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High Performance Organic Nonvolatile Memory Device ----a Direct Challenge to the Si Technology

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1. Introduction

Electrical bistability is a phenomenon in which a device exhibits two states of different conductivities at the same applied voltage, which is promising for switch and memory devices application. We demonstrate a high performance organic electrical bistable device (OBD) with the structure of organic/metal/organic multi-layers interposed between two electrodes [1,2].

2. Organic bistable device (OBD)

The structure of our OBD is simple and consists of an organic/metal/organic (O/M/O), triple-layer structure interposed between an anode and a cathode (Fig. 1a). We selected organic compounds with relatively high dielectric constant and good film-forming characteristics. we discuss the results obtained using 2-amino-4, 5-imidazoledicarbonitrile (AIDCN) as the organic layer, and aluminum (Al), as the embedded metal layer and also the electrode layers. The chemical structure of AIDCN is shown in Fig.1b.

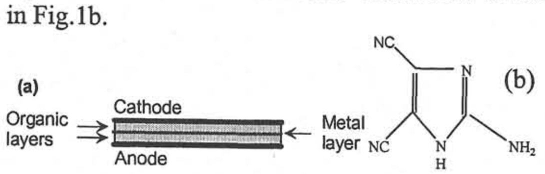

Fig. 1 (a) the device structure, (b) AIDCN.

The first voltage scan, depicted by curve *a*, shows a sharp increase in the injection current at about 2 volts indicating the transition of the device from the low conductivity state (OFF state) to a high conductivity state (ON state). This transition from the OFF state to the ON state is equivalent to the "writing" process in a digital memory cell. The ratio of the conductivities achieved between the two states is in several orders in magnitude. After this transition, the device remains in this state even after turning off the power. This can be seen in the second voltage scan (curve *b*) in Figure 2. One of the most important features of our OBD is that the OFF state can be recovered by the simple application of a reverse voltage pulse. This is equivalent to the "erasing" process. Curve *c* in Figure 2 shows the I-V characteristics of the device after the application of a –3V bias; However, the bistable behavior, the OFF-ON transitions, and the creation of nonvolatile memory effects can be observed only in the presence of the embedded thin metal layer.

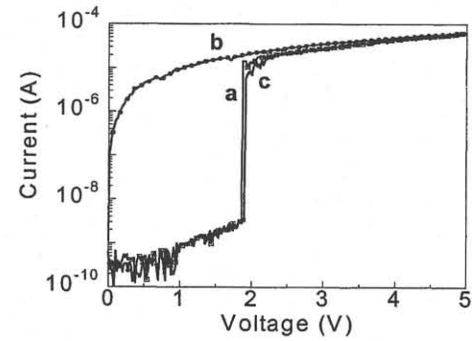

Fig. 2 I-V characteristics of an OBD. (a) and (b) are for the first and second bias scan respectively. (c) the third bias scan after the application of a reverse voltage pulse.

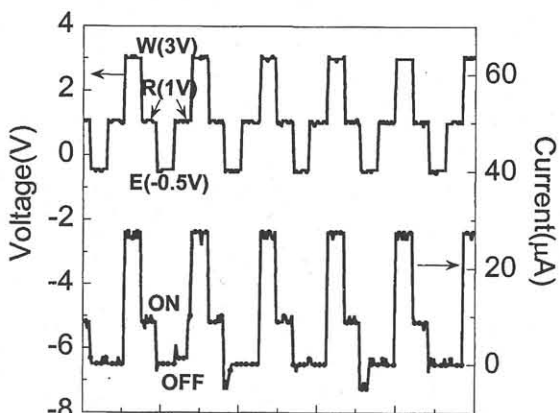

Fig. 3 Typical current responses of an OBD during the write-read-erase-read voltage cycles; the writing voltage pulse (W) is 3 V, the erasing voltage pulse (E) is –0.5V. In order to confirm the successful registration of the ON and OFF states, a small reading bias (R) of 1V was applied to the device immediately following the writing and erasing pulses to determine the state of the OBD.

One of the promising applications of the OBD is the organic rewritable memory (ORAM), which can be used in personal computers, personal digital assistants (PDA), and digital cameras etc. The precise control over the ON-OFF states, multiple rewriting ability, and device stability are the key issues for these applications. More than 1 million write-erase cycles were conducted on our OBD with good rewritable characteristics as shown in Figure 3.

The switching time for the OBD is in the nanoseconds time scale (Figure 4). The switching time of 10 nanoseconds originates from the RC time constant of the measurement system. The actual switching time is likely to be faster than 10 ns.

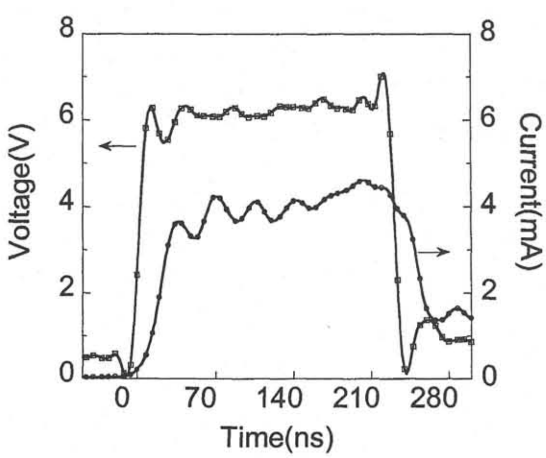

Fig. 4 Dynamic response of an OBD initially at OFF-state. Under a voltage pulse (6 V) higher than the switch-on voltage for ~10 nanoseconds transforms it to the high conductivity state.

3. Organic bistable light-emitting diode

The OBD device can easily incorporate with other organic devices and having new characteristics. For example, we demonstrate a new type of memory device by incorporating the OBD with a polymer light-emitting diode (PLED). This combination makes the organic bistable light-emitting device (OBLED) a unique memory device which can be addressed electrically, but the readout is both electrical (in serial) or optical (in parallel). In addition to being a high throughput memory device, this device is also ideal used as an electronic book. The device structure is simply stacking the OBD with a PLED, and the device I-V curves are shown in Fig. 5.

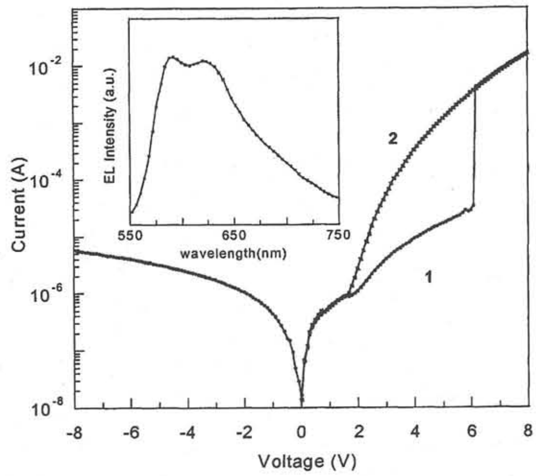

Figure 5. I-V characteristics of an OBLED (curve 1 is for the first bias scan and curve 2 is for the second bias scan). The inset is the EL spectrum.

4. Summary

We report a novel organic electrical bistable device comprising of a thin metal layer embedded within the organic material, as the active medium. The performance of this new device makes it attractive for memory cell type of applications. The two states of the OBD differ in their conductivity by several orders in magnitudes, and show remarkable stability, i.e., once the device reaches either state, it tends to remain in that state for a prolonged period of time. More importantly, the high and low conductivity states of an OBD can be precisely controlled by the application of a positive voltage pulse (to write) or a negative voltage pulse (to erase), respectively. One million writing-erasing cycles for the OBD have been achieved in ambient conditions without significant device degradation. These discoveries pave the way for newer applications, such as low-cost, large-area, flexible, high-density, electrically addressable data storage devices.

Acknowledgements

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References

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