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Dependence of Memory Characteristics of Organic Bi-stable Device on Structural Parameters

Jae June Lee, Chung Kun Song*

Dept. of Electronics Engineering, Dong-A University
840 Hadan-dong, Saha-gu, Busan, 604-714, Korea
*Phone: +82-51-200-7711 E-mail: cksong@dau.ac.kr

1. Introduction

Recently the interests in memory devices exhibiting the large memory capacity, nonvolatile behavior and high operation speed rapidly increased due to rapid growth of IT industry. To satisfy these needs, research and development are being done widely by many groups. The organic bi-stable device (OBD), one of PoRAMs, with organic/metal/organic sandwiched structure can satisfy those needs sufficiently [1-2]. However, the details about device structural correlation to electrical characteristics were not reported yet.

In this paper, we investigated the effects of the device structure such as organic layer thickness, middle metal layer thickness and middle metal layer deposition rate on the memory characteristics. And also we found structure parameters suitable to high memory property.

2. Experiments and Results

The OBD has the structure of bottom-electrode / bottom organic / middle-metal / top organic / top-electrode and 2-amino-4,5-imidazoledicarbonitrile(AIDCN) is used for the organic layers [1]. The fabrication was carried out under the vacuum of about 1×10^{-6} torr without breaking the vacuum of the chamber. We varied the thickness of organic layer and the thickness as well as the deposition rate of the middle Al nano-cluster layer to find out the proper conditions for a large on/off current ratio. The deposition rate of fabricated OBD's top and bottom electrodes was 0.1 nm/s and thickness of them was 50 nm.

Effect of organic layer thickness

First of all, to investigate the relationship between the organic layer thickness and the memory effect, the organic layer thickness was varied from 40 nm to 250 nm with deposition rate of 0.1 nm/s at that time we fixed middle metal layer conditions which were the deposition rate of 0.03 nm/s and the thickness of 20 nm. In that experiment memory effects were observed when the thickness of organic film was under 40 nm above which the memory effect was disappeared since the current was rapidly decreased as the thickness increased. Thus, we found that the optimum thickness of organic layer was 40nm.

Effect of middle-metal layer's deposition rate

Second, we investigated the relationship between deposition rate of middle-metal film and memory effect by varying the deposition rate from 0.02 nm/s to 0.08 nm/s with the fixed deposition rate of 0.1 nm/s rate and thickness of 40 nm as the above conclusion. The thickness of middle metal film was fixed at 20 nm thick. As shown in Fig.1 the on/off current ratio was strongly dependent on the deposition rate. For the low rate Al particles are quickly oxidized during deposition so that the insulation of middle layer increased, resulting in reducing memory effect. Meanwhile for the high rate Al particles do not have a sufficient time to be oxidized to decrease the ability of charge trapping, resulting in reducing the on/off current ratio, finally eliminating memory effect. Therefore, there was a optimum deposition rate which was 0.03 nm/s. Fig 2. shows FE-SEM image of the middle-metal film having thickness of 20 nm deposited with the rate of 0.03 nm/s, and the mean grain size was 100 nm.

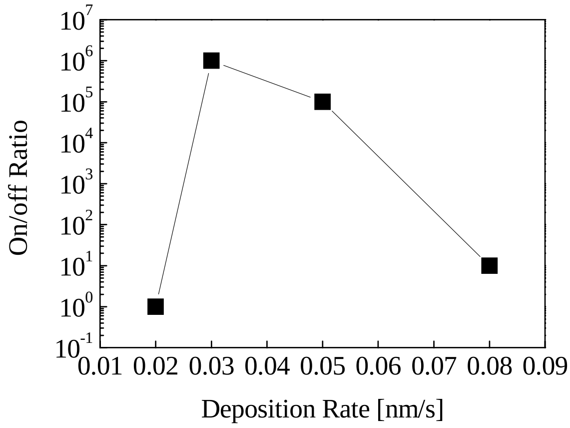

Figure 1. The on/off current ratio of OBD depending on deposition rate of middle-metal layer.

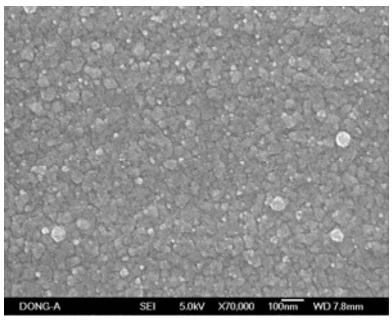

Figure 2. FE-SEM image of the middle metal film having of 20nm thickness deposited with the rate of 0.03 nm/s

Effect of middle-metal layer's thickness

Third, we studied the relationship between middle-metal film thickness and memory effect by varying the thicknesses 20 nm, 30 nm and 40 nm when the other conditions are fixed as the above results. In this experiment, we can obtain the memory effect from the device with the thickness of middle-metal film under 30 nm. But the characteristic of the device having middle-metal film of 20 nm was better than that having 30 nm film thickness. Our OBD has the same structure proposed by Y. Yang group. They explain the relationship between nano-cluster size of middle-metal layer and middle-metal film thickness as follows. Their grain size is about 10 nm so memory effect can be seen when the thickness is above 20 nm by separation two organic layers [4]. But we obtained the memory effect with our grain size about 100 nm and thickness of 20 nm. On the other hand, M. Kano group reported a memory effect using bottom-electrode / organic / top electrode structure. There is no middle-metal layer between two organic layers [5]. As we don't know the exact reason, the research on the role of nano-cluster layer must be done fully.

The Figure 3 shows the on/off ratio variation depended on middle-metal layer's thickness. On/off ratio is the highest at the thickness of 20 nm and the on/off ratio is decreasing when the thickness is increasing. So we decided the optimum thickness of middle-metal layer as 20 nm.

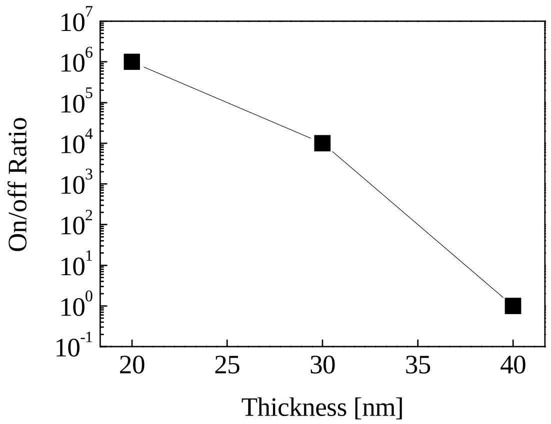

Figure 3. The on/off current ratio of OBD depending on the thickness of the middle-metal layer.

From the results obtained all of the above experiments, we determined the best condition to fabricate OBD and summaried in Table 1. The Figure 4 is the I-V curve of OBD fabricated by the above condition. The fabricated OBD shows the on/off current ratio of 10^6~10^7 and V_{th} about 2.8 V. OBDs sustained the on state for several weeks.

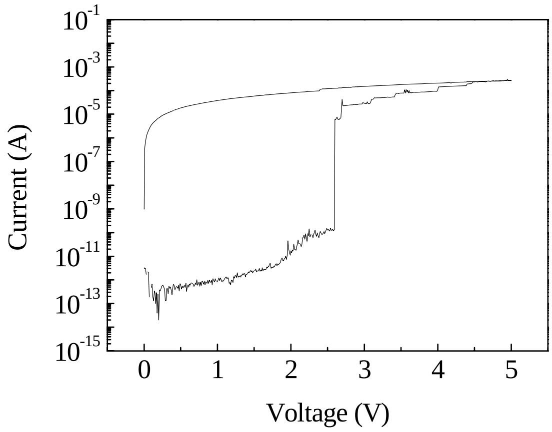

Figure 4. I-V Curve of OBD (50 um × 50 um)

Table 1. Fabrication Process

Layer	Material	Rate [nm/s]	Thickness [nm]	Vacuum [Torr]
Top electrode	Al	0.1	50	Under 3×10^{-6}
Top Organic	AIDCN	0.1	40	Under 3×10^{-6}
Middle-metal	Al	0.03	20	Under 3×10^{-6}
Bottom Organic	AIDCN	0.1	40	Under 3×10^{-6}
Bottom electroed	Al	0.1	50	Under 3×10^{-6}

4. Conclusions

We investigated dependence of memory characteristics of OBDs on device structure. The high on/off current ratio of 10^6 was obtained when the organic layer thickness of 40 nm, the organic layer deposition rate of 0.1 nm/s, the middle-metal layer thickness of 20 nm and the middle-metal layer deposition rate of 0.03 nm/s.

Acknowledgements

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