Electrical Conductivity of Insulating SrTiO$_3$ and LaGaO$_3$ at Phase Transitions

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Many properties of BaTiO$_3$ have been studied motivated by the basic and the application oriented interests. However, few reports on the electrical conductivity of undoped pure insulating BaTiO$_3$ single crystals exist so far. Recently, we have reported that the quasi-equilibrium electric conductivity ($\sigma$) of undoped insulating BaTiO$_3$ single crystals exhibits sharp peaks at the phase transitions. To investigate the origin, the present paper studies the effect of the spontaneous polarization $P_S$ on the peaks by measuring the $\sigma$-temperature ($T$) characteristics of LaGaO$_3$ that undergoes the ferroelastic phase transition at 160 °C and SrTiO$_3$ that undergoes nonferroelectric structural phase transition at 105 K.

Whereas BaTiO$_3$ single crystals show the conductivity peaking at phase transitions (Fig.1), LaGaO$_3$ single crystal shows only a small change in the $\sigma$-$T$ characteristics at phase transitions (Fig.2). This small change is explicable by the change of the carrier mobility and the carrier activation energy at the phase transition.

SrTiO$_3$ is known to undergo nonferroelectric structural phase transition at 105K and be quantum paraelectric at low temperature due to the ground state vibration of the lattice. Figure 3 shows that no peak is present at 105 K. These results indicate that the ferroelectric phase transition or $P_S$ is essential for the peaking in the $\sigma$-$T$ characteristics.

However, Fig.3 shows unusual $\sigma$-$T$ characteristics. The apparent quasi-equilibrium $\sigma$ increases toward 0 K. One of the plausible origins is the dielectric relaxation or the relaxation of the polar clusters [3]. However, this interpretation appears to be difficult, because the IV characteristics are ohmic (Fig.3). However, the $\sigma$ extracted from the current-time ($I$-$t$) characteristics at fixed temperatures disagree with $\sigma$ extracted from the $I$-$V$ characteristics. To understand this discrepancy, we have examined the effects of change of the dielectric constant due to the temperature fluctuations. This is because the temperature fluctuation can yield current even at constant applied voltage according to $j=(dC/dt)V=(dC/dT)(dT/dt)V$. This effect could not resolve the discrepancy and we are at present uncertain whether the observed increase toward 0K represents the current conduction.

**Fig. 1** $\sigma$-$T$ characteristics of pure undoped stoichiometric BaTiO$_3$ single crystal.

**Fig. 2** The electric conductivity of LaGaO$_3$ single crystal vs. temperature ($\sigma$-$T$ characteristics)

**Fig. 3** Preliminary $\sigma$-$T$ characteristics of SrTiO$_3$ single crystal (left) extracted from the $I$-$V$ characteristics (right). The thickness is 0.54mm.

References