Infrared probing of a large electron-hole drop in germanium

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It was observed that at 2°K, when inhomogeneously deformed germanium disks are exposed to pulsed photoexcitation, the absorption of radiation with $\lambda = 3.39\ \mu$ by the disks corresponds to a single electron-hole drop of ~1 mm in size, and the radiation scattering typical of a cloud of minute droplets vanishes.

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Recent communications (see, e.g., [1]) report the possibility of producing, in inhomogeneously deformed germanium, an electron-hole drop (EHD) of macroscopic dimensions (~1 mm) with a lifetime reaching 500 μsec. The authors claim that the luminescent region photographed in[1] corresponds to a single drop, and not to a cloud of droplets localized in a potential well produced by deformation, because the dimension of this region is approximately equal to the drop dimension determined under analogous conditions from the microwave size-effect (Alfven) magnetoabsorption. In this paper we present new evidence of the existence of large EHD with long lifetimes in deformed germanium.

We investigated samples of dislocation-free germanium with residual impurity density 10^{11} and 10^{14} cm^{-3} and with approximate exciton lifetime 10 μsec at 4.2°K. The samples, just as in[1], were disks 2 mm thick and 4 mm in diameter, with bases in the (100) plane. The chemically-polished disks, in caprone holders, were placed in a 2°K helium bath. The pressure on the disk generatrix in the (110) direction was produced by a pin of 1.6 mm diameter and regulated by a lever mechanism located outside the cryostat. The source of the photoexcitation was a nitrogen laser with $\lambda = 0.337\ \mu$, a pulse energy 5×10^{-5} J, and a pulse duration 40 nsec. The laser radiation was focused into a spot measuring ~50 μ on one of the bases of the germanium disk. The spatial distribution of the nonequilibrium charges and of the EHD was determined from the absorption and scattering of the beam from an helium-neon laser with $\lambda = 3.39\ \mu$.[2] The probing beam of ~50 μ diameter passed through the disk parallel to its generatrix and could be moved with precision independently of the exciting beam. The absorption of the probing radiation, and also the intensity of the radiation scattered into a cone restricted to 10—20° in angle, was registered with an indium-antimonide photodiode. The recombination radiation of the EHD was registered simultaneously. The time dependence of the absorption, scattering, and radiation signals was determined with an oscilloscope and registered with a strobe-integrator.

In the absence of pressure, the EHD radiation relaxation time had the usual 2°K value of about 40 μsec. The relaxation times of the absorption and scattering of the probing radiation were approximately of the same value. The absorption did not exceed 12%, and the intensity of the scattered light was about 1%

of the absorbed intensity. The spatial distribution of the absorption of the probing radiation in the absence of pressure is shown in the figure. It agrees well with the spatial distribution of the recombination radiation of minute drops at large levels of stationary photoexcitation.[3]

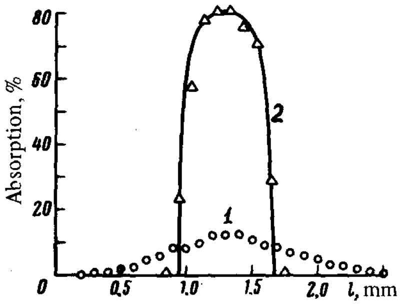

FIG. Spatial distribution of the absorption of probing 3.39 μ-radiation in a germanium disk at 2 °K under pulsed photoexcitation: 1—in the absence of a deforming stress, with a delay 30 μsec relative to the excitation pulse; 2—at a deforming force 18 kg with a 40-μsec delay. The solid line corresponds to the calculated absorption by a homogeneous sphere of 0.4 mm radius and with an absorption coefficient 16 cm^{-1}.

The deformation of the germanium disks resulted in an increase of the relaxation time of the recombination radiation of the condensed phase, which reached 350 μsec when a force 15—30 kg was applied. At these pressures, the scattered radiation signal vanished, and the absorption increased abruptly. The absorption approached 80% in the case when the exciting and probing beams were superimposed and focused on the germanium disk directly below the deformation-producing pin. The absorption reached a maximum value with a delay 40—80 μsec after the excitation pulse, then decreased slowly for 400—500 μsec, after which it dropped abruptly.

The spatial distribution of the absorption of the probing radiation, following application of a force of 18 kg, is also shown in the figure. It is seen from the figure that in this case the absorption is localized in a greatly restricted region measuring about 1 mm. The distribution of the absorption and its absolute value correspond to absorption by a uniform sphere of radius 0.4 mm with absorption coefficient 16 cm^{-1}. It is known that in germanium the cross section for absorption of 3.39-μ radiation by holes is close to 1.5×10^{-16} cm^2,[4] from which it follows that the carrier density in the absorbing sphere is $\sim10^{17}$ cm^{-3}. Recognizing that this corresponds to a carrier density in the condensed phase of the deformed germanium,[1] it can be concluded that under the experimental conditions a single large EH drop is produced. This is also evidenced by the vanishing of the large-angle scattering of the light, which is a characteristic of a cloud of minute EHD.

The increase of the lifetime of the large EHD may be due to a decrease of the equilibrium carrier density in the condensed phase as a result of the deformation.[1] In this case, the strong increase of the lifetime can be typical of large EHD produced in the case of inhomogeneous deformation. Indeed, we have observed that uniform compression of germanium[5] in the (111) direction at 2 °K also causes an increase of the relaxation time of the EHD recombination radiation, from 40 μsec in the absence of pressure to 200 μsec at 380 kgf/cm^2.

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[1]J.P. Wolfe, W.L. Hansen, E.E. Haller, R.S. Markiewicz, C. Kittel, and C.D. Jeffries, Phys. Rev. Lett. **34**, 1292 (1975).

[2]Ya. E. Pokrovskiĭ and K.I. Svistunova, Pis'ma Zh. Eksp. Teor. Fiz. **13**, 297 (1971) [JETP Lett. **13**, 212 (1971)].

[3]Ya. E. Pokrovskiĭ and K.I. Svistunova, Fiz. Tverd. Tela **16**, 3399 (1974) [Sov. Phys. Solid State **16**, 2202 (1975)].

[4]M.N. Gurnee, M. Glicksmann, and Ph. W. Yu, Solid State Commun. **11**, 11 (1972).

[5]Ya. E. Pokrovskiĭ and K.I. Svistunova, Zh. Eksp. Teor. Fiz. **68**, 2323 (1975) [Sov. Phys.-JETP **41**, 1161 (1975)].