Resistance change phenomena: what lies at the root?

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Charge-storage memories as represented by the flash memory are dominating commercial markets of storage media. However, there is an anxiety that they face a fatal miniaturisation limit within the next decade. The so-called resistance-change memory is considered to be an emerging candidate for passing the limit; three types of the resistance-change memories are now in competition for superseding the mighty charge-storage memories [1]. Among the three, "electroformed"[2] metal/oxide/metal sandwiches are reviewed in this talk from a viewpoint of understanding the mechanism of the resistance change.

Recent intensive and worldwide researches 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**" [3, 4].

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 [5]. 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 [6] 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 [7]. 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.

Financial supports are provided by New Energy and Industrial Technology Development Organization (NEDO), and Grant-in-Aid for Scientific Research from MEXT, Japan.

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[4] 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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