MAGNETOOSCILLATIONS OF THE EHD LUMINESCENCE IN As-DOPED Ge

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According to Keldysh and Silin [1], electron-hole droplets [2,3] (EHD) in a magnetic field have an oscillating equilibrium density as a function of the applied magnetic field. This oscillating density is caused by oscillating contributions to the total free energy [4] and gives rise to intensity oscillations of the EHD luminescence in Ge [5,6]. Here we present for the first time measurements of the intensity oscillations of the EHD luminescence in doped Ge. The phonon-assisted (LA) line and the n-phonon (NP) line show a different behaviour in their time dependence, which leads to the conclusion that they are caused by different states.

The measurements were carried out on As-doped Ge samples with a donor-concentration of about 7.10^{15} cm^{-3}. The samples were immersed in liquid helium which was pumped to about 1.5 K. For carrier excitation a pulsed Ga As laser was used with a peak power of 5 W, pulse length of 2 μsec, and duty factor of 0.2 %. The power density on the sample was about 5 W cm^{-2} during the pulse. A magnetic field in Faraday configuration could be applied in (100) direction to the samples by means of a superconducting coil ($H < 32$ kOe). The detection system consisted of an MDR-2 grating monochromator used here as a narrow band filter for the different lines and a Ge photodiode (risetime $\approx$ 1 μsec). The signal-to-noise ratio was improved by conventional boxcar-technique.

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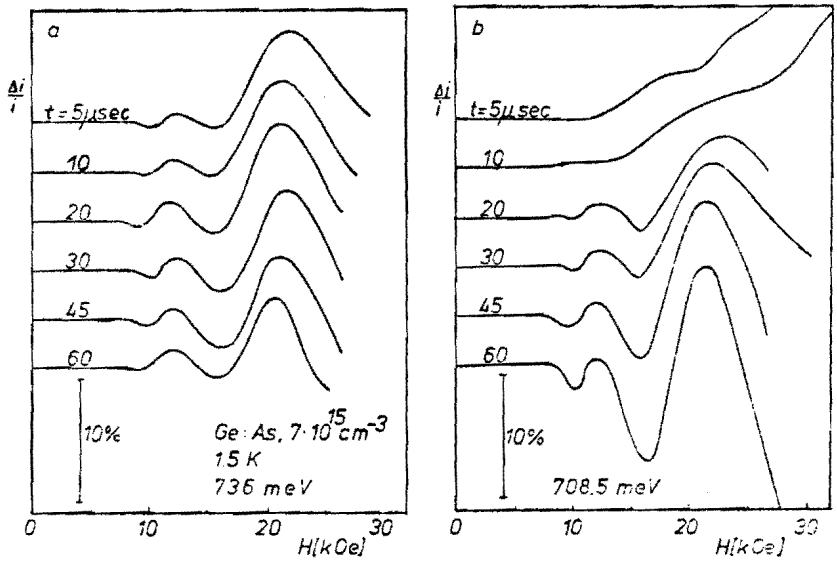

Fig. 1. Magnetooscillations of the "EHD" luminescence lines from As-doped Ge. Parameter to the curves is the delay time between excitation and signal detection.
a) NP line (736 meV)
b) LA-phonon assisted line (708.5 meV).

Fig. 1 shows the measured luminescence intensity as a function of the magnetic field for both the NP and the LA line at different delay times between excitation and detection. Magnetooscillations are found for both lines ; they are nearly time independent for the NP line, whereas those for the LA line vary considerably with delay time. The behaviour of the LA line is very similar to that in undoped material [6].

The lifetimes of the two lines at zero magnetic field also show up characteristic differences. The LA line decays exponentially with a constant lifetime of 36 μsec which corresponds to the EHD lifetime in pure Germanium. In contrast to this the lifetime of the NP line changes continuously from about 50 μsec at short delay times to about 70 μsec at longer ones. From both facts, the difference in the magnetooscillations and the difference in the lifetime,

it must be concluded, that the two lines, which usually both are ascribed to the electron-hole droplets, are caused by different states. The state responsible for the LA line seems to be the EHD as in pure material. The time dependence of the LA-line magnetooscillations can be well described in the frame of the EHD model as in pure Germanium [6]. As proposed by Keldysh and Silin [1], the carrier density inside the EHD oscillates as a function of the magnetic field. This gives rise to oscillations in the EHD lifetime which are the reason for the time dependence of the intensity oscillations. The lifetime of the states responsible for the NP line is not influenced by the magnetic field (no time dependence of the oscillations), these states may be bound multiple excitons as found by Martin [7] and Sauer [8] in the luminescence spectra or other bound states.

The oscillating intensity of the NP line then should be due to an oscillating occupation of these states which is connected with the oscillating total free energy of the EHD states. To explain this we must assume that both states are in some equilibrium during excitation, but no longer when they are ready formed, so that both states are able to decay independently from one another.

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