EVOLUTION OF ELECTRIC FIELD INDUCED POLAR MICROREGIONS IN PLZT CERAMICS

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ABSTRACT

An experimental study of electric field controlled birefringence and light scattering in hot-pressed PLZT 8.5/65/35 at wavelength 0.425 - 5.56 μm is reported. The diameter of electric field induced polar microregions vs field intensity is determined.

DIELECTRIC POLARISATION

In coarse graine (4 - 6 μm) hot-pressed optically transpatent PLZT 8.5/65/35 dielectric polarization P vs temperature decreases rapidly at 17 °C. At the temperature 21 °C a double dielectric hysteresis loop P(E), polarisation vs electric field E is observed (Fig.1).

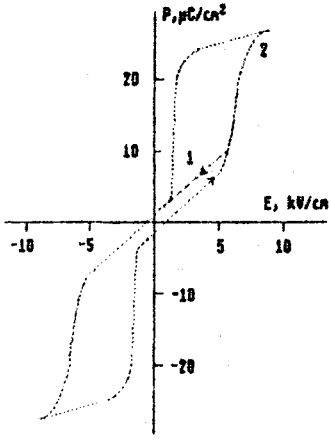

FIGURE 1 PLZT 8.5/65/35 polarisation P vs electric field hysteresis loop. T = 21 °C. 1 - $E_{max} < E_{k1}$, 2 - $E_{max} > E_{k1}$.

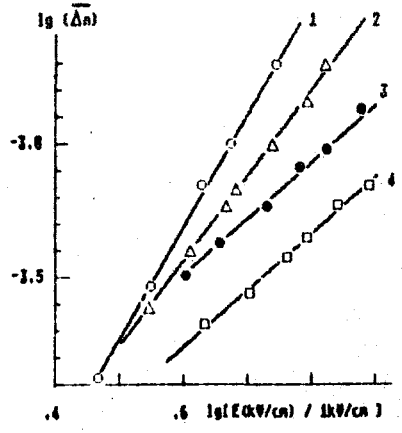

FIGURE 2 Birefringence Δn vs electric field E of different temperatures. λ = 5.56 μm. 1 - 25 °C, 2 - 40 °C, 3 - 60 °C, 4 - 80 °C.

At the field intensity $E > E_{k1} = 6.8$ kV/cm a ferroelectric phase is induced, a following decrease of E reverts to the non-ferroelectric state at $E < E_{k2} = 1.6$ kV/cm. It corresponds to the quasiparaelectric–ferroelectric phase transition [1].

BIREFRINGENCE

In order to eliminate the light scattering and depolarization the measurements of birefringence $\Delta n(E)$ were carried out using a CO cw laser ($\lambda = 5.56$ μm). At room temperature we observed (Fig.2) an anomalous $\Delta n(E) \sim E^4$ at $4 < E < 6$ kV/cm. We suppose that it is due to the increase of the amount of field-induced ferroelectric phase according to

$$\Delta n = \nu \cdot \Delta n_{sp} + 0.5 n^3 r \nu E + 0.5 n^3 R (1-\nu) E^2 \qquad /1/$$

where ν — volume concentration of polar phase, Δn_{sp} — spontaneous birefringence, r and R — electrooptic coeficients, n — refractive index.

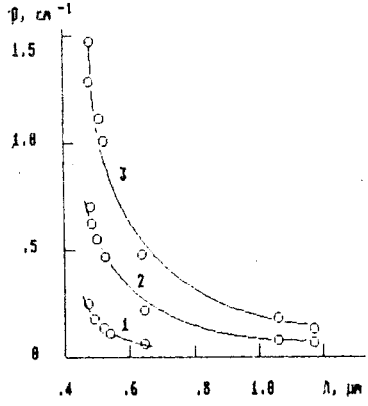

FIGURE 3 Spectra of the extinction coeficient β for PLZT 8.5/65/35 at different values of the electric field E. 1 - E = 4 kV/cm, 2 - 5 kV/cm, 3 - 6 kV/cm. Temperature 23 °C. Optical aperture 4.10^{-3} rad. Circles - experiment, curve - calculation according to /3/.

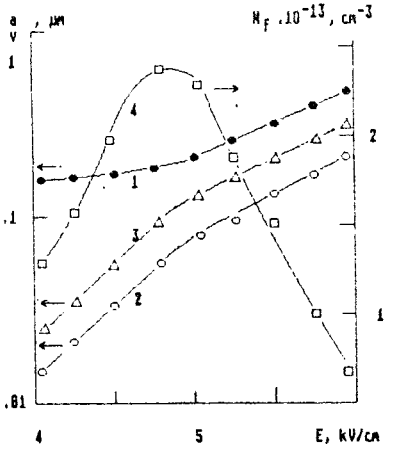

FIGURE 4 Electric field E dependence of polarised microregions diameter a - 1, volume concentration of polar phase ν - 2 (determined from scattering data) and 3 (determined from birefringence data), concentration of the pola sed microregions N_f - 4.

SCATTERING

The values of the extinction coeff icient β determined by scattering were measured vs the light wave length λ at different constant values of $E < E_{k1}$ (Fig. 3). The experimental value of β was calculated from :

$$I = I_o \exp(-\beta d) \qquad /2/$$

where I_o is the intensity of transmitted light at $E = 0$, I is the intensity of transmitted light at $E > 0$, and d is the sample thickness.

To explain the scattering behavior we use the Usov-Shermergor relationship /3/ [2,3]. for light scattering in heterogeneous dielectrics. We suppose the scattering on polarized microregions to be expessed by

$$\beta = \frac{4\pi v(1-v)\Delta n_{sp}^2}{\lambda n^2} \cdot \left[\frac{\lambda}{4\pi a} - \frac{16\pi^2 a^3}{\lambda^3(1+4\pi^2 a^2/\lambda^2)} - \frac{\lambda}{8\pi^2 a} \ln\left(1 + \frac{16\pi^2 a^2}{\lambda^2}\right) \right] \qquad /3/$$

The diameter of microregions a and volume concentration of ferroelectric phase v change vs E is shown in Fig. 4. The amount of microregions per cm³ N_R is calculated from a and v. We have obtained both the increase of microregion diameter and the concentration of ferroelectric phase with E. The number of polarized microregions vs E shows the increase up to E = 4.8 kV/cm which is followed by a drop as E > 4.8 kV/cm.

REFERENCES

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3. M. Knite, A. Kapenieks, A. Sternberg, and M. Livins. Ferroelectrics, 90, 71 (1989).