A New Type of Multilevel Organic Field Effect Memory Transistors using Lithium-ion-encapsulated Fullerene

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Memories based on organic field-effect transistors (OFETs) have been researched intensively in recent years because of their simple structure of a single transistor, less lost of reading as well as easily integrated in electronic circuits[1]. Memory effect can be observed by using polymer electrets such as Cytop[2]. The development of multilevel data storage has captivated considerable attention in order to get more than 1 bit data in each cell[3,4]. In this paper, we report the multilevel organic field effect memory transistors using lithium-ion-encapsulated fullerene ($Li^+@C_{60}$) (Fig. 1a).

The top-contact OFETs using heavily doped p-type silicon wafers with a 400-nm-thick silicon dioxide were fabricated (Fig. 1b). The layers of $Li^+@C_{60}$ NTf_2^- (island-formed) and Cytop (10 nm) were spin-coated on the silicon dioxide. Subsequently, a 50-nm layer of pentacene and copper electrodes (50 nm) were deposited at the pressure of 2.5×10^{-5} Torr.

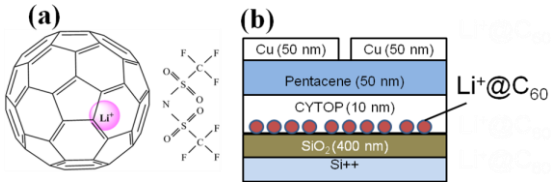

Fig. 1. (a) The chemical structure of $Li^+@C_{60}$ NTf_2^- and (b) the schematic structure of memory OFETs

The OFET memories exhibited a good performance with low threshold voltage (V_{th}) of ‑ 5.98 V and high electron mobility (μ) of 0.75 $cm^2V^{-1}s^{-1}$. For programming, a voltage of 150 V was applied to the gate for 0.5 s, 5 s, and 50 s, which causes the shifts of transfer curve from the initial state. The estimated shifts of V_{th} are 10 V, 16 V and 32 V, respectively (Fig. 2). In order to go back to erased state, a negative voltage of –150 V is applied for 0.17 s, 1.7 s and 17 s, respectively. The most important feature of our memory devices is that the transfer curve of programmed states can go back to that of erased state. This characteristic can not be observed in the devices without $Li^+@C_{60}$ layer. Thus, it is clear that $Li^+@C_{60}$ make these OFETs function as multilevel memories. In addition, we confirmed that the each states can be clearly distinguished after 1000 seconds by the measurement of the retention characteristic (Fig. 3), which suggests that $Li^+@C_{60}$ would be a promising material for multilevel memories based on OFETs.

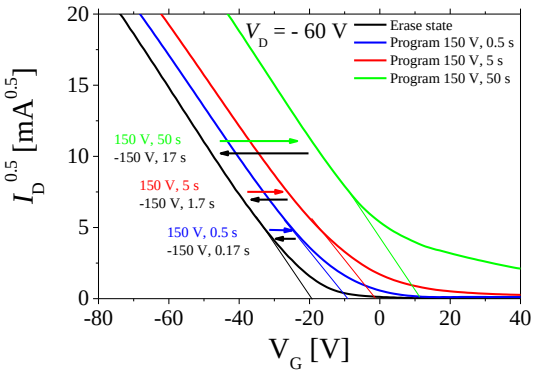

Fig. 2. $(I_D)^{0.5} - V_G$ curves of memory transistor

In conclusion, the multilevel memory transistors were fabricated using $Li^+@C_{60}$. More details of device operation and an analysis on operation mechanism will be reported in the presentation.

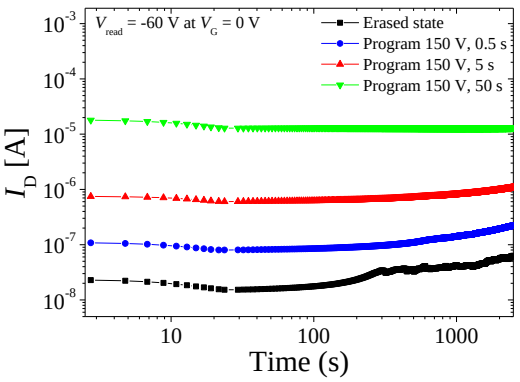

Fig. 3. Retention time characteristics of I_D in various programmed and erased states

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[3] K. Tripathi et al., Adv. Mater. **23** (2011) 4146.
[4] K.-J. Baeg et al., Adv. Mater. **22** (2012) 2915.