

Supporting Information

Efficient and Modular Biofunctionalization of Thiophene-based Conjugated Polymers through Embedded Latent Disulfide

Wenting Wu*, Songyan Yu, Dylan S. Forbes, Hanning Jiang, Mustafa Ahmed, Jianguo Mei*

¹Department of Chemistry, Purdue University, West Lafayette, IN, USA

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1. General Information

1.1 Materials and reagents

3,3-Bis(bromomethyl)-3,4-dihydro-2H-thieno[3,4-b][1,4]dioxepine was prepared according to literature³⁴. Sulfur (powder, 99.0+%), Na₂S (anhydrous), *o*-dichlorobenzene (*o*-DCB, anhydrous, 99%), hydrazine hydrate (reagent grade, N₂H₄ 50–60%), and phosphate buffered saline (PBS, pH 7.4, liquid) were purchased from Sigma-Aldrich. Tin(IV) chloride (SnCl₄, 99%), glucose (99%), and 2,2-dimethoxy-2-phenylacetophenone (DMPA, 98.0+%) were purchased from Oakwood Products, Inc. Tris(hydroxypropyl)phosphine (THPP, 95%) was purchased from Combi-Blocks Inc. Avidin-glucose oxidase was purchased from Genprice Inc. Dimethyl formaldehyde (DMF), dichloromethane (DCM), tetrahydrofuran (THF) and chloroform were purchased from Fisher Scientific. All chemicals were used as received unless otherwise specified.

1.2 General Analytical Information

All the organic compounds were characterized by ¹H and ¹³C NMR as well as HRMS spectroscopies (unless otherwise noted). Copies of the ¹H and ¹³C spectra can be found at the end of the Supporting Information. All the conjugated polymers were characterized by ¹H NMR and FTIR spectroscopies and gel permeation chromatography (GPC). NMR spectra were recorded on the Bruker AV-III-800 MHz, Bruker AV-III-400 MHz instrument, and a Bruker DRX-500 MHz instrument. Unless otherwise stated, all ¹H NMR experiments are reported in δ units, parts per million (ppm), and were measured relative to the signals of the residual proton resonances CDCl₃ (7.26 ppm), DMSO-*d*₆ (2.50 ppm) or MeOD (3.31 ppm) in the deuterated solvents. All ¹³C NMR spectra are measured decoupled from ¹H nuclei and are reported in δ units (ppm) relative to CDCl₃ (77.16 ppm), DMSO (39.52 ppm) or MeOD (49.00 ppm) unless otherwise stated. All FTIR spectra were recorded on a Thermo Scientific – Nicolet iS5 spectrometer (iD5 ATR – diamond). High-resolution mass spectra were recorded on an Agilent 6530 LC Q-TOF mass spectrometer using electrospray ionization with fragmentation voltage set at 70 V and processed with an Agilent MassHunter operating system.

The HPLC system used was a LABOACE LC-5060 recycling preparative system (Japan Analytical Industry Co., Ltd., JAI) in combination with two columns JAIGEL-

3HR (JAI) and JAIGEL-2.5HR (JAI) with exclusions limit of 70000 and 20000, respectively. As a detector system, a UV-VIS4CH LA was used (JAI). For purifications, a concentration of 100 mg material in 1 mL CHCl₃ (ROTISOLV® HPLC, Carl Roth GmbH+ Co. KG, stabilizer: 1 % ethanol) was used.

The polymer molecular weight (number-average, M_n) and polydispersity ($\mathcal{D}$) relative to polystyrene were measured by TOSOH Bioscience EcoSEC GPC equipped with a Bryce-type double path refractive index detector and two TSKgel SuperMuiltiporeHZ-M columns. The masses of the polystyrene standards for calibration range from 500 to 2,890,000 g mol⁻¹. HPLC grade THF was used as mobile phase with 0.35 mL/min. The elution rate was 0.35 mL/min (column temperature, 40 °C). All samples/standards were tested at 100 μ L loadings (1.0 mg/mL).

2. X-Ray Structure Determination

Low-temperature diffraction data (φ - and w -scans) was collected on a Bruker-AXS X8 Kappa Duo diffractometer coupled to a Smart Apex2 CCD detector with Mo K α radiation ($\lambda = 0.71073$ Å) from an *I μ S* micro-source for the structure of compound **DSP**. The structure was solved by direct methods using SHELXS² and refined against F^2 on all data by full-matrix least squares with *SHELXL-97*³ using established refinement techniques. All non-hydrogen atoms were refined anisotropically. All hydrogen atoms were included into the model at geometrically calculated positions and refined using a riding model. The isotropic displacement parameters of all hydrogen atoms were fixed to 1.2 times the U value of the atoms they are linked to (1.5 times for methyl groups). All disordered atoms were refined with the help of similarity restraints on the 1,2- and 1,3-distances and displacement parameters as well as rigid bond restraints for anisotropic displacement parameters unless otherwise noted below.

X-ray quality crystals of **DSP** were obtained by vapor diffusion of a CHCl₃ solution of **DSP** with hexane.

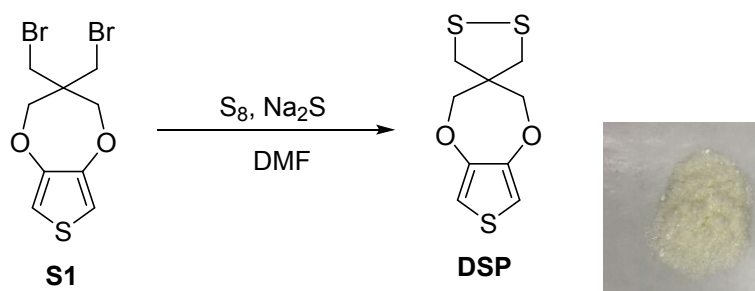
Table S1. Crystal data and structure refinement for **DSP**.

Empirical formula	C ₉ H ₁₀ O ₂ S ₃	
Formula weight	246.35	
Temperature	150 K	
Wavelength	0.71073 Å	
Space group	P 21/n	
Unit cell dimension	a = 8.0335 (3) Å	$\alpha = 90^\circ$

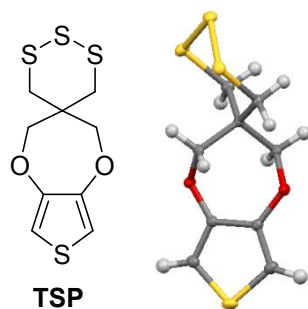
	b = 6.3292 (3) Å	β = 97.0023°
	c = 20.4829 (8) Å	γ = 90°
Volume	1033.70(7) Å ³	
Z	4	
Density (Calculated)	1.583 Mg/m ³	
Absorption coefficient	0.685 mm ³	
F000	512	
h, k, lmax	-18 ≤ h ≤ 18, -31 ≤ k ≤ 31, -19 ≤ l ≤ 19	
N(reflection)	3959	
Data completeness to theta = 33.167°	0.994	
R(reflections)	0.0274 (3622)	
wR2(reflections)	0.0766 (3935)	

3. Modification through Thiol-ene Chemistry

3.1 Synthesis of Model Monomer **DSP**



To DMF (15 mL) were added sulfur (93.7 mg, 2.92 mmol) and Na₂S (114.1 mg, 1.46 mmol). The reaction mixture was stirred for 2 h at 80 °C and turned deep blue. After addition of 3,3-bis(bromomethyl)-3,4-dihydro-2H-thieno[3,4-b][1,4]dioxepine (500 mg, 1.46 mmol), the mixture was heated to 120 °C overnight. To the mixture was added ice, and the water layer was extracted with DCM three times. The combined organic phases were washed with brine, dried over MgSO₄, and concentrated under reduced pressure. The crude product was recrystallized (DCM/MeOH) to yield **DSP** (300 mg, 85%, light yellow crystal). Mp: 95.4 °C. ¹H NMR (800 MHz, CDCl₃) δ(ppm) 6.52 (d, *J* = 1.3 Hz, 1H), 3.97 (d, *J* = 1.4 Hz, 2H), 3.02 (d, *J* = 1.4 Hz, 2H). ¹³C NMR (201 MHz, CDCl₃) δ(ppm) 149.28, 106.03, 76.11, 45.01. **HRMS (ESI)**: calcd for C₉H₁₁O₂S₃ [M+H]⁺ 246.9921, found 246.9918. Note: a trisulfide analogue (**TSP**) was observed as the byproduct. See crystal data in Table S2. **HRMS (ESI)**: calcd for C₉H₁₀O₂S₄ [M+H]⁺ 277.9558, found 277.9560.

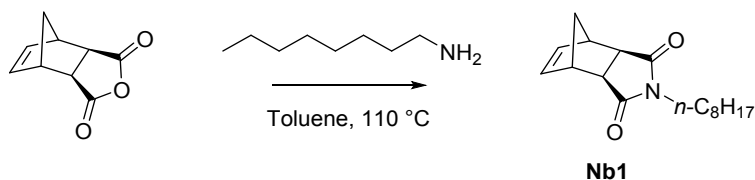


X-ray quality crystals of **TSP** were obtained by vapor diffusion of a CHCl_3 solution of **TSP** with hexane.

Table S2. Crystal data and structure refinement for **TSP**.

Empirical formula	$\text{C}_9\text{H}_{10}\text{O}_2\text{S}_4$	
Formula weight	278.42	
Temperature	150 K	
Wavelength	0.71073 Å	
Space group	P 21/n	
Unit cell dimension	$a = 8.7019 (3) \text{ Å}$	$\alpha = 90^\circ$
	$b = 11.9006 (5) \text{ Å}$	$\beta = 104.3564^\circ$
	$c = 10.9447 (5) \text{ Å}$	$\gamma = 90^\circ$
Volume	$1098.02(8) \text{ Å}^3$	
Z	4	
Density (Calculated)	1.684 Mg/m ³	
Absorption coefficient	0.839 mm ⁻¹	
F000	576	
h, k, lmax	13, 18, 16	
N(reflection)	4161	
Data completeness to theta = 33.167°	0.990	
R(reflections)	0.0219 (3901)	
wR2(reflections)	0.0583 (4161)	

3.2 Synthesis of Norbornene Derivative **Nb1**



According to literature procedure¹, norbornene exo-anhydride (1.0 eq), octan-1-amine (1.0 eq), and toluene (25 mL) were mixed in a round bottom flask equipped with a reflux condenser. The reaction was heated to reflux (110 °C) for 16 h, then cooled to

room temperature. The toluene was removed via rotary evaporation until dryness. The crude solid was dissolved into dichloromethane, washed with water, then dried with sodium sulfate. The solvent was stripped in vacuo to yield target product with no further purification.

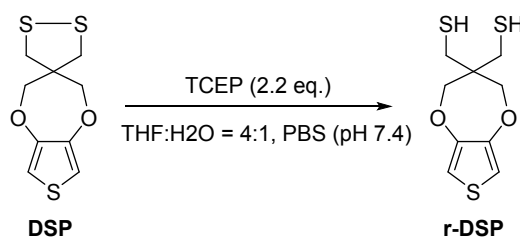
Physical Properties: Colorless oil

¹H NMR (400 MHz, CDCl₃) δ(ppm) 6.28 (t, *J* = 1.9 Hz, 2H), 3.49–3.36 (m, 2H), 3.27 (s, *J* = 1.8 Hz, 2H), 2.67 (s, *J* = 1.4 Hz, 2H), 1.60–1.46 (m, 3H), 1.26 (tt, *J* = 9.8, 6.1 Hz, 13H), 0.91–0.83 (t, 3H).

¹³C NMR (101 MHz, CDCl₃) δ(ppm) 178.01, 137.73, 77.22, 76.91, 76.59, 47.70, 45.07, 42.61, 38.67, 31.64, 29.00, 27.67.

3.3 Evaluation of Model Functionalization

3.3.1 **DSP** Reduction



To a round bottom flask were charged TCEP (769 mg, 2.68 mmol, 2.2 eq) and the phosphate buffered solution (pH 7.4, 13.0 mL). The reaction mixture was stirred at room temperature for about 5 min and then to this homogenous solution was charged the solution of **DSP** (300 mg, 1.22 mmol, 1.0 eq.) in 12 mL of THF. This homogeneous aqueous reaction mixture was stirred at room temperature until the reaction completes (about 45 min). The mixture was extracted three times with DCM. After completion of the reaction, the reaction mixture was extracted with DCM (2 x 10 mL). The combined organic layer was washed with 10% NaCl solution, separated and dried over anhydrous Na₂SO₄. The volatiles were evaporated under vacuum at 25–30 °C to yield the free thiol **r-DSP** (300 mg, 99%).

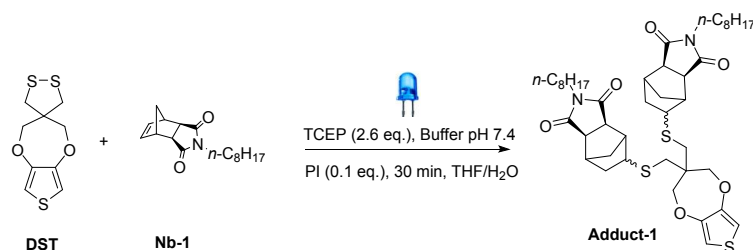
Physical Properties: Pale-yellow oil

¹H NMR (400 MHz, CDCl₃) δ(ppm) 6.48 (s, 1H), 3.98 (s, 3H), 2.75 (d, *J* = 8.9 Hz, 3H), 1.30 (t, *J* = 8.9 Hz, 1H).

¹³C NMR (101 MHz, CDCl₃) δ(ppm) 149.21, 105.71, 74.89, 46.04.

HRMS (ESI): calcd for C₉H₁₃O₂S₃ [M+H]⁺ 249.0072, found 249.0073.

3.3.2 In-situ Reduction and Photoinitiated Thiol-Norbornene Reaction of **DSP**



Procedures and Recycling Preparative HPLC Traces for Experiments

General Procedure:

DSP (50.0 mg, 0.2 mmol, 1 eq.), **Nb1** (105.0 mg, 0.44 mmol, 2.2 eq.), and TCEP·HCl (128.0 mg, 0.44 mmol, 2.2 eq.) were combined in a 20 mL VOA glass vial with 0.125 in. septum. 1 mL THF and 1 mL buffer were added as mixed solvents and the resulting solution was bubbled with N₂ for 10 min. After stock solutions of photoinitiator (DMPA) (0.1 M, 0.2 mL) in THF was added in one portion, the reaction vial was stirred to ensure proper reagent mixing and then irradiated under blue LED for 30 min. The reaction mixture was extracted with chloroform (2 x 2 mL). The combined organic layer was washed with 10% NaCl solution, separated, and dried over anhydrous Na₂SO₄. The solvent was removed under reduced pressure and analyzed by recycling preparative HPLC.

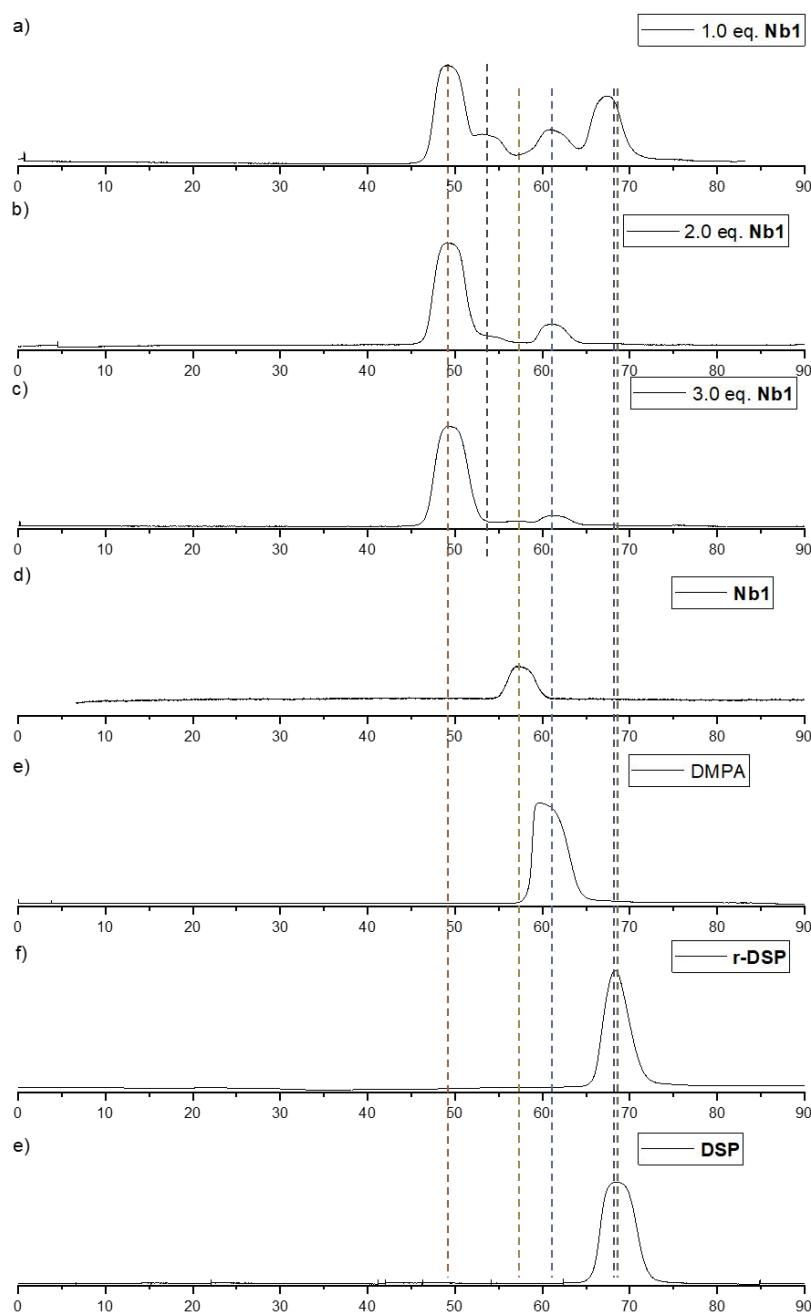


Figure S1. The recycling preparative high performance liquid chromatography (HPLC) traces of the model reactions of **DSP** with varying molar equivalents of **Nb1**. **a–c** represent 1, 2, and 3 equiv. of **Nb1**. **d–g** depict **Nb1**, DMPA, **r-DSP**, and **DSP**, respectively, for comparison.

Brief discussion. Due to the robustness of thiol-ene chemistry, **DSP** and **Nb1** were fully converted to the thiol-ene adduct (**TEA**) while no significant crosslinking byproducts from the alkene or thiol were detectable.

TEA was collected for further characterizations.

Physical Properties: Colorless oil

¹H NMR (800 MHz, CDCl₃) δ(ppm) 6.51 – 6.47 (m, 2H), 4.01 – 3.93 (m, 4H), 3.43 (t, *J* = 7.5 Hz, 4H), 2.85 – 2.74 (m, 6H), 2.69 (dd, *J* = 10.1, 5.5 Hz, 4H), 2.57 (dd, *J* = 20.9, 7.0 Hz, 4H), 1.90 – 1.85 (m, 2H), 1.68 – 1.65 (m, 2H), 1.51 (p, *J* = 7.2 Hz, 4H), 1.42 – 1.38 (m, 2H), 1.25 (dd, *J* = 13.4, 5.6 Hz, 14H), 1.07 – 1.04 (m, 2H), 0.88 – 0.85 (m, 6H).

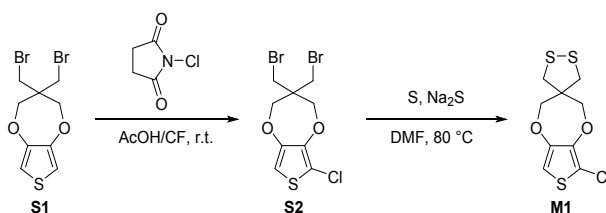
¹³C NMR (201 MHz, CDCl₃) δ(ppm) 178.09, 177.67, 177.65, 149.20, 149.17, 105.82, 105.71, 105.65, 76.07, 75.76, 75.48, 47.89, 47.81, 47.06, 46.96, 46.51, 46.40, 45.24, 45.14, 39.43, 38.89, 37.26, 37.23, 34.75, 34.66, 31.66, 30.08, 30.04, 29.62, 29.03, 28.99, 27.69, 26.85, 22.53, 14.01.

HRMS (ESI): calcd for C₄₃H₅₃N₂O₆S₃ [M+H]⁺ 799.3848, found 799.3838.

4. Exploration of Transition Metal-free Cationic Chain-growth Polymerization Featuring S–S Compatibility

4.1 Monomer Synthesis

Synthesis of **M1**



S2: To a stirred solution of **S1** (4.0 g, 9.73 mmol) in a mixture CHCl₃/AcOH (20 mL/20 mL) at 0 °C a solution of *N*-chlorosuccinimide (1.72 g, 12.86 mmol) in 10 mL of chloroform was added dropwise, and the reaction mixture was stirred at room temperature overnight. To the mixture was added ice, and the water layer was extracted with DCM three times. The combined organic phases were washed with brine, dried over MgSO₄, and concentrated under reduced pressure. The crude product was purified by column chromatography (hexane/DCM) to yield **S2** (2.1 g, 48%).

Physical Properties: white solid

¹H NMR (800 MHz, CDCl₃) δ(ppm) 6.32 (s, 1H), 4.18 (s, 2H), 4.10 (s, 2H), 3.61 (d, *J* = 1.0 Hz, 4H).

¹³C NMR (201 MHz, CDCl₃) δ(ppm) 147.35, 144.42, 110.24, 101.80, 74.41, 74.18, 46.25, 34.08.

HRMS (ESI): calcd for C₉H₁₀Br₂ClO₂S [M+H]⁺ 374.8451, found 374.8436.

M1: To DMF (15 mL) were added sulfur (85.2 mg, 2.66 mmol) and Na₂S (103.6 mg, 1.33 mmol). The reaction mixture was stirred for 2 h at 80 °C and turned deep blue. After addition of **S2** (500 mg, 1.33 mmol), the mixture was heated to 120 °C overnight. To the mixture was added ice, and the water layer was extracted with DCM three times. The combined organic phases were washed with brine, dried over MgSO₄, and concentrated under reduced pressure. The crude product was recrystallized (DCM/MeOH) to yield **M1** (280 mg, 75%).

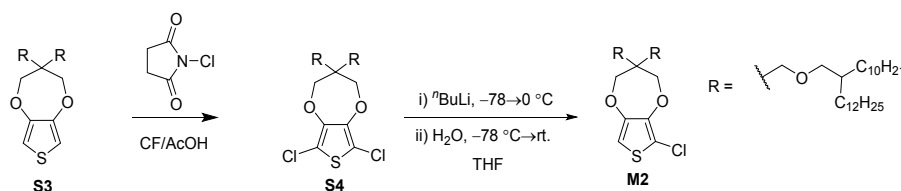
Physical Properties: White crystal

¹H NMR (400 MHz, CDCl₃) δ(ppm) 6.34 (d, *J* = 1.1 Hz, 1H), 4.05 (d, *J* = 1.3 Hz, 2H), 3.98 (d, *J* = 1.2 Hz, 2H), 3.02 (dd, *J* = 2.9, 1.2 Hz, 4H).

¹³C NMR (201 MHz, CDCl₃) δ(ppm) 147.99, 145.03, 110.50, 102.03, 76.21, 76.15, 58.85, 44.96.

HRMS (ESI): calcd for C₉H₁₀ClS₃O₂ [M+H]⁺ 280.9526, found 280.9520.

Synthesis of **M2**



S3 are prepared according to the literature method².

¹H NMR (800 MHz, CDCl₃) δ(ppm) 6.43 (s, 2H), 4.01 (s, 4H), 3.46 (s, 4H), 3.27 (d, *J* = 5.7 Hz, 4H), 1.30 (d, 36H), 0.89 (t, *J* = 7.3 Hz, 6H).

¹³C NMR (201 MHz, CDCl₃) δ(ppm) 149.64, 104.81, 74.71, 73.70, 69.78, 47.83, 38.10, 31.89, 31.48, 30.08, 29.68, 29.66, 29.64, 29.54, 29.33, 26.84, 22.65, 14.06.

HRMS (ESI): calcd for C₅₇H₁₀₉O₄S [M+H]⁺ 889.8046, found 889.8048.

S4: To a solution of **S3** (5.0 g, 5.12 mmol) in a mixture CHCl₃/AcOH (50 mL/50 mL) at 0 °C *N*-chlorosuccinimide (1.5 g, 11.26 mmol) was added, and the mixture stirred during 16 h. Then water 30 mL was added, and the phases were separated, and the aqueous fraction washed with dichloromethane (2x20 mL). The combined organic phases were washed with brine, dried over MgSO₄, and concentrated under reduced

pressure. The crude product was purified by column chromatography (acetone/DCM) to yield **S4** (5.2 g, 97%).

Physical Properties: Colorless oil

¹H NMR (400 MHz, CDCl₃) δ(ppm) 4.08 (s, 4H), 3.47 (s, 4H), 3.26 (d, 4H), 1.65–1.41 (m, 2H), 1.26 (s, 80H), 0.93–0.83 (t, 12H).

¹³C NMR (101 MHz, CDCl₃) δ(ppm) 144.67, 105.05, 74.68, 74.31, 69.58, 48.01, 38.06, 31.84, 31.43, 30.03, 29.64, 29.59, 29.29, 26.81, 22.60, 14.02.

HRMS (MALDI): calcd for C₅₇H₁₀₇Cl₂O₄S [M+H]⁺ 957.72618, found 957.7255.

M2: To a stirred solution of **S4** (1.0 g, 1.04 mmol) in dry THF (12 mL) at –78 °C, ⁿBuLi in hexane (2.5 M, 1.25 mmol, 0.50 mL) was added slowly. After the addition was completed, the mixture was stirred for 30 min at 0 °C. Then the reaction was cooled to –78 °C and water was added (30 mL) and the temperature rose to room temperature. The mixture was extracted with dichloromethane (3x20 mL). The combined organic phases were washed with brine, dried over MgSO₄, and concentrated under reduced pressure. The crude product was purified by column chromatography (acetone/DCM) to yield **M2** (960 mg, 99%).

Physical Properties: Colorless oil

¹H NMR (400 MHz, CDCl₃) δ(ppm) 6.25 (s, 1H), 4.04 (d, 4H), 3.46 (s, 4H), 3.26 (d, 4H), 1.53 (br, 2H), 1.26 (m, 80H), 0.88 (t, 12H).

¹³C NMR (101 MHz, CDCl₃) δ(ppm) 148.40, 145.39, 109.20, 100.83, 74.68, 74.11, 73.85, 69.67, 47.92, 38.06, 31.85, 31.44, 30.04, 29.64, 29.60, 29.29, 26.81, 22.61, 14.02.

HRMS (ESI): calcd for C₅₇H₁₀₈ClO₄S [M+H]⁺ 923.7657, found 923.7644.

4.2 Polymerization Establishment for ***PDSP***

Table S3. Polymerization screening for disulfide-containing conjugated polymers

Run	Coupling reaction	Catalytic system	Phenomenon
1	Direct arylation (Pd)	Pd(OAc) ₂ (2.5% mol), K ₂ CO ₃ (2.0 eq.), PivOH (0.3 eq.), DMAc (0.1 M)	Solution turned black (Pd black)
2	Direct arylation (Cu)	Cu(phen)(PPh ₃)Br (15% mol), K ₂ CO ₃ (4.0 eq.), DMAc/m-xylene (0.1 M)	No polymer formed
3	Stille (Pd)	Pd ₂ (dba) ₃ (2.5% mol), P(<i>o</i> -Tol) ₃ (10% mol), toluene (0.1 M)	Solution turned black (Pd black)
4	Suzuki (Pd)	Pd(PPh ₃) ₄ (2.5% mol), K ₂ CO ₃ (4.0 eq.), THF/water (0.1 M)	Solution turned black (Pd black)
5	Yamamoto (Ni)	Ni(COD) ₂ (1.2 eq.), COD (1.0 eq.), 2,2'-bipyridine (1.2 eq.), DMF (0.1 M)	No polymer formed
6	Chemical oxidation (Fe)	FeCl ₃ (0.6 mol%), (NH ₄)S ₂ O ₈ (1.5 eq.) CHCl ₃ /CH ₃ CN (0.1 M)	Superior S–S oxidation
7	Lewis acid as a mediator	SnCl ₄ (10 mol%), <i>o</i> -DCB (0.15 M)	High-quality polymer formed

Chemical oxidation polymerization

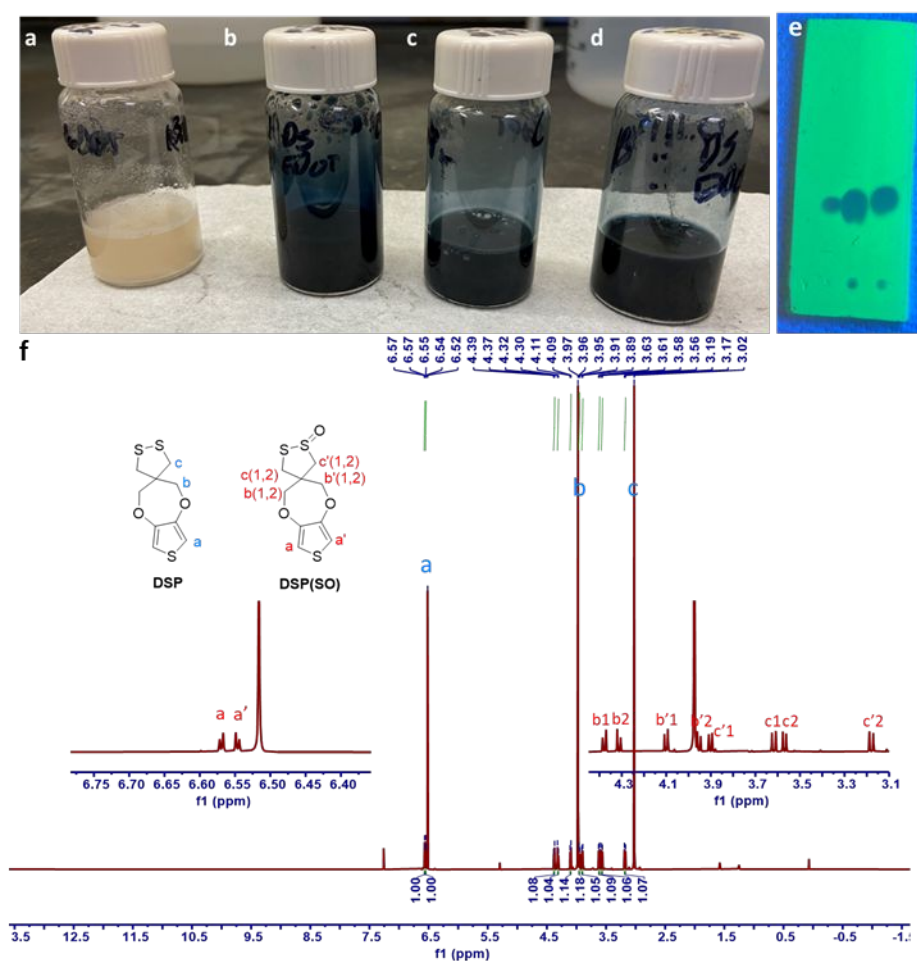


Figure S2. Comparative chemical oxidative polymerizations of **DSP** and 3,4-ethylene dioxothiophene (**EDOT**) with different molar ratios. **a–d**, **DSP:EDOT** = 1:0, 1:9, 3:7, 1:1, respectively. **e**, TLC plate of reaction **a**. Left: pure **DSP**; middle: mixture of pure **DSP** and crude reaction; right: crude reaction. **f**, ^1H NMR spectra of crude reaction mixture. As for **DSP(SO)**, ^1H NMR (800 MHz, CDCl_3) δ 6.57 (d, J = 3.9 Hz, 1H), 6.55 (d, J = 3.9 Hz, 1H), 4.38 (d, J = 12.3 Hz, 1H), 4.31 (d, J = 12.3 Hz, 1H), 4.10 (d, J = 12.1 Hz, 1H), 3.95 (d, J = 12.1 Hz, 1H), 3.90 (d, J = 12.1 Hz, 1H), 3.62 (d, J = 13.7 Hz, 1H), 3.57 (d, J = 12.1 Hz, 1H), 3.18 (d, J = 13.8 Hz, 1H). This structure was confirmed according to literature³.

As shown in Figure S2a, the chemical oxidation of a sole monomer of **DSP** was performed with ammonium persulfate as the oxidant and FeCl_3 as the catalyst. Figure S2e shows that the majority of **DSP** remained, and a trace of high polar impurity was detected. The ^1H NMR spectra of the crude reaction mixture (Figure S2f) demonstrates that disulfide bond of **DSP** was oxidized into thiolosulfinate with high polarity, implying the superior oxidation of S–S over thiophene moiety under the oxidized

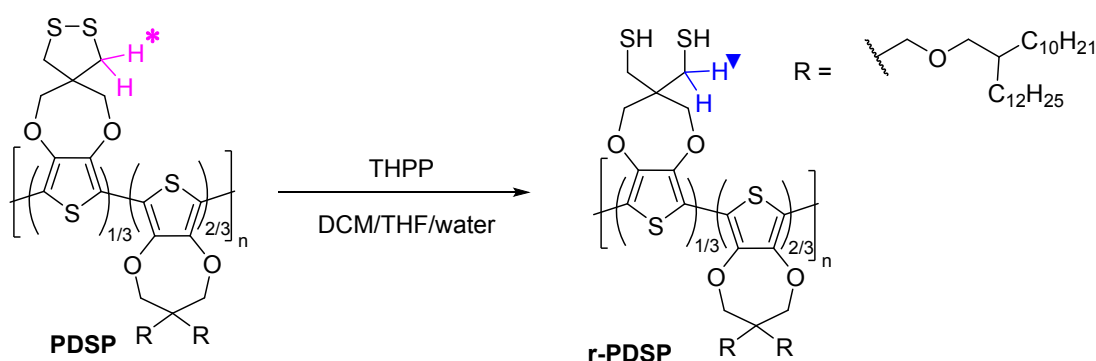
conditions. Figure S2b–d display the homopolymerization reactions of electron-rich **EDOT**. These results suggested that S–S bond in **DSP** is resistant to oxidation.

SnCl₄-promoted cationic chain-growth polymerization

To a solution of **M1** (152 mg, 0.5 mmol, 1 equiv.) and **M2** (1.0 g, 1.0 mmol, 2 equiv.) in anhydrous *o*-DCB (11 mL), a stock solution of SnCl₄ (1.0 M, 18.6 μ L, 0.1 equiv.) in anhydrous *o*-DCB was added and the resulting solution was stirred at 120 °C for 12 h. The disappearance of the monomers was checked by thin-layer chromatography (TLC) and if there were still monomers another charge of SnCl₄ was added to the mixture and stirred at 120 °C for another 12 h. The reaction mixture was poured into MeOH (100 mL) and a few drops (2–5) of hydrazine hydrate were added to neutralize/de-dope the polymer. The mixture was stirred for 1–3 h to allow the precipitation of the product. The solid was collected in a Soxhlet thimble, and it was then purified by Soxhlet extraction under N₂ using successive washes with methanol, acetone, hexane, and chloroform. The collected polymer solution from the chloroform fraction was reprecipitated into methanol and dried at 60 °C under vacuum for 24 h to give 1.2 g of polymer **PDSP** (95%). M_n = 13.2 kDa, D = 1.4. ¹H NMR (800 MHz, CDCl₃) δ (ppm) 4.13 (–CH₂O–C=), 3.59 (–C–CH₂O–), 3.31, (–CH–CH₂O–), 3.14, (–C–CH₂S–), 1.58 (–CH–CH₂O–), 1.33–1.24 (C–CH₂–C), 0.880.86 (–CH₃). FTIR ν (neat, cm^{–1}) 2916, 2852 (C–H stretching), 1467 (C–H bending), 1431 (C–H bending), 1366 (C–H bending), 1100 (C–O stretching), and 1044 (C–O stretching).

5. Post-polymerization Modification through Thiol-ene Chemistry

5.1 **PDSP** Reduction



General Procedure: To a round bottom flask were charged various volumes of THPP stock buffer solution (pH 7.4, 0.5 M). The reaction mixtures were stirred at room temperature for about 5 min and then to this homogenous solution was charged the

solution of **PDSP** (10 mg) in 1.0 mL of THF and 2 mL DCM. This reaction mixture was stirred at room temperature until the reaction completes (about 12 h). After completion of the reaction, the reaction mixture was extracted with chloroform (2 x 2 mL). The combined organic layer was washed with 10% NaCl solution, separated and dried over anhydrous Na₂SO₄. The solvent was removed under reduced pressure. Polymer samples (~10 mg) synthesized at different concentrations of THPP buffer solutions were dried and transferred to NMR tubes.

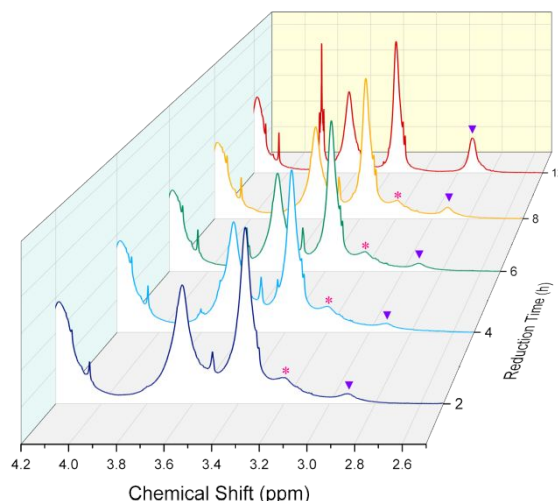
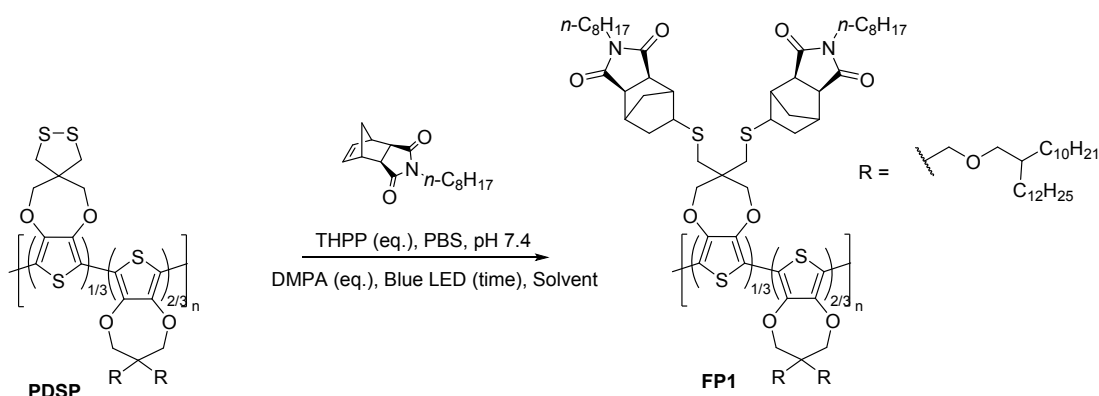


Figure S3. Temporal evolution of the ¹H NMR spectra of PDSP reduction. The chemical shifts at 3.14 and 2.86 ppm were labeled as * and ▼ corresponding to disulfide and thiol-adjacent protons (SS-CH₂- and HS-CH₂-), respectively.

5.2 Post-polymerization Modification of **PDSP**



A 20 mL VOA glass vial with 0.125in. septum. was charged with **PDSP** (40.0 mg, 1.0 eq. for **DSP** unit) and **Nb1** (54.4 mg, 10 eq.), 2 mL DCM and 0.5 mL THF under an inert atmosphere. After the polymer was dissolved completely, a stock solution of THPP (0.22 M, 0.25 mL) in PBS (pH 7.4) was added (total concentration of THPP =

20 mM). The resulting solution was stirred at room temperature for 12 h to reduce the disulfide bonds in **PDSP**, followed by being irradiated under double-density sapphire blue LEDs (Creative Lighting Solutions) for another 24 h. Then, the reaction mixture was transferred into cold method (10 mL) to allow the precipitation of the product. The polymer solid was collected and dried at 60 °C under vacuum for 24 h to give ~45 mg of **FP1**, which was directly used for ^1H NMR and FTIR spectroscopies. $M_n = 19.5$ kDa, $D = 2.0$. **^1H NMR** (800 MHz, CDCl_3) δ (ppm) 4.13 ($-\text{CH}_2\text{O}-\text{C}=\text{}$), 3.58 ($-\text{C}-\text{CH}_2\text{O}-$), 3.42 ($-\text{CH}_2-\text{N}$), 3.30($-\text{CH}-\text{CH}_2\text{O}-$), 2.91 ($\text{S}-\text{CH}_2-$), 2.86 ($-\text{S}-\text{CH}-$), 2.71 ($-\text{CH}-\text{C}=\text{}$) 2.60 ($\text{CH}_2-\text{CH}-$), 2.56 ($\text{CH}-\text{CH}-$), 1.57 ($-\text{CH}-\text{CH}_2\text{O}-$), 1.331.24($\text{C}-\text{CH}_2-\text{C}$), 0.880.86 ($-\text{CH}_3$). **FTIR** ν (neat, cm^{-1}) 2919, 2849 (C–H stretching), 1700 (C=O stretching), 1467 (C–H bending), 1431 (C–H bending), 1366 (C–H bending), 1259 cm^{-1} (C–N stretching), 1100 (C–O stretching), 1044 (C–O stretching).

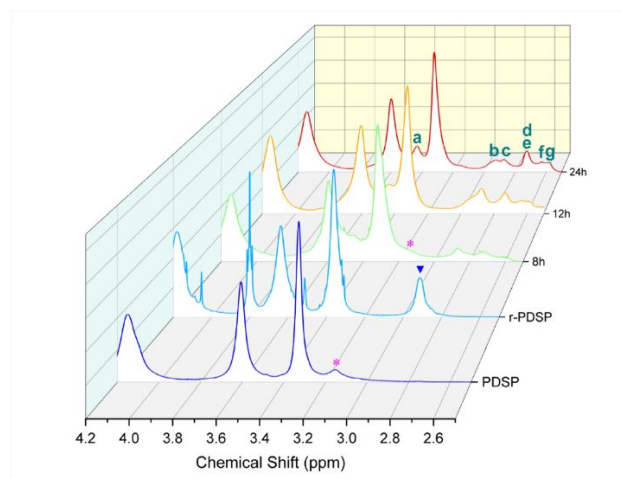


Figure S4. Temporal evolution of the ^1H NMR spectra of **PDSP** reduction. The chemical shifts were labeled as *, ▼, and a–g corresponding to disulfide, thiol, and thiol-ene hub groups, respectively.

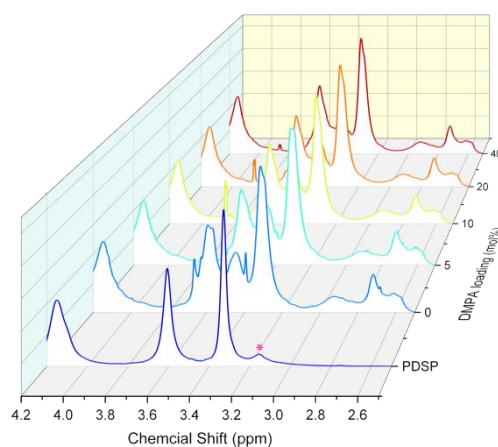


Figure S5. Comparative of post-functionalized polymer samples using different loadings of DMPA, where ^1H NMR spectrum of **PDSP** was illustrated for comparison.

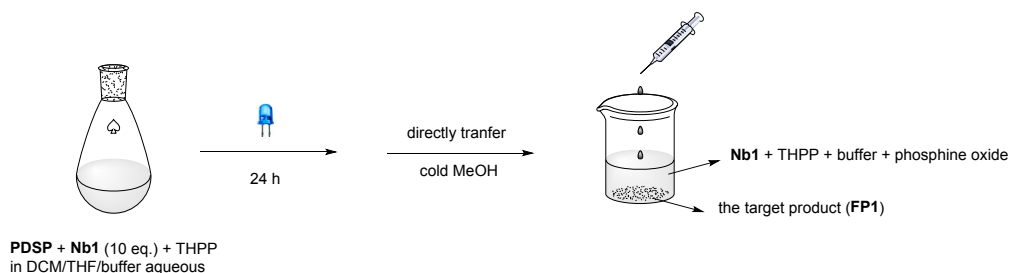


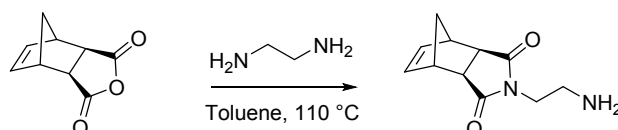
Figure S6. Schematic procedures of the photoreaction under optimized conditions and the following work-up.

6. Substrate Scope: Post-polymerization Biofunctionalization with Various Biofunctional Motifs

6.1 Synthesis of Norbornene Derivatives

Nb-COOH and **Nb2** were prepared according to previous work in our group⁴.

Synthesis of **Nb-NH2**



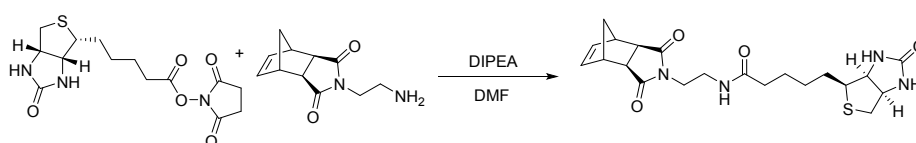
Nb-NH2 was prepared following literature procedure¹.

Physical properties: White solid

^1H NMR (500 MHz, CDCl_3) δ (ppm) 6.36 – 6.28 (m, 2H), 3.54 (dd, $J = 7.9, 4.9$ Hz, 2H), 3.26 (dd, $J = 3.6, 1.8$ Hz, 2H), 2.88 (t, $J = 6.4$ Hz, 2H), 2.71 (t, $J = 2.4$ Hz, 2H), 1.54 – 1.47 (m, 1H), 1.41 – 1.31 (m, 1H).

^{13}C NMR (125 MHz, CDCl_3) δ (ppm) 178.09, 137.98, 137.30, 47.74, 47.56, 45.01, 44.95, 41.27, 39.75.

Synthesis of **Nb3**



Nb3. DIPEA (227 mg, 2.0 eq.) was added to a solution of **Nb-NH2** (181 mg, 1.0 eq.) and Biotin-NHS (300 mg, 1.0 eq.) in 10 mL of DMF. The reaction mixture was stirred

at room temperature overnight. Subsequently, the solvent was evaporated, and the residue purified directly by preparative RP HPLC to afford **Nb3** (370 mg, 97%).

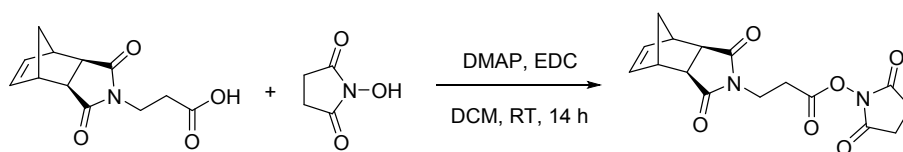
Physical properties: Pale-yellow solid

¹H NMR (800 MHz, DMSO-*d*₆) δ(ppm) 7.84 (t, *J* = 6.0 Hz, 1H), 6.30 (t, *J* = 1.8 Hz, 2H), 4.31 (dd, *J* = 7.8, 5.0 Hz, 1H), 4.13 (dd, *J* = 7.7, 4.4 Hz, 1H), 3.41 (t, *J* = 6.2 Hz, 2H), 3.18 (q, *J* = 6.1 Hz, 2H), 3.12 – 3.06 (m, 3H), 2.82 (dd, *J* = 12.5, 5.1 Hz, 1H), 2.65 (d, *J* = 1.4 Hz, 2H), 2.58 (d, *J* = 12.4 Hz, 1H), 1.98 (td, *J* = 7.4, 3.1 Hz, 2H), 1.59 (ddt, *J* = 12.0, 10.0, 6.1 Hz, 1H), 1.50 – 1.41 (m, 3H), 1.34 (dt, *J* = 9.8, 1.7 Hz, 1H), 1.35 – 1.21 (m, 1H), 1.18 (d, *J* = 9.7 Hz, 1H).

¹³C NMR (201 MHz, DMSO-*d*₆) δ(ppm) 178.01, 172.70, 163.12, 138.04, 61.41, 59.60, 55.79, 47.76, 44.80, 42.91, 38.27, 36.38, 35.60, 28.57, 28.42, 25.48.

HRMS (ESI): C₂₁H₂₉N₄O₄S, [M+H]⁺ cal. 433.190953, found 433.19191; C₂₁H₂₈N₄O₄Na, [M+Na]⁺ cal. 455.17289, found 455.17380.

Synthesis of **Nb4**



Nb4 was prepared via Steglich Esterification protocol. Nb-COOH (500 g, 1.0 eq), 1-hydroxypyrrolidine-2,5-dione imide (245 mg, 1.0 eq), 1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide (1.31 g, 3.5 eq), 4-dimethylaminopyridine (0.52 g, 0.2 eq), and dichloromethane (20 mL) were mixed into a 50 mL round bottom flask. The reaction was stirred for 14 h at room temperature. The reaction was washed with 1 M HCl and extracted with dichloromethane. The organic layer was then washed with 1M NaHCO₃, dried with Na₂SO₄, and evaporated thoroughly to yield **Nb4** (500 mg, 71% yield).

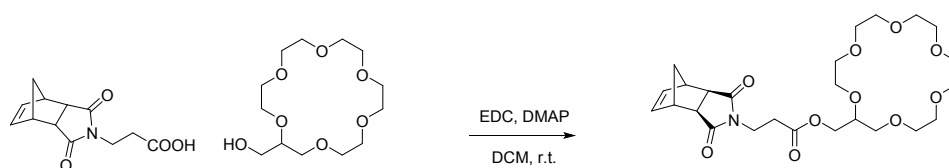
Physical properties: White solid

¹H NMR (800 MHz, CDCl₃) δ(ppm) 6.28 (t, *J* = 1.8 Hz, 2H), 3.87 (td, *J* = 7.0, 2.0 Hz, 2H), 3.28 (q, *J* = 1.9 Hz, 2H), 3.00 (td, *J* = 7.0, 1.5 Hz, 2H), 2.81 (s, 4H), 2.73 (d, *J* = 1.5 Hz, 2H), 1.51 (dd, *J* = 10.0, 1.6 Hz, 1H), 1.20 (dd, *J* = 10.0, 1.9 Hz, 1H).

¹³C NMR (201MHz, CDCl₃) δ(ppm) 177.49, 168.64, 165.96, 137.77, 47.81, 45.13, 42.86, 33.60, 28.78, 25.47.

HRMS (ESI): calcd for $C_{16}H_{17}N_2O_6$ $[M+H]^+$ 333.1087, found 333.1082.

Synthesis of **Nb5**



Nb5 was prepared via Steglich Esterification protocol. **Nb-COOH** (200 g, 1.0 eq), 2-hydroxymethyl-18-crown-6 (250 mg, 1.0 eq), 1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide (570 mg, 3.5 eq), 4-dimethylaminopyridine (21 mg, 0.2 eq), and dichloromethane (10 mL) were mixed into a 50 mL round bottom flask. The reaction was stirred for 14 h at room temperature. The reaction was washed with 1 M HCl and extracted with dichloromethane. The organic layer was then washed with 1M $NaHCO_3$, dried with Na_2SO_4 , and evaporated thoroughly to yield **Nb5** (220 mg, 51% yield).

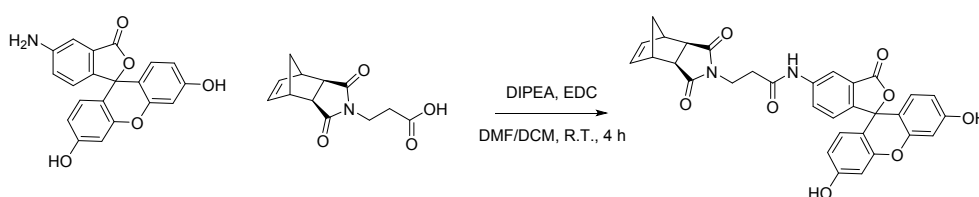
Physical properties: Pale-yellow oil

^1H NMR (800 MHz, $CDCl_3$) δ (ppm) 6.27 (s, 2H), 4.22 (dd, $J = 11.5, 3.9$ Hz, 1H), 4.10 (dd, $J = 11.6, 5.2$ Hz, 1H), 3.78 – 3.60 (m, 25H), 3.26 (s, 2H), 2.67 (s, 2H), 2.62 (dd, $J = 8.6, 5.8$ Hz, 2H), 1.50 (d, $J = 9.8$ Hz, 1H), 1.24 (d, $J = 9.7$ Hz, 1H).

^{13}C NMR (200 MHz, $CDCl_3$) δ 177.56, 170.44, 137.78, 70.93, 70.83, 70.77, 70.69, 70.63, 69.88, 64.31, 47.76, 45.13, 42.71, 34.29, 31.93.

HRMS (ESI): calcd for $C_{25}H_{38}NO_{10}$ $[M+H]^+$ 512.2495, found 512.2489.

Synthesis of **Nb6**



Nb6. In a round bottom flask, **Nb-COOH** (339 mg, 1.0 eq.), 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide (EDC, 1.15 g, 3.5 eq.) were dissolved in 10 ml of dichloromethane and *N,N*-dimethylformamide (v/v, 1/4). The mixture was stirred for 30 min at room temperature. After the addition of 5-amino-fluorescein (500 mg, 1.0 eq.) and DIPEA to pH 9, the reaction mixture was stirred for 12 h. The reaction mixture was poured in water and acidified with concentrated HCl to less than pH 2. The mixture was further stirred for an hour, and then extracted with dichloromethane. The organic

layer was separated and dried with Na₂SO₄. The crude oil was purified by automated preparative column chromatography (2% of MeOH in CH₂Cl₂ containing 0.1% TFA). The desired fraction with R_f of 0.45 in a TLC system of CH₂Cl₂–MeOH (9:1) with 1% AcOH was evaporated to yield **Nb6** (350 mg, 43%).

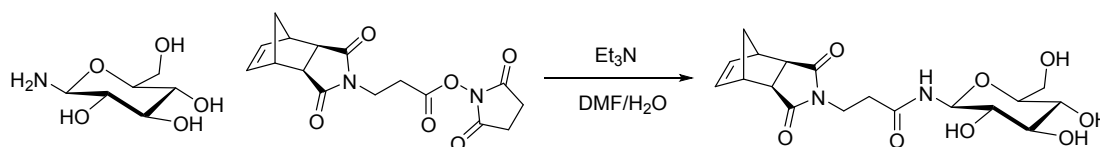
Physical properties: Dark brown solid

¹H NMR (800 MHz, DMSO-d₆) δ (ppm) 7.17 (d, *J* = 2.2 Hz, 1H), 7.03 (d, *J* = 2.1 Hz, 1H), 7.00 – 6.96 (m, 1H), 6.92 (d, *J* = 8.1 Hz, 1H), 6.90 – 6.85 (m, 2H), 6.69 (d, *J* = 2.3 Hz, 1H), 6.65 (d, *J* = 8.7 Hz, 1H), 6.59 (dd, *J* = 8.6, 2.4 Hz, 1H), 6.31 – 6.29 (m, 2H), 3.75 (t, *J* = 6.7 Hz, 2H), 3.10 (s, 2H), 2.82 (t, *J* = 6.8 Hz, 2H), 2.71 (s, 2H), 1.35 – 1.32 (m, 1H), 1.24 (d, *J* = 9.7 Hz, 1H).

¹³C NMR (201 MHz, DMSO-d₆) δ(ppm) 177.44, 169.18, 169.15, 159.44, 151.59, 151.35, 151.14, 150.02, 139.92, 137.63, 129.06, 128.97, 127.09, 124.21, 122.13, 117.79, 117.74, 112.85, 110.08, 106.70, 102.11, 81.63, 47.29, 44.45, 42.29, 34.06, 32.16, 20.70.

HRMS (ESI): C₃₂H₂₅N₂O₈, [M+H]⁺ cal. 565.161093, found 565.16025.

Synthesis of **Nb7**



Nb7. Et₃N (227 mg, 1.5 eq.) was added to a solution of D-glucopyranosyl amine (65 mg, 1.0 eq.) and **Nb4** (120 mg, 1.0 eq.) in 10 mL of DMF/H₂O (v/v, 4/1). The reaction mixture was stirred at room temperature overnight. Subsequently, the solvent was evaporated, and the residue purified directly by preparative RP HPLC to afford a **Nb7** (140 mg, 98%).

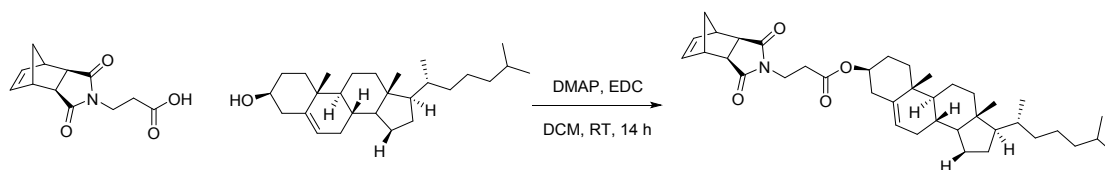
Physical properties: White solid

¹H NMR (800 MHz, MeOD-d₄) δ(ppm) 6.32 (d, *J* = 1.9 Hz, 2H), 3.83 – 3.80 (m, 1H), 3.76 (td, *J* = 7.3, 1.8 Hz, 2H), 3.65 – 3.62 (m, 1H), 3.38 (t, *J* = 9.0 Hz, 1H), 3.31 – 3.32 (m, 2H), 3.28 – 3.25 (m, 1H), 3.22 (t, *J* = 9.1 Hz, 1H), 3.18 (s, 2H), 2.72 (d, *J* = 1.4 Hz, 2H), 2.59 – 2.50 (m, 2H), 1.48 (d, *J* = 11.4 Hz, 1H), 1.29 (d, *J* = 9.9 Hz, 1H).

¹³C NMR (201 MHz, MeOD-d₄) δ(ppm) 179.84, 179.81, 173.73, 138.95, 80.93, 79.59, 78.97, 73.97, 71.46, 62.77, 46.32, 43.70, 35.86, 34.51.

HRMS (ESI): C₁₈H₂₅N₂O₈, [M+H]⁺ cal. 397.161093, found 397.15984.

Synthesis of **Nb8**



Nb8. was prepared via Steglich Esterification protocol. **Nb-COOH** (200 g, 1.0 eq), 2-hydroxymethyl-18-crown-6 (250 mg, 1.0 eq), 1-Ethyl-3-(3-dimethylaminopropyl) carbodiimide (570 mg, 3.5 eq), 4-dimethylaminopyridine (21 mg, 0.2 eq), and dichloromethane (10 mL) were mixed into a 50 mL round bottom flask. The reaction was stirred for 14 h at room temperature. The reaction was washed with 1 M HCl and extracted with dichloromethane. The organic layer was then washed with 1M NaHCO₃, dried with Na₂SO₄, and evaporated thoroughly to yield a pale-yellow oil (220 mg, 51% yield).

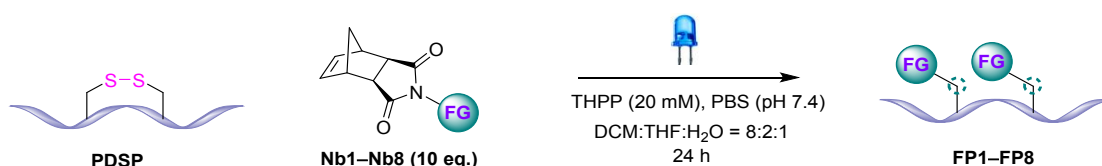
Physical properties: White solid

¹H NMR (800 MHz, CDCl₃) δ(ppm) 6.28 (s, 2H), 5.36 (dd, *J* = 4.5, 2.3 Hz, 1H), 4.63 – 4.54 (m, 1H), 3.77 (t, *J* = 7.2 Hz, 2H), 3.27 (t, *J* = 1.8 Hz, 2H), 2.67 (d, *J* = 1.4 Hz, 2H), 2.58 (t, *J* = 7.2 Hz, 2H), 2.31 – 2.25 (m, 2H), 2.02 – 1.98 (m, 1H), 1.98 – 1.93 (m, 1H), 1.86 – 1.79 (m, 3H), 1.64 – 1.40 (m, 9H), 1.38 – 1.30 (m, 3H), 1.28 – 1.22 (m, 2H), 1.19 – 1.02 (m, 7H), 1.02 – 0.95 (m, 5H), 0.91 (d, *J* = 6.6 Hz, 3H), 0.86 (dd, *J* = 6.7, 3.6 Hz, 6H), 0.67 (s, 3H).

¹³C NMR (201 MHz, CDCl₃) δ(ppm) 177.56, 169.99, 139.42, 137.79, 122.71, 74.47, 56.61, 56.06, 49.94, 47.75, 45.14, 42.71, 42.24, 39.65, 39.45, 37.92, 36.87, 36.49, 36.11, 35.72, 34.44, 32.42, 31.82, 31.78, 28.16, 27.94, 27.58, 24.21, 23.76, 22.75, 22.49, 20.95, 19.24, 18.64, 11.79.

HRMS (ESI): C₁₈H₂₅N₂O₈, [M+H]⁺ cal. 603.87418, found 604.43639.

6.2 Biofunctionalization of **PDSP** with Various Biofunctional Motifs



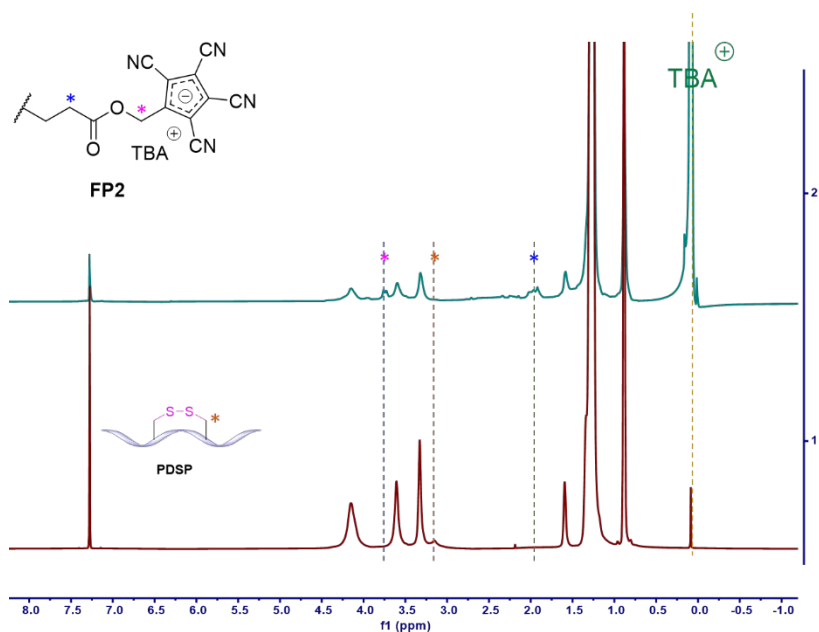


Figure S7. Comparative ^1H NMR spectra of **PDSP** (red) and **FP2** (green).

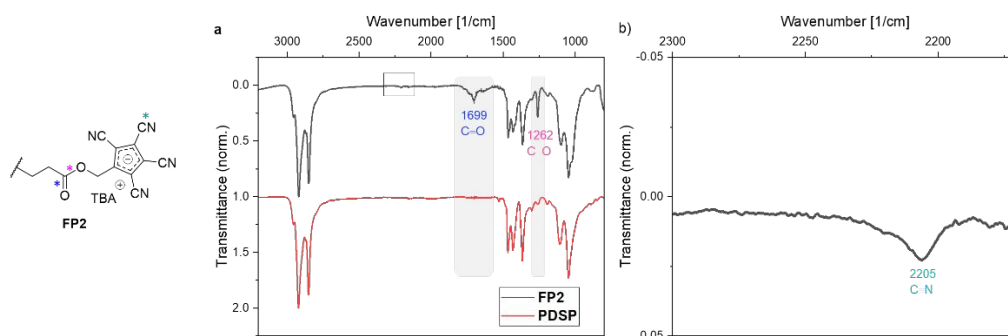


Figure S8. Comparative FTIR spectra of **PDSP** (red) and **FP2** (grey).

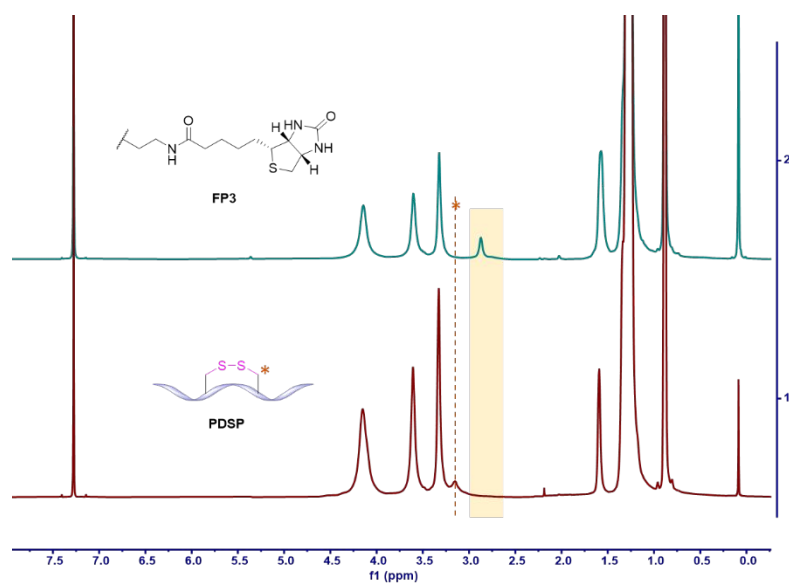


Figure S9. Comparative ^1H NMR spectra of **PDSP** (red) and **FP3** (green).

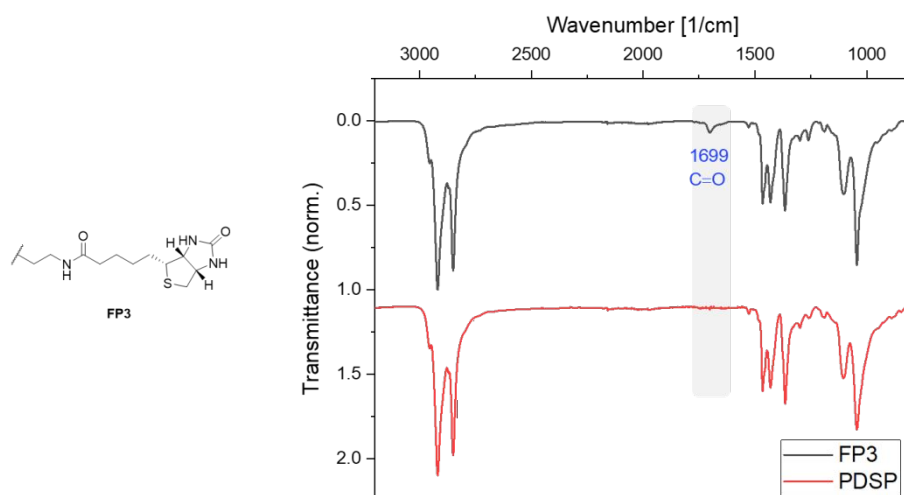


Figure S10. Comparative FTIR spectra of PDSP (red) and FP3 (grey).

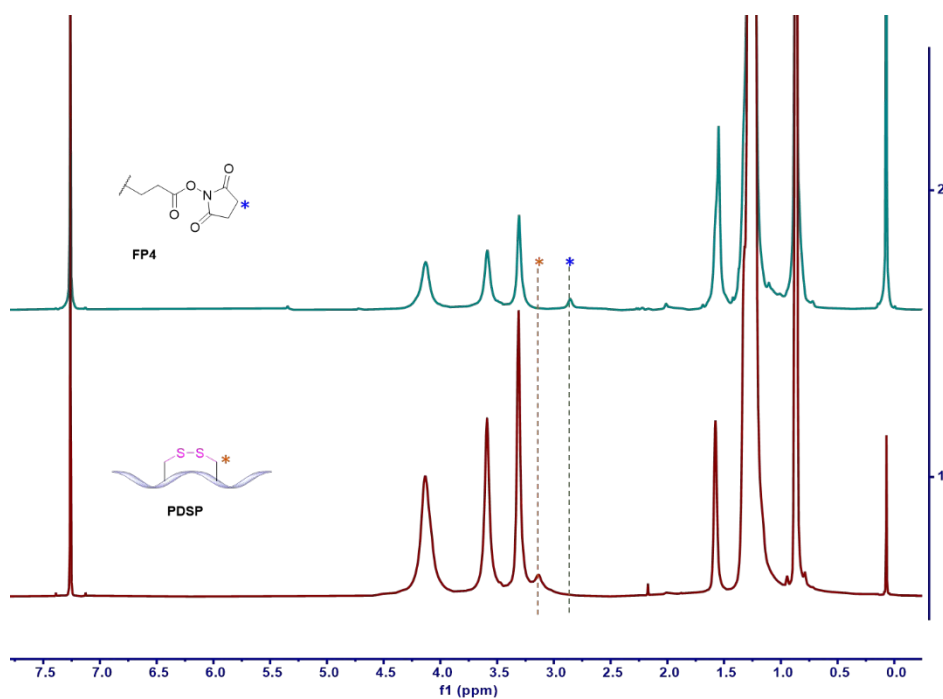


Figure S11. Comparative ¹H NMR spectra of PDSP (red) and FP4 (green).

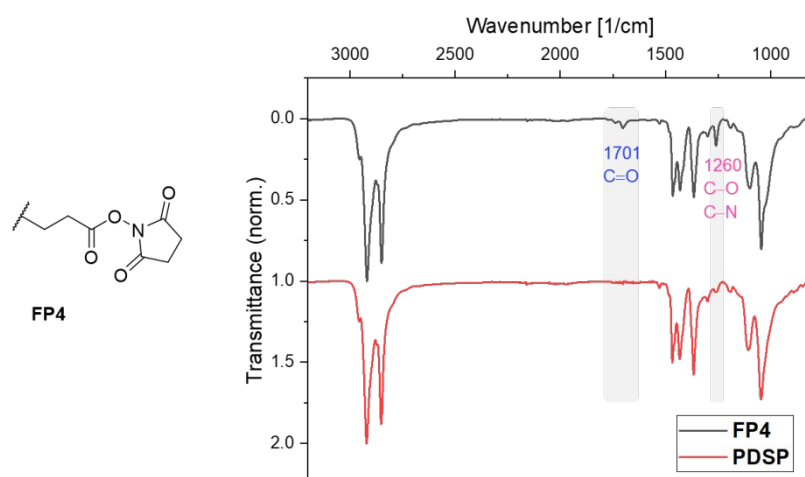


Figure S12. Comparative FTIR spectra of PDSP (red) and FP4 (grey).

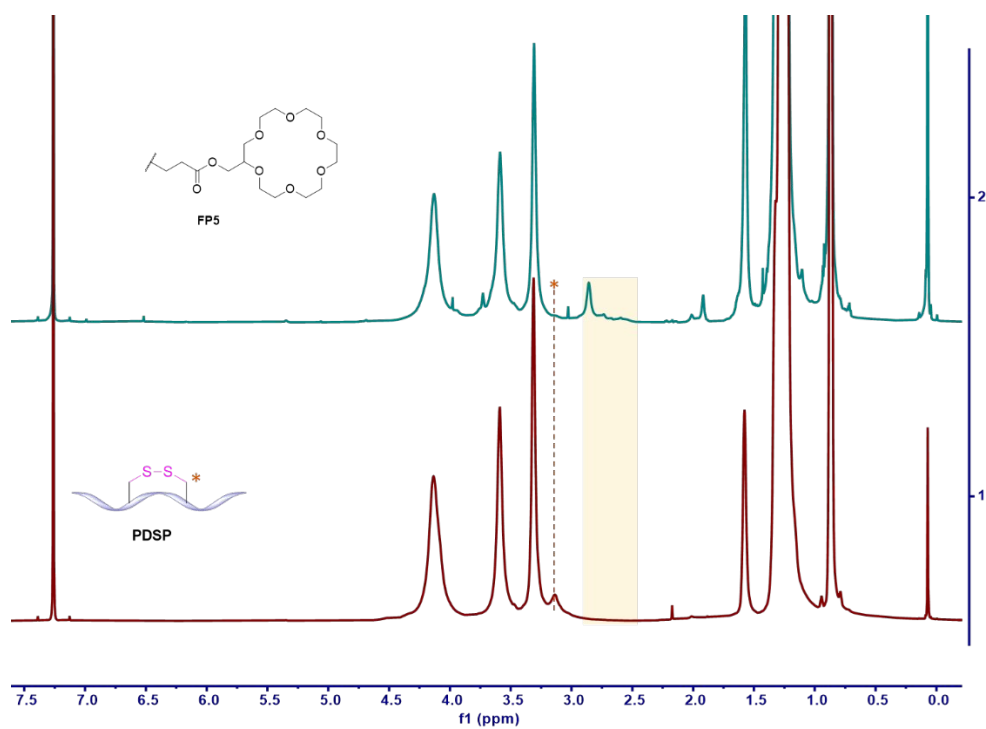


Figure S13. Comparative ^1H NMR spectra of PDSP (red) and FP5 (green).

SI-25

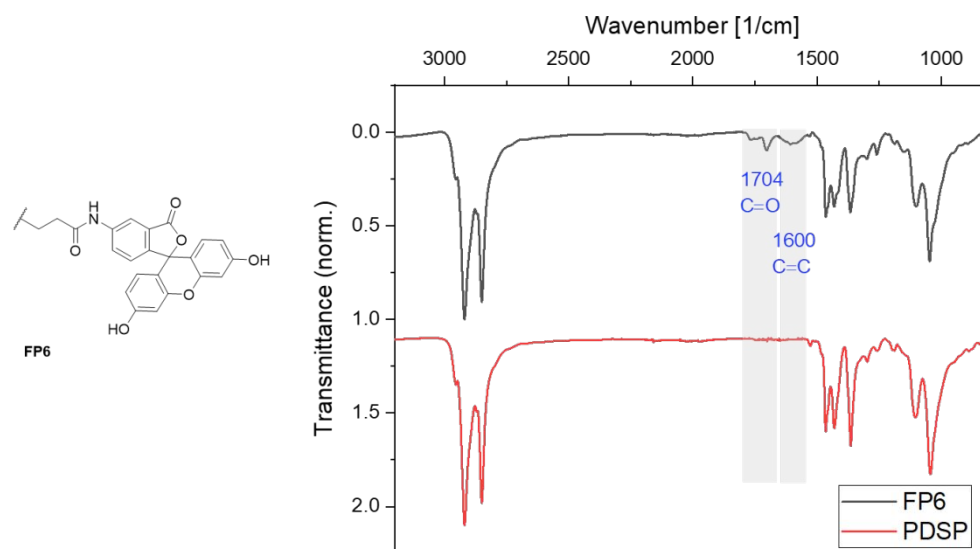


Figure S16. Comparative FTIR spectra of PDSP (red) and FP6 (grey).

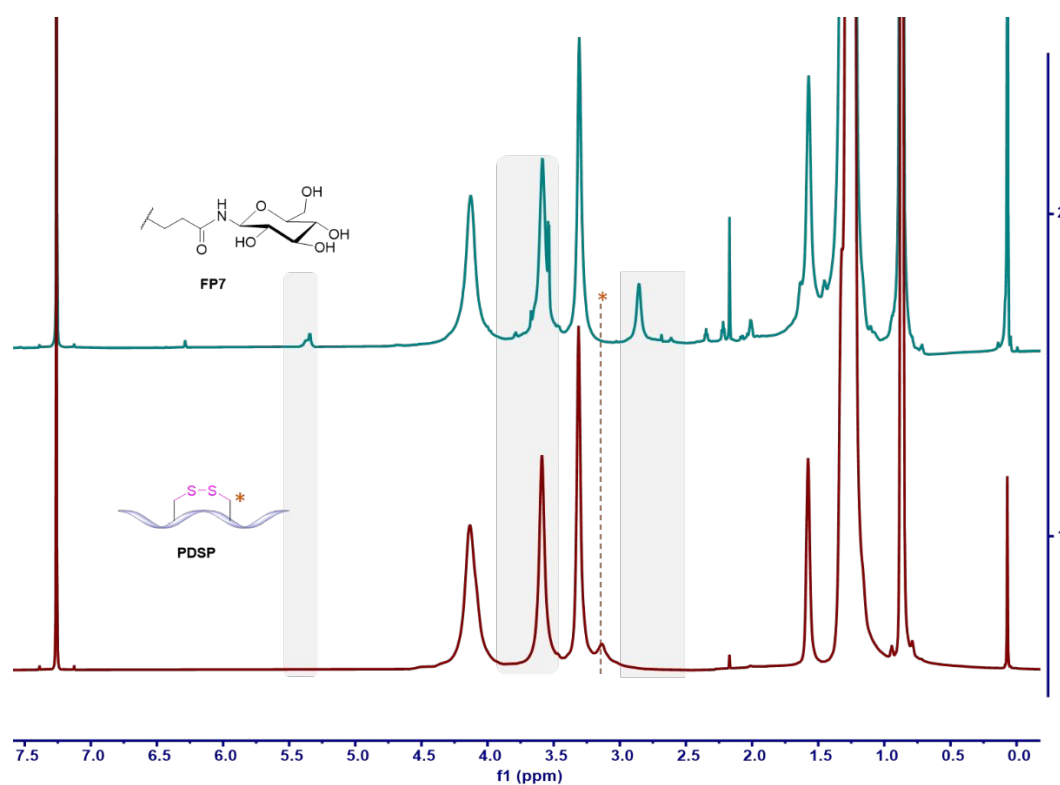


Figure S17. Comparative ¹H NMR spectra of PDSP (red) and FP7 (green).

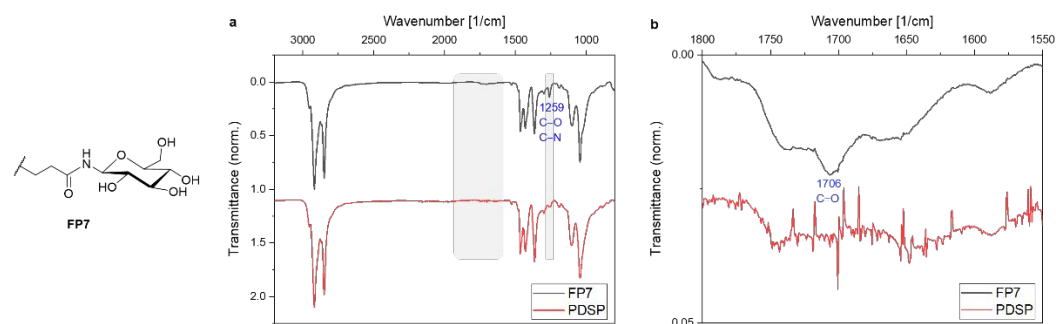


Figure S18. Comparative FTIR spectra of PDSP (red) and FP7 (grey).

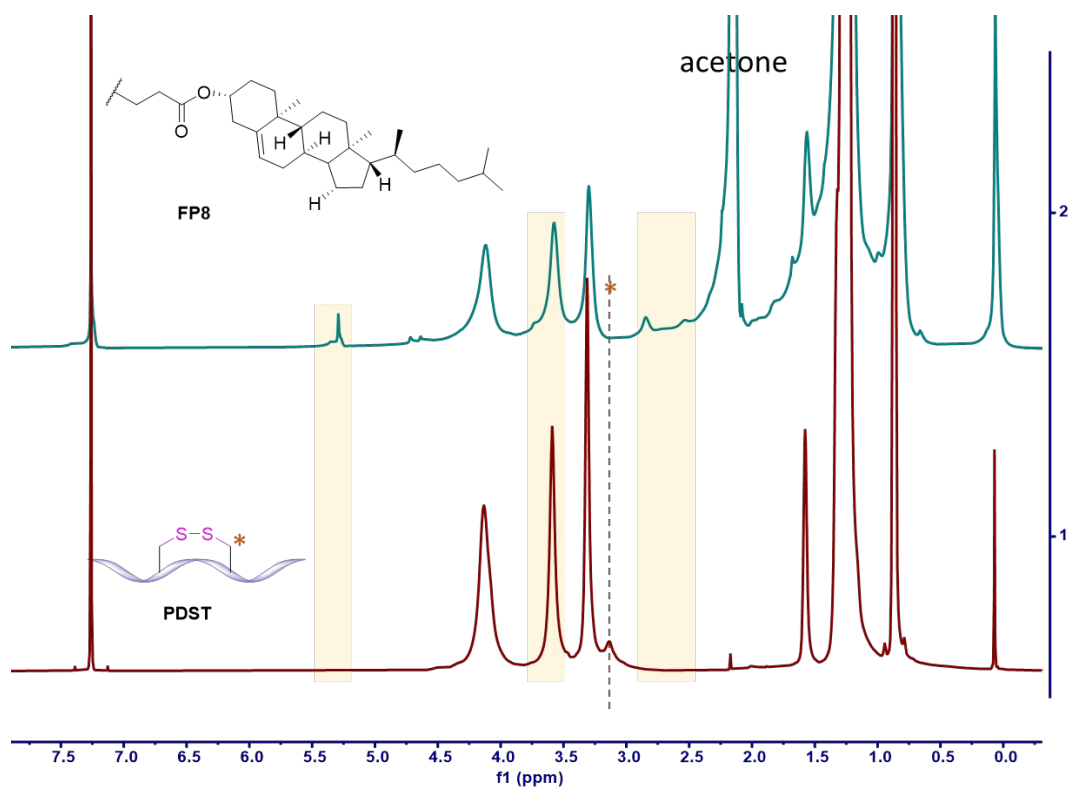


Figure S19. Comparative ¹H NMR spectra of PDSP (red) and FP8 (green).

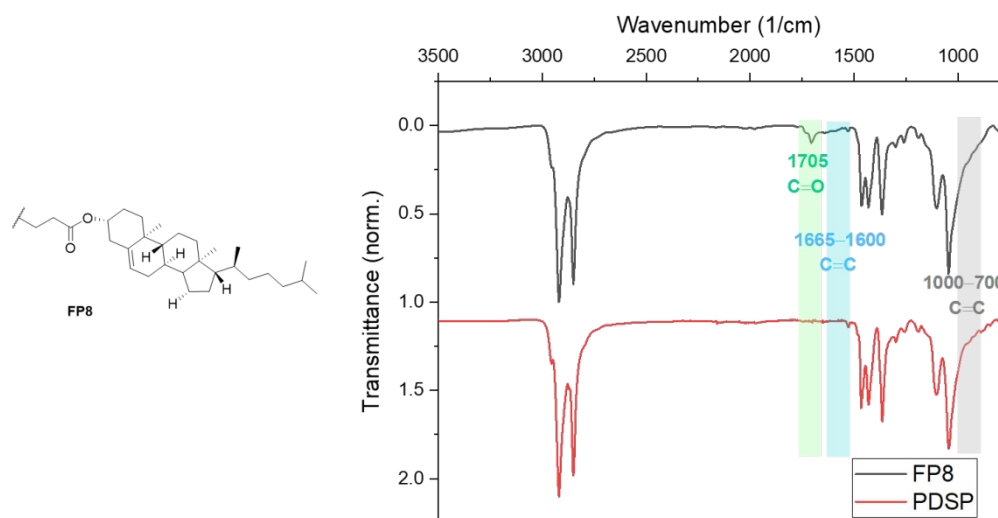
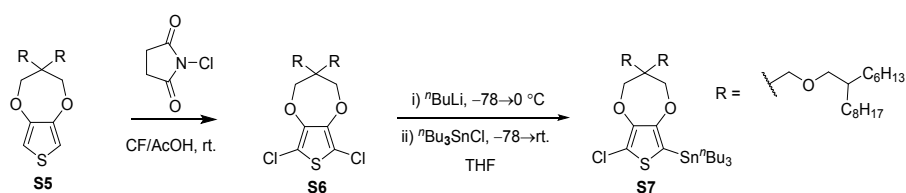


Figure S20. Comparative FTIR spectra of **PDSP** (red) and **FP8** (grey).

7. Substrate Scope: Disulfide-containing Donor-Acceptor CPs

7.1 Monomer Synthesis

Synthesis of **S7**



S5 was prepared according to the literature method².

Physical Properties: colorless oil

¹H NMR (800 MHz, CDCl₃) δ(ppm) 6.43 (s, 2H), 4.00 (s, 4H), 3.46 (s, 4H), 3.26 (s, 4H), 1.52 (q, *J* = 5.7 Hz, 2H), 1.28 (dd, *J* = 27.8, 6.1 Hz, 48H), 0.88 (t, *J* = 7.1 Hz, 12H).

¹³C NMR (201 MHz, CDCl₃) δ(ppm) 149.64, 104.85, 74.72, 73.73, 69.80, 47.82, 38.09, 31.87, 31.84, 31.47, 30.06, 29.71, 29.58, 29.31, 26.82, 26.78, 22.63, 22.59, 14.05.

HRMS (ESI): calcd for C₄₁H₇₇O₄S [M+H]⁺ 665.5542, found 665.5534.

S6 was prepared according to the synthetic procedure of **S4**.

Physical Properties: colorless oil

^1H NMR (400 MHz, CDCl_3) δ (ppm) 4.08 (s, 4H), 3.47 (s, 4H), 3.27 (d, J = 5.6 Hz, 4H), 1.53 (br, 2H), 1.27 (br, 48H), 0.89 (t, J = 6.7 Hz, 12H).

^{13}C NMR (101 MHz, CDCl_3) δ (ppm) 144.69, 105.09, 74.67, 74.32, 69.64, 48.01, 38.07, 31.84, 31.81, 31.45, 30.02, 29.68, 29.56, 29.29, 26.81, 26.76, 22.61, 14.01.

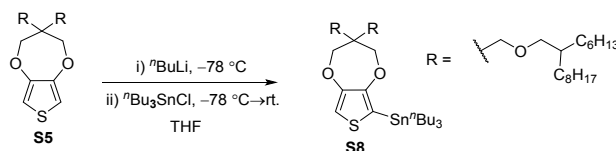
HRMS (ESI): calcd for $\text{C}_{41}\text{H}_{75}\text{Cl}_2\text{O}_4\text{S}$ $[\text{M}+\text{H}]^+$ 733.4763, found 733.4752.

S7. To a THF solution (12 mL) of **S6** (1.2 g, 1.63 mmol) was added *n*-butyllithium (2.5 M, 1.96 mmol) in hexane at -78°C under N_2 . After stirring for 1 h at 0°C , tributyltin chloride (720.64 mg, 2.13 mmol) was added dropwise to the reaction mixture and then allowed to warm to room temperature. After stirring overnight, the reaction mixture was quenched with water, extracted with hexane, and dried over Na_2SO_4 . The crude product was concentrated under vacuum and used for next step without further purification.

Physical Properties: colorless oil

^1H NMR (400 MHz, CDCl_3) δ (ppm) 4.05 (s, 2H), 3.91 (s, 2H), 3.46 (s, 4H), 3.26 (dd, J = 5.7, 2.1 Hz, 4H), 1.54 – 1.48 (m, 8H), 1.34 (d, J = 7.4 Hz, 6H), 1.29 – 1.23 (m, 48H), 1.11 – 1.03 (m, 6H), 0.89 (td, J = 7.1, 4.8 Hz, 24H).

Synthesis of **S8**

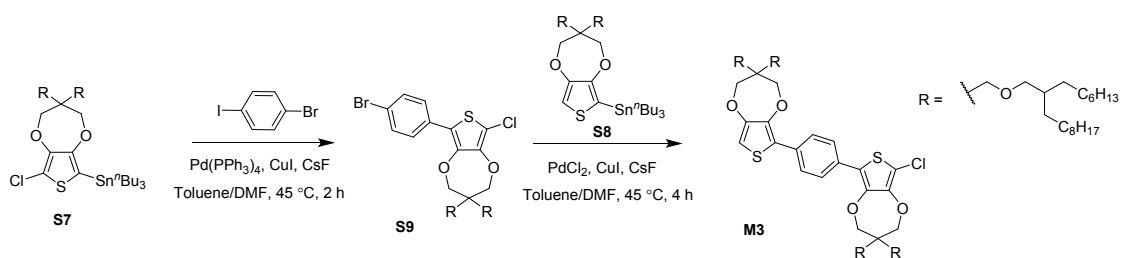


S8. To a THF solution (27 mL) of **S5** (2.76 g, 5.15 mmol) was added *n*-butyllithium (2.5 M, 4.15 mmol) in hexane at -78°C under N_2 . After stirring for 1 h at -78°C , tributyltin chloride (1.83 g, 5.39 mmol) was added dropwise to the reaction mixture and then allowed to warm to room temperature. After stirring overnight, the reaction mixture was quenched with water, extracted with hexane, and dried over Na_2SO_4 . The crude product was concentrated under vacuum and used for next step without further purification.

Physical Properties: colorless oil

^1H NMR (400 MHz, CDCl_3) δ (ppm) 6.68 (s, 1H), 3.98 (s, 2H), 3.91 (s, 2H), 3.45 (s, 4H), 3.28 – 3.24 (m, 4H), 1.56 – 1.50 (m, 8H), 1.35 (d, J = 7.4 Hz, 6H), 1.26 (s, 48H), 1.10 – 1.04 (m, 6H), 0.88 (dt, J = 7.0, 3.2 Hz, 21H).

Synthesis of **M3**



S9 was prepared according to the literature method³. In a 50 mL Schlenk tube, **S7** (1.6 g, 1.6 mmol), 1-bromo-4-iodobenzene (457.9 mg, 1.62 mmol), Pd(PPh₃)₂ (5 mol%, 93.5 mg, 0.1 mmol), CuI (10 mol %, 61.7 mg, 0.3 mmol), Cs₂CO₃ (2.0 eq., 491.7 mg, 3.24 mmol) were added, vacuumed for 30 minutes, and then subjected to N₂ purge cycles three times. Anhydrous toluene (10 mL) and DMF (3 mL) was added via needle and syringe. The reaction was heated at 45 °C in an oil bath for 2 h. The reaction mixture was quenched with water and extracted with dichloromethane. The organic layer was washed with water twice, then once with brine. The organic layer was separated and dried over MgSO₄, then filtered and concentrated under reduced pressure. The crude product was purified by SiO₂ column chromatography to yield **S9** (1.3 g, 94%).

Physical Properties: colorless liquid

¹H NMR (400 MHz, CDCl₃) δ(ppm) 7.29 (d, *J* = 4.3 Hz, 4H), 3.95 (d, *J* = 8.4 Hz, 4H), 3.34 (s, 4H), 3.11 (d, *J* = 5.7 Hz, 4H), 1.37 (br, 2H), 1.10 (br, 48H), 0.77 – 0.57 (m, 12H).

¹³C NMR (101 MHz, CDCl₃) δ(ppm) 146.00, 144.89, 131.59, 131.28, 127.83, 120.69, 116.90, 108.00, 74.68, 74.07, 73.91, 69.81, 47.94, 38.10, 31.85, 31.83, 31.51, 31.47, 30.05, 29.71, 29.58, 29.31, 26.83, 26.78, 22.62, 22.57, 14.03.

HRMS (ESI): calcd for C₄₇H₇₉BrClO₄S [M+H]⁺ 853.4571, found 853.4558.

M3 was prepared according to the literature method.³ In a 10 mL Schlenk tube, **S9** (320.0 mg, 0.37 mmol), **S8** (357.3 mg, 0.37 mmol), PdCl₂ (2 mol%, 1.3 mg, 0.01 mmol), CuI (4 mol %, 2.85 mg, 0.01 mmol), Cs₂CO₃ (2.0 eq., 113.8 mg, 0.75 mmol) were added, vacuumed for 30 minutes, and then subjected to N₂ purge cycles three times. Anhydrous toluene (2 mL) and DMF (0.3 mL) was added via needle and syringe. The reaction was heated at 45 °C in an oil bath for 2 h. The reaction mixture was quenched with water

and extracted with dichloromethane. The organic layer was washed with water twice, then once with brine. The organic layer was separated and dried over MgSO₄, then filtered and concentrated under reduced pressure. The crude product was purified by SiO₂ column chromatography to yield **M3** (501 mg, 93%).

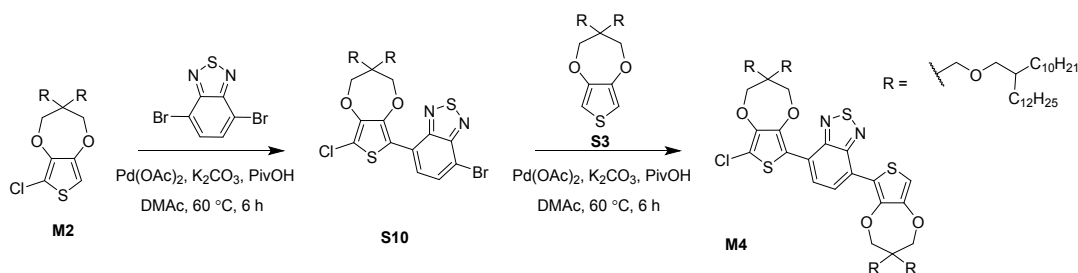
Physical Properties: deep yellow liquid

¹H NMR (400 MHz, CDCl₃) δ(ppm) 7.70 – 7.63 (m, 2H), 7.62 – 7.55 (m, 2H), 6.45 – 6.36 (m, 1H), 4.15 – 4.03 (m, 8H), 3.50 (d, *J* = 3.1 Hz, 8H), 3.28 (dd, *J* = 6.0, 2.5 Hz, 8H), 1.57 – 1.48 (m, 8H), 1.31 – 1.22 (m, 96H), 0.87 (ddt, *J* = 8.7, 6.3, 2.7 Hz, 24H).

¹³C NMR (201 MHz, CDCl₃) δ(ppm) 150.27, 146.02, 145.89, 144.63, 132.02, 130.72, 126.49, 126.39, 121.41, 118.14, 107.47, 102.54, 74.71, 74.11, 73.91, 73.70, 69.92, 69.85, 47.97, 47.87, 38.11, 31.87, 31.85, 31.48, 30.07, 29.72, 29.60, 29.32, 26.84, 26.79, 22.64, 14.06.

HRMS (ESI): calcd for C₈₈H₁₅₄Cl₂O₈S₂ [M+H]⁺ 1438.0773, found 1438.0746.

Synthesis of **M4**



In a 10 mL Schlenk tube, **M2** (500 mg, 0.54 mmol), dibromo-BTD (1.59 mg, 5.4 mmol), Pd(OAc)₂ (2.5 mol%, 3.0 mg, 0.01 mmol), pivalic acid (0.2 eq., 11.1 mg, 0.1 mmol), K₂CO₃ (4.0 eq., 299.1 mg, 2.16 mmol) were added, vacuumed for 30 minutes, and then subjected to N₂ purge cycles three times. Anhydrous toluene (5 mL) and DMAc (1 mL) was added via needle and syringe. The reaction was heated at 70 °C in an oil bath for 2 h. The reaction mixture was quenched with water and extracted with dichloromethane. The organic layer was washed with water twice, then once with brine. The organic layer was separated and dried over MgSO₄, then filtered and concentrated under reduced pressure. The crude product was purified by SiO₂ column chromatography to yield **S10** (350 mg, 57%)

Physical Properties: deep yellow oil

¹H NMR (400 MHz, CDCl₃) δ(ppm) 8.14 (d, *J* = 7.9 Hz, 1H), 7.76 (d, *J* = 7.9 Hz, 1H), 4.19 (d, *J* = 17.4 Hz, 4H), 3.55 (s, 4H), 3.31 (d, *J* = 5.7 Hz, 4H), 1.26 (m, 82H), 0.87 (t, 12H).

¹³C NMR (101 MHz, CDCl₃) δ(ppm) 153.20, 151.61, 147.14, 145.37, 132.36, 126.88, 124.85, 112.99, 112.85, 111.24, 74.68, 74.06, 73.95, 69.78, 47.87, 38.11, 31.86, 31.48, 30.08, 29.66, 29.61, 29.31, 26.85, 22.62, 14.03.

HRMS (ESI): calcd for C₆₃H₁₀₉BrClN₂O₄S₂ [M+H]⁺ 1135.6701, found 1135.6696.

In a 25 mL Schlenk tube, **S10** (320.0 mg, 0.28 mmol), **S3** (2.5 g, 2.81 mmol), Pd(OAc)₂ (2.5 mol%, 1.6 mg, 0.01 mmol), pivalic acid (0.2 eq., 5.75 mg, 0.06 mmol), K₂CO₃ (4.0 eq., 155.6 mg, 1.13 mmol) were added, vacuumed for 30 minutes, and then subjected to N₂ purge cycles three times. Anhydrous toluene (2 mL) and DMAc (0.3 mL) was added via needle and syringe. The reaction was heated at 70 °C in an oil bath for 2 h. The reaction mixture was quenched with water and extracted with dichloromethane. The organic layer was washed with water twice, then once with brine. The organic layer was separated and dried over MgSO₄, then filtered and concentrated under reduced pressure. The crude product was purified by SiO₂ column chromatography to yield **M4** (300 mg, 55%)

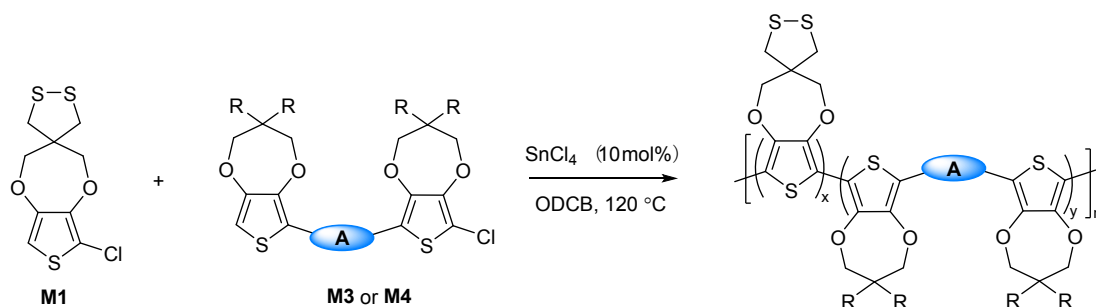
Physical Properties: deep red oil

¹H NMR (800 MHz, CDCl₃) δ(ppm) 8.32 (d, *J* = 7.9 Hz, 1H), 8.27 (d, *J* = 7.8 Hz, 1H), 6.66 (s, 1H), 4.22 (s, 2H), 4.20 (s, 2H), 4.18 (s, 2H), 4.10 (s, 2H), 3.54 (d, *J* = 12.9 Hz, 8H), 3.30 (dd, *J* = 5.8, 3.4 Hz, 8H), 1.55 (s, 4H), 1.30 – 1.24 (m, 96H), 0.88 – 0.86 (m, 24H).

¹³C NMR (201 MHz, CDCl₃) δ(ppm) 152.46, 152.28, 149.70, 147.83, 146.71, 145.44, 127.49, 127.37, 124.25, 123.21, 117.41, 114.13, 111.78, 106.50, 74.73, 74.15, 74.01, 73.83, 73.73, 69.91, 69.85, 47.93, 47.85, 38.13, 31.87, 31.48, 30.09, 29.68, 29.63, 29.32, 26.85, 22.63, 14.05.

HRMS (ESI): calcd for C₁₂₀H₂₁₆ClN₂O₈S₃ [M+H]⁺ 1944.5404, found 1944.5391.

7.2 Synthesis of Disulfide-containing Donor-Acceptor CPs



polymer	A	R	x	M_n (kDa)	$\bar{D}$
PDSP-Bz			0.33	77.6	1.8
PDSP-BT			0.33	69.3	1.9

PDSP-Bz.

Physical Properties: Orange solid

^1H NMR (800 MHz, CDCl_3) δ (ppm) 7.74 (br, 4H), 4.17 (br, 8H), 3.60 (br, 8H), 3.32 + 3.16 (br, 8H), 1.59 (br, 4H), 1.31–1.23 (br, 96H), 0.87–0.85 (br, 24H).

GPC (THF as mobile phase): $M_n = 77.6$ kDa, $\bar{D} = 1.8$.

PDSP-BT.

Physical Properties: Purple solid

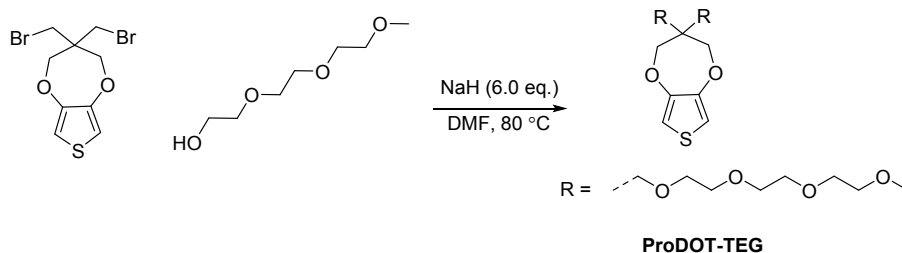
^1H NMR (800 MHz, CDCl_3) δ (ppm) 8.36 (br, 2H), 4.28 (br, 8H), 3.68–3.64 (br, 8H), 3.34 + 3.16 (br, 8H), 1.59 (br, 4H), 1.31–1.23 (br, 96H), 0.87–0.85 (br, 24H).

GPC (THF as mobile phase): $M_n = 69.3$ kDa, $\bar{D} = 1.9$.

8. Glucose Detection Enabled by Biotin-Functionalized CP (FP3) with Glucose Oxidase

8.1 Synthesis of Monomer and Blending Polymer

Synthesis of monomer **ProDOT-TEG**



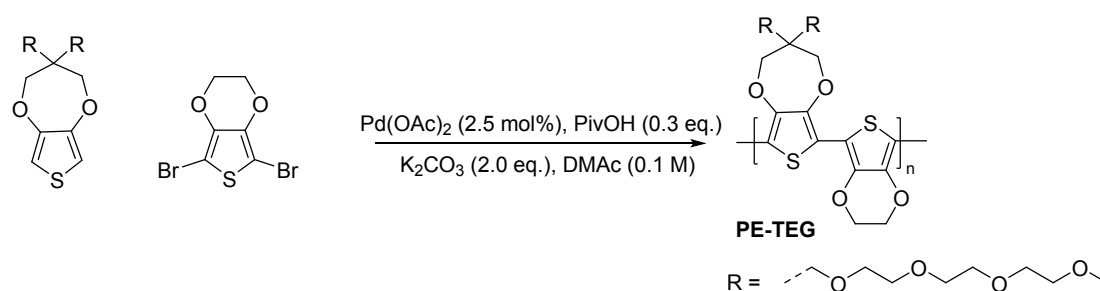
ProDOT-TEG. **S1** (5.00 g, 14.6 mmol), triethylene glycol monomethyl ether (7.20 g, 43.8 mmol), and sodium hydride (3.51 g, 60% dispersion in mineral oil) were added to 100 mL of dimethylformamide (DMF). The mixture was stirred under N_2 at room temperature for 30 min and then the temperature was raised to 80 °C. Then, the reaction was allowed to stir at this temperature for 12 h. The reaction mixture was cooled, extracted with DCM, and dried over Na_2SO_4 . After removal of solvent under reduced pressure, the residue was purified by silica chromatography (CH_2Cl_2 : acetone = 10:1) to give the product **ProDOT-TEG** (81% yield).

Physical Properties: Near-colorless oil.

^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 6.37 (s, 2H), 3.95 (d, J = 1.9 Hz, 4H), 3.59 – 3.53 (m, 20H), 3.50 – 3.46 (m, 8H), 3.31 (d, J = 1.9 Hz, 6H).

*Spectroscopic data are in agreement with previous literature*⁵.

Synthesis of **PE-TEG**



PE-TEG. **ProDOT-TEG** (1.0 eq., 500 mg, 0.98 mmol), dibromo-EDOT (1.0 eq., 295 mg, 0.98 mmol), K_2CO_3 (2.6 eq., 353 mg, 2.56 mmol), PivOH (0.3 eq., 30 mg, 0.29 mmol) and $Pd(OAc)_2$ (0.025 eq., 5.52 mg, 0.025 mmol) are added to a Schlenk tube. The tube is kept under vacuum for about 15 minutes and then purged with N_2 . The above process is repeated for three cycles. Then, nitrogen degassed solvent DMAc is added into the tube and heated to 120 °C for 12 hours under nitrogen. Transfer the hot reaction mixture to cold CH_3OH while stirring. Filter to get solid. The solid is dissolved in chloroform and washed with 10% brine. The organic phase is concentrated and

precipitated with CH₃OH. Filter and dry to get the desired polymer (310 mg). Yield 98%.

Physical Properties: Blue solid

¹H NMR (400 MHz, CDCl₃) δ(ppm) 4.41 (–OCH₂–), 4.19 (–OCH₂–), 3.65 (–OCH₂–), 3.51 (–OCH₂–), 3.36 – 3.31 (–OCH₃).

Spectroscopic data are in agreement with previous literature^{6–7}.

8.2 Glucose Detection

Fabrication of organic electrochemical transistor devices

The silicon substrates (Dow Corning) were cleaned by sonicating in deionized water, ethanol, and acetone for 10 min sequentially and dried via a nitrogen gun. The patterned Ti (20 nm)–Au (50 nm) source, drain and gate electrodes were thermally deposited on the substrates with the assistance of a shadow mask at a pressure of 1×10^{-6} Pa, achieving channel length and width of 100 μm and 1500 μm, respectively. Given the difference in solubility, **PE-TEG** and **FP3** were dissolved in THF and chloroform, respectively, both at a concentration of 6 mg/mL. The two stock solutions were then mixed at varying weight ratios and the obtained polymer solution was spin-coated at 1,000 rpm for 50 s. The film was annealed at 50 °C for 30 min in an N₂ environment. Thereafter, the OECT channels were covered with patterned polydimethylsiloxane (PDMS) masks for oxygen plasma treatment (PE25, Plasma Etch, Inc.) for 25 min, during which time the area under the PDMS was maintained while the rest was removed. A PDMS well that covered the gate and channel area was used to confine the electrolyte. PBS solution as the electrolyte was dropped into the PDMS well. The gate electrode was Ag/AgCl wire (Warner Instruments), which was immersed in the electrolyte. The electrical measurements were performed on Keysight B2902 under normal atmospheric conditions.

Enzyme immobilization and glucose sensing

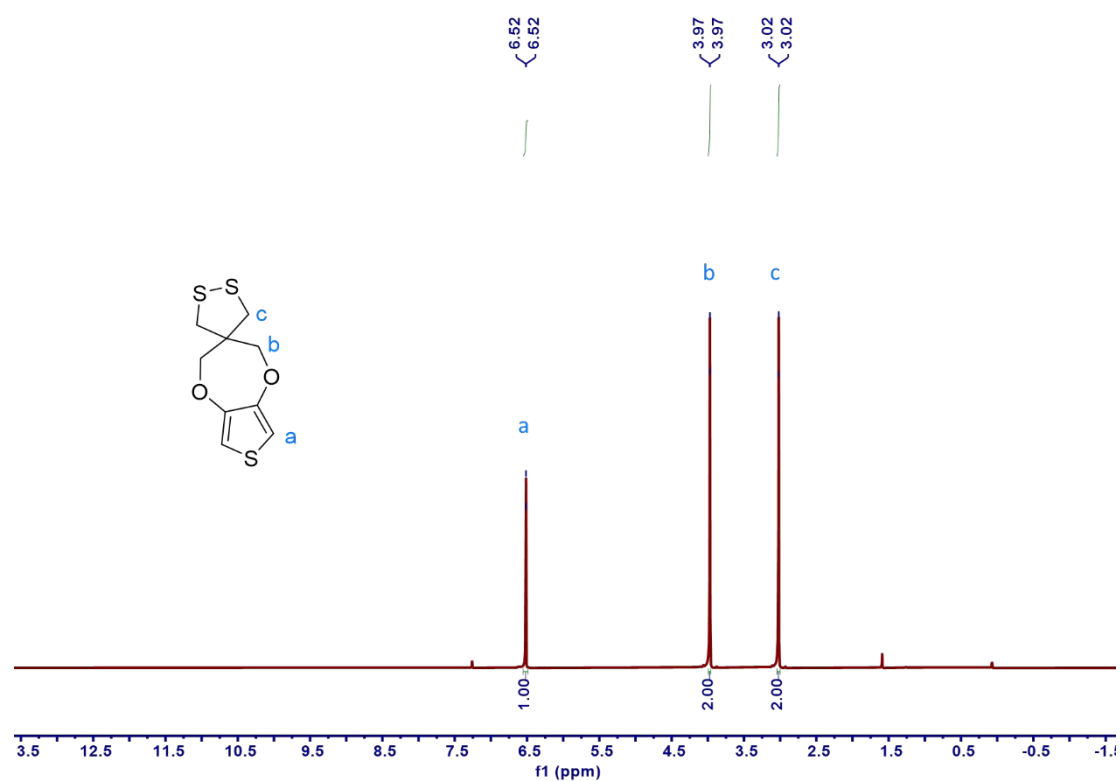
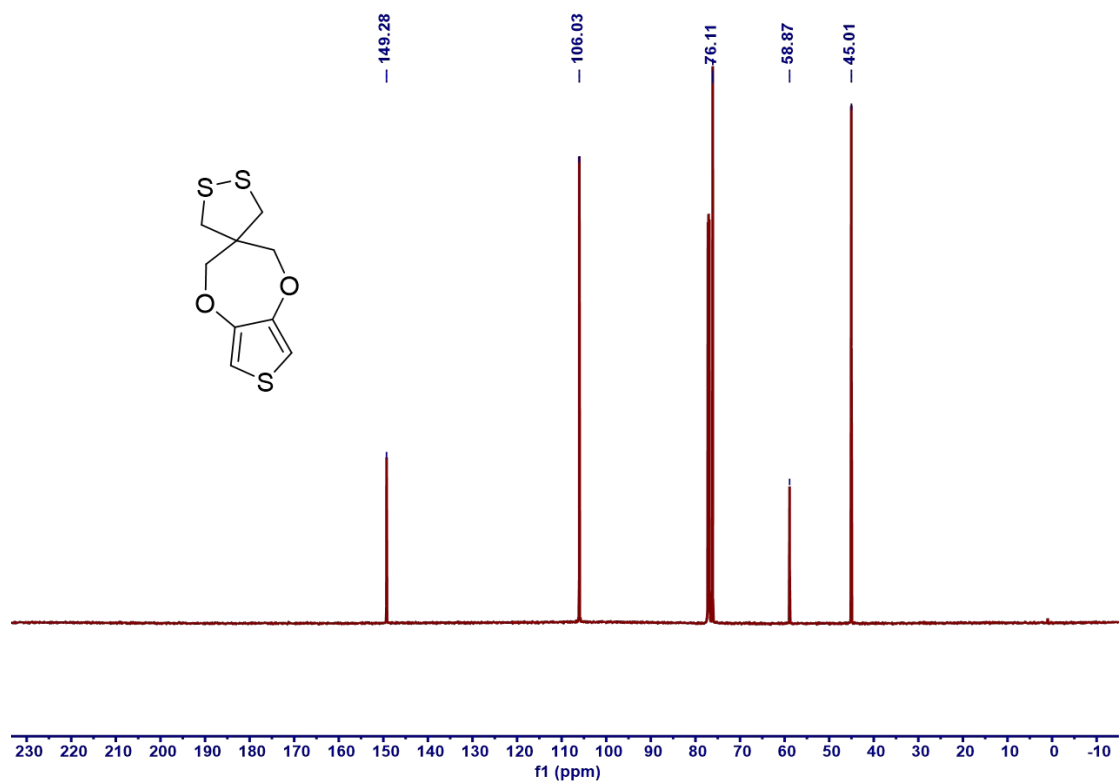
A solution containing avidin-glucose oxidase (GOx) was prepared by dissolving GOx in 0.1 M PBS with a pH of 7.4. The resulting GOx solution had a concentration of 0.4 mg/mL and was stored at a 4 °C. The GOx enzyme was then immobilized onto the OECT channel. This was achieved by applying 20 μL of the GOx solution onto the channel area, followed by a 2-hour incubation period. To ensure proper attachment, the channel was rinsed thoroughly with PBS three times to eliminate any loosely bound

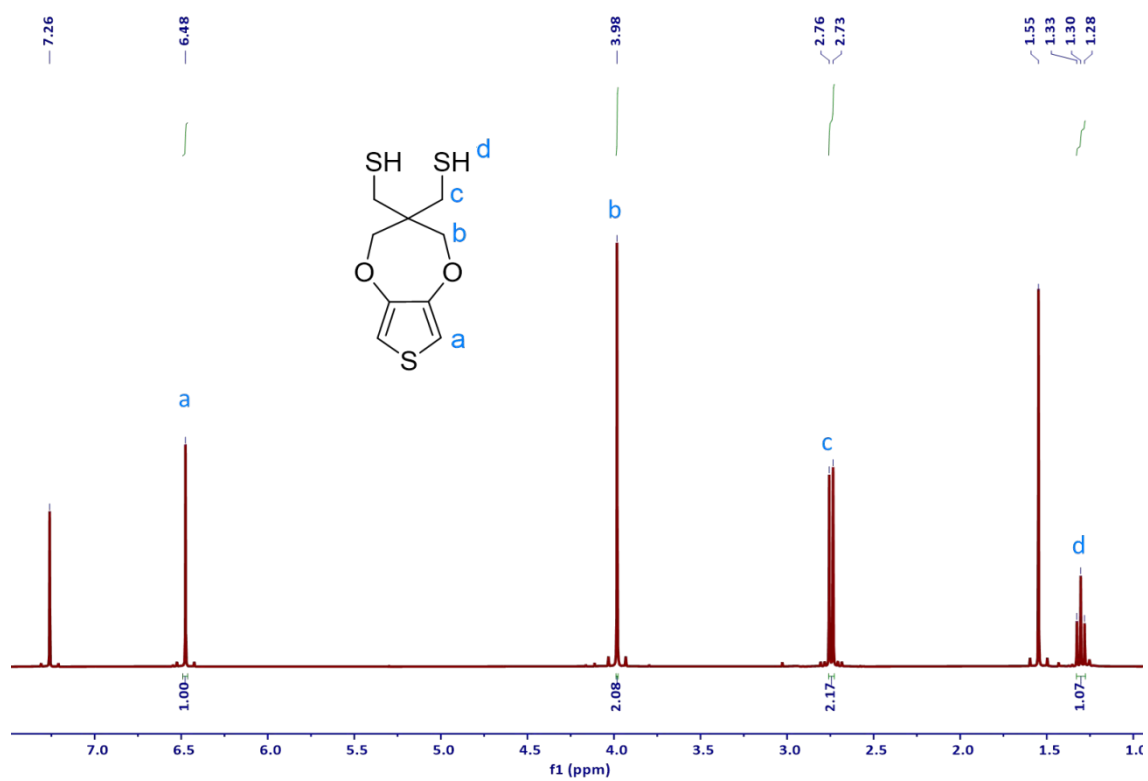
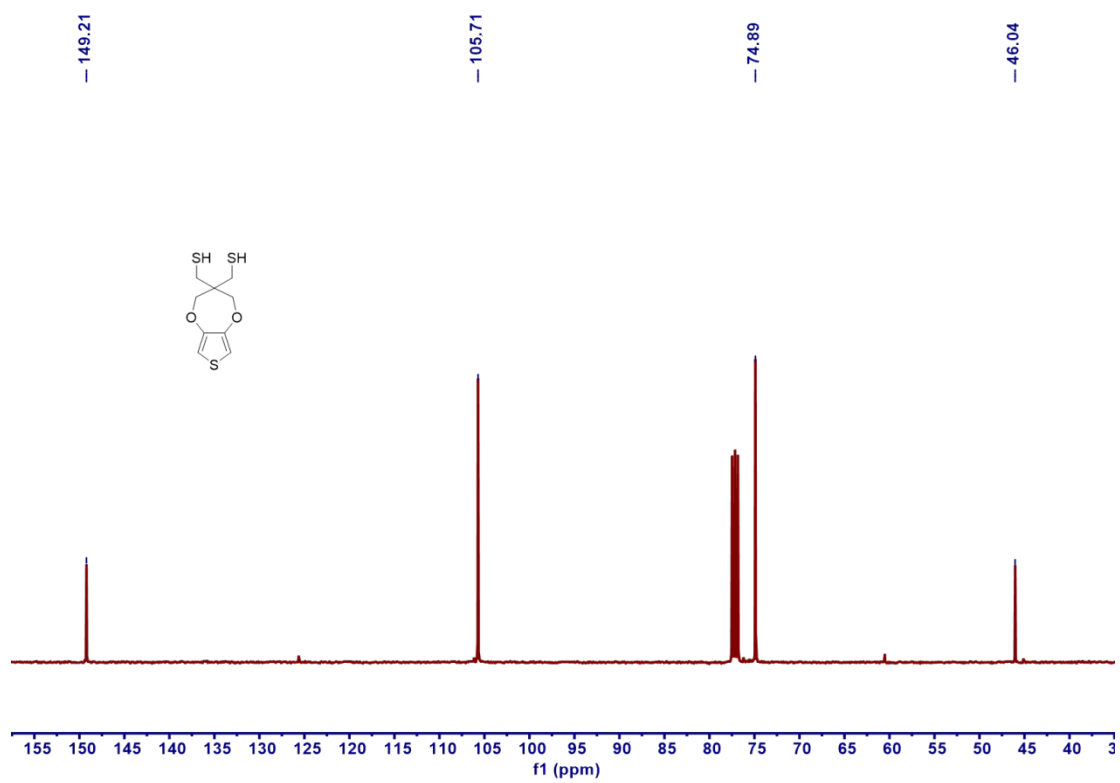
GOx molecules. Glucose was prepared in stock solutions using PBS as the solvent. The current-voltage characteristics of the devices were measured using a Keysight B2902 instrument under normal atmospheric conditions. Once a stable baseline drain current was established, glucose stock solution (4 mL each time) was introduced into the electrolyte in a controlled manner. Throughout the experiments, the volume of the electrolyte solution remained constant at 0.4 mL. The changes in drain current, occurring over time, in response to successive additions of glucose solutions with increasing concentrations were then observed and recorded.

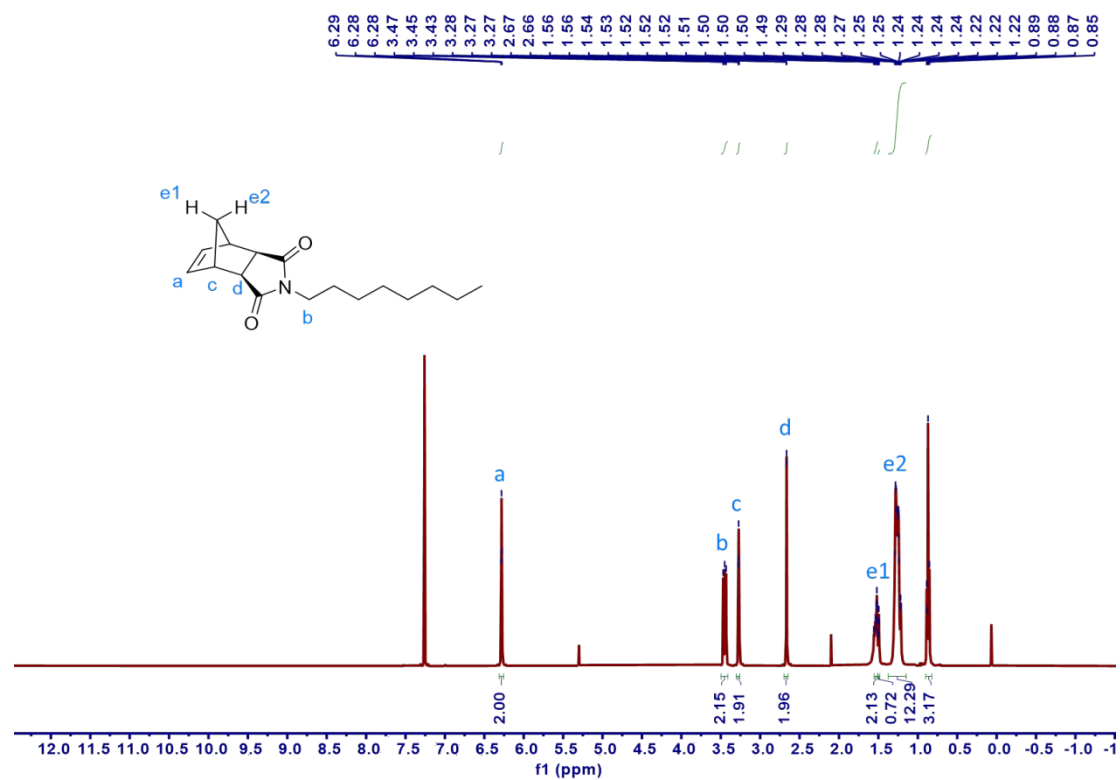
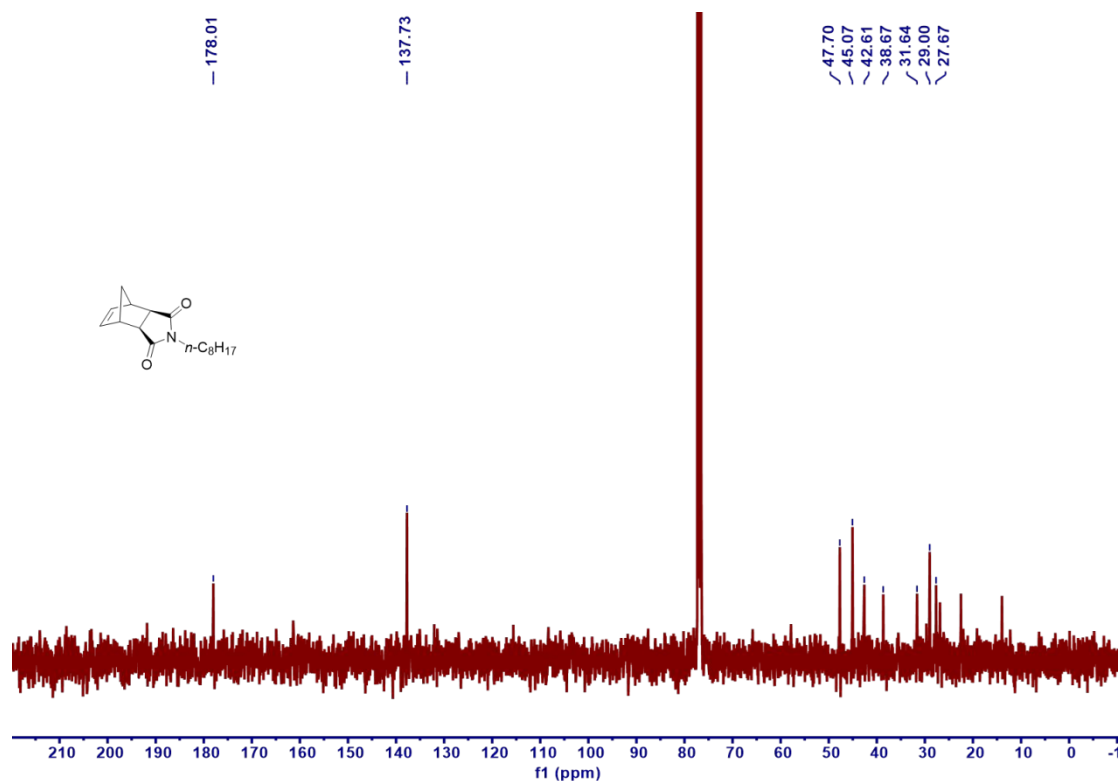
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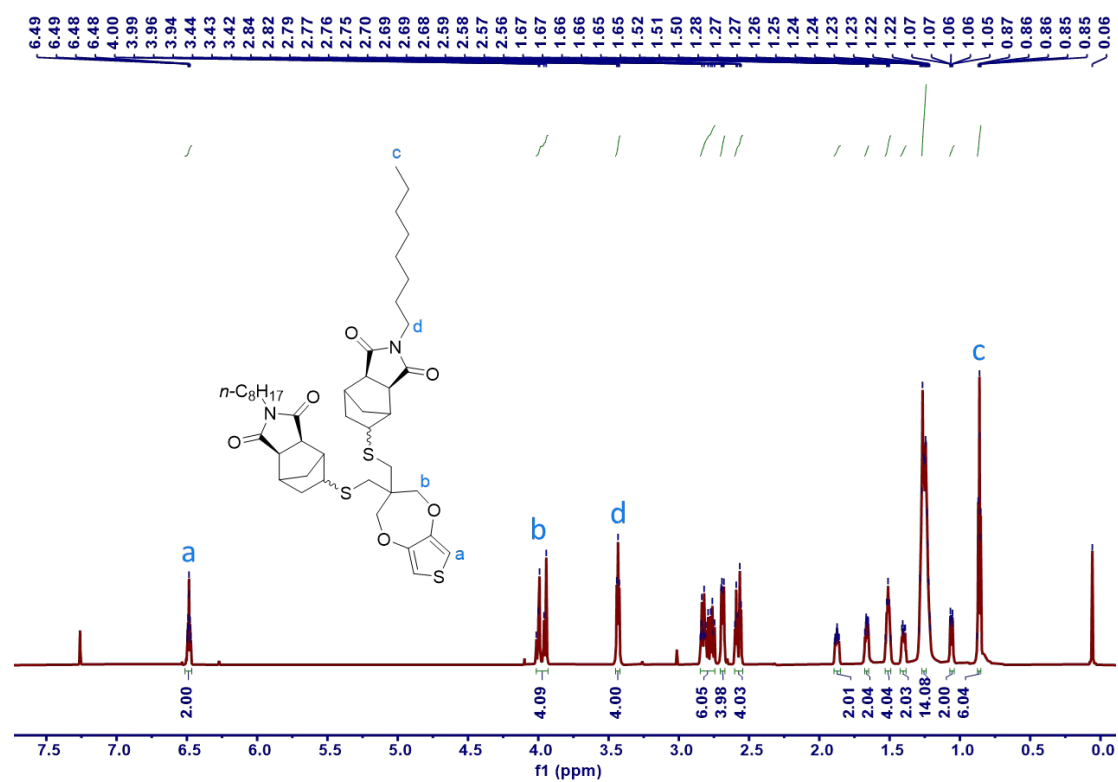
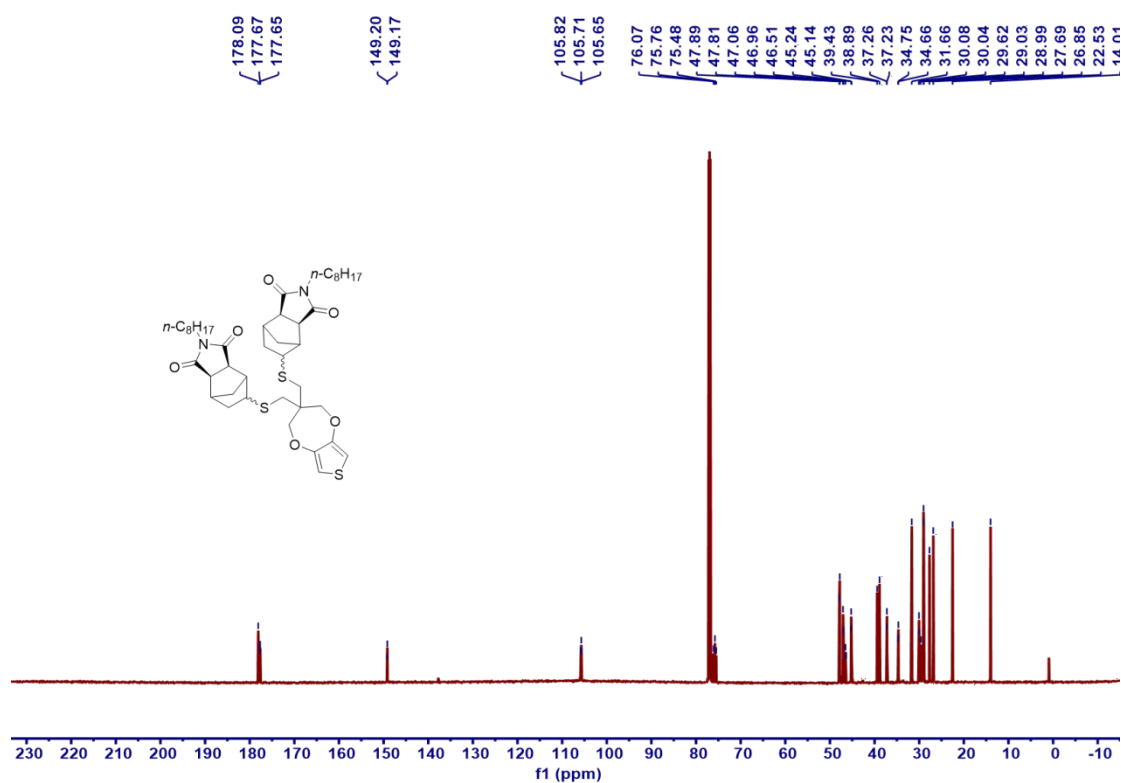
1. Egunlusi, A. O.; Malan, S. F.; Joubert, J. Synthesis of 4-oxatricyclo[5.2.1.0^{2,6}]dec-8-ene-3,5-dione derivatives as lead scaffolds for neuroprotective agents. *Arkivoc* **2020**, 28–38 (2020).
2. Ke, Z.; You, L.; Tran, D. T.; He, J.; Perera, K.; Gumyusenge, A.; Mei, J. Thermally stable and solvent-resistant conductive polymer composites with cross-linked siloxane network. *ACS Appl. Polym. Mater.* **3**, 1537–1543 (2021).
3. Glass, R. S.; Petsom, A.; Wilson, G. S.; Martinez, R.; Juaristi, E. Electrosynthesis of 1, 2-dithiolane 1-oxides from substituted 1, 3-dithianes. *J. Org. Chem.* **51**, 4337–4342 (1986).
4. Ahmed, M.; Tran, D. T.; Putziger, J.; Ke, Z.; Abtahi, A.; Wang, Z.; Chen, K.; Lang, K.; Mei, J. Tetracyanocyclopentadienide-based stable poly(aromatic) anions. *ACS Macro. Lett.* **11**, 72–77 (2022).
5. Luo, X.; Shen, H.; Perera, K.; Tran, D. T.; Boudouris, B. W.; Mei, J. Designing donor–acceptor copolymers for stable and high-performance organic electrochemical transistors. *ACS Macro. Lett.* **10**, 1061–1067 (2021).
6. Savagian, L. R.; Österholm, A. M.; Ponder Jr., J. F.; Barth, K. J.; Rivnay, J.; Reynolds, J. R. Balancing charge storage and mobility in an oligo(ether) functionalized dioxothiophene copolymer for organic- and aqueous- based electrochemical devices and transistors. *Adv. Mater.* **30**, 1804647 (2018).
7. Jones, A. L.; De Keersmaecker, M.; Savagian, L. R.; DiTullio, B. T.; Pelse, I.; Reynolds, J. R. Branched oligo(ether) side chains: A path to enhanced processability and elevated conductivity for polymeric semiconductors. *Adv. Funct. Mater.* **31**, 2102688 (2021).

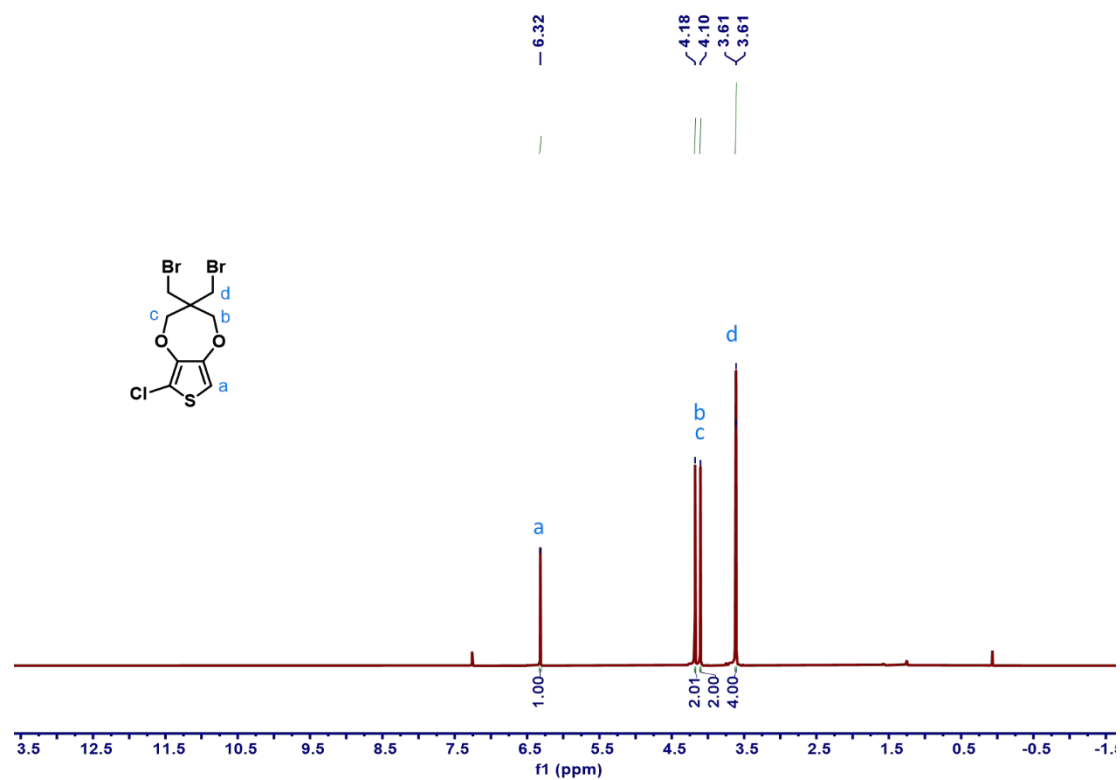
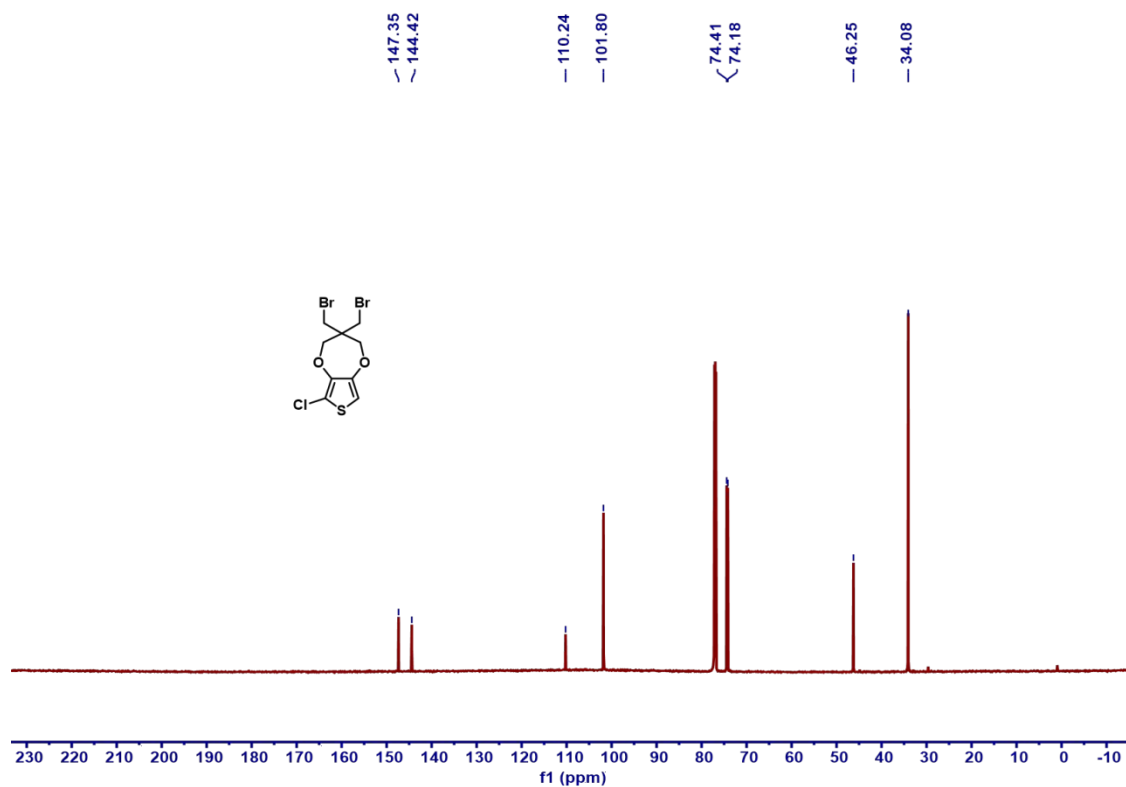
NMR data

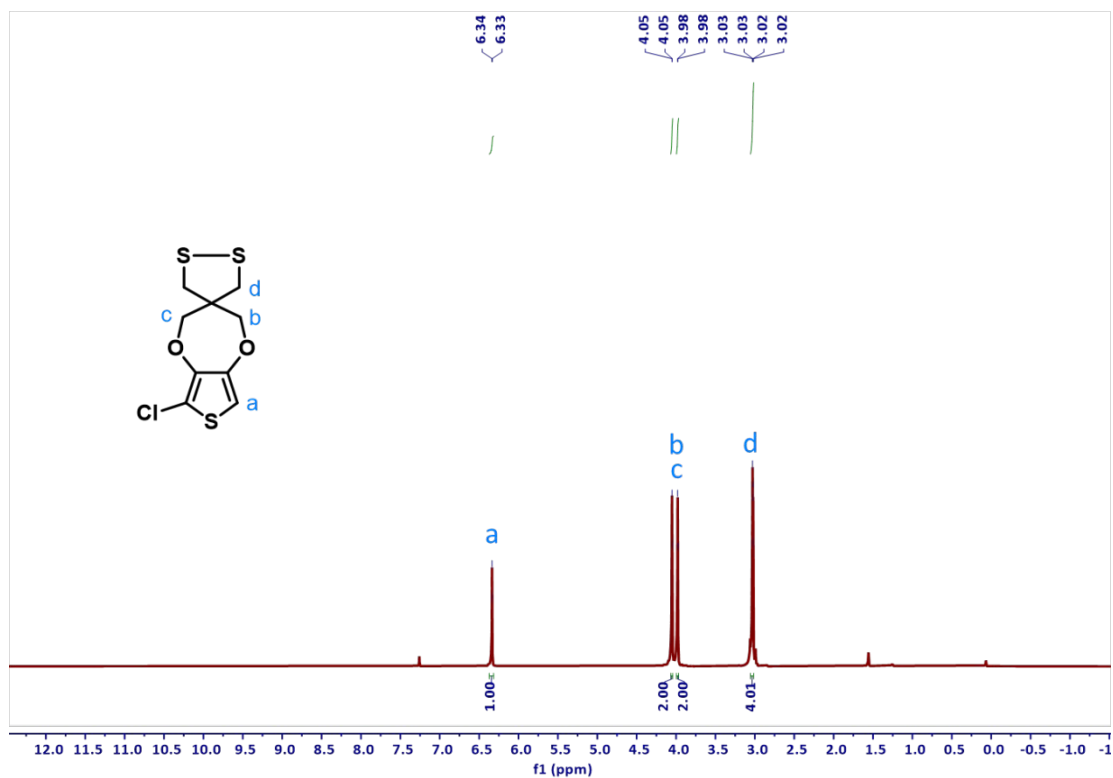
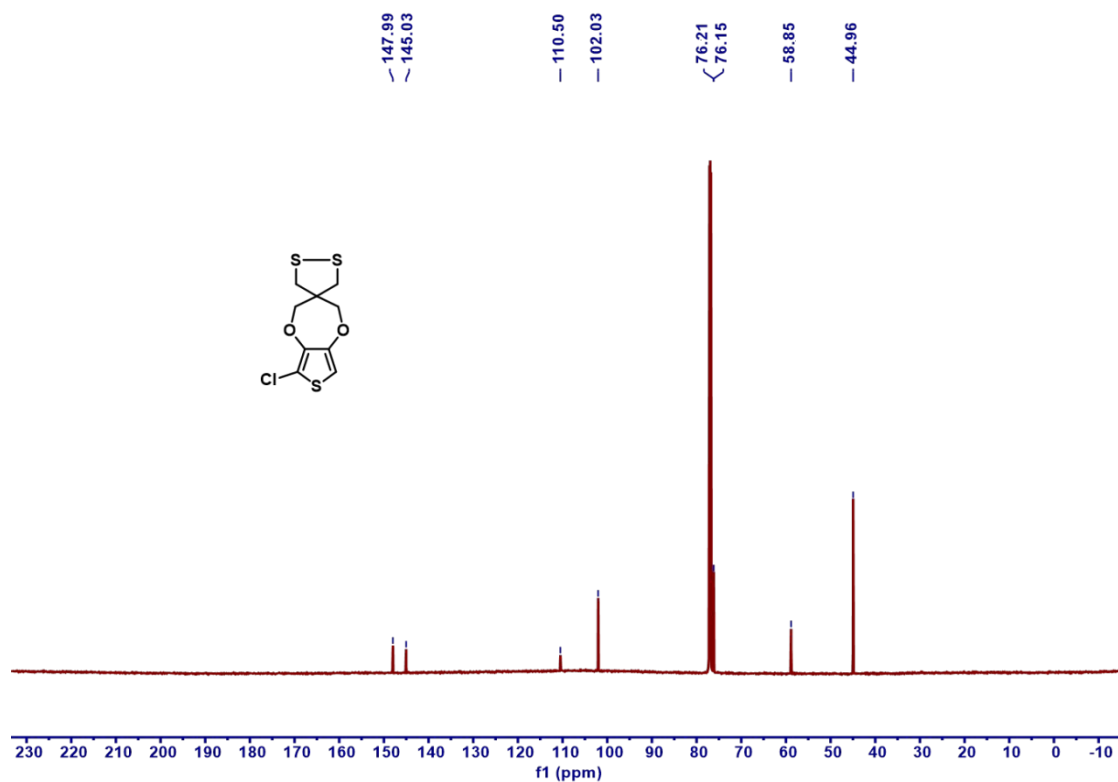


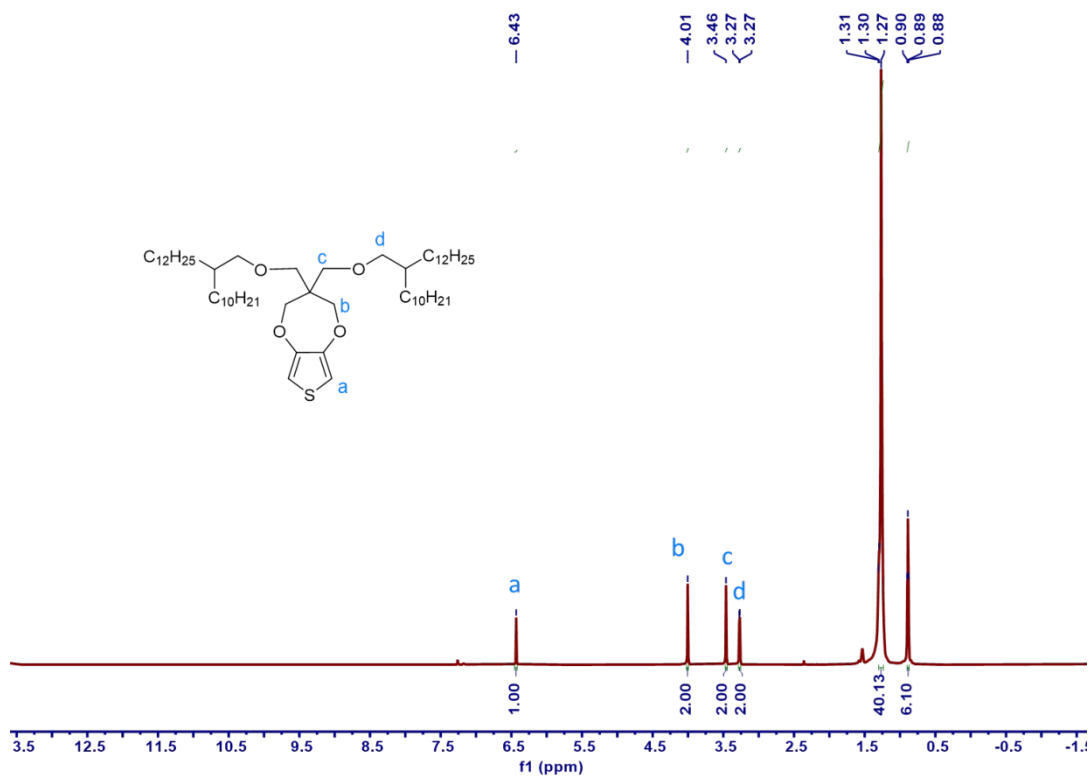
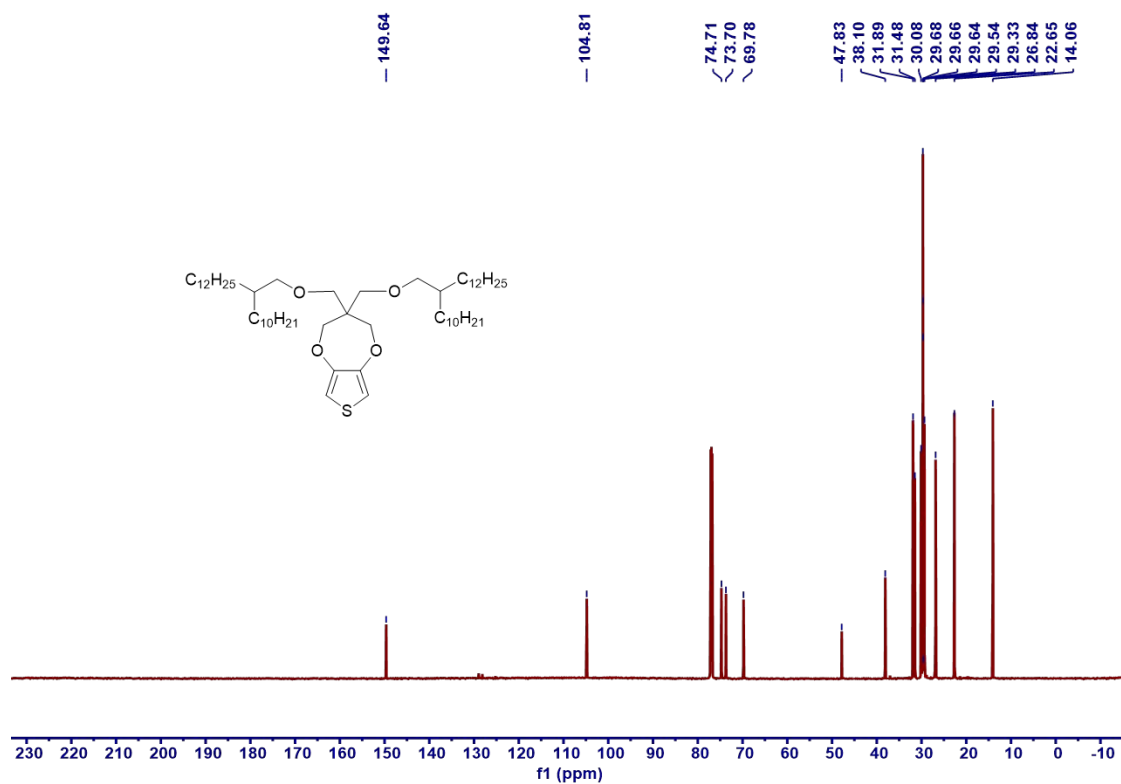


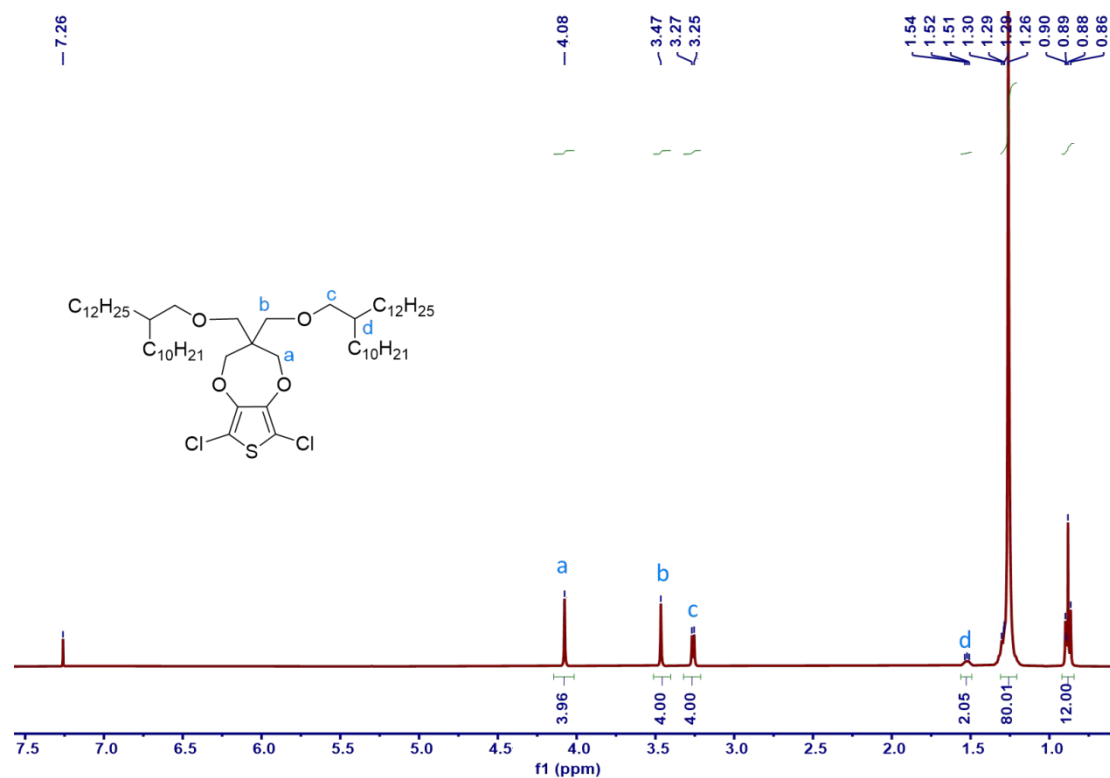
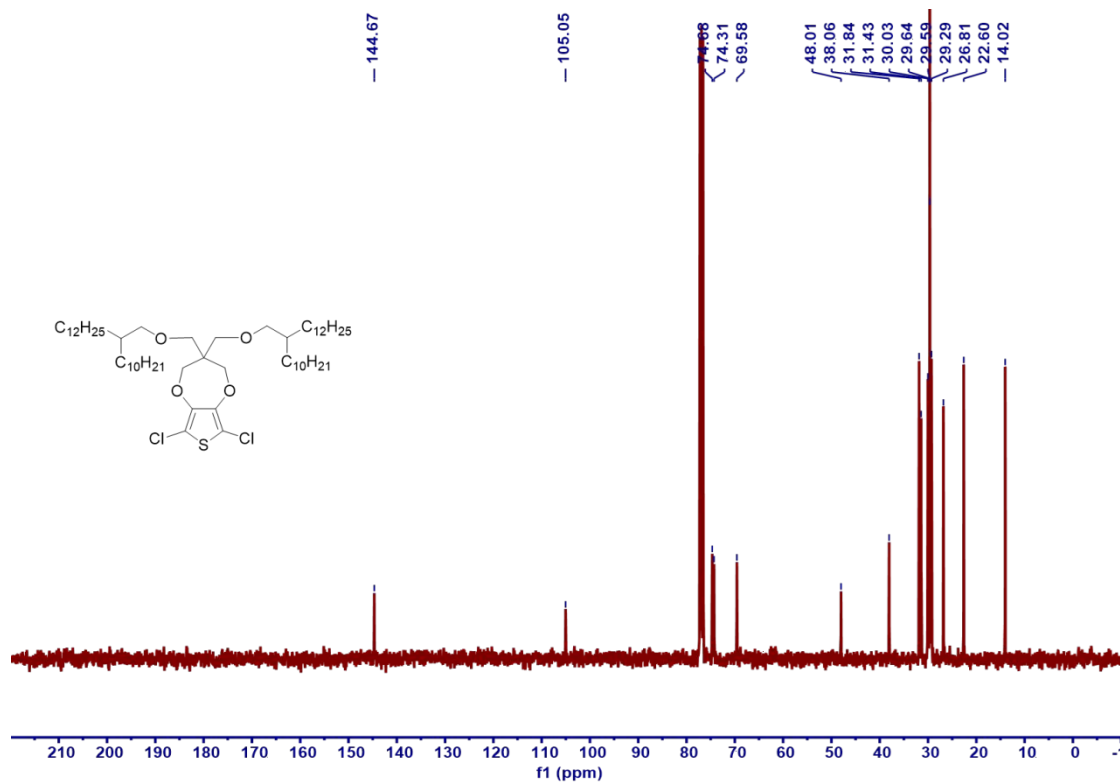


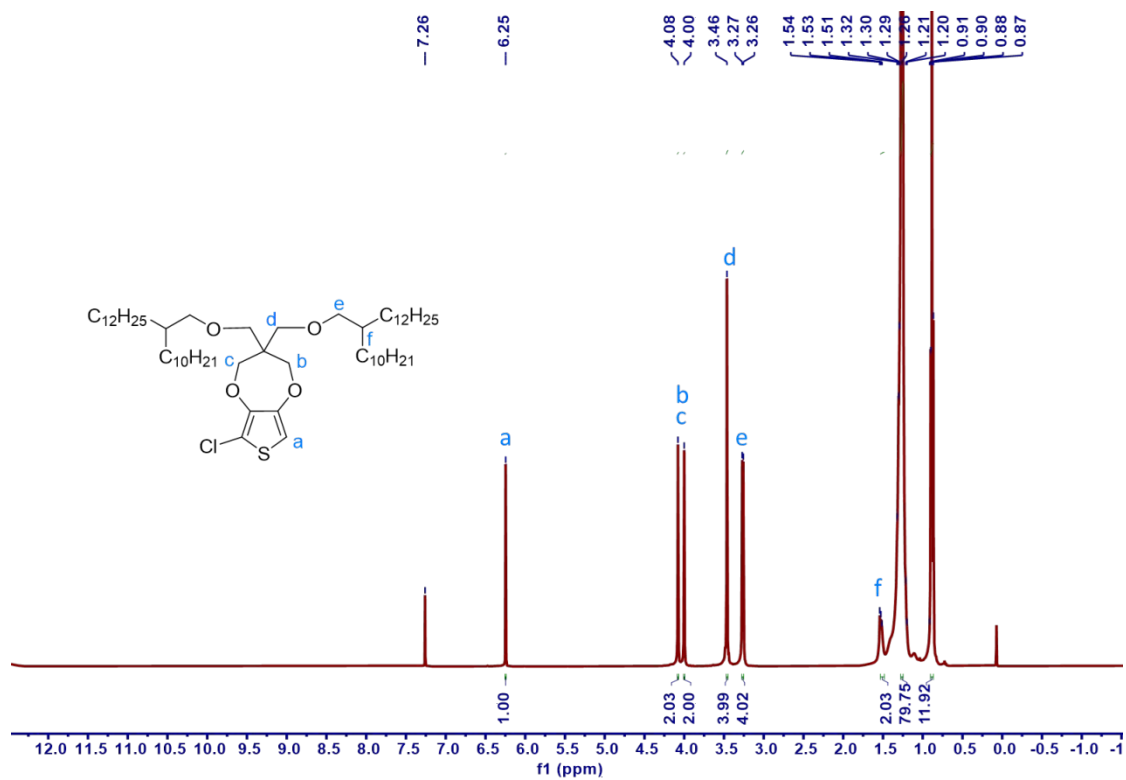
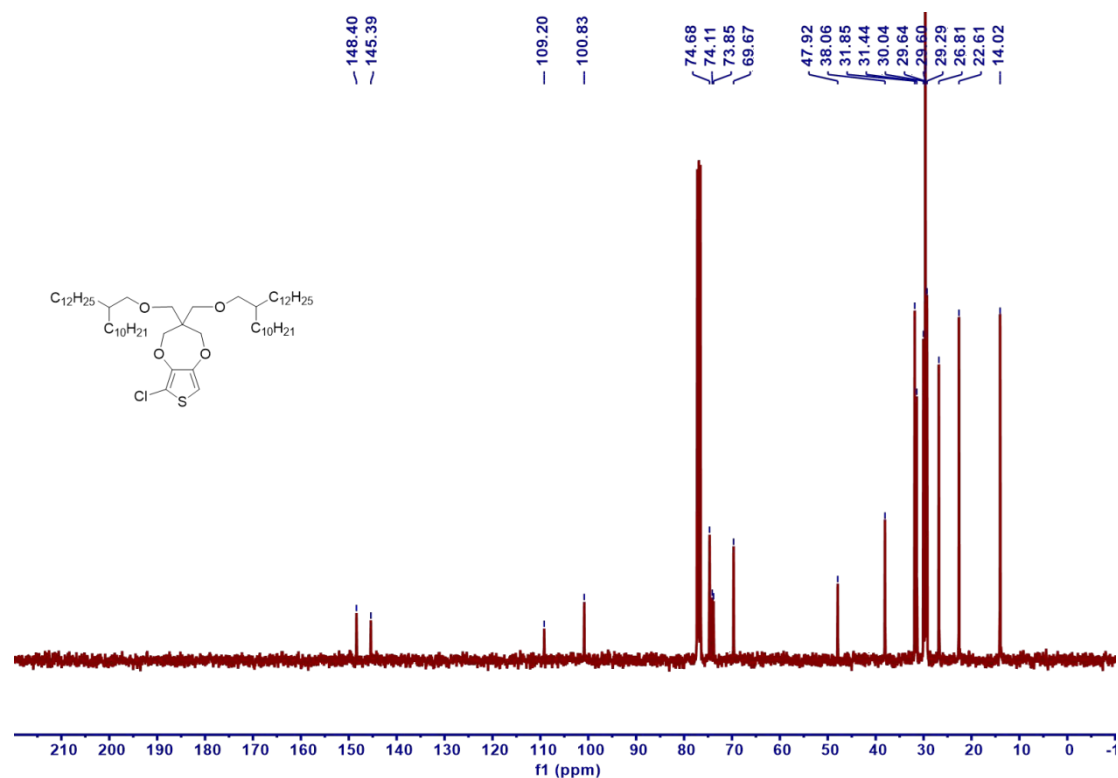


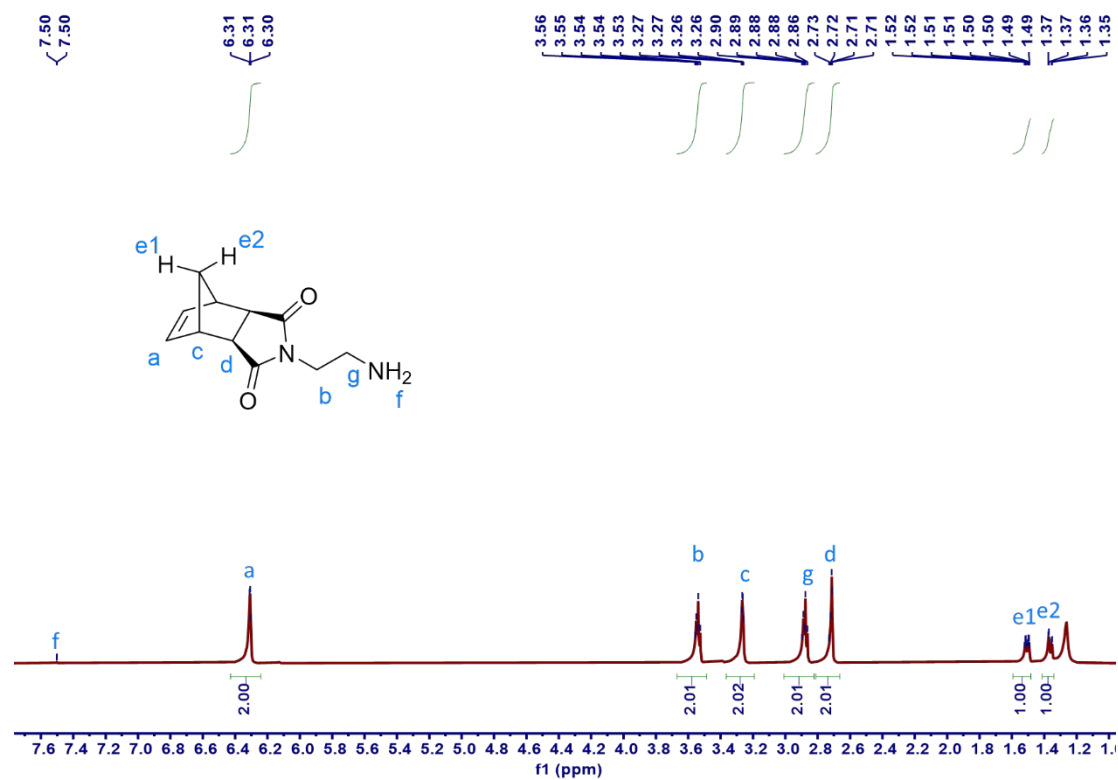
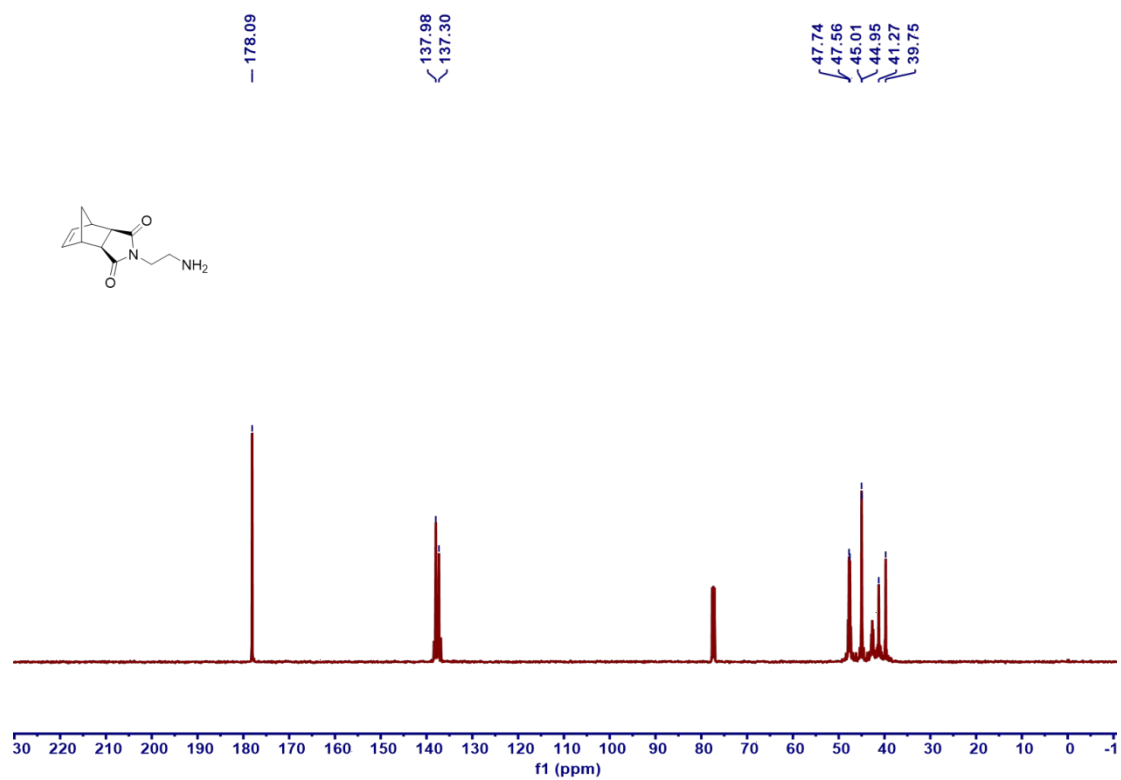


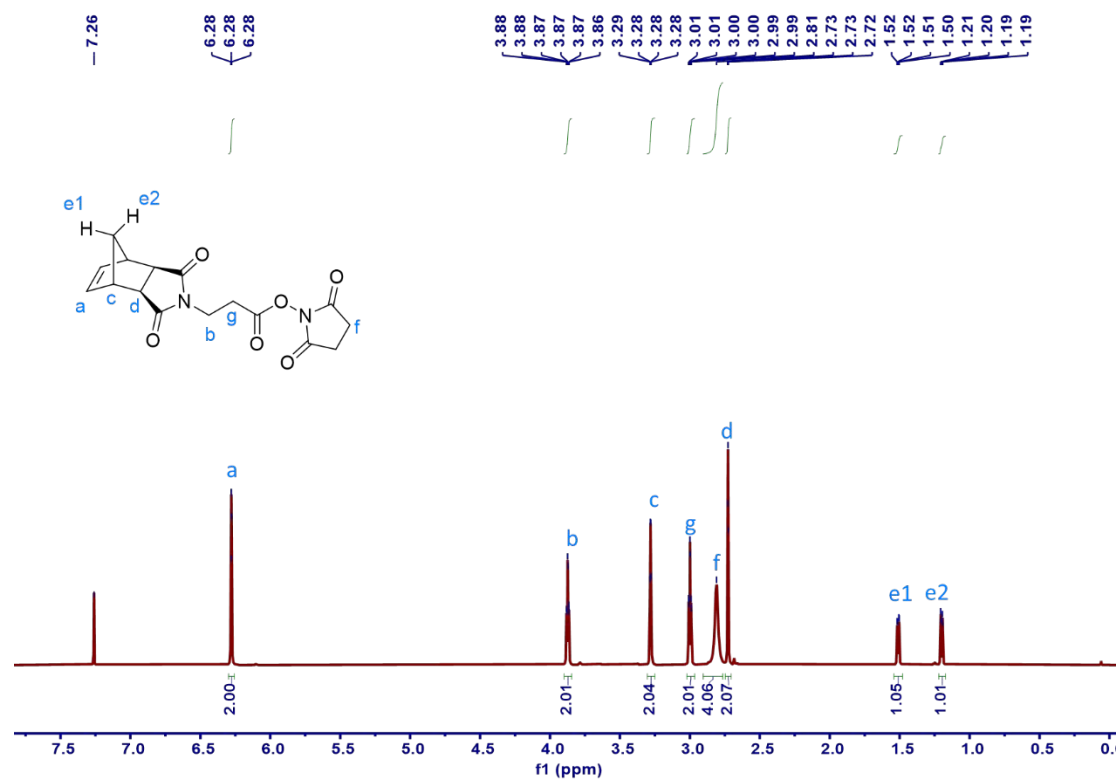
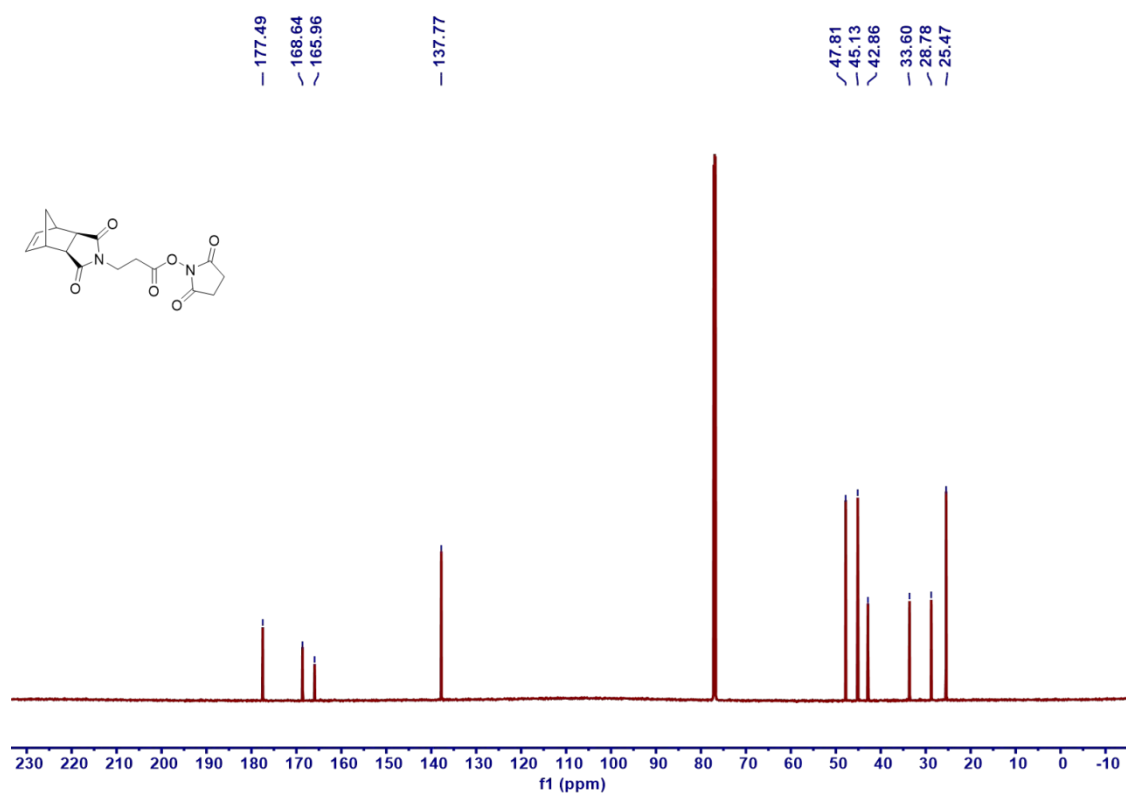


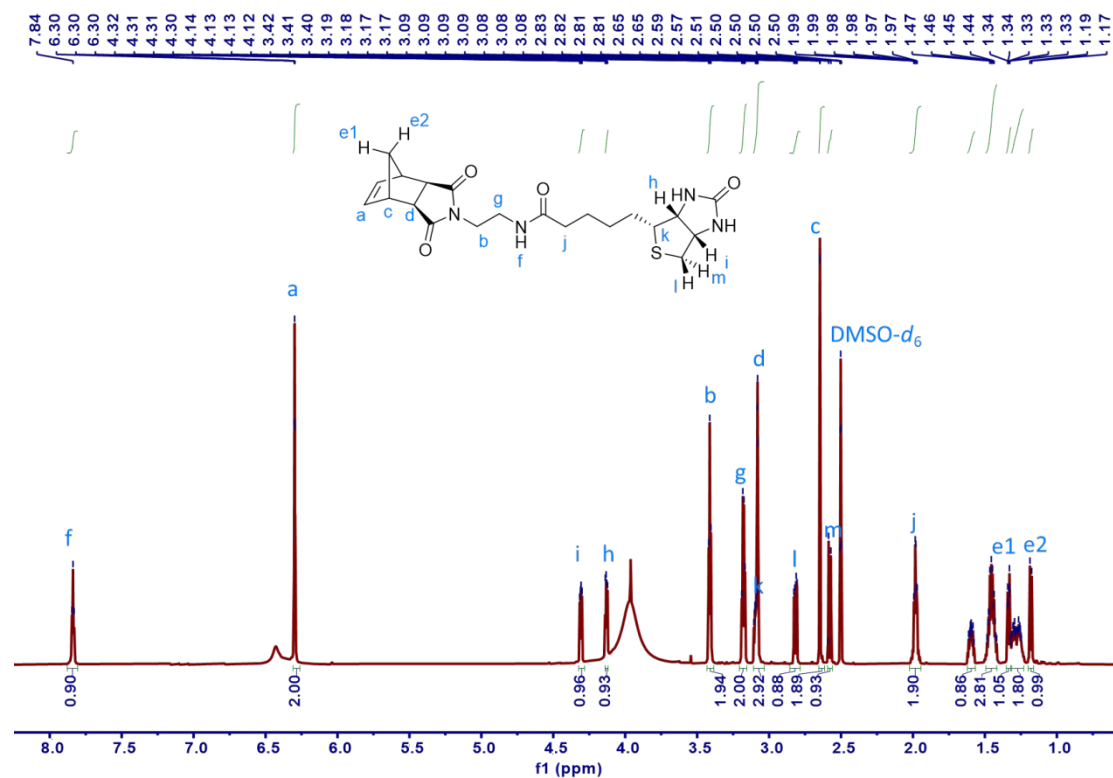
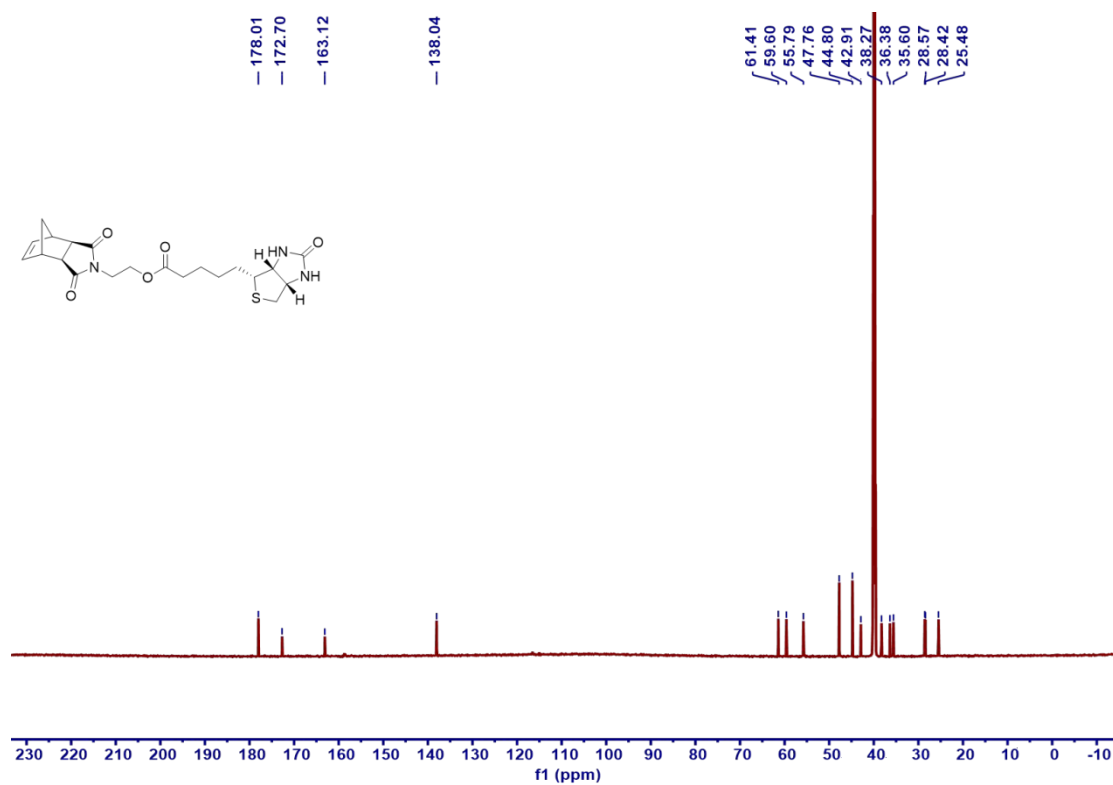


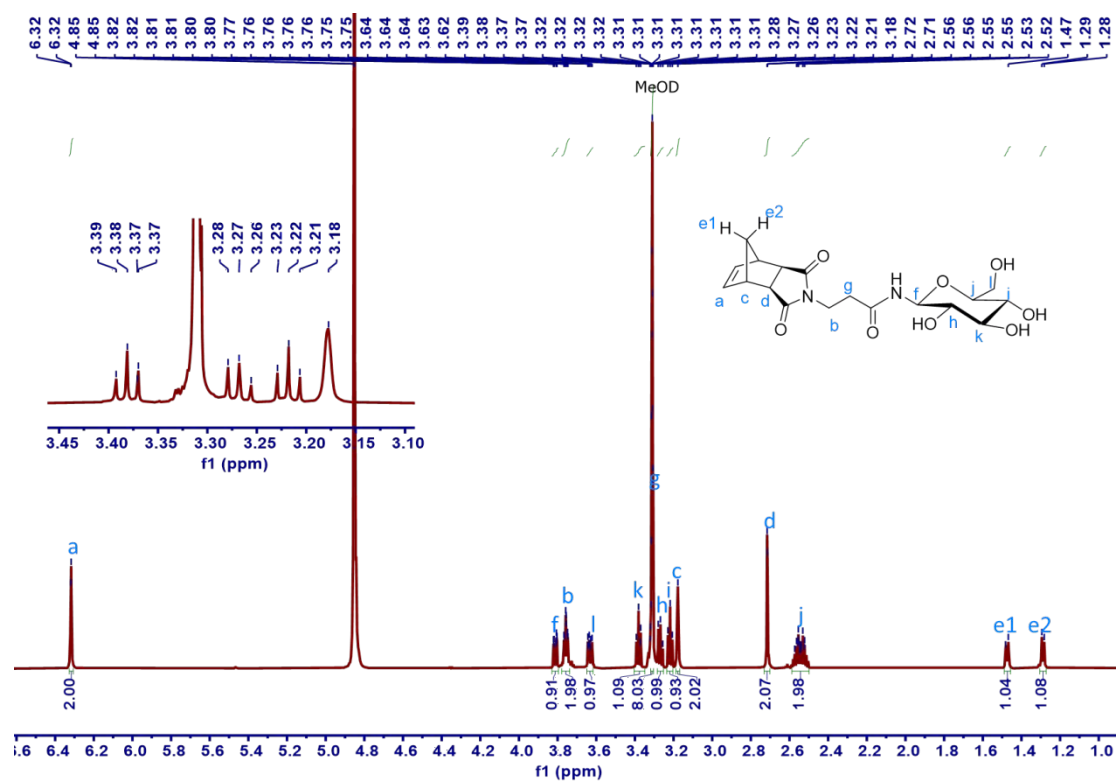
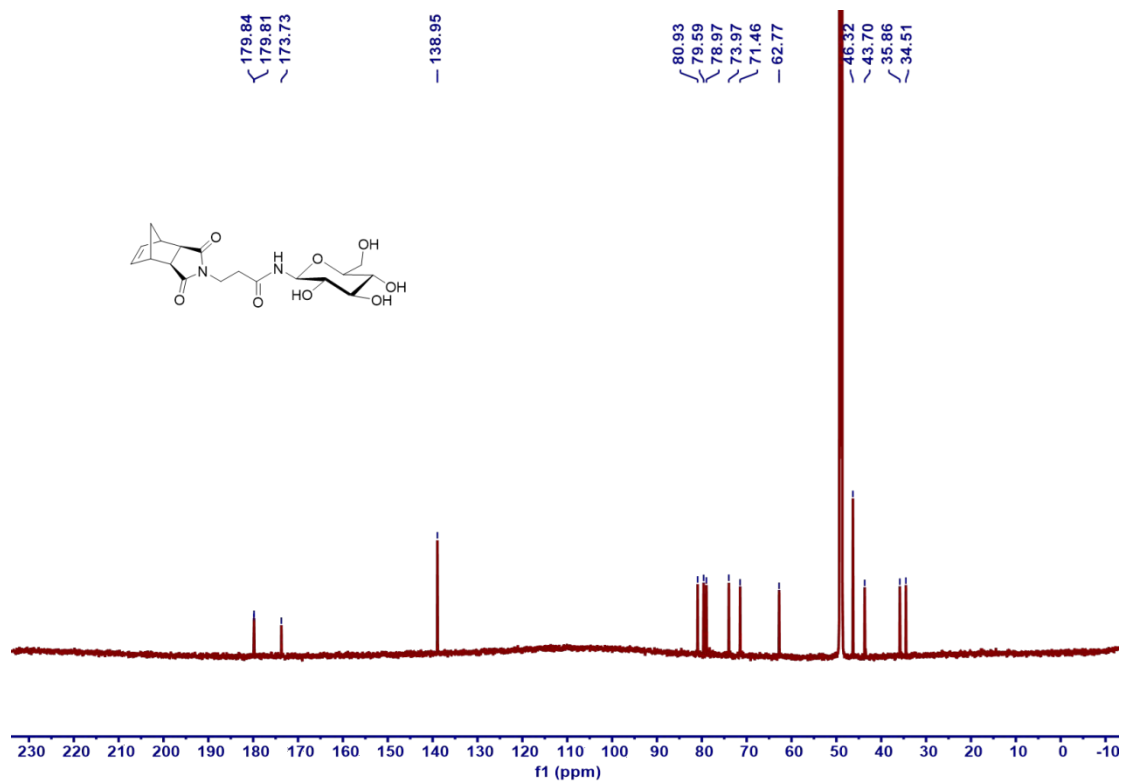


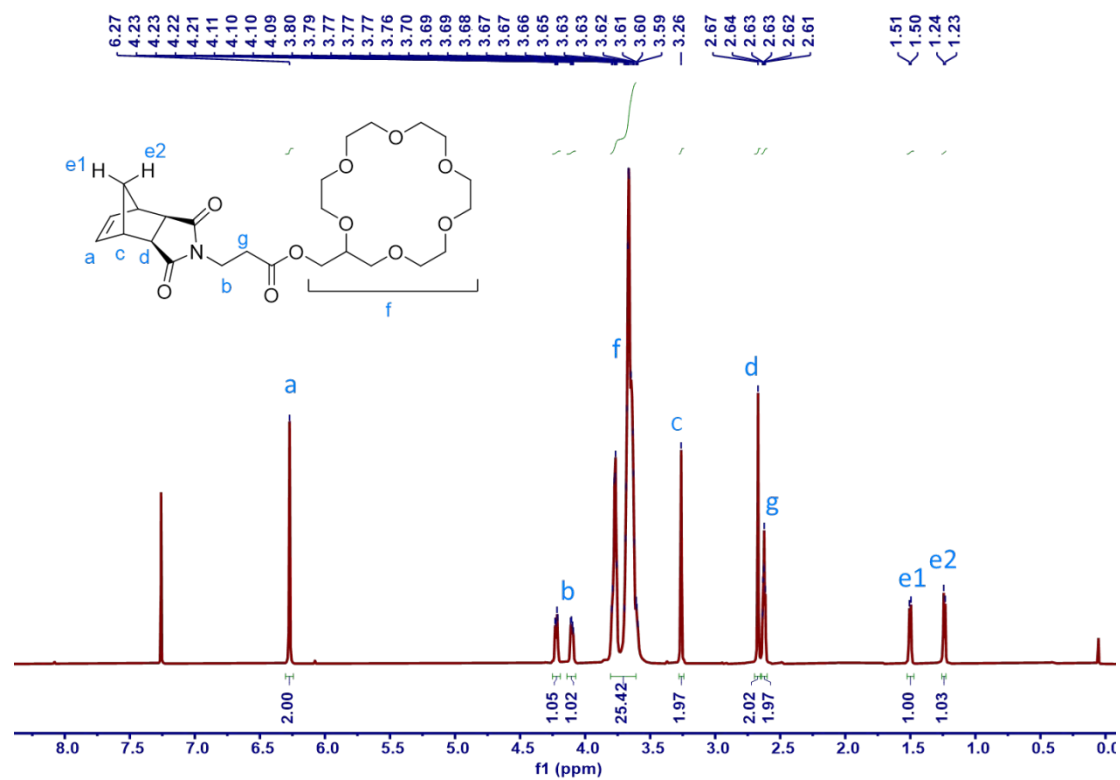
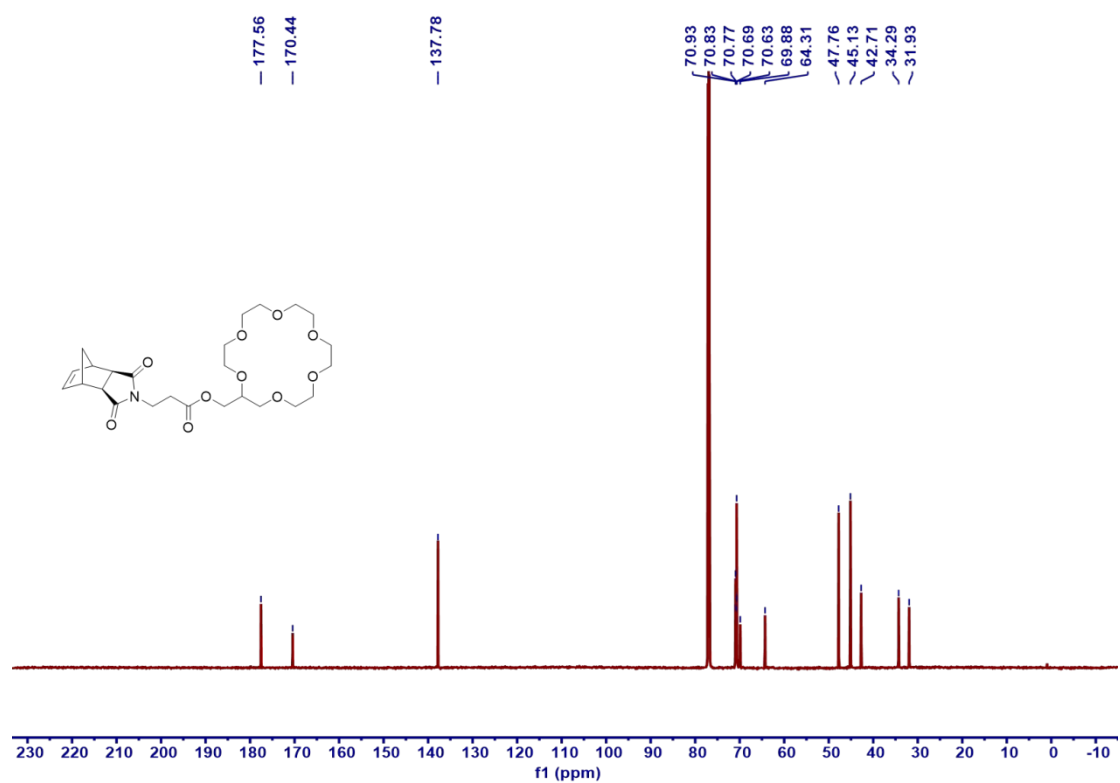


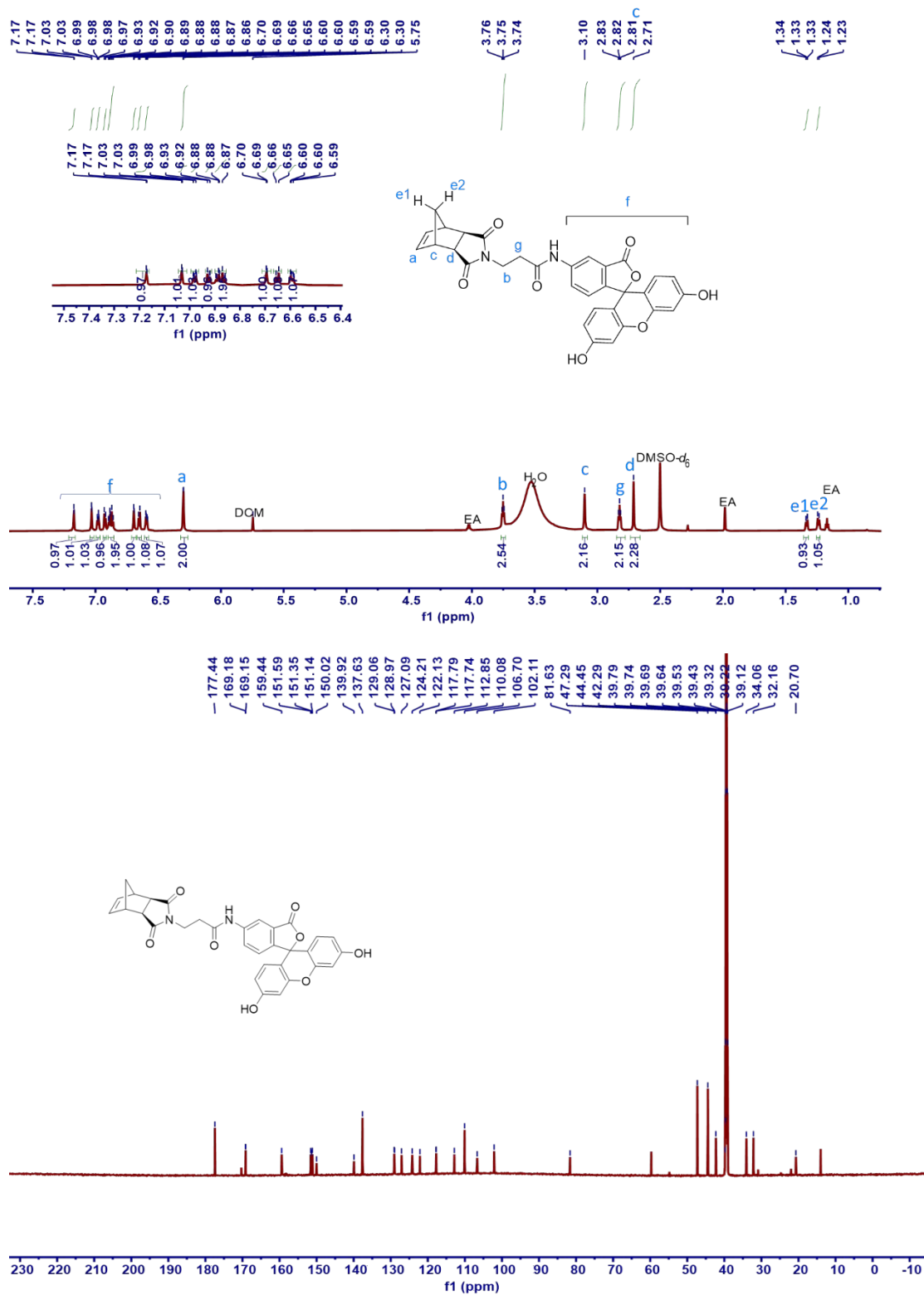


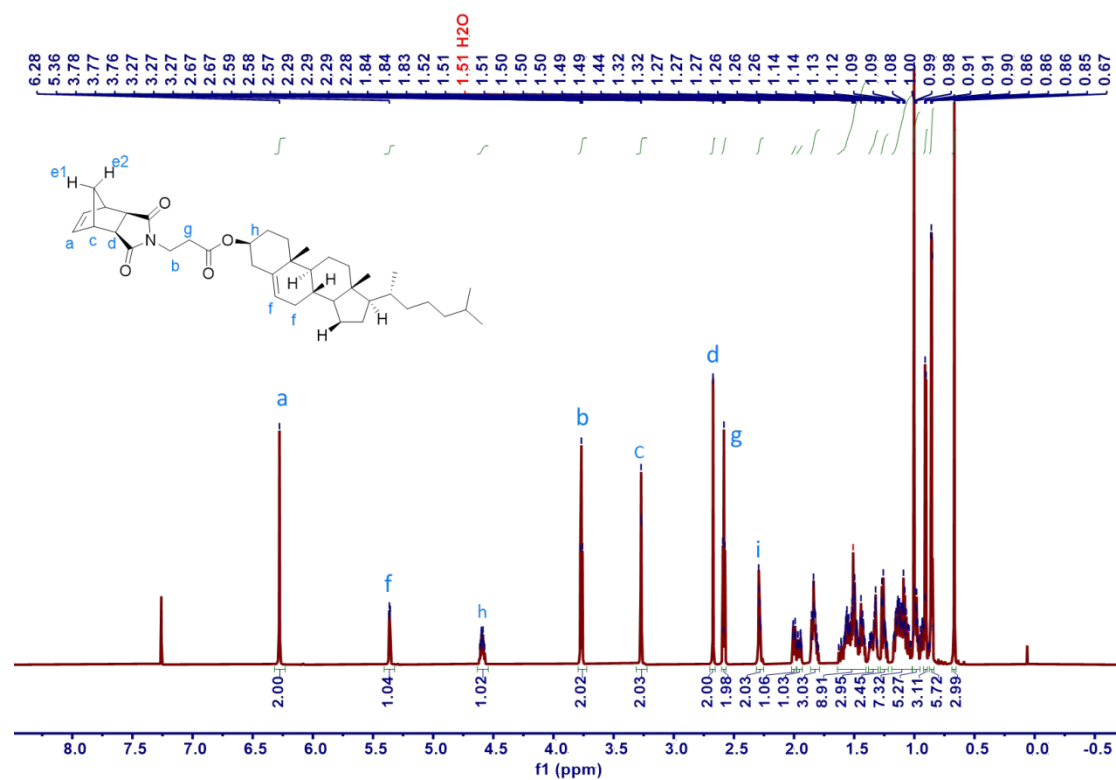
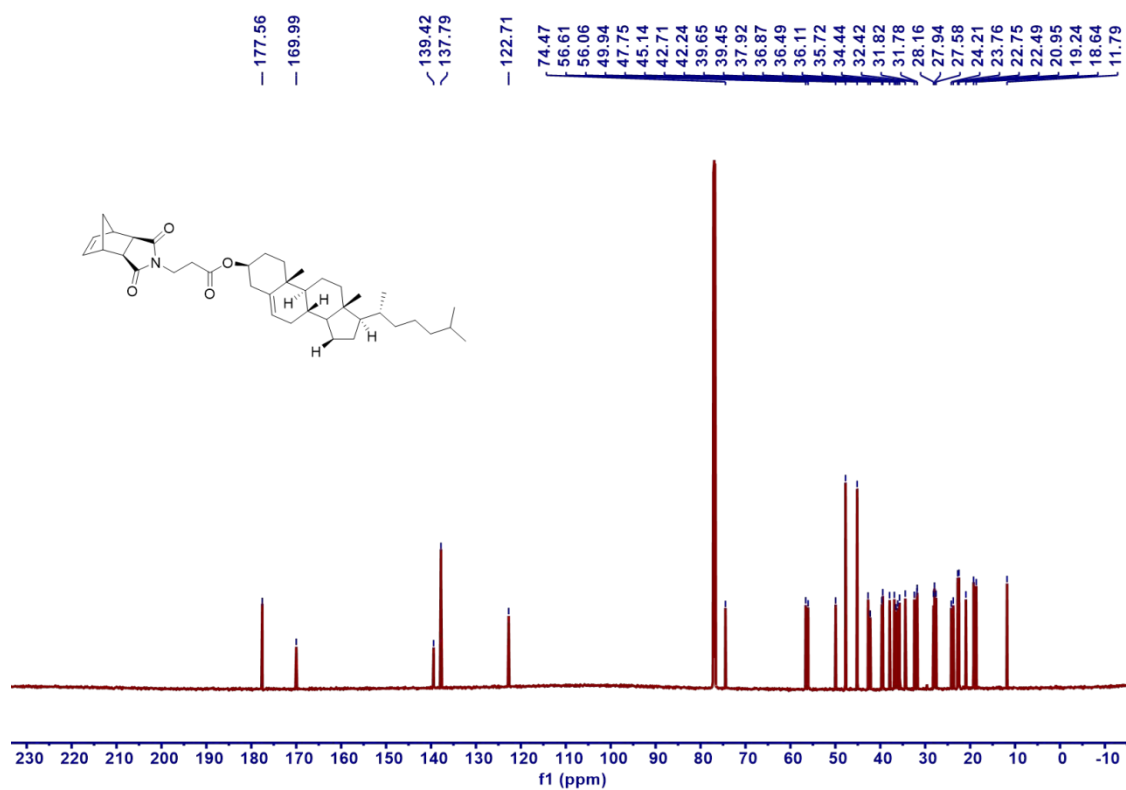


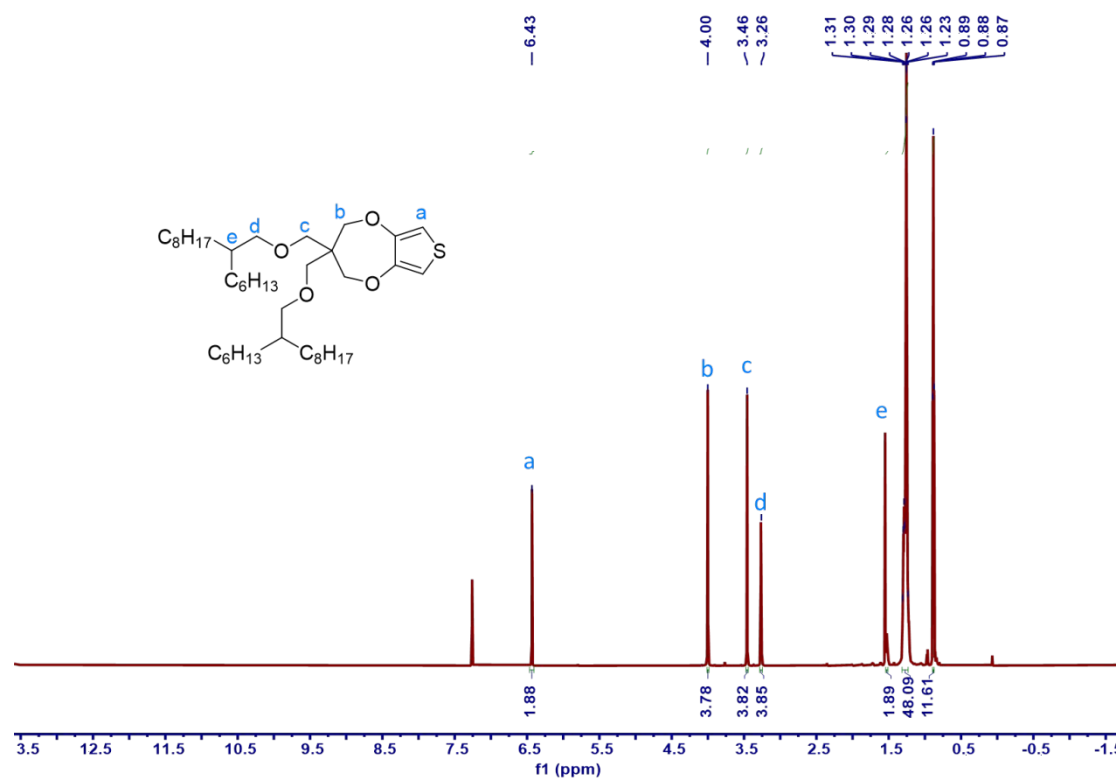
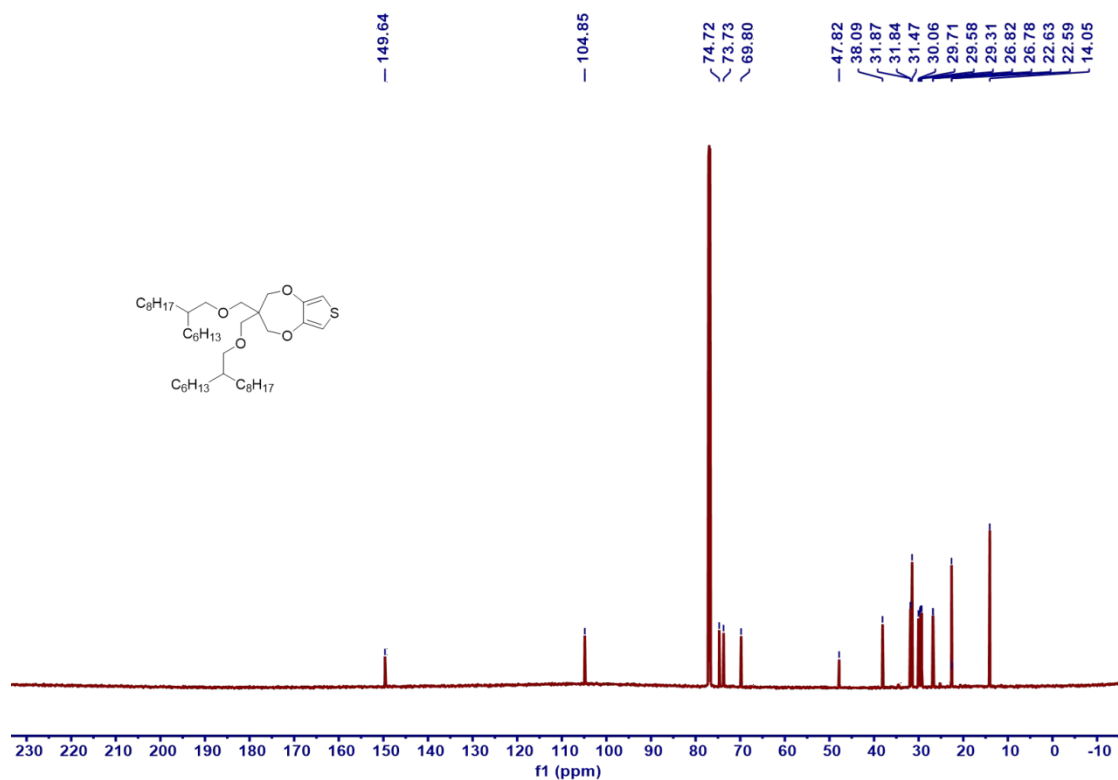


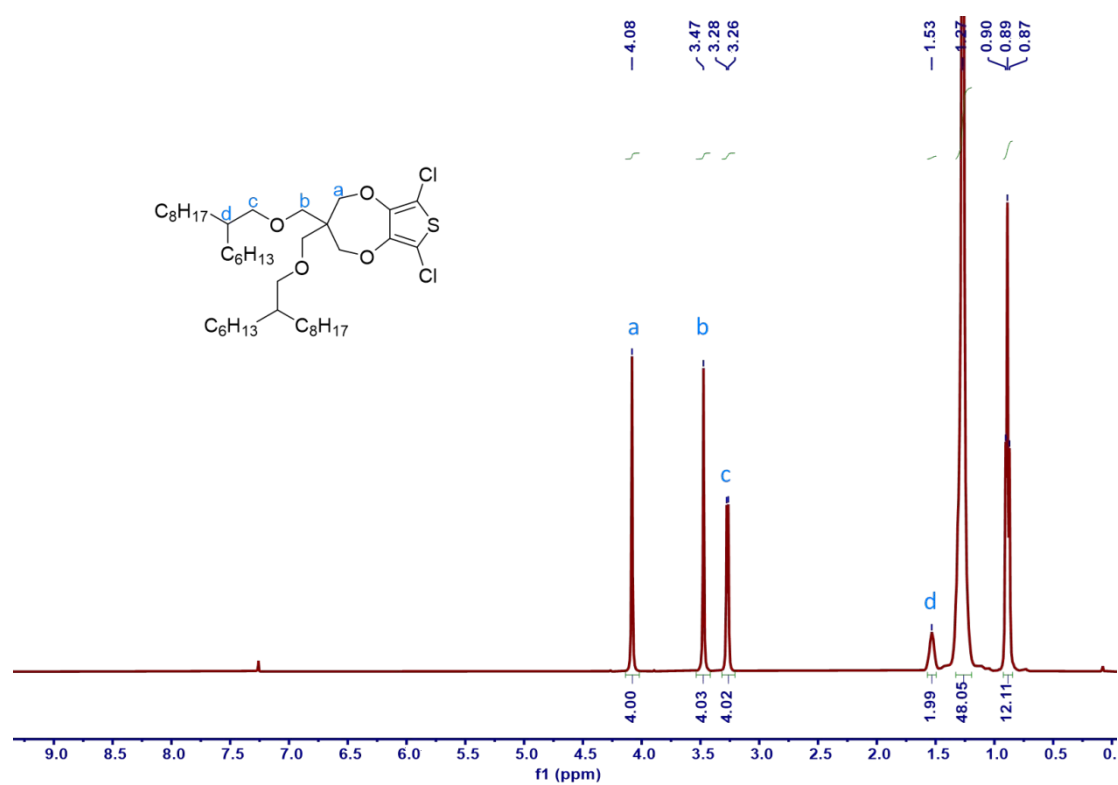
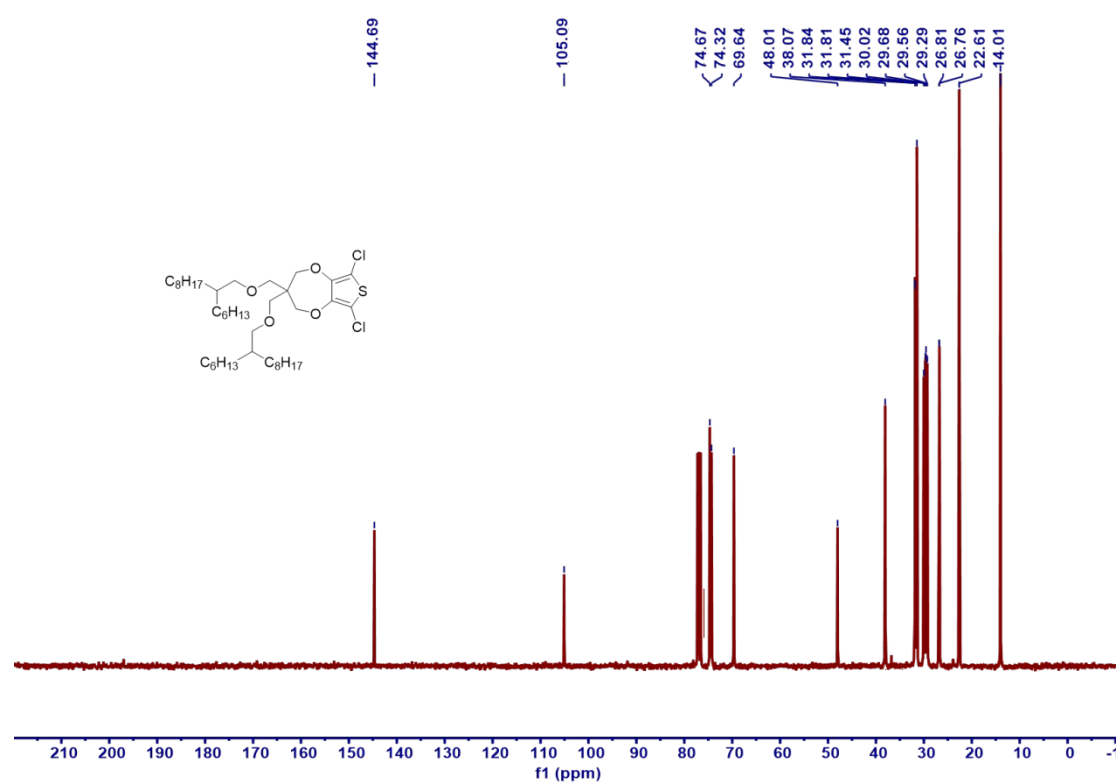


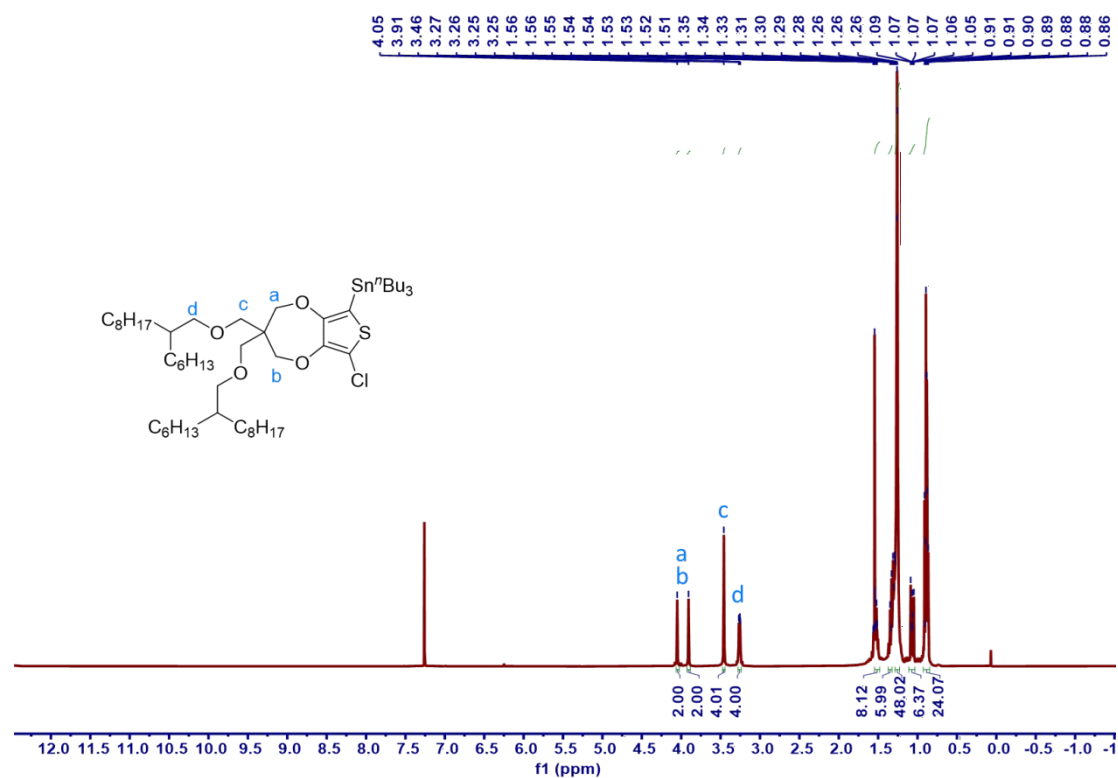
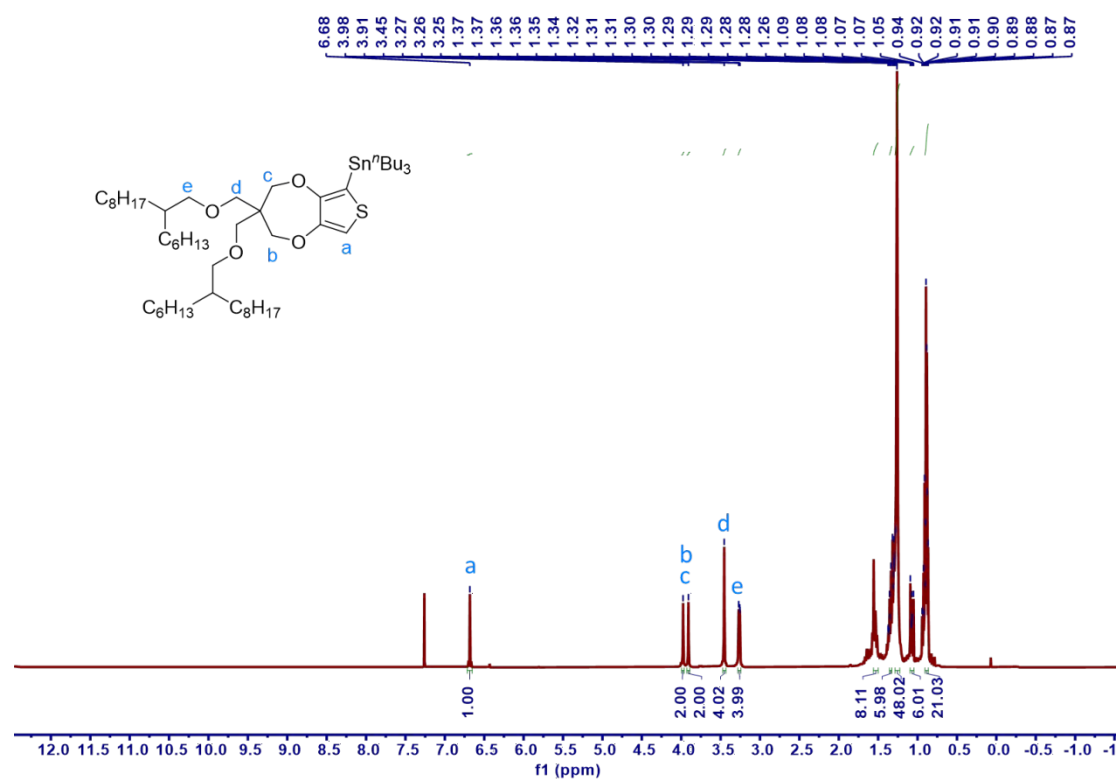


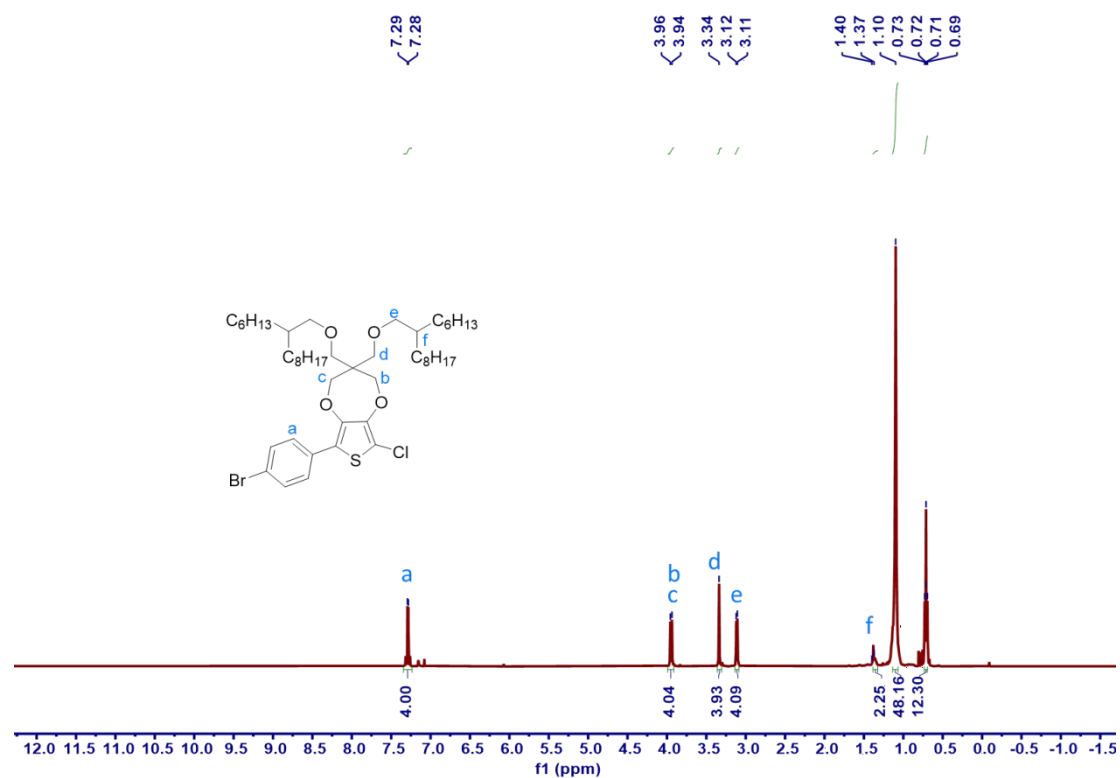
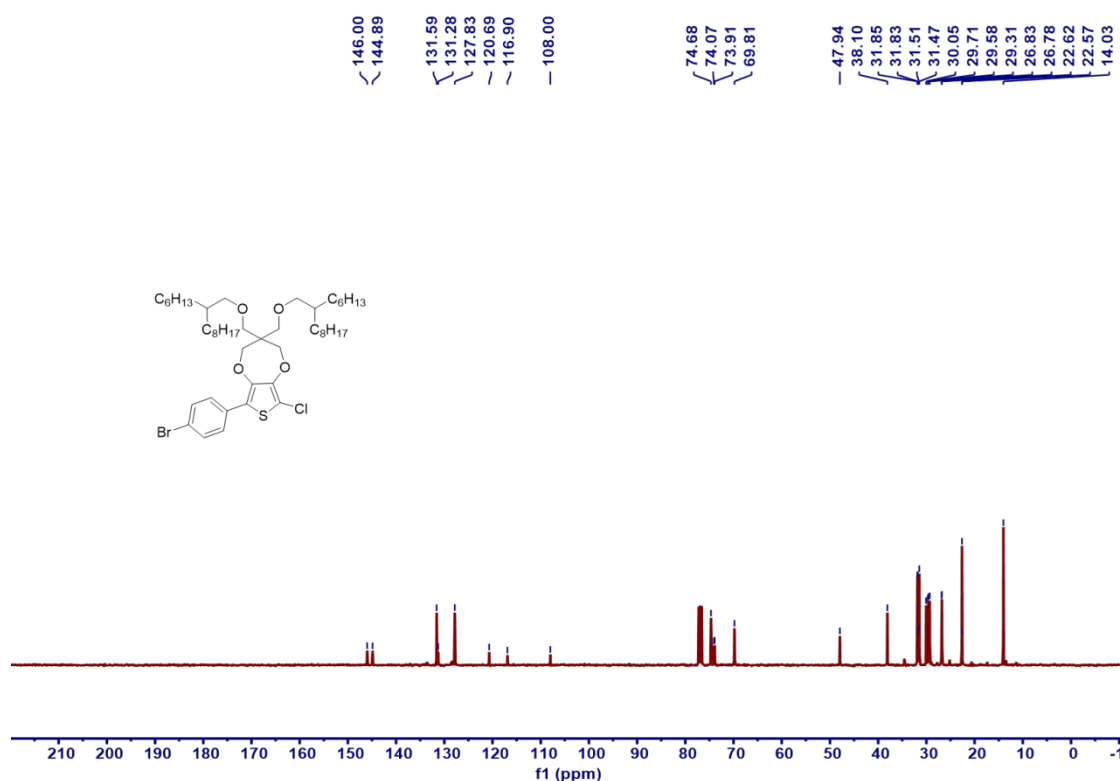


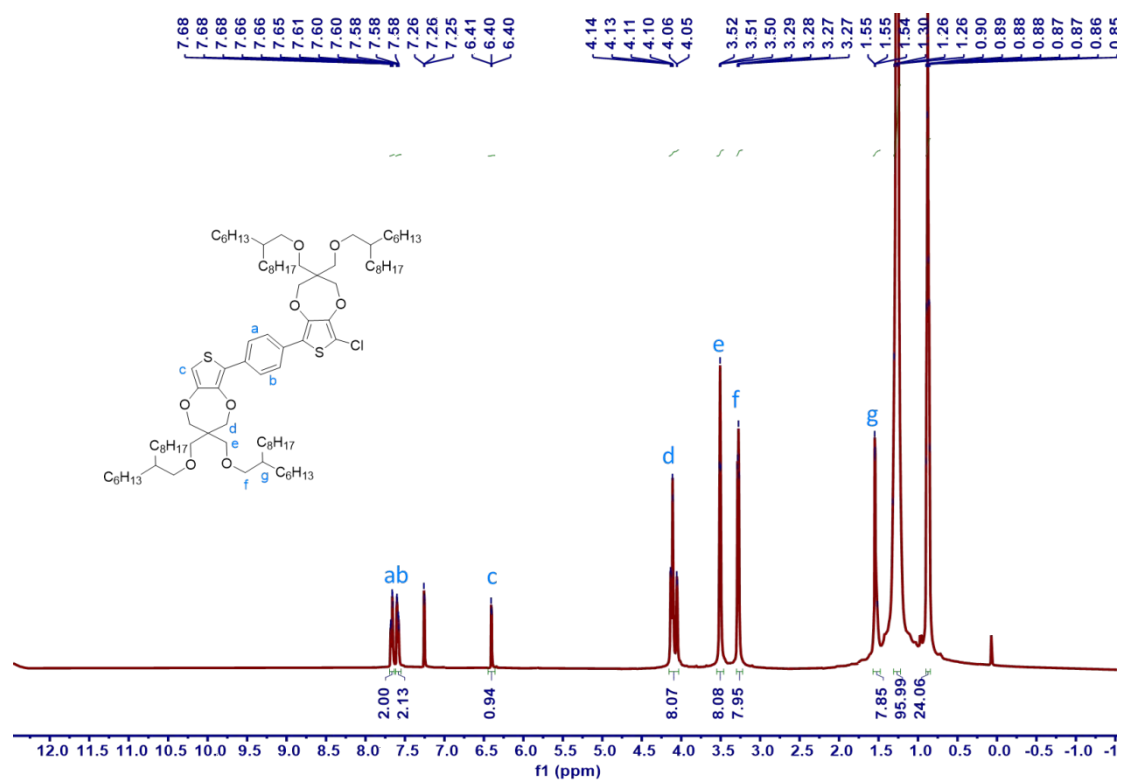
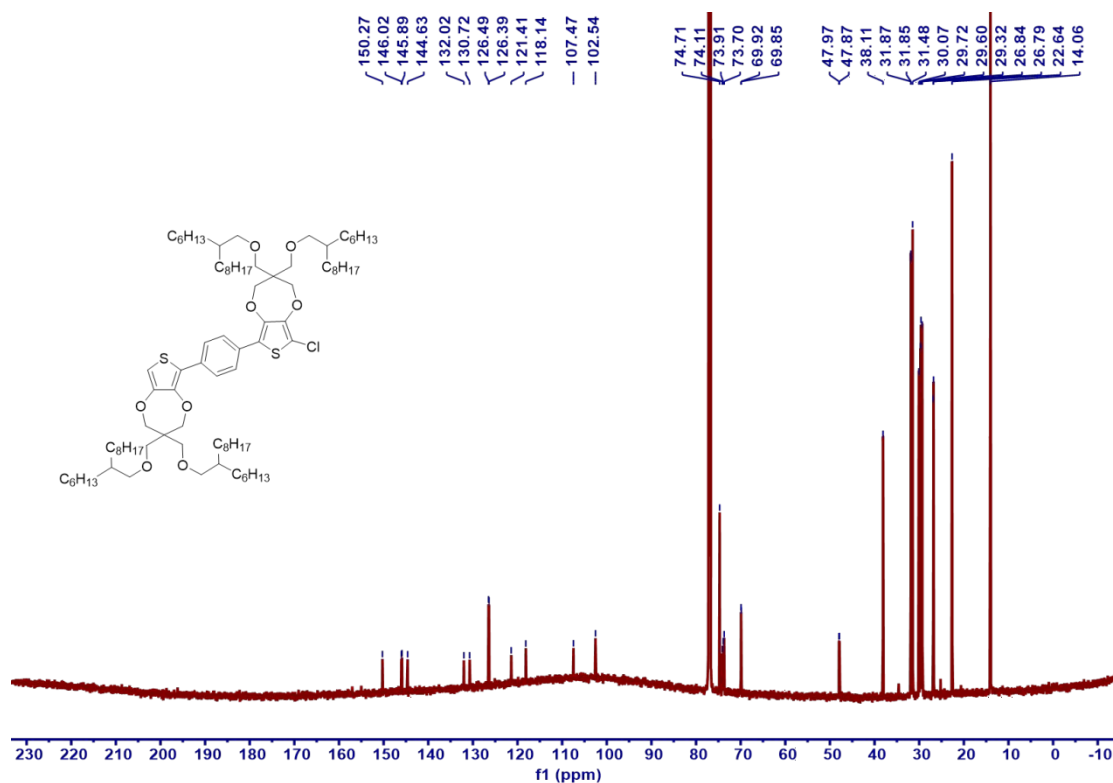


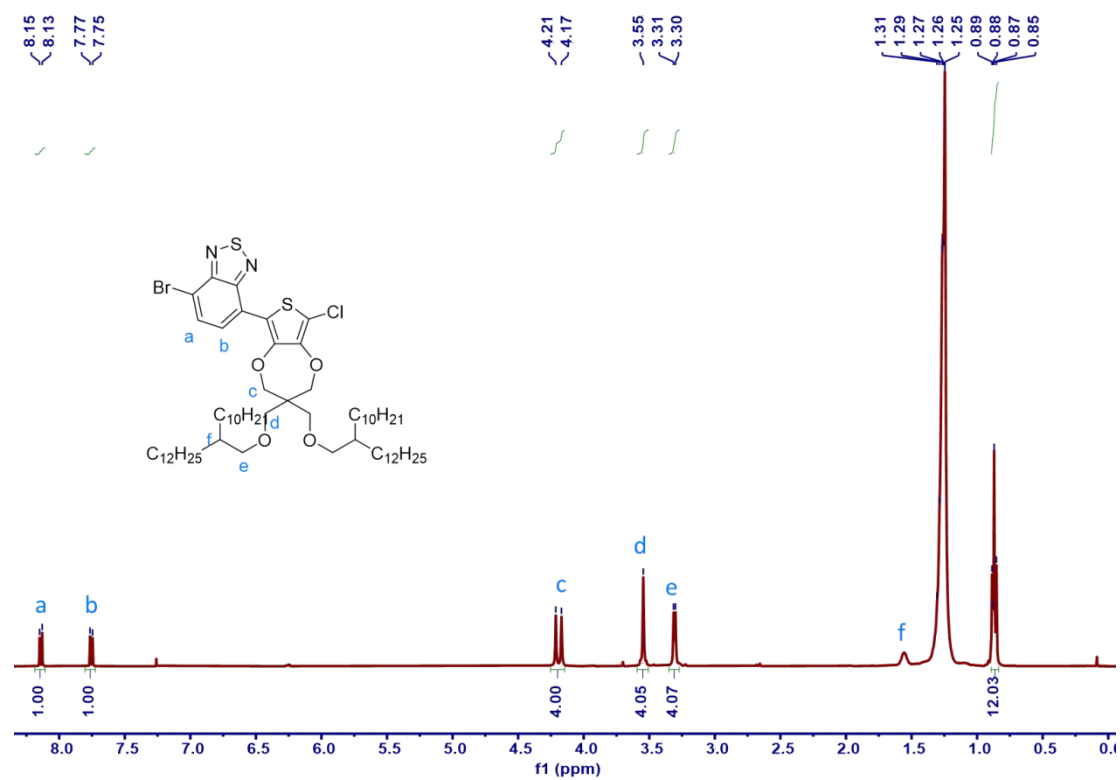
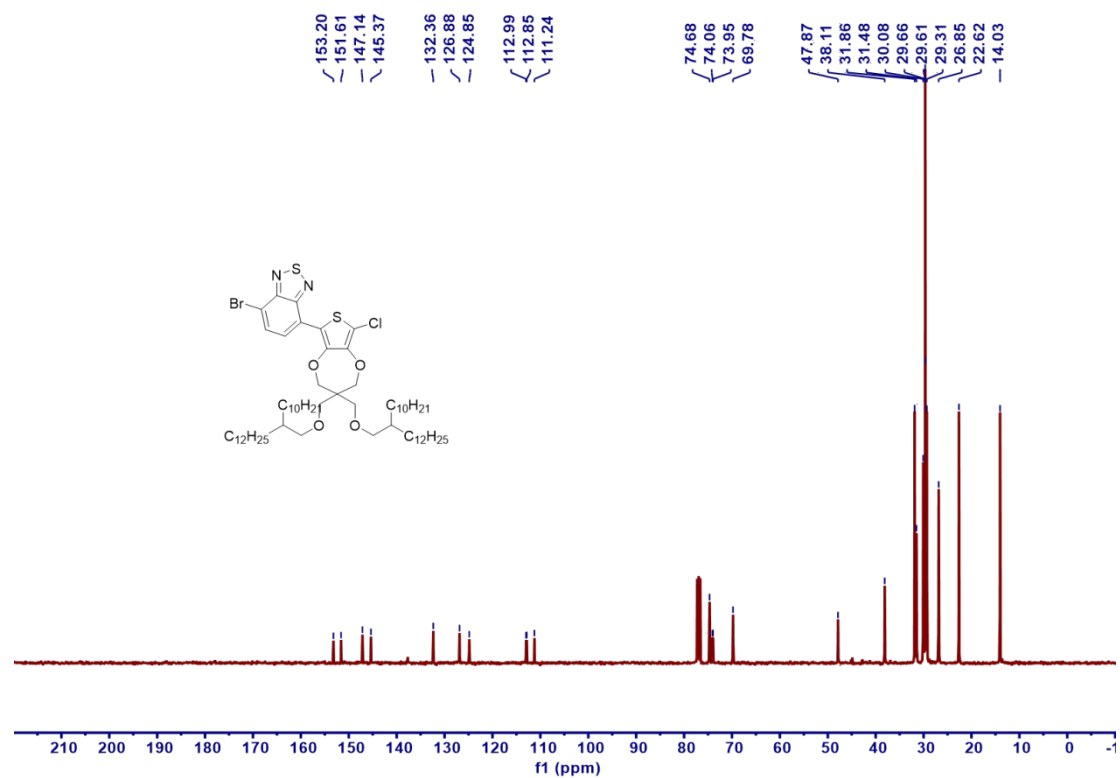


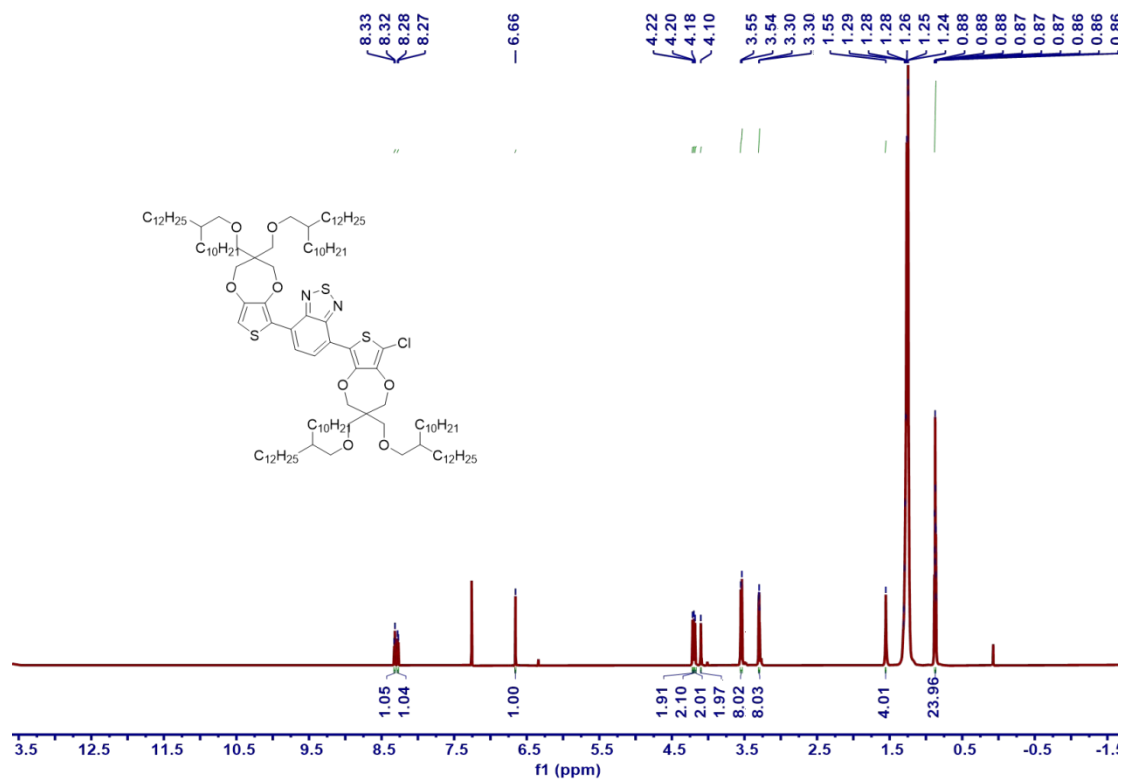
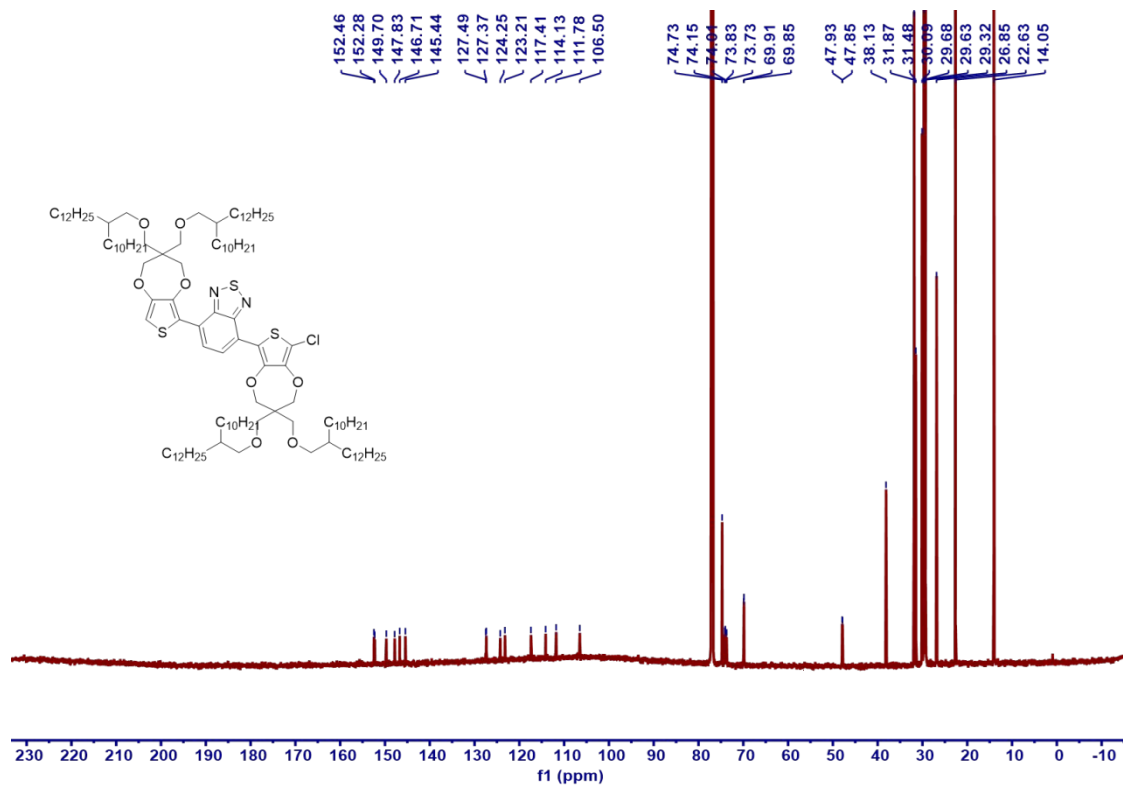


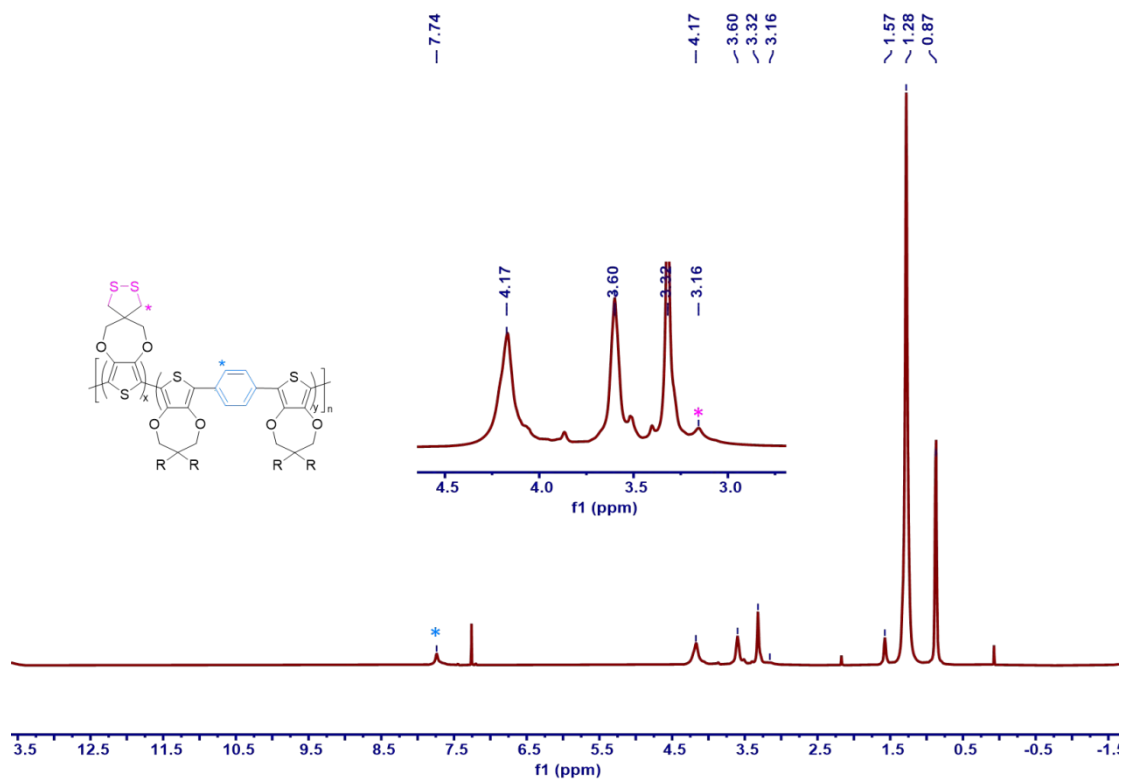
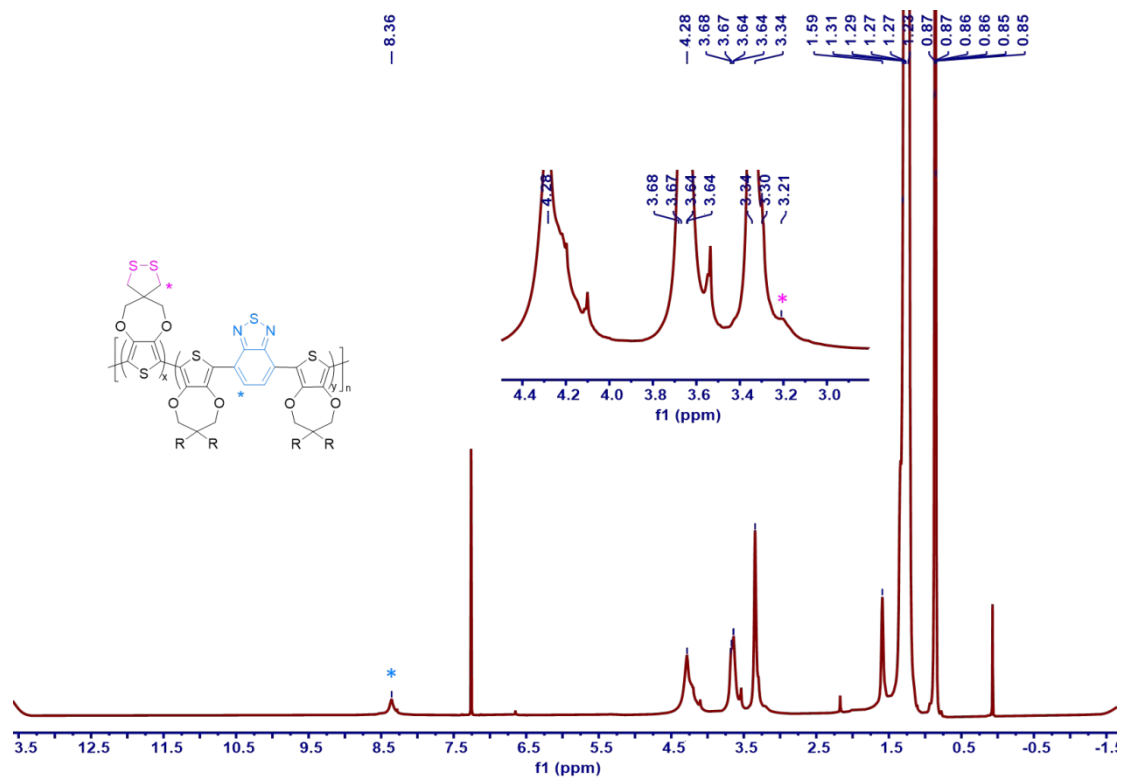


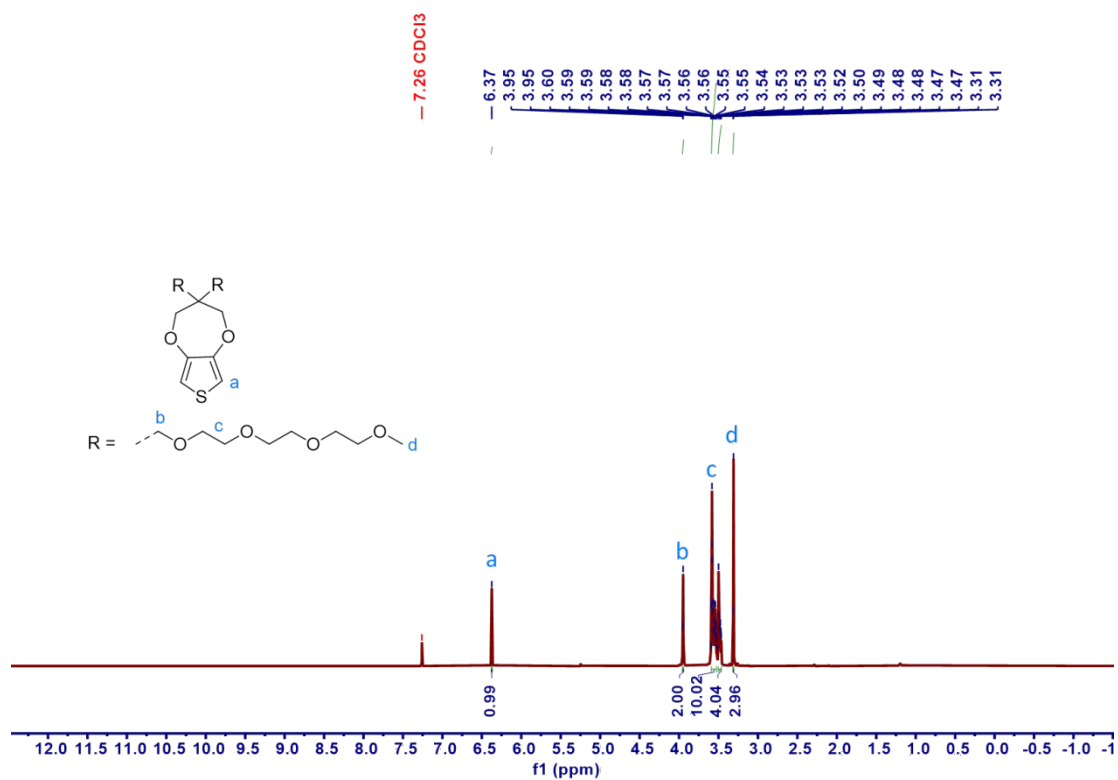
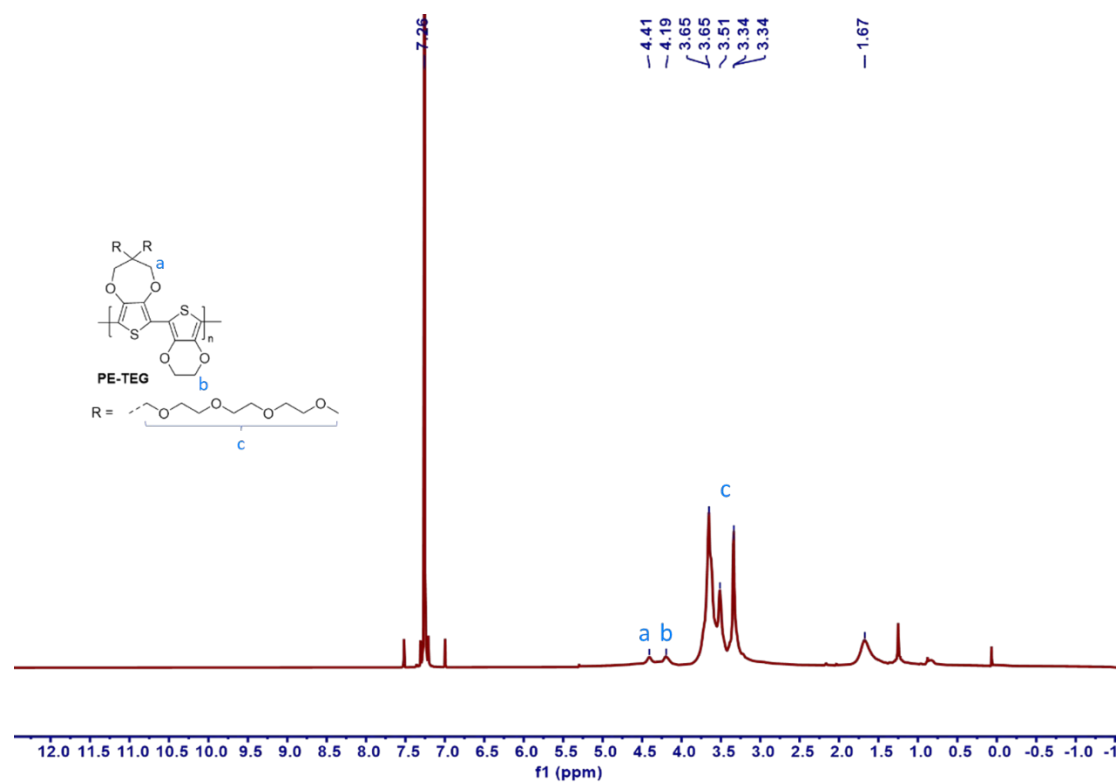












GPC traces

