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Temperature and Frequency Dependence of Electric Properties in Terbium Nitrate Crystal

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The spectra of ac conductivity in the frequency range from 50 Hz to 100 kHz at temperature in the range from 30°C to −65°C have been measured in a terbium nitrate crystal. The experimental results indicate a metastable property in the crystal. © 1993 Academic Press, Inc.

Crystallographic structures of $Ln(NO_3)_3 \cdot 6H_2O$ compounds have been isotypic (*1*). The characteristic electric behaviors have been found in the temperature region from room temperature to ~ −45°C in the rare earth nitrate crystals *Ln* = Sm, Gd, Nd, Eu, and Er (*2–6*). However, the electric properties of terbium nitrate crystal, $Tb(NO_3)_3 6H_2O$, have not been studied (*7*). In the present note, the authors have reported crystal growth of the terbium nitrate and the electric properties obtained from the measurements on the frequency dependence of the ac electric conductivity from 50 Hz to 100 kHz at temperatures in the region from room temperature to −65°C by using the apparatus controlled automatically with a computer.

Experimental

The single crystals of terbium nitrate were grown from the saturated solution by slow cooling from 32.8 to 30.5°C for 2400 hr. The crystal habit of the terbium nitrate was similar to those of the other rare earth nitrate crystals.

The ac conductivity of the crystal in the frequency range from 50 Hz to 100 kHz was measured by a lock-in amplifier (NF LI-574A with preamp P-51A) with a frequency synthesizer (TOA FS-1301) and a computer (NEC PC9801E). The GPIB interface was used for the measurements and control. The precision of the data obtained in the measurement is ~0.1%.

The dimensions of the sample for the present measurement are 0.083(5) cm in thickness and 0.4263(5) cm^2 in area. Specimens were prepared by cutting the crystal perpendicular to the *c*-axis. The contact electrodes used in the measurements were made up of the silver paste (Tokuriki Chem. Inst. P255). The spectra for the ac conductivity was measured at constant temperature, obtained by a copper–constantan thermocouple mounted in the sample cell, which was controlled to ±0.1°C.

Temperature Dependence of ac Conductivity

The temperature dependence of the real part σ' for the complex electric conductivity σ^* at 1 kHz is given in Fig. 1 for two measuring runs with both heating and cooling processes in the range from room temperature to −65°C. The temperature dependence of the imaginary part σ'' for the σ^* at 1 kHz is given in Fig. 2.

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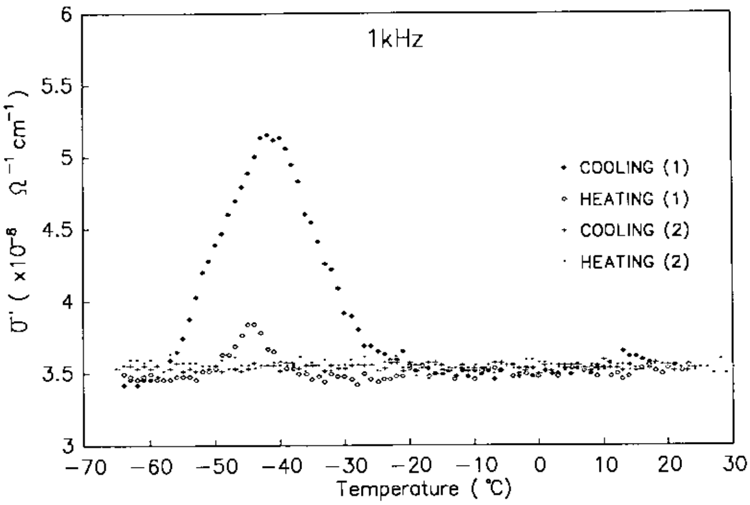

FIG. 1. The real part σ' of the complex conductivity σ^* in a terbium nitrate crystal at temperatures between room temperature and −65.0°C for the measuring runs $N = 1, 2$ in both the cooling and heating processes.

As given in Fig. 1, the temperature variation of the real part $\sigma'(T)$ obtained in the measuring run $N = 1$ shows broad peaks at ~ -45°C with thermal hysteresis. The imaginary part $\sigma''(T)$ for $N = 1$ in Fig. 2 shows smaller variation in the temperature region. As found in these figures, however, the conductivities measured for $N = 2$ show independent on temperature in the region.

The facts given in Figs. 1 and 2 would suggest that the electric property in the temperature region from ~ -20 and ~ -55°C is

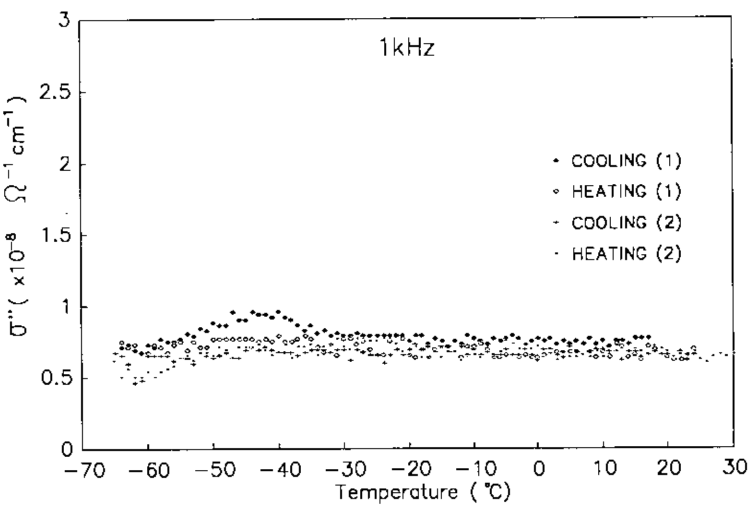

FIG. 2. The imaginary part σ'' of the complex conductivity σ^* in a terbium nitrate crystal at temperatures between room temperature and −65.0°C for $N = 1, 2$ in both cooling and heating processes.

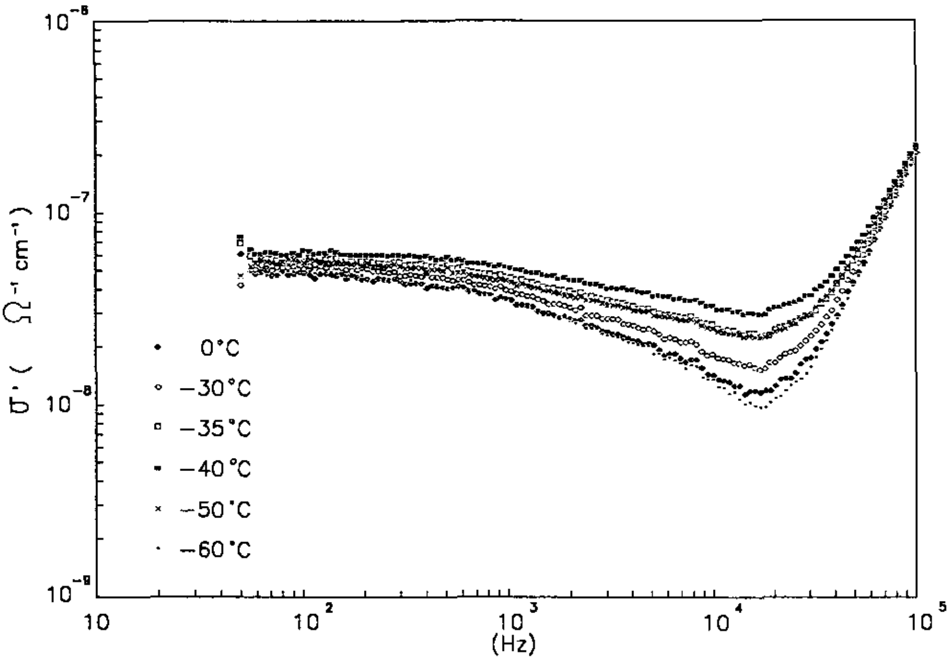

FIG. 3. Frequency variation of the real part σ' for the complex conductivity σ^* at several temperatures in the cooling process of the measuring run $N = 1$.

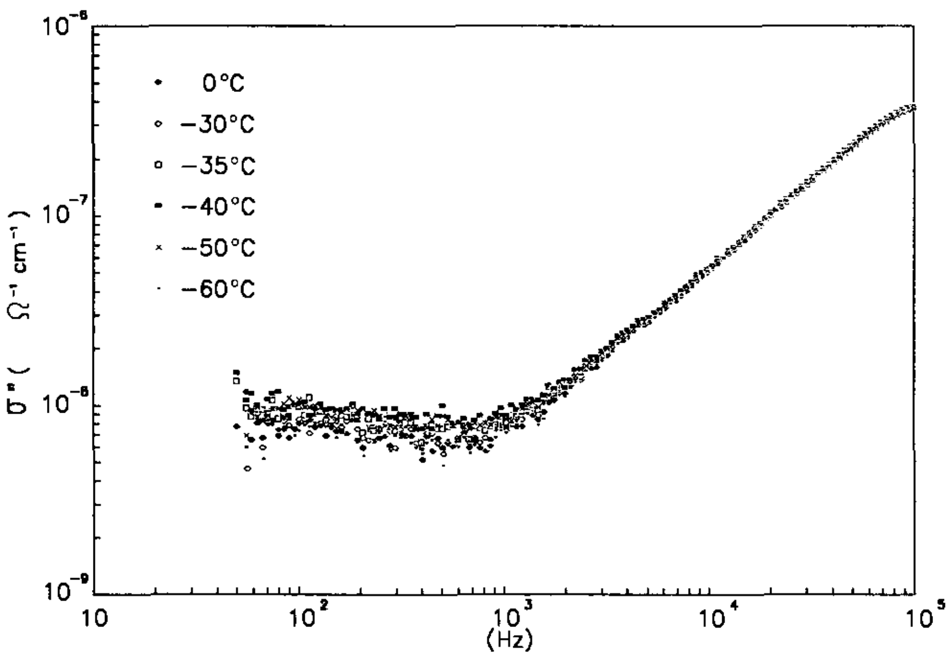

FIG. 4. Frequency variation of the imaginary part σ'' for the complex conductivity σ^* at several temperatures in the cooling process of the run $N = 1$.

metastable. The metastable behavior of the terbium nitrate crystal has been found in other rare earth nitrate crystals (*2–6*).

Frequency Dependence of ac Conductivity

Figure 3 shows the frequency dependence of σ' on the logarithmic plane in the range from 50 Hz to 100 kHz at several temperatures in the region from 0°C to −60°C in the cooling process for the measuring run $N = 1$. Figure 4 shows the frequency dependence of σ'' at temperatures in the cooling process for the measuring run $N = 1$.

The frequency dependence of σ' in the terbium nitrate crystal could be different to those in other rare earth nitrate ones (*2–6*). However the frequency dependence of σ'' in Fig. 4 has been found in other rare earth nitrate crystals (*2–6*).

Conclusion

By the measurement of the ac conductivities in the terbium nitrate crystal, metastable behavior, similar to those in the rare earth nitrate crystals $Ln(NO_3)_3 \cdot 6H_2O$ (Ln = Sm, Gd, Nd, Eu and Er), has been found. But the frequency dependence of the conductivity in the crystal are different than those in other rare earth nitrate crystals. This fact can be attributed to the variation in the inner electronic structure (*8*) of the rare earth ions in the crystals.

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