Electrical transport properties in phase-separated manganite nanowires investigated using terahertz time domain spectroscopy

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1. Introduction

The typical perovskite manganite (La,Pr,Ca)MnO_3 shows exotic colossal magnetoresistivity which is associated to the insulator-metal transition (IMT) [1] from an insulator behavior at a high temperature to a metallic behavior at a low temperature through a critical transition temperature T_{IM}. Around T_{IM}, the phase-separated metal and insulator domains coexist in a nanometer scale. Since the conductive property in a phase-separated material is determined by the conductivity behaviors of metal/insulator nanodomains, understanding the electrical transport properties, i.e., quantitative evaluation of the change of metal fraction ($X(T)$) and the dc conductivity ($\sigma_{dc}(T)$) are required. Interestingly, owing to the confinement of nanodomains, the peculiar property was observed in a nanostructure [1], therefore the investigation of their electrical transport properties becomes extremely important. However this is still a challenging issue by using the electrical measurement with attached electrodes.

Freshly, a reliable technique for investigation electrical transport properties using terahertz time domain spectroscopy (THz-TDS) has been proposed for a phase-separated manganite film [2]. Thanks to the non-contact manner, the electrical transport properties of phase-separated nanostructures such as a $(La_{0.275}Pr_{0.35}Ca_{0.375})MnO_3$ (LPCMO) nanowires structure have been be investigated as demonstrated in this study.

2. Results and Discussion

A high density of 100-nm-width-LPCMO nanowires was integrated on a MgO(001) substrate by using the nanoimprint-based lithography technique (Fig. 1). In the THz-TDS, the structure effect, associating to the polarization direction ($\vec{P}$) of THz pulse versus the wire alignment, was observed with the change of conductivity behavior of the nanowires at 10 K from metallic in the parallel configuration to insulator in the perpendicular alignment. To obtain the intrinsic electrical transport properties for the nanowires sample, the parallel configuration was conducted in the THz-TDS experiments in a temperature range from 10 K to 300 K. We obtained the temperature dependent THz conductivity ($\sigma_{THz}(\omega,T)$ curves in Fig. 2). These $\sigma_{THz}(\omega,T)$ curves could be well explained by the insulator-metal composite model:

$$\sigma_{THz}(\omega,T) = (1 - X(T))(\sigma_0^{I}(T) + A\omega^{s}) + X(T)\frac{\sigma_0^{M}(T)}{1+\tau^2\omega^2}. \quad (1)$$

in which, $X(T)$ is defined as the fraction of metallic phase in

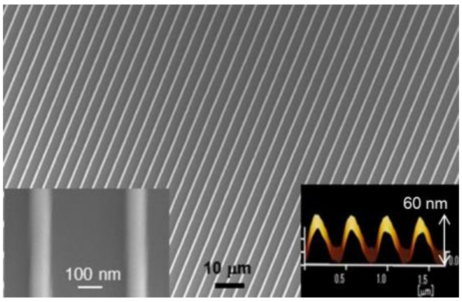

Fig. 1: (a) SEM image of a typical 100-nm-width nanowires sample

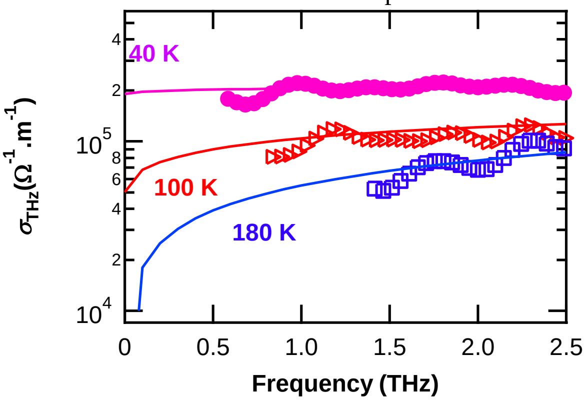

Fig. 2: Typical $\sigma_{THz}(\omega,T)$ curves at different temperatures (marks) and corresponding fit lines

the nanowires at a temperature T; $\sigma_0^{I}(T)$ and $\sigma_0^{M}(T)$ are the dc conductivities for insulator and metal phases, respectively; A and s are the amplitude and power parameter of the hopping conductivity in insulator state; τ is the relaxation time for free electrons in metallic state. By fitting the $\sigma_{THz}(\omega,T)$ curves with Eq. (1), we could simultaneously estimate the $X(T)$ and $\sigma_{dc}(T)$ through the IMT for the nanowires sample. In the presentation, the detail explanation on analyzing procedure and electrical transport properties will be discussed.

3. Conclusions

The investigation of electrical transport properties has been obtained in a typical phase-separated nanowires sample. This novel technique is applicable for study the electrical transport properties in nano-composite structures, such as the core-shell nanoparticles, the nano-heterostructures.

References

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