Room-Temperature Manipulation of Magnetization Direction in Magnetite, Achieved with an All-solid-state Redox Transistor

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Abstract

Magnetic tunnel junction (MTJ) has been prospected as promising device for not only high integrated magnetic random access memory but also artificial intelligence (AI).[1] Although there are many studies to manipulate magnetization direction with high efficiency (i.e. magnetization reversal with low electric power loss at room temperature) through introductions of carrier doping and mechanical stress with electric fields and pure spin current, serious problems (e.g. low operation temperature, small change of ~10° by electrostatic carrier doping, and electric power loss) are still remained. To overcome the drawbacks, we fabricated all-solid-state redox transistor, which can tune electronic carrier concentration with Li^+ transport, to manipulate magnetization direction with low electric power consumption at 300 K.[2]

Our all-solid-state redox transistor consists of magnetite (Fe_3O_4), Zr-doped Li_4SiO_4 (LZSO) electrolyte, $LiCoO_2$ (LCO) gate electrode, and Pt current collector thin films, as shown in Figure 1. Epitaxial growth of magnetite thin film on MgO (110) single crystal was confirmed by a high resolution-transmission electron microscope (HR-TEM). To evaluate magnetization rotation, planar Hall measurement, which detects transverse resistance depending on magnetization direction by applied magnetic field of 0.47 T and electric current of 7 μA, was performed at various gate voltage (V_G).At $V_G = 0.0$ V, magnetization aligns to $[1\bar{1}\bar{1}]$, as shown in Figure 2. Magnetization direction rotated clockwise as V_G increases. Finally, magnetization direction rotated 56° and aligned to $[1\bar{1}1]$ through $[1\bar{1}0]$ by electronic carrier doping of 6.3×10^{21} cm^{-3} with $V_G = 2.0$ V application. This result improved operation temperature up to 300 K and magnetization rotation angle of 56° and reduced electric power loss below 10^{-3} J/cm^2.

REFERENCES

[1] J. Torrejon, M. Riou, F.A. Araujo, S. Tsunegi, G. Khalsa et al., Nature **547**, 428 (2017)
[2] W. Namiki, T. Tsuchiya, M. Takayanagi, T. Higuchi, K. Terabe, ACS Nano **14**, 16065 (2020).

FIGURES

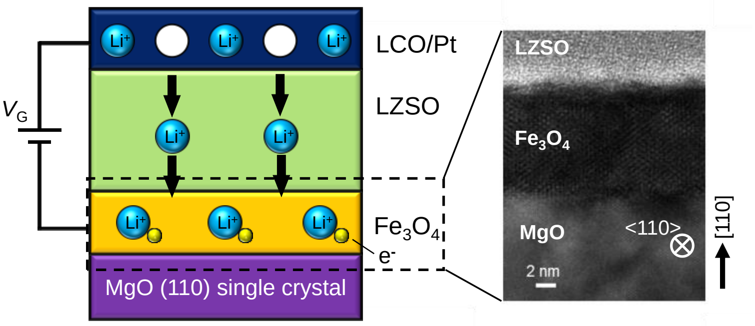

Figure 1: Schematic illustration of an all-solid-redox device and its measurement configuration. Inset shows HR-TEM image of cross-section of the device. Scale bar is 2 nm.

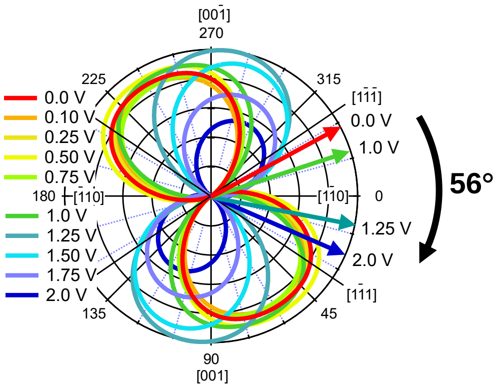

Figure 2: Polar graph of magnetic anisotropy field variations of magnetite thin film at 0.0 < V_G < 2.0 V. Color arrows indicate magnetization direction, which corresponds to the minimum of magnetic anisotropy field.