Resistance switching: what lurks at the root?

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Charge-storage memories as represented by the flash memory [1] are dominating commercial markets of storage media. However, there is an emergent anxiety that they face a miniaturisation limit (currently estimated $\sim$20 nm) in a few years. The so-called resistance-change memory is considered to be an emerging candidate of scalable replacement for flash; three types of the resistance-change memories are now under development [2]. Those are the phase-change memory (PCM), the programmable metallisation cell (PMC), and the resistive random-access memory (RRAM). The third one uses "electroformed"[3] metal/oxide/metal sandwiches, which are reviewed in this talk from a viewpoint of understanding the mechanism of the weird resistance change phenomenon.

Recent intensive and worldwide researches of RRAM have clarified that the current flows inhomogeneously through the oxide in the low-resistance state, even when it does rather homogeneously in the high-resistance state. This indicates that there appears a **current constriction** structure, most probably at the interface. Thanks to the constriction, the current density becomes extremely large especially when the resistance state changes from low to high. This current constriction structure is the most essential matter of the resistance change phenomenon, and we call it a "**faucet**" [4, 5].

In several combinations of the oxide and metal electrode, the averaged free enthalpy of oxygen segregation is close to the free reaction enthalpy of oxide precipitation from the metal [6]. Then, the large current density can easily drive local chemical reactions such as electro-oxidation and electro-reduction, and the reactions can be drastically accelerated by a local Joule heating due to the current concentration. In addition, a possible direct effect of the oxygen and/or cation electromigration [7] may play an important role. It has been actually demonstrated that the current density of 10^7 A/cm^2 induces intriguing local oxidation on thin titanium strip [8]. I would like to review and discuss the essential faucet structure, as well as the possibility of those local chemical reactions at the non-equilibrium interface between the metal electrode and the oxide matrix, suggesting what is necessary to realise the resistance-change memory.

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[1] A typical example of the flash memory is a NAND-type data storage device integrated with a universal serial bus (USB) interface — USB flash drive.

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[5] Although there has been no definitive experimental evidence on the total area of the faucet(s), if we naively assume it a circle of 300nm in diameter, the critical current density for 'reset' (change from low to high resistance state) is typically 10^7 A/cm^2.

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