Extended Abstracts of the 2013 International Conference on Solid State Devices and Materials, Fukuoka, 2013, pp346-347

# Organic resistive memories composed of Au nanoparticle/polystyrene with embedded nanoparticle on the electrode.

Atsushi Fukushima[1], Katsuhiko Fujita[1,2]

[1]Interdisciplinary Graduate School of Engineering Science, Kyushu University
Phone: +81-92-583-7533 E-mail: hukusima1@asem.kyushu-u.ac.jp
[2]Institute Materials Chemistry Engineering, Kyushu University
6-1 Kasuga Kouen, Kasuga, Fukuoka 816-8580, JAPAN

## Abstract

We fabricated organic bistable memory device of Au nanoparticles embedded in a polystyrene layer. We study the effect which the interfacial Au nanoparticles exert on the characteristics. Fabricated device exhibited good non-volatile memory characteristics. Moreover, the device showed significantly higher device yield and reproducibility.

## 1. Introduction

Recently, an organic bistable memory devices (OBDs)[1] have been actively investigated due to their potential advantages of low-cost production, flexible electronic applications, and easy fabrication process. Especially, an OBD using a composite film of nanoparticles (NPs) and polymer has attracted considerable attention [2]-[4]. However, driving mechanism of an OBDs hasn't been clearly revealed yet, and reproducibility and device yield are not so suficient for practical applications. The mechanism of the bistability has not yet clearly understood though it has been discussed by many rearch group [3],[5]-[7].

We have reported that the OBDs using Au NPs embedded in a hyper-branched polystyrene (HPS) layer show the low resistance state based on conduction path formation with series of NPs in polymer layer (formation of conduction path)[5]. Illustration of formation of conduction path is shown in Fig. 1. The particles aggregate at the electrode interface during device fabrication, the conduction paths would grow by applied voltage. Since the state of nanoparticles in organic layer is the key point of the reproducibility and device characteristics, we study the effect which the interfacial Au nanoparticles exert on the characteristics.

## 2. Experiment

We employed standard polystyrene (PS) with very narrow molecular weight distribution as matrix polymer and Au NPs which are covered by hyper-branched polystyrene (HPS-Au). The chemical structure of the materials used in the present study is shown in Fig. 2.

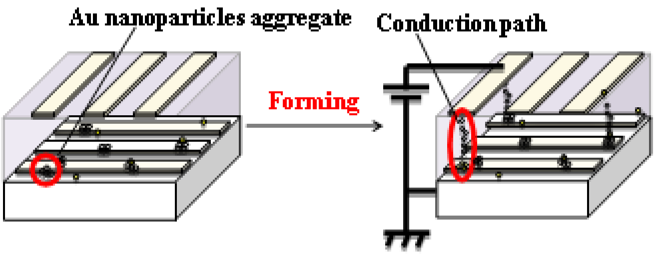
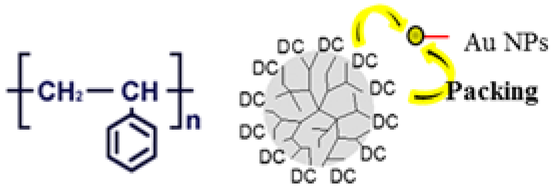


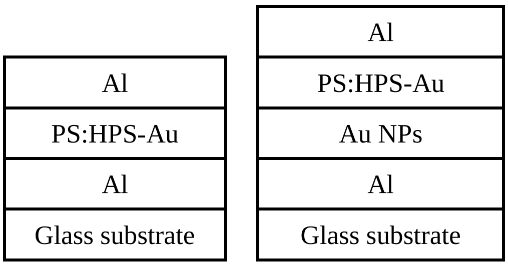

Figure1 Illustration of conduction path formation

The OBDs were fabricated as following aluminum (Al) bottom electrode was formed on a pre-cleaned glass by vacuum evaporation. The *o*-dichlorobenzene solution of HPS was spin-coated onto the Al bottom electrode, followed by thermal treatment at 150 °C for 30 min in a nitrogen atmosphere. Subsequently, Au nanoparticles were obtained by arc plasma gun (APG). The solution containing the active-layer materials was spun on the substrate, followed by thermal treatment at 150 °C for 30 min in a nitrogen atmosphere. Finally, an Al top electrode was formed by evaporation, resulting in the cell area at 2×2 $mm^2$. The device structure is shown in Fig.3 (a), (b).




Polystyrene HPS-Au

Figure2 Chemical structure of the materials used




Device(a) Device(b)

Figure3 Device structure

## 3. Result and Discussion

Current density-voltage (J-V) characteristics are shown in Fig. 4. Initially the device (a) and (b) showed the very high resistance below the high resistance state (off state) upon resistive switching. Current density abruptly increased at around 3.0 V and switched to the low resistance state (on state). Once the abrupt increase appeared, the resistive switching was observed. The device remained on state when applied voltage is instantly cut off at the negative differential resistance (NDR) region. After applied voltage turned off at higher voltage region, the device remained off state. This feature exhibits that our device has non-volatility. As described above, our devices exhibited good electrical bistability.

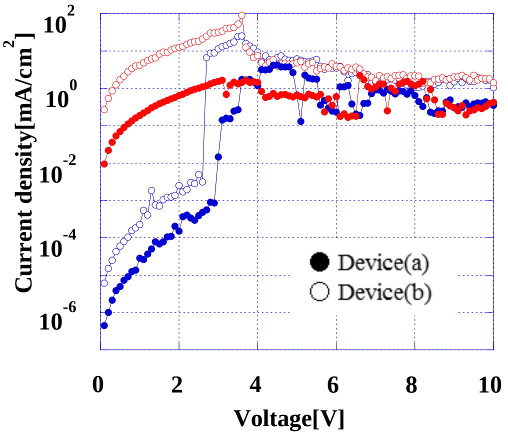



Figure4 Current density-voltage (J-V) characteristics of each device.

The cycle endurance of the device (a) and (b) by pulse voltage is shown in Fig.5 (a), (b). The device (b) was observed a smaller variation of the current than the device (a). Moreover, the device (b) was shown longer cycle endurance (1200~ times).

The device (b) is embedded the Au NPs between the bottom electrode and the polymer layer by using APG. The dispersion of Au NPs should stimulate the uniform conductive path formation. The interfacial particle on bottom electrode could significantly improve reproducibility and performance of device due to particle aggregate dispersed more uniformly. Therefore, these findings suggest that in the OBDs using Au NPs, the process of conductive path formation may influence the state of interfacial NPs.

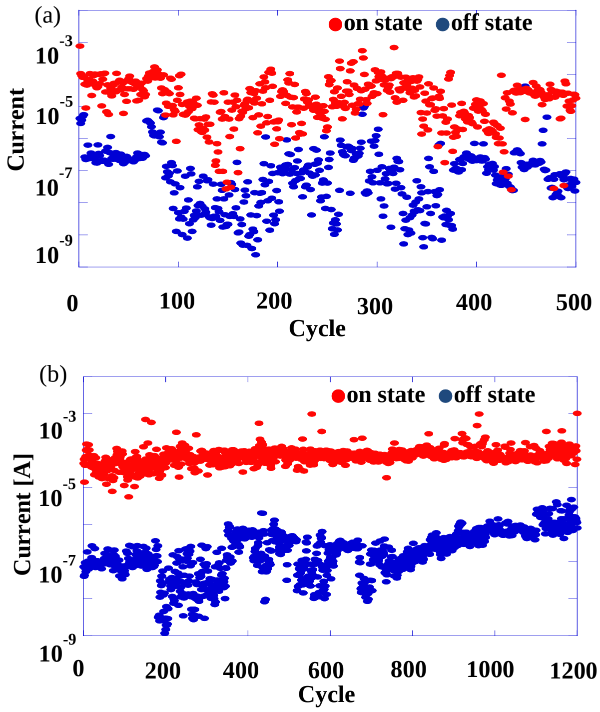



Figure5 Cycle endurance of the device (a) and (b)

## 4. Conclusions

We have fabricated nonvolatile organic resistive memory devices of Au NPs embedded in a polystyrene layer, and have investigated the effect of interfacial Au NPs exert on the characteristics. In comparison with the Al/PS:HPS-Au/Al, the Al/Au NPs/PS:HPS-Au/Al exhibited longer cycle endurance and better reproducibility.

Therefore, it is suggested that the process of conductive path formation may influence the state of interfacial NPs between bottom electrode and polymer layer in the OBDs using metal NPs.

## Reference


[1] Q.-D. Ling, D.-J. Liaw, C. Zhu, D. S.-H. Chen, E.-T. Kang and K.-G. Neoh, Proggress in Polymer Science **33** (2008) 917-978

[2] J. Ouyang, C.-W. Chu, C. R. Szmanda, L. Ma, and Y. Yang, Nature Mater 2004;3:918–22.

[3] Bozano LD, Kean BW, Beinhoff M, Carter KR, Rice PM, Scott JC. Adv Funct Mater 2005;15:1933–9.

[4] H. Ichikawa, K. Yasuda, M. Ozawa, K. Fujita, Synth. Met., **159** (2009) 973-976

[5] B. Cho, T.-W. Kim, M. Choe, G. Wang, S. Song and T. Lee, Org. Electr. **10** (2009) 473-477

[6]B. Cho, J.-M. Yun, S. Song, Y. Ji, D.-Y. Kim, T. Lee, Adv. Funct. Mater. **2011**, 21, 3976–3981

[7]J. Lee, and O. Kim, Jpn. J. Appl. Phys. 50 (2011)