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Mechanisms of Resistance Switching Memory Effect in Oxides

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1. Introduction

Recently, much attention has been paid to the resistance change nonvolatile memories. Here, various kinds of oxide layers are used to be an insulative or semiconducting component sandwiched between metallic electrodes forming a capacitor-like structure. The resistance of or leakage current through the oxide layer can be changed in a reversible fashion by the application of voltage pulses shorter that 100ns. The resistance change can extend over decades and can be multilevel. If one can employ cross-point configuration in matrix-type memory cell array, the integration can be very high yielding a cell are of $4F^2$ where F to be minimum feature size. However, the mechanism of these phenomena is mot settled yet and optimization of materials sets and device structures have not been attained. In this presentation, we review the device structures and possible mechanisms for colossal electro-resistance (CER) phenomena reported so far. We will focus on our research on Metal/Oxide interface with both p- and n-type semiconducting properties to highlight the Schottky junction model.

2. Types and mechanisms of CER effect

The CER effects reported so far are summarized Table 1 and Fig. 1. These can be classified into two types according to the difference of conducting path. One is the interface type, in which the CER effect takes place at the interface between a metal electrode and insulating (or semiconducting) oxides and the contact resistance is changed by the application of electric field at the interface. The other is the filament type, in which the CER effect results from the formation and rapture of conductive filaments in insulating oxides. In the former case, the junction resistance is proportional to the junction area, while the junction resistance is independent of the junction area in the later case.

There is another categorization of the CER effects according to the resistance switching mode, i.e., bipolar or nonpolar type. The bipolar-type CER effect means that the resistance switching is induced by changing the polarity of the applied voltage, which has been usually observed in the junctions consisting of perovskite-type transition metal oxides. In the nonpolar-type CER effect, the resistance state depends on the amplitude of the applied voltage, inde-

Table 1. CER effect reported in various materials sets and exhibiting different device actions.

Sample	Group	Driving mode*	Conduction path	I-V characteristics (transport mechanism)	Mechanism
Ag/PCMO/YBCO or Pt	Houston [1,2]	b	Plane (Interface)		①Oxygen diffusion
Ag/PCMO, Ag/$LaCoO_3$	Houston[3,4]	b		Space charge limited current	
Ag/PCMO/Pt	Matsushita, AIST-CERC[5]	b			②Trapping
TiN/Cu_xO/Cu	Spansion[6]	b			
Ti/PCMO, SRO/Nb:STO	AIST-CERC[7,8]	b		Schottky	③Charging
Pt/Nb:STO	GIST[9]	b			
Theory	AIST-CERC[10]	b			④Mott transition
Au or Pt/STO/Au or Pt	Jülich[11]	b	Filament	Tunneling or Hopping	⑤Oxygen diffusion
Pt/(NiO/)TiO_2/Pt	Fujitsu[12]	n			
Pt/NiO/Pt	Samsung[13-15]	n			
Theory, Pt/NiO/Pt	Paris-Sud, AIST-CERC[16-18]	n			⑥Mott transition

*b: bipolar, n: nonpolar

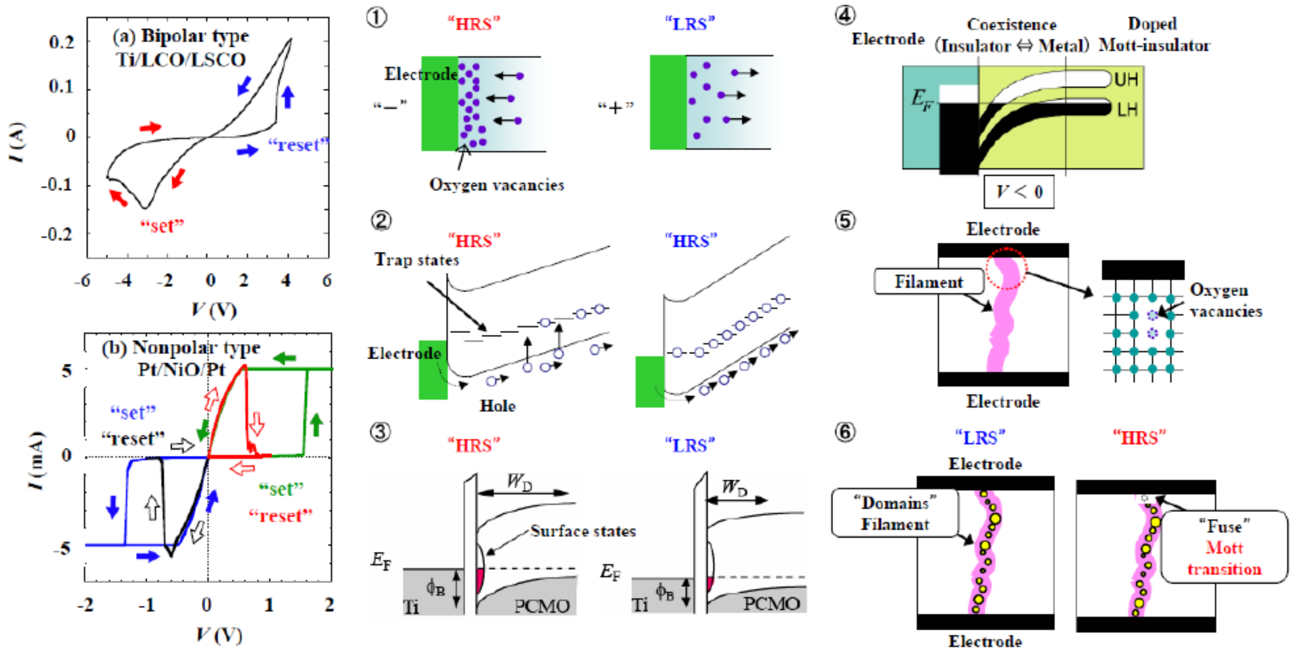

Fig. 1 Typical *I-V* characteristics of CER effect (a) bipolar-type and (b) nonpolar type. Possible origins of CER effect (①-⑥) postulated in references given in Table 1.

pendently of the polarity. This resistance switching mode has been usually observed in the filament type CER effect.

Because of the variety of CER properties, one can expect that the driving mechanism of the CER effect depends on materials consisting of the devices. Reflecting such a situation, as the origin of the CER effect, electrochemical migration of oxygen ions, charging effect of Schottky-like interface, Mott transition induced by carrier doping have been proposed for the interface type, while electrochemical migration of oxygen ions, Joule heating, anodization, and Mott transition for the filament type. The details are to be discussed elsewhere [19].

We have been working on various materials set to support the model ③ and performing interface engineering with use of modern thin film technology. The results and concept will be reported.

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