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Positive MR and Large Temperature−Field Sensitivity in Manganite Based Heterostructures

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Studies on the ZnO/$La_{0.5}Pr_{0.2}Sr_{0.3}MnO_3$ (LPSMO)/$SrNb_{0.002}Ti_{0.998}O_3$ (SNTO) heterostructure having varying thickness of p-type LPSMO (100 nm − LP1) and (200 nm − LP2) manganite are carried out. ZnO/LPSMO (n−p) and LPSMO/SNTO (p−n) junctions of both the heterostructures exhibit good rectifying behavior in a wide range of temperature and applied field. Forward and reverse bias characteristics of both the junctions of heterostructures show opposite behavior. The observation of negative magnetoresistance (MR) at 5 K and positive MR at 300 K, in both the heterostructures, has been explained in the context of interface region effects and filling of energy bands of LPSMO manganite. Further, at high temperature, the heterostructures exhibit large temperature (46%K^{-1}) and field (40%T^{-1}) sensitivities. Dependence of transport, magnetotransport, *I*−*V* and sensing properties of the heterostructures, on the temperature, field and film thicknesses have been discussed in this communication.

KEY WORDS: Interfaces; Thin films; Pulsed laser deposition; X-ray diffraction; Electric properties

1. Introduction

Studies on colossal magnetoresistance (CMR) manganites are interestingly different from other oxides due to the substitutional effects and the tunability of their transport properties under applied electric and magnetic fields[1,2]. Various interactions among spin, charge, orbital and lattice degrees of freedom in manganites can be understood on the basis of field dependent modifications in their transport behavior. Observation of large magnetoresistance (MR) defined as MR $= ((\rho_H - \rho_0)/\rho_0) \times 100$ at low transition temperature (insulator − metal (T_P) and paramagnetic − ferromagnetic (T_C)) under large applied field, in most of the doped rare earth based manganites, has been a major bottleneck in their practical applications in the form of thin film devices[3,4]. Hence, enormous amount of researches are being devoted to the fabrication and studies on various manganite based thin film devices suitable for applications[5−7].

Xu et al. demonstrated the use of polycrystalline manganites as magnetic field sensors with the field sensitivity ~200%T^{-1} at RT within a field range of 1−3 mT[8]. Markna et al. also reported large field (~30%T^{-1}) and temperature (~60%K^{-1}) sensitivities exhibited by manganite films and nanostructured heterostructures[9,10]. High temperature large negative field sensitivity ~20%T^{-1} has been observed in low cost chemical solution deposited manganite films[11]. Substrate dependent transport and magnetotransport studies on multilayered manganite based structure shows large field sensitivity ~35%T^{-1} at room temperature (RT) under a field of 100 Oe[12] which is larger than that of the manganite based thin film and nanostructured heterostructure[9,10]. Vachhani et al. reported a high field sensitivity at RT in the manganite based p−n junction diodes[13].

$La_{0.7}Sr_{0.3}MnO_3$ (LSMO) manganite is a large one electron bandwidth system having electric/magnetic transition well above RT[14] while Pr^{3+} doped LSMO [$La_{0.5}Pr_{0.2}Sr_{0.3}MnO_3$ (LPSMO)] having T_P near RT with comparatively large MR, has been well studied in the form of nanostructures, thin films and heterostructure[10,15]. Manganite based thin film diodes consisting of p-type manganite and n-type SNTO[16−18] and ZnO[19,20] have been well studied. Hu et al. observed the phase separation scenario in $La_{0.9}Sr_{0.1}MnO_3/SrNb_{0.01}Ti_{0.99}O_3$ device and showed that, ferromagnetic−metallic phase exhibited negative MR while paramagnetic−insulating phase showed positive MR[16], while Lu et al. reported a large current sensitivity as a function of applied voltage during reverse bias mode in the $LaSrMnO_3/SrTiNbO_3$

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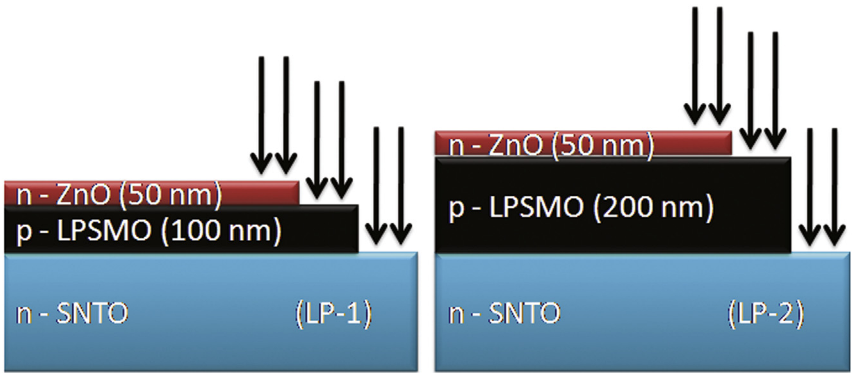

Fig. 1 Schematic representation of devices under study along with the transport measurement-current perpendicular to plane (CPP)-geometry.

based p−n junction diodes[17]. Jin et al. studied and discussed the existence of negative and positive MR in the $La_{0.9}Sr_{0.1}MnO_3$/$SrNb_{0.01}Ti_{0.99}O_3$ device and explained the dominance of positive MR at low applied fields in high temperature range using the interface and phase co-existence in the device[18]. ZnO is a wide band gap semiconductor, useful for many practical applications. Device based on the combination of ZnO−manganite have been successfully studied and found to exhibit positive MR effect and rectification in a wide temperature range[19]. Tiwari et al. investigated the thickness dependent electrical transport of LSMO films in LSMO/ZnO heterojunction[20].

In the present work, the heterostructures having combination of n-type ZnO/p-type LPSMO grown on n-type conducting SNTO single crystalline substrates are studied to understand the mechanism responsible for the rectifying behavior and the transport properties are also reported. Temperature and field dependent transport and magnetotransport in the heterostructure with varying thicknesses of p-type LPSMO manganite, have been understood in the light of interface effects and the filling of energy bands of the LPSMO manganite. Large temperature and field sensitivity has been observed in these heterostructures across both the back-to-back junctions.

2. Experimental

Bulk single phase crystalline targets of $La_{0.5}Pr_{0.2}Sr_{0.3}MnO_3$ (LPSMO) and ZnO synthesized by solid state reaction (SSR) route were used for ablation of 100 and 200 nm LPSMO films on properly masked $SrNb_{0.002}Ti_{0.998}O_3$ (SNTO) single crystalline substrates (Fig. 1) using Pulsed Laser Deposition (PLD) technique. ZnO with a desired thickness of ∼50 nm was deposited on the top of LPSMO layer (after masking the LPSMO/SNTO film (Fig. 1)) in both the heterostructures, referred as LP1 (100 nm LPSMO) and LP2 (200 nm LPSMO), respectively. A 248 nm KrF excimer laser with fluence of ∼1.80 J/cm^2 was used to ablate the targets. During all the depositions, the substrate temperature was maintained at 600 °C, with the oxygen partial pressure of ∼40 Pa (∼300 mTorr) and substrate to target distance ∼50 mm. Single phasic epitaxial nature of the heterostructure was confirmed by using θ−2θ XRD measurements as well as using Φ-scan measurements at RT. R−T measurements, in the temperature range of 2−400 K were taken using d.c. four probe method in PPMS (Quantum Design) with current perpendicular to plane (CPP) geometry (Fig. 1) for understanding the junction resistance behavior. I−V characteristics were obtained across n (ZnO) − p (LPSMO) and p (LPSMO) − n (SNTO) junctions for both LP1 and LP2, heterostructures in the temperature range of 5−300 K under the fields of 0−8 T using a four probe technique. Field dependent resistance measurements were carried out to study the field sensitivity across both the junctions of the heterostructures.

3. Results and Discussion

Typical XRD patterns of LP1 and LP2 heterostructures (Fig. 2) clearly show single crystalline nature and *a*-axis oriented growth with the lattice mismatch between LPSMO film and SNTO substrate evident from the positional difference between film and substrate peaks at ∼23° and 47°. Structural strain,

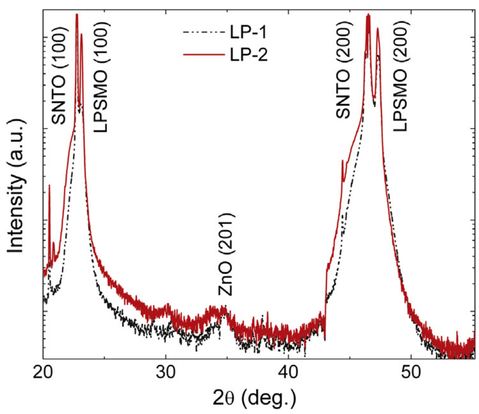

Fig. 2 Typical XRD patterns of LP1 and LP2 heterostructures.

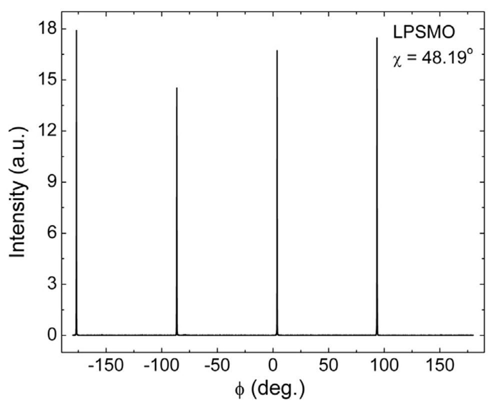

Fig. 3 XRD Φ-scan on LP1 heterostructure.