Resistive Switching induced Multi-State Tunnel Magneto-Resistance in Wurtzite-MgZnO MTJs

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ウルツ鉱型 MgZnO トンネルバリアを持つ MTJ に於ける抵抗スイッチングによる磁気抵抗の多値動作

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In this study we challenged the realization of four-state magnetic tunnel junction (MTJ) controllable with electric field with a tunnel barrier that can be fabricated on metallic ferromagnetic (FM) buffer, in order to contribute to the finding of appropriate solutions for the technical issues concerning the enhancement of magnetic recording density by innovation of multifunctional MTJs. Also another motivation is the technological issues of ferroelectric (FE) $BaTiO_3$ based MTJs related to difficulties in fabricating these MTJ stacks on metallic FM electrodes and the lower T_C of used FM electrodes reported up to now[1]. In addition to this, the chosen tunnel barrier is the wurtzite (WZ) Mg doped ZnO for the next reasons: (1) Simplicity of the crystal structure and the low lattice mismatch with Pt and related FM alloys[2] (2) Possibility of FE property in WZ-ZnMgO[3], (3) The total absence of trustable scientific reports dealing with physical properties in MgZnO based MTJs.

Sample of our study were prepared using the following stack: c-plane Al_2O_3 Sub./Pt(30)/$Co_{0.3}Pt_{0.7}$(10)/$Mg_{0.23}Zn_{0.77}O$(7)/Co(2)/CoFe(2)/IrMn(14)/Ru(5) [thickness in nm]. This stack exhibited good crystalline and texture properties investigated by X-ray diffractions. Electrical characterization of our MTJ proved their tunneling behavior with a high R·A product (R·A∼1.05 MΩ.μm^2). Tunneling Magnetoresistance (TMR) has been detected at RT (3~5 %) and 2 K (7~15 %) with an acceptable tunnel spin polarization of $Co_{0.3}Pt_{0.7}$ (~29 %) very close to that reported by S. S. Parkin [4]. Numerical fitting of tunneling *I-V* data gave a barrier height and an effective thickness of 280 meV and 4 nm. This is consistent with the electron dispersive X-ray analysis showing the formation of a ~ 3nm thick ZnO intermediate-layer.

Electrical field cooling (FC) [Similar to Electrical Poling utilized in FE barriers] and zero field heating (ZFH) has been performed to investigate resistive switching behavior after applying +1 V and -1 V between 360 K (T_C of FE-$Mg_{0.3}Zn_{0.7}O$ bulk = 345K[3]) and 2 K. Clear increase of resistance has been detected after -1 V FC (inset of fig.1) with a change ratio of ~ 320 % at 2 K (Fig.1). Temperature dependence of this change ratio showed a clear decrease when increasing the device temperature and almost vanished at ~ 150 K. This implies the possibility of ferroelectric-like effect which was confirmed by fitting experimental data with FE-based models[5].

In addition to resistance switching as shown in Fig.1, measured TMR at -5 mV has been increased by ~ 7 times after -1V FC (fig.2). The same result was obtained in FE-$BaTiO_3$ MTJ[1]. Interestingly, bias voltage-dependent *dI/dV* exhibited a clear negative shift of localized-states peaks and valleys after -1 V FC with ~17 meV. A closer value was extracted from the estimation of the barrier height. These two changes are produced by the polarization reversal, inducing also a resistive switching, as a direct consequence of barrier height change due to the charge screening at metals interfaces. **Realization of four-state magnetoresistance in WZ-MgZnO based MTJ has been demonstrated repetitively at 2 K showing the good correlation of measured magneto- and electrical properties with the ferroelectric-like behavior of $Mg_{0.23}Zn_{0.77}O$ tunnel barrier in this study.**

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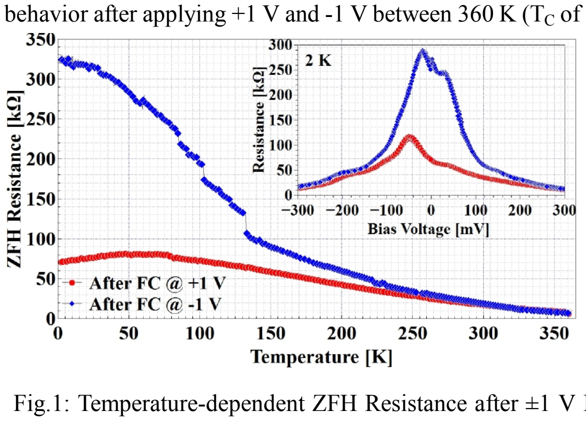

Fig.1: Temperature-dependent ZFH Resistance after ±1 V FC (inset: Bias voltage-dependent resistance after ±1 V FC).

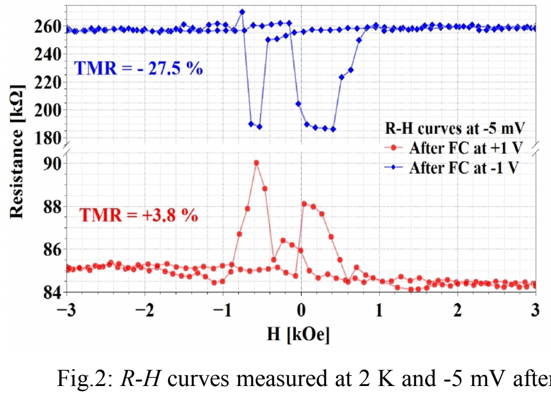

Fig.2: *R-H* curves measured at 2 K and -5 mV after ±1 V ***electric FC (field cooling)*** showing clear separation of TMR four-state.