

Relationship between interfacial chemical states and resistive switching in Al/Fe₃O₄ structures

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Introduction

There has been a growing demand for high-performance memory devices made of common metals so as to reduce environmental burdens and to ensure a sustainable supply of devices. The resistive random access memory (ReRAM) is one of the promising candidates for the purpose. Since the bipolar resistive switching (RS) may occur through the interfacial redox reaction between metal electrodes and transition metal oxides [1], the ReRAM devices that consist only of materials with high Clarke number can be fabricated by controlling the interfacial redox reaction. In this study, we have focused on the interface between Al electrodes and magnetites (Fe₃O₄) that is made of high Clarke number elements, and characterized the device performance. Furthermore, the interfacial chemical states were also investigated by *in-situ* photoemission spectroscopy (PES).

Experimental

Al metals were deposited on as-received Fe₃O₄ substrates without any surface treatments and Fe₃O₄ thin films grown on MgO substrates by a pulsed laser deposition (PLD) method. The device characteristics were investigated by *I-V* measurements, and it was found that the former stacked structure showed the typical bipolar RS while the latter exhibited the ohmic behaviour. *In-situ* PES measurements using synchrotron radiation were performed at the undulator beamline BL2C.

Result

Figure 1 shows the Fe 2*p* core-level spectra with and without Al electrodes for both Al/ Fe₃O₄ stacked structures. For Al/ Fe₃O₄ substrates showing the RS behaviour, the core level spectra show that Fe ions at the surface of Fe₃O₄ substrates exist in Fe³⁺ states. Meanwhile, for Al/ Fe₃O₄ films showing the ohmic behaviour the spectra exhibit the typical mixed valence of Fe²⁺ and Fe³⁺ states [2]. As expected from the difference in the surface chemical states before Al deposition, there is a significant difference in interfacial chemical states between the two interfaces. For Al/ Fe₃O₄ substrates, Fe ions at the surface are reduced from Fe³⁺ to Fe²⁺ states at the interface owing to the redox reaction at the interface between Al and Fe₃O₄. In fact, Al 2*p* core level showed that Al metal was oxidized along with the reduction of Fe ions (not shown).

On the other hand, Fe ions in PLD-grown Fe₃O₄ films are reduced to Fe⁰ states, resulting in the disappearance of the RS behaviour, that is the ohmic contact between the Al electrode and Fe₃O₄. These results suggest that appropriate fabrication processes for controlling interfacial layers between Al electrodes and Fe₃O₄ are the key to the development of the environmentally-friendly memory devices with high performance.

References

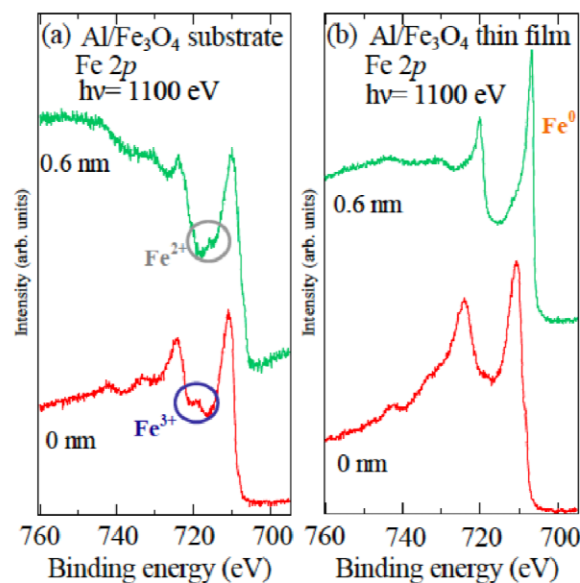


Fig. 1 Fe 2*p* core-level spectra with and without Al metals for (a) the stacked structures of the Al electrode on Fe₃O₄ substrates and (b) those of Al/Fe₃O₄ thin films.

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