

## Simple Patterning Techniques for fabrication of Organic Thin Film Transistors

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### Abstract

The influence of oxygen plasma and octadecyltrichlorosilane (OTS) treatment of SiO<sub>2</sub> on the patterning of poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT:PSS) is presented. A significant difference in surface energies between plasma treated and OTS treated SiO<sub>2</sub> was noted. Such heterogeneous surface energy guides PEDOT:PSS to wet and spread on the wettable region and to dewet and retract from other regions.

### 1. Introduction

Organic thin film transistors (OTFTs) have been extensively studied for many applications such as display operation, identification tags, and sensors. The reasons why we investigate the organic transistors are their low cost and simpler packaging, relative to conventional inorganic electronics, and their compatibility with flexible substrates. This capability, however, has practical advantage only when it is coupled with low cost patterning approaches that can be applied directly to these materials or to those that are compatible with them.<sup>1</sup>

Conventional patterning techniques, such as photolithography and electron beam lithography, are not well suited to plastic electronics because

they are expensive and generally require multiple processing steps with resists, solvents, and developers that can be difficult to use with organic active materials.<sup>2</sup>

Particularly in the context of low cost, large volume manufacturing, there is a need to demonstrate that inexpensive material deposition and patterning processes can be integrated with existing device concepts with adequate performance. As an alternative to the vacuum deposition and photolithographic patterning of the various functional films, the use of high-resolution patterning techniques is of particular interest.

Here, we have developed a process in which microcontact printing of a self-assembling layer is used to create hydrophobic regions on the hydrophilic surface and report this simple patterning technique to form organic source/drain microstructure for OTFT.

### 2. Experiment

Thermally grown SiO<sub>2</sub> was used as the substrate. It was first cleaned in a trichloroethylene, acetone, and isopropyl alcohol in an ultrasonic bath, rinsed in deionized water and finally dried in a high purity N<sub>2</sub> gas stream. After cleaning, the substrate was oxygen plasma treated in a plasma etcher for

30 sec at RF power of 30 W. The pressure of the chamber and the flow rate of the oxygen were 150 mTorr and 15 sccm, respectively. Surface energy values as a sum of dispersion and polar components were calculated using the geometric-mean method from contact angles measured with water and di-iodomethane. Contact angles were measured by sessile drop technique at room temperature in air using a contact angle analyzer (SEO Phoenix300).

After oxygen plasma treatment, OTS was deposited by microcontact printing method using micropatterned PDMS (Sylgard 184, Dow Corning) mold. The PDMS molds used in the experiment were prepared by casting PDMS with a curing agent in the ratio of 10 to 1 against the master prepared by photolithography. And then PEDOT:PSS was spin coated on patterned substrate.

### 3. Results

Table 1 shows the measured contact angles for different surface treatments of the SiO<sub>2</sub>. In comparison with as-received SiO<sub>2</sub> sample, plasma treated SiO<sub>2</sub> showed much smaller contact angles with water. This result can be attributed to plasma treatment removes effectively the contaminants from the surface and formation of surface hydroxyl species.

We also calculated the dispersion and polar components of the surface energy and the polarity ( $\gamma_p = \gamma^p/\gamma$ ) of each sample is shown in table 2.<sup>3</sup> The oxygen plasma shows a large increase in the surface energy and polarity compared to the as-received SiO<sub>2</sub>, mainly due to significant enhanced the polar component. This indicates that the

plasma treated surfaces are highly polar. The high value of polar component represents a strong polar interaction, which also would improve adhesion.

**Table 1. Contact angles of SiO<sub>2</sub>.**

	As-received	Plasma treated	OTS treated
water	59.3 °	14.2 °	89.4 °
di-iodomethane	33.4 °	54.7 °	58.2 °

**Table 2. Surface tension parameters (in mJ/m<sup>2</sup>) of test liquids.**

	$\gamma$	$\gamma^p$	$\gamma^d$	$\gamma_p$
As-received	49.2	15.0	34.2	0.30
Plasma treated	70.9	53.6	17.3	0.76
OTS treated	29.9	3.1	26.8	0.10

For the contact with water, we note that OTS treatment produces a significant increase of the measured contact angle compared with the as-received SiO<sub>2</sub> from 59.3° to 89.4°. The surface energies and polarities of OTS treated SiO<sub>2</sub> are also listed in Table 2. In comparison with the as-received sample, SiO<sub>2</sub> treated by OTS had a lower surface energy and polarity. This implies that the OTS treated SiO<sub>2</sub> surface is nonpolar.

The results we obtained confirm that the total surface energy of SiO<sub>2</sub> was changed considerably by the treatments used here. A significant difference in surface energies between plasma treated and OTS treated SiO<sub>2</sub> was noted. Such

heterogeneous surface energy guides PEDOT:PSS to wet and spread on the wettable region and to dewet and retract from other regions.<sup>4</sup>

The patterned microstructure was investigated using scanning electron microscope (SEM) (Hitachi S4200) and optical microscopy. Figure 1. provides well defined OTS patterns on SiO<sub>2</sub> surface with spacing 150  $\mu$ m. During the spin coating, PEDOT:PSS selectively deposits only in regions with similar wettability and the result was shown in Fig. 2.

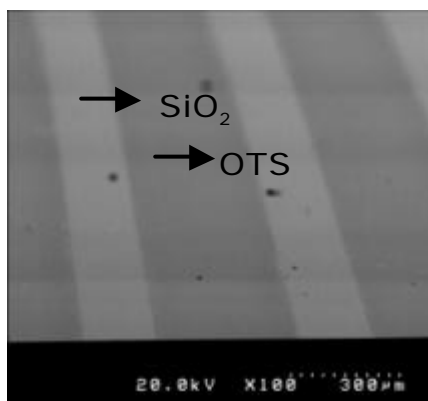


Figure 1. SEM image of patterned SiO<sub>2</sub> surface.

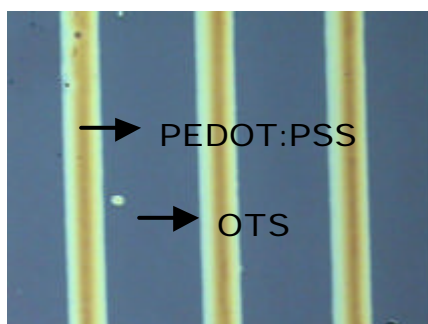


Figure 2. Optical microscopy image of patterned SiO<sub>2</sub> surface.

#### 4. Conclusion

In organic electronics, the polymers need to be patterned using methods suitable for polymers and which do not add great cost to device fabrication. The simple patterning technique developed here replaces the several complex steps required for photolithography. We report simple patterning techniques to form organic source/drain microstructure for organic thin film transistors (OTFTs). Next, Fabrication of OTFTs with micron feature sizes will be presented to demonstrate this approach.

#### 5. References

- [1] D. A. Pardo, G. E. Jabbour, N. Peyghambarian, *Adv. Mater.* **12**, 1249 (2000).
- [2] J. Birnstock et al., *Appl. Phys. Lett.* **78**, 3905 (2001).
- [3] D.K. Owens, R.C. Wendt, *J. Appl. Polym. Sci.* **13**, 1791 (1969).
- [4] T. Shimoda, S. Kanbe, H. Kobayashi, S. Seki, H. Kiguchi, I. Yudasak, M. Kimura, S. Miyashita, R.H. Friend, J.H. Burroughes, C.R. Towns, *Tech Digest of SID 376* (1999).