



Article Development of Dithieno[3,2-b:2',3'-d]thiophene (DTT) Derivatives as Solution-Processable Small Molecular Semiconductors for Organic Thin Film Transistors

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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). **Abstract:** Novel solution-processable dithieno[3,2-d:2',3'-d]thiophene (DTT) derivatives with alkylated thiophene or alkyl chain substituents, 2,6-bis(5-octylthiophen-2-yl)dithieno[3,2-b:2',3'-d] thiophene (compound 1), 2,6-bis(5-(2-ethylhexyl)thiophen-2-yl)dithieno[3,2-b:2',3'-d]thiophene (compound 2), and 2,6-dioctyldithieno[3,2-b:2',3'-d]thiophene (compound 3), have been synthesized and employed as small molecular organic semiconductors for organic field-effect transistors (OFETs). All compounds exhibited good thermal stability over 290 °C, while different side groups of DTT compounds afforded different melting temperatures. The molecular orbital energy levels were experimentally and theoretically calculated, and their trend was almost the same. The developed compounds were employed as active layers for top-contact/bottom-gate OFETs with average charge carrier mobility as high as 0.10 cm²/Vs and current on/off ratio > 10⁷ in ambient atmosphere. Notably, DTT derivative with linear alkyl chain (-octyl) substituents showed the best device performance. High device performance could be attributed to the large grains and continuous surface coverages as well as high film texture of the corresponding semiconductor films.

Keywords: organic semiconductor; organic thin-film transistor; solution process; dithieno[3,2-b:2',3'-d]thiophene

1. Introduction

For decades, studies on organic semiconductors (OSCs) have been conducted for various optoelectronic applications in mechanically flexible, cost-effective, and large-area electronics such as organic field-effect transistors (OFETs), organic light-emitting diodes (OLEDs), and organic photovoltaics (OPVs) [1–11]. Research advances on OFETs have focused on improving the electrical performance and stability of π -bonded organic semiconductors exhibited very high electrical performance with carrier mobility > 1–10 cm²/Vs [12–19]. Among two types of organic semiconductors, small molecular organic semiconductors generally show higher purity, better synthetic reproducibility, and higher solubility in common solvents with enhanced electrical performance, than polymeric counterparts.

Among the various chemical structures that make up organic semiconductors, fused-thiophene derivatives have attracted much attention [20–47]. Along with the properties of

fused-thiophene, dithieno[3,2-d:2',3'-d]thiophene (DTT) moiety is considered as a promising backbone structure because of its rigid and flat molecular structure, and extended π -conjugation, affording compact molecular packing in thin films and enhanced electrical performance [34–47]. In addition to π - π interactions, intermolecular S-S interactions, coming from the S atoms in the DTT structure, furnish more pathways for charge transport with the effective dimensionality of the electronic structure [48]. Furthermore, DTT derivatives exhibit large bandgap energy due to their high resonance stabilization energy, resulting in excellent ambient stability [34,35]. Note that compounds including DTT derivatives are generally treated as the ambient stable materials when they have larger energy band gaps (>2.09 eV) and lower HOMO levels (<-5.02 eV) than pentacene [49].

There have been several reports on the characterization of DTT derivatives as active layers in OFETs [34–47]. For instance, Shi et al. reported a vacuum-deposited DTT-based small molecule with terminal phenyl groups with high carrier mobility of 2.2 cm²/Vs [45]. In the case of solution-processed DTT derivatives, Ho et al. showed that solution-sheared DTT-based material afforded uniaxially aligned fiber-based morphology with hole mobility of 0.32 cm²/Vs [46]. In addition, Vegiraju et al. reported 3,5-dithioalkyl DTT-based small molecular semiconductors end-capped with diverse fused thiophenes and the resulting solution processed OFETs showed high device performance with hole mobility as high as 2.6 cm²/Vs [47]. To this end, it is worth further developing solution-processable DTT derivatives as OSC for OFETs.

In this study, we newly designed and synthesized three DTT-based compounds with terminal alkyl chains (Figure 1). Our research team previously reported a study that improved conjugation by additional thiophene rings. In order to achieve the same effect, thiophene rings were attached to DTT moiety [50]. The solution-processability of the compounds was enhanced with a linear (octyl) or branched (2-ethylhexyl) terminal chain, and the solution-shearing (SS) method was performed to produce semiconductor thin film. To analyze thermal, optical, and electrochemical properties of the corresponding materials, thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), UV-vis spectroscopy, and cyclic voltammetry (CV) were conducted. Density functional theory (DFT) calculation was carried out to examine the molecular structure and theoretical orbital distribution of each compound. Furthermore, the developed compounds were characterized and employed as active layers for top-contact and bottom-gate OFETs. All the compounds showed p-channel activity with hole mobility as high as $0.10 \text{ cm}^2/\text{Vs}$ and a current on/off ratio $>10^7$. Thin-film microstructure and surface morphology of thin films were investigated by X-ray diffraction (XRD) and atomic force microscopy (AFM) to correlate with performance. In particular, compound 2, which showed the best average hole mobility, exhibited relatively high XRD peak intensity and smooth terrace-like film morphology, facilitating the extension of the π orbital overlap.



Figure 1. Chemical structures of DTT-derivatives developed in this study.

2. Materials and Methods

2.1. General Materials and Methods

Under an Ar environment, air and/or moisture sensitive reactions were implemented in oven-dried glassware and with anhydrous solvents. Unless otherwise specified, all compounds were purchased from commercial sources and used without further purification. Tributyl(5-(2-ethylhexyl)thiophen-2-yl)stannane and tributyl(5-octylthiophen-2yl)stannane were synthesized, as stated in the literature [51]. Solvents were used after freshly distilled or dried by passing through an alumina column. In previous work, General analysis method of the synthesized compounds was already described [36].

Poly(styrene) (ω -hydroxy-terminated, 32,000 g/mol) was purchased from Polymer Source. Thermogravimetric analysis (TGA, NETZSCH instrument TG 209 F3 Tarsus, Selb, Germany) was implemented in a N₂ atmosphere with a flow rate of 20 mL/min. The temperature range was from 40 to 700 °C at a heating rate of 10 °C/min. Differential scanning calorimetry (DSC, TA instrument Q20-2487, New castle, DE, USA) was performed from 20 to 260 °C with a heating or cooling rate of 10 °C /min. UV-vis (JASCO V-770 spectrometer, Tokyo, Japan) spectroscopy was implemented from 190 to 900 nm for chloroform solution of each compound. Three-electrode cyclic voltammetry (CV, PGSTAT204 electrochemical analyzer, Metrohm Autolab, Utrecht, The Netherlands) method was performed with working electrode (platinum), counter electrode (platinum wire), and reference electrode (Ag/AgCl in saturated KCl). Tetrabutylammonium perchlorate, dichloromethane, and ferrocene/ferrocenium (Fc/Fc⁺) were used as electrolyte, solvent, and internal standard, respectively.

2.2. Synthesis

Dithieno[3,2-*b*:2',3'-*d*]thiophene (4) [52] and 2,6-diiododithieno[3,2-*b*:2',3'-*d*]thiophene (4a) [53] were synthesized in accordance with reference methods. Accordingly, 2,6-Dioctyldithieno[3,2-*b*:2',3'-*d*]thiophene (1) was synthesized through lithiation and alkylation, as shown in Scheme 1. Sonogashira coupling of compound 4a with proper tin compounds afforded 2,6-bis(5-octylthiophen-2-yl)dithieno[3,2-*b*:2',3'-*d*]thiophene (2) and 2,6-bis(5-(2-ethylhexyl)thiophen-2-yl)dithieno[3,2-*b*:2',3'-*d*]thiophene (3).



Scheme 1. Synthetic scheme for compounds 1–3 employed in this study.

2.2.1. Synthesis of Dithieno[3,2-b:2',3'-d]thiophene (4)

Compound 4 was synthesized, following process from previous literature [52]. ¹H NMR (400 MHz, CDCl₃): δ 7.35 (d, J = 5.0 Hz, 2H), 7.28 (d, J = 5.0 Hz, 2H).

2.2.2. Synthesis of 2,6-Diiododithieno[3,2-b:2',3'-d]thiophene (4a)

Compound **4a** was synthesized, following process from previous literature [53]. ¹H NMR (400 MHz, CDCl₃): δ 7.40 (s, 2H).

2.2.3. Synthesis of 2,6-Dioctyldithieno[3,2-b:2',3'-d]thiophene (1)

To a -78 °C solution of compound 4 (100 mg, 0.51 mmol) in anhydrous THF (20 mL), 2.5 M n-BuLi solution (1.0 mL) under a N₂ atmosphere was added, dropwise. The solution was stirred at -78 °C for 30 min, and 1-bromooctane (246 mg, 1.27 mmol) was added to this solution. Then, the reaction mixture was stirred overnight at room temperature. The reaction was quenched by water and extracted with CH₂Cl₂. The organic layers were collected, washed with water, brine, and dried over anhydrous MgSO₄. The solvent was removed under reduced pressure. The crude product was purified by flash column chromatography on silica gel using hexanes as the eluent to afford compound 1 as white solid (47.7 mg, 22.3%) [54]. ¹H NMR (400 MHz, CDCl₃): δ 6.92 (s, 2H), 2.86 (t, J = 7.3 Hz, 4H), 1.73–1.66 (m, 4H), 1.40–1.26 (m, 20H), 0.86 (t, J = 6.9 Hz, 6H) ¹³C NMR (101 MHz, CDCl₃): δ 146.4, 139.3, 129.1, 117.5, 32.0, 31.7, 31.2, 29.4, 29.3, 29.1, 22.8, 14.2. HRMS-El(m/z): [M + H⁺] calcd. for C₂₄H₃₆S₃, 421.2052; found, 421.2055.

2.2.4. Synthesis of 2,6-Bis(5-octylthiophen-2-yl)dithieno[3,2-b:2',3'-d]thiophene (2)

Compound **4a** (200 mg, 0.45 mmol), tributyl(5-octylthiophen-2-yl)stannane (477 mg, 0.98 mmol), and Pd(PPh₃)₄ (26 mg, 0.02 mmol) were dissolved in dry toluene (15 mL) and refluxed for 12 h under N₂ atmosphere. After cooling to room temperature, the mixture was extracted with CH₂Cl₂ and dried over anhydrous MgSO₄. The solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel using hexanes as the eluent to afford compound **2** as yellow solid (77.8 mg, 29.8%) [55]. ¹H NMR (400 MHz, CD₂Cl₂): δ 7.29 (s, 2H), 7.06 (d, J = 3.7 Hz, 2H), 6.73 (d, J = 3.7 Hz, 2H), 2.81 (t, J = 7.5 Hz, 4H), 1.73–1.66 (m, 4H), 1.40–1.29 (m, 20H), 0.90–0.89 (m, 6H) ¹³C NMR (101 MHz, CDCl₃): δ 146.2, 141.3, 138.3, 134.9, 129.2, 125.0, 123.7, 116.3, 32.0, 31.7, 30.3, 29.4, 29.3, 29.2, 22.8, 14.2. HRMS-El(m/z): [M + H⁺] calcd. for C₃₂H₄₀S₅, 585.1806; found, 585.1807.

2.2.5. Synthesis of 2,6-Bis(5-(2-ethylhexyl)thiophen-2-yl)dithieno[3,2-b:2',3'-d]thiophene (3)

Compound **4a** (200 mg, 0.45 mmol), tributyl(5-(2-ethylhexyl)thiophen-2-yl)stannane (477 mg, 0.98 mmol), and Pd(PPh₃)₄ (26 mg, 0.02 mmol) were dissolved in dry toluene (15 mL) and refluxed for 12 h under N₂ atmosphere. After cooling to room temperature, the mixture was extracted with CH₂Cl₂ and dried over anhydrous MgSO₄. The solvent was removed under reduced pressure and the residue was purified by flash column chromatography on silica gel using hexanes as the eluent to afford compound **3** as red solid (106 mg, 40.6%) [55]. ¹H NMR (400 MHz, CD₂Cl₂) δ 7.30 (s, 2H), 7.06 (d, J = 3.7 Hz, 2H), 6.72 (d, J = 3.7 Hz, 2H), 2.76 (d, J = 6.9 Hz, 4H), 1.61 (t, J = 5.7 Hz, 2H), 1.41–1.27 (m, 16H), 0.93–0.89 (m, 12H) ¹³C NMR (101 MHz, CDCl₃): δ 144.7, 141.3, 138.6, 135.1, 129.1, 126.1, 123.6, 116.2, 41.5, 34.2, 32.4, 29.0, 25.6, 23.1, 14.3, 10.9. HRMS-El(m/z): [M + H⁺] calcd. for C₃₂H₄₀S₅, 585.1806; found, 585.1809.

2.3. Theoretical Calculation

Density functional theory (DFT) calculations on DTT derivatives were performed to estimate optimized HOMO and LUMO energy profiles using B3LYP method (Becke's 3 parameters, the Lee-Yang-Parr) with 6-31G(d) basis sets, as implemented in Gaussian 09W program (9.5 version).

2.4. Device Fabrication

Highly n-doped Si wafers (resistivity <0.005 $\Omega \cdot cm$) with a 300 nm thermally grown SiO₂ gate dielectric (areal capacitance: 11.4 nF/cm²) were used as substrates for the top-contact/bottom-gate OTFTs. The Si/SiO₂ substrates were sonicated in isopropyl alcohol (IPA) for 15 min and treated with O₂ plasma for 10 min (Harrick Plasma, 18 W). For PS-brush treatment, a toluene solution (0.5 wt%) of ω -hydroxy-terminated polystyrene (PS) (M_w: 32,000 g/mol) was spin-coated at the spin rate of 3000 rpm for 30 s onto the Si/SiO₂ substrates, followed by thermal annealing at 170 °C for 48 h in a vacuum oven. Then the PS-brush-treated substrates were rinsed with toluene and placed in the vacuum oven for annealing at 100 °C for 24 h. Organic semiconductor layers were deposited by solution-shearing (SS) method with different solvents (chloroform, toluene), concentration, coating speed, and substrate temperature to optimize semiconductor performance. To remove the residual solvent, the solution-sheared films were placed in a vacuum oven at the same temperature as the shearing temperature. Source/drain electrodes of 40 nm Gold were thermally evaporated with a decomposition rate of 0.2 Å/s utilizing a shadow mask with a channel length of 50 µm and width of 500 µm.

2.5. Device Characterization

The microstructure and surface morphology of the thin film semiconductor was characterized by X-ray diffractometer (D8 Advance (TRIO/TWIN), Bruker, Billerica, MA, USA) and atomic force microscope (AFM, Park Systems, Suwon, Korea), respectively. The electrical performance parameters of OTFTs were determined in ambient utilizing a semiconductor parameter analyzer (Keithley 4200-SCS, Keithley Instruments, OH, USA). Charge carrier mobility in the saturation regime (μ_{sat}) was calculated by the general equation, $\mu_{sat} = (2I_{DS} \times L)/[WC_i \times (V_G - V_{TH})^2]$. (I_{DS} ; the source-drain current, L; the channel length, W; the channel width, C_i ; the areal capacitance of the gate dielectric, V_G ; the gate voltage, V_{TH} ; the threshold voltage) [56,57].

3. Results

3.1. Thermal, Optical, and Electrochemical Properties

Thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) were carried out to characterize the thermal properties of newly synthesized DTT derivatives. Due to the molecular structure, thermal stability was anticipated to be good and suitable for the solution process method. Compounds **1**, **2**, and **3** showed the decomposition temperatures (5% weight loss) of 292, 396, and 392 °C, respectively, (Figure S1 and Table 1),

showing high thermal stability of the developed compounds. The DSC measurements of compounds **1–3** revealed sharp endotherms above 42, 139, and 127 °C, respectively, (Figure S2 and Table 1). Higher melting temperature of compounds **2** and **3** than that of compound **1** is due to stronger intermolecular interaction with more thiophene rings [58]. Similarly, linear alkyl chain (-octyl) of compound **2** could promote stronger intermolecular interactions than branched alkyl side chain (-ethylhexyl) of compound **3**, resulting in slightly higher melting temperature of compound **2** [59,60].

| | DSC T _m (°C) ^a | TGA T _d (°C) ^b | UV-Vis λ_{max} (nm) ^c | E _{gap} (eV) ^d | E _{ox} ^{onset} (eV) ^e | HOMO (eV) ^e | LUMO (eV) ^f |
|---|---|---|--|---------------------------------------|---|---------------------------|---------------------------|
| 1 | 42 | 292 | 262 | 3.75 | 1.14 | -5.42 | -1.67 |
| 2 | 139 | 396 | 400 | 2.78 | 0.81 | -5.09 | -2.31 |
| 3 | 127 | 392 | 399 | 2.73 | 0.90 | -5.19 | -2.46 |

Table 1. Physicochemical Properties of DTT Derivatives developed in this study.

^a Melting temperature, ^b Decomposition temperature(5%), ^c Measured in chloroform solution, ^d Band gap was estimated using the tangent line at the onset of UV-vis spectra, ^e Measured by cyclic voltammetry in CH₂Cl₂ at room temperature (using ferrocene/ferrocenium as internal standard), ^f $E_{LUMO} = E_{HOMO} + E_{gap}$.

The optical properties of the compounds in diluted chloroform solution were investigated by the UV-vis spectroscopy (Figure 2). As shown, compounds **2** and **3** with more thiophene rings exhibited significantly red-shifted maximum absorption peaks because of the extended conjugation length, compared to compound **1**. The optical energy band gaps obtained from the UV-vis onset wavelengths (λ_{onset}) of each compound were 3.75, 2.78, and 2.73 eV, for compounds **1**, **2**, and **3**, respectively, (Table 1).



Figure 2. The optical absorption spectra of the compounds 1–3 in chloroform solution.

Electrochemical properties of compounds were determined by cyclic voltammetry (CV) using CH_2Cl_2 at room temperature. Oxidation potentials of the compounds 1–3 were 1.14, 0.81, and 0.90 V, respectively, (Figure 3). The HOMO level was calculated by ferrocene/ferrocenium internal standard with the regular formula:

$$E_{HOMO} (eV) = -e(E_{ox}^{onset} - E_{Fc/Fc} + {}^{onset}) - 4.80 eV$$
(1)

where E_{ox}^{onset} is the onset of oxidation potential. Hence, HOMO levels were calculated as -5.42, -5.09, and -5.19 eV, ensuring high oxidative stability [61,62]. Moreover, the experimental HOMO level of compound **2** fits well with the work function of gold, which can contribute to high device performance by facilitating charge injection [41]. The LUMO level was obtained by adding the energy band gap obtained from UV-vis spectra to the HOMO level, which resulted in -1.67, -2.31, and -2.46 eV for compound 1, 2, and 3, respectively.



Figure 3. Cyclic voltammetry (CV) curves of newly synthesized DTT derivatives at room temperature in CH₂Cl₂.

3.2. Theoretical Calculation

Density functional theory (DFT) calculations were implemented to optimize the molecular geometry and HOMO/LUMO orbital energy distribution of DTT derivatives. As shown in Figure 4, the theoretically optimized HOMO/LUMO energy of the compounds 1–3 were -5.21/-0.86 eV for compound 1, -4.91/-1.68 eV for compound 2, and -4.92/-1.70 eV for compound 3, respectively. Hence, the calculated energy band gaps were 4.35, 3.23, and 3.22 eV for compounds 1, 2, and 3, respectively, showing similar trend to the experimentally determined band gap energies (Table 1). For all the compounds, HOMO and LUMO orbitals were dispersed on the main backbone and thiophene derivative moiety.



Figure 4. Optimized HOMO/LUMO energy profiles of (a) compound 1, (b) compound 2, and (c) compound 3.

3.3. Thin-Film Transistor Characterization

To evaluate the semiconducting properties of the DTT derivatives, OFET devices were fabricated in a top-contact, bottom-gate configuration employing each compound as an active layer. The thin films of each compound were deposited by the solution-shearing method on the PS-treated SiO₂/Si substrate. All solution-processed semiconductor

films exhibited p-channel activity in ambient conditions (Figures 5 and S3). As shown, compounds with more extended conjugation (compound **2** and **3**) exhibited higher electrical performance of 0.067 and 0.0091 cm²/Vs, respectively, than compound **1** (carrier mobility of 0.000028 cm²/Vs). Lower electrical performance of compound **3**, compared to compound **2**, can be ascribed to the reduced intermolecular π - π interaction and molecular packing from steric hindrance around the aromatic plane with the branched (2-ethylhexyl) side chain (Table 2) [63]. Relatively large threshold voltages might be due to interface trap states between semiconductor and dielectric, as reported in several studies in the literature on DTT-based small molecules [34,35,64–66]. Note that a "kink" feature in Figure 5a could be caused by contact resistance, and mobility can be overestimated higher than the actual value. Therefore, in order to prevent the overestimation of mobility, actual carrier mobility was extracted, as specified in the literature [56,67].



Figure 5. Representative (**a**) transfer and (**b**) output curves of organic thin-film transistor fabricated with compounds **2**.

| Compound | μ ^{max} (cm ² /Vs) (μ ^{avg} (cm ² /Vs)) | Ion/Ioff | <i>V</i> _{TH} (V) |
|----------|--|---------------------------|----------------------------|
| 1 | $\begin{array}{c} 0.000028 \pm 0.000002 \\ (0.000030) \end{array}$ | $(4.6\pm2.0)\times10^3$ | -13 ± 4 |
| 2 | 0.067 ± 0.033 (0.10) | $(1.4\pm0.8)	imes10^7$ | -23 ± 4 |
| 3 | $\begin{array}{c} 0.0091 \pm 0.0019 \\ (0.011) \end{array}$ | $(7.6\pm1.3)\times10^{6}$ | -22 ± 1 |

Table 2. Optimized OTFT Device Performance based on the Thin Films of DTT Derivatives ^a.

^a μ : charge carrier mobility, I_{on}/I_{off} : current on/off ratio, V_{TH} : threshold voltage. The average values were obtained from 5 devices under ambient condition.

3.4. Thin-Film Microstructure and Morphology

Solution-sheared semiconductor films of compounds **1–3** were characterized by θ –2 θ XRD and AFM to evaluate thin-film microstructure and surface morphology. As shown in Figure 6, thin films of compounds **2** and **3** exhibited higher XRD peak intensity than compounds **1**, in accordance with the device performance of the corresponding devices (vide supra). The primary diffraction peaks (001) of the compounds **1–3** appeared at $2\theta = 4.70^{\circ}$ (d-spacing = 18.8 Å), $2\theta = 3.66^{\circ}$ (d-spacing = 24.1 Å), and $2\theta = 4.13^{\circ}$ (d-spacing = 21.4 Å), respectively. The theoretically estimated molecular lengths obtained by DFT calculation were 28.7 Å for compound **1**, 30.6 Å for compound **2**, and 23.4 Å for compound **3**, respectively. The molecular lengths were longer than the corresponding d-spacing values, suggesting that the molecules were vertically aligned but slightly tilted on the surface.



Figure 6. θ -2 θ XRD patterns of the solution-processed thin films of three synthetic compounds.

Surface morphologies of thin films of compounds **1–3** were characterized by AFM (Figure 7). The fabricated thin films of compound **1** showed rod-like morphology with relatively high roughness with root-mean-square (RMS) roughness of 30.4 nm. Conversely, thin films of compounds **2** and **3** exhibited interconnected terrace-like layered morphologies with relatively small RMS roughness of 1.67 and 1.20 nm, respectively. High electrical performance of compound **2** and **3** could be ascribed to large grains and continuous surface coverages. Notably, the step heights of the large islands were 2.3–2.5 nm for compound **2** and **2**.1–2.3 nm for compound **3**, corresponding to the d-spacing of thin films of each compound (vide supra).



Figure 7. Cont.





4. Conclusions

In summary, we have developed a new class of solution-processable dithieno[3,2b:2',3'-d]thiophene-based semiconductors through reasonable molecular design to accomplish environmental stability, excellent solution processability, and high transistor performance. Compared to pentacenes or oligothiophenes, these DTT derivatives show low HOMO levels, affording high oxidative stability. Furthermore, we have successfully fabricated OTFTs based on a new series of organic semiconductors. Thin films of all DTT compounds exhibited p-channel field-effect performance, with mobilites as high as 0.10 cm²/Vs and current on/off ratio ~10⁷. In particular, linear alkyl chains in compound **2** facilitate molecular packing to enhance π - π interaction and charge transport, resulting in the highest device performance. Our study suggests that dithieno[3,2-b:2',3'd]thiophene derivatives are attractive candidates for solution-processable, small molecule semiconductors.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10 .3390/coatings11101222/s1, Figure S1: Thermogravimetric analysis (TGA) of (a) compound **1**, (b) compound **2**, and (c) compound **3**, Figure S2: Differential scanning calorimetry (DSC) analysis of (a) compound **1**, (b) compound **2**, and (c) compound **3**, Figure S3: Representative transfer characteristics of the fabricated OFETs of (a) compound **1** and (b) compound **3**.

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