3A, 4C/2008S2-004, 2009S2-003

Diffraction study on “Magnetically tunable metal-insulator superlattices”

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Introduction

Recent development of the growth technique of the thin film enable us to architect the artificial superlattice structure with different electronic phases in the accuracy of the order of atomical-size scale. New superlattices with functionable feature, for example superconductor and ferromagnetisum and ferroelectric and ferromagnetisum, have been realized. In this report, we introduce a new superlattice with magnetically tunable metal-insulator boundary consisted of insulator $Pr_{0.5}Ca_{0.5}MnO_3$ (PCMO) and ferromaginetic metal $La_{0.5}Sr_{0.5}MnO_3$ (LSMO).

Experimental results and Analysis

The superlattice structure of LSMO and PCMO fabricated on LSAT(011) substrate. The superlattice is denoted in the formular of [PCMO(m layer)/LSMO(n layer)]^{15}. A schematic view of the ion arrangement of a [5/5] superlattice is illustrated in Fig. 1 (a). These films were deposited in a layer-by-layer growth mode and the layer thickness were precisely controlled. The observed sharp satellite peaks around (0 2 2) reflection with 13 clear Laue fringes between satellite peaks indicate the accuracy of [5/5] structure and 15 times repetation of [PCMO/LSMO] superlattice. The x-ray experiments were performed on a four-circle diffractometer installed at the beamline 3A and 4C. The energy of incident x-ray was tuned near 9.5 keV.

Figs. 1 (b) and (c) show the temperature dependences of the resistivity and magnetization of the superlattices, respectively. The pure LSMO film is metalic and ferromagnetic below 350 K. With increasing PCMO layer, the magnetic transition temperature becomes lowering. At the intermediate [5/5] superlattice, the remarkable behavior, appearance of the continuous phase transition, is observed. The ferromagnetic and metallic phase appear before entering the insulating phase around 200 K with decreasing temperature. Further increase of PCMO layer grows a robust insulating phase. Finally, the resistivity and magnetization curves close in on that of pure PCMO film. In PCMO film, the charge- and orbital-ordering is observed [1]. To characterize the insulating phase of the superlattice, we performed diffraction experiment in [5/5] superlattice. In the result, we observed the superlattice reflection with propagation vector (1/4 1/4 0) under the insulating phase as shown in Fig. 1 (d), which represents the emergence of the stripe-type charge and orbital order [1]. The schematic cartoon of Fig. 1 (e) explains what happens through the continuous phase transition. First, all layers of PCMO and LSMO would be ferromagnetic and metallic state. With decreasing temperature, the charge and orbital order takes place on PCMO layer, and the atomical-scale phase separation is realized. Furthermore, the boundary of the phase separation can be freely controlled by the external magnetic field. Detailed informations are reported in ref. [2].

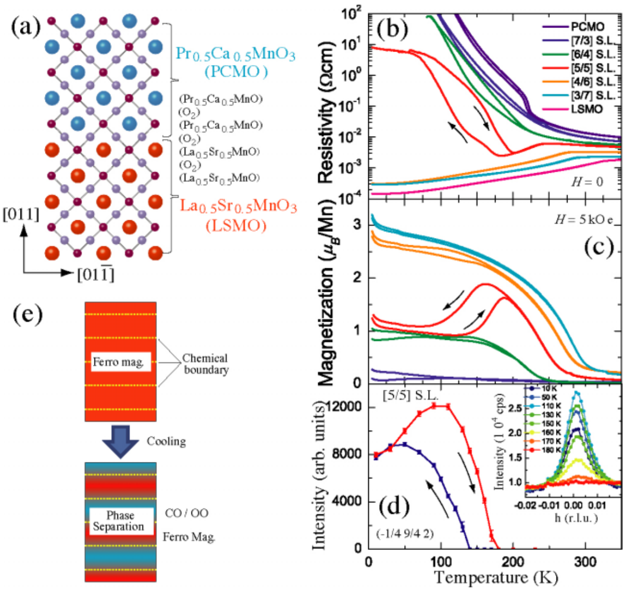

Fig. 1: (a) A schematic view of the [5/5] superlattice of PCMO and LSMO. The resistivity (b) and magnetization (c) data of [m/n] superlattices, respectively. (d) The (-1/4 9/4 2) reflection due to the charge and orbital order measured by x-ray diffraction. (e) Cartoon for explaining the continuous transition observed in [5/5] superlattice.

References

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