Hetero-epitaxial strain dependence of Terahertz conductivity in $NdNiO_3$

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Abstract— **Terahertz Time domain spectroscopic investigations on the effects of hetero-epitaxial strain on $NdNiO_3$ are presented. The terahertz optical conductivity data obtained for thin films of $NdNiO_3$ points towards stronger electron-electron correlation effects under compressive strain as a higher resistive state manifests, whereas, they are weaker for the tensile strained films.**

I. INTRODUCTION

THE application potential of Terahertz technology in Materials research has unveiled plenty of novel fundamental and technological encompassing a variety of complex systems.[1,2] Terahertz (THz) time-domain spectroscopy (TDS), in particular, has proven efficacy in exploring the low energy (0.5-10 meV) excitation in the strongly correlated systems. Among these, one of the most promising classes of materials belongs to the 3d-transition metal oxides where competing interactions between the spin, charge, orbital and lattice degrees of freedom exists. The $NdNiO_3$ belongs to one such class of correlated materials which exhibits concomitant insulator-metal (*I-M*) and antiferromagnetic ordering at ~ 205 K. This system exhibits fascinating tunability of *I-M* transition by temperature, pressure and epitaxial strain. However, its insulating state is rather debatable.[3] Here, we have investigated the impact of the epitaxial strain on the Terahertz dynamic response of the $NdNiO_3$ and try to establish a novel epitaxial strain induced cause-effect relationship.

II. Results

In this work, we have performed temperature dependent (5- 300 K) THz time-domain spectroscopic (TDS) measurements in the energy range of 0.5 – 7 meV on $NdNiO_3$ thin films. THz-TDS measurements were carried out on the $NdNiO_3$ epitaxial thin films prepared on $(LaAlO_3)_{0.3}(Sr_2AlTaO_6)_{0.7}$ [LSAT] (100) and $LaAlO_3$ (LAO) (100) single crystal substrates. The temperature dependent THz conductivity of $NdNiO_3$ (100) films, is obtained by solving Fresnel's equations.[2] The X-ray diffraction in figure 1(a) shows the phase purity of $NdNiO_3$ films grown on LAO and LSAT substrate. Further the information on the strained can be found using the reciprocal space maps for the $NdNiO_3$ thinfilms. It may be seen that the $NdNiO_3$ film peak reflection does not lie on the same pseudomorphic line as of the substrate (Figure 1(b)). Hence the $NdNiO_3$ film on the LSAT (100) substrate is relaxed. Further, the single crystal LAO (100) and LSAT (100) substrates provide -0.3% and +1.7% lattice mismatch for $NdNiO_3$, respectively. As the films are 200 nm thick and were found to be partially relaxed with the c-axis parameters as deduced from the reciprocal space map of $NdNiO_3$ is 3.803 Å on LAO and 3.811 Å on LSAT.

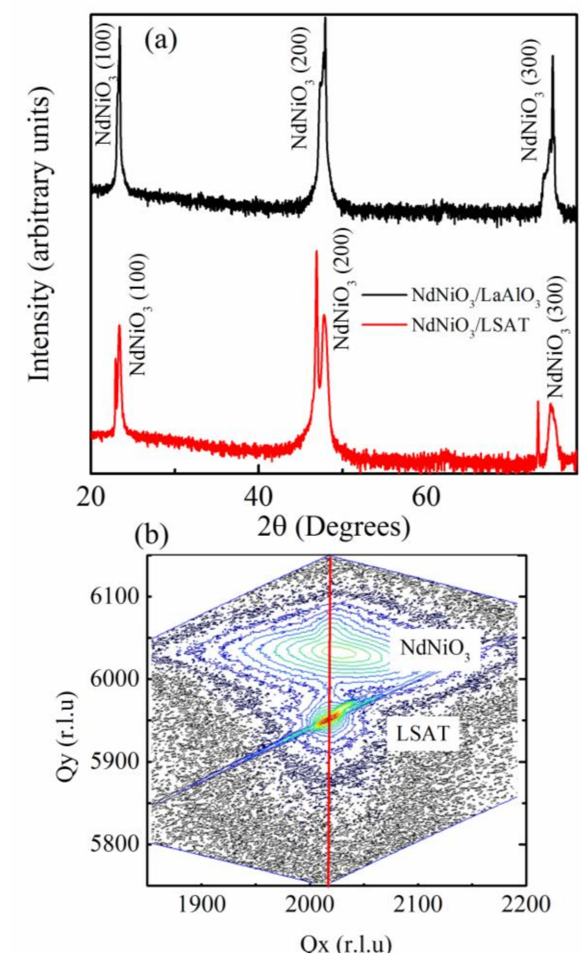

Figure 1. (a) shows the X ray diffraction for $NdNiO_3$ on $LaAlO_3$ and LSAT substrates and (b) shows the reciprocal space map along the asymmetric peak reflection (301) of the LSAT substrate for the $NdNiO_3$ (100), here the red line indicates the pseudomorphic line and (r.l.u) denotes the reciprocal lattice units.

The temperature dependence of terahertz conductivity (σ_{THz}) provides crucial information about the underlying mechanisms driving the $NdNiO_3$ films and for selected photon energies and is shown in figure 2. The insulator-metal transition for the $NdNiO_3$ thin-film is around ~ 200 K on the LSAT(100) is much sharper than that grown on the $LaAlO_3$(100) substrate. Further, a larger conductivity may be observed on the LSAT (tensile strain) vis-à-vis LAO (compressive strain) and displays a direct correspondence with the dc transport data (not shown). To understand the carrier dynamics across various NNO films, the Drude carrier concentration (N) was calculated from the Drude plasma frequency (ω_{PD}) using the relation, $\omega_{PD}^2 = 4\pi Ne^2/m^*$, where, m^* ~6 m_o is the effective mass and m_o is the mass of the free electron.[4] An N of the order of $\sim10^{19}$ and $\sim10^{20}$ was obtained, respectively, in the insulating and the metallic states for the LSAT (100) and the value of N varied from $\sim10^{18}$ in the insulating state to $\sim10^{19}$ in the metallic state for the LAO (100) substrate. This clearly indicates that the larger Drude carriers are present in the tensile strained film as compared to the compressive strained counterpart. This reduction in the number of electrons in the low temperature phase may be associated with the setting of the unusual AFM order in $NdNiO_3$. Further, we obtained higher values of ω_{PD} for the tensile strained films than the compressive strained films highlighting the weaker electronic correlations in the former.

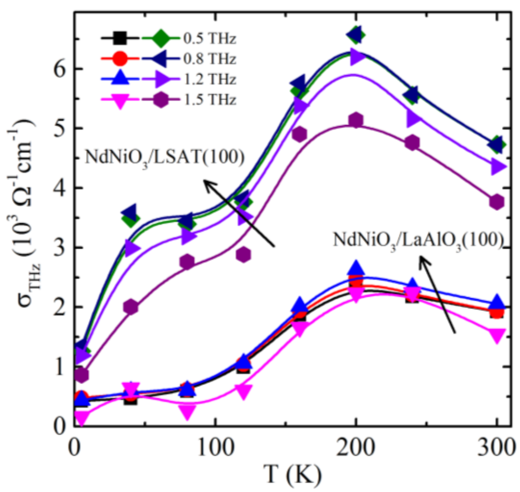

Figure 2. Optical terahertz conductivity (σ_{THz}) as a function of temperature for $NdNiO_3$thin-films.

III. SUMMARY

The low energy THz-TDS measurements in $NdNiO_3$ films present the subtle electron-electron correlations can be effectively engineered using the hetero-epitaxial strain.

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