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4,4′-Diarylsulfanyl-2,2′,5,5′-tetraoxybiaryl Derivatives as a Water-Soluble Fluorescent Dye

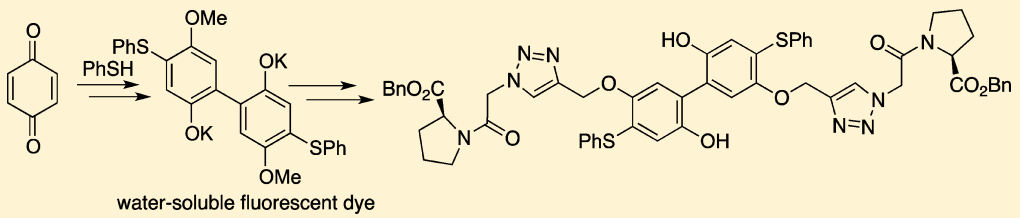
Akio Kamimura,*[,†] Tomomi Nokubi,[†] Ryusuke Watanabe,[†] Mari Ishikawa,[†] Kotaro Nasu,[†] Hidemitsu Uno,[‡] and Michinori Sumimoto[§]

[†]Department of Applied Molecular Bioscience, Graduate School of Medicine, Yamaguchi University, Ube 755-8611, Japan

[‡]Department of Chemistry, Graduate School of Science and Engineering, Ehime University, Matsuyama 790-8577, Japan

[§]Department of Applied Chemistry, Graduate School of Science and Engineering, Yamaguchi University, Ube 755-8611, Japan

Supporting Information



ABSTRACT: 4,4′-Disulfanyl-2,2′,5,5′-tetrahydrobiaryl (5,5′-disulfanyl hydroquinone dimer) derivatives were readily synthesized from benzoquinone and thiols via an oxidative coupling reaction. The hydroquinone dimers showed strong fluorescence upon excitation at 330 nm, and it was observed that the presence of the sulfanyl groups at the C4 and C4′ positions is important for achieving strong photoluminescence. The tetrapotassium salts of the hydroquinone dimers also showed good water solubility, but the fluorescence disappeared rapidly on dissolution in water. 2,2′- and 5,5′-protected biaryls were synthesized. The dipotassium salt of the 5,5′-dimethoxy-2,2′-dihydroxy derivative was observed to show good and stable fluorescence in water, while the dipotassium salt of the 2,2′-dimethoxy-5,5′-dihydroxy derivative showed less water solubility. Introduction of propargyl groups was demonstrated to provide a convenient method for installing amino acids derivatives. This derivatization afforded potentially useful compounds for attaching the biologically active fragment to the fluorescent unit.

INTRODUCTION

Water-soluble fluorescent dyes are recognized as important tools for imaging chemical, biological, and environmental processes.[1] Many types of fluorescent dyes have been developed to date and are actively used in probing biological processes.[2] For example, BODIPY-based thioethers,[3] fluorescein derivatives,[4] rhodamines,[5] boronic acids,[6] peptides,[7] polyfluorene derivatives,[8] and nanoclusters[9] have been reported as water-soluble fluorescent dyes. Some of dyes are tunable for emission wavelengths.[10]

Recently, we reported a short synthesis of 4,4′-disulfanyl-2,2′,5,5′-tetrahydroxylbiaryls, which are hydroquinone dimer derivatives bearing arylthio groups at the 4 and 4′ positions.[11] Direct linkage of hydroquinone or quinone units effectively achieves a unique construction of π-extended molecules[12] and natural product synthesis.[13] Quinone dimer units are observed among natural products.[14] However, although the quinone dimer is regarded as a good candidate structure for developing new functional molecules, there have been few studies on the synthesis of these compounds because of their poor stability. Our new sulfanyl quinone dimers are readily available from quinone in short steps and showed sufficient stability. They also exhibit strong fluorescence near 400 nm upon UV excitation. Because the molecules based on this structure contain four phenolic hydroxyl groups, we have expected that these compounds have a potential modification to be water-soluble fluorescent dyes upon deprotection of the hydroxyl groups.[15] In this study, we describe the synthesis of a new type of water-soluble fluorescent dye and its physical properties in detail. We have also investigated that the introduction of bioactive groups such as amino acid to the new dyes are possible via a simple synthetic method.

RESULTS AND DISCUSSION

Synthesis of 4,4′-disulfanyl-2,2′,5,5′-tetrahydrobiaryl **1** was performed using the previously reported method.[11] The results are summarized in Table 1.

Thus, conjugate addition of various thiols to 1,4-benzoquionone provided 2-sulfanylhydroquinones **2**, the hydroxyl groups of which were protected using methyl groups on treatment with base and MeI to produce **3**. The protection of the hydroxyl groups required the addition of 18-crown-6 and excess amounts of NaH. The oxidative dimerization of **3** progressed smoothly,[16] and the desired dimers **4** were obtained in good yield except for **4i**, which was obtained only in 62% yield under the same reaction conditions. Removal of the

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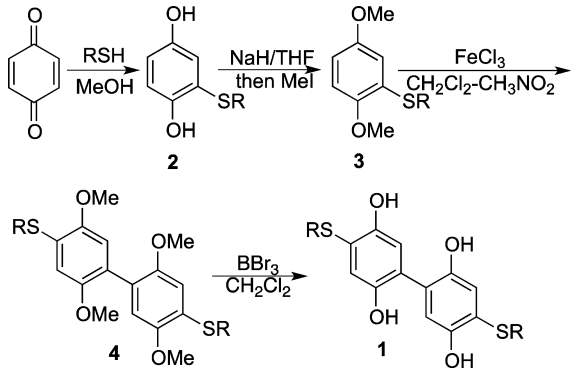
Table 1. Synthesis of 5,5′-Disulfanyl-1,1′,4,4′-hydroxybiaryls 1



entry	R	2: yield[a] (%)	3: yield[a] (%)	4: yield[a] (%)	1: yield[a] (%)
1	Ph	**2a**: 99	**3a**: 93	**4a**: 94	**1a**: 89
2	*o*-BrC_6H_4	**2b**: 93	**3b**: 98	**4b**: 97	**1b**: 94
3	*m*-BrC_6H_4	**2c**: 97	**3c**: 81	**4c**: 99	**1c**: 88
4	*p*-BrC_6H_4	**2d**: 98	**3d**: 96	**4d**: 98	**1d**: 70
5	*p*-ClC_6H_4	**2e**: 87	**3e**: 98	**4e**: 100	**1e**: 80
6	*o*-MeC_6H_4	**2f**: 100	**3f**: 91	**4f**: 100	**1f**: 90
7	*p*-MeC_6H_4	**2g**: 96	**3g**: 85	**4g**: 99	**1g**: 81
8	2-naphthyl	**2h**: 24	**3h**: 93	**4h**: 100	**1h**: 77
9	2-py	**2i**: 97	**3i**: 66	**4i**: 62	**1i**: 60

[a]Isolated yield.

methyl groups in **4** was readily achieved via treatment with BBr_3 and afforded compounds **1** in good to excellent yields.

The UV−vis absorption and fluorescence properties of compounds **1** were investigated. The absorption and fluorescence peaks, extinction coefficients, and quantum yields for each compound are listed in Table 2.

Table 2. UV-vis Absorption and Fluorescence Peaks for Compounds 1

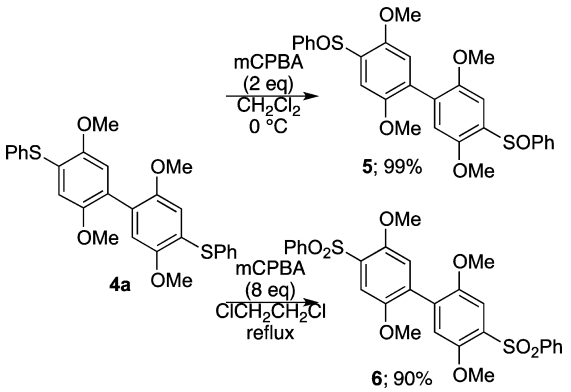
compd	R	absorption peak (nm)[a]	log ε	fluorescent peak (nm)[b]	Φ_F[c]
1a	Ph	330	4.31	408	0.39
1b	*o*-BrC_6H_4	330	4.29	411	0.16
1c	*m*-BrC_6H_4	331	4.32	410	0.18
1d	*p*-BrC_6H_4	330	4.32	409	0.16
1e	*p*-ClC_6H_4	330	4.26	409	0.13
1f	*o*-MeC_6H_4	331	4.39	408	0.25
1g	*p*-MeC_6H_4	331	4.38	408	0.24
1h	2-naphth	332	4.15	400	0.12
1i	2-py	326	4.10	400	0.017

[a]UV−vis spectra; concentrations are 1×10^{-5} M to 4×10^{-5} M in MeOH. [b]Fluorescence spectra; concentration is 1×10^{-6} M in MeOH. [c]Quantum yields of compounds **1** in MeOH were measured with an absolute photoluminescence quantum yield measurement system (Hamamatsu Photonics, C9920-02G). Concentration was 1×10^{-5} M in MeOH, excited at the absorption peak for each compound.

Most compounds **1** were colorless in MeOH, and their absorption spectra were measured at ~10^{-5} M concentration. Their peaks appeared near 330 nm in their UV−vis spectra. The extinction coefficients were measured using the least-squares method with three different concentrations. Photoluminescence spectra for compounds **1** were measured in MeOH at 10^{-6} M concentrations. The spectra excited at about 330 nm, which was at the absorption peak, and exhibited relatively strong fluorescence from 400 to 410 nm. These wavelengths were almost independent of the substituents on the arylthio group. The quantum yield (Φ_F) of **1a**, which was measured using absolute quantum yield measuring system, reached 0.39 in MeOH. The quantum yields for other compounds **1** were also measured in a similar manner, and most of compounds **1** showed the values in a range between 0.1 and 0.25. Unfortunately, none of compounds **1** was sufficiently water-soluble and showed weak or no fluorescence in water. We could not observe any effective fluorescence in the solid-state phase of compounds **1**.

The fluorescence properties of oxidized derivatives of **4** were investigated. Sulfoxide **5** and sulfone **6** were readily synthesized in 99% and 90% yield, respectively, via the oxidation of **4a** with 2 equiv or a large excess of *m*-chloroperbonzoic acid (*m*-CPBA) (Scheme 1). The conversion to sulfoxide **5** took place smoothly at room temperature, while the oxidation to sulfone **6** required heating conditions.

Scheme 1



The UV−vis absorption and fluorescence spectra of compounds **4a**, **5**, and **6** in MeOH were then observed, and the spectra are shown in Figure 1.

Compound **4a** had nearly the same UV−vis absorption spectrum as that of compound **1a**, while sulfoxide **5** and sulfone **6** showed weaker absorption than compound **4a**. All of the compounds showed the peak absorption at 324 nm. The extinction coefficients for compounds **4a**, **5**, and **6** at the absorption wavelength (324 nm) were estimated to be 2.16×10^4, 1.25×10^4, and 5.40×10^3 cm^{-1} M^{-1}, respectively. Thus, these values for **5** and **6** were approximately 60% and 25% of the corresponding value of **4a**. Fluorescence spectra were observed for these compounds in MeOH by excitation at 324 nm. The spectra were obtained in 1×10^{-6} M concentration. The peaks of the fluorescence appeared at 387 nm for **4a**, 406 nm for **5**, and 393 nm for **6**. The fluorescent intensity upon excitation at 324 nm was weaker for compounds **5** and **6** and approximately one-third and 20% of that of **4a**, respectively. The quantum yields for these compounds in MeOH at 1×10^{-5} M concentration were estimated using absolute photoluminescence quantum yield measurement system (see footnote c in Table 2) to be 0.22 for **4a**, 0.15 for **5**, and 0.14 for **6**, respectively. We assume that the strong photoluminescence of the sulfanyl derivatives is likely because the lone pair at the sulfur atom plays a key role for giving the photoluminescence properties for **1** and **4**. Thus, the sulfanyl group at the C4 and

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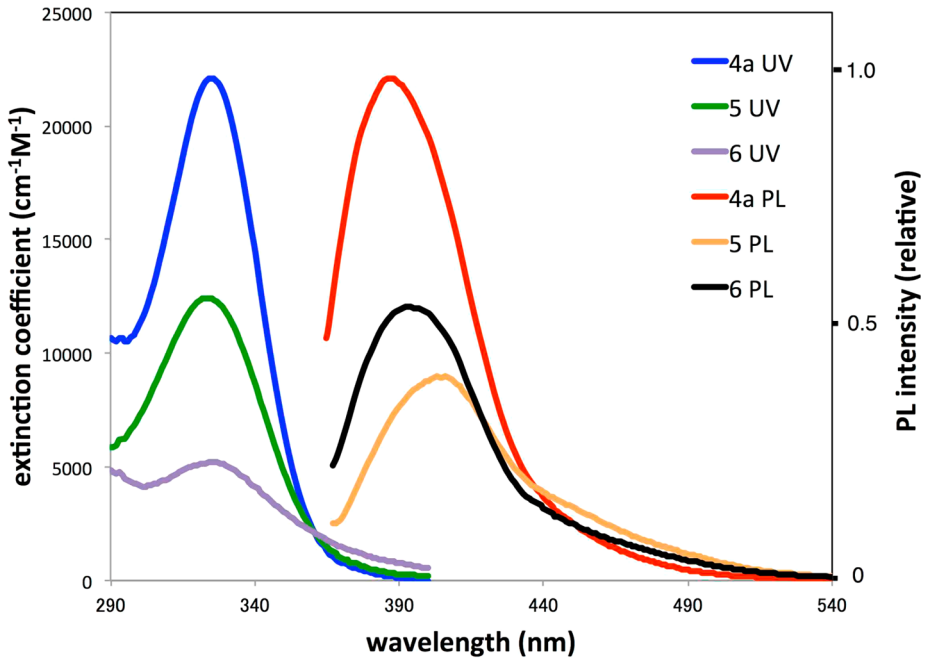

Figure 1. UV−vis absorption (10^{-5} M in MeOH) and photoluminescence spectra (1×10^{-6} M in MeOH, excited at 330 nm for **4a** and 324 nm for **5** and **6**) for compounds **4a**, **5**, and **6**.

C4′ positions significantly contributes to the strong fluorescence intensity of the dimers.

X-ray analysis of compound **4a** revealed that the twist angle of the two aromatic groups is 76°.[17] Molecular orbital calculations for compound **4a** were then performed using the X-ray structure data for the initial structure. The geometry optimization of **4a** was carried out using the DFT method, where the B3PW91 functional was used for the exchange-correlation term. Analytical vibrational frequency computations at the optimized structure were then performed to confirm that the optimized structure was at an energy minimum. For the first excited state, the geometry was optimized from the optimized ground-state structures without constraint using the TD-B3PW91 method. The UV and fluorescence spectra calculations were performed from ground-state and first excited-state optimized structures using TD-B3PW91 method with CPCM. The 6-311+G(d) basis sets were employed in these calculations. The calculations were performed using the Gaussian09 program.[18] The optimized structures for the ground and excited states of **4a** are depicted in Figure 2 along with HOMO and LUMO, respectively.

The twist angle and carbon−carbon bond length between the two aromatic rings in the ground state of **4a** were estimated to be 66.98° and 1.485 Å, respectively. This value of the twist angle was in good agreement with that obtained from the X-ray structure analysis. On the other hand, the twist angle and the carbon−carbon bond length in the excited-state structure were estimated to be 36.33° and 1.437 Å, respectively. These results indicate that the carbon−carbon bond is shortened by 0.05 Å upon excitation. In addition, the twist angle decreased and the two aromatic rings become more planar when the molecule is excited. The HOMO of **4a** is centered mainly around the aromatic rings but also includes the lone pair orbitals of the sulfur atoms, while the LUMO is located only in the aromatic rings, and there is no contribution by the lone pair orbitals of the sulfur atoms. This is probably one of the reasons why the sulfanyl group is important for the photoluminescence

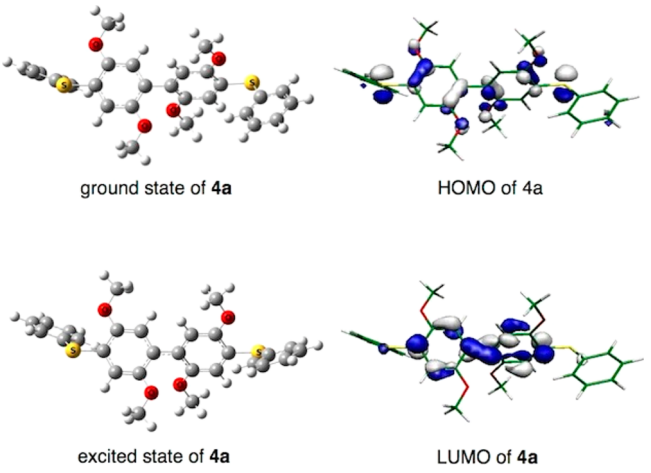

Figure 2. Optimized structures of the ground and excited states of **4a** and the HOMO and LUMO of **4a**.

properties. Calculation results for the HOMO and LUMO are also in good agreement with the experimental data. For example, the calculated HOMO−LUMO excitation occurs at 327.7 nm, which is very close to the actual λ_{max} of 324 nm in MeOH for **4a**. The calculated fluorescence band from the singlet state of **4a** appears at 392.2 nm, which is close to the actual fluorescence λ_{em} of 387 nm in MeOH. These results clearly support the conclusion that the fluorescence of compounds **4a** occurs from the singlet to the excited state.

To improve water solubility of compound **1**, the protons of the four phenolic hydroxyl groups were exchanged with potassium by treatment with 4 equiv KOH in MeOH. Unfortunately, while these compounds were water-soluble, they were ineffective as water-soluble fluorescent dyes because they lost their fluorescence immediately upon dissolution in water. This disappearing of the photoluminescence again happened when the salt was dissolved in an aqueous solution

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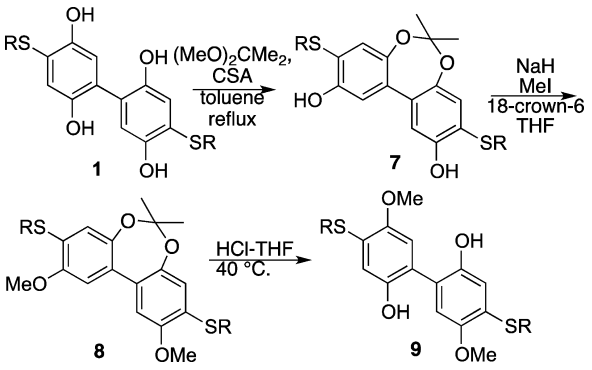
of $Na_2S_2O_4$. Thus, modification of compound **1** was necessary such that they were resistant to oxidation, which was accomplished via protection of some of the hydroxyl groups. Compounds **1** were converted to the corresponding acetals **7**, which were then methylated to afford derivatives **8**. Subsequent treatment with acid provided the 5,5′-protected biaryls **9**. The results are summarized in Table 3.

Table 3. Conversion of 1 to Dimethyl Ether 9



entry	1	R	7: yield[a] (%)	8: yield[a] (%)	9: yield[a] (%)
1	**1a**	Ph	**7a**: 87	**8a**: 100	**9a**: 71
2	**1b**	*o*-BrC_6H_4	**7b**: 100	**8b**: 99	**9b**: 86
3	**1c**	*m*-BrC_6H_4	**7c**: 88	**8c**: 93	**9c**: 93
4	**1d**	*p*-BrC_6H_4	**7d**: 82	**8d**: 97	**9d**: 98
5	**1e**	*p*-ClC_6H_4	**7e**: 93	**8e**: 100	**9e**: 93
6	**1f**	*o*-MeC_6H_4	**7f**: 92	**8f**: 100	**9f**: 86
7	**1g**	*p*-MeC_6H_4	**7g**: 100	**8g**: 85	**9g**: 95
8	**1h**	2-naphth	**7h**: 90	**8h**: 96	**9h**: 87

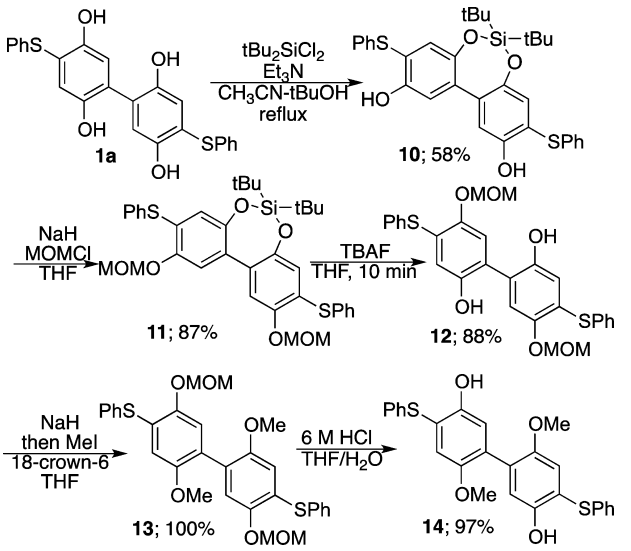
[a]Isolated yield.

Acetalification of compound **1** took place smoothly by treatment with 2,2-dimethoxypropane in the presence of catalytic amounts of camphorsulfonic acid (CSA) and the desired acetal **7** in good to almost quantitative yields. Protection of 5- and 5′-hydroxyl groups was performed under standard methylation conditions by adding 18-crown-6, and compounds **8** were prepared in good yields. The removal of the acetal was readily achieved by acidic treatment of compound **8**, and the desired 5,5′-dimethyl-protected 2-sulfanylhydroquinone dimer **9** was isolated in good yields.

2,2′-Protected biaryl was synthesized (Scheme 2). Thus, treatment of **1a** with dibutylsilyl dichloride in acetonitrile/*tert*-butyl alcohol mixed solvent at reflux provided the silyl acetal **10** in 58% yield. Temporary protection of the 5- and 5′-hydroxyl groups in compound **10** was achieved by treatment with MOMCl under basic conditions to give **11** in 87% yield. TBAF treatment of **11** then afforded 2,2′-unprotected **12** in 88% yield, which was subjected to methylation conditions to provide **13** quantitatively. Acidic treatment resulted in removal of the MOM groups to provide 2,2′-protected **14** in 97% yield.

The UV−vis absorption and fluorescence spectra of the half-protected dyes **9a** and **14** in MeOH solution were examined. These compounds showed similar UV−vis absorption fluorescence spectra (Figure 3). For example, UV−vis absorption peaks appeared at 330 nm for **9a** and 322 nm for **14**. Extinction coefficients for these compounds in MeOH were 1.7×10^4 and 2.3×10^4 cm^{-1} M^{-1}, respectively. Photoluminescences for these compounds in MeOH were observed at 403 nm upon excitation at their absorption peak wavelengths. The shape of

Scheme 2



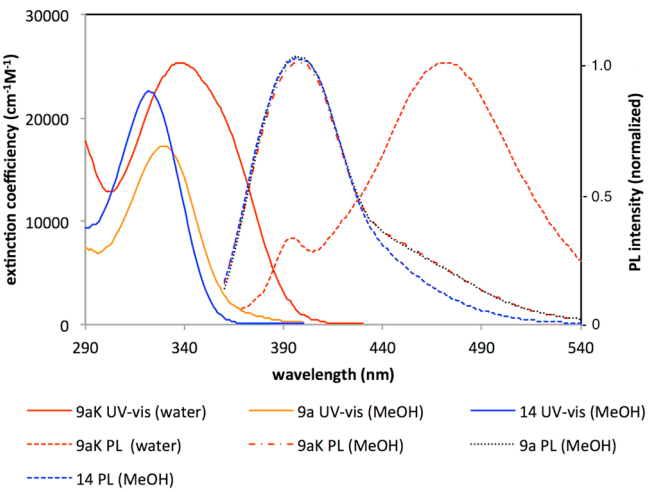


Figure 3. UV−vis and fluorescent spectra of **9a**, **14**, and **9aK** in MeOH and water. UV−vis absorption spectra were measured at 10^{-5} M concentration in MeOH or water, and photoluminescence spectra were measured at 1×10^{-6} M concentration in MeOH upon excitation at 330 nm UV light and in water upon excitation at 350 nm UV light.

the PL spectra was almost the same around their peak wavelength. The quantum yields for these compounds in MeOH were measured using their 10^{-5} M solution by absolute photoluminescence quantum yield measurement system, and their values were estimated to be 0.22 for both compounds. Conversion of these compounds to the corresponding dipotassium salts was readily achieved by treatment with 2 equiv of KOH in MeOH. However, the dipotassium salt of **9a** (**9aK**) showed good solubility in water, while the corresponding dipotassium salt of **14** (**14K**) was less soluble in water and did not give a homogeneous aqueous solution at 10^{-6} M concentration. Thus, we examined the photophysical properties for **9aK** in MeOH and water. The absorption spectrum for **9aK** in water showed its peak at 350 nm, where extinction coefficient was 2.5×10^4 cm^{-1} M^{-1}. An aqueous solution of **9aK** exhibited strong fluorescence upon excitation at 350 nm with the fluorescence peak significantly red-shifted to 471 nm (red dotted line in red in Figure 3). The fluorescence was stable

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in water, and no decay was observed. The quantum yield of **9aK** in water was estimated to be 0.15.

Figure 4 shows the fluorescence intensity of **9aK** in the presence of several selected metal cations. Compound **9aK** was

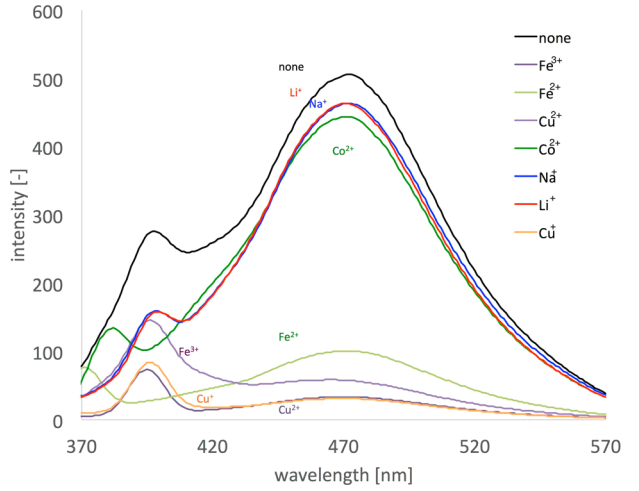

Figure 4. Fluorescence spectra for compound **9aK** in the presence of various transition metal salts. Fluorescent spectra were measured in 1 × 10^{-6} M solution in water upon excitation at 350 nm UV light.

observed to exhibit strong fluorescence in the presence of most alkali metal salts such as sodium and lithium cation. On the other hand, its fluorescence intensity decreased to varying degrees in the presence of transition-metal cations in an aqueous solution. For example, the addition of Cu^{2+} and Fe^{3+} significantly reduced the fluorescence intensity, and almost no fluorescence was observed upon irradiation at 350 nm. Recently, the presence of Cu^{2+} in BINOL solution selectively quenches its fluorescence.[19] Since compound **9aK** has a similar structure, the presence of transition metal cations such as Cu^{2+} and Fe^{3+} may cause a similar effect to quench the fluorescence. The presence of other metal cations such as Ag^{+}, Mg^{2+}, Ca^{2+}, Mn^{2+}, Zn^{2+}, Ni^{2+}, Pd^{2+}, Al^{3+}, and Cr^{3+} partially reduced the fluorescence intensity.

Preliminary modification of **1a** for pursuing the possibility of the application to a bioimaging material was examined. Acetal **7a** was treated with base and propargyl bromide to afford the propargylic ether **15** in 85% yield. Subsequent treatment with HCl led the removal of the acetal group to provide 2,2′-dihydro-5,5′-dipropargyloxy biaryl **16** in 90% yield. A click reaction with an azide-tethered amino acids was performed to synthesize the amino acid-modified biaryl **17** in 24% yield (Scheme 3).[20] The conversion of dipotassium salt **17K** was achieved by treatment with 2 equiv of KOH in MeOH. Compound **17K** was observed to be sufficiently soluble in water and exhibited strong fluorescence upon UV excitation at 365 nm by a black light (Figure 5). The quantum yield of **17K** in water upon excitation at 350 nm was measured at 1 × 10^{-5} M concentration and estimated to be 0.21. The fluorescence peak was observed at 470 nm, which is almost the same as that observed for **9aK** in water. Thus, these dihydroxyl biaryls have a good possibility of being a useful material as a bioimaging agents.

In conclusion, we have successfully synthesized new water-soluble fluorescent dyes based on sulfanyl hydroquinone dimers. The preparation of the compounds is achieved in a few steps with easy manipulation. Efficient protection of half of

Scheme 3

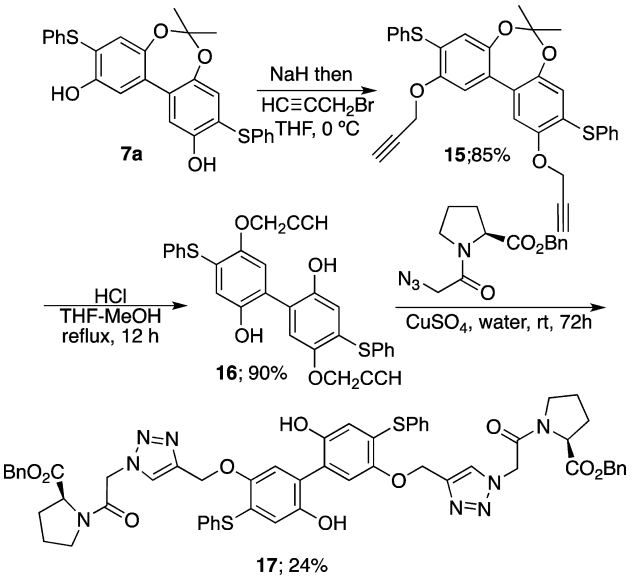

Figure 5. Fluorescence of **17K** in water (10^{-4} M) upon excitation at 365 nm.

the hydroxyl groups was readily achieved via the corresponding acetal and provided compounds with sufficient water-solubility and good stability in an aqueous solution. Relatively high quantum yields were observed in MeOH, and strong fluorescence was achieved for the protected derivatives in an aqueous solution. Fluorescent properties were not affected by the presence of alkali metal ions but strongly influenced by the presence of transition-metal cations such as Fe^{3+} and Cu^{2+}. An installation of biologically active molecule such as amino acids was successfully achieved using click chemistry with propargylic derivatives. Further application and investigation of these disulfanylhydroquinone dimers including their possible use as bioimaging agents is now underway in our laboratory.

EXPERIMENTAL SECTION

Preparation of 2-(Phenylthio)benzene-1,4-diol (2a). A mixture of thiophenol (5.2 mL, 50.5 mmol) and 1,4-benzoquinone (5404.5 mg, 50.0 mmol) in MeOH (100 mL) was stirred at room temperature for 6 h. The reaction was monitored by TLC. MeOH was removed under reduced pressure, and the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 10:1 then 3:1 v/v) to give **2a** in 99% yield (10.7676 g, 49.3 mmol): yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.17 (d, J = 7.9 Hz, 1H), 7.14−7.02 (m, 3H), 6.94 (d, J = 3.0 Hz, 1H), 6.89 (d, J = 8.9 Hz, 1H), 6.81 (dd, J = 8.7, 3.0 Hz, 1H), 6.02 (br, 1H), 4.43 (br, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.4, 149.3, 135.6, 129.4 (2C), 127.2 (2C), 126.4, 122.4, 119.7,

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116.8, 116.3; HRMS (ESI-TOF) calcd for $C_{12}H_{10}NaO_2S$ 241.0299 [M + Na^+], found 241.0295.

Preparation of 2-((2-Bromophenyl)thio)benzene-1,4-diol (2b). A mixture of 2-bromothiophenol (3.8 mL, 31.5 mmol) and 1,4-benzoquinone (3242.1 mg, 30.0 mmol) in MeOH (50 mL) was stirred at room temperature for 6 h. The reaction was monitored by TLC. MeOH was removed in vacuo, and the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 10:1 then 3:1 v/v) to give **2b** in 93% yield (8276.6 mg, 27.9 mmol): white solid; mp 126.5−127.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.53 (dd, J = 7.9, 1.4 Hz, 1H), 7.12 (td, J = 7.7, 1.4 Hz, 1H), 7.05−6.99 (m, 2H), 6.98 (s, 1H), 6.93 (dd, J = 8.8, 3.0 Hz, 1H), 6.64 (dd, J = 8.0, 1.6 Hz, 1H), 6.00 (s, 1H), 4.74 (s, 1H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 150.9 (2C), 138.3, 133.3, 128.7, 128.7, 127.5, 121.6, 121.2, 118.5, 117.4, 116.8; HRMS (ESI-TOF) calcd for $C_{12}H_9BrNaO_2S$ 318.9404 [M + Na^+], found 318.9397.

Preparation of 2-((3-Bromophenyl)thio)benzene-1,4-diol (2c). A mixture of 3-bromothiophenol (3.9 mL, 33.0 mmol) and 1,4-benzoquinone (3242.0 mg, 30.0 mmol) in MeOH (50 mL) was stirred at room temperature for 12 h. The reaction was monitored by TLC. MeOH was removed in vacuo, and the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 10:1 then 3:1 v/v) to give **2c** in 97% yield (8686.7 mg, 29.2 mmol): white solid; mp 109−110 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29 (dt, J = 7.9, 1.3 Hz, 1H), 7.22 (t, J = 1.8 Hz, 1H), 7.10 (t, J = 7.9 Hz, 1H), 7.01−6.98 (m, 2H), 6.97 (s, 1H), 6.91 (dd, J = 8.9, 2.9 Hz, 1H), 6.00 (s, 1H), 4.57 (s, 1H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 150.8, 150.4, 139.8, 131.5, 130.4, 129.2, 127.6, 122.7, 120.5, 118.0, 117.8, 117.3; HRMS (ESI-TOF) calcd for $C_{12}H_9BrNaO_2S$ 318.9404 [M + Na^+], found 318.9404.

Preparation of 2-((4-Bromophenyl)thio)benzene-1,4-diol (2d). A mixture of 4-bromothiophenol (1039.7 mg, 5.5 mmol) and 1,4-benzoquinone (539.9 mg, 5.0 mmol) in MeOH (10 mL) was stirred at room temperature for 18 h. The reaction was monitored by TLC. MeOH was removed in vacuo, and the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 10:1 then 3:1 v/v) to give **2d** in 98% yield (1458.3 mg, 4.9 mmol): yellow solid; mp 115.5−116.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 (d, J = 7.6 Hz, 2H), 7.00−6.95 (m, 3H), 6.95 (d, J = 4.8 1H), 6.88 (dd, J = 8.8, 3.0 Hz, 1H), 6.02 (s, 1H), 4.74 (s, 1H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 150.8, 149.8, 136.0, 132.5 (2C), 131.5 (2C), 119.8, 119.6, 119.1, 117.3, 117.1; HRMS (ESI-TOF) calcd for $C_{12}H_9BrNaO_2S$ 318.9404 [M + Na^+], found 318.9405.

Preparation of 2-((4-Chlorophenyl)thio)benzene-1,4-diol (2e). A mixture of 4-chlorothiophenol (4355.0 mg, 30.3 mmol) and 1,4-benzoquinone (3243.5 mg, 30.0 mmol) in MeOH (50 mL) was stirred at room temperature for 6 h. The reaction was monitored by TLC. MeOH was removed in vacuo, and the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 10:1 then 3:1 v/v) to give **2e** in 87% yield (6602.4 mg, 26.1 mmol): white solid; mp 119.5−120 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.22 (d, J = 8.6 Hz, 1H), 7.04 (d, J = 9.0 Hz, 2H), 6.98 (d, J = 3.0 Hz, 1H), 6.96 (d, J = 8.8 Hz, 1H), 6.89 (dd, J = 8.9, 3.0 Hz, 1H), 6.01 (s, 1H), 4.55 (s, 1H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 150.9, 149.8, 135.4, 131.6 (2C), 131.4 (2C), 129.7, 119.5, 119.4, 117.2, 117.1; HRMS (ESI-TOF) calcd for $C_{12}H_9ClNaO_2S$ 274.9910 [M + Na^+], found 274.9906.

Preparation of 2-((2-Methylphenyl)thio)benzene-1,4-diol (2f). A mixture of *o*-thiocresol (3.7 mL, 31.5 mmol) and 1,4-benzoquinone (3242.7 mg, 30.0 mmol) in MeOH (50 mL) was stirred at room temperature for 6 h. The reaction was monitored by TLC. MeOH was removed in vacuo, and the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 10:1 then 3:1 v/v) to give **2f** in 100% yield (6954.4 mg, 29.9 mmol): white solid; mp 51.5−52.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.17 (d, J = 7.9 Hz, 1H), 7.12−7.00 (m, 2H), 6.99−6.91 (m, 2H), 6.87 (dd, J = 8.7, 3.0 Hz, 1H), 6.76 (dd, J = 7.8, 1.4 Hz, 1H), 5.97 (s, 1H), 4.64 (s, 1H), 2.43 (s, 3H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 150.7, 148.5, 138.9, 133.6, 131.7, 130.7, 127.6, 127.0, 120.8, 117.1, 116.4, 115.3, 20.1; HRMS (ESI-TOF) calcd for $C_{13}H_{12}NaO_2S$ 255.0456 [M + Na^+], found 255.0454.

Preparation of 2-((4-Methylphenyl)thio)benzene-1,4-diol (2g). A mixture of *p*-thiocresol (2653.2 mg, 21.4 mmol) and 1,4-benzoquinone (2162.8 mg, 20.0 mmol) in MeOH (30 mL) was stirred at room temperature for 2 h. The reaction was monitored by TLC. MeOH was removed in vacuo, and the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 10:1 then 3:1 v/v) to give **2g** in 96% yield (4458.2 mg, 19.2 mmol): yellow solid; mp 63.5−64.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08−7.04 (m, 4H), 6.98 (d, J = 3.0 Hz, 1H), 6.93 (d, J = 8.8 Hz, 1H), 6.84 (dd, J = 8.8, 3.0 Hz, 1H), 6.11 (s, 1H), 4.63 (s, 1H), 2.29 (s, 3H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 151.0, 148.5, 137.4, 132.1(2C), 131.3, 130.7 (2C), 122.6, 117.5, 116.7, 115.5, 21.2; HRMS (ESI-TOF) calcd for $C_{13}H_{12}NaO_2S$ 255.0456 [M + Na^+], found 255.0460.

Preparation of 2-(Naphthalen-2-ylthio)benzene-1,4-diol (2h). A mixture of 2-thionaphthol (810.3 mg, 5.06 mmol) and 1,4-benzoquinone (538.5 mg, 4.98 mmol) in MeOH (10 mL) was stirred at room temperature for 3 h. MeOH was removed in vacuo, and the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 10:1 then 3:1 v/v) to give **2h** in 24% yield (301.2 mg, 1.20 mmol): yellow solid; mp 62.5−62 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.76 (d, J = 8.0 Hz, 1H), 7.72 (dd, J = 8.8, 1.9 Hz, 1H), 7.66 (d, J = 7.8 Hz, 1H), 7.53 (s, 1H), 7.49−7.39 (m, 2H), 7.23 (dt, J = 8.7, 2.1 Hz, 1H), 7.04 (t, J = 2.6 Hz, 1H), 6.98 (dd, J = 8.8, 2.1 Hz, 1H), 6.90 (dt, J = 8.8, 2.6 Hz, 1H), 6.12 (d, J = 2.1 Hz, 1H), 4.58 (d, J = 2.0 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 150.4, 148.7, 133.5, 132.6, 131.8, 128.8, 128.6, 128.2, 127.7, 127.2, 126.8, 126.2, 120.4, 118.0, 116.4, 115.8; HRMS (ESI-TOF) calcd for $C_{16}H_{12}NaO_2S$ 291.0456 [M + Na^+], found 291.0457.

Preparation of 2-(Pyridin-2-ylthio)benzene-1,4-diol (2i). A mixture of 2-mercaptopyridine (564.1 mg, 5.05 mmol) and 1,4-benzoquinone (536.2 mg, 5.0 mmol) in MeOH (50 mL) was stirred at room temperature for 3.5 h. The reaction was monitored by TLC. MeOH was removed under reduced pressure, and the residue was subjected to flash chromatography (silica gel/EtOAc) to give **2i** in 97% yield (1060.0 mg, 4.83 mmol): yellow solid; mp 91.5−92.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.41 (d, J = 4.4 Hz, 1H), 7.59 (td, J = 7.8, 1.8 Hz, 1H), 7.23 (d, J = 7.9 Hz, 1H), 7.12 (dd, J = 7.6, 5.1 Hz, 1H), 7.07−6.95 (m, 2H), 6.85 (dd, J = 8.8, 2.9 Hz, 1H), 4.98−4.46 (br, 1H), 3.80−3.38 (br, 1H); ^{13}C NMR (126 MHz, CD_3OD) δ 162.5, 152.8, 152.1, 149.9, 138.8, 123.4, 122.4, 121.3, 120.1, 118.4, 116.9; HRMS (ESI-TOF) calcd for $C_{11}H_9NNaO_2S$ 242.0252 [M + Na^+], found 242.0257.

Preparation of 2-Phenylsulfanyl-1,4-dimethoxybenzene (3a). Under a nitrogen atmosphere, a solution of **2a** (4365.4 mg, 20.0 mmol) in dry THF (100 mL) was added to a suspension of NaH (2456.9 mg, 60%, 61.4 mmol) in THF (100 mL) over 15 min at 0 °C. MeI (12.5 mL, 200 mmol) was added to the reaction mixture at 0 °C, and the resulting solution was stirred at the same temperature for an additional 15 min and at room temperature for 24 h. Saturated NH_4Claq (100 mL) was added, and THF was removed by rotary evaporator. The aqueous solution extracted with EtOAc (40 mL × 3). The organic phases were combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **3a** in 93% yield (4578.9 mg, 18.6 mmol): yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32 (d, J = 7.5 Hz, 2H), 7.27−7.19 (m, 3H), 6.76 (d, J = 8.8 Hz, 1H), 6.66 (dd, J = 8.9, 3.0 Hz, 1H), 6.53 (d, J = 3.0 Hz, 1H), 3.76 (s, 3H), 3.59 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.0, 151.5, 133.8, 132.2 (2C), 129.3 (2C), 127.5, 125.8, 116.8, 112.5, 111.9, 56.5, 55.6; HRMS (ESI-TOF) calcd for $C_{14}H_{14}NaO_2$ 269.0612 [M + Na^+], found 269.0615.

Preparation of 2-(2-Bromophenyl)sulfanyl-1,4-dimethoxybenzene (3b). Under a nitrogen atmosphere, a solution of **2b** (7429.4 mg, 25.0 mmol) in dry THF (50 mL) was added to a suspension of NaH (3174.5 mg, 60%, 79.4 mmol) in THF (50 mL) over 15 min at 0 °C. MeI (7.8 mL, 125.0 mmol) was added to the reaction mixture at 0 °C, and the resulting solution was stirred at the same temperature for an additional 15 min and at room temperature for 12 h. Saturated NH_4Cl aq (50 mL) was added, and THF was removed by using a rotary evaporator. The aqueous solution extracted with EtOAc (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the

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organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **3b** in 98% yield (7938.5 mg, 24.4 mmol): yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 (d, J = 7.9 Hz, 1H), 7.16 (t, J = 7.2 Hz, 1H), 7.05 (t, J = 6.9 Hz, 1H), 6.96 (dd, J = 7.9, 1.4 Hz, 1H), 6.91−6.86 (m, 2H), 6.82 (d, J = 2.6 Hz, 1H), 3.80 (s, 3H), 3.72 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.0, 153.1, 137.1, 133.0, 130.3, 127.8, 127.5, 123.8, 122.0, 119.4, 114.9, 112.4, 56.6, 55.7; HRMS (ESI-TOF) calcd for $C_{14}H_{13}BrNaO_2S$ 346.9717 [M + Na^+], found 346.9726.

Preparation of 2-(3-Bromophenyl)sulfanyl-1,4-dimethoxybenzene (3c). Under a nitrogen atmosphere, a solution of **2c** (7429.0 mg, 25.0 mmol) in dry THF (130 mL) was added to a suspension of NaH (3161.8 mg, 60%, 79.0 mmol) in THF (100 mL) over 15 min at 0 °C. MeI (7.8 mL, 125.0 mmol) was added to the reaction mixture at 0 °C, and the resulting solution was stirred at the same temperature for an additional 15 min and at room temperature for 12 h. Saturated NH_4Cl aq (50 mL) was added, and THF was removed by use of a rotary evaporator. The aqueous solution extracted with EtOAc (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **3c** in 81% yield (6569.4 mg, 20.2 mmol): yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 (t, J = 1.8 Hz, 1H), 7.34 (ddd, J = 7.9, 1.9, 1.1 Hz, 1H), 7.21 (dt, J = 7.8, 1.4 Hz, 1H), 7.14 (t, J = 7.9 Hz, 1H), 6.86 (d, J = 8.9 Hz, 1H), 6.82 (dd, J = 8.9, 2.9 Hz, 1H), 6.76 (d, J = 2.9 Hz, 1H), 3.80 (s, 3H), 3.71 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 153.9, 152.3, 137.6, 132.6, 130.3, 129.7, 128.7, 123.0, 122.8, 118.6, 114.1, 112.2, 56.4, 55.6; HRMS (ESI-TOF) calcd for $C_{14}H_{13}BrNaO_2S$ 346.9717 [M + Na^+], found 346.9720.

Preparation of 2-(2-Bromophenyl)sulfanyl-1,4-dimethoxybenzene (3d). Under a nitrogen atmosphere, a solution of **2d** (537.2 mg, 1.8 mmol) in dry THF (30 mL) was added to a suspension of NaH (229.0 mg, 60%, 5.4 mmol) in THF (30 mL) over 15 min at 0 °C. MeI (1.1 mL, 18.0 mmol) was added to the reaction mixture at 0 °C, and the resulting solution was stirred at the same temperature for an additional 15 min and at room temperature for 3.5 h. Saturated NH_4Cl aq (20 mL) was added, and THF was removed by use of a rotary evaporator. The aqueous solution extracted with EtOAc (20 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **3d** in 96% yield (561.4 mg, 1.7 mmol): yellow solid; mp 47.5−48.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 (d, J = 8.6 Hz, 2H), 7.19 (d, J = 8.6 Hz, 2H), 6.84 (d, J = 8.9 Hz, 1H), 6.78 (dd, J = 8.9, 3.0 Hz, 1H), 6.67 (d, J = 3.0 Hz, 1H), 3.81 (s, 3H), 3.70 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.0, 152.0, 134.0, 132.7 (2C), 132.3 (2C), 124.2, 121.2, 117.9, 113.4, 112.1, 56.6, 55.8; HRMS (ESI-TOF) calcd for $C_{14}H_{13}BrNaO_2S$ 346.9717 [M + Na^+], found 346.9717.

Preparation of 2-(4-Chlorophenyl)sulfanyl-1,4-dimethoxybenzene (3e). Under a nitrogen atmosphere, a solution of **2e** (6309.4 mg, 25.0 mmol) in dry THF (50 mL) was added to a suspension of NaH (3217.6 mg, 60%, 80.4 mmol) in THF (50 mL) over 15 min at 0 °C. MeI (7.8 mL, 125.0 mmol) was added to the reaction mixture at 0 °C, and the resulting solution was stirred at the same temperature for an additional 15 min and at room temperature for 12 h. Saturated NH_4Claq (50 mL) was added, and THF was removed by use of a rotary evaporator. The aqueous solution extracted with EtOAc (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **3e** in 98% yield (6850.8 mg, 24.4 mmol): yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.27−7.25 (m, 4H), 6.83 (d, J = 8.9 Hz, 1H), 6.77 (dd, J = 8.9, 3.0 Hz, 1H), 6.64 (d, J = 3.0 Hz, 1H), 3.81 (s, 3H), 3.69 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.0, 151.8, 133.0, 132.7 (2C), 129.4 (2C), 124.6, 117.6, 113.2, 112.0, 105.4, 56.5, 55.7; HRMS (ESI-TOF) calcd for $C_{14}H_{13}ClNaO_2S$ 303.0223 [M + Na^+], found 303.0220.

Preparation of 2-(2-Methylphenyl)sulfanyl-1,4-dimethoxybenzene (3f). Under a nitrogen atmosphere, a solution of **2f** (5807.5 g, 26.0 mmol) in dry THF (50 mL) was added to a suspension of NaH (3017.2 mg, 60%, 75.4 mmol) in THF (50 mL) over 15 min at 0 °C. MeI (7.8 mL, 125.0 mmol) was added to the reaction mixture at 0 °C, and the resulting solution was stirred at the same temperature for an additional 15 min and at room temperature for 12 h. Saturated NH_4Cl aq (50 mL) was added, and THF was removed by use of a rotary evaporator. The aqueous solution extracted with EtOAc (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **3f** in 91% yield (5935.0 mg, 22.8 mmol): yellow liquid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35 (d, J = 7.6 Hz, 1H), 7.31−7.22 (m, 2H), 7.16 (t, J = 7.4 Hz, 1H), 6.82 (d, J = 8.7 Hz, 1H), 6.67 (dd, J = 8.7, 3.0 Hz, 1H), 6.31 (d, J = 3.0 Hz, 1H), 3.86 (s, 3H), 3.63 (s, 3H), 2.40 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.2, 150.9, 141.3, 134.4, 131.7, 130.8, 128.6, 127.0, 126.4, 115.1, 111.6, 111.2, 56.6, 55.7, 20.7; HRMS (ESI-TOF) calcd for $C_{15}H_{16}NaO_2S$ 283.0769 [M + Na^+], found 283.0768.

Preparation of 2-(4-Methylphenyl)sulfanyl-1,4-dimethoxybenzene (3g). Under a nitrogen atmosphere, a solution of **2g** (1108.1 mg, 4.8 mmol) in dry THF (25 mL) was added to a suspension of NaH (800.0 mg, 60%, 20.0 mmol) in THF (25 mL) over 15 min at 0 °C. MeI (1.5 mL, 23.9 mmol) was added to the reaction mixture at 0 °C, and the resulting solution was stirred at the same temperature for an additional 15 min and at room temperature for 12 h. Saturated NH_4Cl aq (20 mL) was added, and THF was removed by use of a rotary evaporator. The aqueous solution extracted with EtOAc (20 mL × 3). The organic phases were combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 9:1 v/v) to give **3g** in 85% yield (1048.7 mg, 4.03 mmol): white solid; mp 68.0−68.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34 (d, J = 8.1 Hz, 2H), 7.16 (d, J = 8.4 Hz, 2H), 6.79 (d, J = 8.8 Hz, 1H), 6.66 (dd, J = 8.8, 3.0 Hz, 1H), 6.46 (d, J = 3.0 Hz, 1H), 3.84 (s, 3H), 3.64 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.2, 150.8, 138.2, 133.6 (2C), 130.4 (2C), 129.3, 127.6, 115.7, 111.7, 111.3, 56.6, 55.7, 21.3; HRMS (ESI-TOF) calcd for $C_{15}H_{16}NaO_2S$ 283.0769 [M + Na^+], found 283.0762.

Preparation of 2-(2-Naphthyl)sulfanyl-1,4-dimethoxybenzene (3h). Author: Under a nitrogen atmosphere, a solution of **2h** (199.1 mg, 0.74 mmol) in dry THF (10 mL) was added to a suspension of NaH (138.4 mg, 60%, 3.46 mmol) in THF (5 mL) over 15 min at 0 °C. 18-Crown-6 ether (785.1 mg, 3.0 mmol) and MeI (709.7 mg, 5.0 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 12 h. Saturated NH_4Claq (10 mL) was added. The resulting biphasic mixture was extracted with EtOAc (20 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **3h** in 93% yield (204.5 mg, 0.69 mmol): white solid; mp 31.5−32.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.88 (s, 1H), 7.84−7.72 (m, 3H), 7.51−7.46 (m, 2H), 7.44 (dd, J = 8.5, 1.8 Hz, 1H), 6.86 (d, J = 8.9 Hz, 1H), 6.76 (dd, J = 8.8, 2.9 Hz, 1H), 6.65 (d, J = 2.9 Hz, 1H), 3.84 (s, 3H), 3.64 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.0, 151.6, 133.9, 132.5, 131.3, 130.9, 129.3, 128.9, 127.7, 127.5, 126.5, 126.3, 125.7, 117.0, 112.6, 111.9, 56.5, 55.6; HRMS (ESI-TOF) calcd for $C_{18}H_{16}NaO_2S$ 319.0769 [M + Na^+], found 319.0772.

Preparation of 2-((2,5-Dimethoxyphenyl)thio)pyridine (3i). Under a nitrogen atmosphere, a solution of **2i** (648.3 mg, 3.0 mmol) in dry THF (10 mL) was added to a suspension of NaH (483.7 mg, 60%, 12.0 mmol) in THF (10 mL) over 15 min at 0 °C. 18-Crown-6 ether (785.1 mg, 3.0 mmol) and MeI (0.93 mL, 15.0 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 12 h. Saturated NH_4Claq (20 mL) was added. The resulting biphasic mixture was extracted with EtOAc (30 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4.

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After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **3i** in 66% yield (485.9 mg, 1.96 mmol): yellow solid; mp 47.5−48.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.41 (dd, J = 3.9, 1.0 Hz, 1H), 7.43 (td, J = 7.8, 1.9 Hz, 1H), 7.14 (d, J = 2.9 Hz, 1H), 7.03−6.89 (m, 3H), 6.86 (dt, J = 8.2, 1.0 Hz, 1H), 3.76 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 160.6, 154.1, 153.9, 149.4, 136.7, 121.6, 121.3, 119.9, 119.7, 116.6, 112.9, 56.7, 55.9; HRMS (ESI-TOF) calcd for $C_{13}H_{13}NNaO_2S$ 270.0565 [M + Na$^+$], found 270.0571.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis-(phenylsulfanyl)biphenyl (4a). Compound **3a** (9018.1 mg, 36.6 mmol) in CH_2Cl_2 (200 mL) was added to a solution of $FeCl_3$ (17811.8 mg, 109.8 mmol) in CH_3NO_2 (200 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (350 mL) and water (350 mL) were added to the reaction mixture, and the organic phase was separated from a biphasic resulting mixture. The aqueous phase was extracted with CH_2Cl_2 (50 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure, giving **4a** in 94% yield (8623.3 mg, 17.1 mmol): brown solid; mp 149.0−149.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42 (d, J = 7.1 Hz, 4H), 7.37−7.27 (m, 6H), 6.85 (s, 2H), 6.71 (s, 2H), 3.83 (s, 6H), 3.56 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.4 (4C), 134.5 (2C), 131.7 (4C), 129.3 (4C), 127.4 (2C), 126.8 (2C), 123.9 (2C), 115.2 (2C), 114.7 (2C), 56.7 (2C), 56.5 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{26}NaO_4S_2$ 513.1170 [M + Na$^+$], found 513.1164; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 325 (22) nm.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis((2-bromophenyl)sulfanyl)biphenyl (4b). Compound **3b** (7480.1 mg, 23.0 mmol) in CH_2Cl_2 (100 mL) was added to a solution of $FeCl_3$ (11176.8 mg, 72.2 mmol) in CH_3NO_2 (100 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (250 mL) and water (250 mL) were added to the reaction mixture, and the organic phase was separated from a biphasic resulting mixture. The aqueous phase was extracted with CH_2Cl_2 (50 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure, giving **4b** in 97% yield (7264.4 mg, 11.2 mmol): brown solid; mp 167.5−168.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 (dd, J = 7.9, 1.3 Hz, 2H), 7.18 (td, J = 7.6, 1.4 Hz, 2H), 7.05 (td, J = 7.6, 1.6 Hz, 2H), 6.99 (dd, J = 7.9, 1.6 Hz, 2H), 6.96 (s, 2H), 6.95 (s, 2H), 3.82 (s, 6H), 3.68 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 153.0 (2C), 151.3 (2C), 137.6 (2C), 133.0 (2C), 129.6 (2C), 128.6 (2C), 127.7 (2C), 127.2 (2C), 123.1 (2C), 120.3 (2C), 117.9 (2C), 115.1 (2C), 56.6 (2C), 56.5 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{24}Br_2NaO_4S_2$ 668.9381 [M + Na$^+$], found 668.9371.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis((3-bromophenyl)sulfanyl)biphenyl (4c). Compound **3c** (6569.4 mg, 20.0 mmol) in CH_2Cl_2 (50 mL) was added to a solution of $FeCl_3$ (9605.0 mg, 59.2 mmol) in CH_3NO_2 (50 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (200 mL) and water (200 mL) were added to the reaction mixture, and the organic phase was separated from the resulting biphasic mixture. The aqueous phase was extracted with CH_2Cl_2 (50 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure, giving **4c** in 99% yield (6423.9 mg, 9.91 mmol): brown solid; mp 109.5−110.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 (t, J = 1.8 Hz, 2H), 7.34 (ddd, J = 7.9, 1.9, 1.0 Hz, 2H), 7.26 (ddd, J = 8.0, 1.8, 1.0 Hz, 2H), 7.16 (t, J = 7.9 Hz, 2H), 6.90 (s, 2H), 6.89 (s, 2H), 3.82 (s, 6H), 3.65 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.3 (2C), 151.3 (2C), 138.1 (2C), 132.3 (2C), 130.3 (2C), 129.6 (2C), 128.4 (2C), 128.1 (2C), 122.9 (2C), 121.5 (2C), 116.9 (2C), 115.0 (2C), 56.6 (2C), 56.5 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{24}Br_2NaO_4S_2$ 668.9381 [M + Na$^+$], found 668.9380.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis((4-bromophenyl)sulfanyl)biphenyl (4d). Compound **3d** (742.6 mg, 2.3 mmol) in CH_2Cl_2 (10 mL) was added to a solution of $FeCl_3$ (1460.3 mg, 9.0 mmol) in CH_3NO_2 (10 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (50 mL) and water (50 mL) were added to the reaction mixture, and the organic phase was separated from a biphasic resulting mixture. The aqueous phase was extracted with CH_2Cl_2 (20 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure, giving **4d** in 98% yield (735.6 mg, 1.13 mmol): brown solid; mp 125.0−125.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43 (d, J = 8.4 Hz, 4H), 7.23 (d, J = 8.5 Hz, 4H), 6.87 (s, 2H), 6.83 (s, 2H), 3.81 (s, 6H), 3.63 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.8 (2C), 151.2 (2C), 134.4 (2C), 132.0 (4C), 131.9 (4C), 127.5 (2C), 122.3 (2C), 120.6 (2C), 116.1 (2C), 114.8 (2C), 56.6 (2C), 56.4 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{24}Br_2NaO_4S_2$ 668.9381 [M + Na$^+$], found 668.9368.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis((4-chlorophenyl)sulfanyl)biphenyl (4e). Compound **3e** (6457.7 mg, 23.0 mmol) in CH_2Cl_2 (100 mL) was added to a solution of $FeCl_3$ (11471.2 mg, 70.7 mmol) in CH_3NO_2 (100 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (300 mL) and water (300 mL) were added to the reaction mixture, and the organic phase was separated from a biphasic resulting mixture. The aqueous phase was extracted with CH_2Cl_2 (50 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure, giving **4e** in 100% yield (6486.7 mg, 11.6 mmol): brown solid; mp 112.0−112.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 (d, J = 11.0 Hz, 4H), 7.28 (d, J = 11.0 Hz, 4H), 6.85 (s, 2H), 6.79 (s, 2H), 3.81 (s, 6H), 3.61 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.8 (2C), 151.3 (2C), 133.6 (2C), 133.0 (2C), 132.1 (4C), 129.3 (4C), 127.4 (2C), 122.8 (2C), 115.9 (2C), 114.8 (2C), 56.6 (2C), 56.5 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{24}Cl_2NaO_4S_2$ 581.0391 [M + Na$^+$], found 581.0393.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis((2-methylphenyl)sulfanyl)biphenyl (4f). Compound **3f** (5207.0 mg, 20.0 mmol) in CH_2Cl_2 (100 mL) was added to a solution of $FeCl_3$ (9762.7 mg, 60.2 mmol) in CH_3NO_2 (100 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (250 mL) and water (250 mL) were added to the reaction mixture, and the organic phase was separated from a biphasic resulting mixture. The aqueous phase was extracted with CH_2Cl_2 (50 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure, giving **4f** in 100% yield (5232.7 mg, 10.0 mmol): brown solid; mp 57.0−57.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34 (dd, J = 7.7, 1.2 Hz, 2H), 7.28 (d, J = 6.5 Hz, 2H), 7.23 (dd, J = 7.5, 1.3 Hz, 2H), 7.17 (td, J = 7.5, 1.3 Hz, 2H), 6.84 (s, 2H), 6.44 (s, 2H), 3.85 (s, 6H), 3.49 (s, 6H), 2.45 (s, 6H).; ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.6 (2C), 151.0 (2C), 140.6 (2C), 133.6 (2C), 132.6 (2C), 130.8 (2C), 128.3 (2C), 127.0 (2C), 126.1 (2C), 124.4 (2C), 114.6 (2C), 113.7 (2C), 56.9 (2C), 56.7 (2C), 20.8 (2C); HRMS (ESI-TOF) calcd for $C_{30}H_{30}NaO_4S_2$ 541.1483 [M + Na$^+$], found 541.1503.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis((4-methylphenyl)sulfanyl)biphenyl (4g). Compound **3g** (2597.3 mg, 10.0 mmol) in CH_2Cl_2 (50 mL) was added to a solution of $FeCl_3$ (5222.8 mg, 32.2 mmol) in CH_3NO_2 (50 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (150 mL) and water (150 mL) were added to the reaction mixture, and the organic phase was separated from a biphasic resulting mixture. The aqueous phase was extracted with CH_2Cl_2 (50 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure, giving **4g** in 99% yield (2562.3 mg, 4.94 mmol): brown solid; mp 81.5−82.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 (d, J = 7.9 Hz, 4H), 7.18 (d, J = 7.8 Hz, 4H), 6.84 (s, 2H), 6.63 (s, 2H), 3.85 (s, 6H), 3.54 (s, 6H), 2.37 (s, 6H).; ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.4 (2C), 150.8 (2C), 137.9 (2C) (2C), 132.9 (4C), 130.2 (4C), 130.0 (2C), 126.2 (2C), 125.4 (2C), 114.6 (2C), 114.1 (2C), 56.7 (2C), 56.6 (2C), 21.3 (2C); HRMS (ESI-TOF) calcd for $C_{30}H_{30}NaO_4S_2$ 541.1483 [M + Na$^+$], found 541.1498.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis((2-naphthyl)-sulfanyl)biphenyl (4h). Compound **3h** (2330.9 mg, 7.86 mmol) in

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CH_2Cl_2 (100 mL) was added to a solution of $FeCl_3$ (3993.3 mg, 24.0 mmol) in CH_3NO_2 (100 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (100 mL) and water (100 mL) were added to the reaction mixture, and the organic phase was separated from a biphasic resulting mixture. The aqueous phase was extracted with CH_2Cl_2 (10 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 3:1 then 1:1 v/v) to give **4h** in 100% yield (2321.6 mg, 3.93 mmol): brown solid; mp 90−91 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, J = 1.7 Hz, 2H), 7.72−7.57 (m, 6H), 7.44−7.26 (m, 6H), 6.80 (s, 2H), 6.70 (s, 2H), 3.71 (s, 6H), 3.41 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.6 (2C), 151.5 (2C), 134.0 (2C), 132.4 (2C), 132.1 (2C), 130.2 (2C), 129.0 (2C), 128.8 (2C), 127.9 (2C), 127.5 (2C), 127.1 (2C), 126.6 (2C), 126.3 (2C), 123.9 (2C), 115.5 (2C), 114.9 (2C), 56.7 (2C), 56.5 (2C); HRMS (ESI-TOF) calcd for $C_{36}H_{30}NaO_4S_2$ 613.1483 [M + Na^+], found 613.1485.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis((2-pyridyl)-sulfanyl)biphenyl (4i). Compound **3i** (227.2 mg, 0.92 mmol) in CH_2Cl_2 (10 mL) was added to a solution of $FeCl_3$ (537.2 mg, 3.3 mmol) in CH_3NO_2 (10 mL) at room temperature, and the reaction mixture was stirred for 3 h. MeOH (10 mL) and water (10 mL) were added to the reaction mixture, and the organic phase was separated from a biphasic resulting mixture. The aqueous phase was extracted with CH_2Cl_2 (10 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 3:1 then 1:1 v/v) to give **4i** in 62% yield (140.1 mg, 0.28 mmol): orange solid; mp 144.5−145.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.44 (ddt, J = 4.8, 1.7, 0.9, 2H), 7.56−7.41 (m, 2H), 7.23 (s, 2H), 7.04−6.99 (m, 4H), 6.97 (s, 2H), 3.79 (d, J = 0.6, 6H), 3.75 (d, J = 0.6, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 160.6 (2C), 153.7 (2C), 151.2 (2C), 149.4 (2C), 136.8 (2C), 129.6 (2C), 121.4 (2C), 119.9 (2C), 119.6 (2C), 118.5 (2C), 115.3 (2C), 56.8 (2C), 56.6 (2C); HRMS (ESI-TOF) calcd for $C_{26}H_{24}N_2NaO_4S_2$ 515.1075 [M + Na^+], found 515.1059.

Preparation of 4,4′-Bis(phenylsulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1a). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 38.0 mL, 38.0 mmol) was added to a solution of **4a** (8389.8 mg, 17.1 mmol) in CH_2Cl_2 (100 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 12 h. MeOH (50.0 mL) was added slowly and the mixture concentrated under reduced pressure. Water was added and the mixture extracted with CH_2Cl_2 (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **1a** in 89% yield (6595.4 mg, 15.2 mmol): white solid; mp 160.5−161.0 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.25 (s, 2H), 8.77 (s, 2H), 7.37 (t, J = 7.6 Hz, 4H), 7.32−7.26 (m, 6H), 6.75 (s, 2H), 6.60 (s, 2H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 148.9 (2C), 147.8 (2C), 135.6 (2C), 130.7 (4C), 129.9 (4C), 127.3 (2C), 126.2 (2C), 119.7 (2C), 119.3 (2C), 118.5 (2C); HRMS (ESI-TOF) calcd for $C_{24}H_{18}NaO_4S_2$ 457.0544 [M + Na^+], found 457.05356; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 330 (20) nm.

Preparation of 4,4′-Bis((2-bromophenyl)sulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1b). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 50.0 mL, 50.0 mmol) was added to a solution of **4b** (6484.3 mg, 10.0 mmol) in CH_2Cl_2 (50 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 12 h. MeOH (50.0 mL) was added slowly and the mixture concentrated under reduced pressure. Water was added and the mixture extracted with CH_2Cl_2 (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 3:1 v/v) to give **1b** in 94% yield (5571.5 mg, 9.41 mmol): amber solid; mp 80.0−81.0 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.41 (s, 2H), 8.96 (s, 2H), 7.63 (d, J = 7.9 Hz, 2H), 7.30 (t, J = 7.6 Hz, 2H), 7.11 (t, J = 7.6 Hz, 2H), 6.80 (s, 2H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 150.0 (2C), 147.6 (2C), 137.6 (2C), 132.9 (2C), 128.8 (2C), 128.3 (2C), 127.5 (2C), 127.3 (2C), 121.6 (2C), 121.0 (2C), 118.6 (2C), 115.9 (2C); HRMS (ESI-TOF) calcd for $C_{24}H_{16}Br_2NaO_4S_2$ 612.8755 [M + Na^+], found 612.8758; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 330 (20) nm.

Preparation of 4,4′-Bis((3-bromophenyl)sulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1c). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 50.0 mL, 50.0 mmol) was added to a solution of **4c** (3232.9 mg, 5.0 mmol) in CH_2Cl_2 (50 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 12 h. MeOH (50.0 mL) was added slowly and the mixture concentrated under reduced pressure. Water was added and the mixture extracted with CH_2Cl_2 (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **1c** in 88% yield (2578.8 mg, 4.35 mmol): brown solid; mp 87.5−88.0 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.38 (s, 2H), 8.92 (s, 2H), 7.42 (d, J = 7.9 Hz, 2H), 7.35 (s, 3H), 7.30 (t, J = 7.9 Hz, 2H), 7.24 (d, J = 7.9 Hz, 2H), 6.85 (s, 2H), 6.78 (s, 2H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 149.9 (2C), 147.9 (2C), 139.5 (2C), 131.7 (2C), 130.9 (2C), 129.5 (2C), 128.1 (2C), 127.4 (2C), 122.8 (2C), 120.8 (2C), 118.9 (2C), 117.3 (2C); HRMS (ESI-TOF) calcd for $C_{24}H_{16}Br_2NaO_4S_2$ 612.8755 [M + Na^+], found 612.8748; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 331 (21) nm.

Preparation of 4,4′-Bis((4-bromophenyl)sulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1d). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 20.0 mL, 20.0 mmol) was added to a solution of **4d** (648.4 mg, 1.0 mmol) in CH_2Cl_2 (10 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 12 h. MeOH (30.0 mL) was added slowly and the mixture concentrated under reduced pressure. Water was added and the mixture extracted with CH_2Cl_2 (20 mL × 3). The organic phases were combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **1d** in 70% yield (414.3 mg, 0.70 mmol): brown solid; mp 79.0−79.5 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.31 (s, 2H), 8.82 (s, 2H), 7.55 (d, J = 8.5 Hz, 4H), 7.20 (d, J = 8.5 Hz, 4H), 6.78 (s, 2H), 6.67 (s, 2H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 149.2 (2C), 147.8 (2C), 135.7 (2C), 132.6 (4C), 131.9 (4C), 126.7 (2C), 120.0 (2C), 119.8 (2C), 118.7 (2C), 118.4 (2C); HRMS (ESI-TOF) calcd for $C_{24}H_{16}Br_2NaO_4S_2$ 612.8755 [M + Na^+], found 612.8750; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 330 (21) nm.

Preparation of 4,4′-Bis((4-chlorophenyl)sulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1e). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 50.0 mL, 50.0 mmol) was added to a solution of **4e** (5595.0 mg, 10.0 mmol) in CH_2Cl_2 (50 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 12 h. MeOH (50.0 mL) was added slowly and the mixture concentrated under reduced pressure. Water was added and the mixture extracted with CH_2Cl_2 (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **1e** in 80% yield (4011.1 mg, 7.97 mmol): brown solid; mp 80.0−80.2 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.28 (s, 2H), 8.78 (s, 2H), 7.39 (d, J = 8.5 Hz, 4H), 7.24 (d, J = 8.5 Hz, 4H), 6.75 (s, 2H), 6.62 (s, 2H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 149.2 (2C), 147.8 (2C), 135.1 (2C), 131.8 (4C), 129.8 (4C), 126.7 (2C), 119.7 (4C), 118.7 (4C); HRMS (ESI-TOF) calcd for $C_{24}H_{16}Cl_2NaO_4S_2$ 524.9765 [M + Na^+], found 524.9766; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 330 (18) nm.

Preparation of 4,4′-Bis((2-methylphenyl)sulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1f). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 80.0 mL, 80.0 mmol) was added to a solution of **4f** (4145.0 mg, 8.0 mmol) in CH_2Cl_2 (50 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 12 h. MeOH (50.0 mL) was added slowly and the mixture concentrated under reduced pressure. Water was added and the mixture extracted with CH_2Cl_2 (50 mL × 3). The organic phases were combined, washed with brine (100

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mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **1g** in 90% yield (3327.1 mg, 7.19 mmol): brown solid; mp 74.5−75.0 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.25 (s, 2H), 8.72 (s, 2H), 7.32 (d, J = 7.2 Hz, 3H), 7.26−7.19 (m, 8H), 6.78 (s, 2H), 6.41 (s, 2H), 2.36 (s, 6H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 148.5 (2C), 147.8 (2C), 139.4 (2C), 133.8 (2C), 132.3 (2C), 131.1 (2C), 128.1 (2C), 127.5 (2C), 125.5 (2C), 120.2 (2C), 118.4 (2C), 117.9 (2C), 20.5; HRMS (ESI-TOF) calcd for $C_{26}H_{22}NaO_4S_2$ 485.0857 [M + Na^+], found 485.0866; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 331 (25) nm.

Preparation of 4,4′-Bis((4-methylphenyl)sulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1g). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 45.0 mL, 45.0 mmol) was added to a solution of **4g** (1553.5 mg, 3.0 mmol) in CH_2Cl_2 (20 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 12 h. MeOH (30.0 mL) was added slowly and the mixture concentrated under reduced pressure. Water was added and the mixture extracted with CH_2Cl_2 (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **1g** in 81% yield (1138.3 mg, 2.46 mmol): brown solid; mp 72.0−72.5 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.15 (s, 2H), 8.62 (s, 2H), 7.20 (d, J = 8.1 Hz, 4H), 7.15 (d, J = 8.1 Hz, 4H), 6.65 (s, 2H), 6.40 (s, 2H), 2.24 (s, 6H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 148.1 (2C), 147.7 (2C), 137.5 (2C), 132.3 (4C), 131.0 (2C), 130.7 (4C), 125.4 (2C), 121.6 (2C), 118.2 (2C), 117.9 (2C), 21.2; HRMS (ESI-TOF) calcd for $C_{26}H_{22}NaO_4S_2$ 485.0857 [M + Na^+], found 485.0867; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 331 (24) nm.

Preparation of 4,4′-Bis(2-naphthylsulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1h). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 40.0 mL, 40.0 mmol) was added to a solution of **4h** (1185.4 mg, 2.01 mmol) in CH_2Cl_2 (10 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 17 h. MeOH (25.0 mL) was added slowly and the mixture concentrated under reduced pressure. Water was added and the mixture extracted with CH_2Cl_2 (50 mL × 3). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated in vacuo. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 7:1 then 3:1 v/v) to give **1h** in 77% yield (823.0 mg, 1.54 mmol): brown solid; mp 159−160 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 9.28 (s, 2H), 8.72 (s, 2H), 7.96−7.85 (m, 8H), 7.55−7.49 (m, 4H), 7.41 (d, J = 7.4 Hz, 2H), 6.78 (s, 2H), 6.58 (s, 2H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 148.7 (2C), 147.8 (2C), 134.0 (2C), 132.7 (2C), 132.4 (2C), 129.7 (2C), 129.4 (2C), 129.1 (2C), 128.2 (2C), 127.8 (2C), 127.3 (2C), 126.8 (2C), 125.9 (2C), 120.3 (2C), 118.7 (2C), 118.5 (2C); HRMS (ESI-TOF) calcd for $C_{32}H_{22}NaO_4S_2$ 557.0857 [M + Na^+], found 557.0866; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 332 (14) nm.

Preparation of 4,4′-Bis(2-pyridylsulfanyl)-2,2′,5,5′-tetrahydroxybiphenyl (1i). Under a nitrogen atmosphere, BBr_3 (1.0 M in CH_2Cl_2, 20.0 mL, 40.0 mmol) was added to a solution of **4i** (1918.3 mg, 3.89 mmol) in CH_2Cl_2 (20 mL) at 0 °C, and the reaction mixture was stirred at the same temperature for 24 h. MeOH (20.0 mL) was added slowly and the mixture concentrated under reduced pressure to give **1i** in 60% yield (1013.6 mg, 2.32 mmol): pale yellow solid; mp 183.8−184.5 °C; ^{1}H NMR (500 MHz, DMSO-d_6) δ 8.51 (s, 2H), 7.89 (d, J = 7.1 Hz, 2H), 7.34 (s, 2H), 7.10 (d, J = 7.9 Hz, 2H), 7.01 (d, J = 2.6 Hz, 2H), 6.90 (d, J = 2.5 Hz, 2H), 5.5−7.5 (br, 4H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 159.2 (2C), 151.0 (2C), 148.1 (2C), 147.1 (2C), 141.0 (2C), 129.1 (2C), 122.8 (4C), 121.6 (2C), 119.3 (2C), 112.9 (2C); HRMS (ESI-TOF) calcd for $C_{22}H_{16}N_2NaO_4S_2$ 459.0449 [M + Na^+], found 459.0456; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 326 (13) nm.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis(phenylsulfinyl)biphenyl (5). *m*-CPBA (80%, 588.4 mg, 2.63 mmol) was added to a solution of **4a** (493.4 mg, 1.0 mmol) in CH_2Cl_2 (5 mL), and the reaction mixture was stirred at room temperature for 90 min. $NaHCO_3$aq (10 mL) and $Na_2S_2O_3$aq (10 mL) were added to the reaction mixture, and the resulting mixture was extracted with CH_2Cl_2 (3 × 10 mL). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 3:1 then 1:1 v/v) to give **5** in 99% yield (517.4 mg, 0.99 mmol). Diastereomeric mixture: yellow solid; mp 90−91 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04−7.74 (m, 4H), 7.62−7.39 (m, 6H), 6.82−6.70 (m, 2H), 3.84−3.78 (m, 6H), 3.77−3.65 (m, 6H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 152.1 (2C), 152.0 (2C), 151.9 (2C), 150.7 (2C), 149.2 (2C), 149.1 (2C), 145.4 (2C), 145.4 (2C), 133.1 (2C), 133.0 (2C), 131.0 (4C), 130.1 (2C), 130.0 (2C), 129.1 (4C), 128.6 (4C), 125.4 (4C), 114.9 (2C), 114.8 (2C), 114.6 (2C), 107.2 (2C), 56.7 (2C), 56.7 (2C), 56.6 (2C), 56.4 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{26}NaO_6S_2$ 545.1069 [M + Na^+], found 545.1062; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 324 (16) nm.

Preparation of 2,2′,5,5′-Tetramethoxy-4,4′-bis(phenylsulfonyl)biphenyl (6). *m*-CPBA (80%, 1791.1 mg, 8.0 mmol) was added to a solution of **4a** (490.6 mg, 1.0 mmol) in $ClCH_2CH_2Cl$ (5 mL), and the reaction mixture was stirred at refluxing temperature for 90 min. After the mixture was cooled, $NaHCO_3$aq (20 mL) and $Na_2S_2O_3$aq (20 mL) were added, and the resulting mixture was extracted with CH_2Cl_2 (3 × 20 mL). The organic phases were combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration, the organic phase was concentrated under reduced pressure. The residue was purified by flash chromatography (silica gel/hexane−EtOAc, 5:1 then 3:1 v/v) to give **5** in 86% yield (480.8 mg, 0.86 mmol): yellow solid; mp 86−87 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.01 (d, J = 7.8 Hz, 4H), 7.74 (s, 2H), 7.59 (t, J = 7.3 Hz, 2H), 7.51 (t, J = 7.6 Hz, 4H), 6.76 (s, 2H), 3.82 (s, 6H), 3.68 (s, 6H); ^{13}C NMR (126 MHz, DMSO-d_6) δ 150.7 (2C), 150.6 (2C), 141.3 (2C), 133.2 (4C), 133.1 (2C), 129.0 (2C), 128.8 (2C), 128.6 (4C), 116.2 (2C), 112.2 (2C), 56.7 (2C), 56.6 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{26}NaO_8S_2$ 577.0967 [M + Na^+], found 577.0963; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 324 (5.4) nm.

Preparation of 6,6-Dimethyl-3,9-bis(phenylthio)dibenzo[*d*,*f*][1,3]dioxepine-2,10-diol (7a). Under a nitrogen atmosphere, a solution of **1a** (82.6 mg, 0.19 mmol), camphorsulfonic acid (23.2 mg, 0.10 mmol), and 2,2-dimethoxypropane (0.12 mL, 0.95 mmol) in toluene (4 mL) was stirred at 100 °C for 3 h. After being cooled, the reaction mixture was concentrated under reduced pressure. The obtained crude product was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **7a** in 87% yield (81.8 mg, 0.17 mmol): white solid; mp 58.5−59 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29 (d, J = 1.0 Hz, 2H), 7.28−7.23 (m, 4H), 7.22 (d, J = 1.1 Hz, 2H), 7.20−7.15 (m, 2H), 7.14 (d, J = 1.3 Hz, 2H), 7.13 (t, J = 1.2 Hz, 2H), 6.40 (s, 2H), 1.60 (d, J = 1.4 Hz, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.7 (2C), 145.1 (2C), 136.5 (2C), 135.5 (2C), 130.6 (2C), 129.4 (4C), 127.2 (4C), 126.5 (2C), 116.8 (2C), 115.1 (2C), 114.8, 24.8 (2C); HRMS (ESI-TOF) calcd for $C_{27}H_{22}NaO_4S_2$ 497.0857 [M + Na^+], found 497.0849.

Preparation of 6,6-Dimethyl-3,9-bis((2-bromophenyl)thio)dibenzo[*d*,*f*][1,3]dioxepine-2,10-diol (7b). Under a nitrogen atmosphere, a solution of **1b** (60.2 mg, 0.10 mmol), CSA (18.2 mg, 0.078 mmol), and 2,2-dimethoxypropane (0.06 mL, 0.50 mmol) in toluene (2 mL) was stirred at 75 °C for 4 h. After being cooled, the reaction mixture was concentrated under reduced pressure. The obtained crude product was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **7b** in 100% yield (64.5 mg, 0.10 mmol): brown solid; mp 41.5−42.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.56 (d, J = 7.9 Hz, 2H), 7.31 (s, 2H), 7.27 (s, 2H), 7.15 (d, J = 7.4 Hz, 2H), 7.04 (t, J = 7.6 Hz, 2H), 6.70 (d, J = 8.0 Hz, 2H), 6.31 (s, 2H), 1.62 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 155.0 (2C), 145.3 (2C), 137.1 (2C), 136.9 (2C), 133.2 (2C), 131.0 (2C), 128.3 (2C), 127.4 (2C), 127.0 (2C), 121.3 (2C), 115.7 (2C), 115.3 (2C), 11.52, 24.7 (2C); HRMS (ESI-TOF) calcd for $C_{27}H_{20}Br_2NaO_4S_2$ 652.9068 [M + Na^+], found 652.9088.

Preparation of 6,6-Dimethyl-3,9-bis((3-bromophenyl)thio)dibenzo[*d*,*f*][1,3]dioxepine-2,10-diol (7c). Under a nitrogen atmosphere, a solution of **1c** (1776.2 mg, 3.0 mmol), CSA (854.8 mg, 3.68 mmol), and 2,2-dimethoxypropane (1.8 mL, 15.0 mmol) in

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toluene (60 mL) was stirred at 100 °C for 30 min. After being cooled, the reaction mixture was concentrated under reduced pressure. The obtained crude product was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 3:1 v/v) to give **7c** in 88% yield (1666.7 mg, 2.64 mmol): brown solid; mp 108.5−109 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34−7.21 (m, 8H), 7.12 (td, J = 7.9, 2.0 Hz, 2H), 7.02 (d, J = 8.0 Hz, 2H), 6.31 (s, 2H), 1.62 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.7 (2C), 145.2 (2C), 137.9 (2C), 136.9 (2C), 130.7 (4C), 129.6 (2C), 129.6 (2C), 125.5 (2C), 123.4 (2C), 115.8 (2C), 115.3 (2C), 115.1, 24.8 (2C); HRMS (ESI-TOF) calcd for $C_{27}H_{20}Br_2NaO_4S_2$ 652.9068 [M + Na^+], found 652.9088.

Preparation of 6,6-Dimethyl-3,9-bis((4-bromophenyl)thio)-dibenzo[*d*,*f*][1,3]dioxepine-2,10-diol (7d). Under a nitrogen atmosphere, a solution of **1d** (288.3 mg, 0.49 mmol), CSA (60.0 mg, 0.26 mmol), and 2,2-dimethoxypropane (0.31 mL, 2.5 mmol) in toluene (10 mL) was stirred at 100 °C for 24 h. After being cooled, the reaction mixture was filtered and concentrated under reduced pressure. The obtained crude product was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **7d** in 82% yield (254.8 mg, 0.40 mmol): brown solid; mp 39.5−40 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37 (dd, J = 8.6, 1.5 Hz, 4H), 7.26 (s, 2H), 7.21 (s, 2H), 6.99 (d, J = 8.5, 1.5 Hz, 4H), 6.32 (s, 2H), 1.60 (d, J = 1.4 Hz, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.6 (2C), 145.2 (2C), 136.7 (2C), 134.8 (2C), 132.5 (4C), 130.5 (2C), 128.7 (4C), 120.4 (2C), 116.3 (2C), 115.2 (2C), 115.0, 24.8 (2C); HRMS (ESI-TOF) calcd for $C_{27}H_{20}Br_2NaO_4S_2$ 652.9068 [M + Na^+], found 652.9065.

Preparation of 6,6-Dimethyl-3,9-bis((4-chlorophenyl)thio)-dibenzo[*d*,*f*][1,3]dioxepine-2,10-diol (7e). Under a nitrogen atmosphere, a solution of **1e** (49.8 mg, 0.10 mmol), CSA (11.5 mg, 0.05 mmol), and 2,2-dimethoxypropane (0.06 mL, 0.5 mmol) in toluene (2 mL) was stirred at 75 °C for 7 h. After being cooled, the reaction mixture was filtered and concentrated under reduced pressure. The obtained crude product was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **7e** in 93% yield (50.3 mg, 0.093 mmol): brown solid; mp 53.0−53.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.26 (s, 2H), 7.22 (d, J = 8.6 Hz, 4H), 7.21 (s, 2H), 7.05 (d, J = 8.6 Hz, 4H), 6.32 (s, 2H), 1.60 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.6 (2C), 145.2 (2C), 136.7 (2C), 134.1 (2C), 132.6 (2C), 130.5 (2C), 129.6 (4C), 128.5 (4C), 116.6 (2C), 115.2 (2C), 115.0, 24.8 (2C); HRMS (ESI-TOF) calcd for $C_{27}H_{20}Cl_2NaO_4S_2$ 565.0078 [M + Na^+], found 565.0089.

Preparation of 6,6-Dimethyl-3,9-bis(2-methylphenylthio)-dibenzo[*d*,*f*][1,3]dioxepine-2,10-diol (7f). Under a nitrogen atmosphere, a solution of **1f** (1384.8 mg, 2.99 mmol), CSA (845.3 mg, 3.64 mmol), and 2,2-dimethoxypropane (1.8 mL, 15.0 mmol) in toluene (60 mL) was stirred at 100 °C for 7 h. After being cooled, the reaction mixture was filtered and concentrated under reduced pressure. The obtained crude product was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **7f** in 92% yield (1383.4 mg, 2.75 mmol): brown solid; mp 41.5− 42.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.25 (s, 2 H), 7.21 (d, J = 7.3 Hz, 2H), 7.15−7.06 (m, 6H), 6.85 (d, J = 7.7 Hz, 2H), 6.30 (br, 2H), 2.48 (s, 6H), 1.63 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.6 (2C), 145.3 (2C), 136.2 (2C), 136.1 (2C), 134.6 (2C), 130.7 (2C), 130.3 (2C), 127.1 (2C), 126.7 (2C), 126.5 (2C), 116.8 (2C), 115.2 (2C), 114.8, 24.8 (2C), 20.3 (2C); HRMS (ESI-TOF) calcd for $C_{29}H_{26}NaO_4S_2$ 525.1170 [M + Na^+], found 525.1184.

Preparation of 6,6-Dimethyl-3,9-bis(4-methylphenylthio)-dibenzo[*d*,*f*][1,3]dioxepine-2,10-diol (7g). Under a nitrogen atmosphere, a solution of **1g** (47.3 mg, 0.102 mmol), CSA (21.1 mg, 0.09 mmol), and 2,2-dimethoxypropane (0.06 mL, 0.5 mmol) in toluene (2 mL) was stirred at 75 °C for 17 h. After being cooled, the reaction mixture was filtered and concentrated under reduced pressure. The obtained crude product was purified by flash chromatography (silica gel/hexane−EtOAc, 8:1 then 5:1 v/v) to give **7g** in 100% yield (51.3 mg, 0.102 mmol): brown solid; mp 45−45.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.26 (s, 2H), 7.17 (s, 2H), 7.06 (s, 8H), 6.39 (s, 2H), 2.29 (s, 6H), 1.59 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.4 (2C), 145.0 (2C), 136.7 (2C), 136.2 (2C), 131.7 (2C), 130.2 (2C), 130.1 (4C), 127.8 (4C), 117.7 (2C), 115.0 (2C), 114.6, 24.6 (2C), 20.9 (2C); HRMS (ESI-TOF) calcd for $C_{29}H_{26}NaO_4S_2$ 525.1170 [M + Na^+], found 525.1177.

Preparation of 6,6-Dimethyl-3,9-bis(2-naphthylthio)-dibenzo[*d*,*f*][1,3]dioxepine-2,10-diol (7h). Under a nitrogen atmosphere, a mixture of **1h** (534.9 mg, 1.0 mmol), CSA (121.0 mg, 0.52 mmol), and MS4A in 2,2-dimethoxypropane (0.61 mL, 5.0 mmol) in toluene (20 mL) was stirred at 75 °C for 7 h. After being cooled the reaction mixture was filtered and concentrated under reduced pressure. The obtained crude product was purified by flash chromatography (silica gel/hexane−EtOAc, 7:1 then 5:1 v/v) to give **7h** in 90% yield (514.3 mg, 0.90 mmol): yellow solid; mp 95−96 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.76 (dd, J = 15.6, 8.1 Hz, 4H), 7.68 (d, J = 7.6 Hz, 2H), 7.57 (d, J = 1.7 Hz, 2H), 7.50−7.40 (m, 6H), 7.35 (s, 2H), 7.27 (s, 2H), 6.42 (s, 2H), 1.62 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.7 (2C), 145.1 (2C), 136.5 (2C), 133.8 (2C), 132.7 (2C), 132.0 (2C), 130.5 (2C), 129.2 (2C), 127.8 (2C), 127.2 (2C), 126.9 (2C), 126.1 (2C), 125.6 (2C), 125.3 (2C), 116.9 (2C), 115.1 (2C), 114.9, 24.6 (2C); HRMS (ESI-TOF) calcd for $C_{35}H_{26}NaO_4S_2$ 597.1170 [M + Na^+], found 597.1195.

Preparation of 2,10-Dimethoxy-6,6-dimethyl-3,9-bis-(phenylthio)dibenzo[*d*,*f*][1,3]dioxepine (8a). Under a nitrogen atmosphere, a solution of **7a** (249.0 mg, 0.5 mmol) in dry THF (5 mL) was added to a suspension of NaH (147.4 mg, 60%, 3.69 mmol) in THF (5 mL) over 15 min at 0 °C. 18-Crown-6 ether (66.1 mg, 0.25 mmol) and MeI (0.16 mL, 2.5 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 12 h. Saturated NH_4Claq (20 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (20 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 8:1 v/v) to give **8a** in 100% yield (251.9 mg, 0.50 mmol): white solid; mp 57.0−58.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.33 (d, J = 9.5 Hz, 2H), 7.29−7.14 (m, 8H), 6.90 (s, 2H), 6.70 (s, 2H), 3.86 (s, 6H), 1.38 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.5 (2C), 145.6 (2C), 133.9 (2C), 132.9 (2C), 132.0 (4C), 129.5 (2C), 129.3 (4C), 127.6 (2C), 125.5 (2C), 115.6 (2C), 110.0, 56.6 (2C), 24.6 (2C); HRMS (ESI-TOF) calcd for $C_{29}H_{26}NaO_4S_2$ 525.1170 [M + Na^+], found 525.1175.

Preparation of 2,10-Dimethoxy-6,6-dimethyl-3,9-bis((2-bromophenyl)thio)dibenzo[*d*,*f*][1,3]dioxepine (8b). Under a nitrogen atmosphere, a solution of **7b** (1321.5 mg, 2.09 mmol) in dry THF (10 mL) was added to a suspension of NaH (280.0 mg, 60%, 7.00 mmol) in THF (10 mL) over 15 min at 0 °C. 18-Crown-6 ether (297.8 mg, 1.13 mmol) and MeI (0.70 mL, 10.5 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 12 h. Saturated NH_4Claq (10 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (20 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **8b** in 99% yield (1370.1 mg, 2.07 mmol): white solid; mp 43.0−43.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.60 (dd, J = 8.2, 1.3 Hz, 2H), 7.19 (dd, J = 7.7, 6.1 Hz, 2H), 7.12−7.07 (m, 4H), 7.04 (s, 2H), 6.92 (s, 2H), 3.93 (s, 6H), 1.52 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 155.8 (2C), 145.6 (2C), 136.4 (2C), 133.6 (2C), 133.3 (2C), 131.3 (2C), 128.1 (2C), 128.0 (2C), 127.8 (2C), 124.8 (2C), 122.4 (2C), 116.1 (2C), 110.5, 56.7 (2C), 24.8 (2C); HRMS (ESI-TOF) calcd for $C_{29}H_{24}Br_2NaO_4S_2$ 680.9380 [M + Na^+], found 680.9382.

Preparation of 2,10-Dimethoxy-6,6-dimethyl-3,9-bis((3-bromophenyl)thio)dibenzo[*d*,*f*][1,3]dioxepine (8c). Under a nitrogen atmosphere, a solution of **7c** (948.6 mg, 1.5 mmol) in dry THF (10 mL) was added to a suspension of NaH (222.2 mg, 60%, 5.56 mmol) in THF (10 mL) over 15 min at 0 °C. 18-Crown-6 ether (396.4 mg, 1.50 mmol) and MeI (0.47 mL, 7.50 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 3.5 h. Saturated

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NH_4Claq (30 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (30 mL × 3).The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 8:1 v/v) to give **8c** in 93% yield (924.4 mg, 1.39 mmol): white solid; mp 47.0−48.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.48 (s, 2H), 7.35 (d, J = 8.6 Hz, 2H), 7.26 (d, J = 7.8 Hz, 2H), 7.15 (t, J = 7.9 Hz, 2H), 7.04 (s, 2H), 6.97 (s, 2H), 3.92 (s, 6H), 1.54 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 155.4 (2C), 145.6 (2C), 137.5 (2C), 133.3 (2C), 133.0 (2C), 130.6 (2C), 130.1 (2C), 129.1 (2C), 127.3 (2C), 123.4 (2C), 123.1 (2C), 116.0 (2C), 110.5, 56.7 (2C), 24.8 (2C); HRMS (ESI-TOF) calcd for $C_{29}H_{24}Br_2NaO_4S_2$ 680.9380 [M + Na^+], found 680.9393.

Preparation of 2,10-Dimethoxy-6,6-dimethyl-3,9-bis((4-bromophenyl)thio)dibenzo[*d*,*f*][1,3]dioxepine (8d). Under a nitrogen atmosphere, a solution of **7d** (183.8 mg, 0.29 mmol) in dry THF (5 mL) was added to a suspension of NaH (85.4 mg, 60%, 2.14 mmol) in THF (5 mL) over 15 min at 0 °C. 18-Crown-6 ether (39.6 mg, 0.15 mmol) and MeI (0.09 mL, 1.5 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 12 h. Saturated NH_4Claq (30 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (30 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 8:1 v/v) to give **8d** in 97% yield (186.6 mg, 0.28 mmol): white solid; mp 49.5−50.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.43 (d, J = 8.4 Hz, 4H), 7.22 (d, J = 8.5 Hz, 4H), 6.97 (s, 2H), 6.84 (s, 2H), 3.92 (s, 6H), 1.56 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.9 (2C), 145.6 (2C), 133.7 (2C), 132.9 (4C), 132.7 (2C), 132.4 (4C), 126.3 (2C), 124.2 (2C), 121.5 (2C), 115.9 (2C), 110.2, 56.7 (2C), 24.8 (2C); HRMS (ESI-TOF) calcd for $C_{29}H_{24}Br_2NaO_4S_2$ 680.9380 [M + Na^+], found 680.9374.

Preparation of 2,10-Dimethoxy-6,6-dimethyl-3,9-bis((4-chlorophenyl)thio)dibenzo[*d*,*f*][1,3]dioxepine (8e). Under a nitrogen atmosphere, a solution of **7e** (234.1 mg, 0.43 mmol) in dry THF (10 mL) was added to a suspension of NaH (107.9 mg, 60%, 2.70 mmol) in THF (10 mL) over 15 min at 0 °C. 18-Crown-6 ether (114.4 mg, 0.42 mmol) and MeI (0.13 mL, 2.15 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 24 h. Saturated NH_4Claq (30 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (30 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 8:1 v/v) to give **8e** in 100% yield (245.8 mg, 0.43 mmol): white solid; mp 49.5−50 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 (s, 8H), 6.96 (s, 2H), 6.81 (s, 2H), 3.92 (s, 6H), 1.49 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.8 (2C), 145.6 (2C), 133.6 (2C), 132.9 (4C), 132.8 (2C), 132.6 (2C), 129.6 (4C), 126.0 (2C), 124.6 (2C), 115.9 (2C), 110.1, 56.7 (2C), 24.7 (2C); HRMS (ESI-TOF) calcd for $C_{29}H_{24}Cl_2NaO_4S_2$ 593.0391 [M + Na^+], found 593.0396.

Preparation of 2,10-Dimethoxy-6,6-dimethyl-3,9-bis((2-methylphenyl)thio)dibenzo[*d*,*f*][1,3]dioxepine (8f). Under a nitrogen atmosphere, a solution of **7f** (752.2 mg, 1.50 mmol) in dry THF (10 mL) was added to a suspension of NaH (264.8 mg, 60%, 6.62 mmol) in THF (30 mL) over 15 min at 0 °C. 18-Crown-6 ether (204.3 mg, 0.77 mmol) and MeI (0.47 mL, 7.50 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 96 h. Saturated NH_4Claq (15 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (50 mL × 3). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 8:1 v/v) to give **8f** in 100% yield (796.1 mg, 1.50 mmol): white solid; mp 42.5−43.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 (d, J = 8.7 Hz, 2H), 7.32−7.23 (m, 4H), 7.18 (td, J = 7.4, 1.8 Hz, 2H), 6.97 (s, 2H), 6.46 (s, 2H), 3.97 (s, 6H), 2.41 (s, 6H), 1.40 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 153.9 (2C), 145.7 (2C), 141.3 (2C), 134.4 (2C), 131.7 (2C), 131.1 (2C), 130.9 (2C), 128.8 (2C), 127.1 (2C), 125.9 (2C), 123.3 (2C), 115.7 (2C), 109.8, 56.7 (2C), 24.6 (2C), 20.6 (2C); HRMS (ESI-TOF) calcd for $C_{31}H_{30}NaO_4S_2$ 553.1483 [M + Na^+], found 553.1477.

Preparation of 2,10-Dimethoxy-6,6-dimethyl-3,9-bis((4-methylphenyl)thio)dibenzo[*d*,*f*][1,3]dioxepine (8g). Under a nitrogen atmosphere, a solution of **7g** (175.7 mg, 0.35 mmol) in dry THF (5 mL) was added to a suspension of NaH (148.5 mg, 60%, 3.71 mmol) in THF (10 mL) over 15 min at 0 °C. 18-Crown-6 ether (192.3 mg, 0.73 mmol) and MeI (0.12 mL, 2.00 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 21 h. Saturated NH_4Claq (20 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (20 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 8:1 v/v) to give **8g** in 85% yield (157.0 mg, 0.30 mmol): white solid; mp 44.0−45.0 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34 (d, J = 8.2 Hz, 4H), 7.16 (d, J = 8.3 Hz, 4H), 6.93 (s, 2H), 6.64 (s, 2H), 3.94 (s, 6H), 2.36 (s, 7H), 1.42 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 153.8 (2C), 145.6 (2C), 138.1 (2C), 133.1 (4C), 131.3 (2C), 130.2 (4C), 129.4 (2C), 126.7 (2C), 124.1 (2C), 115.5 (2C), 109.7, 56.5 (2C), 24.5 (2C), 21.1 (2C); HRMS (ESI-TOF) calcd for $C_{31}H_{30}NaO_4S_2$ 553.1483 [M + Na^+], found 553.1474.

Preparation of 2,10-Dimethoxy-6,6-dimethyl-3,9-bis(2-naphthylthio)dibenzo[*d*,*f*][1,3]dioxepine (8h). Under a nitrogen atmosphere, a solution of **7h** (285.7 mg, 0.48 mmol) in dry THF (5 mL) was added to a suspension of NaH (107.5 mg, 60%, 2.69 mmol) in THF (5 mL) over 15 min at 0 °C. 18-Crown-6 ether (66.1 mg, 0.25 mmol) and MeI (0.16 mL, 2.50 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 17 h. Saturated NH_4Claq (10 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (20 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 7:1 v/v) to give **8h** in 96% yield (289.1 mg, 0.48 mmol): white solid; mp 67−67.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.85 (s, 2H), 7.79−7.66 (m, 6H), 7.46−7.35 (m, 6H), 6.94 (s, 2H), 6.75 (s, 2H), 3.89 (s, 6H), 1.34 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.6 (2C), 145.6 (2C), 133.9 (2C), 132.6 (2C), 132.1 (2C), 131.3 (2C), 131.0 (2C), 129.2 (2C), 129.0 (2C), 127.8 (2C), 127.5 (2C), 126.6 (2C), 126.4 (2C), 125.6 (2C), 125.4 (2C), 115.7 (2C), 110.0, 56.6 (2C), 24.5 (2C); HRMS (ESI-TOF) calcd for $C_{37}H_{30}NaO_4S_2$ 625.1483 [M + Na^+], found 625.1478.

Preparation of 4,4′-Bis(phenylsulfanyl)-2,2′-dihydroxy-5,5′-dimethoxybiphenyl (9a). HClaq (12 M, 0.1 mL) was added to a solution of **8a** (50.2 mg, 0.10 mmol) in THF (0.4 mL) and MeOH (0.2 mL), and the reaction mixture was stirred at room temperature for 12 h. Water (10 mL) was added and the mixture extracted with Et_2O (3 × 10 mL). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give **9a** in 71% yield (32.8 mg, 0.07 mmol): brown solid; mp 64−65 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.48 (d, J = 7.2 Hz, 4H), 7.43−7.30 (m, 6H), 6.76 (s, 2H), 6.53 (s, 2H), 5.60−5.47 (m, 2H), 3.86 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 151.1 (2C), 146.8 (2C), 133.2 (2C), 132.5 (4C), 129.5 (4C), 128.1 (2C), 127.3 (2C), 123.4 (2C), 118.2 (2C), 113.4 (2C), 56.7 (2C); HRMS (ESI-TOF) calcd for $C_{26}H_{22}NaO_4S_2$ 485.0857 [M + Na^+], found 485.0868; λ_{abs} (MeOH, ε × 10^{-3}) 330 (17) nm.

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Preparation of 4,4′-Bis((2-bromophenyl)sulfanyl)-2,2′-dihydroxy-5,5′-dimethoxybiphenyl (9b). HClaq (12 M, 0.5 mL) was added to a solution of **8b** (328.8 mg, 0.50 mmol) in THF (2.0 mL) and MeOH (1.0 mL), and the reaction mixture was stirred at room temperature for 9 h. Water (20 mL) was added and the mixture extracted with Et_2O (3 × 20 mL). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give **9b** in 86% yield (265.3 mg, 0.43 mmol): brown solid; mp 61.0−62.0 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.64 (d, J = 7.7 Hz, 2H), 7.28−7.23 (m, 4H), 7.19−7.11 (m, 2H), 6.84 (s, 2H), 6.69 (s, 2H), 5.46 (br, 2H), 3.86 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 152.4 (2C), 146.9 (2C), 135.3 (2C), 133.5 (2C), 132.8 (2C), 128.8 (2C), 128.2 (2C), 126.2 (2C), 124.7 (2C), 124.0 (2C), 120.1 (2C), 113.6 (2C), 56.8 (2C). Anal. Calcd for $C_{26}H_{20}Br_2O_4S_2$: C, 50.34; H, 3.25. Found: C, 50.41; H, 3.53.

Preparation of 4,4′-Bis((3-bromophenyl)sulfanyl)-2,2′-dihydroxy-5,5′-dimethoxybiphenyl (9c). HClaq (12 M, 1.0 mL) was added to a solution of **8c** (656.6 mg, 0.99 mmol) in THF (4.0 mL) and MeOH (2.0 mL), and the reaction mixture was stirred at room temperature for 12 h. Water (50 mL) was added and the mixture extracted with Et_2O (3 × 50 mL). The organic phase was combined, washed with brine (100 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give **9c** in 93% yield (571.7 mg, 0.92 mmol): brown solid; mp 61.0−62.0 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.55 (t, J = 1.8 Hz, 2H), 7.42 (dd, J = 8.0, 1.9 Hz, 2H), 7.34 (dd, J = 7.8, 0.9 Hz, 2H), 7.21 (t, J = 7.9 Hz, 2H), 6.80 (s, 2H), 6.70 (s, 2H), 5.69 (br, 2H), 3.85 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 151.9 (2C), 146.9 (2C), 136.0 (2C), 134.6 (2C), 130.8 (2C), 130.7 (4C), 125.8 (2C), 123.8 (2C), 123.1 (2C), 119.6 (2C), 113.6 (2C), 56.8 (2C); HRMS (ESI-TOF) calcd for $C_{26}H_{20}Br_2NaO_4S_2$ 640.9067 [M + Na^+], found 640.9084.

Preparation of 4,4′-Bis((4-bromophenyl)sulfanyl)-2,2′-dihydroxy-5,5′-dimethoxybiphenyl (9d). HClaq (12 M, 0.2 mL) was added to a solution of **8d** (132.1 mg, 0.20 mmol) in THF (0.8 mL) and MeOH (0.4 mL), and the reaction mixture was stirred at room temperature for 14 h. Water (20 mL) was added and the mixture extracted with Et_2O (3 × 20 mL). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give **9d** in 98% yield (126.0 mg, 0.196 mmol): brown solid; mp 54.5−55.0 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.49 (d, J = 8.5 Hz, 4H), 7.32 (d, J = 8.5 Hz, 4H), 6.77 (s, 2H), 6.61 (s, 2H), 5.20−5.30 (br, 2H), 3.86 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 151.5 (2C), 146.8 (2C), 134.2 (4C), 132.6 (4C), 132.4 (2C), 126.5 (2C), 123.5 (2C), 122.2 (2C), 118.7 (2C), 113.4 (2C), 56.7 (2C); HRMS (ESI-TOF) calcd for $C_{26}H_{20}Br_2NaO_4S_2$ 640.9067 [M + Na^+], found 640.9077.

Preparation of 4,4′-Bis((4-chlorophenyl)sulfanyl)-2,2′-dihydroxy-5,5′-dimethoxybiphenyl (9e). HClaq (12 M, 0.1 mL) was added to a solution of **8e** (55.8 mg, 0.098 mmol) in THF (0.4 mL) and MeOH (0.2 mL), and the reaction mixture was stirred at room temperature for 12 h. Water (20 mL) was added and the mixture extracted with Et_2O (3 × 20 mL). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give **9e** in 93% yield (48.5 mg, 0.091 mmol): brown solid; mp 61.5−62.0 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.31 (d, J = 8.5 Hz, 4H), 7.25 (d, J = 8.5 Hz, 4H), 6.71 (s, 2H), 6.51 (s, 2H), 5.65 (br, 2H), 3.78 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 151.4 (2C), 146.8 (2C), 134.3 (2C), 131.4 (4C), 129.7 (2C), 127.0 (4C), 125.9 (2C), 123.0 (2C), 118.3 (2C), 113.3 (2C), 56.6 (2C); HRMS (ESI-TOF) calcd for $C_{26}H_{20}Cl_2NaO_4S_2$ 553.0078 [M + Na^+], found 553.0081.

Preparation of 4,4′-Bis((2-methylphenyl)sulfanyl)-2,2′-dihydroxy-5,5′-dimethoxybiphenyl (9f). HClaq (12 M, 0.5 mL) was added to a solution of **8f** (265.4 mg, 0.50 mmol) in THF (2.0 mL) and MeOH (1.0 mL), and the reaction mixture was stirred at room temperature for 17 h. Water (30 mL) was added and the mixture extracted with Et_2O (3 × 20 mL). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give **9f** in 86% yield (211.4 mg, 0.43 mmol): white solid; mp 41.5−42.0 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.36 (d, J = 7.7 Hz, 2H), 7.20 (d, J = 6.6 Hz, 4H), 7.10 (t, J = 7.1 Hz, 2H), 6.68 (s, 2H), 6.18 (s, 2H), 5.62 (br, 2H), 3.79 (s, 6H), 2.33 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 150.6 (2C), 147.0 (2C), 142.1 (2C), 135.5 (2C), 130.9 (2C), 130.6 (2C), 129.2 (2C), 128.1 (2C), 127.1 (2C), 121.6 (2C), 115.9 (2C), 113.1 (2C), 56.6 (2C), 20.6 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{26}NaO_4S_2$ 513.1170 [M + Na^+], found 513.1187.

Preparation of 4,4′-Bis((4-methylphenyl)sulfanyl)-2,2′-dihydroxy-5,5′-dimethoxybiphenyl (9g). HClaq (12 M, 0.2 mL) was added to a solution of **8g** (103.8 mg, 0.20 mmol) in THF (0.8 mL) and MeOH (0.4 mL), and the reaction mixture was stirred at room temperature for 12 h. Water (30 mL) was added and the mixture extracted with Et_2O (3 × 20 mL). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give **9g** in 95% yield (93.9 mg, 0.19 mmol). White solid; mp 61.5−62.0 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.30 (d, J = 7.8 Hz, 4H), 7.09 (d, J = 7.7 Hz, 4H), 6.65 (s, 2H), 6.34 (s, 2H), 3.77 (s, 6H), 2.27 (s, 6H), 1.20−1.13 (m, 2H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 150.5 (2C), 146.9 (2C), 138.8 (2C), 134.4 (4C), 130.4 (2C), 129.1 (4C), 128.0 (2C), 121.9 (2C), 116.6 (2C), 113.0 (2C), 56.6 (2C), 21.1 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{26}NaO_4S_2$ 513.1170 [M + Na^+], found 513.1170.

Preparation of 4,4′-bis(2-naphthylsulfanyl)-2,2′-dihydroxy-5,5′-dimethoxybiphenyl (9h). HClaq (12 M, 0.3 mL) was added to a solution of **8h** (180.8 mg, 0.30 mmol) in THF (1.2 mL) and MeOH (0.6 mL), and the reaction mixture was stirred at refluxing temperature for 14 h. Water (10 mL) was added and the mixture extracted with Et_2O (20 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 7:1 then 5:1 v/v) to give **9h** in 87% yield (147.0 mg, 0.26 mmol): brown solid; mp 44−45 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.02 (s, 2H), 7.88−7.82 (m, 4H), 7.81−7.76 (m, 2H), 7.56−7.47 (m, 6H), 6.78 (s, 2H), 6.53 (s, 2H), 5.11−5.47 (br 1H), 3.89 (d, J = 1.8 Hz, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 151.1 (2C), 147.0 (2C), 134.0 (2C), 133.1 (2C), 133.0 (2C), 130.6 (2C), 129.7 (2C), 129.3 (2C), 128.2 (2C), 127.9 (2C), 127.7 (2C), 126.8 (2C), 126.7 (2C), 122.4 (2C), 117.7 (2C), 113.2 (2C), 56.8 (2C); HRMS (ESI-TOF) calcd for $C_{34}H_{26}NaO_4S_2$ 585.1170 [M + Na^+], found 585.1160.

Preparation of 6,6-Di-*tert*-butyl-3,9-bis(phenylthio)dibenzo[*d*,*f*][1,3,2]dioxasilepine-2,10-diol (10). Di-*tert*-buthyl dichloride (0.12 mL, 0.55 mmol) was added to a solution of **1a** (216.8 mg, 0.50 mmol), Et_3N (0.35 mL, 2.5 mmol), and *t*-BuOH (4.4 mg, 0.05 mmol) in CH_3CN (5 mL). The mixture was heated at 80 °C for 11 h. After being cooled, the reaction mixture was poured into ice−water (20 mL), and the resulting biphasic mixture was extracted with Et_2O (30 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc 12:1 to 1:1 v/v) to give **10** in 58% yield (166.8 mg, 0.29 mmol): white solid; mp 54−55 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.15−7.28 (m, 10 H), 7.12 (s, 2H), 6.29 (s, 2H), 1.05 (s, 18H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 152.3 (2C), 147.2 (2C), 135.6 (2C), 132.1 (2C), 129.4 (4C), 128.3 (2C), 127.5 (4C), 126.5 (2C), 117.6 (2C), 117.5 (2C), 27.7 (6C), 21.4 (2C); HRMS (ESI-TOF) calcd for $C_{32}H_{34}NaO_4S_2Si$ 597.1566 [M + Na^+], found 597.1577.

Preparation of 6,6-Di-*tert*-butyl-2,10-bis(methoxymethoxy)-3,9-bis(phenylthio)dibenzo[*d*,*f*][1,3,2]dioxasilepine (11). A solution of compound **10** (1150.6 mg, 2.0 mmol) and 18-crown-6 ether (535.0 mg, 2.0 mmol) in THF (10 mL) was added to a suspension of NaH (321.5 mg, 60%, 8.0 mmol) in THF (15 mL) at 0 °C. MOMCl (0.76 mL, 10 mmol) was added to the reaction mixture, and the

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resulting solution was stirred for 2 h at room temperature. NH_4Claq (20 mL) was added to the reaction mixture, and THF was removed under reduced pressure. The aqueous residue was extracted with EtOAc (3 × 20 mL). The organic phase was combined, washed with brine (1 × 20 mL), and dried over Na_2SO_4. After filtration, the organic solution was concentrated and the residue was purified by flash chromatography (silica gel/hexane−EtOAc 13:1 then 10:1 v/v) to give **11** in 87% yield (1153.5 mg, 1.74 mmol): brown solid; mp 45−46 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.42−7.38 (m, 4H), 7.36−7.31 (m, 4H), 7.30−7.27 (m, 2H), 7.10 (s, 2H), 6.70 (s, 2H), 5.17 (s, 4H), 3.47 (s, 6H), 0.91 (d, J = 1.9 Hz, 18H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 150.2 (2C), 148.6 (2C), 134.1 (2C), 132.3 (4C), 129.4 (4C), 127.7 (2C), 127.7 (2C), 127.4 (2C), 123.3 (2C), 118.2 (2C), 96.0 (2C), 56.4 (2C), 27.7 (6C), 21.3 (2C); HRMS (ESI-TOF) calcd for $C_{36}H_{42}NaO_6S_2Si$ 685.2090 [M + Na^+], found 685.2095.

Preparation of 4,4′-Bis(phenylsulfanyl)-2,2′-dihydroxy-5,5′-di(methoxymethyloxy)biphenyl (12). TBAF (1,0 M in THF, 1.45 mL, 1.45 mmol) was added to a solution of **11** (1153.5 mg, 1.74 mmol) in THF (30 mL). The reaction mixture was stirred for 10 min at room temperature. Water (30 mL) was added to the solution, and THF was removed under reduced pressure. The aqueous residue was extracted with EtOAc (3 × 30 mL). The organic phase was combined, washed with brine (1 × 30 mL), and dried over Na_2SO_4. After filtration, the organic solution was concentrated, and the residue was purified by flash chromatography (silica gel/hexane−EtOAc 5:1 then 3:1 v/v) to give **12** in 88% yield (805.3 mg, 1.53 mmol): orange solid; mp 45−46 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.56−7.40 (m, 4H), 7.40−7.29 (m, 6H), 6.98 (s, 2H), 6.49 (s, 2H), 6.11−5.87 (br, 2H), 5.14 (s, 4H), 3.47 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 148.7 (2C), 148.4 (2C), 133.3 (4C), 132.8 (2C), 129.5 (4C), 128.9 (2C), 128.2 (2C), 123.7 (2C), 118.5 (2C), 118.1 (2C), 96.0 (2C), 56.4 (2C); HRMS (ESI-TOF) calcd for $C_{28}H_{26}NaO_6S_2$ 545.1069 [M + Na^+], found 545.1062.

Preparation of 4,4′-Bis(phenylsulfanyl)-2,2′-dimethoxy-5,5′-di(methoxymethyloxy)biphenyl (13). A solution of compound **12** (805.3 mg, 1.53 mmol) and 18-crown-6 ether (1625.0 mg, 1.53 mmol) in THF (20 mL) was added to a suspension of NaH (251.0 mg, 60%, 6.12 mmol) in THF (25 mL) at 0 °C. MeI (0.80 mL, 12.9 mmol) was added to the reaction mixture, and the resulting solution was stirred for 1 h at room temperature. The reaction mixture was concentrated, and NH_4Claq (20 mL) was added to the residue. The aqueous solution was extracted with EtOAc (3 × 20 mL). The organic phase was combined, washed with brine (1 × 20 mL), and dried over Na_2SO_4. After filtration, the organic solution was concentrated, and the residue was purified by flash chromatography (silica gel/hexane−EtOAc 13:1 then 10:1 v/v) to give **13** in 100% yield (872.4 mg, 1.58 mmol): pale yellow solid; mp 32−33 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.47−7.38 (m, 4H), 7.39−7.23 (m, 6H), 7.10 (s, 2H), 6.72 (s, 2H), 5.14 (s, 4H), 3.57 (s, 6H), 3.45 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 152.4 (2C), 149.0 (2C), 134.7 (2C), 131.6 (4C), 129.3 (4C), 127.3 (2C), 126.8 (2C), 125.4 (2C), 119.4 (2C), 114.8 (2C), 95.9 (2C), 56.4 (2C), 56.3 (2C); HRMS (ESI-TOF) calcd for $C_{30}H_{30}NaO_6S_2$ 573.1382 [M + Na^+], found 573.1369.

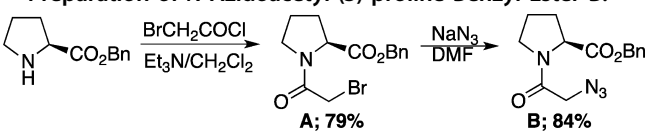
Preparation of 4,4′-Bis(phenylsulfanyl)-2,2′-dimethoxy-5,5′-dihydroxybiphenyl (14). A solution of **13** (299.6 mg, 0.544 mmol) in THF (2 mL) and 12 M HClaq (2 mL) was heated to refluxing temperature for 2 h. THF was removed under reduced pressure, and the remaining aqueous solution was extracted with EtOAc (3 × 20 mL). The organic phase was combined, washed with brine (1 × 20 mL), and dried over Na_2SO_4. After filtration, the organic solution was concentrated, and the residue was purified by flash chromatography (silica gel/hexane−EtOAc 10:1 then 4:1 v/v) to give **14** in 97% yield (244.9 mg, 0.529 mmol): pale yellow oil; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.27 (q, J = 7.7 Hz, 4H), 7.20−7.16 (m, 6H), 7.11 (s, 2H), 7.04 (s, 2H), 6.15 (s, 2H), 3.73 (s, 6H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 151.2 (2C), 151.1 (2C), 135.9 (2C), 131.1 (4C), 129.4 (4C), 127.1 (2C), 126.3 (2C), 118.6 (2C), 118.4 (2C), 115.4 (2C), 56.6 (2C); HRMS (ESI-TOF) calcd for $C_{26}H_{22}NaO_4S_2$ 485.0857 [M + Na^+], found 485.0880; λ_{abs} (MeOH, $\varepsilon \times 10^{-3}$) 322 (22) nm.

Preparation of 2,10-Dipropargyloxy-6,6-dimethyl-3,9-bis(phenylthio)dibenzo[*d*,*f*][1,3]dioxepine (15). Under a nitrogen atmosphere, a solution of **7a** (1176.9 mg, 2.0 mmol) in dry THF (5 mL) was added to a suspension of NaH (350.0 mg, 60%, 8.0 mmol) in THF (5 mL) over 15 min at 0 °C. 18-Crown-6 ether (1057.0 mg, 4.0 mmol) and propargyl bromide (951.2 mg, 8.0 mmol) were added to the solution at 0 °C, and the reaction mixture was stirred at 0 °C for an additional 15 min and at room temperature for 24 h. Saturated NH_4Claq (40 mL) was added, and THF was removed by rotary evaporator under reduced pressure. The resulting aqueous mixture was extracted with EtOAc (20 mL × 3). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 8:1 v/v) to give **15** in 85% yield (1105.4 mg, 1.7 mmol): white solid; mp 39−39.5 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.48−7.25 (m, 10H), 7.19 (s, 2H), 6.77 (s, 2H), 4.80 (s, 4H), 2.57 (s, 2H), 1.46 (s, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.4 (2C), 146.4 (2C), 133.7 (2C), 132.3 (4C), 131.7 (2C), 129.5 (4C), 127.8 (2C), 126.8 (2C), 125.4 (2C), 115.9 (2C), 112.8, 78.5 (2C), 76.4 (2C), 57.3 (2C), 24.8 (2C); HRMS (ESI-TOF) calcd for $C_{33}H_{26}NaO_4S_2$ 573.1170 [M + Na^+], found 573.1159.

Preparation of 4,4′-Bis(phenylsulfanyl)-2,2′-dihydroxy-5,5′-dipropargyloxybiphenyl (16). HClaq (12 M, 5 mL) was added to a solution of **15** (812.9 mg, 1.3 mmol) in THF (20 mL) and MeOH (25 mL), and the reaction mixture was stirred at refluxing temperature for 12 h. Water (10 mL) was added and the mixture extracted with Et_2O (3 × 20 mL). The organic phase was combined, washed with brine (50 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give **16** in 90% yield (709.3 mg, 1.1 mmol): brown solid; mp 52−52.5 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.41 (d, J = 7.1 Hz, 4H), 7.36−7.25 (m, 6H), 6.90 (s, 2H), 6.43 (s, 2H), 5.75 (s, 2H), 4.67 (s, 4H), 2.47 (s, 2H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 148.9 (2C), 147.9 (2C), 134.0 (4C), 132.3 (2C), 129.7 (4C), 129.6 (2C), 128.6 (2C), 122.2 (2C), 117.8 (2C), 116.4 (2C), 78.7 (2C), 76.3 (2C), 57.5 (2C); HRMS (ESI-TOF) calcd for $C_{30}H_{22}NaO_4S_2$ 533.0857 [M + Na^+], found 533.0839.

Proline-Attached Fluorescence Compound 17. A solution of $CuSO_4{\cdot}5H_2O$ (3.5 mg, 0.0105 mmol) and sodium ascorbate (10.7 mg, 0.0525 mmol) in water (1 mL) was added to a solution of compounds **16** (224.6 mg, 0.35 mmol) and *N*-azidoacetyl-(*S*)-proline benzyl ester (231.6 mg, 0.713 mmol, the preparation is described below) in THF, and the reaction mixture was stirred at room temperature for 72 h when compound **16** disappeared in TLC monitoring. Water (50 mL) was added to the mixture, and the resulting heterogeneous mixture was filtered. The filtrate was concentrated under reduced pressure, and MeOH (100 mL) was added to the residue. The MeOH solution gradually precipitated the products **17** that was isolated by filtration after 3 days: 24% yield (89.8 mg, 0.083 mmol); brown solid; mp 42−43 °C; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.09 (s, 2H), 7.44 (s, 2H), 7.27−7.04 (m, 20H), 6.79 (s, 2H), 6.53 (s, 2H), 5.21−4.83 (m, 12H), 4.36 (d, J = 8.2 Hz, 2H), 3.60−3.26 (m, 4H), 2.27−1.60 (m, 8H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 171.7 (2C), 164.1 (2C), 149.6 (2C), 148.0 (2C), 144.3 (2C), 135.5 (2C), 133.7 (2C), 132.4 (2C), 129.4 (4C), 128.9 (2C), 128.7 (4C), 128.5 (2C), 128.2 (4C), 127.6 (4C), 125.3 (2C), 124.7 (2C), 119.3 (2C), 116.7 (2C), 67.1 (2C), 63.2 (2C), 59.4 (2C), 51.6 (2C), 46.6 (2C), 28.9 (2C), 24.7 (2C); HRMS (ESI-TOF) calcd for $C_{58}H_{54}N_8NaO_{10}S_2$ 1109.3302 [M + Na^+], found 1109.3260.

Preparation of *N*-Azidoacetyl-(*S*)-proline Benzyl Ester B.



Preparation N-Bromoacetyl-(S)-proline Benzyl Ester A. Bromoacetyl chloride (1.0 mL, 10 mmol) was added to a suspension of L-proline benzyl ester (2408.3 mg, 10 mmol) and Et_3N (1.5 mL, 10.8 mmol) in CH_2Cl_2 (12 mL) at room temperature. The reaction mixture was stirred for 1 h. $NaHCO_3aq$ (10 mL) was added to the reaction

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mixture, and the resulting biphasic mixture was extracted with CH_2Cl_2 (3 × 20 mL). The organic phase was combined, washed with brine (10 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 3:1 then 1:1 v/v) to give *N*-bromoacetyl-(*S*)-proline benzyl ester in 79% yield (2556.2 mg, 7.9 mmol): yellow oil; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.45−7.28 (m, 5H), 5.18 (d, J = 12.3 Hz, 1H), 5.15 (d, J = 12.4 Hz, 1H), 4.57 (dd, J = 8.9, 3.9 Hz, 1H), 4.08 (d, J = 12.5 Hz, 1H), 4.04 (d, J = 12.6 Hz, 1H), 3.74−3.52 (m, 2H), 2.36−1.95 (m, 4H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 171.6, 165.2, 135.6, 128.9 (2C), 128.7, 128.2 (2C), 67.1, 59.4, 47.2, 41.9, 29.1, 24.9; HRMS (ESI-TOF) calcd for $C_{14}H_{16}BrNNaO_3$ 348.0211 [M + Na^+], found 348.0208.

Preparation of N-Azidoacetyl-(S)-proline Benzyl Ester B. Compound *N*-bromoacetyl-(*S*)-proline benzyl ester (2556.2 mg, 7.9 mmol) was added to a solution of NaN_3 (1.60 g, 23.7 mmol) in DMF (20 mL), and the reaction mixture was stirred at room temperature for 15 h. DMF was removed under reduced pressure, and water was added to the residue. The aqueous mixture was extracted with EtOAc (3 × 20 mL). The organic phase was combined, washed with brine (30 mL), and dried over Na_2SO_4. After filtration and concentration of the filtrate, the residue was subjected to flash chromatography (silica gel/hexane−EtOAc, 5:1 v/v) to give *N*-azidoacetyl-(*S*)-proline benzyl ester in 84% yield (1914.2 mg, 6.6 mmol): yellow oil; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.40−7.28 (m, 5H), 5.18 (d, J = 12.6 Hz, 1H), 5.13 (d, J = 12.3 Hz, 1H), 4.60 (dt, J = 7.1, 2.0 Hz, 1H), 3.90 (d, J = 16.2 Hz, 1H), 3.86 (d, J = 15.9 Hz, 1H), 3.63−3.52 (m, 1H), 3.47−3.36 (m, 1H), 2.34−1.76 (m, 4H); ^{13}C NMR ($CDCl_3$, 126 MHz) δ 171.6, 166.2, 135.6, 128.7 (2C), 128.4, 128.2 (2C), 67.1, 59.2, 51.0, 46.4, 29.0, 24.8; HRMS (ESI-TOF) calcd for $C_{14}H_{16}N_4NaO_3$ 311.1120 [M + Na^+], found 311.1113.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

Compound characterization data, UV/PL spectra of **1**, **4a**, **5**, **6**, **9a**, and **14**, MO calculation results, and X-ray data for **4a** (CIF). This material is available free of charge via Internet at http://pubs.acs.org.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: ak10@yamaguchi-u.ac.jp.

Notes

The authors declare no competing financial interest.

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