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Letter

Influence of passivation with non-charged fluorinated ethylene propylene on the properties of pentacene organic thin film transistor

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ABSTRACT

High electronegativity of non-charged fluorinated ethylene propylene (FEP) affected the performance of pentacene organic thin film transistors (OTFTs). The threshold voltage of the OTFT shifted from −14.7 V to −12.5 V without deterioration of on–off ratio and charge mobility. The degree of shift was related to the coverage of the FEP film on an active layer. No further shift was observed upon reaching the full coverage of surface at a 3-nm thickness of FEP. Encapsulation of the FEP-covered pentacene OTFT in a multilayer of PMMA/PUA/PET protected the device from oxygen and moisture.

The study of organic thin film transistors (OTFTs) has been a major area of research on organic semiconducting materials and devices. Compared with inorganic devices, OTFTs have many advantageous features, such as low cost, easy packaging, and more adaptability for flexible substrates. Therefore, OTFTs have been used for various applications, including integrated circuits [1], flat panel displays [2], chemical vapor sensors [3], and solar cells [4].

Various materials have been studied as organic semiconductors. Among those, pentacene is considered to be promising for OTFTs because of its high hole mobility [5]. Many characteristics of pentacene transistors have been investigated, including study of the influence of various dielectrics [6,7], solvent exposure [8], and hysteresis on the performance of OTFTs [9]. However, despite extensive research, it has not yet been possible to extend the lifetime of pentacene OTFTs to an acceptable period because of their high susceptibility to moisture and oxygen. To protect the device from these damaging factors and expand device lifetime, a process of passivation [10] is required. A previous passivation method using a polymer layer consisting of polymethylmethacrylate (PMMA) was observed to impair device performance, because the organic solvent used in the coating process eroded the surface of the pentacene layer. PMMA (10 wt% in toluene) coating of the pentacene transistor was also shown to decrease charge-carrier mobility.

In this paper, we introduce a method of passivation that uses fluorinated ethylene propylene (FEP) to reduce the deterioration caused by encapsulating pentacene OTFTs with a polymer solution. It has been reported that corona-charged Teflon can be used as a material for the passivation of pentacene OTFT [11]. However, although passivation with corona-charged Teflon favorably controls the threshold voltage, it causes a decrease in the on–off current ratio and mobility. We were motivated to use non-charged FEP as the passivation material because of its potential to block organic solvents during the coating process without decreasing the on–off ratio and charge mobility. We therefore investigated the effect of using FEP as the passivation material on–off ratio and charge

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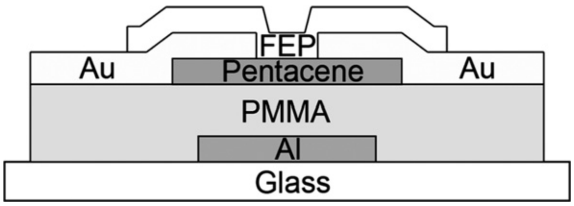

Fig. 1. Schematic illustration of the bottom-gate and top-contact pentacene OTFT with FEP capping.

mobility. We also investigated the level of threshold voltage shift as a function of the coverage of FEP film on the surface of the pentacene and the effects of further covering the device with a polymer multilayer to improve air resistivity.

We used a bottom-gate and top-contact OTFT as shown in Fig. 1. The glass substrate was washed with detergent solution rinsed with de-ionized water and placed in trichloroethylene, acetone, and isopropyl alcohol. An aluminum gate (50 nm) was deposited onto the glass substrate by thermal evaporation. Optical PMMA in toluene was then spin-coated for a gate dielectric layer (1 μm) in air. After annealing at 80 °C for 1 h, the device was transferred into an argon-purged glove box. Pentacene (70 nm) and gold electrode (70 nm) were thermally evaporated on the PMMA surface in a sequential manner. Subsequently, FEP was deposited by thermal evaporation on the pentacene layer, which was located between the source and the drain electrode (Fig. 1). The rate of deposition was 0.5–0.7 Å/s as measured by a quartz-crystal deposition monitor (Sycon Instruments, STM-100/MF). Thermal evaporation was performed in a high vacuum of 5×10^{-6} Torr. All measurements were made in an argon-purged glove box to avoid the influence of oxygen and moisture. The carrier mobility in the saturated region was determined by the following equation:

$$I_D = \frac{WC_i}{2L}\mu_e(V_G - V_T)^2 \tag{1}$$

where I_D is the drain current; W and L are the channel width and length, respectively; μ_e is the effective mobility;

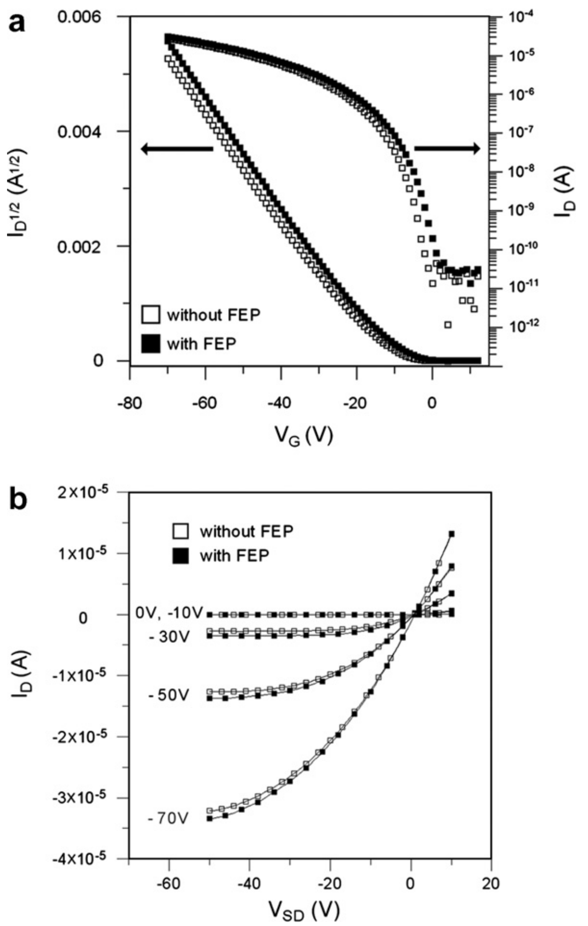

Fig. 2. Electrical characteristics of the pentacene OTFTs without and with FEP layer. (a) Drain current (I_D) (right y-axis, logarithmic scale) and the square root of I_D (left y-axis) versus gate voltage (V_G) curves. The data points were obtained while the gate voltage was scanned from +10 to −70 V. (b) Drain current (I_D) versus source–drain voltage (V_{SD}) curves.

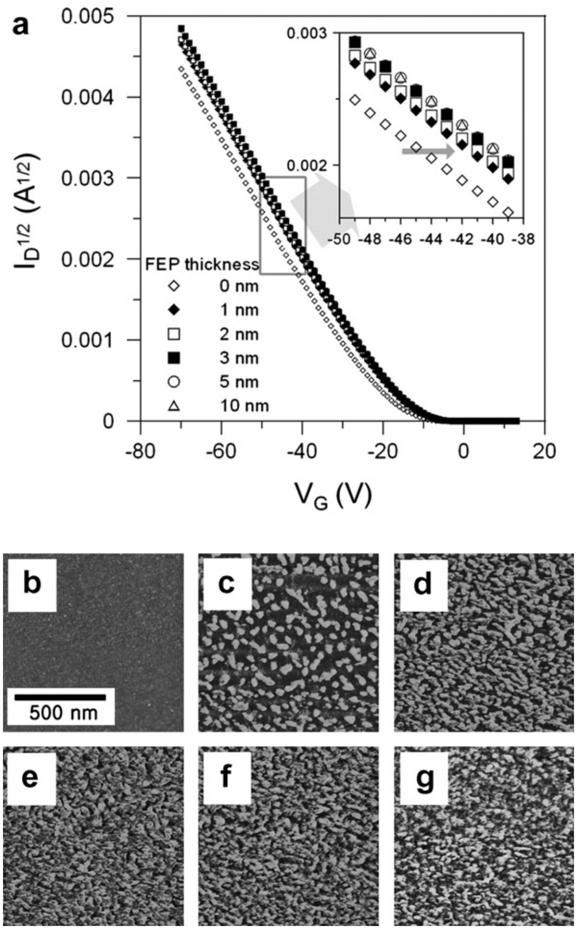

Fig. 3. (a) Characteristics of the pentacene OTFT with varying FEP thickness of 0, 1, 2, 3, 5 and 10 nm. Inset is the zoom image of the indicated area. (b–g) AFM images of the pentacene surface, where FEP is deposited with different thickness: (b) 0, (c) 1, (d) 2, (e) 3, (f) 5 and (g) 10 nm.