International Journal of Electrical Electronics & Computer Science Engineering
Volume 2, Issue 4 (August, 2015) | E-ISSN : 2348-2273 | P-ISSN : 2454-1222
Available Online at www.ijeecse.com

Analysis of MIM Structure for RRAM Under Different Conductive Mechanisms

Divyangna Sharma
Department of Electronics and Communication Engineering,
Saroj Institute of Technology & Management, Lucknow
contactdivyangna@gmail.com

***Abstract:** This review represents the analysis done on metal oxide memory cell under different biasing conditions and conductive mechanisms, the resistive switching effects can be roughly classified into filament type and interface type according to conductive behavior in LRS(R_{ON}).In this work, the migration behavior of metallic cations, oxygen vacancies, joule heating effect, parasitic capacitance and resistance effects are discussed. For the interface based system the methods of barrier height modulation using different electrodes and by tunneling layer insertion is described.*

***Keywords:** MIM, RAM, DRAM, MRAM, FRAM and RRAM.*

I. INTRODUCTION

There are various Random Access Memories competing with each other for next generation memory as for e.g. DRAM, MRAM, FRAM and Si based Flash memory. However, all these memories possesses one or many drawbacks like energy costing and additional periphery circuitry in DRAM; low endurance, low speed and high voltages requirement during write operation in Si based Flash RAM; magnetic tunnel junctions and reverse polarization in MRAM and FRAM respectively and they both face severe scaling problems [1,4].

Considering these circumstances a new candidate has emerged: resistance switching random access memory (RRAM). Metal oxide based RRAM has attracted considerable interest of next generation memory in which the memory cell have theoretically the smallest area. Most of RRAM cells have MIM structure where M is metal electrode and I stands for insulator, till now many materials have been found to show the resistive switching characteristics, including binary oxides such as ZnO [2,3], NiO [6,7,8], TiO2 [5], electrolytes such as Ag2 S[9], GeSe [10], organic material and nitrides.

As shown in Fig.1, each cross point between word line and bit line become storage cell. Thus the cell size of memory can be reduced using nanowires. Different switching behaviors such unipolar and bipolar switching, various switching mechanisms such as filament model, trapped controlled model and interface barrier model are involved in RRAM researches. But here, only recent progresses are described.

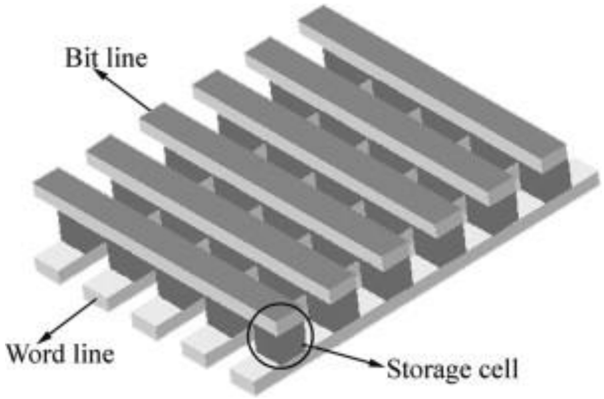


Fig:1 Configuration of Crossbar Memory Structure

II. RESISTIVE SWITCHING EFFECTS

In the filamentary resistive switching, current in LRS flows through confined local path in insulator while current in HRS flows through the entire matrix homogeneously. The constituents of filaments seems vary from one to another; metallic nano-bridges [11],oxygen vacancies (V^{2+}_O) composed conductive channels, dislocations are possible filaments which switch the device to LRS. In the interface type resistive switching system, the current which flows through the film is determined by the barrier height at the interface between the metal electrode and semiconductor layer or insulting layer. The interface barrier height can be modified by electrical stimuli. It has been reported [12,13] that negative voltage on metal electrode drifts V_O toward the interface and reduces the barrier height, resulting in resistive switching from HRS to LRS and vice versa. The phenomenon occurs due to the formation and rupture of CF (conductive filament) and switching characteristics are strongly correlated with the geometry of CF as the direct result of generation and recombination of oxygen vacancies (V_O) in the oxide layer. The physical process is shown in Fig.2. there are two different filament in RRAM device: redox reaction induced metallic filament and oxygen ion defects composed metallic filament, the redox reaction formed filament is defined as electrochemical metallization cell (ECM) and also called conductive bridge (CB),the corresponding fig. describes the redox reaction under applied voltage in EM cell. The electrochemically active metal is oxidized (a) at the interface when positive voltage is applied M M^{Z+} + ze$^-$, where M^{Z+} represents the cation .The mobile M^{Z+} cations migrate through solid electrolyte layer toward the electrochemically inert electrode where they are reduced by electrons flowing from the cathode, i.e., $M^{Z+}+ze^{-}$ M. The successive precipitations (b) of active metal atoms at the cathode lead to a growth of metal protrusion which finally reaches the anode to form highly conductive filament, and switch the device to LRS. When a negative voltage is applied on the active electrode, an electrochemical dissolution takes place in the weakest part of filament and rest the device to HRS(c).

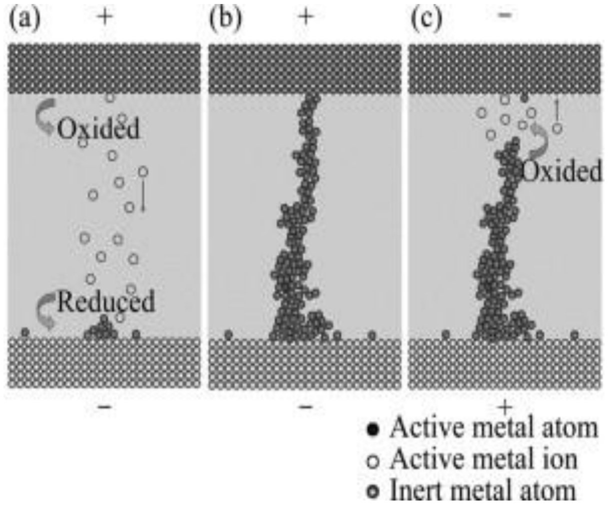
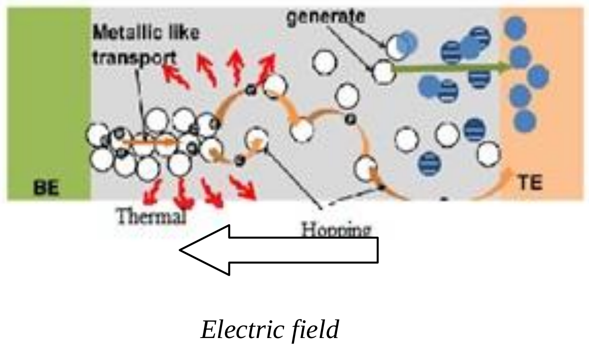


Fig 2- Schematic Diagram for ECM Resistive Switching Effects in ECM Cell.

In oxygen vacancies composed filaments shown in fig:3 during SET process ,both generation of V_O and drift of oxygen ion to(O^{2-}) to the top electrode cause the formation of CF connecting anode and cathode, which results in cell switching to LRS whereas for the HRS the recombination between O^{2-} and V_O would rupture the CF and cell would switched to HRS. The TE (Top electrode) is active and act as O^{2-} reservoir to release or absorb O^{2-}.

(A) Set Process   (Generate Vo & O^{2-})



(B) Reset Process

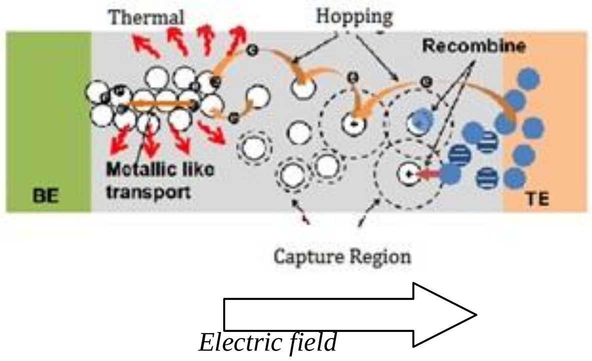


Fig3: Physical Process of Resistive Switching Including the Generation of Oxygen Vacancies, Oxygen Ions Hopping, Oxygen Ions Absorbed and Released by Electrode, Recombination Between Oxygen Vacancies and Oxygen Ions.

Resistive switching effects illustrates about the temperature dependence of R_{LRS} and R_{HRS} on MIM structure depicted in fig 4, as it is seen that R_{LRS} increases with increase in temperature, which indicates that phonon scattering is dominant in the electronic transport, this indicates that metallic filament is formed in LRS; R_{HRS} decreases with increase in temperature and exhibits exponential manner with 1/T. This phenomenon implies that metallic filament may rupture incompletely in the RESET process. Thus, the residual metallic defects contribute metallic conduction in low temperature.

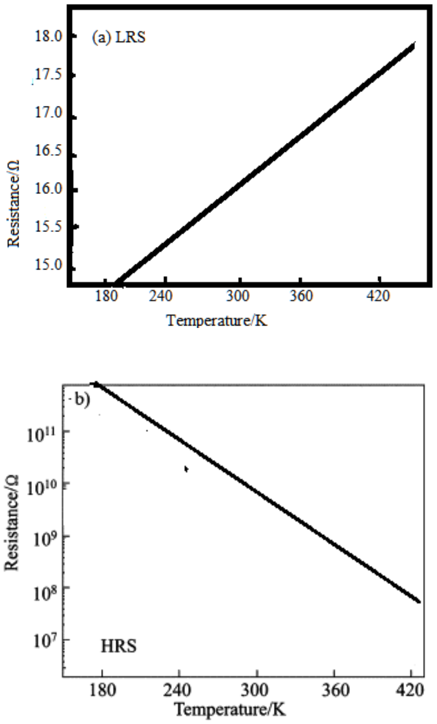


Fig 4: Temperature Dependence of R_{LRS} (A) And R_{HRS}(B) in Zno Memory Device.

III. RESULTS & DISCUSSION

Through this phenomenon discussed the joule heating effect in resistive switching is seen. In unipolar, the high current generates joule heating switches the device to HRS by fusing the filament in RESET process. Though a low rest current is beneficial to low power consumption, it often shortens the retention time owing to low current caused small filament size. In bipolar switching, Joule heating is not the main driving force in RESET process, but it still plays an important role in accelerating the dissolution of the filament. However, it can also lead to the rupture of the filament when sufficiently high current flows through the filament. If this rupture happens in SET process, it becomes a valid operation since the resistance did not stay in LRS. This phenomenon can be seen in both unipolar and bipolar resistive switching. Severe Joule heating will be generated when large current passes through the filament. If the heat cannot dissipate in time, there will be a steep increase of the temperature in the filament, which finally blows out the filament. Therefore, large current should be avoided in the device, which is harmful to the performance or even leads a failure. The parasitic effects have been considered during transient operation. The circuit including parasitic capacitance is shown in fig 5.It consists of parallel capacitance, a large parallel resistance, contact resistance and the resistive switching element. Fig 6-7 shows the model calculated and measured transient response during SET/RESET process.

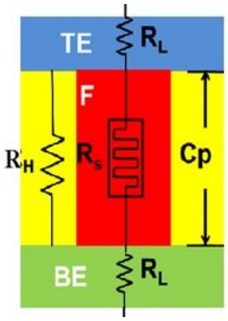


Fig.5 Equivalent Circuit of RRAM With Parasitic Element

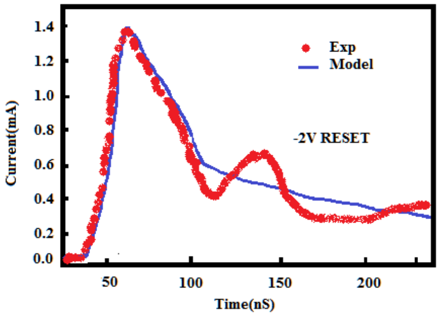


Fig.6 The Transient Response During RESET Process.

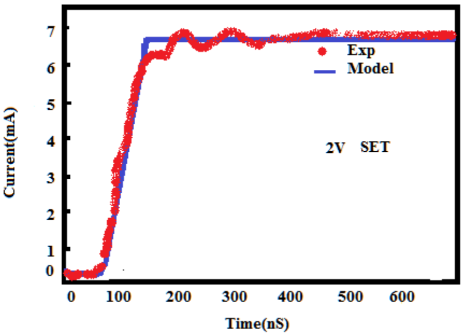


Fig.7 The Transient Response During SET Process.

IV. REFERENCES

[1] GI MEIJER Materials science—Who wins the nonvolatile memory race? [J]Science, 319 (5870) (2008), pp. 1625–1626.

[2] YC YANG, F PAN, Q LIU, et al. Fullyroom-temperature-fabricated nonvolatile resistive memory for ultrafast and high-density memory application[J] Nano Lett, 9 (4) (2009), pp. 1636–1643

[3] WY CHANG, YC LAI, TB WU, et al.Unipolar resistive switching characteristics of ZnO thin films for nonvolatile memory applications[J] Appl Phys Lett, 92 (2) (2008), p. 022110

[4] A SAWA Resistive switching in transition metal oxides[J] Mater Today, 11 (6) (2008), pp. 28–36

[5] DH KWON, KM KIM, JH JANG, et al. Atomic structure of conducting nanofilaments in TiO_2 resistive switching memory[J]Nat Nanotechnol, 5 (2) (2010), pp. 148–153

[6] ASAMITSU, Y TOMIOKA, H KUWAHARA, al Current switching of resistive states in magnetoresistive manganites[J] Nature, 388 (6637) (1997), pp. 50

[7] A BECK, JG BEDNORZ, C GERBER, et al. Reproducible switching effect in thin oxide films for memory applications[J] Appl Phys Lett, 77 (1) (2000), pp. 139–141

[8] MN KOZICKI, M YUN, L HILT, et al. Applications of programmable resistance changes in metal-doped chalcogenides[J] Solid- State Ionic Devices, 99 (13) (1999), pp. 298–309

[9] K TERABE, T HASEGAWA, T NAKAYAMA, et al Quantized conductance atomic switch[J] Nature, 433 (7021) (2005), pp. 47

[10] R SONI, P MEUFFELS, H KOHLSTEDT, et al. Reliability analysis of the low resistance state stability of $Ge_{0.3}Se_{0.7}$ based solid electrolyte

nonvolatile memory cells[J] Appl Phys Lett, 94 (12) (2009), p. 123503

[11] W.C. Chien, F.M. Lee, Y.Y. Lin, M.H. Lee, S.H. Chen, C.C. Hsieh, E.K. Lai, H.H. Hui, Y.K. Huang, C.C. Yu, C.F. Chen, H.L. Lung, K.Y. Hsieh, and Chih-Yuan Lu "Multi-Layer Sidewall WOX Resistive Memory Suitable for 3D ReRAM", Symp. on VLSI Tech. Dig., pp.153-154, 2012.

[12] S.R. Lee, Y.-B. Kim, M. Chang, K.M. Kim, C.B. Lee, J.H. Hur, G.-S. Park, D. Lee, M.-J. Lee, C.J. Kim, U-I. Chung, I.-K. Yoo and K. Kim, "Multi-level Switching of Triple-layered TaOx RRAM with Excellent Reliability for Storage Class Memory", Symp. on VLSI Tech. Dig., pp.71-72, 2012.

[13] B. Gao, J. F. Kang, Y. S. Chen, F. F. Zhang, B. Chen, P. Huang, L. F. Liu, X. Y. Liu, Y. Y. Wang, X. A. Tran, Z. R. Wang, H. Y. Yu, and Albert Chin, "Oxide-Based RRAM: Unified Microscopic Principle for both Unipolar and Bipolar Switching", IEDM. Tech.Dig., 2011, pp.417-420.