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Colossal Electroresistance and Resistive Switching in Manganite Based Heterostructures : A Review

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ABSTRACT

In this communication, I present the review on the reported work on colossal electroresistance and resistive switching observed in manganite based heterostructures. Role of inert and active top electrode is discussed in detail. Interface related modifications in resistive switching are explained. Mott transition at interface plays an important role in resistive switching, which is understood by modifying the layers in heterostructure. At last several mechanisms of resistive switching in manganites are compared.

Keywords : Heterostructures, Pulsed Laser Deposited, Magnetoresistance, PZT, CER, RS, PCMO

I. INTRODUCTION

Coming from one of the strongly correlated electrons family, manganites posses various interesting key factors such as magnetoresistance (MR), spin, charge, orbital and lattice correlations, percolative phase competitions, various ground states , which gives wide attentions to practical applications and also important from the point of theoretical understanding. Manganites are known to exhibit various physical properties such as metal – insulator transition at phase separation temperature, paramagnetic – ferromagnetic transition at curie temperature, moreover antiferromagnetic – ferromagnetic insulating phase, ferromagnetic metallic phase, etc. Manganites are very useful for various practical applications such as p – n junctions [1], capacitors [2], field effect devices [3], temperature sensors [4], magnetic tunnel junctions [5], spin transistors [6], memory devices [7] etc. Keeping in mind all the above important aspects and results of the studies on manganite based devices,, in this communication, I report the overview and important features of few reported work, as a review, on colossal electroresistance (CER) and resistive switching (RS) in manganite based heterostructures.

II. MATERIALS

In this review article, three different published articles have been discussed in detail. First article covers the pulsed laser deposited (PLD) $Pr_{0.7}Ca_{0.3}MnO_3$ thin films, in oxygen efficient and deficient environment to vary the oxygen content and then Al top electrodes were sputtered on top of it using shadow mask [8]. Second article is based on various sandwich structures of $PrMnO_3$, $CaMnO_3$ and $Pr_{0.7}Ca_{0.3}MnO_3$ made by PLD technique [9].Wherein function of each layer is discussed on the basis of experimental results. Third report covers the colossal electroresistance (CER) behavior, implemented using $PbZr_{0.2}Ti_{0.8}O_3$ (PZT) or dielectric gates. The field effect device geometry was fabricated using PLD technique [10], where the polarizable nature of gate is found to be responsible for CER effect.

III. REVIEW

Li et al [8] have prepared PCMO thin films on silicon substrate using pulsed laser deposition technique. They tried to increase oxygen vacancies in PCMO thin film by maintaining low oxygen pressure and temperature around 620 °C. Oxygen-stoichiometric thin films were prepared by maintaining comparatively high oxygen pressure. They sputtered different electrode materials such as Au, Ag, Cu and Al and understood their activeness on the basis of standard Gibbs free energies of those materials. They obtained contradictory behavior compared to binary transition oxide materials (TMO). In TMOs forming process produces a soft breakdown, but in this case junction resistance continuously increases. They also found that Al electrode can be easily oxidized by oxygen stoichiometric PCMO and AlO_x is responsible for active-TE based resistive switching junctions. For Al/PCMO junction they observed another unique feature, which is at positive bias clockwise I – V behavior is observed whereas for Cu and Ag based junctions anticlockwise I – V behavior is observed. They suggested that the Ag and Cu should be categorized as inert TE materials for PCMO junctions. They finally concluded that all RS features exhibited by Al/PCMO/Pt junctions are due to formation and dissociation of the alumina layer at the interface between Al and PCMO.

Wu et al [10] have published a nice paper on electroresistance and phase separation in Mixed-Valent Manganites They fabricated devices in field effect configurations with $La_{0.7}Ca_{0.3}MnO_3$ (LCMO), $Nd_{0.7}Sr_{0.3}MnO_3$ (NSMO), $La_{0.7}Ba_{0.3}MnO_3$ (LBMO), and $La_{0.5}Ca_{0.5}MnO_3$ (0.5-doped LCMO) channels, and PZT or dielectric $SrTiO_3$ as a gate. They observed 76% ER in LCMO with PZT-ferroelectric gate, but in other channels less ER is observed. They also mentioned that the percolative phase separation is the key to understand CER effect in manganite based devices. They gave a clear idea about why LCMO is giving much larger ER, where two phases in system must be present in balanced fraction, In case of 0.5-doped LCMO, it is in strongly insulating state, NSMO is in a weakly insulating state. The most part of LBMO is metallic, so that is the reason that ER is not observed or less observed.

Kim et al [9] have studied the resistive switching characteristics of Au / $Pr_{0.7}Ca_{0.3}MnO_3$ (PCMO) / Pt sandwich structure by varying growth parameters such as temperature and oxygen pressure, and also modified the above sandwich structure by inserting dielectric materials such as $PrMnO_3$ (PMO) or $CaMnO_3$ (CMO) layer at the Au / PCMO interface. They found that value of resistance ratio of HRS and LRS is increasing with increased substrate temperature, so they concluded that the RS behavior is strongly dependent of crystallinity of thin film. Also by varying growth parameter, change in RS behavior is observed. Now, they introduced PMO and CMO at Au / PCMO interface; they found that structure was not showing the hysteretic I – V characteristics irrespective of thickness of PMO layer. Au / PMO / Pt structure was fabricated to check I – V characteristics of PMO layer itself, and they have not found any hysteresis. Similar thing also happened with CMO layer. These results proved that Au / PCMO interface plays a key role in the resistive switching of the Au / PCMO / Pt structure. To clear all this confusion, they fabricated Au / PCMO / PMO (or CMO) / PCMO / Pt structure and in I – V curves they found hysteresis. By doing all the exercise they concluded that at the Au / PCMO interface, Mn^{4+} / Mn^{3+} must be present in a mixed valent states to get the RS behavior. If Mn ions are present in a single valence state, such as Mn^{3+} or Mn^{4+} at interfaces, the resistive switching cannot be observed. So, the RS phenomenon is srongly dependent upon the mixed valence state of Mn ions at metal / PCMO interface.

IV. CONCLUSION

In conclusion, PLD method can be used to precisely control the growth parameters and fabrication of high quality, reproducible multilayer thin films can be done. RS behavior can be explained by the CER effects and the metal / manganite interface plays a very important role. CER effect can be enhanced by using polarizable or dielectric gates in field effect configuration. RS behavior can be understood by various mechanism such as oxidation and reduction process at interface or in other words Mott transitions at interface which results into a mixed valent states of Mn^{3+} / Mn^{4+} at interface. In all these process percolative phase separation in manganites is a important feature to be understood.

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