ULTRASOUND ABSORPTION IN THE VICINITY OF THE MAGNETIC PHASE TRANSITION OF SINGLE-CRYSTAL $Y_3Fe_5O_{12}$

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Although there is still no complete theory of second-order phase transitions, there has been marked progress in the investigation of the Curie point in spontaneously-ordering substances [1 - 3]. Whereas in the past principal attention was paid to the study of the equilibrium parameters, much interest has been evinced recently also in studies of the kinetic coefficients near the Curie or Neel point.

This pertains primarily to the study of sound absorption [2]. There is a gap in this respect, however, when it comes to ferrimagnets.

We present here the results of measurements of the absorption of longitudinal ultrasonic waves at 5 MHz frequency in the garnet $Y_3Fe_5O_{12}$ in the crystallographic directions [100] and [110]. We measured the absorption by the standard echo-pulse procedure with an absolute error not larger than 5%. The temperature was stabilized within 0.01°C. The absolute error in the temperature measurement was 0.5°C. The temperature T_c of the ferrimagnetic-paramagnetic transition of $Y_3Fe_5O_{12}$ was also determined by us by the method of thermodynamic coefficients and equalled 275°C. This is approximately the temperature at which the sound absorption has a maximum (Fig. 1). It is known that the magnetoelastic interaction in $Y_3Fe_5O_{12}$ has a single-ion nature and is small. This apparently explains the observed relatively small anomalous damping of sound near T_c and, in general, the smallness of the magnetostriction constants of $Y_3Fe_5O_{12}$.

Below the Curie point (not shown in the figure) we have also observed in $Y_3Fe_5O_{12}$ a rather large absorption due possibly to losses in the domain walls. Anisotropy and ultrasound absorption peaks are observed near T_c in the directions [100] and [110], as seen from Fig. 1. The maximum of the frequency-dependence relaxation absorption of sound near T_c follows from the Landau-Khalatnikov phenomenological theory, which is based on the existence of a linear connection between the acoustic deformation and the ordering parameter [4]. The Landau-Khalatnikov thermodynamic absorption theory was first applied to ferromagnets by Belov and Levitin [3]. In addition to this type of relaxation absorption of sound, there exists in principle the possibility of observing of at least two other mechanisms, namely the fluctuation mechanism connected with the correlation energy and the domain mechanism [2]. It is also necessary to take into account magnetoelastic and other effects in ferrimagnets, which can make an appreciable contribution to sound absorption near T_c. All this indicates that the question of sound absorption in the vicinity of the Curie point is not a trivial one. A good test of the theoretical predictions is afforded by the critical exponents, the determination of which, generally speaking, is one of the most complicated and yet unsolved problems in the physics of phase transitions. It should be noted that in Kadanoff's scaling

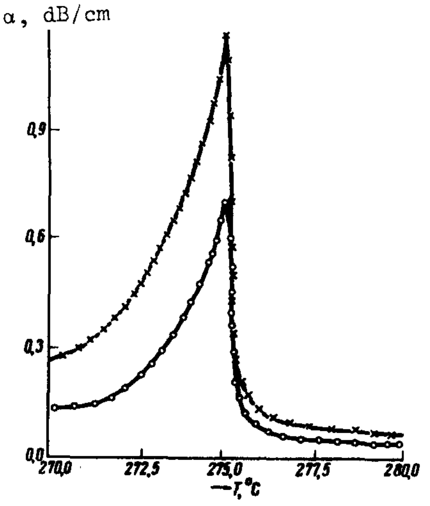

Fig. 1. Temperature dependence of the absorption coefficient: o) [100], ×) [110] (5 MHz).

theory [5] knowledge of one exponent makes it possible to find a few others. Thus, for example, in antiferromagnets $\eta = 1 - \alpha/2$ [6], where α is the critical index of specific heat. To determine the critical index of ultrasound absorption from the expression $\kappa \sim \omega^2 \varepsilon^{-\eta}$, where $\varepsilon = (T - T_c)/T_c$ is the reduced temperature, ω the cyclic frequency of sound, and η the critical exponent characterizing the degree of temperature dependence of κ, we have reduced the experimental results to fit them to power and logarithmic laws. As seen from Fig. 2, the experimental points fit a power law with a critical exponent $\eta = 0.53$ which has the same value for the directions [100] and [110] up to the reduced temperature $\varepsilon = 1.3 \times 10^{-3}$. Starting with $\varepsilon = 1.3 \times 10^{-3}$, the experimental points reveal considerable deviations from the relation $\kappa \sim \omega^2[(T - T_c)/T_c]^{-0.53}$. In the immediate vicinity of T_c, the critical absorption is affected by the impurities and the temperature dependence of κ is given by

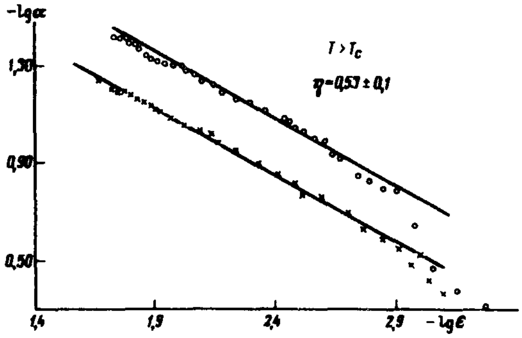

Fig. 2. Doubly-logarithmic dependence of κ on ε: o) [100], ×) [110] (5 MHz).

$$\kappa \sim e^{-\gamma\varepsilon}, \text{ where } \gamma = 4.4.$$

The critical exponent η for $Y_3Fe_5O_{12}$ is much smaller than the values predicted theoretically for ferro- and antiferromagnets [6 - 8], i.e., a situation analogous to Heisenberg isotropic magnets is observed [9 - 10]. In this case, we explain the anomalies of the absorption κ by using two relaxation times corresponding to the spin and spin-lattice relaxation. Two temperature intervals with different critical exponents η then appear on the $\ln \kappa = f(\ln \varepsilon)$ curve. Within the framework of these representations we find that the spin-lattice relaxation time depends little on the temperature, and the temperature dependence of the spin relaxation is given by the formula $\tau^{-1} \sim \omega_\infty \varepsilon$. The characteristic relaxation time for $Y_3Fe_5O_{12}$, as shown by our experimental results, depends little on the temperature, as indicated by the observed equality of the critical exponents for absorption and of the velocity of the ultrasonic waves (data on the velocity will be published elsewhere). It follows therefore, according to [9], that the main contribution to the anomaly of the absorption near T_c in $Y_3Fe_5O_{12}$ is made by spin lattice relaxation.

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ENERGY SPECTRUM AND NATURE OF TRAPPING CENTERS IN SINGLE CRYSTAL CdSe FILMS

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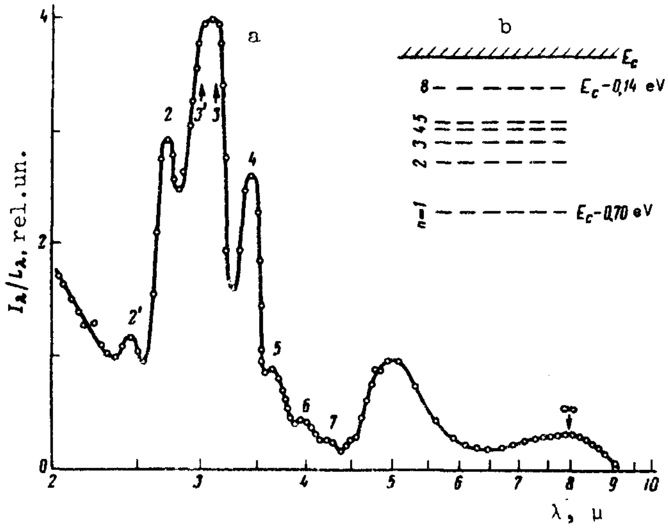
The most important problem in the investigation of trapping centers in semiconductors is to establish their nature. In spite of the considerable number of investigations performed for this purpose on II - VI semiconductors, the concrete physical and chemical nature of the trapping centers is still unknown. The lack of reliable information on the structure of these centers does not make it possible to interpret a number of experimental results, particularly the existence in semiconductors of a large number of levels of traps whose spectra can be discrete as well as quasicontinuous [1, 2].

We present here data on the investigation of traps in single-crystal CdSe films with wurtzite structure, by the method of induced impurity photoconductivity (IIP), and the results of their analysis. The technology of film production is described in [3], and the procedure of measuring the IIP is given in [4].

Under the usual conditions, the photoconductivity in CdSe films is observed in the region of their intrinsic absorption. Preliminary photoexcitation of films in this region, at 95°K, leads to the appearance of IIP due to optically excited electrons with non-uniformly filled trapping levels, in the interval 1 - 9 μ (curve a in the figure). We see on the IIP curves of the investigated films a number of bands with different half-widths, indicating that the traps have a complicated energy spectrum.

To identify the IIP peaks it is assumed that CdSe contains in addition to isolated trapping centers also pairs consisting of a trapping center and a shallow ionized donor. The trapping centers and the donors are distributed over the anion and cation sites, respectively. In the sphalerite lattice the



a) Spectral distribution of IIP in single-crystal CdSe films.
b) Scheme of trapping energy levels due to the presence of CdSe of pairs from anion vacancies and donors in the cation sites. The integers on the figure denote the numbers of the coordination spheres, and the primed figures are the numbers of additional coordinate spheres in the wurtzite lattice, unlike the sphalerite lattice.