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On the dielectric and elastic properties of $NaKSO_4$ crystals

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Résumé. — Les propriétés pyroélectriques, diélectriques et les coefficients de cisaillement G_x, G_y et G_z ainsi que la friction interne Q^{-1} des cristaux $NaKSO_4$ ont été étudiés dans l'intervalle de température entre 100 et 300 K. Une technique de pendule de torsion inverse a été utilisée pour déterminer la dépendance en température des coefficients de cisaillement et de friction interne. Les résultats des mesures pyroélectriques sont en accord avec la classe à symétrie centrale de $NaKSO_4$. La variation de la constante diélectrique avec la température a montré deux segments de pentes différentes. Un comportement anisotrope, en fonction de la température, a aussi été observé pour les coefficients de cisaillement. La friction interne a montré un maximum prononcé dans la direction *z* à 200 K.

Abstract. — The pyroelectric, dielectric properties and shear moduli G_x, G_y and G_z as well as the internal friction Q^{-1} of $NaKSO_4$ crystals were studied in the temperature range from 100 up to 300 K. An inverted torsion pendulum technique was used to determine the temperature dependence of both shear moduli and internal friction. The results of the pyroelectric measurements are in agreement with the centrosymmetric class of $NaKSO_4$. The variation of the dielectric constants with temperature shows two segments with different slopes. Anisotropic behaviour in the temperature dependence of the shear moduli was also observed. The internal friction showed a pronounced maximum in the *z*-direction at 200 K.

1. Introduction.

It is well known [1] that $NaKSO_4$ crystals have orthorhombic symmetry at 300 K and belong to the mmm point group. The growing interest in studying the physical properties of the double sulphate crystals is due to the fact that they show anomalous behaviour at different phase transition temperatures [2-5]. The recently obtained results of the thermal studies of $NaKSO_4$ crystals [6], in the temperature range from 300 to 500 K, point out the existence of a structural phase transition in these crystals at 453 K. However, the lack of information concerning the dielectric and elastic properties of $NaKSO_4$ crystal drew our attention to make further investigations of such crystals.

The present work describes the measurements of the temperature dependences of the dielectric constant, shear moduli as well as the internal friction of $NaKSO_4$ crystals in the temperature range from 100 up to 300 K.

2. Crystal preparation.

Single crystals of $NaKSO_4$ were grown isothermally at 315 K by the dynamical method from aqueous solutions containing the initial salts at stoichiometric ratio. Samples in the form of plates and rods, cut from single crystals, were oriented along the fundamental crystallographic axes. Samples in the form of circular discs of diameter 12 mm and thickness of 0.3-0.8 mm were used for measurements of the pyroelectric and dielectric properties. Silver electrodes of diameter 10 mm were deposited on the flat surface of the plates by evaporation in vacuum. For studies of the shear moduli and internal friction, using the torsion pendulum technique, the samples were prepared in the form of rectangular rods with the dimensions of 2 × 2 × 20 mm^3. The longer part of the rods were oriented in the direction of crystallographic axes.

3. Experimental technique.

The temperature dependences of the dielectric constant, shear moduli and internal friction, in the temperature range from 100 to 300 K, were studied using the following techniques :

a) The pyroelectric properties of $NaKSO_4$ crystals were studied at constant stress σ, using the dynamical method of Chynoweth [7-10] and that of Lang *et al.* [11-13]. In the latter case the temperature of the crystal was made to vary at a rate of 0.5 K/min. Samples, coated with silver, were placed inside a special evacuated holder [14], which was filled with hydrogen as a heat exchange medium. The temperature of the crystal was measured to within $\pm$ 0.1 degree by means of a copper constantan thermocouple.

b) The dielectric constant of $NaKSO_4$ crystal were studied by applying an automatic capacity digital bridge type E-315 Meratronik at a frequency 1 kHz and a measuring field strength of 30 V/cm.

c) An inverted torsion pendulum [15] was used for the measurements of the temperature dependences of shear moduli G_x, G_y and G_z as well as the internal friction Q^{-1}. The magnitude of strain occurring in the crystal at its torsion vibration was measured by the direct visual observation of the light beam reflected by a mirror attached to the movable part of the pendulum. The temperature dependence of shear moduli was studied by the static method with the constant stress of the order of 10^5 N/m^2 at a frequency of 10^{-2} Hz. The numerical values of the shear moduli were obtained from the simple relation between stress and strain $\sigma = G\eta$.

The temperature variation of the internal friction Q^{-1} was determined by the resonance method.

4. Results and discussion.

The variation of the dielectric constant ε_x, ε_y and ε_z of $NaKSO_4$ with temperature are shown in figure 1. It is clear from the figure that an increase of the dielectric constant with temperature takes place in the temperature range from 100 to 300 K. It can also be seen that the values of the dielectric constant, measured along the three fundamental crystallographic axes, show a characteristic break at about T = 200 K. Moreover, it is important to underline that the crystal did not show any change in the pyroelectric coefficient, which may be taken as an indication that $NaKSO_4$ crystals have a centre of symmetry.

The curves in figure 2 illustrate the temperature variation of the shear moduli G_x, G_y and G_z of $NaKSO_4$ crystals. From the curves it is clear that G_x decreases with temperature, G_y keeps constant whereas G_z increases with temperature and has a break in slope at T = 200 K. The elastic moduli in $NaKSO_4$ show anisotropic behaviour in the range of temperature of interest.

Figure 3 shows the variation of the internal friction Q^{-1} with temperature. It is clear from the figure that slow increase with temperature takes place in the components Q_x^{-1} and Q_y^{-1} of the internal friction

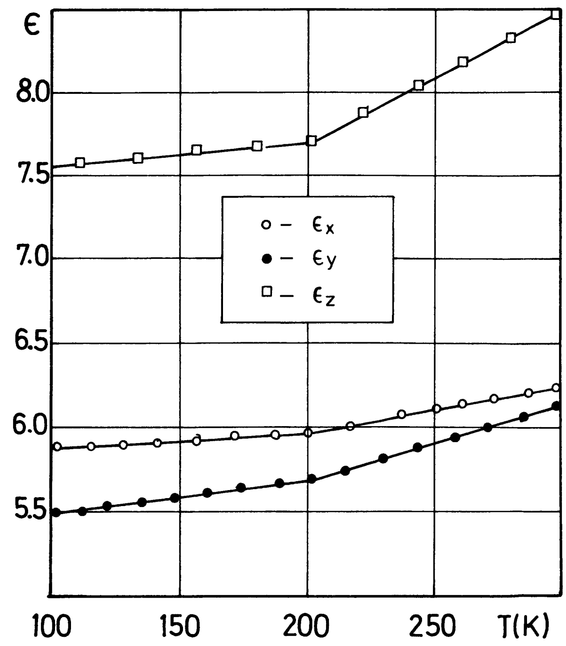

Fig. 1. — Temperature dependence of dielectric constant ε_x, ε_y and ε_z in $NaKSO_4$ crystals.

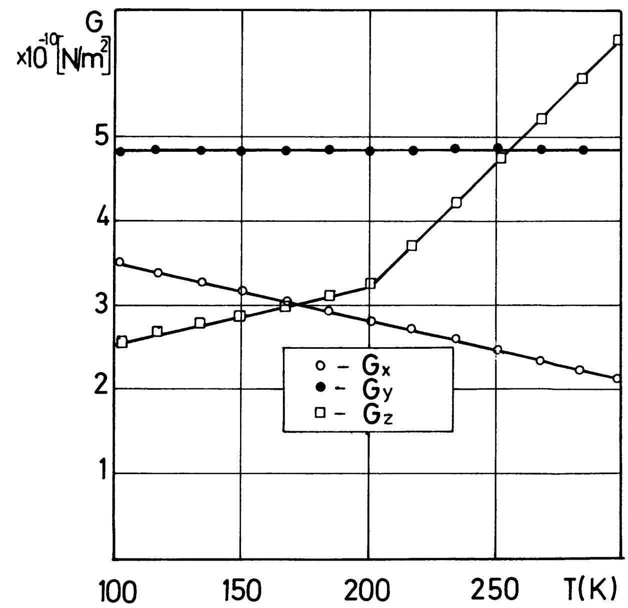

Fig. 2. — Temperature dependence of shear moduli G_x, G_y and G_z in $NaKSO_4$ crystals.

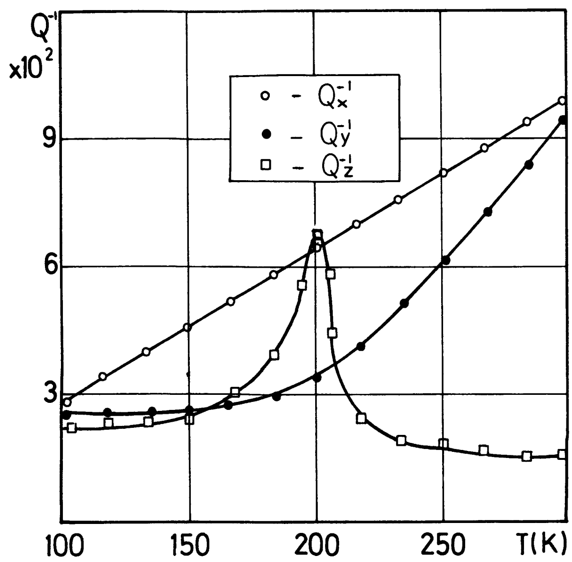

Fig. 3. — Temperature dependence of internal friction Q_x^{-1}, Q_y^{-1} and Q_z^{-1} in $NaKSO_4$ crystals.

measured in the x- and y-directions. While, the variation of the internal friction with temperature, in the z-direction shows a pronounced maximum at T = 200 K. This indicates that the domain walls, due to deformation twins, can move under the action of mechanical stress.

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