A Structurally Simple but High-Performing Donor–Acceptor Polymer for Field-Effect Transistor Applications

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A straightforward synthesis is reported for four structurally simple donor–acceptor conjugated polymers based on an alkylated difluorobenzotriazole and either unsubstituted bithiophene (T2) or thienylvinylthiophene (TVT) co-monomers. Two solubilizing sidechains are investigated in which the position of the branching point is moved away from the conjugated backbone. Optoelectronic measurements and density functional theory calculations show very similar energetic properties between the polymers, with a slightly narrower bandgap for the vinylene incorporating TVT polymers as a result of extended conjugation. Transistor measurements demonstrate that the simplest polymer, containing a readily available 2-decyltetradecyl sidechain with a T2 co-monomer, exhibits the best device performance, with an average saturated mobility of 0.2 cm² V⁻¹ s⁻¹.

1. Introduction

Conjugated polymers have been widely studied for a variety of applications, including organic photovoltaics (OPVs), organic field-effect transistors (OFETs), and organic light-emitting diodes (OLEDs).[3] Their attractive properties such as solution processability and mechanical flexibility make such materials ideal for the development of cheap, lightweight, and conformable electronics.[2] Over the last few decades much effort has focused upon developing and optimizing polymeric materials for these applications.[3] For transistor applications, new material design has led to performance comparable to, or in excess of amorphous silicon, the benchmark commercial material semiconductor for thin-film transistors.[6] Despite this impressive progress, many reported high-performance materials have a relatively complex molecular structure, with multiple synthetic steps required in their preparation. Such synthetic complexity adds cost and hinders scalability, and is therefore unattractive for some applications. As such, there is a continuing need for the development of synthetically accessible polymers exhibiting high charge carrier mobility in OFET devices.

One particularly promising class of polymers for OFET applications is donor–acceptor (D–A) materials, sometimes also referred to as push–pull polymers. Judicious choice of donor and acceptor monomers allows tuning of many of the important properties of the polymers, such as bandgap, energy levels, and polymer solubility.[5,6] 2,1,3-Benzothiadiazole (BT) and its derivatives have been a commonly utilized acceptor unit in D–A polymers, many which have shown good performance in both transistor and photovoltaic applications.[7–10] For example, co-polymerization with indacenodithiophene (IDT) or indacenodithienothiophene (IDTT) leads to polymers exhibiting excellent device performance,[11,12] with devices exhibiting none of the nonidealities that have resulted in overestimated charge carrier mobility for some materials.[13–15] However, both IDT and IDTT require complex multistep synthesis. In contrast, simpler D–A polymers based solely on benzothiadiazole and alkylated thiophene have been developed, with Reichmanis and co-workers reporting one of the earliest examples, with an average hole mobility of up to 0.5 cm² V⁻¹ s⁻¹.[16] Following this report, further improvements in device performance have been reported by, for example, the inclusion of fluorine groups on the BT, or the incorporation of vinylene spacer groups along the conjugated backbone.[17–20] However, one drawback in utilizing BT...
as the electron acceptor is the lack of a solubilizing group on the monomer. In order to make the polymers processable, it has therefore been necessary to include the solubilizing group on the thiophene co-monomer. However, the low symmetry of 3-alkylthiophene monomer results in additional synthetic complexity due to the necessity to carefully control the regiochemistry of the conjugated backbone.

With a heterocyclic structure similar to that of BT, 2,1,3-benzotriazole (BTz) is an interesting alternative that has the advantage of allowing the addition of a solubilizing group in the 2-position of the BTz, potentially allowing the copolymerization with unalkylated co-monomers. However, BTz is a weaker electron acceptor compared to BT, reducing the D–A character of the polymer. This has been addressed by the fusion of additional heterocycles in the 5,6-positions of the BTz ring.[25–29] Alternatively, additional electron-withdrawing groups such as fluorne or nitrile can be added to the BTz to increase the acceptor strength. Such derivatives have been extensively used in the development of polymers for OPV devices, while there has been comparatively less work on the use of BTz as a co-monomer in materials for transistor applications.[35–37]

In this work, aiming for structural simplicity, we present a series of benzotriazole-co-thiophene based D–A polymers using unalkylated thiophene as donor co-monomers. These polymers rely solely on a solubilizing alkyl chain attached to the BTz moiety, and we investigate two different sidechains which differ only in the positioning of the alkyl chain branching point. Despite the molecular simplicity of these polymers, their performance is close to, or in some cases better than, many similar and more complex polymers, with average hole mobilities of up to 0.2 cm² V⁻¹ s⁻¹.

2. Results and Discussion

2.1. Polymer Design and Synthesis

Our polymer design was driven by a desire to avoid synthetic complexity while maintaining some of the design principles in D–A copolymers that have been shown to have a positive impact on transistor performance, including backbone planarity, the use of electron-deficient co-monomers, conformational locks, and the choice of suitable solubilizing sidechains.[6,13,38,39] Thus, considering the fact that benzotriazole is a relatively weak electron acceptor unit, the 5- and 6-positions have been fluorinated in order to increase electron deficiency. Several studies have suggested that the fluorine group could also increase the backbone planarity, through interaction between fluorine atoms and sulfur atoms of adjacent thiophene, causing conformational locking between the monomer units.[18,40] In addition, the fluorinated benzotriazole unit was alkylated with two types of sidechains, a simple 2-decyldodecyl (2DT) group and a more synthetically demanding 5-decylheptadecyl (5DH) group, to investigate the effect of branching point position. Several studies have indicated that moving the alkyl branching point further away from the backbone resulted in a smaller interchain spacing and improved transistor performance,[41–44] with some studies making direct comparisons between the 2DT and 5DH sidechains.[45,46]

The complete synthetic route is shown in Scheme 1. The key building block 5,6-difluoro-1H-benzotriazole was readily prepared in 75% yield from 5,6-difluorobenzene-1,2-diamine by treatment with sodium nitrite.[47] Alkylation with the appropriate bromoalkane using Cs₂CO₃ in dimethylformamide afforded a mixture of the desired product 2-alkyl-5,6-difluorobenzotriazole (dfBTz)
Absorption (solution, 20 °C) and the isomeric 1-alkyl-5,6-difluorobenzotriazole, which required separation by column chromatography. The synthesis of alkylating agents is shown in Scheme S1 (Supporting Information), but we highlight that 11-(bromomethyl)tricosane (to give 2DT) was readily prepared in one step from the commercial alcohol, whereas 11-(4-bromobutyl)tricosane (to give 5DH) required a four-step synthesis. Direct bromination in the 4,7-positions of the resulting dFBTz was problematic and low yielding, so following the methodology of Price et al.,[32] we initially silylated these positions by treatment with lithium disopropylamide in the presence of trimethylsilyl chloride, followed by bromination of the resulting silyl compound. The resulting monomers were therefore isolated in yields of 46% and 66% for the DT and DH, respectively.

Polymerization was performed via Stille coupling with stannylated co-monomers 5′,5′′-bis(trimethylstannyl)-2,2′-bithiophene (T2) and (E)-1,2-bis(5′-(trimethylstannyl)thiophen-2-yl)ethene (TVT) under microwave irradiation. Crude polymers were purified by Soxhlet extraction, using methanol, acetone, and then hexane to remove impurities. The crude polymer was extracted into chloroform, concentrated and precipitated into methanol to afford the final polymers as intensely colored powders.

The molecular weights were determined initially using gel permeation chromatography (GPC) in chlorobenzene at 80 °C against polystyrene standards. The results were complicated by the fact that polymers appeared to strongly aggregate in solution under these conditions, affording bimodal peaks with high apparent dispersity. Changing the eluent to 1,2-dichlorobenzene removed this issue and monomodal distributions were observed in all cases. The resultant molecular weights are summarized in Table 1. Relatively low molecular weights were found in all cases. We note that previous reports on the use of dibrominated dFBTz as a co-monomer have reported similarly low molecular weights,[33] much lower than the analogous non-fluorinated BTz monomers.[48] It appears that the presence of the fluorine substituents impairs the cross-coupling polymerization.

2.2. Optical and Electrochemical Properties

Table 1. Physical and optical properties of synthesized polymers.

| Polymer       | M_10 [kDa] | M_6 [kDa] | D   | Absorption (solution, 20 °C) | HOMO [eV] | E_{opt} [eV] |
|---------------|------------|-----------|-----|-------------------------------|-----------|-------------|
|               | λ_{max} [nm] | Onset [nm] |     |                               |           |             |
| 2DT-dFBTz-T2  | 4.7        | 5.4       | 1.16| 559, 596                  | 646       | 561, 611    | 5.50 1.88  |
| 5DH-dFBTz-T2  | 3.7        | 4.2       | 1.15| 560, 613                  | 651       | 563, 614    | 5.44 1.86  |
| 2DT-dFBTz-TVT | 4.8        | 7.0       | 1.46| 541, 565, 617             | 665       | 569, 620    | 5.46 1.83  |
| 5DH-dFBTz-TVT | 4.0        | 5.2       | 1.31| 537, 568, 630             | 673       | 560, 620    | 5.44 1.82  |

*a*) Measured with gel permeation chromatography in 1,2-dichlorobenzene against polystyrene standards; b*) Estimated from oxidation peak onset in cyclic voltammetry scans; c*) Estimated from the onset of thin-film absorption spectra; d*) Shoulder peak.

Figure 1 shows the absorption spectra of each of the polymers in both dilute chlorobenzene solution and as thin films. The optical bandgap energies were estimated from the onset wavelengths of the thin-film absorption (Table 1). The two vinylene containing polymers (dFBTz-TVT) showed similar optical bandgaps at around 1.83 and 1.82 eV, slightly smaller than the thiophene (dFBTz-T2) counterparts (1.88 and 1.86 eV) due to the longer conjugation length resulting from the additional vinylene group. Inspection of the room-temperature absorption spectra in chlorobenzene shows that both dFBTz-T2 polymers exhibit a main peak near 560 nm, with a pronounced shoulder at longer wavelengths and a less pronounced shoulder at shorter wavelengths. Heating the solution from 20 to 80 °C results in a decrease in the intensity of the longer-wavelength shoulder relative to the main peak, as well as blueshift in the absorption peaks (Figure 1a,b). Both behaviors suggest that the long-wavelength shoulder is associated with aggregation/pla-
The HOMO energy levels varied very little between polymers, ranging from $-5.44$ to $-5.50$ eV, all within the experimental error of the technique ($\pm 0.1$ eV).

To gain further insight into the geometry of the polymer backbone, and any possible noncovalent interaction between the fluorinated BTz and the adjacent thiophene groups, density functional theory (DFT) calculations were performed at the B3LYP/6–311G* level. Previous reports on a repeat unit comprising one thiophene and dFBTz have suggested that noncovalent interactions between the fluorinated BTz and the adjacent thiophene can lead to a preference for one conformer, with a trans-like geometry (with respect to the triazole ring and the thiophene) favored. Here we performed a similar investigation on the longer thiophene-dFBTz–thiophene repeat unit. The results of the potential energy scan (PES) (Figure 2a) were in agreement with the earlier studies and demonstrated a small energetic preference ($\approx 1$ kcal mol$^{-1}$) for the "trans" geometry versus the "cis," with a barrier for interconversion of 5 kcal mol$^{-1}$. Therefore, trimers corresponding to the dFBTz–T2 and dFBTz–TVT polymers were investigated, with the conformation of the thiophene with respect to the dFBTz fixed in the trans-like geometry. The sidechains were replaced with simple methyl sidechains for the sake of computational feasibility. The calculations suggest that the dFBTz–TVT polymers possess a completely planar backbone, whereas there is a degree of torsional disorder in the dFBTz–T2 polymer due to some minor steric hindrance between the thiophenes (Figure 2b,c). The inclusion of the vinylene spacer between the thiophenes removes this steric interaction, in agreement with previous results. We note, however, that inclusion of the vinylene leads to a possible increase in conformational disorder, due to the additional degrees of freedom with respect to rotation around the thiophene-vinylene single bonds. Previous studies have found relatively low energetic differences between these different conformers. Therefore, the overall effect of the vinylene on charge mobility may depend on two competing features: the enhancement of backbone planarization leading to an increase in intra-chain charge transport along the polymer backbone, and additional conformational disorder, reducing interchain charge transport between polymers. Visualization of the frontier molecular orbitals (Figure 2d–g) demonstrates that both the HOMO and the lowest unoccupied molecular orbital (LUMO) are well delocalized over the conjugated framework, without a strong localization on either monomer. This is in agreement with the reduced electron-accepting character of BTz compared to BT.

### 2.3. Thin-Film Structure

Grazing-incidence wide-angle X-ray scattering (GIWAXS) measurements were performed on polymer thin films to investigate microstructural differences between the polymers. The 2D GIWAXS patterns of as-cast and annealed (200 °C) thin films are shown in Figure 3, with the 1D line cuts along the meridian (out of plane) and horizon (in plane) shown in Figure S2 (Supporting Information). In general, all of the polymers exhibited ordered structures in the solid state, with the polymers packing in a lamellar-type fashion with a predominate edge-on orientation (i.e., the lamellar stacking direction is orientated parallel...
Annealing the polymers resulted in an increase in crystalline order in all cases, with up to five orders of lamellar stacking reflections observed out of plane. Annealing, in general, also leads to an improvement in film texture with a reduced “arcing” of peaks resulting in a more pronounced edge-on orientation.

Examining Table 2 that summarizes the crystallographic parameters of the annealed samples, it is apparent that changes in sidechain geometry and backbone chemistry bring about systematic changes in crystal spacings and crystallite size. Polymers with 2DT sidechains have a shorter lamellar stacking distance of ≈20 Å compared to ≈24 Å for the polymers with 5DH sidechains. These differences are consistent with the shorter nature of 2DT sidechains compared to 5DH sidechains. On the other hand, the polymers with 5DH sidechains in general have shorter π–π stacking distances with values of 3.54 and 3.51 Å for 5DH-dFBTz-T2 and 5DH-dFBTz-TVT, compared to 3.57 and 3.55 Å for 2DT-dFBTz-T2 and 2DT-dFBTz-TVT, respectively.

This observation is consistent with other studies that have shown that increasing the distance of the alkyl branching point from the backbone affords a tighter π–π spacing. The TVT polymers in general also have shorter π–π stacking distances compared to the T2 polymers.

Looking at the coherence length (CL) values—which provide an indication of crystallite size along particular crystallographic directions—the T2 polymers tend to have larger π–π stacking CLs while the TVT polymers tend to have larger lamellar stacking CLs. In particular, annealed 5DH-dFBTz-T2 has a π–π stacking CL of ≈150 Å compared to ≈100 Å for 2DT-dFBTz-T2, ≈80 Å for 2DT-dFBTz-TVT, and ≈70 Å for 5DH-dFBTz-TVT. The differences in lamellar stacking CLs are not quite as stark, with the TVT polymers having values about 10–15% larger than their T2 counterparts. For the sidechains, both 5DH polymers have shorter lamellar stacking CLs than their 2DT analogs. However, the trend for π–π coherence length is not clear, as it is larger for 5DH-dFBTz-T2 but shorter for 5DH-dFBTz-TVT.

Figure 2. Energy dependence of angular conformation between dFBTz and adjacent thiophene units computed using a) DFT, and images of optimized trimer structures of b) dFBTz-T2 and c) dFBTz-TVT polymers, and their respective d,e) LUMOs and f,g) HOMOs.
versus their 2DT analogs. Overall, the GIWAXS data show that these polymers are rather crystalline with changes in molecular structure bringing about systematic differences in molecular packing.

The surface topology of the annealed films was also examined with atomic force microscopy (AFM). Surface topology images (Figure S3, Supporting Information) reveal smooth and largely homogeneous surfaces with uniform grain sizes. While the use of different sidechains does not seem to significantly impact surface topology, the TVT polymers exhibited smaller grain sizes than their respective T2 analogs, in agreement with their smaller \( \pi-\pi \) stacking CLs. This resulted in smoother surfaces with smaller root mean square (RMS) values for TVT polymers compared to T2 polymers (0.50 and 0.60 nm for 2DT-dFBTz-TVT and 5DH-dFBTz-TVT, compared to 1.46 and 1.53 nm for 2DT-dFBTz-T2 and 5DH-dFBTz-T2, respectively).

### 2.4. Thin-Film Transistor Performance

The charge transport properties of the polymers were investigated in OFETs using a bottom-contact, top-gate device configuration using thermally evaporated gold source/drain electrodes with a pentafluorophenylthiol surface treatment and Cytop as the gate dielectric (Figure S4, Supporting Information). Films of each of the polymers were prepared by spin-coating and annealed at 100 or 200 °C before deposition of the gate dielectric. Despite the rather low molecular weight of the polymers, there were no problems in forming continuous thin films. All polymers exhibited p-type behavior with little hysteresis between the forward and backward sweeps. The device parameters of all polymers annealed at 100 °C are summarized in Table 3, with the transfer and output plots shown in Figure 4. All polymers exhibited reasonable performance, despite the low molecular weights, with the 2DT-dFBTz-T2 polymer showing the highest hole mobility values of 0.2 and 0.09 cm\(^2\) V\(^{-1}\) s\(^{-1}\), in saturation and linear regimes, respectively. We note that annealing at a higher temperature of 200 °C did not significantly alter the carrier mobilities in the polymers (Table S1, Supporting Information) with the exception of 5DT-dFBTz-T2, which increased up to 0.5 cm\(^2\) V\(^{-1}\) s\(^{-1}\). However, the resulting devices displayed increased contact resistance as evident by the non-idealities (Figure S5, Supporting Information), possibly due to some film delamination from the contacts at such high temperatures.

| Polymer | Out of plane (100) | In plane (010) |
|---------|--------------------|----------------|
|         | \( q \) [Å\(^{-1}\)] | \( d \) [Å] | FWHM [Å\(^{-1}\)] | CL [Å] | \( q \) [Å\(^{-1}\)] | \( d \) [Å] | FWHM [Å\(^{-1}\)] | CL [Å] |
| 2DT-dFBTz-T2 | 0.309 | 20.3 | 0.021 | 300 | 1.760 | 3.57 | 0.064 | 98 |
| 5DH-dFBTz-T2 | 0.267 | 23.5 | 0.023 | 270 | 1.776 | 3.54 | 0.042 | 150 |
| 2DT-dFBTz-TVT | 0.321 | 19.6 | 0.017 | 370 | 1.770 | 3.55 | 0.082 | 77 |
| 5DH-dFBTz-TVT | 0.26 | 24.2 | 0.021 | 300 | 1.790 | 3.51 | 0.087 | 72 |

Figure 3. GIWAXS diffraction patterns of a,c,e,g) as-cast and b,d,f,h) annealed thin films of polymers a,b) 2DT-dFBTz-T2, c,d) 5DH-dFBTz-T2, e,f) 2DT-dFBTz-TVT, and g,h) 5DH-dFBTz-TVT.
temperatures. We therefore focus our discussion on the more reliable lower-temperature annealed devices.

Comparing the T2 and TVT polymers initially, the devices based on T2 polymers exhibited better device characteristics and higher mobility values than those based on the analogous TVT polymers. This trend coincides with the findings from the GIWAXS studies, where the T2 polymers exhibited larger π–π stacking CLs, which should enhance interchain charge transport. The reduced crystallinity of TVT polymers in the π–π stacking direction may derive from the additional degrees of freedom around the vinylene linker leading to increased disorder.

A trend was also observed with respect to the nature of the sidechain on the device performance. Both polymers containing the more synthetically complex 5DH sidechains exhibited lower performance than their simpler 2DT analogs when annealed at 100 °C, by a factor of 3 for the T2 polymers and almost an order of magnitude for the TVT polymers. We note that although most studies have found that moving the branching point further away from the conjugated polymer backbone resulted in reduced π–π stacking distance in agreement with these results,[41-45] this has not always correlated to an improved charge carrier mobility, as observed here.[42,52,53] Several studies have also highlighted a pronounced odd–even effect with regard to the length of the spacer chain between the backbone and the branching point.[46,54-56] This was related to subtle differences in sidechain density affecting backbone orientation and tilt. A similar effect may be at play in the current material, as the 2DT sidechains contains a 2C linker (even) while 5DH contains a 5C linker (odd).

Overall, the results highlight that in our case, the synthetically most accessible sidechain (2DT) and co-monomer (T2) afford the polymer with the best device performance. The results do not completely correlate with the trends in π–π stacking CLs observed by GIWAXS, which likely relates to the importance of connectivity between the polymer domains, as well as the paracrystalline disorder within the domains themselves.[57,58]

3. Conclusion

In summary, we report a straightforward synthesis of four structurally simple donor–acceptor co-polymers in which the

| Polymer         | \(\mu_{sat}\) [cm\(^2\) V\(^{-1}\) s\(^{-1}\)] | \(\mu_{lin}\) [cm\(^2\) V\(^{-1}\) s\(^{-1}\)] | \(V_{th}\) [V] | \(I_{on}/I_{off}\) |
|-----------------|------------------------------------------|------------------------------------------|----------------|----------------|
| 2DT-dFBTz-T2    | 0.2 ± 0.03                               | 0.09 ± 0.01                              | −24            | 10\(^3\)       |
| 5DH-dFBTz-T2    | 0.07 ± 0.03                              | 0.05 ± 0.03                              | −29            | 10\(^4\)       |
| 2DT-dFBTz-TVT   | 0.14 ± 0.07                              | 0.06 ± 0.01                              | −40            | 10\(^3\)       |
| 5DH-dFBTz-TVT   | 0.017 ± 0.009                            | 0.010 ± 0.006                            | −56            | 10\(^3\)       |

Table 3. Device performance of bottom-contact top-gate OFET devices with respective polymer as semiconductor.

Figure 4. a,c,e,g) Transfer curves and b,d,f,h) output curves of OFET devices comprising a,b) 2DT-dFBTz-T2, c,d) 5DH-dFBTz-T2, e,f) 2DT-dFBTz-TVT, and g,h) 5DH-dFBTz-T2 annealed at 100 °C.
position of the branching point in the sidechain was varied, along with the donor co-monomer. Optoelectronic measurements and DFT calculations showed very similar energetic properties between the polymers, with a slightly narrower bandgap for the vinylene incorporating TVT polymers as a result of extended conjugation. Comparing crystallinity in the \( \pi-\pi \) stacking direction, the introduction of a vinylene linker along the polymer backbone appeared to reduce crystallinity, possibly as a result of the increased conformational disorder, which was reflected in lower transistor performance compared to the T2 polymers. Moving the branching point further away from the backbone resulted in a decrease in \( \pi-\pi \) stacking distance, but this did not result in improved transistor performance. Out of the four polymers, 2DT-dFBTz-T2 containing the simplest sidechain and co-monomer was the best performing, with good device characteristics and an average hole mobility value of 0.2 cm\(^2\) V\(^{-1}\) s\(^{-1}\). Overall, our results demonstrate the complexity of the interplay between molecular design, thin-film morphology, and transistor performance. Importantly, in terms of synthetic complexity and scalability, these results highlight that simple and readily available sidechains can sometimes outperform their more complex analogs.

4. Experimental Section

**Characterization:** UV-vis absorption spectra were measured using a UV-1800 Shimadzu UV-Vis spectrometer. CV was measured using an Autolab Potentiostat/Galvanostat, employing a Ag/AgCl reference electrode and a Pt counter electrode. Thin films were dropcast onto the Pt working electrode, and measurements were conducted in 0.1 M tetrabutylammonium hexafluorophosphate acetonitrile solution, using the Fe/Fe\(^{3+}\) redox couple as an internal standard. GIWAXS experiments were carried out at the small-angle X-ray scattering/wide-angle X-ray scattering (SAXS/WAXS) beamline at the Australian Synchrotron.\(^{[59]}\) Further details can be found in previous publications.\(^{[60]}\) NMR spectra were measured using a Bruker DMX-400 spectrometer at room temperature. GPC measurements (vs polystyrene standards) were run on an Agilent 1200 Infinity GPC using two PL mixed B columns in series, with 1,2-dichlorobenzene as eluent at 80 °C. AFM images were captured with an Agilent 5500 in tapping mode and were processed using the Gwyddion software.

**DFT Calculations:** Polymers were modeled using a trimer of the repeat unit, with alkyl chains replaced by methyl groups for computational feasibility. Geometry optimization and natural bond orbital population analysis were carried out in Gaussian 09 at the B3LYP/6–311G**\(^{**}\) level. PES scanning was carried out at the B3LYP/6–31G** level. Molecular structure and orbitals were visualized in GaussView 5.0.

**OFET Devices:** Device fabrication and characterization were carried out under nitrogen in a glovebox. Organic field-effect transistors were fabricated with a bottom-contact top-gate architecture. 40 nm thick gold source/drain electrodes were thermally evaporated onto glass substrates through shadow masks at 10\(^{-5}\) mbar, resulting in channel lengths of 30–100 \( \mu \)m and widths of 1 mm. The work function of the gold electrodes was modified to 5.2 eV by treating the substrates with the self-assembled monolayer (SAM) pentfluorobenzethiol (PFBT) in isopropanol solution. Polymers were then spin-coated at 2000 rpm for 1 min from solutions of 10 mg mL\(^{-1}\) in anhydrous chlorobenzene, and films were annealed for 15 min. Finally, a 900 nm thick Cypot dielectric layer was applied via spin-coating followed by the thermal evaporation of aluminum to form a 40 nm thick gate electrode.

Supporting Information

Supporting Information is available from the Wiley Online Library or from the author.

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Conflict of Interest

The authors declare no conflict of interest.

Keywords

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