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Electrogyration and Electro-Optic Properties of the Solid Solutions on the Basis of Lead Germanate

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Spontaneous and induced effects of electrogyration (EG)[1] and electro-optics (EO) in the solid solutions on the basis of lead germanate with partial iso- and heterovalent substitution $Pb^{2+} \rightarrow Ba^{2+}$, $Pb^{2+} \rightarrow Bi^{3+}$, $Ge^{4+} \rightarrow Si^{4+}$ were investigated. The temperature dependence of the refractive index, birefringence and optical activity at $\lambda = 632.8$ nm indicates that the spontaneous EO effect is quadratic and EG effect is linear. This is reflected also in the corresponding hysteresis loop forms (Fig. 1). Spontaneous EG is well described by the thermodynamic theory if optical activity is used as a phase transition parameter (T_c region being the exception). From the experimental data obtained the EO (M_{ij}) and EG (γ^*_{ij}) spontaneous effect coefficients were determined as $M_{13} = 0.31$, $M_{33} = 0.32$ m^4C^{-2} and $\gamma^*_{13} = 9.5$, $\gamma^*_{33} = 8.1 \times 10^{-4} m^2/C$ for pure lead germanate.

Induced effects display interesting features. If the electric field E_z is applied along the z-axis, the induced EO and EG exhibit typical anomalies in the vicinity of the phase transition temperature (Fig. 2), the anomaly being dependent on crystal ion composition (Fig. 3). But they do not fit the known "law of doubling" for a second order phase transition. In the ferroelectric phase, when E_z is larger than E_{coer}, the EO effect is linear (Fig. 1). But the birefringence increase does not change sign when the field sign is reversed. This is the consequence of the spontaneous polarization reversal. From this it follows for pure lead germanate at 20°C $n_0^3 r_{13} - n_e^3 r_{33}$ is equal to 3.82×10^{-11} m/V. In the paraelectric phase the EO effect is quadratic at the same conditions (Fig. 4). But above a certain field strength, the $\delta(\Delta n)$ vs E_z curve becomes linear; the value of the threshold field increases as the temperature goes away from the transition temperature. Both in para- and ferroelectric phases, the EG effect is of linear character, exhibiting tendency to saturation at $T > T_c$ (Fig. 4). The EO and EG effect peculiarities in the paraelectric phase are accounted for by the induced phase trnansition due to the external field ($\Delta T_c/\Delta E = 1 \times 10^{-5}$ K · m/V).

In the case of field applied along x and y axes the birefringence along z axis of a polydomain specimen depends linearly on the field, the direction of the optical indicatrix rotation is

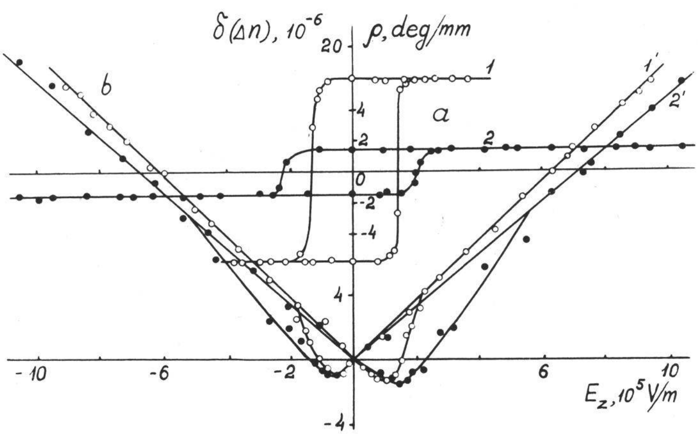

Fig. 1. Hysteresis loops of optical activity (a) and birefringence increase (b) at $t = 20$°C in $Pb_5(Ge_{1-x}Si_x)_3O_{11}$ crystals.

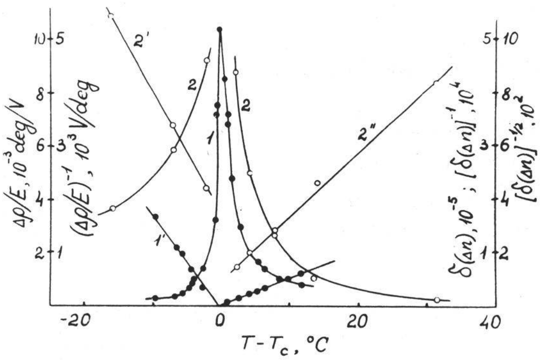

Fig. 2. Temperature dependences of induced EG $\Delta\rho/E$ (1), EO effect $\delta(\Delta n)_{xz}$ (2) at $E=10^6$ V/m and their reciprocals $(\Delta\rho/E)^{-1}$ (1′), $[\delta(\Delta n)_{xz}]^{-1}$ (2′), $[\delta(\Delta n)_{xz}]^{-1/2}$ (2″) in $Pb_5(Ge_{1-x}Si_x)_3O_{11}$ crystals.
1,1′-$x=0.10$; 2,2′,2″-$x=0.40$.

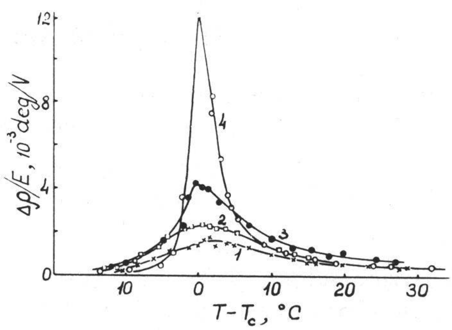

Fig. 3. Temperature dependence of induced EG in pure and impure lead germanate crystals.
1-$Pb_5Ge_3O_{11}$, 2-$(Pb_{0.98}Ba_{0.02})_5Ge_3O_{11}$, 3-$(Pb_{0.9945}Bi_{0.055})_5Ge_3O_{11}$, 4-$Pb_5(Ge_{0.80}Si_{0.20})_3O_{11}$.

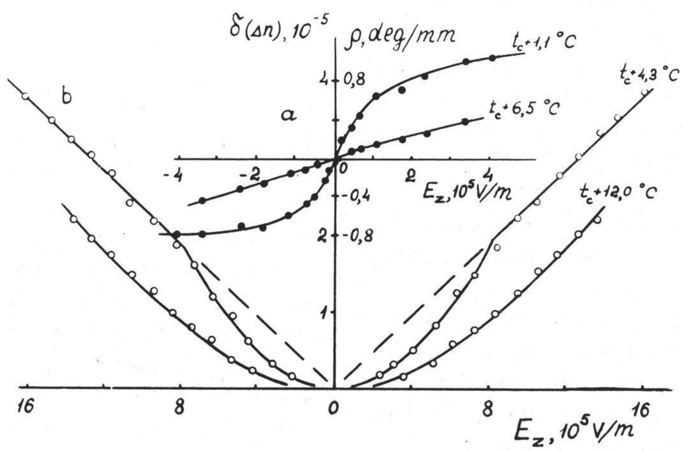

Fig. 4. Polarization plane specific rotation (a) and birefringence increase $\delta(\Delta n)_{xz}$ (b) as functions of the electric field intensity E_z in $Pb_5(Ge_{1-x}Si_x)_3O_{11}$ crystals.
a-$x=0.10$; *b*-$x=0.40$.

opposite for E_x and E_y and totally equals 45°. From these results for pure lead germanate we obtain $r_{11}=(0.7\pm0.1)$ and $r_{22}=(1.51\pm0.02)\times10^{-12}$ m/V.

Reference

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