-7.41 (m, 1H), 7.39 (s, 1H), 7.33 (t, *J* = 7.5 Hz, 1H), 4.01-3.82 (m, 4H), 2.71 (t, *J* = 5.1 Hz, 4H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 159.2, 153.9, 148.1, 126.7, 126.5, 123.7, 122.4, 111.7, 110.6, 27.0; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{13}H_{13}NO_2S$ 247.0667 , found 247.0675.

Benzofuran-2-yl(4-methylpiperazin-1-yl)methanone 4c (CAS No.: 83820-17-1): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (116.4 mg, 95% yield). M.p.: 69 °C (lit.[36] m.p.: 65 °C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.74 (d, *J* = 7.6 Hz, 1H), 7.66 (d, *J* = 8.4 Hz, 1H), 7.47-7.41 (m, 1H), 7.39 (s, 1H), 7.33 (t, *J* = 7.5 Hz, 1H), 3.83-3.55 (m, 4H), 2.37 (t, *J* = 5.0 Hz, 4H), 2.20 (s, 3H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 158.9, 153.9, 148.3, 126.7, 126.5, 123.7, 122.4, 111.8, 110.7, 54.5, 45.6; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{14}H_{16}N_2O_2$ 244.1212 , found 244.1219.

Benzofuran-2-yl(piperidin-1-yl)methanone 4d (CAS No.: 77509-75-2): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (86.9 mg, 76% yield). M.p.: 66 °C (lit.[35] m.p.: 65 °C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.73 (d, *J* = 7.8 Hz, 1H), 7.65 (d, *J* = 8.3 Hz, 1H), 7.43 (t, *J* = 7.8 Hz, 1H), 7.36-7.28 (m, 2H), 3.73-3.55 (m, 4H), 1.68-1.61 (m, 2H), 1.60-1.53 (m, 4H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 158.8, 153.8, 148.7, 126.8, 126.2, 123.6, 122.3, 111.7, 109.9, 47.3, 43.1, 26.2, 25.4, 24.0; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{14}H_{15}NO_2$ 229.1103 , found 229.1109.

Benzofuran-2-yl(4-phenylpiperidin-1-yl)methanone 4e (CAS No.: 312511-61-8): The title compound was purified by flash chromatography (PE/EA = 20/1) to afford the product as a white solid (87.3 mg, 86% yield). M.p.: 140 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.66 (d, *J* = 7.4 Hz, 1H), 7.54 (d, *J* = 8.4 Hz, 1H), 7.40 (t, *J* = 8.4 Hz, 1H), 7.36-7.27 (m, 4H), 7.26-7.20 (m, 3H), 5.00-4.50 (m, 2H), 3.43-2.80 (m, 3H), 1.99 (d, *J* = 12.5 Hz, 2H), 1.87-1.76 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz,$CDCl_3$): δ 160.0, 154.6, 149.4, 145.1, 128.6, 127.1, 126.8, 126.6, 126.3, 123.5, 122.2, 111.9, 111.5, 42.9; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{20}H_{19}NO_2$ 305.1416 , found 305.1420.

Benzofuran-2-yl(pyrrolidin-1-yl)methanone 4f (CAS No.: 92028-90-5): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (91.2 mg, 85% yield). M.p.: 101 °C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.75 (d, *J* = 7.8 Hz, 1H), 7.66 (d, *J* = 8.3 Hz, 1H), 7.49 (s, 1H), 7.46-7.42 (m, 1H), 7.32 (t, *J* = 7.5 Hz, 1H), 3.82 (t, *J* = 6.8 Hz, 2H), 3.51 (t, *J* = 6.8 Hz, 2H), 1.97-1.88 (m, 2H), 1.86-1.80 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 157.5, 154.0, 149.3, 126.9, 126.6, 123.6, 122.5, 111.8, 110.9, 47.7, 46.8, 26.0, 23.3; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{13}H_{13}NO_2$ 215.0946 , found 215.0951.

N,N-dipropylbenzofuran-2-carboxamide 4g (CAS No.: 904081-20-5): The title compound was purified by flash chromatography (PE/EA = 15/1) to afford the product as a yellow oil (101.8 mg, 83% yield); ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.73 (d, *J* = 7.7 Hz, 1H), 7.63 (d, *J* = 8.4 Hz, 1H), 7.46-7.39 (m, 1H), 7.35 (s, 1H), 7.31 (t, *J* = 7.5 Hz, 1H), 3.42-3.25 (m, 4H), 1.65-1.53 (m, 4H), 0.92-0.78 (m, 6H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 159.8, 153.8, 149.3, 126.7, 126.3, 123.6, 122.3, 111.6, 110.1, 49.7, 47.5, 22.1, 20.3, 11.2, 10.9; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{15}H_{19}NO_2$ 245.1416 , found 245.1419.

N-propylbenzofuran-2-carboxamide 4h (CAS No.: 24282-71-1): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a colorless oil (81.4 mg, 80% yield); ^{1}H NMR (500 MHz, DMSO-d_6): δ 8.73 (t, *J* = 5.7 Hz, 1H), 7.75 (d, *J* = 7.9 Hz, 1H), 7.63 (d, *J* = 8.3 Hz, 1H), 7.52 (s, 1H), 7.43 (t, *J* = 7.9 Hz, 1H), 7.31 (t, *J* = 7.5 Hz, 1H), 3.24 (q, *J* = 6.8 Hz, 2H), 1.54 (m, 2H), 0.87 (t, *J* = 7.4 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 158.1, 154.2, 149.4,

127.2, 126.6, 123.6, 122.7, 111.7, 109.1, 40.5, 22.4, 11.4; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{12}H_{13}NO_2$ 203.0946 , found 203.0950.

N-benzylbenzofuran-2-carboxamide 4i (CAS No.: 21315-63-9): The title compound was purified by flash chromatography (PE/EA = 15/1) to afford the product as a white solid (109.3 mg, 87% yield). M.p.: 100 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 9.32 (t, *J* = 6.1 Hz, 1H), 7.77 (d, *J* = 7.7 Hz, 1H), 7.66 (d, *J* = 8.3 Hz, 1H), 7.60 (s, 1H), 7.46 (t, *J* = 7.8 Hz, 1H), 7.38-7.29 (m, 5H), 7.27-7.20 (m, 1H), 7.66 (d, *J* = 6.2 Hz, 2H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 158.2, 154.3, 149.1, 139.3, 128.3, 127.4, 127.2, 126.9, 126.8, 123.7, 122.8, 111.8, 109.6, 42.2; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{16}H_{13}NO_2$ 251.0946 , found 251.0949.

N-phenylbenzofuran-2-carboxamide 4j (CAS No.: 50635-12-6): The title compound was purified by flash chromatography (PE/EA = 15/1) to afford the product as a light yellow solid (59.1 mg, 50% yield). M.p.: 155 °C (lit.[37] m.p.: 158 °C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 10.53 (s, 1H), 7.86-7.79 (m, 3H), 7.78 (s, 1H), 7.73 (d, *J* = 8.4 Hz, 1H), 7.51 (t, J_1 = 7.8 Hz, 1H), 7.41-7.34 (m, 3H), 7.13 (t, J_1 = 7.4 Hz, 1H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 156.7, 154.5, 148.8, 138.4, 128.7, 127.2, 127.1, 124.1, 123.9, 122.9, 120.5, 112.0, 110.7; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{15}H_{11}NO_2$ 237.0790 , found 237.0783.

Benzofuran-2-carboxamide 4k (CAS No.: 50342-50-2): The title compound was purified by flash chromatography (PE/EA = 5/1) to afford the product as a white solid (65.3 mg, 81% yield). M.p.: 162 °C (lit.[38] m.p.: 158-159 °C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 8.21-8.05 (m, 1H), 7.76 (d, *J* = 7.5 Hz, 1H), 7.73-7.65 (m, 1H), 7.63 (d, *J* = 8.4 Hz, 1H), 7.55 (s, 1H), 7.48-7.40 (m, 1H), 7.31 (t, *J* = 7.5 Hz, 1H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 159.9, 154.3, 149.4, 127.3, 126.8, 123.7, 122.8, 111.8, 109.6; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_9H_7NO_2$ 161.0477 , found 161.0480.

(5-Methylbenzofuran-2-yl)(morpholino)methanone 4l (CAS No.: 950255-28-4): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (114.2 mg, 93% yield). M.p.: 120.5 °C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.57-7.47 (m, 2H), 7.35 (s, 1H), 7.26 (d, *J* = 8.5 Hz, 1H), 3.87-3.57 (m, 8H), 2.40 (s, 3H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 159.0, 152.4, 148.2, 132.8, 127.9, 126.8, 121.9, 111.3, 110.9, 66.2, 46.9, 42.9, 20.8; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{14}H_{15}NO_3$ 245.1052 , found 245.1060.

(6-Methylbenzofuran-2-yl)(morpholino)methanone 4m (CAS No.: 1789659-35-3): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (112.9 mg, 92% yield). M.p.: 118.5 °C; ^{1}H NMR (600 MHz, DMSO-d_6): δ 7.60 (d, *J* = 8.0 Hz, 1H), 7.44 (s, 1H), 7.36 (s, 1H), 7.14 (d, *J* = 8.0 Hz, 1H), 3.85-3.57 (m, 8H), 2.42 (s, 3H); ^{13}C{^{1}H} NMR (150 MHz, DMSO-d_6): δ 159.0, 154.4, 147.6, 136.7, 125.1, 124.2, 121.9, 111.7, 111.1, 66.2, 46.8, 42.8, 21.3; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{14}H_{15}NO_3$ 245.1052 , found 245.1060.

(7-Methylbenzofuran-2-yl)(morpholino)methanone 4n (CAS No.: 2215703-74-3): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (104.0 mg, 85% yield). M.p.: 117 °C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.55 (d, *J* = 7.5 Hz, 1H), 7.40 (s, 1H), 7.28-7.20 (m, 2H), 3.85-3.60 (m, 8H), 2.49 (s, 3H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 159.0, 153.0, 147.8, 127.1, 126.2, 123.7, 121.5, 119.8, 111.2, 66.2, 46.9, 42.6, 14.6; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{14}H_{15}NO_3$ 245.1052 , found 245.1059.

(5-Methoxybenzofuran-2-yl)(morpholino)methanone 4o (CAS No.: 92249-04-2): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (101.6 mg, 78% yield). M.p.: 83 °C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.56 (d, *J* = 9.0 Hz, 1H), 7.35 (s, 1H), 7.22 (s, 1H), 7.04 (d, *J* = 9.0 Hz, 1H), 3.83-3.60 (m, 11H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 158.8, 156.1, 148.9, 148.9, 127.3, 115.8, 112.4, 111.3, 103.9, 66.2, 55.6, 46.8, 42.7; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{14}H_{15}NO_4$ 261.1001 , found 261.1009.

(5-(tert-Butyl)benzofuran-2-yl)(morpholino)methanone 4p: The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (116.6 mg, 81% yield). M.p.: 117 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.69 (s, 1H), 7.56 (d, *J* = 8.8 Hz, 1H), 7.51 (d, *J* = 8.8 Hz, 1H), 7.38 (s, 1H), 3.87-3.52 (m, 8H), 1.33 (s, 1H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 159.0, 152.2, 148.2, 146.3, 126.4, 124.6, 118.2, 111.4, 111.1, 66.2, 47.0, 42.6, 34.5, 31.5; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{17}H_{21}NO_3$ 287.1521 , found 287.1528.

Morpholino(5-phenylbenzofuran-2-yl)methanone 4q: The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (138.0 mg, 90% yield). M.p.: 162 °C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.99 (s, 1H), 7.77-7.71 (m, 2H), 7.69 (d, *J* = 7.1 Hz, 2H), 7.51-7.45 (m, 3H), 7.38 (t, *J* = 7.4 Hz, 1H), 3.84-3.61 (m, 8H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 158.8, 153.5, 148.8, 140.2, 136.3, 129.0, 127.4, 127.2, 127.0, 125.8, 120.3, 112.1, 111.2, 67.2; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{19}H_{17}NO_3$ 307.1208 , found 307.1213.

(5-Fluorobenzofuran-2-yl)(morpholino)methanone 4r: The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (105.6 mg, 85% yield). M.p.: 88 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.75-7.65 (m, 1H), 7.60-7.48 (m, 1H), 7.40 (s, 1H), 7.33-7.24 (m, 1H), 3.90-3.51 (m, 8H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 158.8 (d, *J* = 235.9 Hz), 158.6, 150.3, 149.8, 127.6 (d, *J* = 11.4 Hz), 114.4 (d, *J* = 26.7 Hz), 113.2 (d, *J* = 9.8 Hz), 111.1 (d, *J* = 4.1 Hz), 107.7 (d, *J* = 25.2 Hz), 66.2, 47.0, 42.6; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{13}H_{12}FNO_3$ 249.0801, found 249.0804.

(5-Chlorobenzofuran-2-yl)(morpholino)methanone 4s (CAS No.: 882308-53-4): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a light yellow solid (116.8 mg, 88% yield). M.p.: 99 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.81 (s, 1H), 7.71 (d, *J* = 8.8 Hz, 1H), 7.46 (d, *J* = 8.8 Hz, 1H), 7.39 (s, 1H), 3.88-3.51 (m, 8H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 158.5, 152.4, 149.5, 128.3, 128.0, 126.5, 121.8, 113.5, 110.5, 66.2, 47.0, 42.6; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{13}H_{12}ClNO_3$ 265.0506, found 265.0513.

(5-Bromobenzofuran-2-yl)(morpholino)methanone 4t (CAS No.: 838887-57-3): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (135.1 mg, 87% yield). M.p.: 110 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.96 (s, 1H), 7.66 (d, *J* = 8.8 Hz, 1H), 7.58 (d, *J* = 8.8 Hz, 1H), 7.39 (s, 1H), 3.89-3.49 (m, 8H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 158.5, 152.8, 149.3, 129.2, 128.9, 124.8, 115.9, 113.9, 110.4, 66.2, 46.8, 42.6; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{13}H_{12}BrNO_3$ 309.0001, found 309.0006.

Methyl 2-(morpholine-4-carbonyl)benzofuran-5-carboxylate 4u: The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (121.3 mg, 84% yield). M.p.: 129 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.39 (s, 1H), 8.03 (d, *J* = 8.8 Hz, 1H), 7.78 (d, *J* = 8.8 Hz, 1H), 7.54 (s, 1H), 3.88 (s, 1H), 3.83-3.56 (m, 8H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 166.0, 158.5, 156.3, 149.5, 127.5, 127.0, 125.4, 124.5, 112.2, 111.4, 66.2, 52.3, 47.0, 42.6; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{15}H_{15}NO_5$ 289.0950, found 289.0957.

(7-Bromo-5-chlorobenzofuran-2-yl)(morpholino)methanone 4v (CAS No.: 2334613-06-6): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (131.8 mg, 77% yield). M.p.: 130 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.85 (s, 1H), 7.80 (s, 1H), 7.48 (s, 1H), 3.81-3.57 (m, 8H); ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 158.1, 149.9, 149.8, 129.0, 128.6, 128.5, 121.5, 111.0, 104.4, 66.1, 47.0, 42.6; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{13}H_{11}BrClNO_3$ 342.9611, found 342.9620.

(5-Bromo-7-methoxybenzofuran-2-yl)(morpholino)methanone 4w (CAS No.: 2334613-14-6): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (151.5 mg, 89% yield). M.p.: 152 °C; ^{1}H NMR (600 MHz, DMSO-d_6): δ 7.51 (s, 1H), 7.36 (s, 1H), 7.21 (s, 1H), 3.97 (s, 3H), 3.79-3.59 (m, 8H); ^{13}C{^{1}H} NMR (150 MHz, DMSO-d_6): δ 158.4, 149.0, 145.8, 142.3, 129.6, 116.5, 116.1, 112.6, 110.5, 66.1, 56.4, 46.9, 42.5; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{14}H_{14}BrNO_3$ 339.0106, found 339.0112.

Morpholino(naphtho[2,1-b]furan-2-yl)methanone 4x (CAS No.: 915896-13-8): The title compound was purified by flash chromatography (PE/EA = 10/1) to afford the product as a white solid (102.5 mg, 73% yield). M.p.: 145 °C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 8.41 (d, *J* = 8.2 Hz, 1H), 8.15 (s, 1H), 8.07 (d, *J* = 8.1 Hz, 1H), 7.97 (d, *J* = 9.0 Hz, 1H), 7.84 (d, *J* = 9.0 Hz, 1H), 7.68 (t, *J* = 8.2 Hz, 1H), 7.57 (t, *J* = 8.2 Hz, 1H), 3.99-3.59 (m, 8H); ^{13}C{^{1}H} NMR (125 MHz, DMSO-d_6): δ 158.8, 151.8, 147.5, 130.1, 128.8, 127.8, 127.4, 127.0, 125.3, 123.7, 122.2, 112.5, 111.0, 66.2; HRMS(EI-TOF) *m/z*: [M$^+$] calculated for $C_{17}H_{15}NO_3$ 281.1052, found 281.1059.

4. Procedure for the gram-scale syntheses of 2p, 3f and 4a.

To a 50 mL of Young tube, 4-bromo-2-(2,2-dibromovinyl)phenol (5.0 mmol, 1.0 equiv.), $CuBr_2$ (0.25 mmol, 5 mol%), 2,2'-Bpy (0.25 mmol, 5 mol%), $Mo(CO)_6$ (3.0 mmol, 0.6 equiv.), NEt_3 (15 mmol, 3.0 equiv.), EtOH (15 mL) were successively added. Then the tube was purged with N_2, capped and stirred at 90 °C (oil bath) for 8 h. After the reaction finished, the reaction mixture was concentrated under vacuum. The resulted residual was purified by chromatography on silica gel using petroleum ether/ethyl acetate as eluent to afford the desired products **2p** as a light yellow solid (1.07 g, 80% yield).

Similarly, **3f** (0.838 g, 77% yield) was synthesized from 4-(*tert*-butyl)-2-(2,2-dibromovinyl)phenol (5.0 mmol) as a light yellow solid, and **4a** (1.05 g, 91% yield) was synthesized from 2-(2,2-dibromovinyl)phenol (5.0 mmol) as a white solid.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/xx.xxxx/xxxxxxxx

Details of optimization of the reaction conditions.
^{1}H and ^{13}C NMR spectra for all products (PDF).

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