PROC. JSSF-2, KYOTO, 1980
J. PHYS. SOC. JPN. **49** (1980) SUPPL. B, pp. 24–25.

Internal Bias Field in TGS Crystals in the Vicinity of Structural Phase Transition

L. N. KAMYSHEVA, S. D. MILOVIDOVA and A. S. SIDORKIN

Voronezh State University, Voronezh, 394693, USSR

Internal bias field E_b is generated in TGS crystal as the defects are introduced into it either by doping the crystal with admixtures[1,2] or irradiating it.[3]

The field E_b shifts the temperature of the maximum of the dielectric permittivity curve ε from the temperature $T_{\varepsilon\ max}$ towards higher temperatures and decreases the values of ε_{max}. On the other hand the electrons in ferroelectric semiconductors are known to shift the Curie point towards lower temperatures.[4,5]

This paper presents the results of the research of the internal bias field and electronic subsystem effect on structural phase transition in TGS crystal.

Samples with face-parallel *y*-cut of TGS crystal doped with α-alanine molecules (30 weight percent in solution) were investigated. Hereafter we call these TGS samples as α-TGS. Silver electrodes were evaporated in vacuum. Samples of α-TGS crystal were irradiated by X-rays of the energies up to 30 KeV. Under such energies and doses D of irradiation amounting to 10^5 R the concentration of ferroelectric dipoles does not practically decrease and the shift of $T_{\varepsilon\ max}$ may be attributed to either the presence of E_b or to the electrons formed as the result of irradiation.

The field E_b as can be seen from Fig. 1, may be compensated for by an external constant field of the magnitude ~ 13 kV/cm. The further increase of the external field rises $T_{\varepsilon\ max}$ and lower ε_{max}. The experimental values of E_b are in good agreement with the values of the bias field determined from dielectric hysteresis loops. Curie point of α-TGS crystal with compensated bias field is 48.00°C (curves 1,2).

After the irradiation with X-ray doses up to 10^5 R, the field E_b of the same sample were increased up to 2 kV/cm, while the temperature $T_{\varepsilon\ max}$ were decreased from 52.50°C to 51.90°C i.e., by 0.60° (curves 1,3 at $E_= = 0$). The decrease of the temperature $T_{\varepsilon\ max}$ in irradiated crystal is too small compared with the considerable increase of the field E_b. Supposedly that may be explained by the following. Electrons formed as the result of irradiation move in the field of spontaneous polarization and are captured at the boundaries of defect regions in α-TGS crystal. This leads to the increase of the existing field E_b.[3] Thus the temperature $T_{\varepsilon\ max}$ shifts towards higher temperatures. On the other hand, higher concentration of the electrons formed, leads probably to the screening of Coulomb interaction of lattice ions, which in turn leads to the shift of $T_{\varepsilon\ max}$ toward lower temperatures. If the field E_b of α-TGS crystal irradiated with X-rays is compensated, the value of the temperature $T_{\varepsilon\ max}$ becomes 46.75°C (curves 3,4).

As has been mentioned above the temperature $T_{\varepsilon\ max}$ shifts downwards by 0.6°C by the X-ray irradiation, while the increase of internal bias field amounts to about 2 kV/cm.

Proceeding from the known equation by temperature shift under the effect of the field $E_=$ [6]

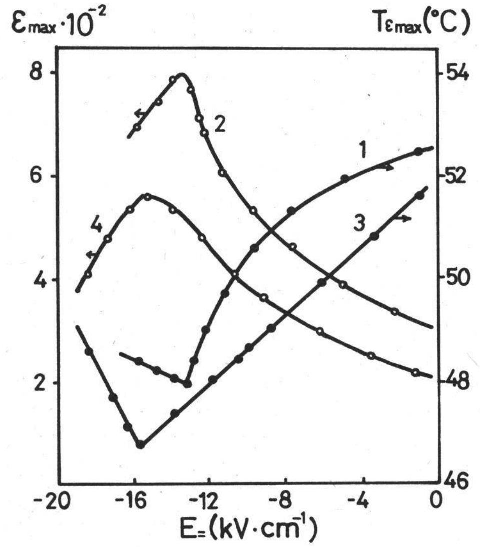

Fig. 1. Dependences of $T_{\varepsilon\max}$ (1, 3) and ε_{max} (2, 4) upon the constant electric field $E_=$ for α-TGS crystal.
1 and 2 – $D = 0$
3 and 4 – $D = 10^5$ R.

$$\Delta T_{\varepsilon\,\max} = 0.75\left(\frac{\beta}{\alpha_0^3}\right)^{1/3} E_{=}^{\,2/3},$$

one can estimate the shift of $T_{\varepsilon\,\max}$ due to E_b. Using the values of $\alpha_0 = 1.96 \cdot 10^{-3}$ degrees^{-1}, $\beta = 3.9 \cdot 10^{-10}$ esu[7)] and $E_{=} = 2$ kV/cm, one gets $\Delta T_{\varepsilon\,\max} = 0.92°$.

Consequently it may be said that under the effect of the field E_b of the value 2 kV/cm, the temperature 52.50°C should have shifted by 0.92° towards higher temperatures and become 53.42°C. The experiment gives the value of $T_{\varepsilon\,\max} = 51.90$°C, which could be ascribed to the influence of the electronic subsystem on the temperature $T_{\varepsilon\,\max}$. Under the influence of the electrons only, formed by X-ray irradiation, the temperature should have decreased by 1.52 degrees. This value is obtained as the difference of the temperatures 53.42°C and 51.90°C. As can be seen from the same figure the difference of temperature values of $T_{\varepsilon\,\max}$ of α-TGS crystal sample, irradiated and non irradiated with X-rays with compensated field amounts 1.25 degrees (48.00°C–46.75°C). This is in good agreement with the value of 1.52 degrees calculated earlier.

The concentration of electrons N may be estimated by the temperature shift under the influence of the electrons using the following relation[4)]

$$\Delta T_{\varepsilon\,\max} = -\frac{C}{2\pi} a N,$$

where C is the Curie-Weiss constant (3200°C), and a is the coefficient equal to 2.0×10^{-22} cm^3.[4)] The calculated value $\sim 10^{19}$ cm^{-3} is a reasonable value.

The results of the present paper show that at low energies and doses of irradiation the shift of $T_{\varepsilon\,\max}$ is associated not with the decrease of the number of ferroelectric dipoles but with the effect of the electronic subsystem and internal bias field.

References

1) K. L. Bye, P. W. Whipps, E. F. Keve: Ferroelectrics **4** (1972) 253.
2) L. N. Kamysheva, O. A. Godovannaya, S. D. Milovidova *et al.*: Izv. Akad. Nauk SSSR, Ser. Fiz. **39** (1975) 857.
3) E. V. Peshikov: *Deistvie radiatsii na segnetoelektriki.* (FAN, Uzb. SSR, Tashkent, 1972).
4) V. M. Fridkin: *Segnetoelektriki-poluprovodniki.* Izd. ("Nauka," M., 1976).
5) N. A. Romanuk, B. V. Andrievskyi: Optika l spektroskopiya **44** (1978) 276.
6) H. H. Wieder: J. Appl. Phys. **30** (1959) 1010.
7) F. Jona, D. Shirane: *Segnetoelektricheskiye krystally*, (Mir, M., 1965).