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Two-Step Synthesis of π-Expanded Maleimides from 3,4-Diphenylfuran-2(5*H*)-ones

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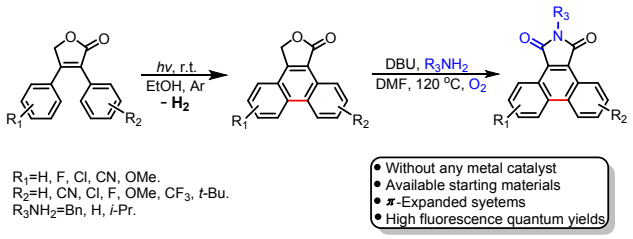


ABSTRACT: An efficient two-step synthesis of π-expanded maleimide derivatives was reported, which proceeded *via* a photoinduced dehydrogenative annulation of 3,4-diphenylfuran-2(5*H*)-ones in EtOH at room temperature for 5 h under the argon atmosphere, followed by interaction with primary amine in the presence of DBU and O_2. The synthesis of highly conjugated maleimides demonstrated that 3,4-diphenylfuran-2(5*H*)-ones were useful precursors for synthesis of π-expanded lactones and π-expanded maleimides with no need of transition metal catalyst. Additionally, the fluorescent properties of the highly conjugated maleimides were characterized and possessed high fluorescence quantum yields in dichloromethane solution.

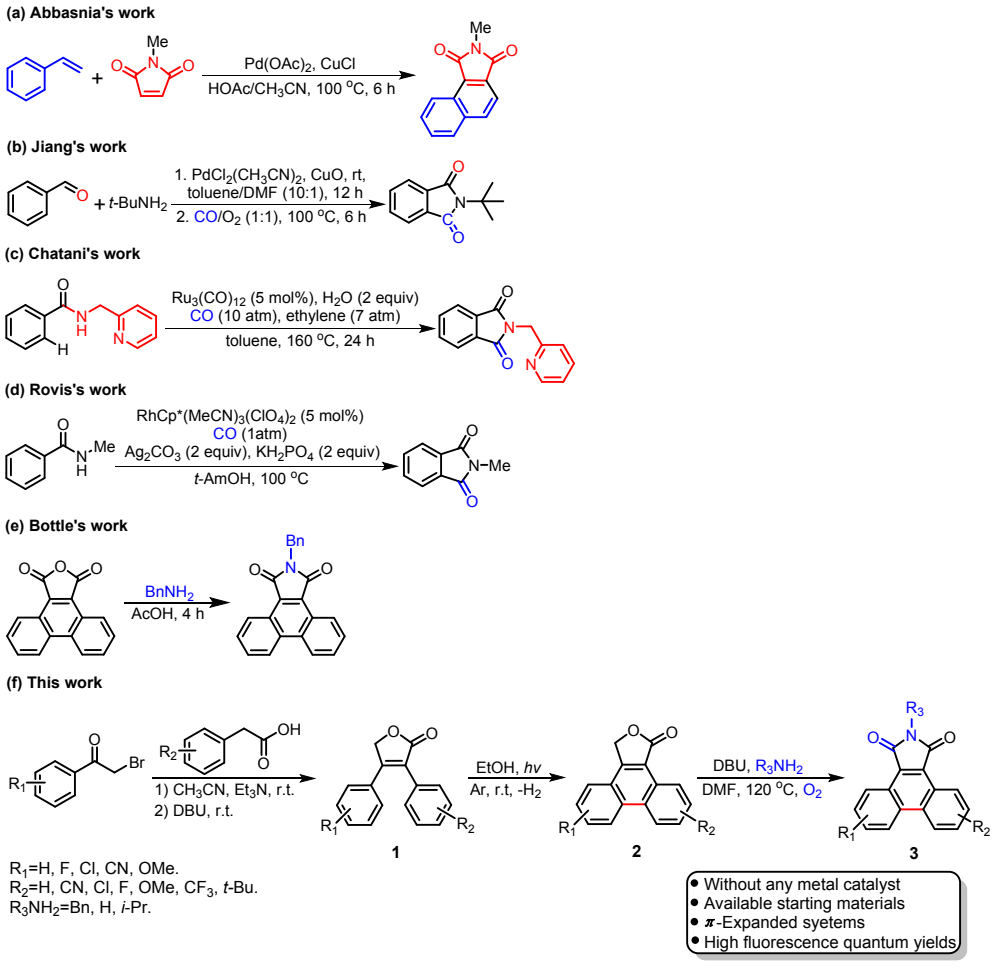
INTRODUCTION

In recent years, photochemical reactions have received increased attention due to the demands of the green concept of energy saving, high atom efficiency and environmental protection.[1, 2] They have been also provided convenient access to obtain the phenanthrene derivatives and polycyclic aromatic hydrocarbons (PAHs), which are hard to access by non-photochemical approaches.[3, 4]

Maleimides have been attracted considerable attention due to their privileged potential activity as androgen antagonists[5a] and TNF-α inhibitor.[5b] Moreover, pyromellitic diimide applied as a high-performance polymeric material for aircraft or spacecraft.[6a, 6b] Despite their wide applicability, the synthesis methods are mainly limited to the dehydrative condensation of either an phthalic acid,[7, 8] or corresponding 1,2-diacids and an amine at high temperature[9, 10] and the cyclization of the amic acid in the presence of acidic catalysts or other promoter (e.g., Lewis acid, base, dehydrating agent, microwave).[8, 10-13] New synthetic methods were reported as well and selected examples were briefly discussed and listed in scheme 1. For instance, Diels-Alder

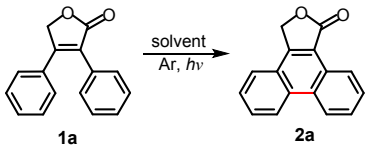
cyclization of styrene with maleimides in the presence of $Pd(OAc)_2$/CuCl and HOAc at 100 °C for 6 h to afford benzo[*e*]isoindole-1,3-diones derivatives was reported (Scheme 1a).[14] Phthalimide derivatives were obtained by the intermolecular Pd-catalyzed one-pot oxidative carbonylation of benzaldehyde with primary imines in the presence of CO/O_2 (Scheme 1b).[15] Alternatively, similar derivatives could be obtained by the intramolecular ruthenium-catalyzed cyclization/carbonylation at ortho C-H bonds in aromatic amides (Scheme 1c).[16] Moreover, rhodium(III)-catalyzed oxidative carbonylation of benzamides in the presence of 1 atm of CO also afforded *N*-substituted phthalimides (Scheme 1d).[17] Last but not least, phenanthro[9,10-*c*]-1,3-anhydride was used for the synthesis of benzyldibenzo[*e,g*]isoindoline-1,3-dione by the reaction with benzylamine in the presence of AcOH (Scheme 1e).[18] In 2007, Cassandra's group have reported that using 3,4-diarylsubstituted furan-2(5*H*)-one react with aniline in the presence of *p*-TsOH at 150 °C for 12 h to afford 3,4-diarylsubstituted maleimide in the yield of 34%.[19] In general, synthesis of maleimide derivatives could be summarized in two strategies: (a) the presence of oxidant and/or catalyst, e.g., Pd, Ru, CuO and Rh; (b) the presence of maleic anhydride and appropriate amine with the presence of acid or base catalyst.

Scheme 1. Synthetic Approaches to π-Expanded Maleimides



To the best of our knowledge, directly synthesis of highly conjugated maleimide derivatives from lactones substrates has not been reported yet. Thus, following our interest in the photocyclization,[20-22] we would like to report a facile stepwise synthesis of π-expanded maleimide derivatives *via* a photoinduced dehydrogenative annulation of 3,4-diphenylfuran-2(5*H*)-ones **1** for the generation of π-expanded lactones **2**, followed by the treatment with primary amines in the presence of DBU under the O_2 atmosphere, which avoid using of any expensive transition metal catalyst and realize one pot oxidation and ammoniation of **2** to afford maleimides (Scheme 1f).

Table 1. Optimization for the Intramolecular Cyclization of 1a [a]



Entry	Concn (mM)	Solvent (v/v)	Time (h)	Conv (%)[b]	Yield (%)[b]
1	5	CH_2Cl_2	5	51	42
2	5	MeCN	5	76	55
3	5	Me_2CO	5	89	75
4	**5**	**EtOH**	**5**	**93**	**78**
5	5	EtOH-H_2O (19:1)	5	70	54
6	3	EtOH	5	81	63
7	7	EtOH	5	60	45
8	5	EtOH	3	72	65
9	5	EtOH	7	100	70
10	5	EtOH	5	83	55[c]

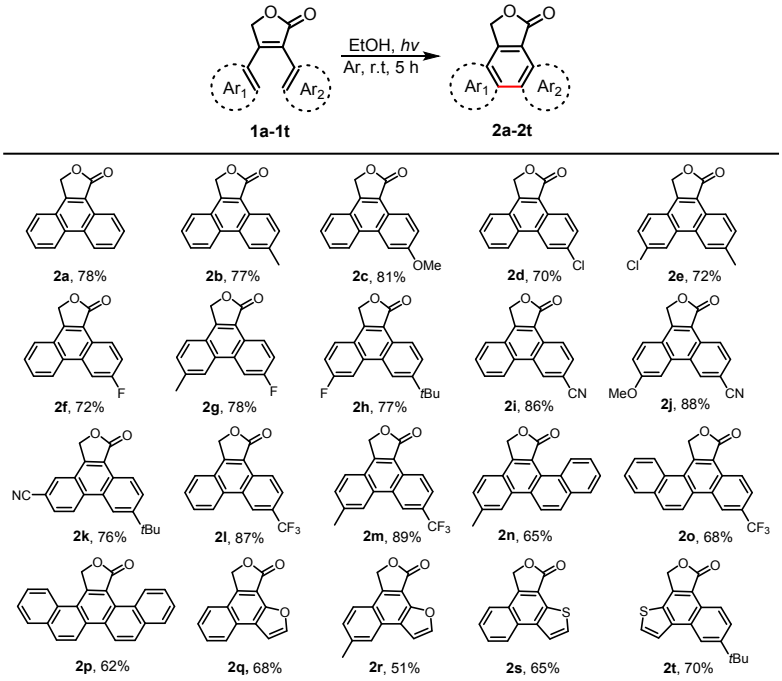
[a]**1a** was irradiated with a 500 W high-pressure mercury lamp in various solvent (0.2 mmol, 40 mL) at room temperature under an Ar atmosphere. [b]Isolated yield. [c]Open air atmosphere.

RESULTS AND DISCUSSION

Initially, the solution of 3,4-diphenylfuran-2(5*H*)-one **1a** in dichloromethane (40 mL) was irradiated with a 500 W high-pressure mercury lamp at room temperature under argon atmosphere for 5 h to give annulation product **2a** in the yield of 42% (Table 1, entry 1). Replacement of CH_2Cl_2 with ethanol gave **2a** in significantly improved yield (78%) among other solvents, e.g. acetonitrile and acetone (Table 1, entry 2-4). However, the formation of **2a** was dramatically suppressed with the presence of added water (Table 1, entries 5, 54%). Meanwhile, the substrate concentration effect was also explored and it is noticed that **2a** was obtained in reduced yields with either higher or lower substrate concentrations (Table 1, entries 6-7, 63% and 45%). Finally, irradiation time was screened and the yields of **2a** were decreased slightly with shortened or prolonged irradiation (Table 1, entries 8 and 9, 65%-70%). It is important to note that the cyclization efficiency was also slightly affected under open air condition (Table 1, entries 10,

55%). As a result, the irradiation of **1a** in EtOH at room temperature for 5 h under the argon atmosphere was determined to be the optimal condition.

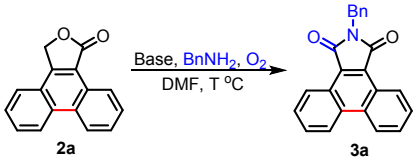
Table 2. Substrate Scope [a]



[a]All reactions were carried out on a 0.2 mmol of scale **1** in EtOH (40 mL) and irradiated with a 500 W high-pressure mercury lamp under the argon atmosphere at room temperature for 5 h.

With the optimal condition in hand, we turned out focus on the scope of functional groups and the yields were summarized in **Table 2**. Generally, the substrates containing electron-withdrawing groups (e.g., CF_3, CN), gave better yields comparing to those bearing electron-donating groups (e.g., Me, OMe). Meanwhile, the halogen atoms, such as F and Cl were well accommodated and gave lower yields comparing to **2a**. Also, substrates with the electron-rich heteroaromatics, such as thiophene and furan (**2q-2t**), gave desired products in lower yields. Under the optimal conditions, 3-(1*H*-indol-3-yl)-4-phenylfuran-2(5*H*)-one **1u** and 3-phenyl-4-(pyridin-2-yl)furan-2(5*H*)-one **1v** were irradiated. They were failure to annulation and did not obtain the annulation products. That is to say that the substrates containing nitrogen atom heteroaromatic ring groups is not dehydrogenative annulation under the irradiation condition.

Table 3. Optimization for the Oxidation and Ammoniation of 2a [a]

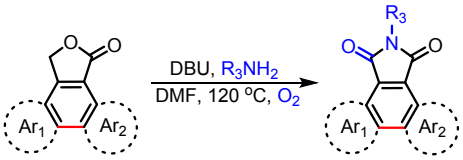


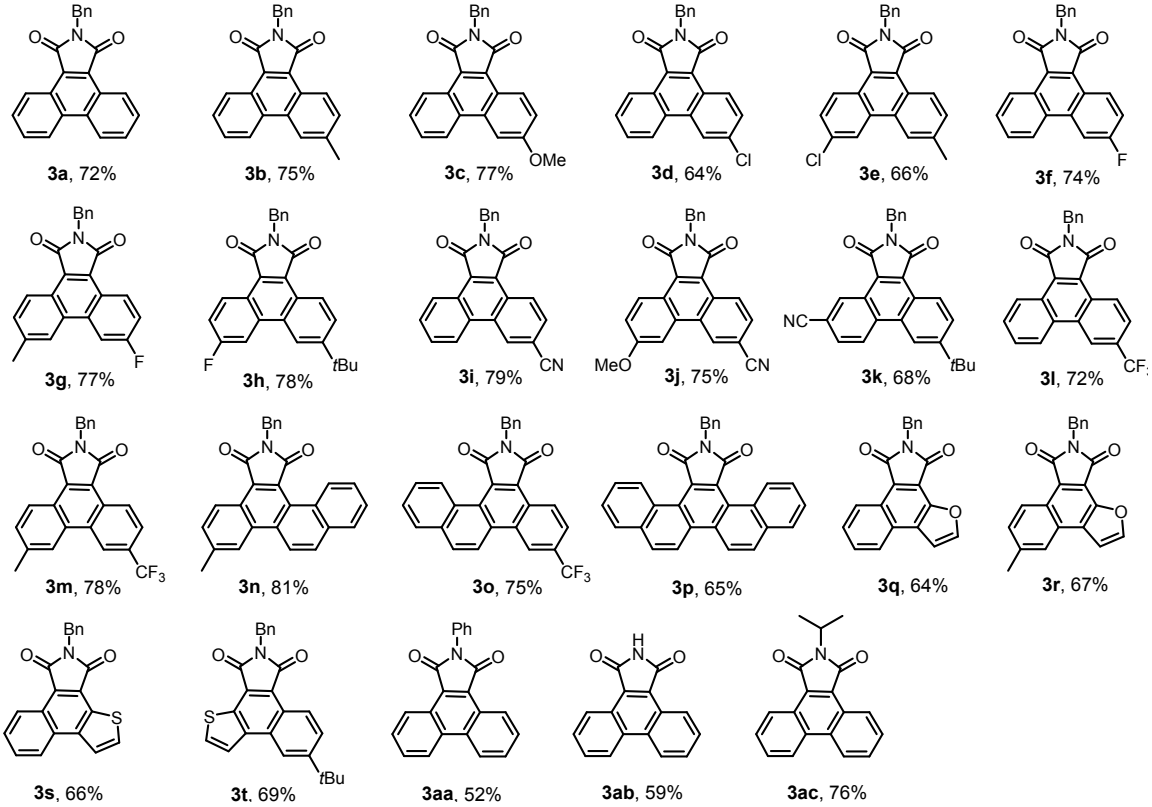
Entry	Base	Temp (°C)	Time (h)	Yield (%)[b]
1	Et_3N	120	4	29
2	DABCO	120	4	47

3	DBU	120	4	54
4	**DBU**	**120**	**4**	**72**
5	DBU	100	4	59
6	DBU	130	4	70
7	DBU	120	2	51
8	DBU	120	5	69
9	DBU	120	4	25[c]

[a]The reaction was carried out in DMF under oxygen atmosphere for 4 h. [b]Isolated yield. [c]Open air atmosphere.

Table 4. Synthesis of Maleimide Derivatives[a, b]





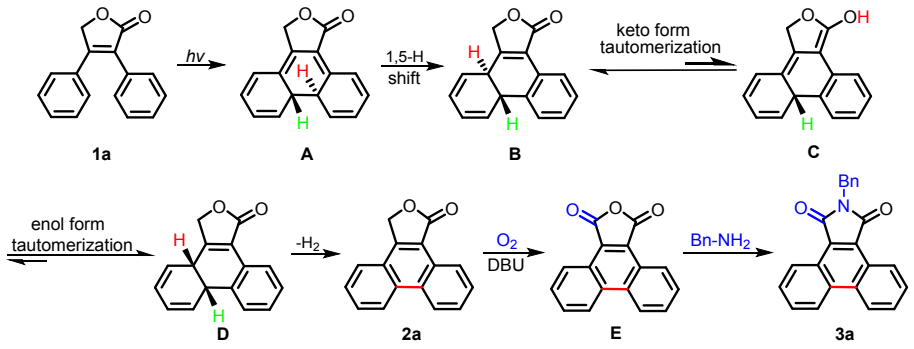
[a]Reaction condition: **2** (0.15 mmol), DBU (0.23 mmol), R_3NH_2 (0.45 mmol), DMF (2.0 ml), 120 °C, 4 h. [b]Isolated yield.

It has been reported that treatment of furanone **1a** with DBU in acetonitrile under oxygen atmosphere at ambient temperature gave maleic anhydride in moderate yield.[23] Further treatment of maleic anhydride with aromatic/aliphatic amines in the presence of catalytic Lewis acid provided maleimide analogues.[11] However, there is no report regarding the direct synthesis of maleimides from lactones **2**. Thus, we turned our attention to the synthesis of maleimide derivatives *via* the reaction of corresponding lactones **2** with primary amine in the presence of base and oxygen.

Initially, **2a** was dissolved in DMF, followed with the addition of Et_3N and $BnNH_2$. The resulting solution was heated at 120 °C by oil bath under O_2 atmosphere for 4 h. As it is expected, **3a** was obtained in 29% yield (Table 3, entry 1). Next, other organic bases, e.g. DABCO and DBU, were examined (Table 3, entries 2–3) and DBU is turned out to be the best choice, which gave **3a** in 54% (Table 3, entry 3). It indicated that strong base DBU was favor to improve the yield of **3a**. Furthermore, the sequence of reagent addition was investigated as well. After DBU was added to the solution of **2a** in DMF at 120 °C and stirred for 15 minutes, $BnNH_2$ was added to the the reaction mixture. It is surprised to found that the yield of **3a** was boosted to 72 % after the reaction mixture was stirred for 4 h under O_2 atmosphere (Table 3, entry 4). As demonstrated, both reaction time and temperature have significant effect on the formation of **3a** (Table 3, entries 5-8). Open air could also afford the oxidation product, but only 25% of **3a** was isolated (Table 3, entries 9). As a result, it is safe to conclude that cyclization of **2a** in the presence of DBU under O_2 atmosphere at 120 ^{o}C for 4 h is optimal condition.

Primary amines such as aniline and ammonium hydroxide, isopropylamine were explored under the optimal conditions. Both aromatic and aliphatic amine could provide the corresponding products in moderate yields (**Table 4)**. However, reaction of lactons **2** with aniline and ammonium hydroxide gave the corresponding products **3aa** and **3ab** in lower yields (52%, 59%), which could be explained by the reduced electron density on the nitrogen atom. Moreover, the structures of both lactons **2** and maleimides **3** were characterized by ^{1}H NMR, ^{13}C NMR, ^{19}F NMR, HRMS and IR. Meanwhile, 1 mmol of scale **1a** was carried out in EtOH (200 mL) and irradiated under the argon atmosphere at room temperature for 5 h. When the reaction was completed, the solvent was removed and further treatment with $BnNH_2$ in the presence of DBU and O_2 provide direct access to product **3a** (205.6 mg, 61 %).

Scheme 2. Proposed Mechanism for the Formation of 3a



On the basis of literature reports[18,20-21, 23-25] and experimental evidence, a plausible mechanism for the formation of **3a** is depicted in Scheme 2. Irradiation of 3,4-diphenylfuran-2(5*H*)-one **1a** with a high-pressure Hg lamp at ambient temperature generates intermediate **A** *via* an intramolecular 6π-electron cyclization.[24] Followed by a thermal suprafacial [1,5]-H shift[25] to give intermediate **B**. The rearomatization of the benzene ring is the force driving

for [1,5]-sigmatropic shift. Subsequently, the stable *syn*-isomer intermediate **D** was obtained *via* the keto-enol isomerization of **B**. The polar protic solvent EtOH plays a significant role in the process of keto-enol isomerization, which accounts for higher yield of **2a** in EtOH compared to acetonitrile and acetone. Finally, the annulation product **2a** was obtained by hydrogen evolution *via syn*-elimination from intermediate **D**, which share a similar concept with literature reports.[20-21] It is important to note that the annulation product **2a** was also obtained under the open air (Table 1, entry 10, 55%), it is believed that the photochemical cyclization proceed through the S1 state.[20] Meanwhile, the byproduct H_2 was successfully detected by GC chromatography during the annulations of **1m**, which proved the solid rationality for the proposed mechanism (Figures S1-2, please see the Supporting Information). The oxidation of **2a** in the presence of DBU gave maleic anhydride **E**, which further reacts with benzylamine gave the final product **3a**. The reaction mechanism of **3a** has been proved on the basis of previous reports.[18, 23]

Lastly, the fluorescence spectra of **3** in CH_2Cl_2 (10^{-5} mol/L) was explored, and the corresponding maxima excitation/emission wavelength and quantum yields were summarized in **Table 5**. The presence of heteroaromatics, such as thiophene and furan, benefited the growth of quantum yields. For instance, **3q-3t** (Φ_F=0.95, 0.84, 0.70, 0.75) have remarkable fluorescence properties, and their fluorescence quantum yields are higher than **3a** (Φ_F=0.58). It is worth noting that the presence of both electron-donating and electron-withdrawing substituent in the same substrate, e.g. **3e, 3g, 3j, 3m,** gave higher quantum yields (Φ_F=0.85, 0.95, 0.80, 0.75) than the one only bearing electron-withdrawing groups, e.g. **3d, 3f, 3i, 3l** (Φ_F=0.77, 0.58, 0.29, 0.26). Furthermore, due to the presence of an extended π-conjugated system and the wavelength of the lowest energy band for **3p** (λ_{em}=545 nm) led to red-shifted compared to **3a** (λ_{em}=462 nm).

Table 5. Spectral Properties of 3 in Dichloromethane Solution (10^{-5} mol/L)

compounds	λex (nm)	λem (nm)	Stokes shift (cm^{-1})	Φ_F
3a	379	462	4740	0.58
3b	386	467	4493	0.88
3c	396	494	5009	0.56
3d	377	460	4786	0.77
3e	388	469	4451	0.85
3f	374	437	3855	0.58
3g	385	468	4607	0.95
3h	385	468	4540	0.84
3i	377	456	4595	0.29
3j	406	489	4180	0.80
3k	379	462	4740	0.89
3l	373	453	4734	0.26
3m	381	460	4507	0.75

3n	398	495	4923	0.92
3o	418	492	3598	0.66
3p	375	545	8319	0.19
3q	392	465	4005	0.95
3r	365	472	6211	0.84
3s	382	464	4626	0.70
3t	384	474	4944	0.75
3aa	378	461	4763	0.77
3ab	372	443	4309	0.52
3ac	376	458	4762	0.81

Conclusions

In summary, we have developed a new two-step synthesis of π-expanded maleimide derivatives. The photoinduced dehydrogenative annulation of 3,4-diphenylfuran-2(5*H*)-ones **1** in EtOH under room temperature provided a quick and easy access to π-expanded lactones **2**, which eliminates the use of any transition metal catalyst. Secondly, oxidation of lactones **2** with oxygen in the presence of DBU gave corresponding anhydride, further treatment with primary amines provide direct access to maleimide derivatives. Comparing to literature reports, the demonstrated methodology offers several notable advantages: a) readily available starting materials, b) π-expanded maleimide and c) no transition metal catalysis required. Additionally, the fluorescent properties of maleimide derivatives were characterized, which possess high fluorescence quantum yields in dichloromethane solution.

Experiment Section

General Information. Unless otherwise noted, commercial reagents were purchased from Energy Chemical. All experiments were determined by thin layer chromatography (TLC). TLC used silica gel 60 GF254 plate. Column chromatography (200–300 mesh) was performed on silica gel. ^{1}H and ^{13}C NMR spectra were recorded on Bruker 400 or 600 MHzspectrometer. ^{1}H and ^{13}C NMR spectra were reported in parts per million (ppm) and referenced to the residual solvent peaks [$CDCl_3$ (7.26 ppm) or DMSO-d_6 (2.50)] for ^{1}H NMR and the $CDCl_3$ (77.16 ppm) or DMSO-d_6 (39.52) for ^{13}C NMR spectra. High-resolution mass spectra (HRMS) were obtained using the electron-spray ionization (ESI) technique. Melting points were measured with a X-5 micro-melting point apparatus and were uncorrected. IR spectra were recorded with a Nicollet 170SX FT-IR spectrophotometer with KBr pellets. The fluorescence spectra were measured on a F-7000 fluorescence spectrometer equipped with a xenon discharge lamp. All the irradiation experiments were performed in a BL-GHX-V photo-chemical reactor equipped with a 500 W medium-pressure mercury lamp at room temperature. The emission spectrum of the 500 W high-pressure mercury lamp was in Supporting Information (Figure S3). The distance from the

light source to the irradiation vessel was 6 cm. The material of the irradiation vessel was quartz glass tube and without use of any filters.

General Procedure A for the Synthesis of 3,4-Diphenylfuran-2(5*H*)-one (1). To a mixture of phenylacetic acid (68 mg, 0.5 mmol) and triethylamine (75.8 mg, 0.75 mmol) was dissolved in dry acetonitrile, phenacyl bromide (108.4 mg, 0.55 mmol) in dry acetonitrile was added dropwise at room temperature. The resulting mixture was stirred at RT for 6 h, followed by adding 1,8-Diazabicyclo[5.4.0]undec-7-ene (DBU) (75.5 mg, 0.5 mmol) and stirred for 30 min. When the reaction was completed (detected by TLC), water was added and extracted with ethyl acetate (10 mL×3). The combined organic layers were dried over Mg_2SO_4 and concentrated *in vacuo*. The residue was purified by column chromatography on silica (ethyl acetate/petroleum ether, 1:15) to afford the corresponding products **1a** (76.7 mg, 65 %).[26] Similarly, compounds **1a-1t** were obtained with the same method as described above.

General Procedure B for the Synthesis of Phenanthro[9,10-*c*]furan-1(3*H*)-one (2). Substrate 3,4-diphenylfuran-2(5*H*)-one **1a** (47.2 mg, 0.2 mmol) was dissolved in EtOH (40 mL) at room temperature in a quartz tube. The solution was deaerated for 30 min by bubbling argon and irradiated with a high pressure mercury lamp (500 W) at 25 ^{o}C for 5 h. When the reaction was completed (detected by TLC), the solvent was removed under reduced pressure. The residue was purified by column chromatographied on silica (ethyl acetate/petroleum ether, 1:25) to give **2a** (36.5 mg, 78 %). Similarly, compounds **2a-2t** were obtained with the same method as described above.

General Procedure C for the Synthesis of 2-Benzyl-1*H*-dibenzo[*e*,*g*]isoindole-1,3(2*H*)-dione (3). A 25 mL round-bottomed flask was charged with phenanthro[9,10-*c*]furan-1(3*H*)-one **2a** (35.4 mg, 0.15 mmol) in DMF. The flask was sealed and degassed with oxygen five times, DBU (33.9 mg, 0.23 mmol) was added to the solution at 120 °C by oil bath and stirred for 15 minutes, followed by adding benzylamine (48.2 mg, 0.45 mmol). The reaction mixture was stirred for 4 h in the presence of atmospheric oxygen. When the reaction was monitored by TLC to achieve full conversion, water was added and extracted with ethyl acetate (10 mL×3). The combined organic layers were dried over Na_2SO_4 and concentrated *in vacuo*. The residue was purified by column chromatography on silica (ethyl acetate/petroleum ether, 1:20) to afford the corresponding products **3a** (36.4 mg, 72 %). Similarly, compounds **3a-3t, 3aa-3ac** were obtained with the same method as described above.

Synthesis of 1 mmol scale 3a. Substrate **1a** (236 mg, 1 mmol) was dissolved in a solution of EtOH (200 mL) at ambient temperature in a quartz tube. The solution was deaerated for 30 min by bubbling argon and irradiated with a high pressure mercury lamp (500 W) at 25 ^{o}C for 5 h. When the reaction was completed (detected by TLC), the solvent was removed under reduced pressure

and followed by dissolved in DMF. The flask was sealed and degassed with oxygen five times, DBU (226.5 mg, 1.5 mmol) was added to the solution at 120 °C and stirred for 15 minutes, followed by adding benzylamine (481.5 mg, 3 mmol). The reaction mixture was stirred for 4 h in the presence of atmospheric oxygen. When the reaction was monitored by TLC to achieve full conversion, water was added and extracted with ethyl acetate (30 mL×3). The combined organic layers were dried over Na_2SO_4 and concentrated *in vacuo*. The residue was purified by column chromatography on silica (ethyl acetate/petroleum ether, 1:20) to afford the corresponding products **3a** (205.6 mg, 61 %).

Detection of H_2. Using argon as carrier gas, stainless steel column (column length 2 m, column temperature at 40 °C, Tam TDS-01 60~80 mesh) and thermal conductivity detector (TCD temperature was 120 °C) were used for gas chromatography analysis. Under the conditions of gas velocity of 0.06 Mpa and the flow rate of 60 mL/min, gas was analyzed at room temperature with injection of 30 uL.

The chromatographic ethanol (150 mL) was degassed for an hour by ultrasonic. In order to remove the solvent deoxidization, sodium sulfite (17 g) and hydroquinone (1.5 g) were added and the mixture was refluxed for 4 h. Then, compound of **1m** (63.2 mg, 0.2 mmol) was dissolved in 40 mL deoxidization chromatographic ethanol at room temperature in a quartz tube **I**. In the same conditions, quartz tube **II** without compound **1m** was prepared. All operations above were conducted in argon atmosphere. After strict sealing, tube **I** and **II** were irradiated with a high-pressure mercury lamp (500 W) for 5 hours.

By the GC analysis, the reference substance H_2 retention time tR1 was 1.099 min (Figure S1); the retention time tR2 in the quartz tube **I** was 1.081 min (Figure S2); the quartz tube **II** was not found H_2.

3,4-Diphenylfuran-2(5*H*)-one (1a).[26] Yield: 49%, 76.7 mg. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.44-7.3 (m, 10H), 5.18 (s, 2H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.5, 156.2, 131.0, 130.7, 130.3, 129.4, 129.1, 128.9, 128.8, 127.6, 126.3, 70.7.

4-Phenyl-3-(*p*-tolyl)furan-2(5*H*)-one (1b).[27] Yield: 52%, 65.0 mg. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.39 (dd, *J* = 5.8, 2.8 Hz, 1H), 7.37 -7.30 (m, 6H), 7.18 (d, *J* = 7.9 Hz, 2H), 5.16 (s, 2H), 2.37 (s, 3H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.7, 155.5, 138.9, 131.2, 130.6, 129.6, 129.3, 129.1, 127.6, 127.3, 126.3, 70.7, 21.5.

3-(4-Methoxyphenyl)-4-phenylfuran-2(5*H*)-one (1c).[27] Yield: 56%, 74.5 mg. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.31 (d, J = 8.4 Hz, 1H), 7.26 (d, J = 4.4 Hz, 2H), 6.82 (d, J = 8.5 Hz, 2H), 5.05 (s, 1H), 3.74 (s, 1H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.8, 160.0, 154.9, 131.2, 130.7, 130.5, 129.1, 127.5, 125.7, 122.4, 114.2, 70.6, 55.3.

3-(4-Chlorophenyl)-4-phenylfuran-2(5*H*)-one (1d).[27] Yield: 44%, 59.4 mg. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.43 (t, J = 7.3 Hz, 1H), 7.40-7.32 (m, 6H), 7.33-7.29 (m, 2H), 5.17 (s, 2H);

$^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.2, 156.8, 135.03, 131.0, 130.8, 130.7, 129.3, 129.1, 128.7, 127.6, 125.2, 70.8.

4-(4-Chlorophenyl)-3-(*p*-tolyl)furan-2(5*H*)-one (1e). Yellow solid. Yield: 51%, 72.4 mg. Mp: 123.7-125.1 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.33-7.26 (m, 6H), 7.19 (d, J = 7.9 Hz, 2H), 5.13 (s, 2H), 2.38 (s,3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.4, 154.0, 139.3, 136.7, 129.7, 129.6, 129.5, 129.2, 128.9, 127.0, 126.9, 70.4, 21.5; IR (KBr), *v* (cm^{-1}) 2920, 1757, 1637, 1442, 1342, 1151, 1036, 823, 513; HRMS (ESI) *m/z*: calcd for $C_{17}H_{14}ClO_2$ $[M + H]^+$ 285.0677; found 285.0680.

3-(4-Fluorophenyl)-4-phenylfuran-2(5*H*)-one (1f).[28] Yield: 40%, 50.8 mg. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.45-7.39 (m, 3H), 7.36 (t, J = 7.5 Hz, 2H), 7.31 (d, J = 7.5 Hz, 2H), 7.06 (t, J = 8.6 Hz, 2H), 5.16 (s, 2H); $^{13}C\{^{1}H\}$ (150 MHz, $CDCl_3$) δ (ppm) 173.4, 163.0 (d, ^{1}J=247.82 Hz), 156.4, 131.3 (d, ^{3}J=8.05 Hz), 130.8, 129.2, 127.5, 126.2 (d, ^{4}J=3.41 Hz), 125.2, 115.9 (d, ^{2}J=21.58 Hz), 70.7.

3-(4-Fluorophenyl)-4-(*p*-tolyl)furan-2(5*H*)-one (1g).[28] Yield: 49%, 65.7 mg. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.44-7.41 (m, 2H), 7.20 (d, J = 8.2 Hz, 2H), 7.16 (d, J = 8.2 Hz, 2H), 7.07 (t, J = 8.7 Hz, 2H), 5.15 (s, 2H), 2.37 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.6, 163.0 (d, ^{1}J=247.30 Hz), 156.4, 141.5, 131.4 (d, ^{3}J=8.17 Hz), 129.9, 127.9, 127.5, 126.5 (d, ^{4}J=3.19 Hz), 124.5, 115.9 (d, ^{2}J=21.22 Hz), 70.7, 21.6.

3-(4-(*Tert*-butyl)phenyl)-4-(4-fluorophenyl)furan-2(5*H*)-one (1h). White solid. Yield: 58%, 89.9 mg. Mp: 135.8-137.1 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.40 (d, J = 8.4 Hz, 2H), 7.36-7.34 (m, 4H), 7.05 (t, J = 8.6 Hz, 2H), 5.14 (s, 2H), 1.33 (s, 9H); $^{13}C\{^{1}H\}$ (150 MHz, $CDCl_3$) δ (ppm) 173.6, 163.9 (d, ^{1}J=250.50 Hz), 154.3, 152.2, 129.7 (d, ^{3}J=7.50 Hz), 129.0, 127.4 (d, ^{4}J=3.00 Hz), 127.0, 126.2, 125.9, 116.4 (d, ^{2}J=22.50 Hz), 70.6, 34.9, 31.4; IR (KBr), *v* (cm^{-1}) 2962, 1738, 1603, 1510, 1352, 1234, 1151, 1034, 839, 580; HRMS (ESI) *m/z*: calcd for $C_{20}H_{19}FO_2Na$ $[M + Na]^+$ 333.1261; found 333.1261.

4-(2-Oxo-4-phenyl-2,5-dihydrofuran-3-yl)benzonitrile (1i). Yellow solid. Yield: 60%, 78.3 mg. Mp: 146.1-147.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.65 (d, J = 8.4 Hz, 2H), 7.57 (d, J = 8.4 Hz, 2H), 7.45 (t, J = 7.4 Hz, 1H), 7.39 (t, J = 7.7 Hz, 2H), 7.28 (d, J = 7.5 Hz, 2H), 5.20 (s, 2H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 172.5, 158.9, 135.0, 132.5, 131.4, 130.2, 130.2, 129.5, 127.6, 124.5, 118.5, 112.6, 70.9; IR (KBr), *v* (cm^{-1}) 2941, 1747, 1601, 1441, 1350, 1155, 1070, 949, 847, 694, 548, 490; HRMS (ESI) *m/z*: calcd for $C_{17}H_{11}NO_2Na$ $[M + Na]^+$ 284.0682; found 284.0684.

4-(4-(4-Methoxyphenyl)-2-oxo-2,5-dihydrofuran-3-yl)benzonitrile (1j). Yellow solid. Yield: 46%, 66.9 mg. Mp: 175.6-176.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.68 (d, J = 8.3 Hz, 2H), 7.58 (d, J = 8.3 Hz, 2H), 7.24 (d, J = 8.8 Hz, 2H), 6.88 (d, J = 8.8 Hz, 2H), 5.19 (s, 2H), 3.84 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 172.9, 162.2, 158.2, 135.7, 132.6, 130.3, 129.3, 122.6, 122.4, 118.7, 114.9, 112.5, 70.7, 55.6; IR (KBr), *v* (cm^{-1}) 2928, 1755, 1607, 1508, 1394,

1261, 1173, 1028, 835, 588; HRMS (ESI) *m/z*: calcd for $C_{18}H_{13}NO_3Na$ $[M + Na]^+$ 314.0788; found 314.0788.

3-(4-(4-(*Tert*-butyl)phenyl)-5-oxo-2,5-dihydrofuran-3 yl)benzonitrile (1k). White solid. Yield: 45%, 71.3 mg. Mp: 148.2-149.7 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.68 (d, J = 7.7 Hz, 1H), 7.61 (s, 1H), 7.58 (d, J = 8.0 Hz, 1H), 7.49 (t, J = 7.8 Hz, 1H), 7.41 (d, J = 8.4 Hz, 2H), 7.32 (d, J = 8.4 Hz, 2H), 5.15 (s, 2H), 1.33 (s, 9H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 172.9, 152.9, 152.5, 133.6, 132.7, 131.8, 131.0, 130.1, 128.8, 128.5, 126.1, 126.1, 117.9, 113.7, 70.4, 34.9, 31.3; IR (KBr), *v* (cm^{-1}) 2962, 1751, 1643, 1454, 1342, 1155, 1036, 821, 619, 552; HRMS (ESI) *m/z*: calcd for $C_{21}H_{19}NO_2Na$ $[M + Na]^+$ 340.1308; found 340.1310.

4-Phenyl-3-(4-(trifluoromethyl)phenyl)furan-2(5*H*)-one (1l). Yellow solid. Yield: 63%, 95.8 mg. Mp: 130.8-132.4 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.63 (d, J = 8.1 Hz, 2H), 7.57 (d, J = 8.1 Hz, 2H), 7.44 (t, J = 7.3 Hz, 1H), 7.38 (t, J = 7.6 Hz, 2H), 7.30 (d, J = 7.5 Hz, 2H), 5.21 (s, 2H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 173.0, 158.1, 134.0, 131.2, 130.9 (q, ^2J=32.51 Hz), 130.4, 129.9, 129.4, 127.6, 125.8 (q, ^3J=3.78 Hz), 125.0, 124.0 (q, ^1J=270.97 Hz), 70.9; IR (KBr), *v* (cm^{-1}) 2933, 1742, 1610, 1443, 1331, 1107, 1065, 835, 688, 625, 478; HRMS (ESI) *m/z*: calcd for $C_{17}H_{11}F_3O_2Na$ $[M + Na]^+$ 327.0603; found 327.0606.

4-(*P*-tolyl)-3-(4-(trifluoromethyl)phenyl)furan-2(5*H*)-one (1m). White solid. Yield: 60%, 95.4 mg. Mp: 132.1-133.5 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.64 (d, J = 8.2 Hz, 2H), 7.57 (d, J = 8.2 Hz, 2H), 7.20-7.16 (m, 4H), 5.19 (s, 2H), 2.38 (s, 3H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 173.1, 158.1, 141.9, 134.3, 130.8 (q, ^2J=32.50 Hz), 130.1, 129.9, 127.6, 125.8 (q, ^3J=3.78 Hz), 124.1 (q, ^1J=270.42 Hz), 123.2, 70.8, 21.6; IR (KBr), *v* (cm^{-1}) 2930, 1738, 1639, 1406, 1331, 1115, 1065, 831, 594; HRMS (ESI) *m/z*: calcd for $C_{18}H_{13}F_3O_2Na$ $[M + Na]^+$ 341.0760; found 341.0759.

3-(Naphthalen-1-yl)-4-(*p*-tolyl)furan-2(5*H*)-one (1n). White solid. Yield: 45%. 67.5 mg. Mp: 156.1-157.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.92 (dd, J = 16.1, 8.2 Hz, 2H), 7.66 (d, J = 8.4 Hz, 1H), 7.54 (dd, J = 8.1, 7.2 Hz, 1H), 7.51-7.47 (m, 1H), 7.45 (dd, J = 7.0, 0.9 Hz, 1H), 7.40-7.38 (m, 1H), 7.04 (d, J = 8.3 Hz, 2H), 6.99 (d, J = 8.3 Hz, 2H), 5.41 (q, J = 16.7 Hz, 2H), 2.26 (s, 3H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 174.1, 157.6, 141.7, 134.0, 131.2, 129.8, 129.5, 128.9, 128.8, 128.0, 127.6, 127.4, 126.7, 126.4, 125.8, 125.1, 124.7, 70.7, 21.6; IR (KBr), *v* (cm^{-1}) 2920, 1747, 1641, 1508, 1340, 1192, 1047, 937, 806, 484; HRMS (ESI) *m/z*: calcd for $C_{21}H_{16}O_2Na$ $[M + Na]^+$ 323.1043; found 323.1040.

4-(Naphthalen-1-yl)-3-(4-(trifluoromethyl)phenyl)furan-2(5*H*)-one (1o). Yellow solid. Yield: 48%, 84.9 mg. Mp: 113.1-114.8 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.97 (d, J = 8.3 Hz, 1H), 7.92 (d, J = 8.2 Hz, 1H), 7.60 (d, J = 8.3 Hz, 1H), 7.57-7.51 (m, 4H), 7.44-7.41 (m, 2H), 7.39 (d, J = 8.3 Hz, 2H), 5.18 (s, 2H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 172.3, 159.6, 133.9, 133.2, 130.6 (q, ^2J=32.1 Hz), 129.5, 129.2, 129.1, 128.9, 127.6, 127.2, 127.0, 125.9, 125.6, 125.3 (q, ^3J=3.64 Hz), 124.4, 123.9 (q, ^1J=271.00 Hz), 72.8; IR (KBr), *v* (cm^{-1}) 3059, 2930, 1753, 1618,

1512, 1327, 1119, 1059, 779, 613; HRMS (ESI) *m/z*: calcd for $C_{21}H_{13}F_3O_2Na$ $[M + Na]^+$ 377.0760; found 377.0757.

3,4-Di(naphthalen-1-yl)furan-2(5*H*)-one (1p). White solid. Yield: 44%, 73.9 mg. Mp: 201.2-202.6 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.76-7.70 (m, 1H), 7.70-7.55 (m, 5H), 7.34-7.24 (m, 5H), 7.19-7.14 (m, 3H), 5.28 (s, 2H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.1, 160.9, 133.7, 133.6, 131.3, 130.2, 130.1, 129.5, 129.4, 128.7, 128.6, 128.2, 127.7, 126.9, 126.5, 126.4, 126.2, 126.2, 126.1, 125.2, 125.2, 124.6, 73.2; IR (KBr), *v* (cm^{-1}) 3053, 1757, 1649, 1437, 1337, 1153, 1039, 928, 773, 646; HRMS (ESI) *m/z*: calcd for $C_{24}H_{16}O_2Na$ $[M + Na]^+$ 359.1043; found 359.1030.

4-Phenyl-3-(furan-2-yl)furan-2(5*H*)-one (1q). White solid. Yield: 58%, 65.5 mg. Mp: 117.1-118.7 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.51 (dd, J = 7.6, 1.8 Hz, 2H), 7.46 (q, J = 5.7 Hz, 3H), 7.38 (s, 1H), 7.22 (d, J = 3.4 Hz, 1H), 6.50 (dd, J = 3.4, 1.8 Hz, 1H), 5.11 (s, 2H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.6, 152.7, 145.6, 143.2, 131.4, 130.5, 128.7, 128.1, 116.1, 112.9, 111.7, 71.3; IR (KBr), *v* (cm^{-1}) 3138, 1753, 1441, 1340, 1178, 1136, 1013, 870, 746, 692, 586, 496; HRMS (ESI) *m/z*: calcd for $C_{14}H_{10}O_3Na$ $[M + Na]^+$ 249.0522; found 249.0521.

4'-(*P*-tolyl)-[2,3'-bifuran]-2'(5'*H*)-one (1r). Yellow solid. Yield: 60%, 72.0 mg. Mp: 132.5-133.8 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.35-7.32 (m, 3H), 7.20-7.17 (m, 2H), 7.13 (d, J = 3.4 Hz, 1H), 6.43 (dd, J = 3.4, 1.8 Hz, 1H), 5.03 (s, 2H), 2.35 (s, 3H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.8, 153.0, 145.7, 143.0, 141.1, 129.5, 128.4, 128.0, 115.4, 112.7, 111.7, 71.2, 21.7; IR (KBr), *v* (cm^{-1}) 2918, 1747, 1624, 1391, 1342, 1180, 1136, 1013, 820, 737, 586, 501; HRMS (ESI) *m/z*: calcd for $C_{15}H_{12}O_3Na$ $[M + Na]^+$ 263.0679; found 263.0678.

4-Phenyl-3-(thiophen-2-yl)furan-2(5*H*)-one (1s). Orange solid. Yield: 49%, 59.3 mg. Mp: 113.6-115.2 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.51 (dd, J = 7.6, 1.8 Hz, 2H), 7.46 (q, J = 5.7 Hz, 3H), 7.38 (s, 1H), 7.22 (d, J = 3.4 Hz, 1H), 6.50 (dd, J = 3.4, 1.8 Hz, 1H), 5.11 (s, 2H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.6, 152.7, 145.6, 143.2, 131.4, 130.5, 128.7, 128.1, 116.1, 112.9, 111.7, 71.3; IR (KBr), *v* (cm^{-1}) 1749, 1639, 1435, 1041, 702, 604; HRMS (ESI) *m/z*: calcd for $C_{14}H_{10}SO_2Na$ $[M + Na]^+$ 265.0294; found 265.0295.

3-(4-(*Tert*-butyl)phenyl)-4-(thiophen-2-yl)furan-2(5*H*)-one (1t). White solid. Yield: 52%, 77.5 mg. Mp: 131.5-132.9 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.48-7.47 (m, 2H), 7.43-7.40 (m, 3H), 7.27 (dd, J = 3.8, 0.9 Hz, 1H), 7.05 (dd, J = 5.0, 3.8 Hz, 1H), 5.20 (s, 2H), 1.36 (s, 9H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.7, 152.5, 149.3, 133.0, 130.1, 129.2, 128.8, 127.7, 127.0, 125.9, 124.2, 70.1, 34.9, 31.4; IR (KBr), *v* (cm^{-1}) 2959, 1742, 1637, 1431, 1340, 1149, 1034, 833, 716, 602; HRMS (ESI) *m/z*: calcd for $C_{18}H_{18}SO_2Na$ $[M + Na]^+$ 321.0920; found 321.0919.

3-(1*H*-indol-3-yl)-4-(*p*-tolyl)furan-2(5*H*)-one (1u).[29] Yellow solid. Yield: 45%, 39.4 mg. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.61 (s, 1H), 7.70 (d, *J* = 2.6 Hz, 1H), 7.41 (d, *J* = 8.2 Hz, 1H), 7.28 (d, *J* = 8.2 Hz, 2H), 7.15 (t, *J* = 7.6 Hz, 1H), 7.09 (d, *J* = 8.0 Hz, 2H), 6.90 (t, *J* = 7.5 Hz, 1H),

6.82 (d, *J* = 8.0 Hz, 1H), 5.25 (s, 2H), 2.34 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 174.9, 152.3, 140.7, 136.3, 129.6, 129.1, 127.6, 126.8, 124.8, 122.5, 121.5, 120.1, 119.3, 111.6, 106.3, 71.0, 21.6.

3-Phenyl-4-(pyridin-2-yl)furan-2(5*H*)-one (1v). White solid. Yield: 55%, 65.2 mg. Mp: 125.1-126.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.65 (m, 1H), 7.54 (m 1H), 7.47-7.42 (m, 5H), 7.35 (d, *J* = 8.0 Hz, 1H), 7.30-7.26 (m, 1H), 5.39 (s, 2H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 173.8, 155.9, 150.2, 150.2, 136.4, 130.3, 129.4, 129.3, 129.1, 128.6, 124.9, 123.8, 71.2; IR (KBr), *v* (cm^{-1}) 2922, 1747, 1632, 1391, 1030, 696; HRMS (ESI) *m/z*: calcd for $C_{15}H_{11}NO_2Na$ $[M + Na]^+$ 260.0682; found 260.0681.

Phenanthro[9,10-*c*]furan-1(3*H*)-one (2a).[30] Yield: 78%, 36.5 mg. ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 9.10 (d, J = 4.8 Hz, 1H), 8.76 (d, J = 8.3 Hz, 1H), 8.70 (d, J = 4.3 Hz, 1H), 7.88-7.81 (m, 2H), 7.78-7.69 (m, 3H), 5.62 (s, 2H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.5, 150.3, 132.4, 130.6, 130.2, 128.3, 128.0, 127.9, 126.0, 125.4, 124.9, 124.1, 123.9, 123.0, 117.5, 68.8.

9-Methylphenanthro[9,10-*c*]furan-1(3*H*)-one (2b). White solid. Yield: 77%, 38.2 mg. Mp: 242.6-243.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.96 (d, J = 8.2 Hz, 1H), 8.74 (d, J = 8.4 Hz, 1H), 8.47 (s, 1H), 7.82 (dd, J = 14.2, 7.3 Hz, 2H), 7.69 (t, J = 7.4 Hz, 1H), 7.58 (d, J = 8.1 Hz, 1H), 5.60 (s, 2H), 2.65 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 172.1, 147.7, 137.9, 133.0, 130.9, 130.0, 127.6, 125.5, 124.6, 124.3, 124.2, 124.1, 123.0, 119.1, 68.5, 22.4; IR (KBr), *v* (cm^{-1}) 1747, 1637, 1412, 1110, 1040, 754, 604; HRMS (ESI) *m/z*: calcd for $C_{17}H_{12}O_2Na$ $[M + Na]^+$ 271.0730; found 271.0729.

9-Methoxyphenanthro[9,10-*c*]furan-1(3*H*)-one (2c). White solid. Yield: 81%, 42.8mg. Mp: 198.6-200.1 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.88 (d, J = 8.8 Hz, 1H), 8.56 (d, J = 8.3 Hz, 1H), 7.93 (d, J = 2.1 Hz, 1H), 7.77 (t, J = 7.6 Hz, 1H), 7.71 (d, J = 7.7 Hz, 1H), 7.66 (t, J = 7.4 Hz, 1H), 7.30 (dd, J = 8.9, 2.3 Hz, 1H), 5.47 (s, 2H), 4.01 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.9, 159.2, 145.9, 132.3, 132.3, 129.4, 127.6, 125.6, 125.5, 124.1, 123.9, 120.8, 118.8, 117.4, 105.1, 68.3, 55.5; IR (KBr), *v* (cm^{-1}) 2934, 1747, 1618, 1450, 1232, 1117, 1024, 835, 758, 609; HRMS (ESI) *m/z*: calcd for $C_{17}H_{12}O_3Na$ $[M + Na]^+$ 287.0679; found 287.0675.

9-Chlorophenanthro[9,10-*c*]furan-1(3*H*)-one (2d). White solid. Yield: 70%, 37.5 mg. Mp: 268.2-269.6 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.01 (d, J = 8.6 Hz, 1H), 8.66 (d, J = 8.3 Hz, 1H), 8.62 (d, J = 1.6 Hz, 1H), 7.87 (dd, J = 17.9, 7.6 Hz, 2H), 7.76 (t, J = 7.4 Hz, 1H), 7.69 (dd, J = 8.6, 1.9 Hz, 1H), 5.62 (s, 2H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.6, 148.8, 134.4, 132.2, 132.1, 130.6, 128.9, 128.5, 125.9, 125.8, 125.0, 124.4, 124.2, 123.0, 118.9, 68.5; IR (KBr), *v* (cm^{-1}) 1745, 1636, 1446, 1124, 1020, 754, 588; HRMS (ESI) *m/z*: calcd for $C_{16}H_9ClO_2Na$ $[M + Na]^+$ 291.0183; found 291.0181.

6-Chloro-9-methylphenanthro[9,10-*c*]furan-1(3*H*)-one (2e). Yellow solid. Yield: 72%, 40.6 mg. Mp: 272.4-273.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.95 (d, J = 8.2 Hz, 1H), 8.65 (s, 1H), 8.35 (s, 1H), 7.74 (d, J = 8.4 Hz, 1H), 7.67-7.63 (m, 1H), 7.61 (d, J = 8.4 Hz, 1H), 5.58 (s, 2H), 2.65 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.7, 147.0, 138.4, 136.4, 134.2,

130.7, 130.0, 128.2, 125.6, 124.9, 124.2, 124.0, 123.8, 123.0, 119.4, 68.3, 22.4; IR (KBr), ν (cm^{-1}) 2924, 1749, 1636, 1406, 1038, 806, 606; HRMS (ESI) *m/z*: calcd for $C_{17}H_{11}ClO_2Na$ $[M + Na]^+$ 305.0340; found 305.0342.

9-Fluorophenanthro[9,10-*c*]furan-1(3*H*)-one (2f). White solid. Yield: 72%, 36.3 mg. Mp: 215.6-217.1 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.12 (dd, J = 8.9, 6.1 Hz, 1H), 8.66 (d, J = 8.5 Hz, 1H), 8.34-8.31 (m, 1H), 7.89-7.87 (m, 2H), 7.77 (t, J = 7.5 Hz, 1H), 7.53-7.49 (m, 1H), 5.65 (s, 2H); $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$) δ (ppm) 171.8, 162.5 (d, ^1J=246.54 Hz), 147.9, 132.9 (d, ^3J=8.57 Hz), 132.6 (d, ^4J=4.28 Hz), 130.4, 128.5, 126.9 (d, ^3J=9.00 Hz), 125.9, 124.4, 124.4, 123.4, 119.0, 117.3 (d, ^2J=23.36 Hz), 108.8 (d, ^2J=22.72 Hz), 68.5; IR (KBr), ν (cm^{-1}) 2170, 1755, 1649, 1406, 1113, 829, 756, 596; HRMS (ESI) *m/z*: calcd for $C_{16}H_{10}FO_2$ $[M + H]^+$ 253.0659, found 253.0647.

9-Fluoro-6-methylphenanthro[9,10-*c*]furan-1(3*H*)-one (2g). White solid. Yield: 78%, 41.5 mg. Mp: 272.2-273.9 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.09 (dd, J = 8.8, 6.1 Hz, 1H), 8.42 (s, 1H), 8.30 (dd, J = 11.0, 2.1 Hz, 1H), 7.76 (d, J = 8.1 Hz, 1H), 7.58 (d, J = 8.0 Hz, 1H), 7.50-7.47 (m, 1H), 5.61 (s, 2H), 2.69 (s, 3H); $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ (ppm) 171.9, 162.3 (d, ^1J=246.20 Hz), 148.0, 140.9, 132.8 (d, ^4J=4.33 Hz), 132.6 (d, ^3J=8.65 Hz), 130.1, 126.8 (d, ^3J=9.20 Hz), 124.3, 124.2, 123.7, 123.5, 118.1, 117.1 (d, ^2J=23.29 Hz), 108.7 (d, ^2J=22.73 Hz), 68.5, 22.6; IR (KBr), ν (cm^{-1}) 1745, 1610, 1522, 1441, 1173, 1022, 851, 548; HRMS (ESI) *m/z*: calcd for $C_{17}H_{11}FO_2Na$ $[M + Na]^+$ 289.0635; found 289.0636.

9-(*Tert*-butyl)-6-fluorophenanthro[9,10-*c*]furan-1(3*H*)-one (2h). White solid. Yield: 77%, 47.4 mg. Mp: 223.2-224.6 °C. ^1H NMR (600 MHz, $CDCl_3$**,** TFA-d_1) δ (ppm) 8.86 (d, J = 8.5 Hz, 1H), 8.53 (s, 1H), 8.37 (dd, J = 11.0, 2.2 Hz, 1H), 7.88 (dd, J = 8.5, 1.6 Hz, 1H), 7.82 (dd, J = 8.7, 5.7 Hz, 1H), 7.47-7.44 (m, 1H), 5.65 (s, 2H), 1.52 (s, 9H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$**,** TFA-d_1) δ (ppm) 175.3, 164.1 (d, ^1J=250.45 Hz), 151.7, 148.8, 136.2 (d, ^3J=8.79 Hz), 130.1 (d, ^4J=3.81 Hz), 127.8, 127.0 (d, ^3J=9.46 Hz), 124.3, 124.0, 121.9, 119.2, 117.9, 117.0 (d, ^2J=24.13 Hz), 109.8 (d, ^2J=22.79 Hz), 69.9, 35.6, 31.5; IR (KBr), ν (cm^{-1}) 3084, 2961, 1747, 1622, 1419, 1257, 1176, 1022, 845, 584, 469; HRMS (ESI) *m/z*: calcd for $C_{20}H_{17}FO_2Na$ $[M + Na]^+$ 331.1105; found 331.1105.

3-Oxo-1,3-dihydrophenanthro[9,10-*c*]furan-6-carbonitrile (2i). White solid. Yield: 86%, 44.5 mg. Mp: >300 °C. ^1H NMR (600 MHz, $CDCl_3$**,** TFA-d_1) δ (ppm) 9.14 (d, J = 8.4 Hz, 1H), 9.11 (s, 1H), 8.79 (d, J = 8.4 Hz, 1H), 8.03 (t, J = 7.7 Hz, 1H), 8.01-7.95 (m, 2H), 7.89 (t, J = 7.5 Hz, 1H), 5.82 (s, 2H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$**,** TFA-d_1) δ (ppm) 174.5, 153.5, 132.4, 132.3, 130.8, 130.2, 129.7, 129.1, 129.0, 125.5, 125.4, 125.1, 124.3, 118.0, 110.6, 70.3; IR (KBr), ν (cm^{-1}) 1749, 1622, 1416, 1117, 1038, 847, 756, 617, 530; HRMS (ESI) *m/z*: calcd for $C_{17}H_9NO_2Na$ $[M + Na]^+$ 282.0525; found 282.0531.

9-Methoxy-3-oxo-1,3-dihydrophenanthro[9,10-*c*]furan-6-carbonitrile (2j). Yellow solid. Yield: 88%, 50.9 mg. Mp: 261.6-262.9 °C. ^1H NMR (400 MHz, $CDCl_3$**,** TFA-d_1) δ (ppm) 9.12 (d,

J = 8.4 Hz, 1H), 8.99 (s, 1H), 8.07 (s, 1H), 7.96 (d, J = 8.4 Hz, 1H), 7.86 (d, J = 8.8 Hz, 1H), 7.46 (d, J = 8.6 Hz, 1H), 5.74 (s, 2H), 4.14 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$, TFA-d_1) δ (ppm) 174.6, 162.8, 153.4, 134.9, 130.2, 130.2, 129.8, 129.1, 126.8, 125.6, 119.8, 119.7, 118.3, 115.6, 110.2, 105.9, 70.0, 56.2; IR (KBr), *v* (cm^{-1}) 2926, 2170, 1749, 1616, 1416, 1244, 1063, 1024, 837, 573; HRMS (ESI) *m/z*: calcd for $C_{18}H_{11}NO_3Na$ $[M + Na]^+$ 312.0631; found 312.0628.

9-(*Tert*-butyl)-1-oxo-1,3-dihydrophenanthro[9,10-*c*]furan-5-carbonitrile (2k). White solid. Yield: 76%, 47.9 mg. Mp: 230.2-231.8 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.05 (d, J = 8.6 Hz, 1H), 8.90 (d, J = 8.6 Hz, 1H), 8.69 (s, 1H), 8.17 (d, J = 1.3 Hz, 1H), 8.03 (dd, J = 8.7, 1.6 Hz, 1H), 7.95 (dd, J = 8.6, 1.7 Hz, 1H), 5.65 (s, 2H), 1.52 (s, 9H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.1, 152.1, 146.5, 135.8, 131.2, 129.8, 129.3, 128.5, 125.5, 125.3, 125.3, 124.4, 121.1, 119.5, 118.3, 111.2, 68.2, 35.7, 31.5; IR (KBr), *v* (cm^{-1}) 2963, 1757, 1630, 1392, 1267, 1117, 1036, 841, 636, 473; HRMS (ESI) *m/z*: calcd for $C_{21}H_{17}NO_2Na$ $[M + Na]^+$ 338.1151; found 338.1147.

9-(Trifluoromethyl)phenanthro[9,10-*c*]furan-1(3*H*)-one (2l). White solid. Yield: 87%, 52.5 mg. Mp: 194.6-196.2 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.18 (d, J = 8.4 Hz, 1H), 8.92 (s, 1H), 8.77 (d, J = 8.4 Hz, 1H), 7.95-7.91 (m, 2H), 7.89 (d, J = 7.6 Hz, 1H), 7.80 (t, J = 7.5 Hz, 1H), 5.66 (s, 2H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.3, 150.8, 132.8, 131.0, 130.5, 129.8 (q, ^{2}J=31.95 Hz), 128.7, 128.6, 125.7, 125.3, 124.6, 123.6 (q, ^{1}J=273.92 Hz), 124.4, 124.2, 120.5 (q, ^{3}J=3.36 Hz), 118.7, 68.5; IR (KBr), *v* (cm^{-1}) 2926, 1744, 1632, 1398, 1335, 1111, 1069, 762, 625; HRMS (ESI) *m/z*: calcd for $C_{17}H_9F_3O_2Na$ $[M + Na]^+$ 325.0447; found 325.0447.

6-Methyl-9-(trifluoromethyl)phenanthro[9,10-*c*]furan-1(3*H*)-one (2m). White solid. Yield: 89%, 56.2 mg. Mp: 238.1-239.3 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.12 (d, J = 8.2 Hz, 1H), 8.85 (s, 1H), 8.49 (s, 1H), 7.89 (d, J = 8.2 Hz, 1H), 7.75 (d, J = 7.9 Hz, 1H), 7.60 (d, J = 7.9 Hz, 1H), 5.59 (s, 2H), 2.71 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 171.5, 150.8, 141.7, 132.9, 130.4, 130.1, 129.5 (q, ^{2}J=33.22 Hz), 128.8, 124.5 (q, ^{1}J=271.41 Hz), 125.2, 124.4, 124.2, 124.0, 123.5, 120.4 (q, ^{3}J=3.21 Hz), 117.7, 68.5, 22.6; IR (KBr), *v* (cm^{-1}) 2926, 1742, 1626, 1423, 1321, 1115, 1016, 831, 654, 569; HRMS (ESI) *m/z*: calcd for $C_{18}H_{11}F_3O_2Na$ $[M + Na]^+$ 339.0603; found 339.0603.

3-Methylchryseno[5,6-*c*]furan-11(13*H*)-one (2n). Yellow solid. Yield: 65%, 38.7 mg. Mp: 231.2-232.6 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.69 (d, J = 8.5 Hz, 1H), 8.66 (d, J = 9.0 Hz, 1H), 8.57 (s, 1H), 8.06 (d, J = 9.0 Hz, 1H), 7.98 (d, J = 7.2 Hz, 1H), 7.79 (d, J = 8.1 Hz, 1H), 7.74-7.71 (m, 1H), 7.70-7.65 (m, 1H), 7.57 (d, J = 7.5 Hz, 1H), 5.70 (s, 2H), 2.70 (s, 3H); $^{13}C\{^{1}H\}$ NMR (150 MHz, $CDCl_3$) δ (ppm) 172.0, 150.0, 141.0, 133.6, 133.3, 130.3, 130.1, 129.6, 129.5, 129.2, 127.8, 127.5, 126.1, 126.1, 124.2, 123.7, 123.4, 120.8, 119.3, 68.0, 22.8; IR (KBr), *v* (cm^{-1}) 2964, 1738, 1622, 1416, 1261, 1030, 800, 592, 442; HRMS (ESI) *m/z*: calcd for $C_{21}H_{15}O_2$ $[M + H]^+$ 299.1067; found 299.1064.

3-(Trifluoromethyl)chryseno[5,6-*c*]furan-13(11*H*)-one (2o). White solid. Yield: 68%, 47.9 mg. Mp: >300 °C. ^{1}H NMR (600 MHz, $CDCl_3$, TFA-d_1) δ (ppm) 9.17 (d, J = 8.5 Hz, 1H), 8.91 (s, 1H), 8.60 (d, J = 9.1 Hz, 1H), 8.17 (d, J = 9.0 Hz, 1H), 8.11-8.06 (m, 1H), 7.94 (d, J = 8.2 Hz, 1H), 7.88 (d, J = 8.0 Hz, 1H), 7.82-7.76 (m, 2H), 5.86 (s, 2H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$, TFA-d_1) δ (ppm) 174.5, 149.7, 133.9, 133.0, 132.8, 130.3, 130.3 (q, ^2J=32.13 Hz), 130.1, 123.0, 129.1, 128.3, 128.0, 124.3 (q, ^1J=270.61 Hz), 124.8 (q, ^3J=3.18 Hz), 123.5, 121.2, 121.2, 121.2, 118.1, 72.9; IR (KBr), *v* (cm^{-1}) 3059, 1749, 1626, 1427, 1321, 1119, 1028, 852, 748, 596, 509; HRMS (ESI) *m/z*: calcd for $C_{21}H_{12}F_3O_2$ $[M + H]^+$ 353.0784; found 353.0797.

Piceno[13,14-*c*]furan-13(15*H*)-one (2p). Yellow solid. Yield: 62%, 41.4 mg. Mp: 220.4-221.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.34 (d, J = 8.1 Hz, 1H), 8.75 (d, J = 9.2 Hz, 1H), 8.66 (d, J = 9.1 Hz, 1H), 8.15 (d, J = 8.8 Hz, 2H), 8.08 (t, J = 7.6 Hz, 2H), 8.01-7.97 (m, 1H), 7.81 (dd, J = 11.1, 4.0 Hz, 1H), 7.77-7.70 (m, 3H), 6.03 (s, 2H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 171.1, 147.4, 133.6, 133.2, 132.9, 131.4, 130.7, 130.6, 130.2, 129.5, 129.5, 128.3, 128.3, 128.0, 127.7, 127.3, 126.8, 125.9, 125.4, 123.8, 122.2, 120.9, 119.9, 71.0; IR (KBr), *v* (cm^{-1}) 2922, 1746, 1630, 1392, 1265, 1151, 868, 802, 664; HRMS (ESI) *m/z*: calcd for $C_{24}H_{14}O_2Na$ $[M + Na]^+$ 357.0886; found 357.0885.

Naphtho[2,1-*b*:3,4-*c*']difuran-10(8*H*)-one (2q). White solid. Yield: 68%, 30.4 mg. Mp: 218.2-219.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.23 (d, J = 8.3 Hz, 1H), 7.89 (d, J = 1.9 Hz, 1H), 7.86 (d, J = 8.3 Hz, 1H), 7.79 (t, J = 7.4 Hz, 1H), 7.63 (t, J = 7.5 Hz, 1H), 7.32 (d, J = 2.0 Hz, 1H), 5.70 (s, 2H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 169.1, 146.1, 145.9, 145.3, 130.8, 129.9, 126.3, 125.2, 124.9, 124.3, 124.1, 111.6, 105.8, 69.9; IR (KBr), *v* (cm^{-1}) 2924, 1761, 1630, 1389, 1269, 1123, 1003, 878, 752, 471; HRMS (ESI) *m/z*: calcd for $C_{14}H_8O_3Na$ $[M + Na]^+$ 247.0366; found 247.0366.

5-Methylnaphtho[2,1-*b*:3,4-*c'*]difuran-10(8*H*)-one (2r). White solid. Yield: 51%, 24.2 mg. Mp: 267.2-268.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.04 (s, 1H), 7.89 (d, J = 1.8 Hz, 1H), 7.79 (d, J = 8.3 Hz, 1H), 7.48 (d, J = 8.2 Hz, 1H), 7.32 (d, J = 1.9 Hz, 1H), 5.71 (s, 2H), 2.64 (s, 3H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 169.2, 145.7, 145.4, 140.6, 131.2, 128.6, 128.3, 124.7, 124.3, 124.2, 122.2, 110.8, 105.8, 69.9, 22.4; IR (KBr), *v* (cm^{-1}) 2924, 2170, 1765, 1657, 1400, 1292, 1105, 760, 548; HRMS (ESI) *m/z*: calcd for $C_{15}H_{10}O_3Na$ $[M + Na]^+$ 261.0522; found 261.0522.

Thieno[2',3':3,4]naphtho[1,2-*c*]furan-10(8*H*)-one (2s). White solid. Yield: 65%, 31.2 mg. Mp: 240.4-242.1 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.46 (d, J = 8.2 Hz, 1H), 8.05 (d, J = 5.1 Hz, 1H), 7.89 (d, J = 8.0 Hz, 1H), 7.85-7.72 (m, 2H), 7.67 (t, J = 7.4 Hz, 1H), 5.72 (s, 2H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 170.5, 146.3, 137.9, 131.2, 130.1, 129.3, 128.7, 126.8, 125.2, 125.1, 124.5, 122.6, 117.6, 70.4; IR (KBr), *v* (cm^{-1}) 3113, 1759, 1630, 1396, 1342, 1134, 1030. 727, 609; HRMS (ESI) *m/z*: calcd for $C_{14}H_8O_2SNa$ $[M + Na]^+$ 263.0137; found 263.0137.

5-(*Tert*-butyl)thieno[2',3':3,4]naphtho[1,2-*c*]furan-8(10*H*)-one (2t). White solid. Yield: 70%, 41.4 mg. Mp: 251.2-253.1 °C. ^{1}H NMR (600 MHz, $CDCl_3$, TFA-d_1) δ (ppm) 9.01 (d, J = 8.7 Hz, 1H), 8.34 (d, J = 1.6 Hz, 1H), 8.13 (d, J = 5.3 Hz, 1H), 7.84 (d, J = 5.3 Hz, 1H), 7.81 (dd, J = 8.7, 1.9 Hz, 1H), 5.43 (s, 2H), 1.49 (s, 9H); ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$) δ (ppm) 171.5, 150.9, 143.4, 141.9, 129.9, 129.7, 129.0, 126.3, 124.8, 124.0, 123.3, 119.6, 117.0, 68.0, 35.4, 31.5; IR (KBr), *v* (cm^{-1}) 2955, 1755, 1512, 1393, 1344, 1178, 1038, 839, 681, 592, 478; HRMS (ESI) *m/z*: calcd for $C_{18}H_{16}O_2SNa$ $[M + Na]^+$ 319.0763; found 319.0766.

2-Benzyl-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3a).[18] Yield: 72%, 36.4 mg. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.14 (d, J = 8.1 Hz, 2H), 8.72 (d, J = 8.3 Hz, 2H), 7.81 (t, J = 7.6 Hz, 2H), 7.76 (t, J = 7.5 Hz, 2H), 7.51 (d, J = 7.6 Hz, 2H), 7.35 (t, J = 7.6 Hz, 2H), 7.28 (d, J = 7.2 Hz, 1H), 4.93 (s, 2H)； ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ 169.8, 136.9, 133.6, 129.6, 128.9, 128.7, 128.6, 127.9, 127.7, 126.4, 125.7, 123.3, 41.6.

2-Benzyl-6-methyl-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3b). Yellow solid. Yield: 75%, 39.5 mg. Mp: 241.5-243.2 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.06 (d, J = 7.9 Hz, 1H), 8.96 (d, J = 8.3 Hz, 1H), 8.63 (d, J = 8.2 Hz, 1H), 8.43 (s, 1H), 7.75-7.69 (m, 2H), 7.55 (d, J = 8.3 Hz, 1H), 7.51 (d, J = 7.5 Hz, 2H), 7.35 (t, J = 7.5 Hz, 2H), 7.28 (d, J = 7.3 Hz, 1H), 4.91 (s, 2H), 2.64 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.9, 139.9, 137.0, 133.7, 133.1, 130.3, 129.3, 128.9, 128.7, 128.4, 127.9, 127.7, 126.5, 126.3, 126.1, 125.8, 123.6, 123.2, 123.0, 41.6, 22.6; IR (KBr), *v* (cm^{-1}) 2930, 1703, 1624, 1392, 1053, 771, 708, 565; HRMS (APCI) *m/z*: calcd for $C_{24}H_{18}NO_2$ $[M + H]^+$ 352.1332; found 352.1321.

2-Benzyl-6-methoxy-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3c). Yellow solid. Yield: 77%, 42.4 mg. Mp: 200.5-201.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.02 (dd, J = 6.7, 2.6 Hz, 1H), 8.97 (d, J = 9.0 Hz, 1H), 8.52-8.48 (m, 1H), 7.92 (d, J = 2.3 Hz, 1H), 7.71-7.66 (m, 2H), 7.51 (d, J = 7.3 Hz, 2H), 7.36-7.31 (m, 3H), 7.28 (d, J = 7.3 Hz, 1H), 4.89 (s, 2H), 4.03 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.9, 169.8, 160.7, 137.0, 135.6, 132.4, 128.9, 128.8, 128.7, 128.6, 127.9, 127.9, 127.8, 126.3, 126.1, 124.7, 123.2, 120.2, 118.7, 104.6, 55.6, 41.5; IR (KBr), *v* (cm^{-1}) 2932, 1699, 1610, 1394, 1227, 1055, 770, 627, 494; HRMS (APCI) *m/z*: calcd for $C_{24}H_{18}NO_3$ $[M + H]^+$ 368.1281; found 368.1277.

2-Benzyl-6-chloro-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3d). Yellow solid. Yield: 64%, 35.62 mg. Mp: 197.5-199.3 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.07-9.02 (m, 1H), 8.99 (d, J = 8.7 Hz, 1H), 8.55 (d, J = 1.4 Hz, 1H), 8.50 (d, J = 8.0 Hz, 1H), 7.77-7.71 (m, 2H), 7.65 (dd, J = 8.7, 1.7 Hz, 1H), 7.51 (d, J = 7.5 Hz, 2H), 7.36 (t, J = 7.6 Hz, 2H), 7.29 (t, J = 7.3 Hz, 1H), 4.90 (s, 2H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.4, 136.7, 136.2, 134.5, 132.3, 129.8, 129.2, 128.9, 128.8, 128.0, 127.7, 127.6, 127.2, 126.4, 126.0, 123.8, 123.3, 123.1, 41.7; IR (KBr), *v* (cm^{-1}) 2934, 1703, 1607, 1394, 1109, 1013, 766, 465; HRMS (APCI) *m/z*: calcd for $C_{23}H_{15}ClNO_2$ $[M + H]^+$ 372.0786; found 372.0787.

2-Benzyl-6-chloro-9-methyl-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3e). Yellow solid. Yield: 66%, 38.1 mg. Mp: 267.2-269.1 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.99 (d, J = 8.7 Hz, 1H), 8.94 (d, J = 8.3 Hz, 1H), 8.56 (d, J = 1.5 Hz, 1H), 8.31 (s, 1H), 7.65 (dd, J = 8.7, 1.8 Hz, 1H), 7.57 (d, J = 8.3 Hz, 1H), 7.50 (d, J = 7.4 Hz, 2H), 7.35 (t, J = 7.6 Hz, 2H), 7.29 (d, J = 7.3 Hz, 1H), 4.90 (s, 2H), 2.64 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.5, 140.4, 136.8, 135.9, 134.2, 132.6, 131.0, 129.0, 128.9, 128.8, 128.0, 127.8, 127.7, 126.2, 124.0, 123.9, 123.1, 123.0, 41.6, 22.6; HRMS (APCI) *m/z*: calcd for $C_{24}H_{17}ClNO_2$ $[M + H]^+$ 386.0942; found 386.0926.

2-Benzyl-6-fluoro-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3f). Yellow solid. Yield: 74%, 39.4 mg. Mp: 198.5-200.5 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.10 (dd, J = 9.0, 6.1 Hz, 1H), 9.08-9.05 (m, 1H), 8.49 (d, J = 7.7 Hz, 1H), 8.23 (dd, J = 10.9, 2.0 Hz, 1H), 7.78-7.73 (m, 2H), 7.51 (d, J = 7.5 Hz, 2H), 7.48-7.46 (m, 1H), 7.35 (t, J = 7.5 Hz, 2H), 7.29 (t, J = 7.3 Hz, 1H), 4.91 (s, 2H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.5, 169.5, 163.3 (d, ^1J=249.81 Hz), 136.8, 135.7 (d, ^3J=8.78 Hz), 132.7 (d, ^4J=4.51 Hz), 129.6, 129.17, 129.0 (d, ^3J=9.01 Hz), 128.9, 128.8, 128.0, 127.4, 126.8 (d, ^4J=2.59 Hz), 126.5, 125.9, 123.4, 122.3, 117.9 (d, ^2J=23.79 Hz), 108.7 (d, ^2J=22.82 Hz), 41.6; ^{19}F NMR (565 MHz, $CDCl_3$) δ -107.4; IR (KBr), *v* (cm^{-1}) 2934, 1703, 1609, 1395, 1344, 1192, 1115, 1055, 831, 766, 619, 501; HRMS (APCI) *m/z*: calcd for $C_{23}H_{15}FNO_2$ $[M + H]^+$ 356.1081; found 356.1073.

2-Benzyl-6-fluoro-9-methyl-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3g). Yellow solid. Yield: 77%, 42.6 mg. Mp: 166.3-167.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.95 (dd, J = 8.8, 6.3 Hz, 1H), 8.81 (d, J = 8.3 Hz, 1H), 8.09 (s, 1H), 8.04 (d, J = 9.7 Hz, 1H), 7.52 (d, J = 7.7 Hz, 2H), 7.47 (d, J = 8.3 Hz, 1H), 7.38-7.34 (m, 3H), 7.29 (t, J = 7.3 Hz, 1H), 4.87 (s, 2H), 2.59 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.5, 163.0 (d, ^1J=249.24 Hz), 139.9, 136.8, 135.0 (d, ^3J=8.73 Hz), 132.7 (d, ^4J=4.20 Hz), 130.8, 128.9, 128.8, 128.7 (d, ^3J=8.88 Hz), 128.0, 126.7 (d, ^4J=2.52 Hz), 126.1, 126.0, 123.6, 123.0, 122.3, 117.6 (d, ^2J=23.85 Hz), 108.5 (d, ^2J=22.78 Hz), 41.5, 22.5; ^{19}F NMR (376 MHz, $CDCl_3$) δ (ppm) -107.8; IR (KBr), *v* (cm^{-1}) 2934, 1703, 1607, 1392, 1165, 1111, 1022, 825, 700, 542, 490; HRMS (APCI) *m/z*: calcd for $C_{24}H_{17}FNO_2$ $[M + H]^+$ 370.1238; found 370.1223.

2-Benzyl-6-(*tert*-butyl)-9-fluoro-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3h). Yellow solid. Yield: 78%, 48.1 mg. Mp: 183.2-184.9 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.11 (dd, J = 8.9, 6.2 Hz, 1H), 9.02 (d, J = 8.6 Hz, 1H), 8.52 (s, 1H), 8.33-8.30 (m, 1H), 7.87 (d, J = 8.8 Hz, 1H), 7.50-7.46 (m, 3H), 7.34 (t, J = 7.5 Hz, 2H), 7.28 (d, J = 7.3 Hz, 1H), 4.91 (s, 2H), 1.51 (s, 9H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.7, 169.7, 163.2 (d, ^1J=249.24 Hz), 153.0, 136.8, 135.7 (d, ^3J=8.74 Hz), 132.7 (d, ^4J=4.29 Hz), 128.9 (d, ^3J=8.98 Hz), 128.9, 128.7, 127.9, 127.8, 126.9, 126.6, 126.1, 123.9, 122.6, 119.1, 117.7 (d, ^2J=23.55 Hz), 108.6 (d, ^2J=22.62 Hz), 41.6, 35.8, 31.4; ^{19}F NMR (376 MHz, $CDCl_3$) δ (ppm) -107.9； IR (KBr), *v* (cm^{-1}) 2955, 1703, 1389, 1013, 822, 727, 571, 471; HRMS (APCI) *m/z*: calcd for $C_{27}H_{23}FNO_2$ $[M + H]^+$ 412.1707; found 412.1706.

2-Benzyl-1,3-dioxo-2,3-dihydro-1*H*-dibenzo[*e,g*]isoindole-6-carbonitrile (3i). Yellow solid. Yield: 79%, 42.9 mg. Mp: 265.7-267.5 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.20 (d, J = 8.5 Hz, 1H), 9.14 (d, J = 8.0 Hz, 1H), 8.98 (s, 1H), 8.62 (d, J = 8.3 Hz, 1H), 7.91-7.89 (m, 2H), 7.83 (t, J = 7.5 Hz, 1H), 7.52 (d, J = 7.5 Hz, 2H), 7.36 (t, J = 7.6 Hz, 2H), 7.30 (t, J = 7.3 Hz, 1H), 4.93 (s, 2H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 168.9, 168.9, 136.4, 132.8, 132.7, 130.8, 130.3, 129.8, 129.7, 129.0, 128.8, 128.5, 128.2, 127.7, 127.4, 126.8, 126.5, 125.9, 123.2, 118.8, 112.9, 41.8; IR (KBr), *v* (cm^{-1}) 2930, 1707, 1609, 1392, 1117, 1032, 777, 623, 488; HRMS (APCI) *m/z*: calcd for $C_{24}H_{15}N_2O_2$ $[M + H]^+$ 363.1128; found 363.1128.

2-Benzyl-9-methoxy-1,3-dioxo-2,3-dihydro-1*H*-dibenzo[*e,g*]isoindole-6-carbonitrile (3j). Yellow solid. Yield: 75%, 44.1 mg. Mp: 298-299.5 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.18 (d, J = 8.5 Hz, 1H), 9.08 (d, J = 9.0 Hz, 1H), 8.92 (s, 1H), 7.95 (d, J = 2.2 Hz, 1H), 7.89 (dd, J = 8.5, 1.2 Hz, 1H), 7.50 (d, J = 7.4 Hz, 2H), 7.46 (dd, J = 9.0, 2.3 Hz, 1H), 7.35 (t, J = 7.6 Hz, 2H), 7.29 (d, J = 7.3 Hz, 1H), 4.91 (s, 2H), 4.09 (s, 3H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.2, 169.1, 161.7, 136.5, 135.1, 131.9, 130.7, 129.7, 128.9, 128.8, 128.7, 128.5, 128.4, 128.1, 127.4, 123.5, 120.6, 120.2, 119.0, 112.2, 104.6, 55.9, 41.8; IR (KBr), *v* (cm^{-1}) 2928, 1703, 1616, 1393, 1248, 1038, 837, 702, 581, 478; HRMS (APCI) *m/z*: calcd for $C_{25}H_{17}N_2O_3$ $[M + H]^+$ 393.1234; found 393.1223.

2-Benzyl-9-(*tert*-butyl)-1,3-dioxo-2,3-dihydro-1*H*-dibenzo[*e,g*]isoindole-5-carbonitrile (3k). Yellow solid. Yield: 68%, 42.6 mg. Mp: 240.5-242.2 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.49 (s, 1H), 9.09 (d, J = 8.6 Hz, 1H), 8.82 (d, J = 8.8 Hz, 1H), 8.69 (s, 1H), 7.95 (d, J = 8.6 Hz, 2H), 7.50 (d, J = 7.5 Hz, 2H), 7.35 (t, J = 7.5 Hz, 2H), 7.29 (d, J = 7.3 Hz, 1H), 4.93 (s, 2H), 1.52 (s, 9H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.1, 154.0, 136.5, 135.4, 132.6, 131.5, 130.3, 129.3, 128.9, 128.8, 128.1, 126.4, 125.7, 125.3, 124.4, 124.39, 124.3, 119.5, 118.6, 111.9, 41.8, 35.9, 31.4; IR (KBr), *v* (cm^{-1}) 2963, 1707, 1624, 1394, 1117, 1036, 841, 700, 633, 490; HRMS (APCI) *m/z*: calcd for $C_{28}H_{23}N_2O_2$ $[M + H]^+$ 419.1754; found 419.1756.

2-Benzyl-6-(trifluoromethyl)-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3l). White solid. Yield: 72%, 43.7 mg. Mp: 203.7-205.6 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.12 (d, J = 8.5 Hz, 1H), 9.02 (d, J = 7.9 Hz, 1H), 8.80 (s, 1H), 8.53 (d, J = 8.3 Hz, 1H), 7.87 (d, J = 8.5 Hz, 1H), 7.78-7.72 (m, 2H), 7.53 (d, J = 7.5 Hz, 2H), 7.37 (t, J = 7.6 Hz, 2H), 7.30 (t, J = 7.3 Hz, 1H), 4.91 (s, 2H); ^{13}C{^{1}H} NMR (151 MHz, $CDCl_3$) δ (ppm) 169.0, 169.0, 136.6, 133.2, 132.7, 130.9 (q, ^2J=32.42 Hz), 130.3, 129.4, 129.3, 128.9, 128.9, 128.1, 127.2, 124.2 (q, ^1J=271.06 Hz), 126.6, 125.7, 124.3 (q, ^3J=3.12 Hz), 123.2, 120.5 (q, ^3J=4.02 Hz), 41.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ (ppm) -62.4; IR (KBr), *v* (cm^{-1}) 2934, 1709, 1612, 1393, 1315, 1122, 1022, 843, 700, 613, 509; HRMS (APCI) *m/z*: calcd for $C_{24}H_{15}F_3NO_2$ $[M + H]^+$ 406.1049; found 406.1034.

2-Benzyl-6-methyl-9-(trifluoromethyl)-1*H*-dibenzo[*e,g*]isoindole-1,3(2*H*)-dione (3m). Yellow solid. Yield: 78%, 49.0 mg. Mp: 242.2-243.8 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.06 (d, J =

8.4 Hz, 1H), 8.88 (d, J = 8.2 Hz, 1H), 8.72 (s, 1H), 8.26 (s, 1H), 7.82 (d, J = 8.4 Hz, 1H), 7.52 (d, J = 6.6 Hz, 3H), 7.36 (t, J = 7.4 Hz, 2H), 7.30 (t, J = 7.1 Hz, 1H), 4.89 (s, 2H), 2.63 (s, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 169.1, 169.1, 140.9, 136.6, 133.3, 132.1, 131.1, 130.5 (q, ^{2}J=31.89 Hz), 129.5, 128.9, 128.8, 128.1, 127.3, 127.1, 126.2, 125.5, 124.2 (q, ^{1}J=271.48 Hz), 124.1 (q, ^{3}J=2.86 Hz), 123.6, 122.9, 120.4 (q, ^{3}J=3.96 Hz), 41.7, 22.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ (ppm) -62.3; IR (KBr), *v* (cm^{-1}) 2934, 1705, 1394, 1321, 1117, 1080, 922, 833, 700, 571, 438; HRMS (APCI) *m/z*: calcd for $C_{25}H_{17}F_3NO_2$ $[M + H]^+$ 420.1206; found 420.1209.

12-Benzyl-3-methyl-11*H*-benzo[*e*]naphtho[2,1-*g*]isoindole-11,13(12*H*)-dione (3n). Yellow solid. Yield: 81%, 48.7 mg. Mp: 176-177.8 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.45 (d, J = 8.3 Hz, 1H), 9.10 (d, J = 8.4 Hz, 1H), 8.42 (d, J = 9.1 Hz, 1H), 8.30 (s, 1H), 7.93 (d, J = 9.1 Hz, 1H), 7.90 (d, J = 7.5 Hz, 1H), 7.70-7.64 (m, 2H), 7.55 (d, J = 7.5 Hz, 2H), 7.50 (d, J = 8.4 Hz, 1H), 7.35 (t, J = 7.6 Hz, 2H), 7.28 (t, J = 7.4 Hz, 1H), 4.92 (s, 2H), 2.60 (s, 3H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 169.4, 169.3, 140.0, 136.9, 133.7, 133.2, 133.0, 130.6, 130.6, 130.2, 129.1, 128.9, 128.8, 128.6, 127.9, 127.8, 127.8, 127.2, 126.4, 125.9, 125.0, 124.0, 123.1, 120.8, 41.9, 22.7; IR (KBr), *v* (cm^{-1}) 2928, 1695, 1392, 1034, 829, 748, 590, 496; HRMS (APCI) *m/z*: calcd for $C_{28}H_{20}NO_2$ $[M + H]^+$ 402.1489; found 402.1471.

12-Benzyl-3-(trifluoromethyl)-11*H*-benzo[*e*]naphtho[2,1-*g*]isoindole-11,13(12*H*)-dione (3o). Yellow solid. Yield: 75%, 51.2 mg. Mp: 243.1-245.2 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.46 (d, J = 8.2 Hz, 1H), 9.42 (d, J = 8.6 Hz, 1H), 8.94 (s, 1H), 8.54 (d, J = 9.0 Hz, 1H), 8.08 (d, J = 9.0 Hz, 1H), 7.95 (dd, J = 15.7, 7.9 Hz, 2H), 7.75-7.70 (m, 2H), 7.55 (d, J = 7.5 Hz, 2H), 7.36 (t, J = 7.6 Hz, 2H), 7.29 (t, J = 7.3 Hz, 1H), 4.97 (s, 2H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 172.4, 159.6, 133.9, 133.2, 130.6 (q, ^{2}J=32.55 Hz), 130.57, 129.5, 129.2, 129.1, 128.9, 127.6, 127.2, 127.0, 123.9 (q, ^{1}J=270.42 Hz), 125.9, 125.6, 125.3 (q, ^{3}J=3.65 Hz), 124.4, 72.8; ^{19}F NMR (376 MHz, $CDCl_3$) δ (ppm) -62.3; IR (KBr), *v* (cm^{-1}) 2951, 1695, 1398, 1311, 1121, 1076, 839, 748, 513; HRMS (APCI) *m/z*: calcd for $C_{28}H_{17}F_3NO_2$ $[M + H]^+$ 456.1206; found 456.1203.

14-Benzyl-13*H*-dinaphtho[1,2-*e*:2',1'-*g*]isoindole-13,15(14*H*)-dione (3p). Yellow solid. Yield: 65%, 42.6 mg. Mp: 175.6-177.4 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 7.77 (d, J = 7.8 Hz, 2H), 7.73 (d, J = 7.7 Hz, 2H), 7.56 (d, J = 7.3 Hz, 3H), 7.40 (t, J = 7.4 Hz, 2H), 7.37-7.32 (m, 6H), 7.21 (t, J = 7.1 Hz, 2H), 4.95 (s, 2H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 170.5, 140.2, 136.6, 133.6, 130.8, 130.5, 129.1, 128.9, 128.9, 128.5, 128.1, 126.4, 126.2, 125.3, 125.2, 42.6; IR (KBr), *v* (cm^{-1}) 2920, 1701, 1394, 1261, 1101, 1022, 789, 532, 478; HRMS (APCI) *m/z*: calcd for $C_{31}H_{20}NO_2$ $[M + H]^+$ 438.1489; found 438.1485.

9-Benzyl-8*H*-benzo[*e*]furo[3,2-*g*]isoindole-8,10(9*H*)-dione (3q). Yellow solid. Yield: 64%, 31.4 mg. Mp: 193.8-195.5 °C. ^{1}H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.03 (d, J = 8.1 Hz, 1H), 8.13 (d, J = 8.1 Hz, 1H), 8.02 (d, J = 1.8 Hz, 1H), 7.71-7.65 (m, 2H), 7.51 (d, J = 7.4 Hz, 2H), 7.35-7.33 (m, 3H), 7.28 (d, J = 7.3 Hz, 1H), 4.92 (s, 2H); $^{13}C\{^{1}H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 169.6, 166.5, 148.8, 144.6, 136.7, 130.8, 130.8, 129.2, 128.8, 128.0, 127.8, 126.2, 125.4, 124.1, 124.1,

117.8, 106.4, 41.7; IR (KBr), *v* (cm^{-1}) 2941, 1701, 1387, 1337, 1057, 1022, 914, 756, 590, 511; HRMS (APCI) *m/z*: calcd for $C_{21}H_{14}NO_3$ $[M + H]^+$ 328.0968; found 328.0970.

9-Benzyl-5-methyl-8*H*-benzo[*e*]furo[3,2-*g*]isoindole-8,10(9*H*)-dione (3r). Yellow solid. Yield: 67%, 34.3 mg. Mp: 241.9-243.8 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.81 (d, J = 8.6 Hz, 1H), 7.90 (s, 1H), 7.81 (s, 1H), 7.43 (d, J = 7.5 Hz, 2H), 7.40 (d, J = 8.6 Hz, 1H), 7.26 (t, J = 7.5 Hz, 2H), 7.21-7.17 (m, 2H), 4.83 (s, 2H), 2.52 (s, 3H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 169.7, 166.6, 148.5, 144.8, 139.7, 136.8, 131.1, 130.0, 128.8, 128.8, 127.9, 125.8, 124.1, 123.5, 123.3, 116.8, 106.3, 41.6, 22.3; IR (KBr), *v* (cm^{-1}) 2932, 1705, 1607, 1387, 1344, 1055, 1024, 827, 741, 617, 447; HRMS (APCI) *m/z*: calcd for $C_{22}H_{16}NO_3$ $[M + H]^+$ 342.1125; found 342.1128.

9-Benzyl-8*H*-benzo[*e*]thieno[3,2-*g*]isoindole-8,10(9*H*)-dione (3s). Yellow solid. Yield: 66%, 33.9 mg. Mp: 244.7-246.4 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.01 (d, J = 8.1 Hz, 1H), 8.35 (d, J = 8.0 Hz, 1H), 8.01 (d, J = 5.2 Hz, 1H), 7.92 (d, J = 5.2 Hz, 1H), 7.73-7.67 (m, 2H), 7.52 (d, J = 7.5 Hz, 2H), 7.35 (t, J = 7.4 Hz, 2H), 7.29 (d, J = 7.3 Hz, 1H), 4.92 (s, 2H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 169.7, 168.3, 142.5, 136.8, 132.9, 132.0, 129.2, 128.9, 128.9, 128.8, 128.1, 128.0, 126.8, 126.0, 125.9, 124.5, 124.1, 122.0, 41.8; IR (KBr), *v* (cm^{-1}) 2930, 1701, 1630, 1394, 1342, 1059, 725, 507; HRMS (APCI) *m/z*: calcd for $C_{21}H_{14}NO_2S$ $[M + H]^+$ 344.0740; found 344.0726.

9-Benzyl-5-(*tert*-butyl)-8*H*-benzo[*e*]thieno[3,2-*g*]isoindole-8,10(9*H*)-dione (3t). Yellow solid. Yield: 69%, 41.3 mg. Mp: 186.5-188.4 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 8.96 (d, J = 8.8 Hz, 1H), 8.34 (s, 1H), 8.09 (d, J = 5.3 Hz, 1H), 7.93 (d, J = 5.3 Hz, 1H), 7.81 (d, J = 8.6 Hz, 1H), 7.51 (d, J = 7.5 Hz, 2H), 7.34 (t, J = 7.5 Hz, 2H), 7.28 (d, J = 7.4 Hz, 1H), 4.92 (s, 2H), 1.48 (s, 9H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 169.9, 168.5, 152.6, 142.4, 136.8, 132.4, 132.3, 128.9, 128.8, 128.7, 127.9, 127.0, 126.1, 125.7, 124.2, 124.0, 122.0, 119.8, 41.8, 35.6, 31.3; IR (KBr), *v* (cm^{-1}) 2957, 1705, 1622, 1394, 1342, 1015, 825, 696, 563; HRMS (APCI) *m/z*: calcd for $C_{25}H_{22}NO_2S$ $[M + H]^+$ 400.1366; found 400.1365.

2-Phenyl-1*H*-dibenzo[*e*,*g*]isoindole-1,3(2*H*)-dione (3aa).[31] Yield: 52%, 25.2 mg. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.15 (d, J = 8.1 Hz, 2H), 8.72 (d, J = 8.4 Hz, 2H), 7.80 (t, J = 7.5 Hz, 2H), 7.74 (t, J = 7.5 Hz, 2H), 7.51-7.45 (m, 4H), 7.37 (t, J = 6.8 Hz, 1H).

1*H*-Dibenzo[*e*,*g*]isoindole-1,3(2*H*)-dione (3ab). Yellow solid. Yield: 59%, 21.8 mg. Mp: 221.5-223.1 °C. ^1H NMR (600 MHz, DMSO) δ (ppm) 11.35 (s, 1H), 9.03 (dd, J = 7.5, 6.3 Hz, 4H), 7.95-7.91 (m, 2H), 7.90-7.87 (m, 2H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$, TFA-d_1) δ (ppm) 172.6, 134.3, 130.6, 129.2, 128.0, 126.2, 125.4, 123.6; IR (KBr), *v* (cm^{-1}) 2170, 1657, 1398, 1290, 1082, 849, 540; HRMS (APCI) *m/z*: calcd for $C_{16}H_{10}NO_2$ $[M + H]^+$ 248.0706; found 248.0710.

2-Isopropyl-1*H*-dibenzo[*e*,*g*]isoindole-1,3(2*H*)-dione (3ac). Yellow solid. Yield: 76%, 34.5 mg. Mp: 212.2-213.9 °C. ^1H NMR (600 MHz, $CDCl_3$) δ (ppm) 9.11 (d, J = 7.8 Hz, 2H), 8.65 (d, J = 8.2 Hz, 2H), 7.78-7.71 (m, 4H), 4.61 (m, 1H), 1.58 (d, J = 7.0 Hz, 6H); $^{13}C\{^1H\}$ NMR (151 MHz, $CDCl_3$) δ (ppm) 170.1, 133.4, 129.3, 128.4, 127.4, 126.2, 125.7, 123.2, 43.0, 20.5; IR (KBr), *v*

(cm^{-1}) 2970, 2170, 1659, 1394, 1082, 762, 544; HRMS (APCI) *m/z*: calcd for $C_{19}H_{16}NO_2$ $[M + H]^+$ 290.1176; found 290.1180.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website, and include NMR spectra, absorption spectra, fluorescence spectra and detection of the generation of H_2 chromatogram (PDF).

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Notes

The authors declare no competing financial interests.

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