PHYSICS

Academician of the Academy of Sciences of the Uzbek SSR S. V. Starodubtsev, L. P. Khizhnichenko,

1960

SovietRxiv

Abstract

Full Text

PHYSICS

Academician of the Academy of Sciences of the Uzbek SSR S. V. Starodubtsev,
L. P. Khizhnichenko,
and I. A. Domoryad

CHANGE IN THE ELASTIC CONSTANTS OF QUARTZ FIBERS UNDER THE ACTION OF Co^{60} GAMMA RADIATION

Quartz is one of the most perfect elastic materials, retaining the constancy of its dimensions and elastic moduli under a variety of changes in external conditions. Therefore it—especially fibers prepared from fused material—is widely used in precision measuring instruments. The behavior of quartz in regions of intense exposure to penetrating radiation is of interest. Studies devoted to this question are few. It follows from work ([1]) that the density and elastic constants of fused and crystalline quartz change noticeably under intense neutron irradiation in a reactor. According to Mayer and Jitton ([2]), a dose of $7 \cdot 10^{18}$ neutrons per 1 cm^2 causes an increase in Young' s modulus of up to 1.42% and an increase in the shear modulus of up to 0.66%. Let us note that until now this effect has been associated with the action of neutrons, since from studies on irradiation of quartz with x rays and γ-rays ([2], [3]) conclusions were drawn that there were no changes, to an accuracy of 0.1%, at a dose of 10^9 r.

The aim of the present work was to determine the effect of Co^{60} γ-rays on the elastic constants of fibers made of fused quartz by more precise methods. To study changes in the elastic moduli, special apparatus was constructed using the method of torsional oscillations.

In the evacuated instrument, quartz fibers of diameter $80 \div 150\ \mu$, drawn from quartz rods with thickened ends serving to fasten the system in clamps and to suspend an inertial load equipped with a small polished plane mirror, could be mounted. The shape of the fiber specimens and the system by which they were fastened excluded motion in the bushings of the holders, which is important for eliminating errors due to friction in the suspensions. Accurate centering of the lower suspension by means of adjusting screws made it possible to reproduce strictly the geometry of the system before and after irradiation. The system was set into torsional oscillations by an external rotating magnetic field (produced by coils carrying three-phase 50-cycle current), interacting with the metal of the moving system. Vacuum pumps ensured that the period and decrement of the oscillations were independent of the residual pressure. As a result of separate control experiments, conditions were selected for limiting the amplitude

Fig. 1. Change in the shear modulus of quartz fibers as a function of irradiation dose: I—without allowance for linear deformations; II—with allowance for them. III—change in $\Delta l/l$. a—fiber No. 9; b—fiber No. 16; c—fiber No. 17

Figure 1: Fig. 1. Change in the shear modulus of quartz fibers as a function of irradiation dose: I—without allowance for linear deformations; II—with allowance for them. III—change in $\Delta l/l$. a—fiber No. 9; b—fiber No. 16; c—fiber No. 17

of oscillations and for temperature stabilization of the instrument.

Two methods were used for registering the number of oscillations as accurately as possible:

1. On the photographic film of a loop oscillograph, the standardizing time signals from the clocks of the Tashkent Astronomical Observatory and the signals corresponding to the zero passages of the beam reflected from the instrument mirror were recorded simultaneously.
2. The number of oscillations was recorded by means of an amplifying and counting circuit over a time interval set by a chronometer.

The principal results were obtained by the second method, which showed a relative accuracy of the order of 0.02%.

Changes in torsional oscillations under the action of γ-rays from Co^{60} were studied on several fibers at successively increasing doses: $81 \cdot 10^6$, $125 \cdot 10^6$, $230 \cdot 10^6$, $460 \cdot 10^6$, $550 \cdot 10^6$, and $845 \cdot 10^6$ r.

In the case of cylindrical fibers, for the frequency ν and period T of elastic oscillations we have

$$\nu = T^{-1} = \frac{1}{2\pi} I^{-1/2} f^{1/2}, \tag{1}$$

where I is the moment of inertia of the system; f is the torsional modulus, determined by the relation

$$f = \frac{\pi G R^4}{2l}, \tag{2}$$

G is the shear modulus; l is the effective length of the fiber; R is its radius.

Fig. 1. Change in the shear modulus of quartz fibers as a function of irradiation dose: *I*—without allowance for linear deformations; *II*—with allowance for them. *III*—change in $\Delta l/l$. *a*—fiber No. 9; *b*—fiber No. 16; *c*—fiber No. 17.

From (1) and (2) it is evident that the change in the shear modulus is determined not only by changes in the frequency ν (or period T), but also by changes in the length l and radius R of the fiber:

$$G = \frac{8\pi I l}{R^4}\nu^2. \tag{3}$$

Thus, in studying changes in G, it is necessary to take into account the contribution made by variations in the linear dimensions of the specimen (l, R). Assuming that the changes in linear dimensions under irradiation are isotropic, i.e., that $\Delta l/l = \Delta R/R$, we obtain

$$\frac{\Delta G}{G} = -3\frac{\Delta l}{l} + 2\frac{\Delta \nu}{\nu}. \tag{4}$$

To determine the share of each of the terms in (4), along with experiments estimating the change in the oscillation frequency ν, special control experiments were carried out to measure relative elongations as a function of irradiation dose. As a result of measurements on an IZA-3 comparator it was found that unannealed quartz fibers first elongate, at $1.8 \cdot 10^8$ r reach their initial value, and then, upon further irradiation, decrease.

Figure 1 presents the results of calculating $\Delta G/G$ as a function of dose, with and without allowance for the contribution of linear changes, for three fibers, and the course of the change in $\Delta l/l$. From consideration of curves I and II it follows that the shear modulus of quartz fibers increases continuously with irradiation, the rate of this increase decreasing at high doses.

Examination of the experimental data obtained makes it possible to draw the following conclusions. The developed torsional-oscillation method made it possible to detect changes in the elastic modulus of fused quartz irradiated with γ-radiation. As a result of the action of γ-rays on fused quartz, its elastic modulus increases by $0.16 \pm 0.02\%$ when irradiated with a dose of $8 \cdot 10^8$ r. The negative results obtained in works ([2], [3]) should be attributed to insufficient measurement accuracy.

The contribution made by factors of geometric deformation to the change in oscillation frequency is comparatively small (0.02%), i.e., it constitutes 16% of the observed changes.

The increase in the modulus of elasticity, indicating hardening of the samples upon irradiation, can presumably be explained by the appearance of ordered regions in the structure of fused quartz, since the modulus of normal elasticity of crystalline quartz is greater than the modulus of elasticity of fused quartz (4).

Institute of Nuclear Physics
Academy of Sciences of the Uzbek SSR

Received
23 II 1960

REFERENCES

1. W. Primak, H. Szymanski, *Phys. Rev.*, **101**, 1268 (1956); F. B. Jonson, R. S. Pease, *Phil. Mag.*, **45**, 641 (1954); M. S. Wittels, *Phil. Mag.*, **2**, 1445 (1957); M. S. Wittels, F. A. Sherrill, *Phys. Rev.*, **93**, 1117 (1954).

2. G. Mayer, J. Gigon, *J. Phys. Rad.*, **18**, 109 (1957).

3. T. S. Zhdanov, V. G. Zubov et al., *Crystallography*, **3**, 6 (1958).

4. D. Kei, T. Lebi, *Handbook of the Experimental Physicist*, IL, 1949.

Note: Figure translations are in progress. See original paper for figures.