18p-E8-21

Investigation of effective carrier characteristics in strongly correlated (La,Pr,Ca)MnO_3 films by the THz Time Domain Spectroscopy

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The strongly correlated oxides have a wide range of unique behaviors owing to the interplay of the spin – charge – lattice – orbital degrees of freedom. Manganites, such as $(La_{5/8-y}Pr_yCa_{3/8})MnO_3$ are of particular interest with the novel properties originating from the electronic phase separation and the competition between the charge ordering insulator phase and the ferromagnetic metal phase through the Insulator – Metal transition (IMT) [1]. Interestingly, these properties are greatly associated to the orbital effect that can be controlled by tuning the Pr content: y in the stoichiometry. The investigation for the effective carrier characteristics across the IMT and the change of number of effective carriers N_{eff} due to the modified orbital effect in this system is essential in the aspects of the scientific understanding and the electronics application. To obtain the N_{eff}, the THz Time Domain Spectroscopy (THz-TDS) is an authorized technique. So far, the THz-TDS is widely applied to various manganite systems to investigate their optical conductivity [2], but the number of papers reported on the effective carrier characteristics is limited.

In this study, the $(La_{5/8-y}Pr_yCa_{3/8})MnO_3$, LPCMO films on MgO(001) substrates were fabricated by using the pulsed-laser deposition technique and the THz-TDS measurements from 0.5 THz to 3 THz were performed to investigate the effective carrier characteristics from 10 K to 250 K. Figure 1 shows a typical temperature dependence of the dc conductivity: σ_{dc}-T curve of the LPCMO film (y=0.35) with ~ 4 orders of magnitude change at the critical temperature of 125 K in the cooling process. From the THz-TDS measurements and analyses, the number of effective carriers N_{eff} at different temperatures in the LPCMO thin film (y=0.35) could be estimated as exhibited in Fig. 2. This result also showed ~ 4 orders of magnitude change of N_{eff} across the IMT with the critical temperature of about 120 K. The observed temperature dependent tendency of the N_{eff} obtained by the THz-TDS is in accordance with that of the dc conductivity σ_{dc}. The estimated value of N_{eff} at 15 K was about 0.01 carriers per unit cell that is comparable to the ones obtained by other optical [3] and electrical [4] techniques. In the presentation, the change of the N_{eff} with the Pr content in the stoichiometry, relating to orbital effect in the LPCMO system will also been discussed. This result illustrates the potential for the investigation of the number of effective carriers in the strongly correlated oxide system using the THz-TDS technique with the advantage of the non-probe measurement.

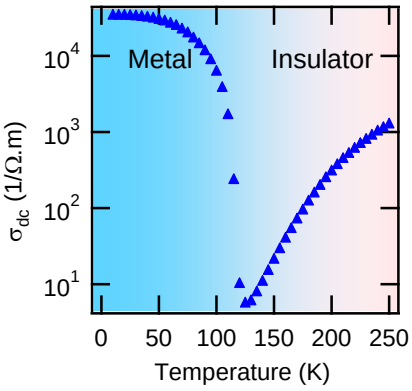

Fig. 1: Temperature dependence of the dc conductivity of the LPCMO film (y=0.35)

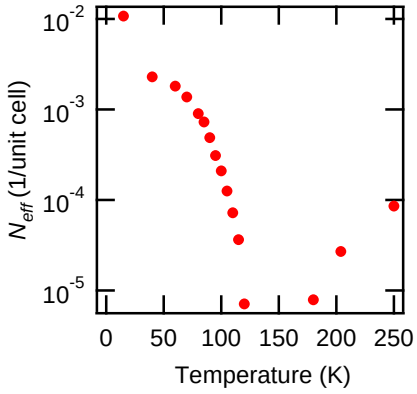

Fig. 2: Temperature dependence of the number of effective carriers of the LPCMO film (y=0.35) obtained from the THz-TDS measurement

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