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Effect of $Ni_{1-X}Pt_X$ Alloy Electrode on the Improved Resistive Switching Characteristics of NiO Thin Films

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1. Introduction

Resistive switching memory has much attention for the next generation non-volatile memory device applications. Contacts between resistive switching materials and metal electrodes involve many important scientific and technological issues. [1-3] Specially, in NiO thin film, noble electrode metals such as Pt and Au show acceptable switching characteristics due to ohmic contacts with NiO. [4] However, their high cost and poor adhesion property are obstacles to their wide application.

In this letter, we report the electromigration effect of Ni, better adhesion, and improved electrical properties with alloy electrode composing appropriate Pt and Ni molar percentage.

2. Experiment

Polycrystalline NiO thin films were deposited on co-sputtered $Ni_{1-X}Pt_X$ alloy, Pt and Ni bottom electrodes by dc magnetron reactive sputtering methods at 300°C, 5% O_2, and 5mTorr pressure respectively. The $Ni_{1-X}Pt_X$ alloy, Pt and Ni top electrodes were formed on the NiO film by photo lithography and lift-off processes.

3. Result and Discussion

For the ohmic contact with polycrystalline NiO film, good adhesion, and low-cost, Ni and alloy electrodes have selected for the metal electrodes in metal/NiO/metal structure. In the current vs. voltage characteristics of NiO film with alloy electrodes composing Pt and Ni, the initial R_{OFF} (OFF state resistance) did not show large difference as Ni portion was increased. However, after forming process (abrupt increase of leakage current), R_{OFF} of the films was abruptly decreased as Ni portion became higher. Due to severe resistance decrease, Ni/NiO/Ni film did not show stable repetitive switching behaviors. It can be explained that Ni affect the off state resistance just after forming. Due to high diffusivity of Ni into NiO films, Ni is well migrated into the NiO film.

Figure 1 shows the evidence of Ni migration from electrode into the NiO layer in the $Ni_{0.83}Pt_{0.17}$/NiO/$Ni_{0.83}Pt_{0.17}$ film. Figures 1(a) and 1(b) are TEM EDX profiles before and after forming process, respectively. Before forming process, there were abrupt drops of Ni signal both at the top and bottom electrode contact interface shown in Fig. 1(a). However, after forming process, Ni migration from top electrode into NiO layer was found from the gradient of Ni signal at the top interface in Fig. 1(b).

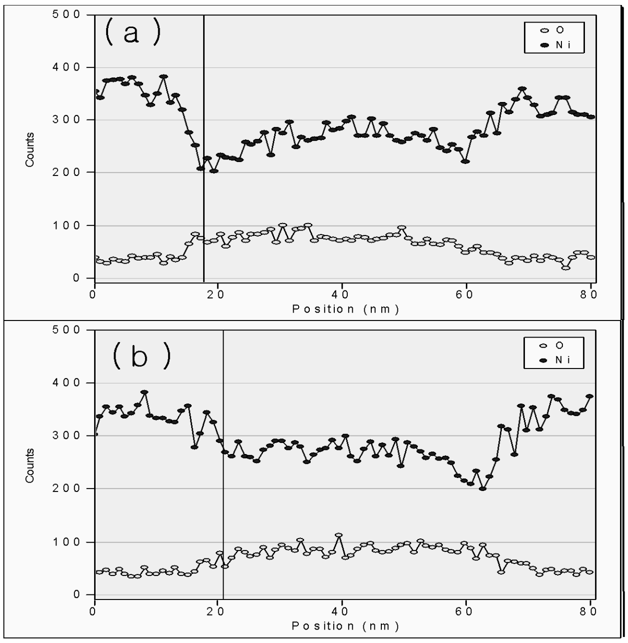

Fig. 1. EDX profile of $Ni_{0.83}Pt_{0.17}$/NiO/$Ni_{0.83}Pt_{0.17}$ film (a) before forming and (b) after forming process. Line about 20nm represents the position of the top electrode and NiO interface

The electromigration of Ni was found to improve the dispersion of memory switching parameters such as R_{ON}, R_{OFF}, V_{SET}, and V_{RESET}. It notes that dispersions for the $Ni_{0.83}Pt_{0.17}/NiO/Ni_{0.83}Pt_{0.17}$ film were greatly improved compared to those for the Pt/NiO/Pt film as shown in Fig. 2.

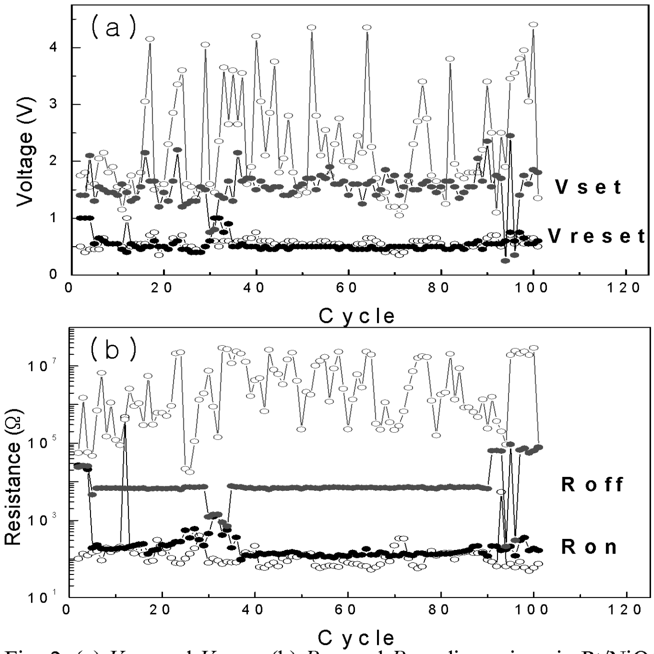

Fig. 2. (a) V_{SET} and V_{RESET} (b) R_{ON} and R_{OFF} dispersions in Pt/NiO/Pt (unfilled circles), and $Ni_{0.83}Pt_{0.17}/NiO/Ni_{0.83}Pt_{0.17}$ (filled circles) with respect to switching cycles.

The improvement of the dispersions may result from the decrease of effective thickness of the film due to the electromigration of Ni into the NiO layer. As shown in Fig. 3, decreased NiO layer thickness made decreased OFF- state resistance and voltage dispersions. This is very similar to the previously mentioned switching characteristics as Ni contents increased.

Generally, unipolar resistive switching observed in NiO films is believed to originate from the formation/rupture of filament-like percolation path. [5] The interface roughness can affect the onset of the filament. However, if film thickness is large compared to roughness spacing, the effect of the rough interface will not be notable. Therefore, the improved dispersions in metal/NiO/metal film can be referred to the enhanced lightning rod effect by the decrease of the thickness/roughness spacing ratio, which reduces the probability for the filament-like path to stagger. The improved dispersion characteristics by the Ni electromigration can not be interpreted as only the effects of decrease in the effective thickness but generation of acute structures in the interface.

Since Pt does not show good adhesion property with insulator layer such as SiO_2, thin Ti layer has been used for improving adhesion of Pt. However, due to decreased Pt and increased Ni portion, it shows that adhesion properties with the insulator layer are improved. Furthermore, the cost down effect as highly reduced Pt portion should be a necessity for mass production in industry.

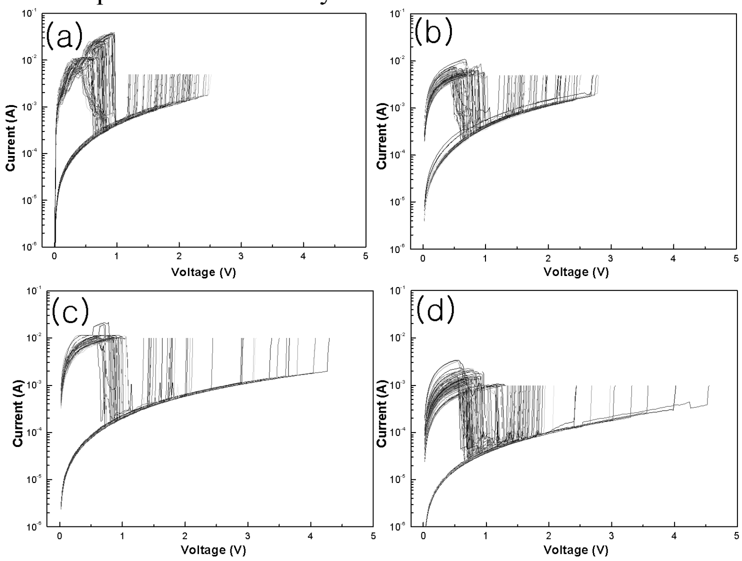

Fig. 3. Memory switching I-V characteristics of Pt/NiO/Pt films with NiO thickness of (a) 50nm, (b) 100nm, (c) 150nm, and (d) 200nm respectively

4. Conclusion

As composition ratio in $Ni_{1-x}Pt_x$ electrode is properly altered, the alloy electrodes affect interface and switching characteristics. Ni electromigration effect by high Ni diffusivity in NiO film was found to cause improvement of dispersion due to the decrease of the effective thickness of NiO films. This work demonstrates that the diffusivity should be considered as important criterion for selection of metal electrodes since it greatly affects the switching characteristics of resistive switching memory devices. Additionally, decreased noble metal portion results in better adhesion property and cost-down effect.

Reference

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