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PIEZOELECTRIC AND MAGNETIC PROPERTIES OF SODIUM ACETYLACETONATE

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Sodium acetylacetonate material was prepared by the interaction of sodium metal with acetylacetone. The piezoelectric modulus d_{33}, the anisotropy and the magnetic properties of the material were studied. The increase of piezoelectric charge with poling field is due to the retained 180° domains. The small proportion of 90° domains which remained after poling process creates internal strains leading to lower values of dielectric constant. The values of the magnetic permeability of the material give an indication that sodium acetylacetonate is a paramagnetic material.

Key Words: Piezoelectric; Sodium Acetylacetonate-Magnetic Properties; Anisotropy; Paramagnetic Material; Dielectrics

Introduction

The temperature dependence of the dielectric constant of sodium acetylacetonate was previously studied[1]. The studies showed that this material Na(ac.ac) undergoes some irreversible structural change at about 70°C from an orthorhombic phase to a triclinic structure. No attempt has been made for measuring the dielectric constant for Na(ac-ac) for polarized samples and for calculating the anisotropy between the polarized and unpolarized sample as a function of temperature and electric field.

The dielectric constant for the polarized sample is about 20 times lesser than that of the unpolarized sample. When electric field is applied, 90°-rotations of domains take place as well as 180°-reversals along the direction of the poling field. The dielectric constant ε_T of the material is reduced very much. Therefore, if 90° rotations of domains remain after the poling process, the dielectric constant of the partly polarized material is expected to be very different from that of the unpolarized ones. The dielectric constant was shown to decrease with increasing the poling field. The polarized preheated sample was found to be reversible and the hysteresis loops obtained on the cathod ray oscilloscope confirmed the existance of the ferroelectric properties in this materials[2]. Generally, the dielectric constant of ferroelectric materials is reduced with an increase of the biasing electric field[3]. The piezoelectric modulus d_{33} for Na(ac.ac) decreases with temperature and increases with the poling field.

The electromechanical properties of sodium acetylacetonate are very important because of the importance of this material in the manufacture of ultrasonic transducers. The magnetic properties of sodium acetylacetonate polycrystalline were studied and indicate that the material has paramagnetic properties.

Experimental Procedures

Sodium acetylacetonate was prepared by the reaction of acetylacetone with sodium metal. The principle of the preparation dependes on the fact that acetylacetone ($CH_3-C-CH_2-C-CH_3$) has a very active hydrogen atom in CH_2 group. This hydrogen tends to be replaced by the metal atom to form acetylacetonate. The material was checked by X-ray diffraction method using X-ray PW 1729, Philips. diffractometer. The diffraction pattern was consistent with ASTM cards. The dielectric constant for polarized and unpolarized sample was measured with an automatic TESLA R.L.C. bridge type BM 591. Temperature was measured with Keithley 871 digital thermometer type (KTC) to an accuracy of 0.1 degree.

The peizoelectric modulus d_{33} is measured by using a system for applying a stress (1, 2, 3, 4, 5) kg. on the sample of Na(ac.ac), and the corresponding charge generated from the sample due to the stress is measured by using a ballistic Galvanometer type (CAN METRIC LTD). An RLC Bridge type Auto compute LRC-SORTESTER Aplab 4912 was used for measured the inductance (L) of the coil wounded on the sample as a core. The values of L were measured as a function of temperature.

Results and Discussion

Dependence of Piezoelectric Charge on the Mechanical Stress of Polycrystalline Sodium Acetylacetonate

The mechanical stress dependence of piezoelectric charge for Na(ac.ac) at various polarizing field (40, 75, 115, 150, 190 volt/cm) at room temperature

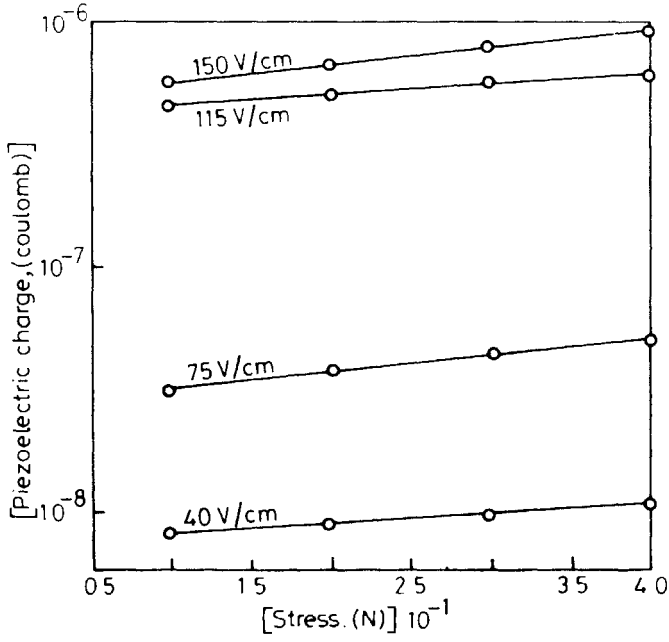

Fig 1 Dependence of piezoelectric charge on the applied stress

(25°C), is diagramatically represented in Fig. 1. It can be seen that the relationships are straight lines at different mechanical stresses. The slope of the linear lines increases with increasing the polarizing field. A pronounced increase in the slope of the straight lines is observed when the sample has poling field of about 150 V/cm. Throughout the region of the curves, the effect of stress on piezoelectric charge for Na(ac.ac) is correlated with the generation of piezoelectric charges. By increasing polarization of the sample, a larger proportion of 180° domains is reversed during the poling process, leading to an increase of the piezoelectric charge as shown in Fig. 2. A similar explanation for the linear effect of stress on the piezoelectric charge for Na(ac.ac) was previously found in ferroelectric materials.

The generated piezoelectric charge increases with increasing the applied stress. It is well known that 180° domains are responsible for piezoelectric effects in the crystals. Therefore, by increasing the polarization of the sample a larger proportion of 180° domains was reversed during the poling process. These domains were retained fully after removing the field. The stress dependence of the generated charge is linear because the charge appearing on the elec-

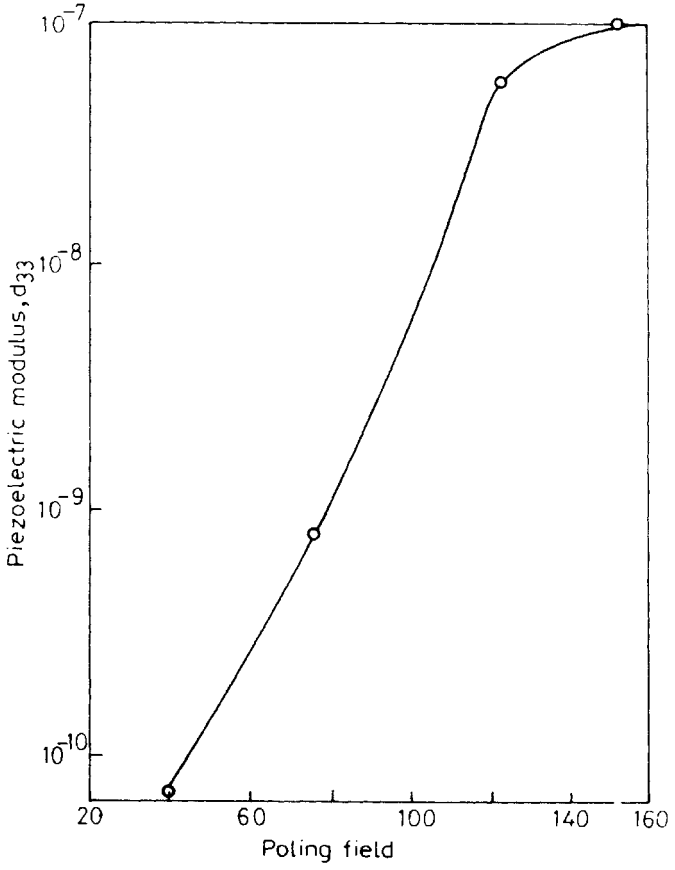

Fig 2 Dependence of piezoelectric modulus on the poling field

trode surface maintains an electric field in the same direction as the original poling field. This field encourages the domains to be reoriented after releasing the static stress.

The piezoelectric modulus d_{33} was evaluated at different poling fields using the following equation

$$d_{33} = \frac{Q}{F},$$

where Q is the generated piezoelectric charge in coulombs and F the force in Newton.

Dependence of Dielectric Constant ε on the Poling Field

Fig. 3 presents the effect of the poling field on the dielectric constant of Na(ac.ac) at room temperature. The decrease of dielectric constant with the poling field is due to the following: It is known that Na^+ cations are weakly bonded with acetylacetone (CH_3-C-CH_2 − C − CH_3) anions. It is well known that 180° domains are responsible for piezoelectric effect in the crystals and

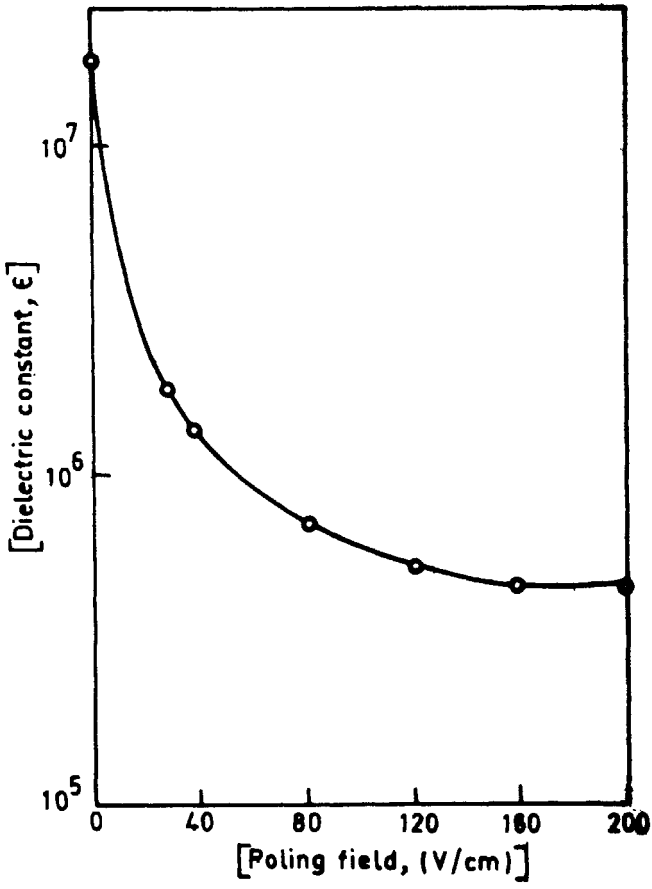

Fig 3 Dependence of dielectric constant on the poling field

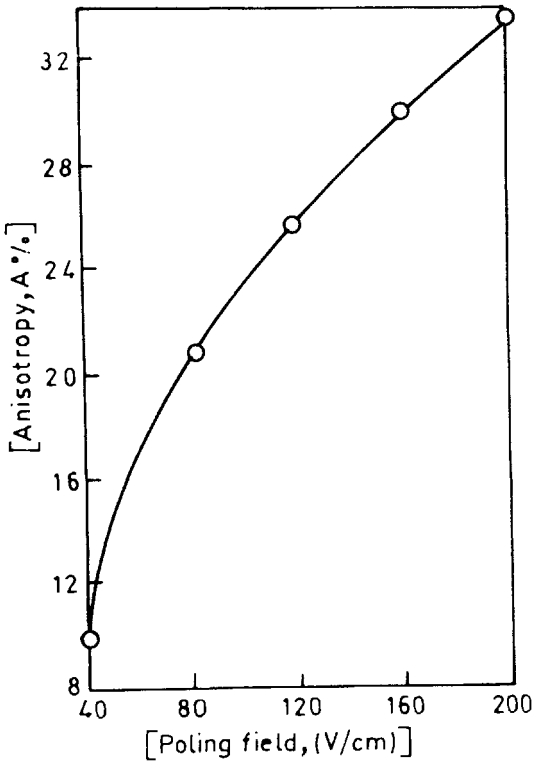

Fig 4 Dependence of anisotropy on the poling field

that a small proportion of 90° domains would also remain after polarization. This type of domains causes internal strains which depress the loosness of the bonding between Na^+ (cation) and acetyleacetone (anion). This may lead to the decrease of the strength of polarization, resulting in a lower net polarization at the surface of the sample and a lower dielectric constant.

Dependence of the Anisotropy on the Poling Field

The anisotropy of Na(ac.ac) polycrystalline increses with the poling field as shown in Fig. 4. The anisotropy A was estimated at room temperature from the relation[4]

$$A = \frac{\varepsilon_0 - \varepsilon_T}{\varepsilon_T} \%,$$

where ε_0 is the dielectric constant at the absence of poling field, ε_T is the dielectric constant in the presence of poling field. The increase of A was attributed to the increase of the internal strain due to the larger proportion of 90° domains which would remain after the poling field. The larger internal strain causes the increase of the anisotropy A of polycrystalline Na(ac.ac).

Temperature Dependence of Magnetic Permeability and Magnetization of Na(ac.ac)

The magnetic permeability μ was calculated from the reaction $\mu=(L\cdot l)/(n^2A)$, where L is the self inductance (emu), n the number of turns, A the cross sectional area in cm^2 and l the length of the sample.

The magnetization M of the samples was determined from the relation[5] $M=\chi\cdot H$, where χ is the magnetic susceptibility and H is the magnetic field intensity which is given from the relation $H=(4\pi In)/l\times 10^{-1}$ in Oersted, I is the current in amperes and l the thickness of the sample in cm.

Fig. (5) represents the relation between the temperature and the magnetic permeability (μ) and the magnetization (M) for the investigated sample. From the figure it can be observed that, there is increase in the magnetic permeability with rising temperature.

The magnetic behaviour of a material is of special interest in conjuction with its structure and the type of bonding in the network. When the magnetic effect of the individual electrons is not mutually neutralized, due to other unpaired electrons, paramagnetism is observed. The total magnetic moment composed of the orbital moment and the spin processes around the direction of the magnetic field.

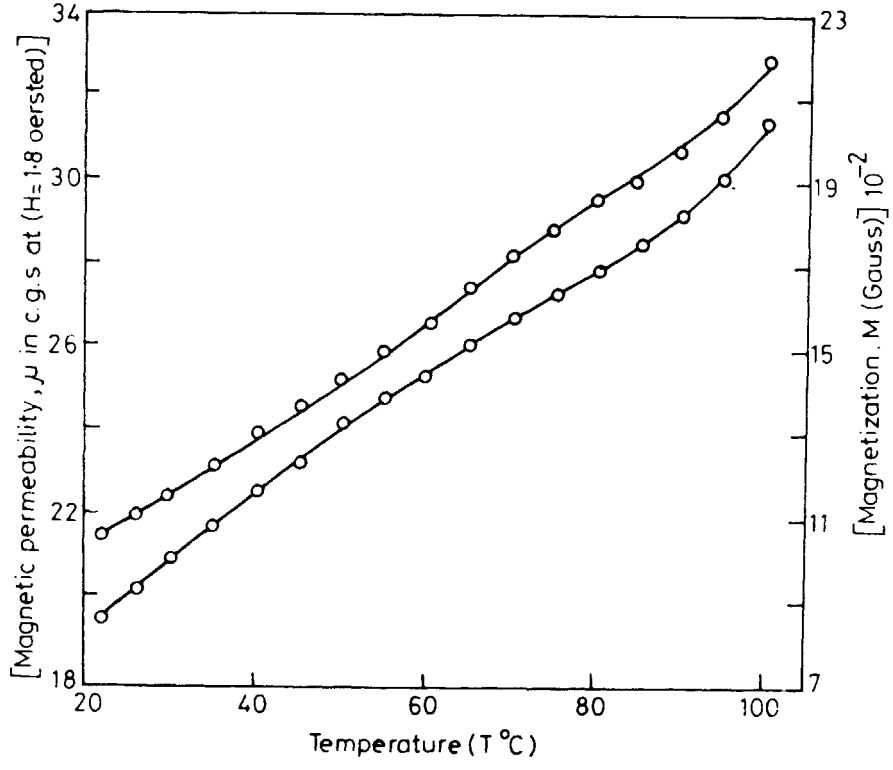

Fig 5 Dependence of magnetic permeability and magnetization on temperature

The orientation of spin of the conduction electrons in the molecule of sodium acetylacetonate (CH_3-C(=O)-CH_2-C(=O)-CH_3) in the magnetic field produces in a total magnetic moment directed along the field. The existance of such a moment leads to Pauli's paramagnetism. The increase of temperature of Na(ac.ac) increases the conduction electrons leading to rising of paramagnetic susceptibility and the permeability of the material. The values of paramagnetic susceptibility of Na(ac.ac) at different temperatures are shown in Table I.

Table I

Paramagnetic susceptibility of Na(ac.ac)

T °C	χ(Gauss/oersted)
22	5.60×10^{-2}
40	7.14×10^{-2}
60	8.95×10^{-2}
80	10.75×10^{-2}
100	12.66×10^{-2}

χ is determined from the relation

$$\chi = \frac{(\mu_r - 1)}{4\pi} \; G/\text{oe}.$$

where μ_r is the relative magnetic permeability and is determined from the relation

$$4\pi\mu_r = \mu$$

In conclusion, sodium acetylacetonate is a paramagnetic material according to the values of magnetic permeability.

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