Effect of Acceptor Strength on Memory Characteristics of Nonvolatile Transistor Memory Devices using Polyimides Electrets

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Introduction

Donor-acceptor polymers can enhance the charge storages through the induced intramolecular charge transfer (ICT) from the donor to acceptor moiety under an applied electric field. Donor-acceptor polyimides (PIs) have been explored for applications in organic electronics,[1-2] due to their good electrical properties, thermal stability and chemical resistance. Among the studied functional PIs, the triphenylamine (TPA)- based PIs attract significant attention.[3] We report the memory behavior of *p*-type pentacene based OFET memory devices using polyimide electrets. The polyimide electrets, PI(6FDA-TPA-CN), PI(DSDA-TPA-CN) and PI(BTDA-TPA-CN), are consisted of electron-donating 4,4′-diamino-4″-cyanotriphenylamine (TPA-CN) and electron-accepting moieties, including 4,4'-(hexafluoroisopropylidene)diphthalic anhydride (6FDA), 3,3′,4,4′-diphenylsulfonyltetracarboxylic dianhydride (DSDA) and 3,3′,4,4′-benzophenonetetracarboxylic dianhydride (BTDA). Our experimental results provide a systematic studying for the relationship among electrets with different electron-accepting moieties, charge transport and memory characteristics.

Results and Discussion

The memory characteristics of PI(BTDA-TPA-CN), PI(DSDA-TPA-CN), and PI(6FDA-TPA-CN) were examined through OFET memory devices with a bottom-gate/top-contact configuration using *p*-type pentacene as a charge transport layer, as shown in **Figure 1**. The order on the mobility of the pentacene devices with different polymer electrets is PI(6FDA-TPA-CN) (0.5 $cm^2V^{-1}s^{-1}$) > PI(DSDA-TPA-CN) (0.21 $cm^2V^{-1}s^{-1}$) > PI(BTDA-TPA-CN) (0.09 $cm^2V^{-1}s^{-1}$). It is in the same trend as the grain size of pentacene on the three PIs. The grain size on the PI(BTDA-TPA-CN), PI(DSDA-TPA-CN) and PI(6FDA-TPA-CN) surfaces are 178, 212, and 305 nm, respectively. **(Figure 2)** To evaluate the electrical memory performance, the device was operated by applying appropriate gate pulse (± 100V) for one second to lead the shifts of the transfer curves. **Figure 3** shows the transfer curves of the OFET memory devices based on the pentacene with polyimides as electrets. The memory windows between writing and erasing process are 30, 65, and 84 V for PI(BTDA-TPA-CN), PI(DSDA-TPA-CN) and PI(6FDA-TPA-CN), respectively. Molecular simulation on the basic unit of PI(6FDA-TPA-CN), PI(DSDA-TPA-CN) and PI(BTDA-TPA-CN) was carried out. **(Figure4)** Moreover, due to the higher dipole moment and larger torsion angle of PI(6FDA-TPA-CN), leading the more stable charge transfer complex. Thus, the device with PI(6FDA-TPA-CN) exhibited the largest memory window of 84 V. The stability for ON and OFF state can maintain 10^4 s with I_{on}/I_{off} current ratios of 10^4 for PI(6FDA-TPA-CN). The write-read-erase-read (WRER) cycles can be operated over 100 cycles. **(Figure 5)**

Conclusions

We have demonstrated that the charge transport and controllable electrical switching behavior of the pentacene-based OFET memory with three high dielectric constant donor-acceptor PIs as electrets. The pentacene OFET memory device based on the PI(6FDA-TPA-CN) electret exhibited the highest field-effect mobility and the largest memory window compared to the others because the relatively higher dipole moments of PI(6FDA-TPA-CN) compared to the PI(DSDA-TPA-CN) or PI(BTDA-TPA-CN) provided a stable CT complex, thus, PI(6FDA-TPA-CN) traps the charges deep and led the larger memory window. Furthermore, the memory devices exhibited high ON/OFF ratio and the ON or OFF state could be retained over 10^4 s. The write-read-erase-read (WRER) cycles could maintain over 100 cycles. The present study suggests that the donor-acceptor polyimide electrets can have potential applications for high performance nonvolatile OFET memory devices.

Reference

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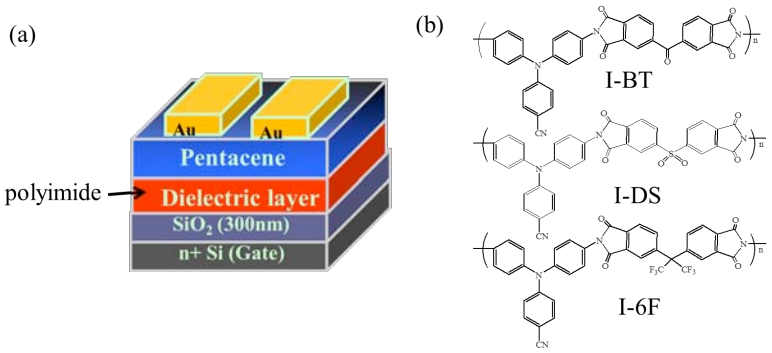

Figure 1. (a) Schematic configuration of the pentacene-based OFET memory device. (b) Chemical structure of various polymer dielectrics.

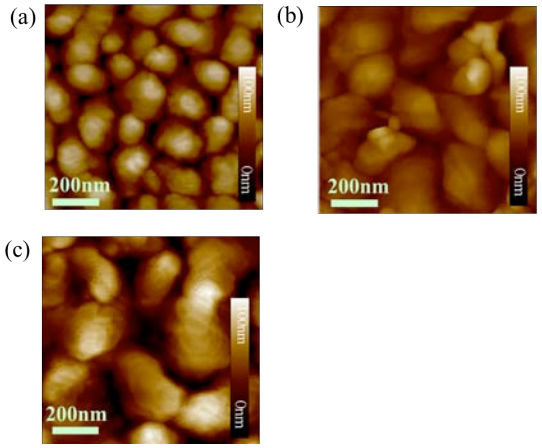

Figure 2. AFM topographic images of pentacene on different polymer surface: (a) PI(BTDA-TPA-CN), (b) PI(DSDA-TPA-CN) and (c) PI(6FDA-TPA-CN) on 1 μm x 1 μm area

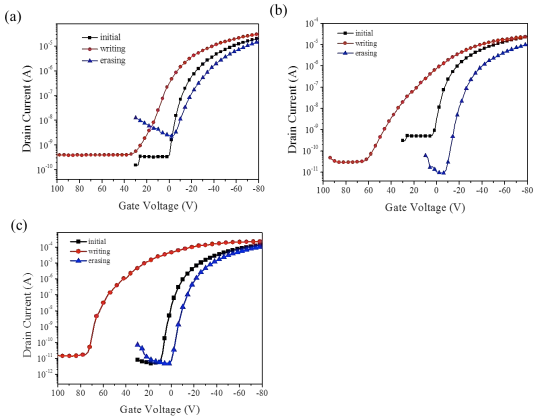

Figure 3. Shifts in transfer curves for BPE-PTCDI OFET memory device with (a) PI(BTDA-TPA-CN), (b) PI(DSDA-TPA-CN) and (c) PI(6FDA-TPA-CN) as polymer electrets.

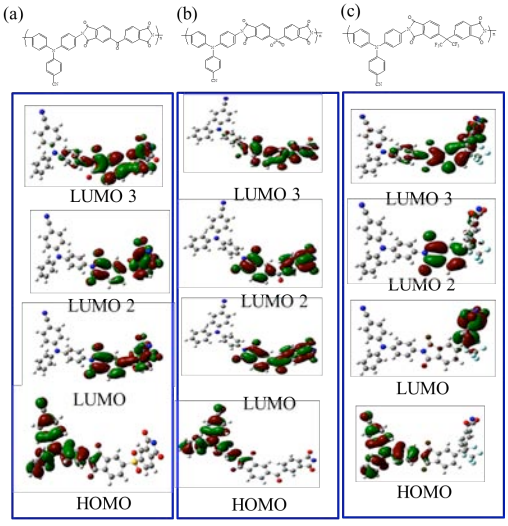

Figure 4. Molecular orbitals of the (a)PI(BTDA-TPA-CN), (b) PI(DSDA-TPA-CN) and (c) PI(6FDA-TPA-CN) as polymer electrets

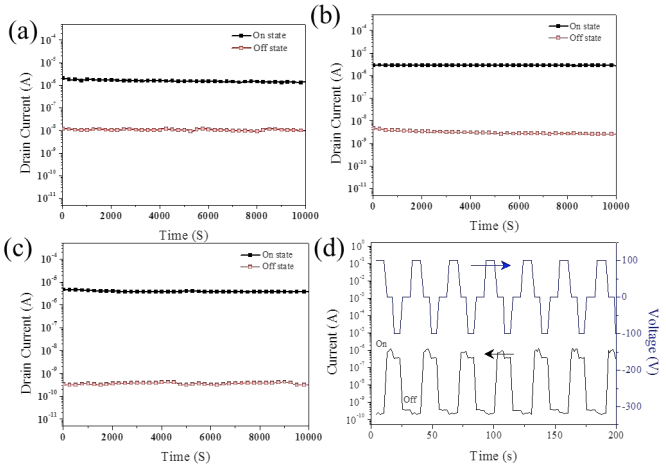

Figure 5. Retention time testing of the OFET memory devices based on pentacene thin film with (a) PI(BTDA-TPA-CN), (b) PI(DSDA-TPA-CN) and (c) PI(6FDA-TPA-CN) as electrets, (d) reversible current response to the WRER cycles of pentacene OFET memory device with PI(6FDA-TPA-CN) as electret.