Polarization of thermal luminescence of uniaxially deformed GaAs crystals

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The degree of polarization of recombination-induced radiation of uniaxially deformed GaAs crystals is found to decrease as the electron energy is increased. This effect is attributable to the increase of the relative contribution to the recombination of the conduction electrons with an orbital angular momentum of 2.

In the absence of external fields, the radiation of unoriented electrons in A_3B_5 crystals by recombination is not polarized. A uniaxial compression of an A_3B_5 crystal causes a linear polarization. The effect is due principally to the lifting of degeneracy in the hole spectrum. The degree of polarization ρ of the edge emission is 0.6 when the

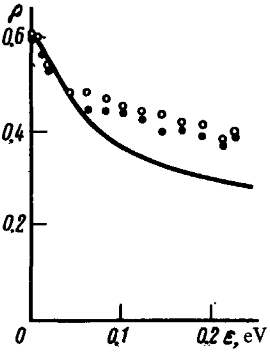

FIG. 1. The degree of linear polarization ρ for the conduction band-acceptor transitions versus the energy of the recombining electrons in the case of a uniaxial deformation of a p-GaAs(Zn) crystal along the $[\bar{1}11]$ axis (filled circles) and the $[1\bar{1}2]$ axis (open circles). $P = 4$ kbar and $T = 2$ K. Solid curve—Theoretical (see the text proper).

crystal is observed across the contraction axis.[1] In this letter we report ρ in GaAs crystals depends on the energy of the recombining electrons, ϵ. We recorded the value $\rho = 0.6$ only when the electrons from the bottom of the conduction band recombine ($\epsilon = 0$). As the energy is increased, however, the degree of polarization decreases (Fig. 1).

The luminescence in a Zn-doped p-GaAs crystal (1.7×10^{17} cm^{-3}) was excited by a beam from a Kr laser (1.92 eV). The luminescence along the [110] or the [111] axis was recorded. A pressure was applied at right angles to the crystal (in the $[\bar{1}11]$ or the $[1\bar{1}2]$ direction in the first case and in the $[1\bar{1}0]$ direction in the second case). The detectable radiation was associated with the recombination of electrons during thermalization (thermal luminescence[2]). We emphasize that we observed the emission of electrons which have undergone many scattering events after their production. The $\rho(\epsilon)$ dependence is therefore not linked with the anisotropy of the momentum distribution of electrons which arises when they are photoexcited from the valence band.[2]

The principal radiative-recombination channel in the case under investigation were the conduction band-shallow acceptor transitions. The effect detected by us is a direct experimental confirmation that the selection rules depend on ϵ in the case of transitions of this type. This effect occurs because of the presence of an orbital d-function (an impurity) in the ground state of the acceptor. The ground state of the hole which is bound on a shallow acceptor is a superposition of the orbital s- and d-functions.[3] A radiative recombination is therefore possible only in the case of electrons that are in the same state. In the case of small values of ϵ, however, only the s-state electrons can recombine because of the inadequate overlapping of the d-functions of an electron and a hole. At energies $\epsilon \gtrsim E_A$, however, (E_A is the ionization energy of an acceptor) this overlapping cannot be ignored, and the channel for the recombination of the d-state electrons (electrons whose orbital angular momentum of free motion is 2) becomes important.[4] The ionization energy of the shallow acceptors in GaAs crystals is $E_A \approx 30$ meV, in agreement with the value of ϵ at which the $\rho(\omega)$ dependence is seen in Fig. 1.

The total angular momentum, which is bound on the acceptor of the ground-state hole, is 3/2. A uniaxial compression of the crystal leads to a level splitting of the hole into two Kramers doublets. The level with $|M| = 1/2$ becomes the ground level (M is

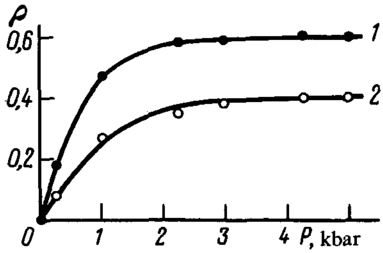

FIG. 2. The degree of linear polarization versus the pressure. 1 — $\epsilon \approx 0$; 2—$\epsilon = 160$ meV. $P \parallel [111]$ and $T = 2$ K.

the projection of the angular momentum of the hole onto the deformation axis). The value of ρ, calculated using the procedure of Ref. 4, upon transitions to this level is

$$\rho = \frac{15 - 9x}{25 + 17x}, \quad x = \left| \frac{Q_2}{Q_0} \right|, \tag{1}$$

where Q_0 and Q_2 are the overlap integrals of the s- and d-functions, respectively. Using the values of Q_0 and Q_2 which were numerically calculated in Ref. 5, we find the $\rho(\epsilon)$ curve (the solid curve in Fig. 1). A slight difference between this curve and those obtained experimentally may stem from the fact that in the derivation of Eq. (1) we assumed that the strain-induced splitting of the acceptor level, Δ, was assumed to be much smaller than E_A, whereas at $P = 4$ kbar the experimental value of Δ turned out to be ≈ 16 meV.

Figure 2 is a plot of ρ as a function of the pressure P applied along the [111] axis at $\epsilon \approx 0$ meV (measured at the maximum of the edge band) and at $\epsilon = 160$ meV. We see that at $P \approx 3$ kbar both curves become saturated when ρ is approximately equal to the calculated values of 0.6 and 0.33 for a recombination to a level with $|M| = 1/2$. Note that the shape of the initial (ascending) parts of the curves is determined by the "suppression" of the random internal fields, rather than by the change in the relative population of the doublet. Similar $\rho(P)$ dependences and similar values of ρ at saturation were observed when the crystal was strained along the [112] and [110] axes.

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