Improving Organic Thin-Film Transistor Performance by Nanoimprint-Induced Chain Ordering

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Organic thin-film transistors (OTFTs) have attracted much attention in recent years, due to their potential in novel flexible electronics. Particularly OTFTs based on polymer semiconductors have been extensively studied because they can be fabricated by high-throughput and low-cost solution processing for ubiquitous electronic circuits. However, polymer OTFTs suffer low performance due to low carrier mobilities in polymer semiconductors [1]. Many techniques have been developed to enhance the carrier mobilities by introducing ordered packing of polymer chains, such as synthesizing regioregular chains [2] and enhancing crystallization by liquid crystals [3] or surface treatment [4]. Recently, we observe that chain ordering can be achieved in nanoimprinted micro- and nanostructures in almost any thermoplastic polymers. In this work, we explore the possibility to enhance the performance of polymer OTFTs by nanoimprint-induced chain ordering.

Bottom-contract OTFTs based on regioregular poly(3-hexylthiophene) (P3HT) are fabricated with commonly used approaches. After photolithography to define the source and drain contacts, 5 nm titanium and 90 nm of gold are evaporated in sequence on a silicon wafer with 100 nm thermally grown oxide and lift off in a developer solution. P3HT solution in dichlorobenzene (20 mg/ml) was then spin-coated on metal contacts to form the active layer. The polymer film was annealed at 140^{o}c for 5 minutes. One P3HT OTFT without any further processing was used as a control device. The P3HT layer on another OTFT was nanoimprinted with a silicon mold at 70^{o}C and 5×10^{6} Pa (Figure 1(a)). The mold is coated with 1H,1H,2H,2H-perfluorodecyltrichlorosilane for anti-sticking and has a grating pattern of 700 nm period with 50% duty cycle. The polarized absorption spectra of the nanoimprinted P3HT is shown in Figure 1(b), which clearly indicates anisotropic absorption due to nanoimprint-induced chain ordering in P3HT. The ordered P3HT film has a stronger absorption when the polarization of the incident light is parallel to the gratings and the contrast ratio is around 3. Figure 2 shows the electrical characteristics of the OTFT devices. The drain current is enhanced by around 10 times for the nanoimprinted OTFT (Fig. 2(b)) over the pristine P3HT device (Fig. 2(a)). Further optimization of nanoimprint processing parameters will be performed to provide better understanding of the nanoimprint-induced chain ordering phenomenon and the information will be used to achieve highest improvement in OTFT performance. The approach developed in this work can be easily extended to other functional polymers to improve their performance.

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4. R. Joseph Kline, M.D. McGehee, and M.F. Toney, *Nat Mater*, 2006. **5**(3): p. 222.

(a) (b)

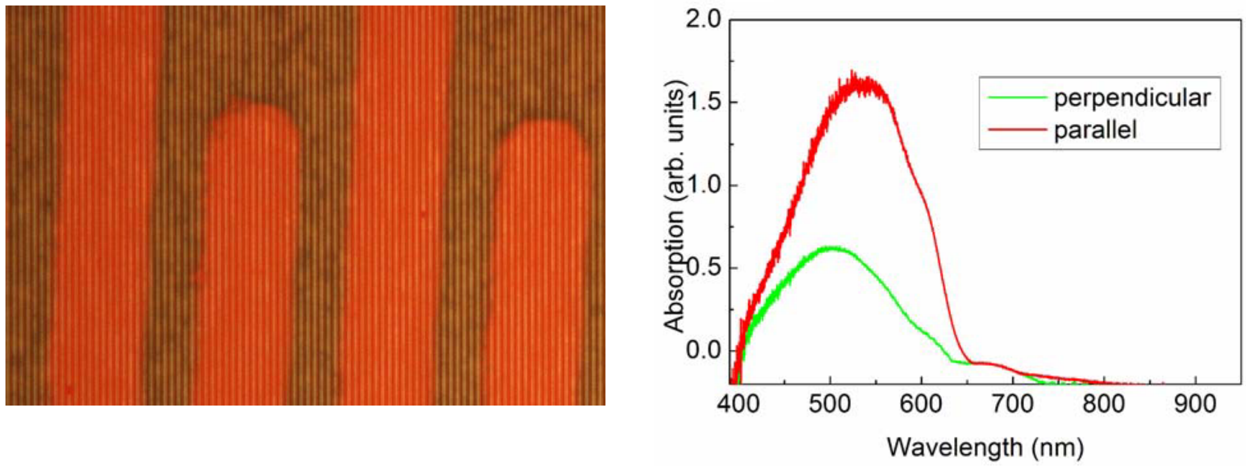

Figure 1. (a) Microscope image of nanoimprinted 700 nm period P3HT grating on gold electrodes; (b) Polarized absorption spectra of nanoimprinted P3HT.

(a) (b)

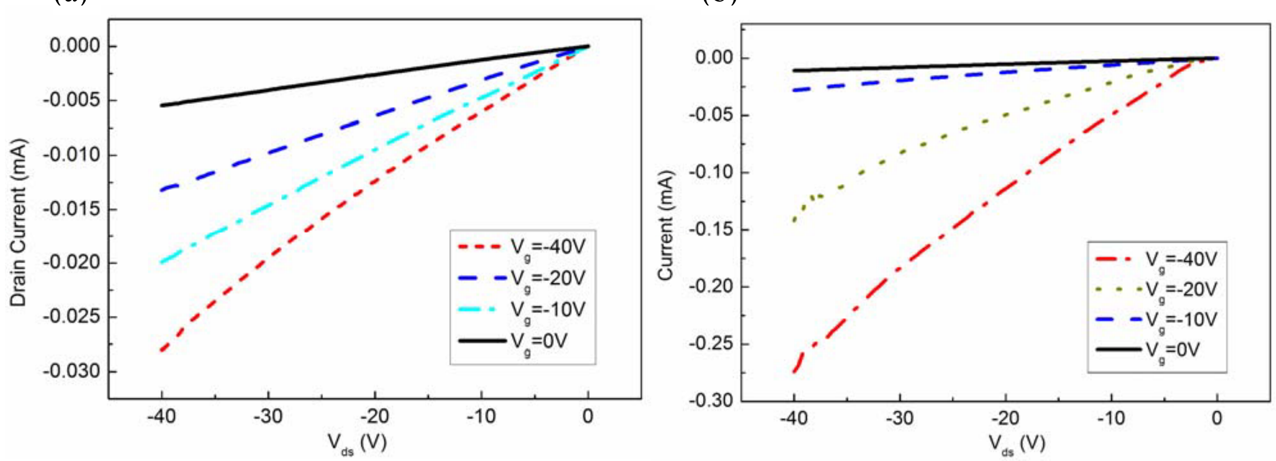

Figure 2. Output characteristics of OTFT. (a) spin-coated P3HT; (b) nanoimprinted P3HT. The current is increased by nearly 10 times in nanoimprinted OTFT.