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Novel Sub-10nm Polymer Thin Film Resistance Switching Device

Dongjin Lee¹, Seungchul Choi², Moonhor Ree² and Ohyun Kim¹

¹Department of Electronic & Electrical Engineering and ²Department of Chemistry,
Pohang University of Science and Technology (POSTECH), Pohang, Gyeongbuk, 790-784, Republic of Korea.
Phone: +82-54-279-5932, Fax: +82-54-279-5894, E-mail: djlee@postech.ac.kr

1. Introduction

Over the past decade, research on conjugated polymers and other organic materials has attracted widespread interest due to their applications in optical and electronic devices [1-3]. Among them, memory devices formed from conjugated polymers have received considerable attention because they have significant advantages over inorganic materials in that their dimensions can easily be miniaturized and their properties can easily be tailored through chemical synthesis. Recently, the Amlan J. Pal group reported that conductance switching behavior can be obtained from Rose Bengal [4]. Tu et al. demonstrated electrical bistability and the memory effect in Alq3 film [5]. Also, two conducting states have been observed at the same applied voltage when a thin metal layer was embedded in the organics [6].

This paper demonstrates the resistive memory device based on ultra-thin (<10nm) poly(o-anthranilic acid-co-aniline) films, which is the copolymerization of anthranilic acid and polyaniline. The as-fabricated device exhibits unipolar switching with control of the current compliance which is different from the bipolar switching process reported previously [7]. As the unipolar switching device can be operated using a diode, memory density can be increased enormously by combining multi-layer and 1D1R cross-point structures [8].

2. Experiments

Figure 1 shows a schematic cross-sectional and TEM images of the simple Ti/polymer/Al device and the chemical structure of the poly(o-anthranilic acid-co-aniline). The memory device was fabricated as follows. 300nm thick Al was deposited on a Si substrate. The polymer solution was spun on the Al/Si substrate at 500 rpm for 10s, followed by 1000 rpm for 30s and then 2000 rpm for 20s. The spun films were dried on a hot plate at 100°C in air ambient for 30min. The thickness of the films was determined to be about 8 ~ 10 nm using a spectroscopic ellipsometer (model VASE, Woollam). Ti-dots were deposited on top of the film at a pressure below 10⁻⁶ Torr by e-beam evaporator. The top electrodes were determined to have a thickness of 300 nm. The active area of the cell was 1 mm². All electrical experiments were conducted in ambient air without any device encapsulation. Current-voltage and retention time characteristics were measured using a semiconductor parameter analyzer (HP 4155A). TEM observations of the cross-sections of the devices were carried out using a FEI microscope (Tecnai G2 F30 S-TWIN).

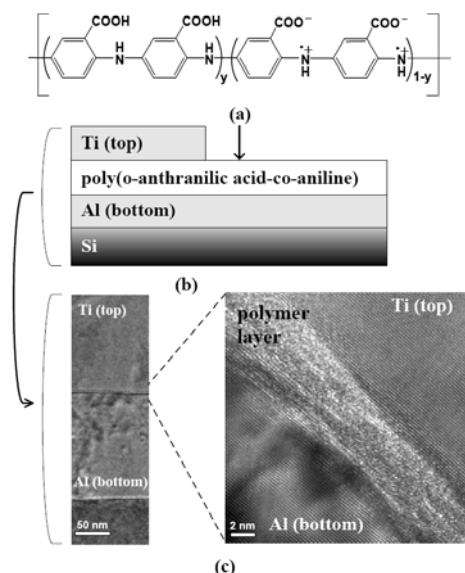


Fig. 1 (a) Chemical structure, (b) schematic diagram and (c) TEM images of the poly(o-anthranilic acid-co-aniline)-based device.

3. Results and Discussion

Figure 2 shows the typical current-voltage characteristic of the unipolar memory device with Ti/PARA/Al structure. When an applied voltage with 10mA current compliance is swept from 0V to 4V, the injection current abruptly increases from 0.49uA (high resistance state) to 10mA (low resistance state) at 2.5V, a difference of 4 orders of magnitude (open circles). The low resistance state (10mA) of the

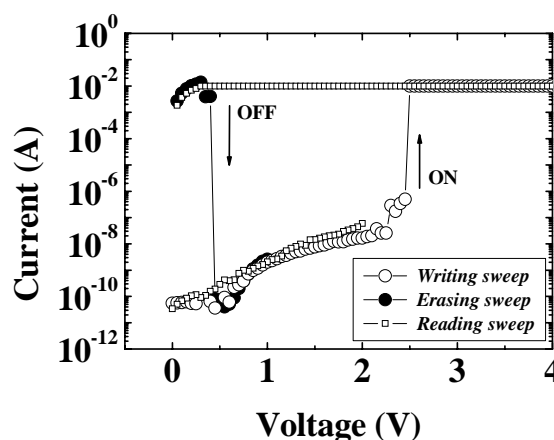


Fig. 2 Typical I-V curves of the device with the simple Ti/polymer/Al structure. Current response of the device during the write-read-erase sweeps.

device is retained even when the voltage was swept continuously (ON-state). However, by sweeping the voltage from 0V to 1V without a compliance current limitation, a sudden decrease of the injection current at 0.45V is observed (closed circles) and the resistance state of the device goes back to its initial value (OFF-state). This unipolar switching characteristic closely resembles switching properties of a binary-oxide device [9]. The result implies that our unipolar resistive memory device has good nonvolatile nature.

Figure 2 also presents the results of a write-read-erase sweep test conducted on the device. Thousands of sweeps were performed without degradation. In addition to the ability to read, write, and erase data, the device has the required characteristics of a memory device in terms of retention time. Figure 3 shows the result of a retention test carried out under air ambient conditions. Once the device is switched to the ON-state by applying the writing voltage with 10mA current compliance whose amplitude (4V) is higher than the on critical voltage (2.5V), the ON-state (10mA) is retained without any degradation for 3×10^3 s. When the ON-state is switched back to the OFF-state by applying the erasing voltage, 1.0V without a compliance current limitation, the OFF-state is well retained without any degradation.

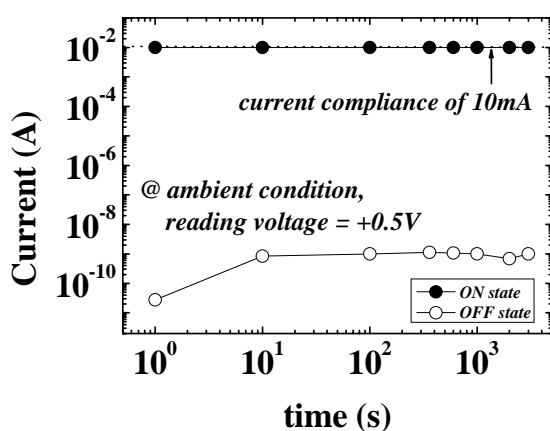


Fig. 3 Retention test of the ON-state and OFF-state currents.

We believe the switching mechanism of the poly(o-anthranilic acid-co-aniline) based device can be explained in terms of filament theory [10]. Figure 4 shows that the conduction mechanism at the off-state is dominated by the ohmic conduction ($I \sim V$) due to thermal hopping at low voltages (< 0.25 V) and the space-charge-limited current (SCLC) ($I \sim V^3$) at high voltages (0.3V \sim 2.5V). With increasing voltage, the space charges increase. Since the metal-polymer interface is not completely smooth, there will be spots where the electric field is particularly high. The localized spots, in which the aggregation and the arrangement of the polymer chains are higher, may reveal better current response for the applied voltages. Localized spots whose doping level is higher may also reveal better

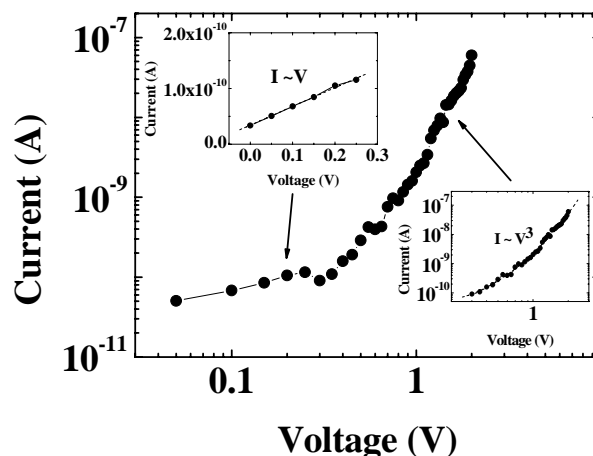


Fig. 4 The I-V curve of the Ti/polymer/Al structure in the OFF-state shown as a logarithmic plot, showing that ohmic and SCLC conduction mechanisms are involved.

current response [7]. These localized spots may play as filaments that can conduct when applying voltages higher than their critical voltages are applied, and then the device switches on. If a higher current than the on-current is injected into the ON-state polymer film, the temperature of the filament is raised by Joule heating [10]. Consequently, the filaments are fractured, resulting in a switching-off.

4. Conclusion

We have fabricated a non-volatile unipolar switching memory device based on poly(o-anthranilic acid-co-aniline) with a simple Ti/PARA/Al structure. With the control of current compliance, our polymer-based device exhibits the nonvolatile memory nature which is similar to the switching properties of binary-oxide. The switching mechanism can be explained by the filament theory. We believe that our polymer device is of potential use in non-volatile memory devices.

Acknowledgements

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References

- [1] B. Crone et al., Nature (London) **403** (2000) 521.
- [2] Organic Light Emitting Devices, edited by J. Shinar (Springer, Berlin, 2003)
- [3] C. W. Tang et al., Appl. Phys. Lett. **51** (1987) 913.
- [4] A. Bandyopadhyay et al., Appl. Phys. Lett. **82** (2003) 1215.
- [5] C. H. Tu et al., IEEE Electron Device Lett. **27** (2006) 354.
- [6] L. Ma et al., Appl. Phys. Lett. **80** (2002) 362.
- [7] D. J. Lee et al., Adv. Funct. Mater. to be published.
- [8] I. G. Baek et al., International Electron Devices Meeting (2005) 750.
- [9] X. Wu et al., Appl. Phys. Lett. **90** (2007) 183507.
- [10] G. Dearnaley et al., Rep. Prog. Phys. **33** (1970) 1129.