AIP | The Journal of Chemical Physics

# Temperature and frequency dependences of dielectric properties of sodium sulfate single crystal

R. K. Khanna and J. Sobhanadri

Citation: The Journal of Chemical Physics **59**, 1547 (1973); doi: 10.1063/1.1680220
View online: http://dx.doi.org/10.1063/1.1680220
View Table of Contents: http://scitation.aip.org/content/aip/journal/jcp/59/3?ver=pdfcov
Published by the AIP Publishing



THE JOURNAL OF CHEMICAL PHYSICS VOLUME 59, NUMBER 3 1 AUGUST 1973

# Temperature and frequency dependences of dielectric properties of sodium sulfate single crystal

R. K. Khanna and J. Sobhanadri
*Department of Physics, Indian Institute of Technology, Madras-36, India*
(Received 17 July 1972)

The dielectric constant ($\epsilon'$) and loss tangent ($\tan\delta$) of sodium sulfate ($Na_2SO_4$) single crystal, grown at 50 °C from aqueous solution, have been determined from room temperature to 250 °C at different frequencies between $10^2$ Hz and $10^5$ Hz and at $10^{10}$ Hz. The dielectric measurements are taken on the setup described earlier.[1]

The variation of $\epsilon'$ and $\tan\delta$ with frequency for a single crystal of $Na_2SO_4$ at five different temperatures is shown in Fig. 1. At room temperature (27 °C), there is a very slow decrease in the dielectric constant with the increase of frequency which attains an almost constant value of 5.68 beyond 3 kHz. With the increase of temperature there is an increase in the dielectric constant, which is more prominent in the low frequency region. The variation of $\tan\delta$ with frequency at various temperatures is similar to that of $\epsilon'$. The dependence of $\epsilon'$ on temperature at the frequencies 2 kHz, 10 kHz, 100 kHz, and 10 GHz for the same crystal is shown in Fig. 2. The variation of $\tan\delta$ with temperature is also shown in the same figure. No loss is observed at the microwave frequency (10 GHz), the minimum detectable loss being 0.005.

The dielectric constant of $Na_2SO_4$ has a positive temperature coefficient at 10 GHz. At low frequen-

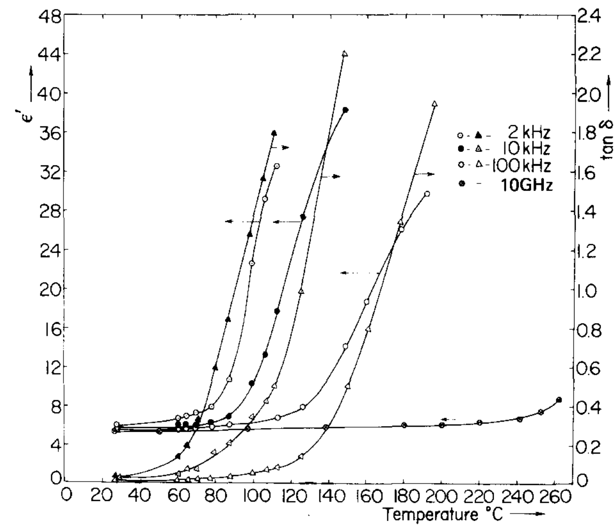


FIG. 2. Temperature variation of dielectic constant and loss tangent of $Na_2SO_4$ crystal at different frequencies.

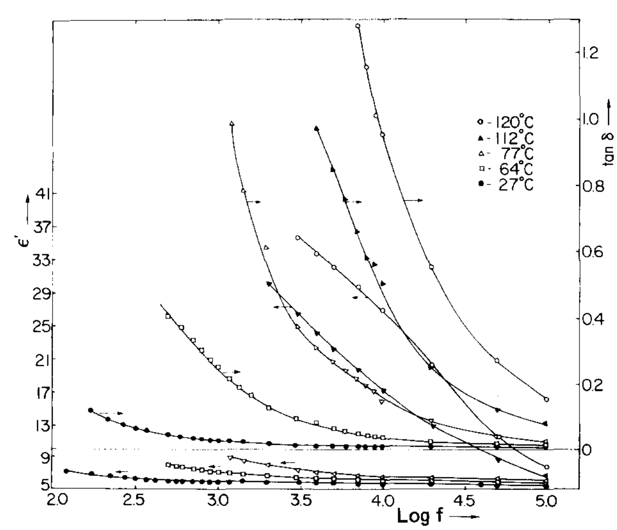


FIG. 1. Variation of dielectric constant and loss tanget of $Na_2SO_4$ crystal with frequency at different temperatures.

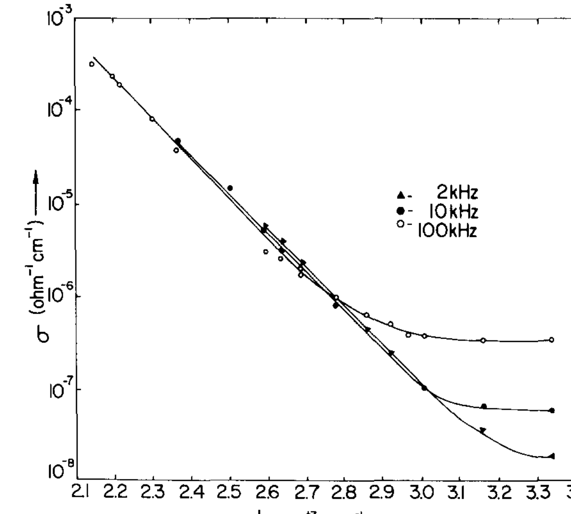


FIG. 3. Dielectric conductivity of $Na_2SO_4$ crystal at different frequencies.

cies, defects and imperfections cause sharp increases in both $\epsilon'$ and $\tan\delta$. Similar results were reported earlier in $KTaO_3$,[2] calcite crystal,[3] and $Li_2SO_4$.[1] The large dielectric constant at high temperature indicates less electrostatic binding between ions; therefore, less energy is required to move charge carriers. Rao and Smakula[4] attributed the high dielectric constant in the high temperature region to the creation and destruction of dipoles.

Using the relation $\epsilon'' = \epsilon' \tan\delta$, the loss factor $\epsilon''$ is obtained and the dielectric conductivity $\sigma = \omega\epsilon_0\epsilon''$ (where $\omega$ is angular frequency and $\epsilon_0$ is vacuum dielectric constant) is calculated at different temperatures for different frequencies. A plot of $\log\sigma$ against $1/T$ is shown in Fig. 3 for 2 kHz, 10 kHz, and 100 kHz. The curves have two distinct regions above room temperature. Below 80 °C, the conductivity is strongly frequency dependent and is due to associated defects as well as free charge carriers. Above 80 °C the dielectric conductivity is frequency independent; this intrinsic region has an activation energy of 0.36 eV, about the same as previously reported for $LiSO_4 \cdot H_2O$ (0.34 eV).[1]

[1] R. K. Khanna and J. Sobhanadri, Phys. Status Solidi A **12**, 225 (1972).
[2] M. D. Agrawal and K. V. Rao, J. Phys. C **3**, 1120 (1972).
[3] K. S. Rao and K. V. Rao, Z. Phys. **216**, 300 (1968).
[4] K. V. Rao and A. Smakula, J. Appl. Phys. **37**, 319 (1966).