

ANOMALOUS ABSORPTION OF ELASTIC WAVES IN PHASE TRANSITION IN GADOLINIUM MOLYBDATE

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Gadolinium molybdate $Gd_2(MoO_4)_3$ has at $\sim 159^\circ C$ a phase transition with a change of the point symmetry group $42m \rightarrow mm2$. It follows from the phenomenological theory of the ferroelectric phase transition in $Gd_2(MoO_4)_3$ [1] that neither polarization nor deformation [2], nor any other tensor quantity, can be chosen as the transition parameter.

To elucidate the character of the phase transition in $Gd_2(MoO_4)_3$, we carried out precision measurements of the rates of propagation and absorption of the elastic wave by an ultrasonic pulsed interference method [3, 4].

Figure 1 shows the temperature dependences of the coefficient κ_{11} of absorption of a longitudinal sound wave propagating in the [100] direction, measured at frequencies 10 - 70 MHz. The anomaly of the absorption coefficient κ_{11} in the region of the phase transition is due to the increase of the relaxation time of the transition parameter as the crystal temperature approaches the Curie temperature, but the relaxation processes above and below the transition temperature have different physical natures.

The anomalies of κ_{11} cannot be described by means of theories in which the transition parameter is the polarization or the deformation.

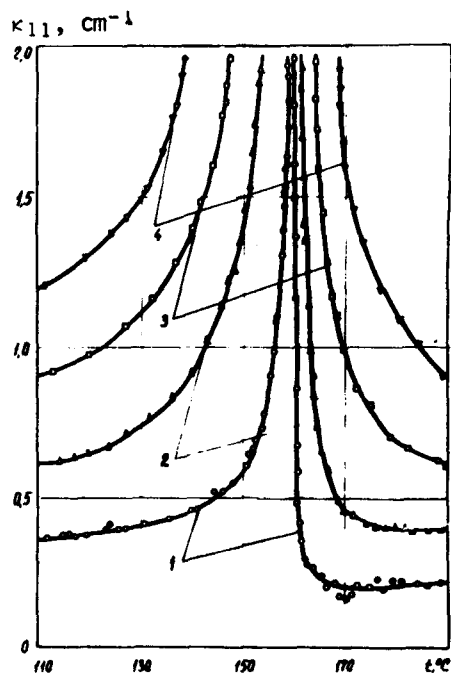


Fig. 1. Temperature dependence of the absorption coefficient of a longitudinal elastic wave: 1 - 0, 2 - 30, 3 - 50, 4 - 70 MHz.

From an analysis of the matrix of piezoelectric moduli of $Gd_2(MoO_4)_3$ it follows that a longitudinal ultrasonic wave propagating in the [100] direction will interact with the polarization both in the ferro- and in the paraelectric phase, giving rise to the relaxation processes described by Landau and Khalatnikov [5]. The temperature dependence of the elastic-wave absorption would then be stronger in the ferroelectric phase and not in the paraphase, as is indeed observed experimentally in the DKDP and Rochelle-salt crystals.

In addition, an increase of the polarization relaxation time, which must be admitted in this case in order to describe the anomaly of κ_{11} and which is connected with the temperature dependence of the coefficient α of the P^2 term in the expansion of the thermodynamic potential $\alpha = \alpha'(T - \theta)$, contradicts the known experimental results, since the dielectric constant ϵ_{33} changes at the transition point from 10 to 11.5 units [6].

The change of the elastic constant C_{11} , determined from the temperature dependence of the elastic-wave propagation velocity (Fig. 2) in the phase transition, namely $C_{11}(T = 180^\circ C)/C_{11}(T \approx \theta) \approx 2$, cannot explain an increase of the damping

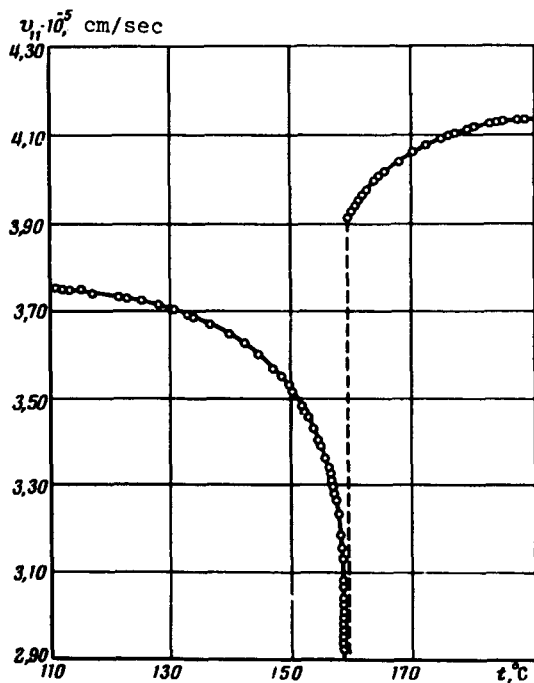


Fig. 2. Temperature dependence of the elastic-wave propagation velocity.

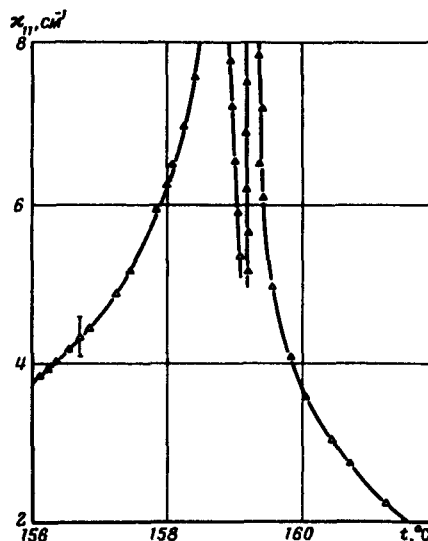


Fig. 3. Anomalous change of the elastic-wave absorption coefficient near the phase transition. Frequency 30 MHz.

coefficient by more than one order of magnitude, and consequently the deformation cannot be chosen to be a parameter of the transition in $Gd_2(MoO_4)_3$.

The fact that a ferroelectric crystal does not behave near the phase transition like a ferroelectric with respect to the absorption of elastic waves confirms the assumptions made in [1] that the occurrence of spontaneous polarization in this crystal is a secondary effect of realignment of the crystal lattice. The realignment itself is determined by the quantities η and ξ , which have the meaning of the relative shifts of the sublattices or their combinations.

Thus, the anomalies of κ_{11} in $Gd_2(MoO_4)_3$ on the ferroelectric side are due to the interaction of acoustic deformation with the two-component transition parameter, and on the paraphase side they are due to an interaction with its fluctuations. Accordingly, $Gd_2(MoO_4)_3$ reveals two absorption maxima corresponding to these interactions (Fig. 3). This fact shows once more that polarization is not the transition parameter in $Gd_2(MoO_4)_3$.

An estimate of the relaxation time of the transition parameter yields $\tau \approx (0.5 - 2) \times 10^{-10} / (T - \theta)$ sec.

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DIELECTRIC - METAL TRANSITION IN THE SYSTEM OF EXCITONS IN GERMANIUM

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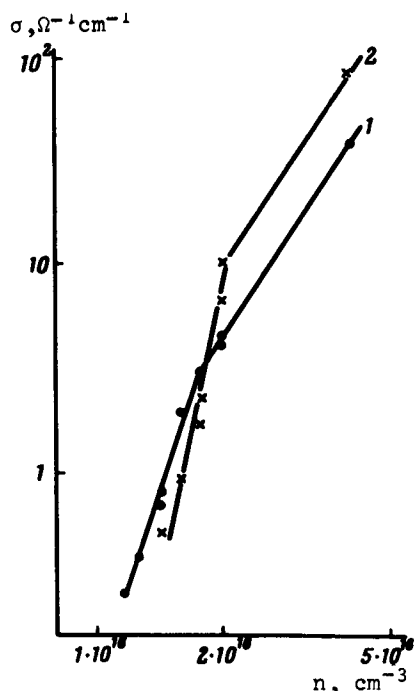
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The transition of the exciton system from the dielectric state into the metallic state was observed in [1], where a jumplike appearance of conductivity was detected in germanium at an exciton concentration close to $5 \cdot 10^{15} \text{ cm}^{-3}$. At somewhat higher excitation levels, the conductivity is described by a relation of the type $\sigma \sim n^3/T^2$, close to that expected for a degenerative electron-hole plasma [1, 2]. However, immediately after the transition to the metallic state, a small region was observed in which the conductivity was independent of the temperature and of the concentration. To explain the nature of such a conductivity, new investigations of the photoconductivity were made. The main results of these investigations are reported in this communication.

The experiments were performed on germanium samples 20 - 40 μ thick, made of germanium single crystals of varying purity. The remaining details of the experiments did not differ from those described in [1]. The measurements have shown that the phenomenon described above, i.e., the independence of the conductivity of the temperature and of the concentration, is observed only in relatively contaminated samples with impurity-center concentration exceeding 10^{14} cm^{-3} . In the purest germanium samples with impurity concentration not higher than $2 \cdot 10^{12} \text{ cm}^{-3}$ this effect was not observed. The dependence of the conductivity of pure germanium on the excitation level is shown in the figure. The appearance of metallic conductivity occurs here at a concentration $(1 - 2) \cdot 10^{16} \text{ cm}^{-3}$, after which the behavior is the same as for the conductivity of degenerate electrons and holes [1, 2].



Conductivity of pure germanium vs. the concentration of the electron-hole pairs, averaged over the sample. 1 - $T = 4.2^\circ\text{K}$, 2 - $T = 2.5^\circ\text{K}$. The curves were obtained with an electric field 40 mV/cm applied to the sample.

The conductivity in the region of the sharp growth near the transition to the metallic state has an unstable character. Even in the case when the intensity of the exciting light pulses was maintained constant within 1%¹⁾ the observed value of $(\Delta\sigma^2/\sigma^2)$ was of the order of unity. To the contrary, in the region of high concentrations, the value of $(\Delta\sigma^2/\sigma^2)$ was determined almost completely by the fluctuations of the intensity of the source of exciting light. Such a

¹⁾We used for this purpose a registration scheme that operated only when the amplitude of the light pulses deviated from the set value by not more than 1%.