Chemically controlled amplified ratiometric fluorescence in surface-immobilized end-capped oligo(*p*-phenylene ethynylene)s

*Jiba Raj Acharya, Huating Zhang, Xian Li, and Evgueni E. Nesterov**

Supporting Information

Additional figures.

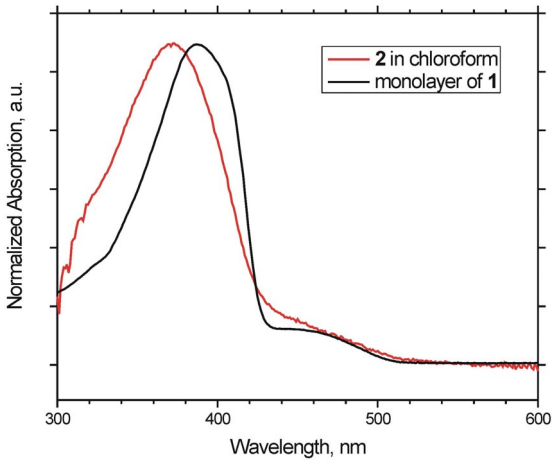


Figure S1. Normalized absorption spectra of **2** in $CHCl_3$ (extinction coefficient ε(379 nm) 1.26×10^6) and surface-immobilized monolayer of **1**.

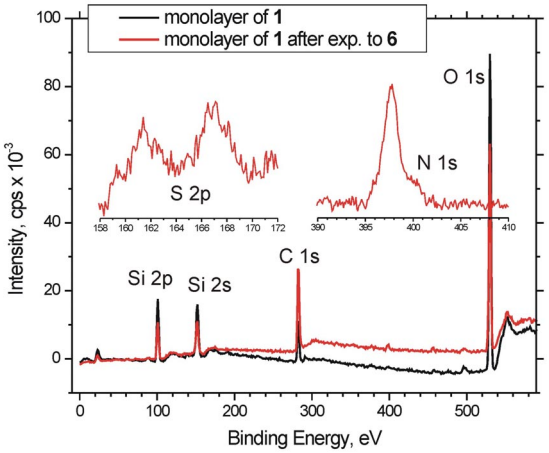


Figure S2. Survey XPS spectra of the monolayer of **1** immobilized on a glass surface before and after exposure to aqueous L-cysteine **6** solution (10 mM). Insets show separately acquired spectra of N1s and S2p regions in a sample after exposure to L-cysteine. Note that the N1s and S2p peaks were not detected in the monolayer before exposure to L-cysteine, and indicate presence of chemically bonded nitrogen and sulfur due to formation of thiazolidine compound in the L-cysteine treated films.

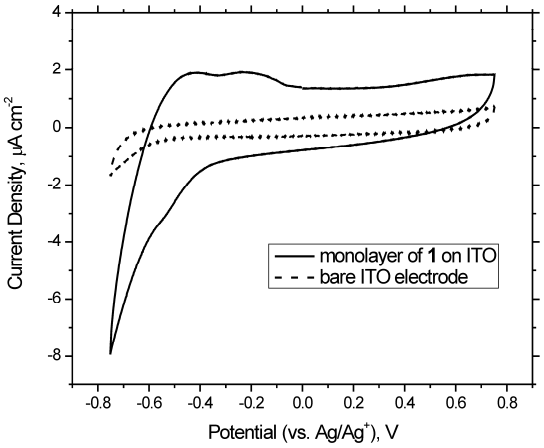


Figure S3. Cyclic voltammogram of a monolayer of **1** immobilized on ITO/glass surface. Experimental conditions: 0.1 M Bu_4NPF_6 in CH_2Cl_2, sweep rate 0.1 V s^{-1}.

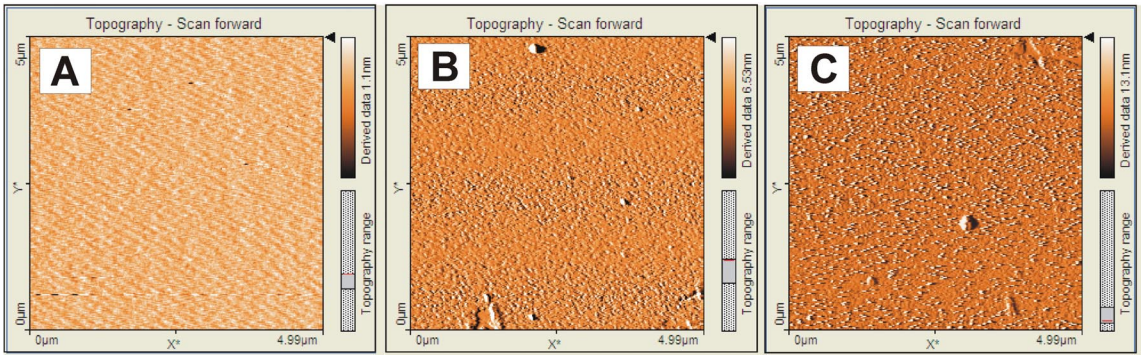


Figure S4. AFM images illustrating evolution of surface topography of a glass substrate: (A) Activated glass slide; (B) Glass slide modified with a covalently immobilized monolayer of **1** after annealing; (C) A monolayer of **1** after exposure to L-cysteine solution.

Experimental Details.

General Procedures. All reactions were performed under an atmosphere of dry nitrogen. Melting points were determined in open capillaries and are uncorrected. Column chromatography was performed on silica gel (Sorbent Technologies, 60 Å, 40-63 μm) slurry packed into glass columns. Tetrahydrofuran (THF), dichloromethane, ether, and toluene were dried by passing through activated alumina, and *N,N*-dimethylformamide (DMF) – by passing through activated molecular sieves, using a PS-400 Solvent Purification System from Innovative Technology, Inc. The water content of the solvents was periodically controlled by Karl Fischer titration (using a DL32 coulometric titrator from Mettler Toledo). All other solvents were additionally purified and dried by standard techniques. High purity $Pd(PPh_3)_4$ was obtained from Strem Chemicals, Inc. All other reagents were obtained from Aldrich and Alfa Aesar and used without further purification.

Indium tin oxide (ITO) coated glass slides with 8-12 Ohm/sq. surface resistivity were purchased from Delta Technologies, Ltd. ^{1}H NMR spectra were recorded at 250, 300 and 400 MHz and are reported in ppm downfield from tetramethylsilane. UV-visible spectra were recorded on Varian Cary 50 UV-Vis spectrophotometer. Fluorescence studies were carried out with a PTI QuantaMaster4/2006SE spectrofluorimeter. Fluorescence quantum yields were determined using ethanol solution of Coumarin 6 (Φ = 0.78[1]) or 0.1 M H_2SO_4 solution of quinine sulphate (Φ = 0.55[2]) as standards. Atomic Force Microscopy (AFM) images were acquired in a tapping mode with easyScan 2 AFM (Nanosurf AG). High resolution mass spectra were obtained at the LSU Department of Chemistry Mass Spectrometry Facility using an ESI or MALDI-TOF method, and a peak matching protocol to determine the mass and error range of the molecular ion.

Synthetic Details

A. General procedure for iodination:

To a stirred solution of an aryl bromide in THF at -78 °C, a solution of *n*BuLi was added dropwise and the reaction mixture was stirred for 3 h. A solution of iodine (or 1,2-diiodoethane) in THF was added dropwise and stirred for an additional 1 h at -70 °C, and was allowed to warm to room temperature overnight. The resulting solution was concentrated to approximately 30% of the initial volume and treated with a 20% $Na_2S_2O_3$ aq. solution. The product was extracted with CH_2Cl_2, washed with water and saturated NaCl solution, and dried over anhydrous Na_2SO_4. After concentration in vacuo, a crude product was purified by recrystallization or column chromatography.

B. General procedure for cross-coupling reaction (Sonogashira coupling):

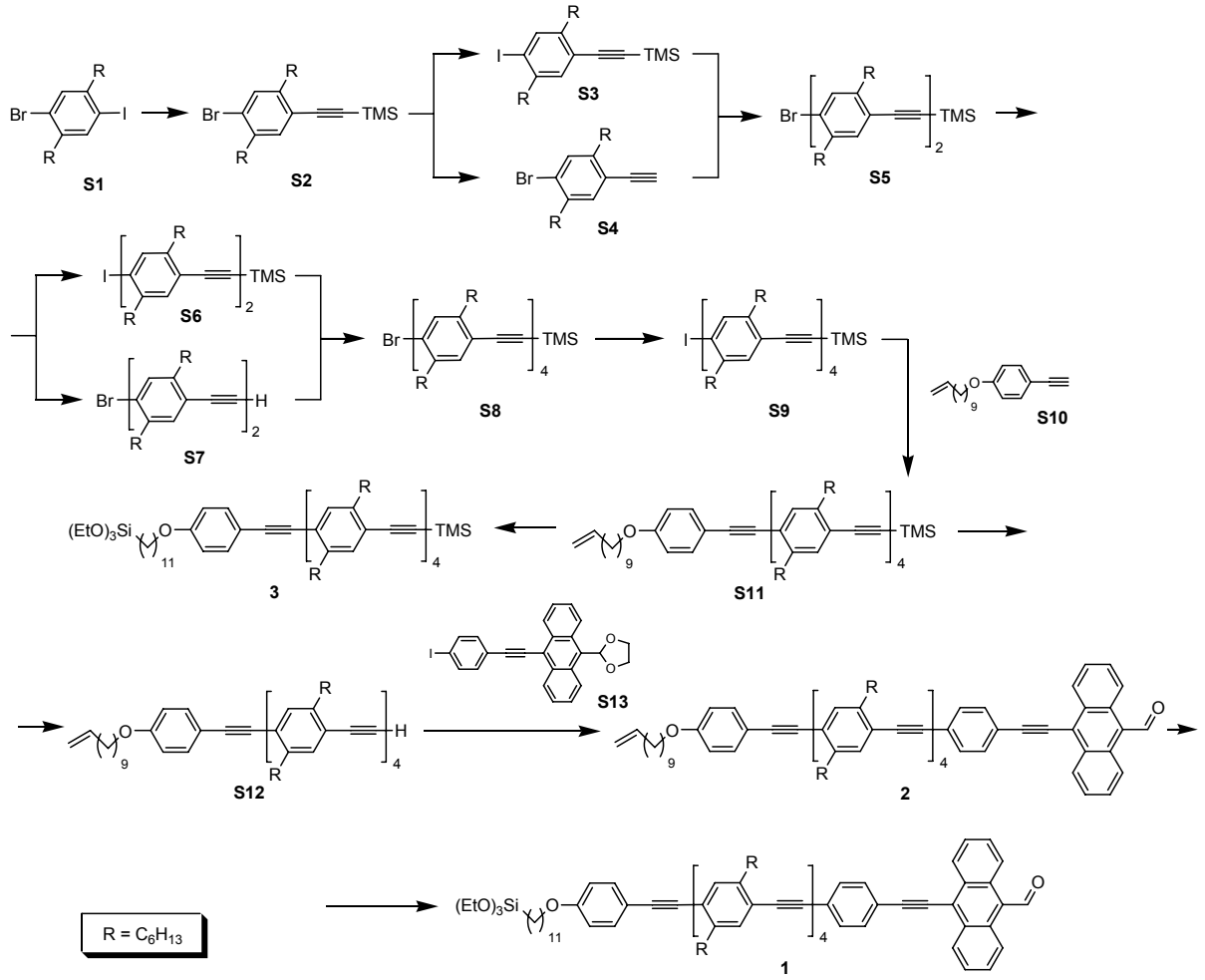
A mixture of acetylene, aryl iodide, $Pd(PPh_3)_4$ and CuI in toluene – diisopropylamine (7:3) was stirred in a sealed flask in argon atmosphere for 24-72 hours at 45-65 °C. The mixture was cooled to room temperature and passed through a short column with silica gel eluted with chloroform to separate inorganic impurities. Concentration in vacuo afforded a crude product that was further purified by column chromatography on silica gel.

C. General procedure for desilylation:

To a stirred solution of KOH in MeOH, a solution of a TMS-protected acetylene in THF was added dropwise and stirred for 40 minutes at room temperature. The resulting solution was concentrated to 30% of the initial volume and then extracted with diethyl ether, washed with water, NaCl and dried over anhydrous Na_2SO_4. The crude product was purified by column chromatography.

1-Bromo-2,5-dihexyl-4-iodobenzene (**S1**) was prepared following the literature procedures.[3,4]

((4-Bromo-2,5-dihexylphenyl)ethynyl)trimethylsilane (**S2**) was prepared following the general procedure **B**. A reaction of a mixture of 28.0 g (0.062 mol) of **S1**, 9.56 ml (6.69 g, 0.0683 mol) of TMS-acetylene, 0.36 g (0.31 mmol) of $Pd(PPh_3)_4$, and 0.06 g (0.31 mmol) of CuI in 250 ml of iPr$_2$NH – toluene (3:7) afforded, after column chromatography on silica gel (eluent hexane), 17.2 g (89%) of **S2** as a colorless oil, R_f 0.78. ^{1}H NMR (250 MHz, acetone-D$_6$) δ 7.46 (s, 1H), 7.33 (s, 1H), 2.78 - 2.63 (m, 4H), 1.68 - 1.50 (m, 4H), 1.45 - 1.25 (m, 12H), 0.95 - 0.85 (m, 6H), 0.25 (s, 9H).



((2,5-Dihexyl-4-iodophenyl)ethynyl)trimethylsilane (**S3**) was prepared following the general procedure **A**. A reaction of 17.2 g (0.041 mol) of **S2,** 28.1 ml (0.044 mol) of 1.6 M nBuLi in hexanes, 13.54 g (0.053 mol) of iodine in 250 ml of THF afforded, after column chromatography on silica gel (eluent hexane), 19.5 g (80%) of **S3** as a colorless oil, R_f 0.71. ^{1}H NMR (250 MHz,

acetone-D_6), δ 7.75 (s, 1H), 7.31(s, 1H), 2.75 - 2.64 (m, 4H), 1.72 - 1.50 (m, 4H), 1.45 - 1.20 (m, 12H), 0.95 - 0.82 (m, 6H), 0.25 (s, 9H).

1-Bromo-4-ethynyl-2,5-dihexylbenzene (**S4**) was prepared following the general procedure **C**. A reaction of 17.5 g (0.042 mol) of **S3** in 150 ml of THF and 7.0 g (0.125 mol) of KOH in 225 ml of methanol afforded, after column chromatography on silica gel (eluent hexane) 14.2 g (98%) of **S4** as a colorless oil, R_f 0.76. ^{1}H NMR (250 MHz, acetone-D_6) δ 7.46 (s, 1H), 7.37 (s, 1H), 3.87 (s, 1H), 2.85 - 2.60 (m, 4H), 1.75 - 1.55 (m, 4H), 1.50 - 1.20 (m, 12H), 0.95 - 0.80 (m, 6H).

TMS-protected dimer S5 was prepared following the general procedure **B**. A reaction of 14.87 g (0.032 mol) of **S3**, 12.3 g (0.035 mol) of **S4**, 0.18 g (0.16 mmol) of $Pd(PPh_3)_4$, and 0.03 g (0.16 mmol) of CuI in 300 ml of *i*Pr_2NH – toluene (3:7) afforded, after column chromatography on silica gel (eluent hexane), 20.69 g (93%) of **2** as a yellowish oil, R_f 0.67. ^{1}H NMR (250 MHz, acetone-D_6) δ 7.52 (s, 1H), 7.45 (s, 1H), 7.41 (s, 1H), 7.34 (s, 1H), 2.90 - 2.63 (m, 8H), 1.80 - 1.55 (m, 8H), 1.50 - 1.25 (m, 24H), 0.95 - 0.80 (m, 12H), 0.26 (s, 9H).

Aryl iodide S6 was prepared following the general procedure **A**. A reaction of 10.5 g (0.015 mol) of **S5**, 10.5 ml (0.017 mol) of 1.6 M solution of *n*BuLi in hexanes, 5.8 g (0.023 mol) of iodine in 200 ml of THF afforded, after column chromatography on silica gel (eluent hexane), 9.61 g (86%) of **S6** as a yellowish oil, R_f 0.65. ^{1}H NMR (250 MHz, acetone-D_6) δ 7.80 (s, 1H), 7.42 (s, 1H), 7.41 (s, 1H), 7.34 (s, 1H), 2.92 - 2.70 (m, 8H), 1.80 - 1.55 (m, 8H), 1.50 - 1.25 (m, 24H), 0.98 - 0.82 (m, 12H), 0.26 (s, 9H).

Arylacetylene S7 was prepared following the general procedure **C**. A reaction of 8.53 g (12.4 mmol) of **S5** in 100 ml of THF, 2.1 g (3.78 mmol) of KOH in 200 ml of methanol afforded, after column chromatography on silica gel (eluent hexane), 7.31 g (97%) of **S7** as a slightly pink solid, R_f 0.64, mp 39-40 °C (lit.[4] mp 39°C). ^{1}H NMR (250 MHz, acetone-D_6), δ 7.52 (s, 1H), 7.45 (s, 1H), 7.41 (s, 1H), 7.38 (s, 1H), 3.93 (s, 1H), 2.95 - 2.63 (m, 8H)), 1.82 - 1.55 (m, 8H), 1.50 - 1.15 (m, 24H), 1.00 - 0.85 (m, 12H).

TMS-protected tetramer S8 was prepared following the general procedure **B**. A reaction of 8.72 g (11.8 mmol) of **S6**, 7.31 g (11.8 mol) of **S7**, 0.10 g (0.089 mmol) of $Pd(PPh_3)_4$, and 0.017 g (0.089 mmol) of CuI in 300 ml of *i*Pr_2NH – toluene (3:7) afforded, after column chromatography on silica gel (eluent hexane), 11.65 g (80%) of **S8** as a greenish-yellow solid, R_f 0.67, mp 77 °C (lit.[4] mp 77 °C). ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.38 (s, 1H), 7.36 - 7.26 (m, 7H), 2.82 - 2.57 (m, 16H), 1.80 - 1.55 (m, 32H), 1.50 - 1.20 (m, 32H), 0.88 - 0.75 (m, 24H), 0.25 (s, 9H). UV ($CHCl_3$) λ_{max} 359 nm ($\varepsilon = 4.45\times10^4$), fluorescence ($CHCl_3$) λ_{max} 421 nm.

Iodide S9 was prepared following the general procedure **A**. A reaction of 9.35 g (7.62 mmol) of **S8**, 5.7 ml (9.14mmol) of 1.6 M solution of *n*BuLi in hexanes, and 2.58 g (9.1 mmol) of 1,2-diiodoethane in 300 ml of THF afforded, after column chromatography on silica gel (eluent hexane), 6.69 g (69%) of **S9** as a yellow solid, R_f 0.65, mp 85-87 °C (lit.[4] mp 85 °C). ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.68 (s, 1H), 7.43 - 7.30 (m, 7H), 2.92 - 2.57 (m, 16H), 1.85 - 1.50 (m, 16H), 1.50 - 1.20 (m, 48H), 1.00 - 0.75 (m, 24H), 0.27 (s, 9H).

Pentamer S11 was prepared following the general procedure **B**. A reaction of 2.0 g (1.6 mmol) of **S9,** 0.75 g (2.8 mmol) of **S10**, 0.036 g (0.03 mmol) of $Pd(PPh_3)_4$, and 0.006 g (0.03 mmol) of CuI in 100 ml of *i*Pr_2NH – toluene (3:7) afforded, after column chromatography on silica gel (eluent hexane : chloroform 10:1), 1.24 g (56%) of **S11** as a greenish-yellow sticky solid, R_f 0.52, mp 101-103 °C. ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.43 (d, J = 8.6 Hz, 2H), 7.38-7.26 (m, 8H), 6.86 (d, J = 8.6 Hz, 2H), 5.88 - 5.72 (m, 1H), 5.05 - 4.86 (m, 2H), 3.96 (t, J = 6.5 Hz, 2H), 2.90 - 2.65 (m, 16H), 2.04 - 1.95 (m, 2H), 1.85 - 1.55 (m, 24H), 1.50 - 1.20 (m, 54H), 0.95 - 0.80 (m, 24H), 0.25 (s, 9H). UV ($CHCl_3$) λ_{max} 374 nm, fluorescence ($CHCl_3$) λ_{max} 412 nm (Φ = 0.41).

Compound 3. One drop of platinum(0)-1,3-divinyl-1,1,3,3-tetramethyl-disiloxane complex (Karstedt's catalyst, 0.1 M solution in poly(dimethylsiloxane)) was added at room temperature to a solution of compound **S11** (23.8 mg, 0.017 mmol) in 6 ml of toluene, and stirred for 10 min. Triethoxysilane (26.5 μl, 0.168 mmol) was added to the resulting solution and stirred for 1 h at room temperature. The reaction mixture was concentrated in vacuo, dissolved in toluene, filtered through a 0.22 μm PTFE filter, and concentrated in vacuo to afford **3** in quantitative yield as a greenish-yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (d, J = 8.9 Hz, 2H), 7.45 - 7.28 (m, 8H), 6.86 (d, J = 8.9 Hz, 2H), 3.96 (t, J = 6.5 Hz, 2H), 3.95 - 3.72 (m, 8H), 2.95 - 2.65 (m, 16H), 1.90 - 1.55 (m, 24H), 1.50 - 1.15 (m, 67H), 0.95 - 0.85 (m, 24H), 0.25 (s, 9H).

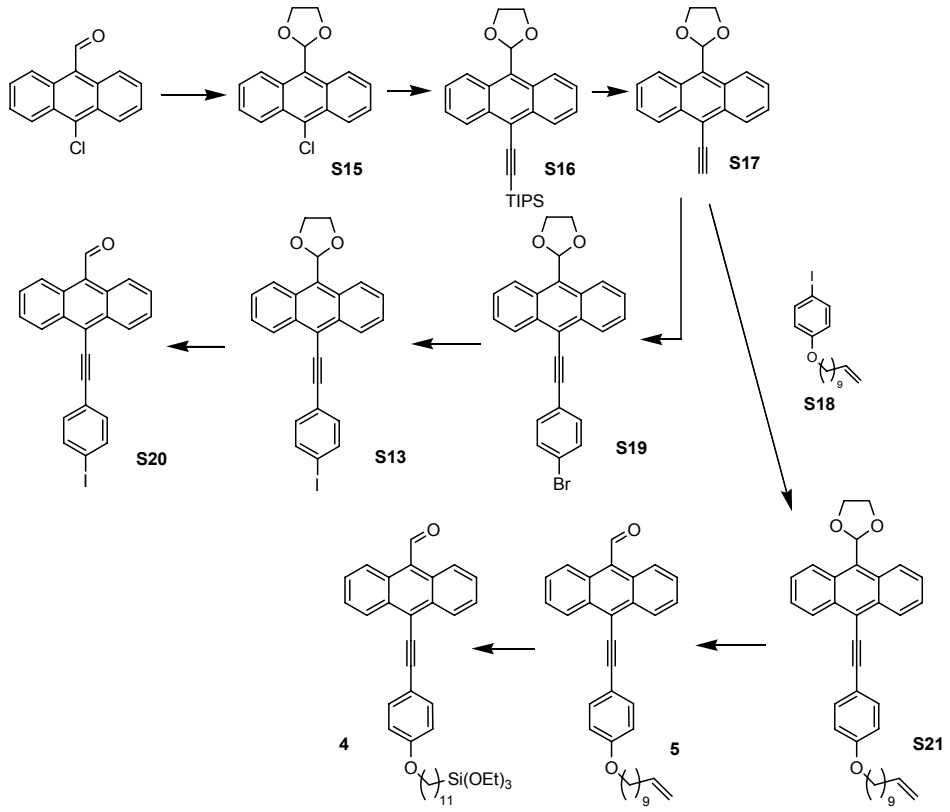
Compound S12 was prepared following the general procedure **C**. A reaction of 1.14g (0.81 mmol) of **S11** in 100 ml of THF and 0.14g (2.5 mmol) of KOH in 20 mL of MeOH afforded, after column chromatography on silica gel (eluent hexane-chloroform 8:1), 0.96 g (87%) of acetylene **S12** as a greenish-yellow solid, R_f 0.55, mp 66-68 °C. ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.47 (d, J = 8.9 Hz, 2H), 7.45 - 7.25 (m, 8H), 6.86 (d, J = 8.9 Hz, 2H), 5.93 - 5.70 (m, 1H), 5.06 - 4.85 (m, 2H), 3.96 (t, J = 6.5 Hz, 2H), 3.28 (s, 1H), 2.88 - 2.65 (m, 16H), 2.12 - 1.99 (m, 2H), 1.84 - 1.55 (m, 16H), 1.50 - 1.15 (m, 62H), 0.95 - 0.75 (m, 24H).

Acetal-protected aldehyde 2 (compound **S14**) was prepared following the general procedure **B**. A reaction of 0.34 g (0.253 mmol) of **S12**, 0.24 g (0.504 mmol) of **S13**, 30 mg (0.0253 mmol) of $Pd(PPh_3)_4$, and 4.9 mg (0.0253 mmol) of CuI in 35 ml of *i*Pr_2NH – toluene (3:7) afforded, after column chromatography on silica gel (eluent chloroform – hexane 1:2), 0.31 g (73%) of **S14**

as a yellow solid, R_f 0.42. The product contained some unidentified impurities, and was used for the next step without further purification. ^{1}H NMR (250 MHz, $CDCl_3$) δ 8.72 (d, J = 8.6 Hz, 2H), 8.56 (d, J = 8.6 Hz, 2H), 7.75 (d, J = 8.6 Hz, 2H), 7.63 - 7.25 (m, 16H), 7.08 (s, 1H), 6.86 (d, J = 8.6 Hz, 2H), 5.92 - 5.71 (m, 1H), 5.08 - 4.86 (m, 2H), 4.58 - 4.43 (m, 2H), 4.32 - 4.21 (m, 2H), 3.95 (t, J = 6.4 Hz, 2H), 2.90 - 2.72 (m, 16H), 2.10 - 1.95 (m, 2H), 1.85 - 1.55 (m, 16H), 1.50 - 1.15 (m, 62H), 0.95 - 0.75 (m, 24H).

Aldehyde 2. A solution of 200 mg (0.118 mmol) of **S14** and 5 mg (0.026 mmol) of *p*-toluenesulfonic acid monohydrate in 15 ml of acetone and 5 ml of chloroform was stirred at room temperature for 5 h. The reaction mixture was poured into water, extracted with CH_2Cl_2 (3×100 ml), washed with saturated aq. $NaHCO_3$ (3×50 ml), water, and dried over Na_2SO_4. Concentration in vacuo afforded a crude product which was purified by column chromatography on silica gel (eluent hexane – chloroform 1:1) to yield 150 mg (77%) of **2** as a yellow solid, R_f 0.55, mp 143-145 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.51 (s, 1H), 8.95 (d, J = 8.8 Hz, 2H), 8.76 (d, J = 8.8 Hz, 2H), 7.77 (d, J = 8.2 Hz, 2H), 7.74 - 7.64 (m, 4H), 7.61 (d, J = 8.6 Hz, 2H), 7.46 - 7.25 (m, 10H), 6.86 (d, J = 8.6 Hz, 2H), 5.90 - 5.72 (m, 1H), 5.05 - 4.85 (m, 2H), 3.96 (t, J = 6.4 Hz, 2H), 2.92 - 2.73 (m, 16H), 2.10 - 1.98 (m, 2H), 1.83 - 1.60 (m, 16H), 1.50 - 1.15 (m, 62H), 0.98 - 0.76 (m, 24H). MS (MALDI-TOF) *m/e* 1648.11 (calcd for $C_{122}H_{150}O_2$ 1648.17). UV ($CHCl_3$) λ_{max} 379 nm (ε = 1.26×10^6), fluorescence ($CHCl_3$) λ_{max} 421 nm (Φ = 0.08).

Compound 1. One drop of platinum(0)-1,3-divinyl-1,1,3,3-tetramethyl-disiloxane complex (Karstedt's catalyst, 0.1 M solution in poly(dimethylsiloxane)) was added to a solution of **2** (98.3 mg, 0.062 mmol) in 15 ml of toluene and stirred at room temperature for 10 min followed by addition of triethoxysilane (0.11 ml, 0.62 mmol). The resulting mixture was stirred at room temperature for 1 h. The reaction mixture was concentrated in vacuo, dissolved in toluene, filtered through a 0.22 μm PTFE filter, and concentrated in vacuo to afford **1** in quantitative yield as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.52 (s, 1H), 8.95 (d, J = 8.8 Hz, 2H), 8.76 (d, J = 8.8 Hz, 2H), 7.77 (d, J = 8.2 Hz, 2H), 7.74 - 7.65 (m, 4H), 7.61 (d, J = 8.2 Hz, 2H), 7.54 - 7.48 (m, 2H), 7.46 - 7.31 (m, 8H), 6.86 (d, J = 8.2 Hz, 2H), 3.96 (t, J = 6.4 Hz, 2H), 3.84 - 3.77 (m, 6H), 2.82 - 2.75 (m, 16H), 2.08 – 1.95 (m, 2H), 1.79 - 1.05 (m, 91H), 0.94 - 0.82 (s, 24H).



2-(10-Chloro-9-anthracenyl)-1,3-dioxolane (**S15**). A mixture of 5.0 g (20.8 mmol) of 10-chloroanthraldehyde, 5.16 g (4.64 ml, 83.2 mmol) of ethylene glycol, and 34 mg (0.18 mmol) of *p*-toluenesulfonic acid monohydrate was refluxed with Dean-Stark adaptor for 21 h. After allowing to cool down to room temperature, the reaction mixture was washed with aq. $NaHCO_3$ (three times), water, and saturated NaCl solution, and dried over anhydrous Na_2SO_4. Concentration in vacuo afforded crude product which was recrystallized from hexane – dichloromethane mixture to yield 5.26 g (89%) of **S15** as yellow needle-like crystals, mp 149-150 °C. ^{1}H NMR (250 MHz, $CDCl_3$) δ 8.64 - 8.52 (m, 4H), 7.63 - 7.48 (m, 4H), 7.07 (s, 1H), 4.54 - 4.46 (m, 2H), 4.30 - 4.22 (m, 2H).

2-(10-Triisopropylsilylethynyl-9-anthracenyl)-1,3-dioxolane (**S10**). The reaction was performed utilizing the conditions developed by Gelman and Buchwald.[5] A mixture of 0.5 g (1.76 mmol) of **S15**, 0.48 g (0.59 ml, 2.64 mmol) of TIPS-acetylene, 4.7 mg (0.018 mmol) of $PdCl_2(CH_3CN)_2$, 25.3 mg (0.053 mmol) of 2-(dicyclohexylphosphino)-2',4',6'-triisopropyl-1,1'-biphenyl (X-Phos), 1.47 g (4.5 mmol) of Cs_2CO_3 in 20 ml of acetonitrile was stirred for 24 h at 90 °C. After allowing to cool to room temperature, the reaction mixture was poured into water, extracted with diethyl ether, washed with water and conc. NaCl, and dried over anhydrous Na_2SO_4. After concentration in vacuo, the crude product was purified by column chromatography on silica gel (eluent hexane – ethyl acetate 3:1), and a fraction with R_f 0.45 afforded 0.45 g (60%) of **S16** as a

dark-red oil crystallizing on standing. Although the product contained some unidentified impurities, it was used for the next step without further purification. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.69 (d, *J* 7.0 Hz, 2H), 8.53 (d, *J* = 7.0 Hz, 2H), 7.60 - 7.45 (m, 4H), 7.06 (s, 1H), 4.55 - 4.43 (m, 2H), 4.32 - 4.21 (m, 2H), 1.38 - 1.12 (m, 21H).

2-(10-ethynyl-9-anthracenyl)-1,3-dioxolane (**S17**). A solution of TBAF (10.8 ml of 1 M solution in THF, 0.01 mmol) was added dropwise to a solution of 1.55 g (3.6 mmol) of **S16** in 30 ml of THF, and the resulting mixture was stirred at room temperature for 5 min, poured into a saturated aq. NH_4Cl solution, extracted with hexane – ethyl acetate (3:1), washed with water, saturated NH_4Cl and NaCl solutions, and dried over anhydrous Na_2SO_4. After concentration in vacuo, the crude product was purified by column chromatography on silica gel (eluent hexane – ethyl acetate 3:1), and the fraction with R_f 0.32 afforded 0.63 g (51%) of **S17** as a brown-red solid. Although the product contained some unidentified impurities, it was used for the next step without further purification. ^{1}H NMR (250 MHz, $CDCl_3$) δ 8.65 (d, *J* = 7.5 Hz, 2H), 8.55 (d, *J* = 7.5 Hz, 2H), 7.62 - 7.45 (m, 4H), 7.07 (s, 1H), 4.56 -4.44 (m, 2H), 4.31 - 4.20 (m, 2H), 4.03 (s, 1H).

2-(10-(4-Bromophenyl)ethynyl-9-anthracenyl)-1,3-dioxolane (**S19**). A mixture of 0.63 g (2.3 mmol) of **S17**, 0.65 g (2.3 mmol) of 1-bromo-4-iodobenzene, 80 mg (0.06 mmol) of $Pd(PPh_3)_4$, 13 mg (0.06 mmol) of CuI in 30 ml of *i*Pr_2NH – toluene (3:7) was stirred at 45 °C for 24 h. After allowing to cool to room temperature, the reaction mixture was poured into water, extracted with CH_2Cl_2, washed with water, conc. NaCl, and dried over anhydrous Na_2SO_4. After concentration in vacuo, the crude product was purified by recrystallization from hexane – CH_2Cl_2 mixture to afford 0.66 g (67%) of **S17** as a yellow crystalline solid, mp 210-212 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.68 (d, *J* = 7.5 Hz, 2H), 8.56 (d, *J* = 7.5 Hz, 2H), 7.70 - 7.40 (m, 8H), 7.07 (s, 1H), 4.61 - 4.41 (m, 2H), 4.33 - 4.18 (m, 2H).

2-(10-(4-Iodophenyl)ethynyl-9-anthracenyl)-1,3-dioxolane (**S13**). The reaction was performed utilizing the conditions developed by Klapars and Buchwald.[6] A mixture of 0.62 g (1.45 mmol) of **S12**, 0.48 g (3.18 mmol) of NaI, 0.08 g (60 μl, 0.58 mmol) of *trans-N,N'*-dimethyl-1,2-cyclohexanediamine, 0.01 g (0.007 mmol) of CuI in 10.0 ml of dioxane was stirred at 110 °C for 24 h. The mixture was cooled down to room temperature, diluted with conc. aq. NH_3 solution, poured into water, extracted with CH_2Cl_2, washed with water, conc. NaCl, and dried over Na_2SO_4. After concentration in vacuo, the residue was dissolved in ethyl acetate and passed through a short column with silica gel eluted with ethyl acetate. The crude product was recrystallized from hexane – dichloromethane to afford 0.55 g (80%) of **S13** as a yellow crystalline solid, mp 216-218 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.67 (d, *J* = 8.8 Hz, 2H), 8.56 (d, *J* = 8.9 Hz, 2H), 7.77 (d, *J* = 8.4 Hz, 2H), 7.65 - 7.50 (m, 4H), 7.47 (d, *J* = 8.4 Hz, 2H), 7.07 (s, 1H), 4.58 - 4.45 (m, 2H), 4.35 - 4.20 (m,

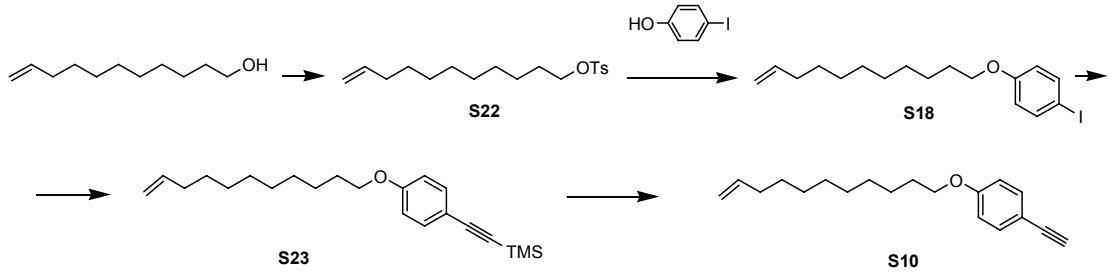
2H). HRMS *m/e* 477.0377 $[M+H]^+$ (calcd for $C_{25}H_{18}IO_2$ 477.0351). UV ($CHCl_3$) λ_{max} 407 (0-1), 432 (0-0) nm, fluorescence ($CHCl_3$) λ_{max} 439 (0-0), 466 (0-1) nm.

10-(4-Iodophenyl)ethynyl-9-anthraldehyde (**S20**). A mixture of 100 mg (0.21 mmol) of **S13** and 5 mg (0.026 mmol) of *p*-toluenesulfonic acid monohydrate in 15 ml of acetone was stirred for 4 h at room temperature. The reaction mixture was poured into water, extracted with CH_2Cl_2 (3×30 ml), the organic fraction was washed with water (3×100 ml), saturated $NaHCO_3$ (3×30 ml), and dried over anhydrous Na_2SO_4 overnight. After concentration in vacuo, the crude product was purified by column chromatography on silica gel (eluent chloroform – hexane 1:1) to afford 78 mg (86%) of **11** as a yellow solid, R_f 0.6, mp 211-215 °C. ^{1}NMR (400 MHz, $CDCl_3$) δ 11.48 (s, 1H), 8.91 (d, *J* = 8.9 Hz, 2H), 8.68 (d, *J* = 8.3 Hz, 2H), 7.79 (d, *J* = 8.4 Hz, 2H), 7.73 - 7.56 (m, 4H), 7.47 (d, *J* = 8.4 Hz, 2H). HRMS *m/e* 433.0101 $[M+H]^+$ (calcd for $C_{23}H_{14}IO$ 433.0089).

2-(10-(4-(10-Undecenyloxy)phenyl)ethynyl-9-anthracenyl)-1,3-dioxolane (**S21**). A mixture of 54 mg (0.20 mmol) of **S17**, 81 mg (0.22 mmol) of **S18**, 11.5 mg (0.01 mmol) of $Pd(PPh_3)_4$, and 1.9 mg (0.01 mmol) of CuI in 10 ml of iPr$_2$NH – toluene (3:7) was stirred in inert atmosphere in a sealed flask at 55 °C for 36 h. After allowing cooling down to room temperature, the reaction mixture was passed through a short column with silica gel eluted with $CHCl_3$, and concentrated in vacuo. The crude product was further purified by column chromatography on silica gel (eluent chloroform – hexane 1:1), to afford 72 mg (70%) of **S21** as a yellow solid, R_f 0.67. The product contained some unidentified impurities, and was used for the next step without further purification. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.72 (d, *J* = 9.1 Hz, 2H), 8.54 (d, *J* = 9.1 Hz, 2H), 7.67 (d, *J* = 8.8 Hz, 2H), 7.58 - 7.46 (m, 4H), 7.07 (s, 1H), 6.94 (d, *J* = 8.8 Hz, 2H), 5.88 - 5.72 (m, 1H), 5.05 - 4.86 (m, 2H), 4.54 - 4.46 (m, 2H), 4.32 - 4.22 (m, 2H), 4.00 (t, *J* = 6.5 Hz, 2H), 2.08 - 1.98 (m, 2H), 1.85 - 1.72 (m, 2H), 1.54 - 1.20 (m, 14H).

10-(4-(10-Undecenyloxy)phenyl)ethynyl-9-anthraldehyde (**5**). A solution of 72 mg (0.14 mmol) of **S21** and 5 mg (0.026 mmol) of *p*-toluenesulfonic acid monohydrate in 20 ml of acetone was stirred for 4 h at room temperature. The reaction mixture was poured into water, extracted with CH_2Cl_2 (3×50 ml), the organic fraction was washed with water (3×100 ml), saturated $NaHCO_3$ (3×30 ml), and dried over anhydrous Na_2SO_4. After concentration in vacuo, the crude product was purified by column chromatography on silica gel (eluent chloroform – hexane 1:1) to yield 55 mg (60%) of **5** as a yellow solid, R_f 0.64, mp 112-115 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.51 (s, 1H), 8.97 (d, *J* = 8.8 Hz, 2H), 8.77 (d, *J* = 8.5 Hz, 2H), 7.79 - 7.60 (m, 6H), 6.98 (d, *J* = 8.6 Hz, 2H), 5.87 - 5.73 (m, 1H), 5.03 - 4.86 (m, 2H), 4.04 (t, *J* = 6.5 Hz, 2H), 2.10 - 2.00 (m, 2H), 1.88 - 1.77 (m, 2H),1.58 - 1.18 (m, 12H). HRMS *m/e* 475.2648 $[M+H]^+$ (calcd for $C_{34}H_{35}O_2$ 475.2637). UV ($CHCl_3$) λ_{max} 432 nm ($\varepsilon = 1.13\times10^4$), fluorescence ($CHCl_3$) λ_{max} 518 nm ($\Phi = 0.02$).

10-(4-(11-(Triethoxysilyl)undecyloxy)phenyl)ethynyl-9-anthraldehyde (**4**). One drop of platinum(0)-1,3-divinyl-1,1,3,3-tetramethyl-disiloxane complex (Karstedt's catalyst, 0.1 M solution in poly(dimethylsiloxane)) was added to a solution of **5** (55 mg, 0.011 mmol) in 6 ml of toluene and stirred at room temperature for 10 min followed by addition of triethoxysilane (0.20 ml, 1.15 mmol). The resulting mixture was stirred at room temperature for 1 h. The reaction mixture was concentrated in vacuo, dissolved in toluene, filtered through a 0.22 μm PTFE filter, and concentrated in vacuo to afford **4** in quantitative yield as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$), δ 11.52 (s, 1H), 8.98 (d, J = 8.6 Hz, 2H), 8.77 (d, J = 8.3 Hz, 2H), 7.80 - 7.60 (m, 6H), 6.98 (d, J = 7.8 Hz, 2H), 4.03 (t, J = 6.6 Hz, 2H), 3.90 - 3.85 (m, 6H), 2.10 - 0.75 (m, 29H).



1-(4-Tolylsulfonyl)-10-undecene (**S22**) was prepared following the literature procedure.[7]

4-Iodo-1-(10-undecenyloxy)benzene (**S18**). A mixture of 2.93 g (0.013 mol) of 4-iodophenol, 8.63 g (0.027 mol) of **S22**, 3.68 g (0.266 mol) of K_2CO_3, and 0.22 g (1.33 mmol) of KI in 200 ml of ethyl methyl ketone was refluxed for 60 h. The mixture was allowed to cool down to room temperature, and the solid precipitate was removed by filtration. The filtrate was concentrated in vacuo, and the crude product purified by column chromatography on silica gel (eluent ethyl acetate – hexane 1:3) to afford 4.7 g (96%) of **S18** as a colorless oil, R_f 0.80. ^{1}H NMR spectrum was in agreement with the literature data.[8]

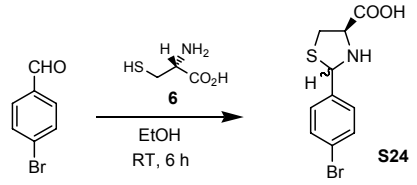
1-(Trimethylsilyl)-2-(4-(10-undecenyloxy)phenyl)acetylene (**S23**). A mixture of 4.12 g (10.1 mmol) of **S18**, 1.98 g (2.85 ml, 20.2 mmol) of trimethylsilylacetylene, 0.12 g (0.1 mmol) of $Pd(PPh_3)_4$, 20 mg (0.1 mmol) of CuI in 100 ml of iPr$_2$NH – toluene (3:7) was stirred in a sealed flask at 55 °C for 30 h. After allowing to cool to room temperature, the reaction mixture was passed through a short column with silica gel eluted with $CHCl_3$. Concentration in vacuo afforded 3.78 g (100%) of **S23** as a yellowish oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, J = 8.6 Hz, 2H), 6.77 (d, J = 8.6 Hz, 2H), 5.90 - 5.72 (m, 1H), 5.05 - 4.85 (m, 2H), 3.91 (t, J = 6.5 Hz, 2H), 2.06 - 1.96 (m, 2H), 1.80 - 1.68 (m, 2H), 1.47 - 1.20 (m, 12H), 0.21 (s, 9H).

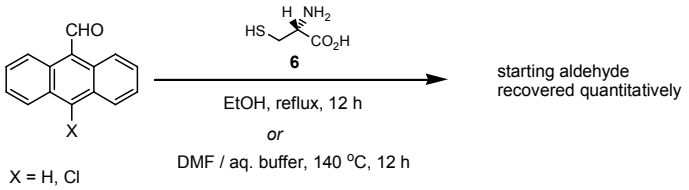
4-(10-Undecenyloxy)phenylacetylene (**S10**). A solution of 3.70 g of **S23** in 170 ml of THF was added dropwise to a stirred solution of 3.1 g (0.055 mol) of KOH in 150 ml of methanol and

stirred at room temperature for 40 min. The reaction mixture was concentrated in vacuo to approximately 30% of its initial volume, poured into water, extracted with CH_2Cl_2 (3×100 ml), the organic fraction was washed with water, and dried over anhydrous Na_2SO_4 overnight. After concentration in vacuo, the crude product was purified by column chromatography on silica gel (eluent hexane) to afford 2.7 g (92%) of **S10** as a colorless oil, R_f 0.34. ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.36 (d, J = 8.6 Hz, 2H), 6.77 (d, J = 8.6 Hz, 2H), 5.91 - 5.72 (m, 1H), 5.05 - 4.85 (m, 2H), 3.93 (t, J = 6.5 Hz, 2H), 2.96 (s, 1H), 2.12 - 1.94 (m, 2H), 1.84 - 1.66 (m, 2H), 1.55 - 1.20 (m, 12H). HRMS m/e 271.2070 $[M+H]^+$ (calcd for $C_{19}H_{27}O$ 271.2062).

Attempted preparative conversion of aromatic aldehydes into corresponding thiazolidines.

As an additional proof in favor of the "turn on" ratiometric fluorescence amplification, experiments to demonstrate significantly decreased reactivity of anthraldehyde derivatives with cysteine to form thiazolidines were carried out. First, a previously described set of experimental conditions was modified and tested on a benzaldehyde derivative to prove almost quantitative formation of a corresponding thiazolidine. Second, similar (and further modified) conditions were applied for the reaction of anthraldehyde derivatives. In agreement with the initial hypothesis, these experiments resulted in almost quantitative recovery of the starting aldehydes, therefore demonstrating likely very unfavorable thermodynamic equilibrium toward thiazolidine formation with anthraldehyde compounds.





The test reaction with *p*-bromobenzaldehyde was performed following modified procedure from ref. 9. A solution of 0.20 g (1.1 mmol) of *p*-bromobenzaldehyde and 0.13 g (1.1 mmol) of L-cysteine in 50 ml of ethanol was stirred for 6 h at room temperature. The crude product as white precipitate was collected by filtration, and recrystallized from ethanol to afford 0.28 g (91%) of (4*R*)-2-(4-bromophenyl)thiazolidine-4-carboxylic acid **S24** as a colorless solid.

A similar reaction with anthraldehyde and 10-chloroanthraldehyde was conducted in refluxing ethanol for 12 h. Upon cooling the reaction mixture to room temperature, a colorless precipitate was formed. The precipitate was separated by filtration, and, after checking ^{1}H NMR, was found to be the initial aldehyde. The reaction was also attempted in modified conditions (DMF – aqueous buffer at pH 8.0 (1:1), stirring at 140 °C for 12 h), but resulted in practically quantitative recovery (precipitating upon cooling to room temperature) of the starting aldehydes.

Preparation of immobilized monolayer modified slides.

Cleaning and activation of glass slides. Microscope glass cover slides (22×22 mm, Slip-Rite No. 1) were sonicated in chloroform for 10 min and then washed with copious amounts of methanol, acetone and DI water, and dried under the flow of nitrogen. The dried slides were sonicated with 25 ml of piranha solution (prepared by mixing conc. H_2SO_4 and 30% H_2O_2 7:3) for 30 min, washed with DI water and dried under the flow of nitrogen. ***NOTE:*** *extreme care must be taken when dealing with piranha solutions as they can detonate when contacted with organic compounds!*

Preparation of ITO-covered glass slides. Rectangular ITO-covered glass slides (approx. 1.1×2.5 cm) were ultrasonicated in CH_2Cl_2 for 20 min, followed by rinsing with acetone and deionized water. The pre-cleaned slides were subjected to an RCA-type cleaning procedure by keeping in a water – 30% H_2O_2 – 30% aqueous NH_3 (5:1:1) mixture at 70 °C for 1 hour. The substrates were then rinsed with copious amount of deionized water and dried in N_2 flow at room temperature for 2 h.

Surface-immobilization procedure. The freshly activated glass (or ITO/glass) slides were immersed into 0.2 mmol solutions of one of the compounds **1**, **3**, or **4** in toluene and kept at 80 °C for 2 h. After cooling to room temperature, the slides were rinsed with copious amount of chloroform upon ultrasonication. After drying, the monolayer-modified slides were annealed by heating to 80 °C in aqueous buffered solution (pH 9.5) for 2 h. The annealed slides were washed with water and dried under the flow of nitrogen.

Exposure to cysteine 6 and glutathione 7. The monolayer-modified glass slides were immersed into buffered (pH 9.5) aqueous solutions of L-cysteine with varying concentrations, or glutathione (20 mM), and kept at 80 °C for 20 minutes. Then the slides were thoroughly rinsed with DI water, dried, and subjected to absorption and fluorescence measurements.

Hydrolysis of surface thiazolidine groups. The monolayer-modified glass slides exposed to cysteine as described above were immersed into an aqueous HCl solution (pH 1) and kept there at 80 °C for 1 h, then thoroughly rinsed with DI water, dried, and subjected to fluorescence measurements.

XPS measurements. XPS data were acquired with a Kratos AXIS 165 system with a monochromatic Al Kα source and a hemispherical electron energy analyzer. The pressure in the analyzing chamber was less than 2×10^{-9} torr. Survey spectra were recorded with 160 eV pass energy, and 150 W X-ray beam power. High-resolution elemental spectra were recorded with 40 eV pass energy and 150 W X-ray beam power. The normal emission angle-integrated, high-resolution scans with 15-20 eV windows were acquired for C1s, O1s, N1s, S2p, Si2s, and Si2p regions. These spectra were averaged over 40 scans each to obtain a good signal-to-noise ratio.

Evaluation of surface density of the monolayer of 1. Cyclic voltammetry measurements were performed using an Autolab PGSTAT 302 potentiostat. The measurements were carried out using a three-electrode system with monolayer-modified ITO/glass working electrode (electrode area ~ 1.9 cm^2), $Ag/AgNO_3$ non-aqueous reference electrode, and a Pt gauze counter electrode in 0.1 M Bu_4NPF_6 solution in CH_2Cl_2 as supporting electrolyte. The reference electrode was checked against ferrocene standard every time before and after the experiments were performed, and the measured potentials were corrected based on the Fc/Fc^+ redox potential value.

The surface coverage density was determined based on the measured area of the redox peak corresponding to reduction of anthraldehyde groups (Figure S3). The value was corrected by the corresponding data for the bare ITO electrode. Assuming the reduction being a one-electron process, the surface density Γ was estimated using the formula:

$$\Gamma = \frac{Q}{F}$$

where Q is the redox peak area (C cm^{-2}), and F is Faraday constant (96500 C mol^{-1}). For the current case ($Q = 2.45\times10^{-16}$ C cm^{-2}, after correcting for the ITO surface roughness[10]), the surface density Γ was estimated as 2.54×10^{-11} mol cm^{-2}.

References

1. Reynolds, G. A.; Drexhage, K. H. *Opt. Commun.* **1975**, *13*, 222-225.
2. Olmsted, III, J. *J. Phys. Chem.* **1979**, *83*, 2581-2584.
3. Rehahn, M.; Schluter, A. D.; Feast, W. J. *Synthesis* **1988**, 386-388.
4. Ziener, U.; Godt, A. *J. Org. Chem.* **1997**, *62*, 6137-6143
5. Gelman, D.; Buchwald, S. L. *Angew. Chem. Int. Ed.* **2003**, *42*, 5993-5996.
6. Klapars, A.; Buchwald, S. L. *J. Am. Chem.Soc*. **2002**, *124*, 14844-14945.

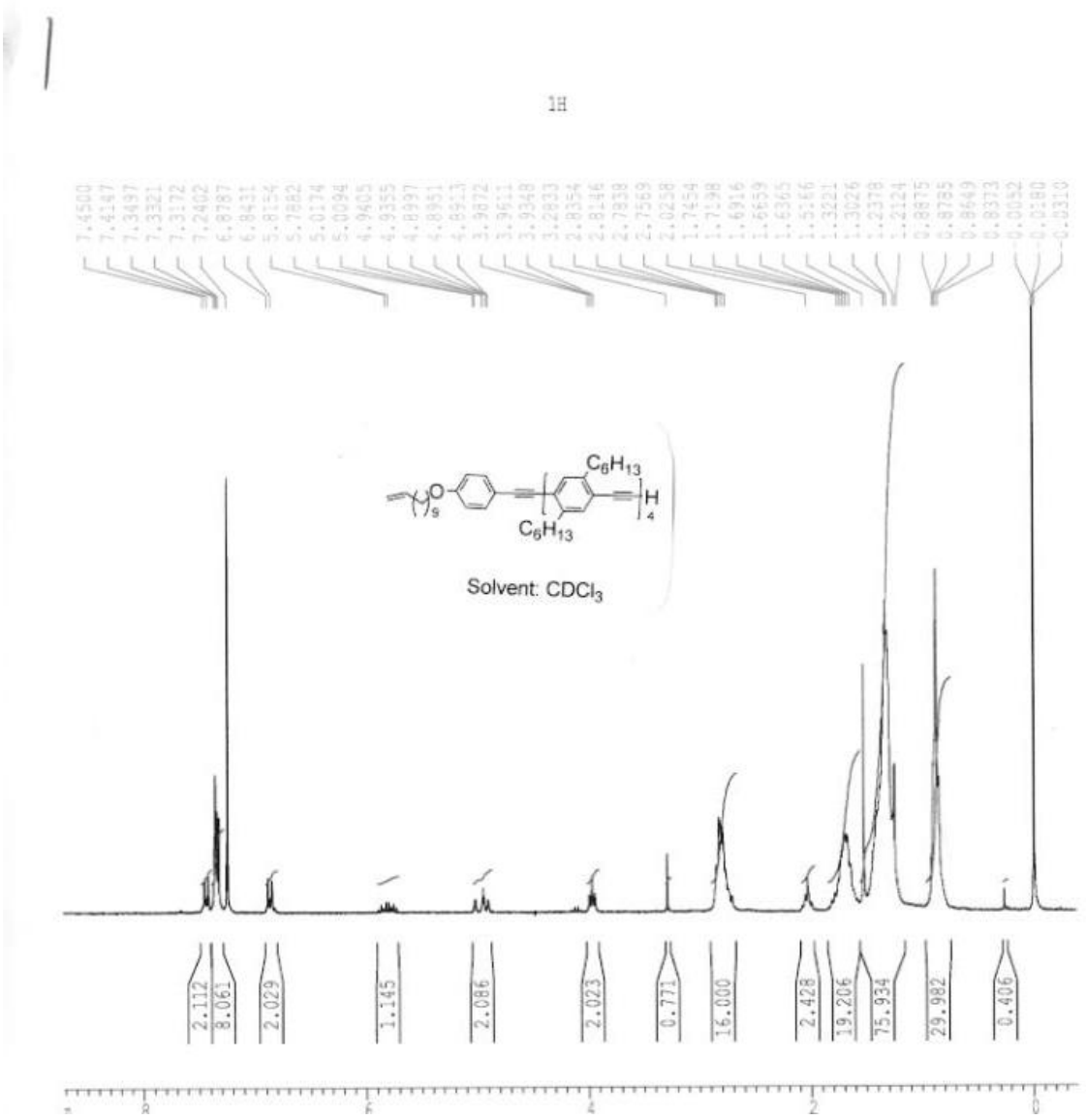
7. Kabalka, G. W.; Varma, M.; Varma, R. S.; Srivastava, P. C.; Knapp, Jr., F. F. *J. Org. Chem.* **1986**, *51*, 2386-2388.

8. Cramer, E.; Percec, V. *J. Polym. Sci., Part A: Polym. Chem.* **1990**, *28*, 3029-3046.

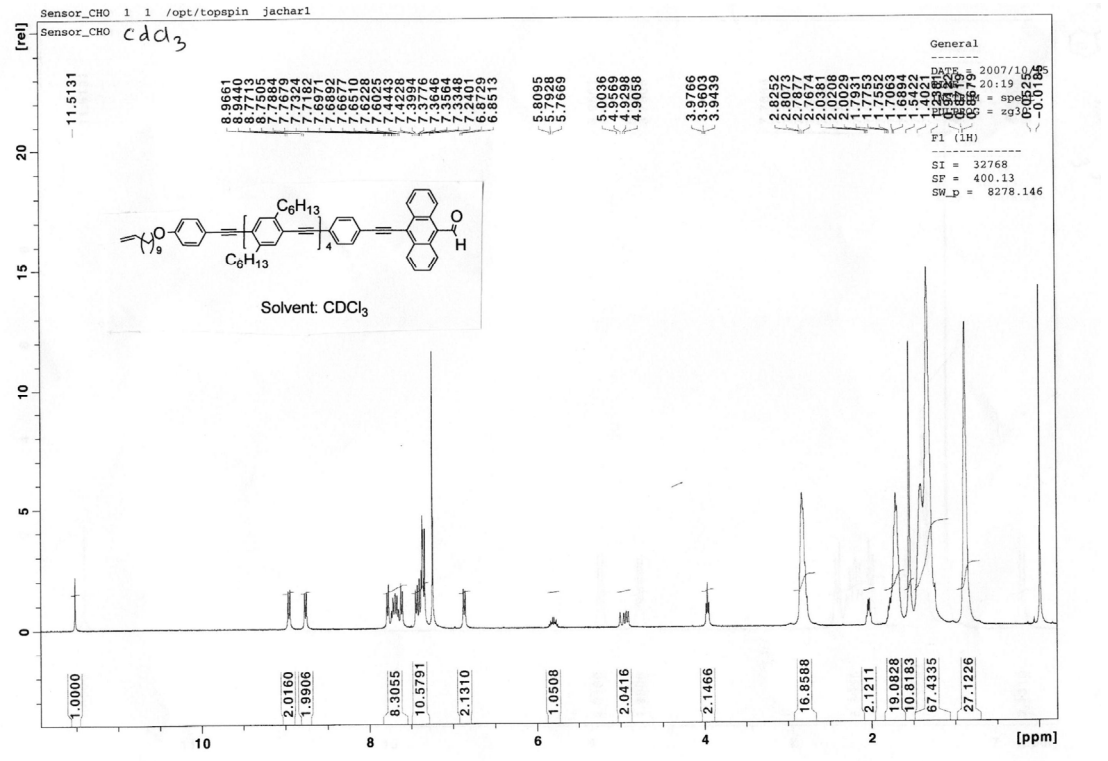
9. Gududuru, V.; Hurh, E.; Dalton, J. T.; Miller, D. D. *J. Med. Chem.* **2005**, *48*, 2584-2588.

10. Hwang, E.; de Silva, K. M. N.; Seevers, C. B.; Li, J.-R.; Garno, J. C.; Nesterov, E. E. *Langmuir* **2008**, *24*, 9700-9706.

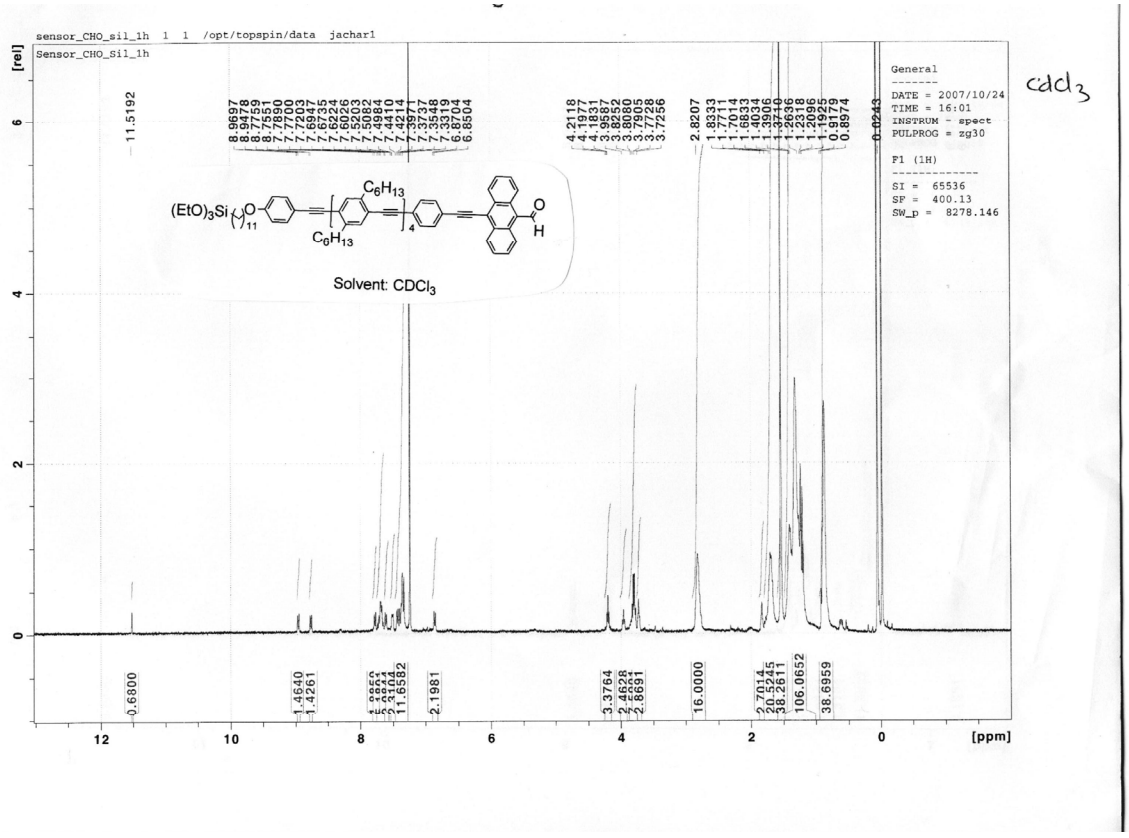
^{1}H NMR Spectra



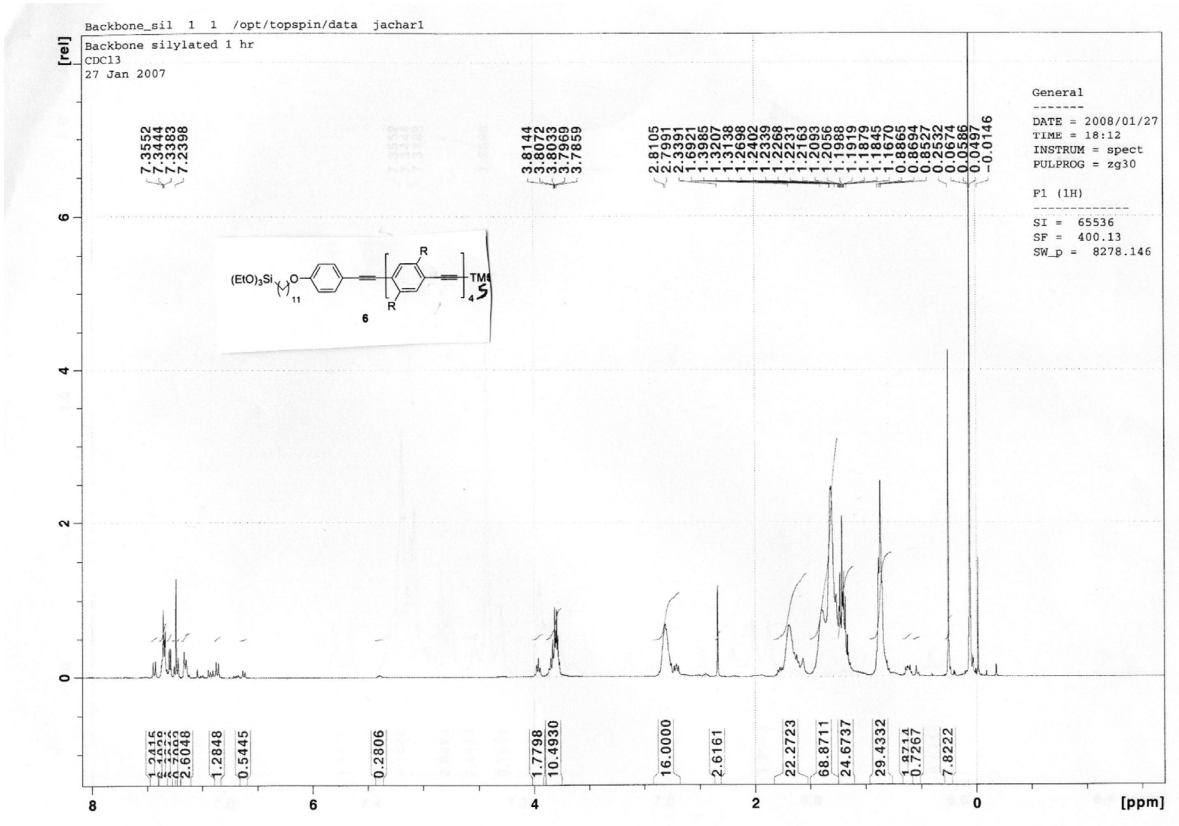
Compound **S12**



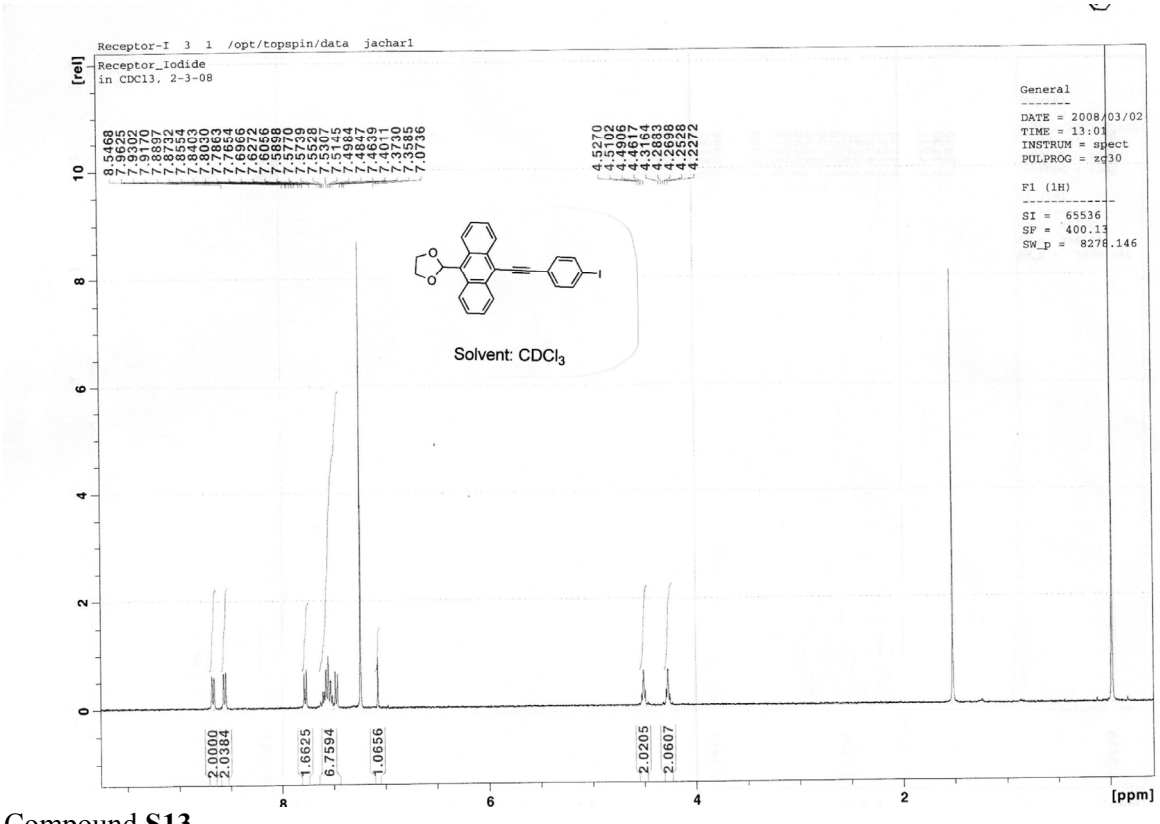
Compound **2**



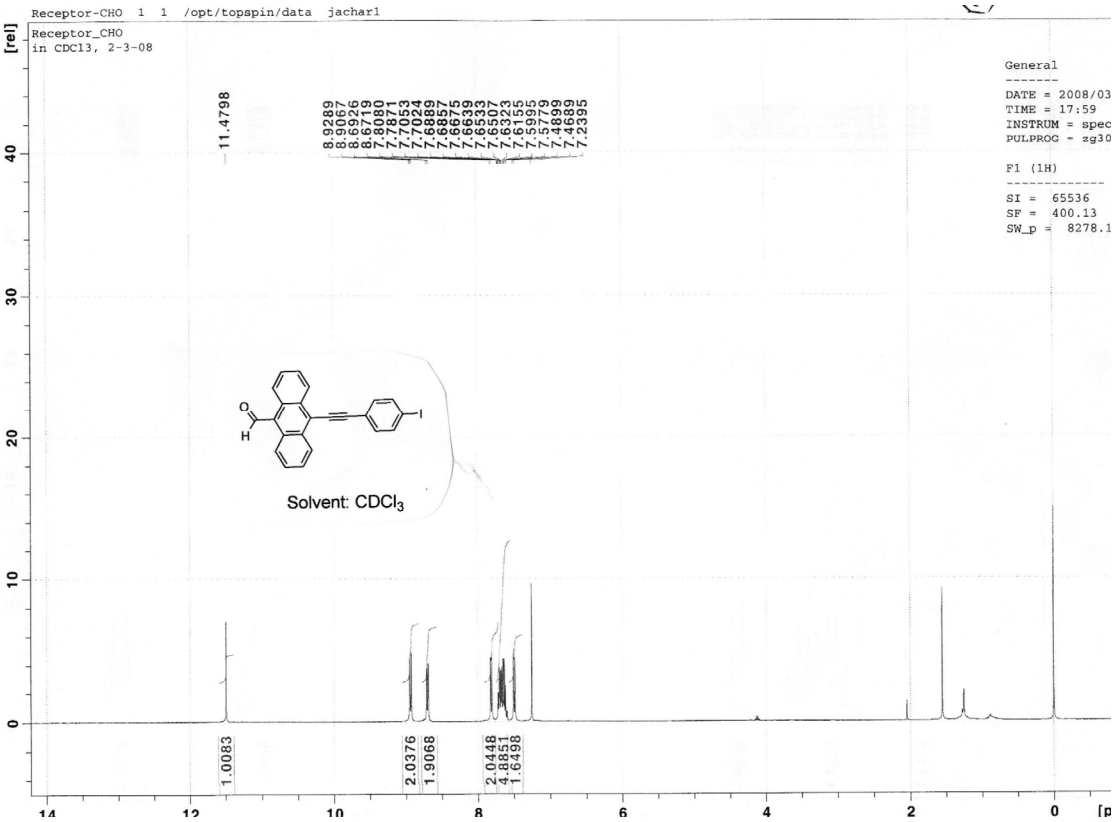
Compound **1**



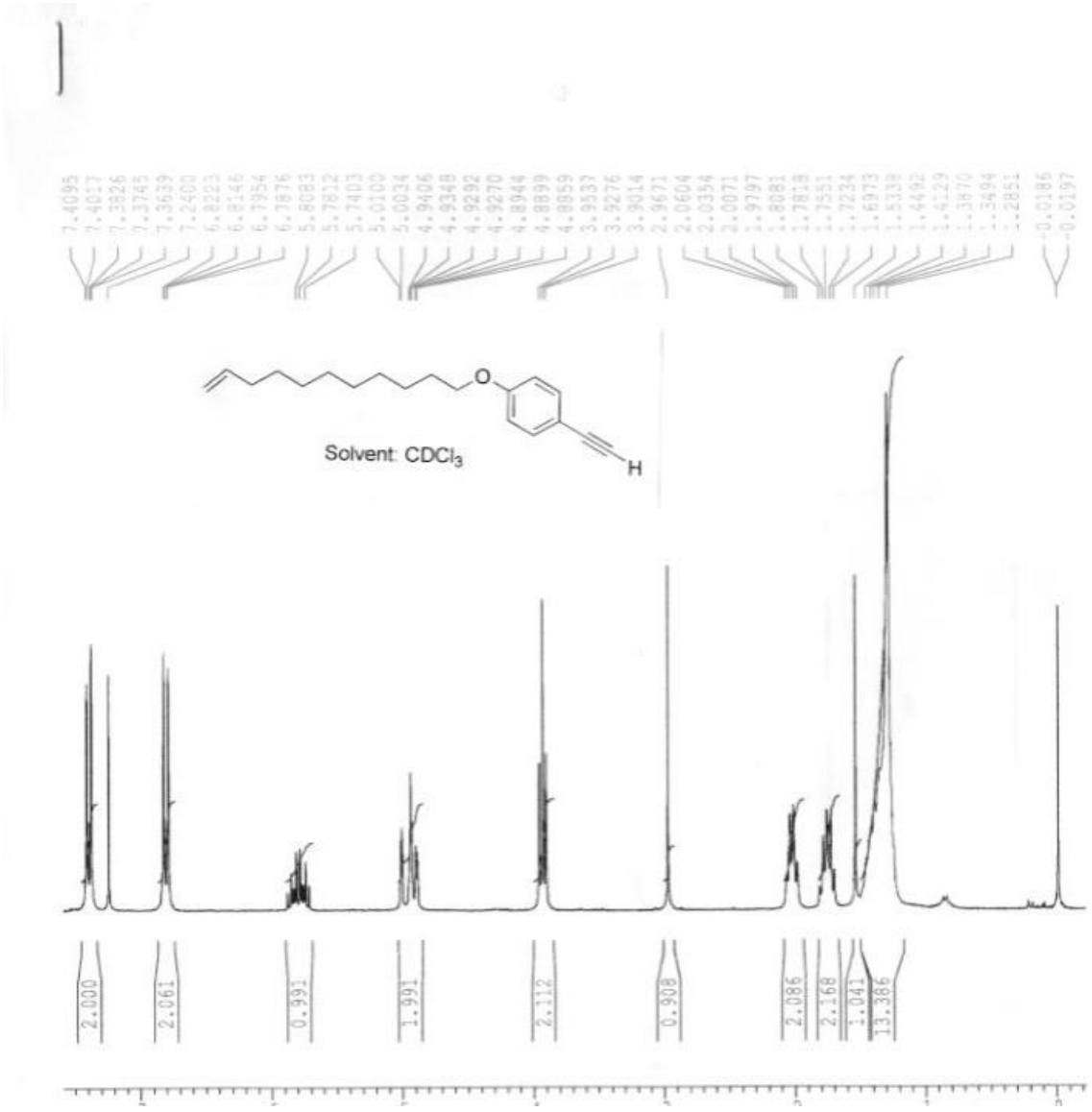
Compound **3**



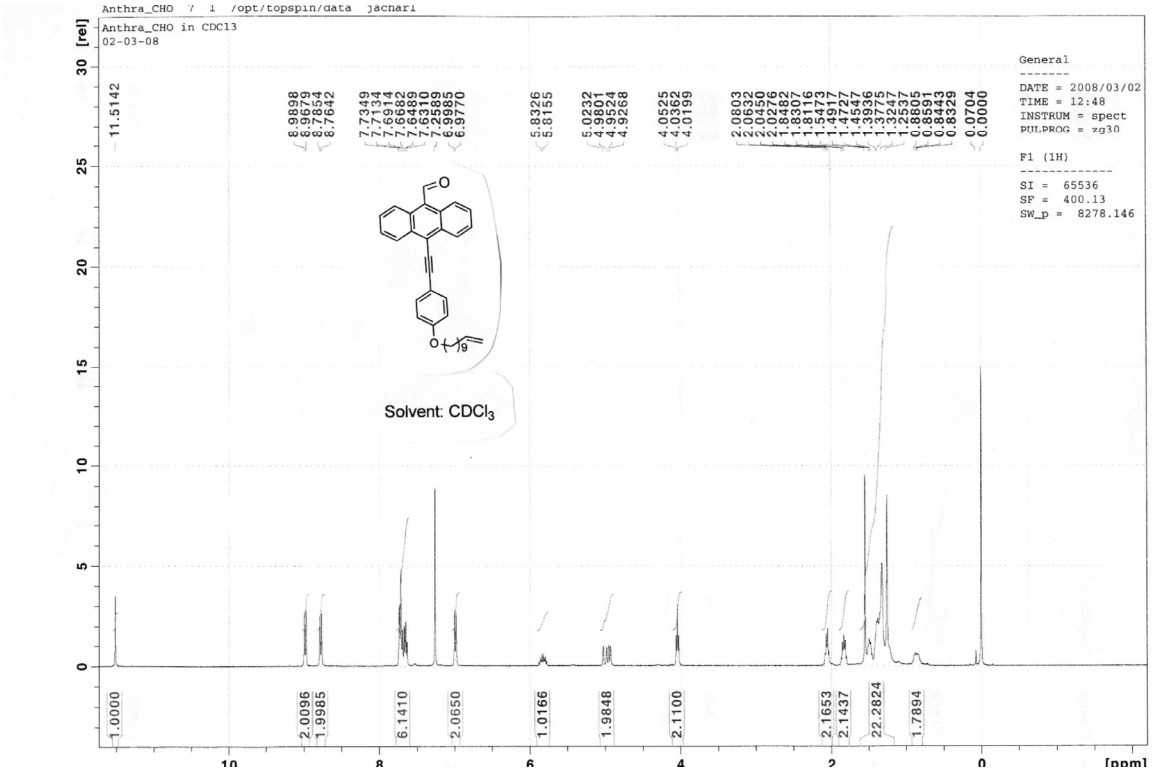
Compound **S13**



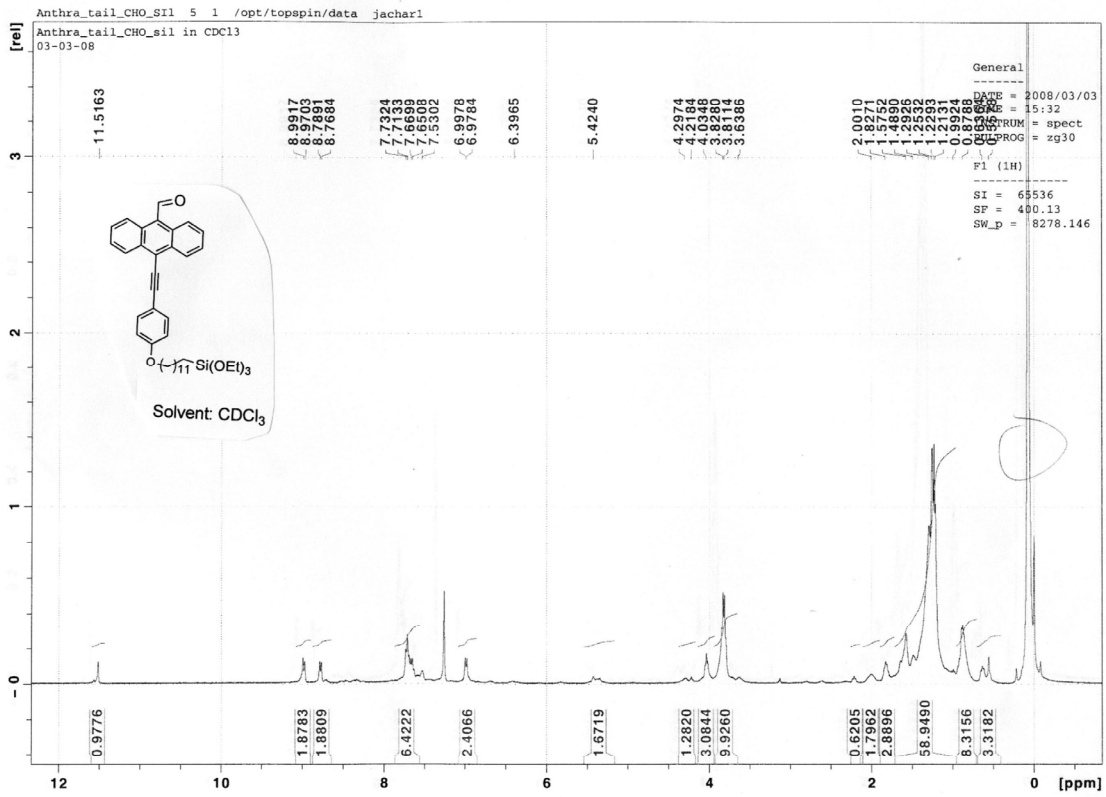
Compound **S20**



Compound **S10**



Compound **5**



Compound **4**