New Donor-Acceptor Oligoimides for High-Performance Memory Device Applications

Tadanori Kurosawa,[1] Yi-Cang Lai,[2] An-Dih Yu,[3]
Tomoya Higashihara,[1] Mitsuru Ueda,[1,*] and Wen-Chang Chen[2,3,*]
[1]Department of Organic and Polymeric Materials, Tokyo Institute of Technology
2-12-1 Ookayama, Meguro-ku, Tokyo 152-8552, Japan
[2]Institute of Polymer Science and Engineering, National Taiwan University, Taipei 10617, Taiwan
[3]Department of Chemical Engineering, National Taiwan University, Taipei 10617, Taiwan
E-mail: (W.-C.C.) chenwc@ntu.edu.tw; (M.U.) ueda.m.ad@m.titech.ac.jp.

Introduction

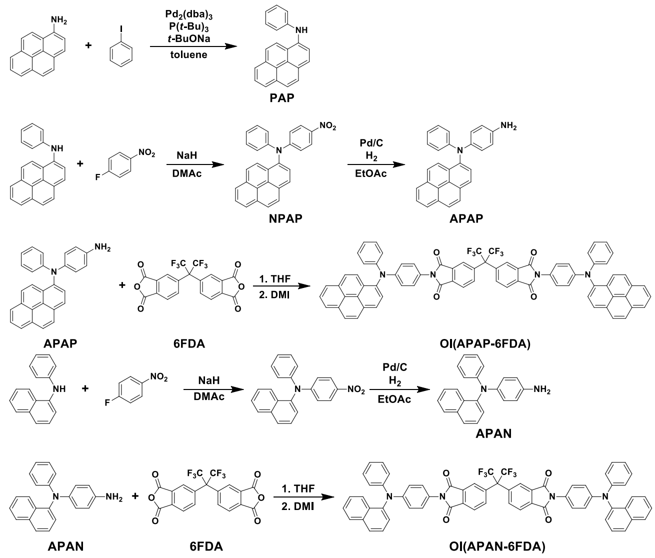
For organic resistor-type memory devices, the relationship between chemical structure and memory characteristic is widely investigated in the polymer system, only few has been done in the small molecule system. Moreover, the application of organic donor-acceptor (D-A) molecules to memory devices has rarely been studied. Previous studies reported that the architecture of conjugated D-A type molecules clearly affected the ON/OFF ratio and reversibility of the memory characteristics[1, 2]. In this report, the I-V study of different donor units assigned in a D-A-D single-molecule-arrangement shows that the effects of the conformation and dipole moment of the molecules resulted in different memory properties.

Results and Discussion

Two novel oligoimides, **OI(APAP-6FDA)** and **OI(APAN-6FDA)**, consisting of electron-donating *N*-(4-aminophenyl)-*N*-phenyl-1-aminopyrene (**APAP**) or *N*-(4-aminophenyl)-*N*-phenyl-1-aminonaphthalene (**APAN**) and electron-accepting 4,4'-(hexafluoroisopropylidene)diphthalic anhydride (**6FDA**) moieties were designed and synthesized for high-performance memory device applications (**Scheme 1**). The devices with indium tin oxide (ITO)/oligoimides/Al configuration (**Figure 2**) showed the multi-memory characteristics changing from high-conductance ohmic current flow (**Figure 1. (a)(d)**) to negative differential resistance (NDR) (**Figure 1. (b)(e)**) with the corresponding film thickness of 38 and 48 nm, respectively. The 48 nm oligoimide film devices exhibited the NDR electrical behavior, resulting from the diffusion of Al atoms into the oligoimide layer. Further increasing the film thickness to 85 nm, **OI(APAP-6FDA)** film device showed the reproducible non-volatile write once read many (WORM) (**Figure 1. (c)**) characteristic with the high ON/OFF current ratio more than 10^4. On the other hand, the device based on 85 nm **OI(APAN-6FDA)** film exhibited volatile static random access memory (SRAM) (**Figure 1. (e)**) property. The longer conjugation length of pyrene unit to naphthalene unit is considered to be responsible for the different memory characteristics between these two oligoimides. The experimental results suggested that the tunable switching behaviors could be controlled through the design of donor-acceptor oligoimide structure and the active layer thickness.

Reference

1. Ma, Y.; Cao, X.; Li, G.; Wen, Y.; Yang, Y.; Wang, J.; Du, S.; Yang, L.; Gao, H.; Song, Y. *Adv. Funct. Mater.* **20**, 803(2010).
2. Lee, W. Y.; Kurosawa, T.; Lin, S. T.; Higashihara, T.; Ueda, M.; Chen, W. C. *Chem. Mater.* **23**, 4487(2011).



Scheme 1. Synthetic routes for **OI(APAP-6FDA)** and **OI(APAN-6FDA)**

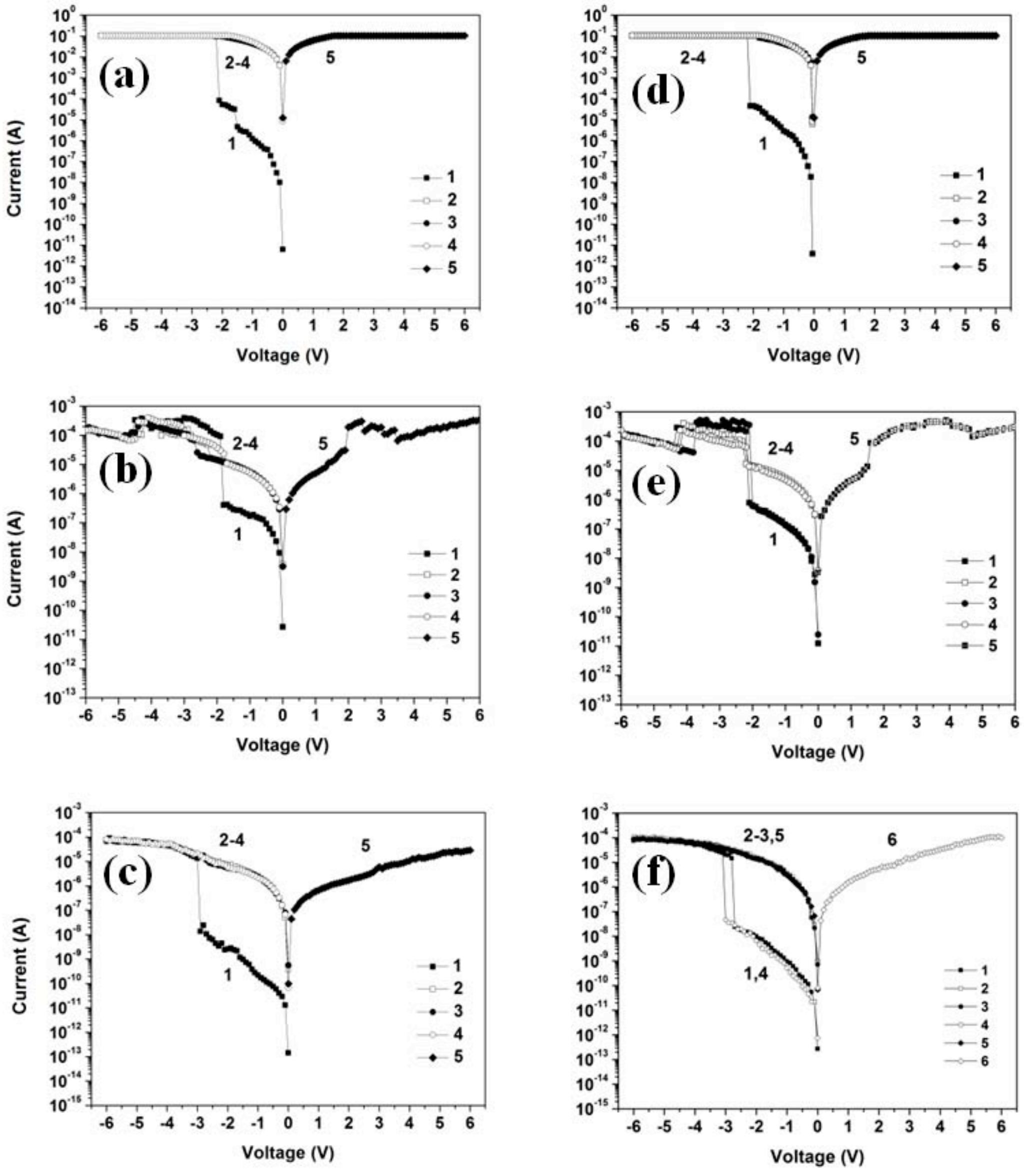


Figure 1. Current-voltage (I-V) characteristic of (a) ITO/**OI(APAP-6FDA)** (38 nm)/Al device, (b) ITO/**OI(APAP-6FDA)** (48 nm)/Al device, (c) ITO/**OI(APAP-6FDA)** (85 nm)/Al device, (d) ITO/**OI(APAN-6FDA)** (38 nm)/Al device, (e) ITO/**OI(APAN-6FDA)** (48 nm)/Al device, and (f) ITO/**OI(APAN-6FDA)** (85 nm)/Al device.

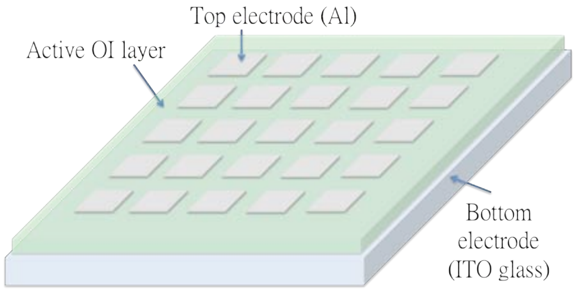


Figure 2. Schematic memory device architecture.

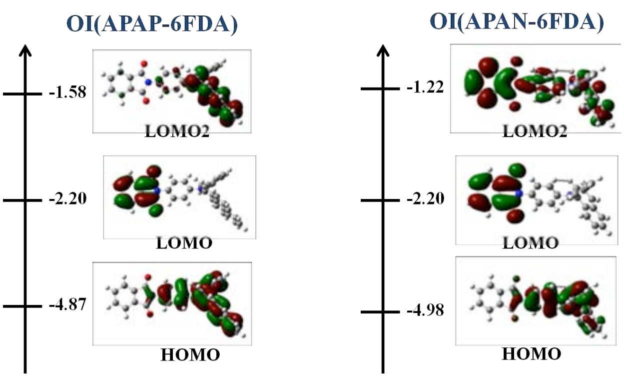


Figure 3. Estimated HOMO and LUMO energy levels of the donor and acceptor moieties.