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EFFECT OF DIFFERENT KINDS OF RADIATION ON VELOCITY AND ATTENUATION OF ELASTIC WAVES IN QUARTZ AND DKT

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The contribution presents some experimental and theoretical results, which concern the influence of different kinds of radiation on resonance frequency of piezoelectric resonators. Comparing the author's and the predecessor's results it was found that the resonance ferquency of piezoelectric resonators from quartz decreases through irradiation by X rays even in such types of resonators in which increase through irradiation by neutrons was expected. An attempt is made to explain the decrease of the resonance frequency by an increase of attenuation. The viscous model which was used has been found to be inadequate. Finally an analysis was made on the basis of which mechanisms are suggested by means of which the radiation defects could be used to explain the measured results.

I. INTRODUCTION

The contribution discusses some experimental results dealing with the effect of neutrons, the X and the γ radiations on the properties of piezoelectric resonators made from natural quartz and DKT. The startintg point of our analysis is the experimental fact that during irradiation of such materials by the X and the γ rays every time a decrease of resonance frequency was observed. This decrease was limited in the case of quartz, it even showed after irradiation a certain saturation [1, 2, 3, 4]. Mayer and Lecomte in their works [5, 6] measured the dependence of elastic coefficients of quartz s_{ij} on pile irradiation by neutrons and they arrived at the results that after exceeding a dose of 2×10^{19} n/cm^2 the natural crystalline quartz has been changed into its amorphous isotropic modification. For this reason the elastic coefficients s_{11} and s_{33} approach the same common value, which is connected with the decrease of s_{11} and the increase of s_{33}, from which there follows the increase and the decrease of the resonance frequency of thin bars with their lengths oriented in the directions of the X and the Y axes. To verify these results also for irradiation by X rays we tried to find among the usual sorts of quartz resonators such orientation in which the irradiation by neutrons causes the increase of frequency [9]. Such resonators, for example, seem to be thin bars with the orientation $XZt\varphi$ $46°30' < \varphi < 105°$. After irradiation of the resonators of $XZt\varphi$ 80°, from this branch, by X rays, however, was a decrease of the resonance frequency observed which was connected with saturation (Fig. 1). The authors Bottom and Nowicki [2] observed after every irradiation of the quartz resonators AT, BT, CT, FT by X rays a decrease of the resonance frequency, although according to the results of our calculation it follows that in the case of BT and FT resonators after neutron irradiation an increase of the resonance frequency should be expected.

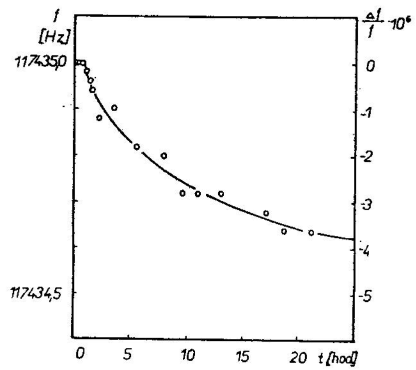

Fig. 1. Decrease of resonance frequency by X ray irradiation.

Since during X ray irradiation no increase of frequency was observed, but on the contrary a decrease, we conclude thas in the case of a neutron irradiation different kinds of microstructural mechanisms take place. One of the works, which suggests a connection between the dependence of the attenuation and the resonance frequency on the X ray irradiation is the work of H. Tilgner [7]. He states in his work, that by X ray irradiation of quartz resonators an increase of δ by about 24% follows and that in this case also a certain saturation of the phenomenon may be observed, which he compares with the saturation of the change of the resonance frequency of quartz resonators, measured during X ray irradiation by Frondel [1].

We shall try to estimate in the following the contribution of the change of δ which was stated by Tilgner to the change of resonance frequency. The estimation was based on the assumption that the stress is connected with the compliances of the strain tensor and the strain velocities $\dot{S}_{kl} = \partial S_{kl}/\partial t$ with the help of equation (1)

$$T_{ij} = c_{ijkl}S_{kl} + \eta_{ijkl}\dot{S}_{kl}, \tag{1}$$

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where the second part of the right-hand side is expressing the dissipative changes connected with the attenuation of elastic waves. By the use of equation (1) we obtained equation (2) for calculating the resonance frequency of longitudinal oscillations of a thin bar

$$f = \frac{h}{2l} \sqrt{\frac{c_{1111}}{\varrho} - \frac{\pi^2 \eta_{1111}^2 h^2}{4\varrho^2 l^2}} \qquad (2)$$

by which we estimated that in the case of quartz the resonance frequency should be influenced by the mentioned mechanism only in the seventeenth decimal place, in the case of resonators from DKT according to our experimental results in the tenth place. Hence it follows that the changes in the dissipative mechanism of a piezoelectric resonator from quartz or DKT would show a certain decrease of the resonance frequency, but this decrease would be so slight that it would not be possible to explain by it the changes of resonance frequency observed during the X and γ irradiation.

II. AN ATTEMPT TO EXPLAIN THE PHENOMENON ON THE BASIS OF MICROSTRUCTURAL CONSIDERATIONS

During interactions between atoms of crystals and the quantum of electromagnetic radiation excitations of electrons or incidentally their ionization follow. In the covalens dielectrics changes of some mechanical bonds follow in the case of excitation. In the case of the ionisation of atoms losses of bond electrons occur, from which weakness of the crystalline lattice follows and by which the decrease of the elastic modulus could be explained and thus also the resonance frequency of the particular piezoelectric resonators. The secondary products of radiation are able to cause on the basis of Varley's mechanism and the dislocation jump damages of the crystalline lattice in the form of vacancies and of atoms in interstitial positions. Dienes in his paper [8] on the affect of radiation on the elastic properties of metals Cu and Na compares the contributions of vacancies and of atoms in interstitial positions to the changes of the elastic stiffness coefficients. He arrives at the conclusions that in the case of these substances is may be expected that the effect of interstitials on the elastic properties will be much greater than the effect of vacancies and that by irardiation the increase of the elastic stiffness follows. The qualitative differences between the experimental results in the case of piezoelectric dielectrics and metals show that the probable cause of difference may be the different crystalline structure. Quartz and DKT belong to substances with a covalent chemical bond, which is created by hybridization of atomic wave functions in such a way that the two-electron bonds have a lower energy among atoms only in certain charasteristic directions. In the case of SiO_2 the four bonds of Si created by excited orbits of the sp^3 type which have the most stable position in the directions of the apices of tetrahedra with the Si atom in the centre. For atoms in interstitial position it is very difficult to reach the minimum of potential energy as the bonds of the lattice atoms, created by pairs of exchange electrons are saturated and besides the geometry of some bonds prevents it. Hence it follows that interstitials do not explain satisfactorily changes of elastic properties. The decrease of the measured elastic stiffnes coefficients may be partly explained on the basis of the Dienes model if only the contribution of the vacancies is taken into consideration.

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