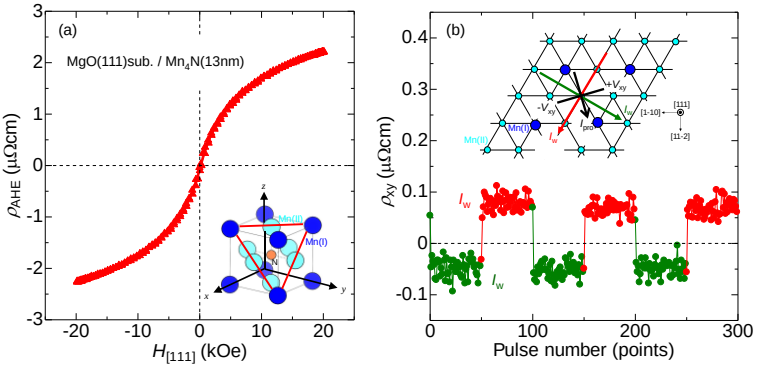
Current-induced electrical switching in (111) crystal oriented ε-Mn_4N films with non-collinear spin structure

NIMS, °Shinji Isogami

E-mail: isogami.shinji@nims.go.jp

Current-induced electrical switching (CIES) in antiferromagnets (AFM) has attracted considerable attention because of its phenomenological interests as well as the possible significant low switching current density compared with conventional ferromagnetic materials.[1-4] For the ferrimagnetic Mn_4N with anti-perovskite structure, spin-transport and magnetic properties have been widely investigated.[5-8] These properties are strongly associated with both the fine crystal growth in (001) plane and [001] pointing collinear spin-structure with ferrimagnetic order.[5] On the other hand, non-collinear spin-structure is predicted by first-principles calculations,[9] resulting in the consistency to AFMs with negligible spontaneous magnetization when the Mn_4N grows in [111] direction. Thus, the present study is intended to prepare (111) crystal oriented Mn_4N epitaxial films and to demonstrate the CIES by flowing the write pulse current in the film plane.

Figure 1 shows the AHE results for the 13-nm thick Mn_4N single layer as a function of external magnetic field in [111] direction ($H_{[111]}$) at room temperature. The $H_{[111]}$ dependent ρ_{AHE} showed no hysteresis, on the other hand, clear hysteresis loop was observed for the case in (001) oriented conventional Mn_4N film (data not shown). These results show that the spin-structure of Mn moments are non-collinear in the (111) plane and are parallel to the (111) plane, which is promising the possible CIES in the (111) crystal oriented Mn_4N. Figure 2 shows the CIES results for the same specimen, in which the I_w was applied along in directions of 60° (red) and 150° (green) as shown in the inset. Note that the offset ρ_{xy} for the $I_w = 0$ was shifted to zero. The clear and repeatable switching were observed, and the amplitude of ρ_{xy} showed slight difference for the two different I_w. The results led us to conclude that the electrical switching behavior obtained in the (111) crystal oriented Mn_4N films might be related to the reversal of Néel vector for antiferromagnetically coupled Mn moments. The possible spin-structures will be discussed based on the AMR measurements, and the CIES data for Pt capped sample are also shown at the conference.



(a) Anomalous Hall resistivity (ρ_{AHE}) for the (111) crystal oriented 13-nm-thick Mn_4N film as a function of external magnetic field sweeping in [111] direction ($H_{[111]}$) at room temperature. The inset represents the unit cell of Mn_4N, and the (111) plane is indicated by red triangle.
(b) Current-induced electrical switching of the transverse resistivity (ρ_{xy}) for the two different writing current pulses (I_w) with 0.5 s duration and 1 mA (~1.2 MA/cm^2) amplitude, where the probing current (I_{pro}) of 6 μA (~7.1 kA/cm^2) was employed. Each I_w direction with respect to the crystal axis is shown by the red and green allows in the inset.

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