AN OLD STORY OF NEW CYCLOTRON RESONANCE PEAKS IN HIGHLY EXCITED GERMANIUM

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ABSTRACT

Some modification is suggested for the interpretation of the emergence of new strange peaks in time-resolved cyclotron resonance of germanium under high excitation. The excitonic polaron model suggested earlier is still kept, but the presence of electron-hole drops as the source of supply of free excitons and carriers has to be called for.

In earlier papers,[1,2] we reported the observation and the tentative interpretation of new strange peaks of cyclotron resonance in germanium in terms of the new-type polaron. It is essentially an electron (or hole) in the boson field of polarized excitons.

The observed phenomenon is the emergence of an extra peak on the high magnetic field side of the ordinary free carrier resonance. Relative intensities of the ordinary and extra-ordinary peaks as well as their separation depend on the delay-time after photoexcitation (Fig. 1). The emergence of strange peaks is accompanied with the appearance of a huge pulse on the tail of the microwave photoconductance signal as shown in Fig. 2. The trace is taken with the magnetic field being set at slightly higher than the position of the proper resonance peak for electron.

Our interpretation of the phenomenon, as mentioned above, is through the formation of a quasiparticle which we tentatively called excitonic polaron. There is, however, an alternative interpretation, suggested by Numata, in terms of dimensional resonance associated with the spherical electron-hole drop.[3] Numata, using a fixed radius of the drop and suitable parameters, predicts appearance of extra peaks

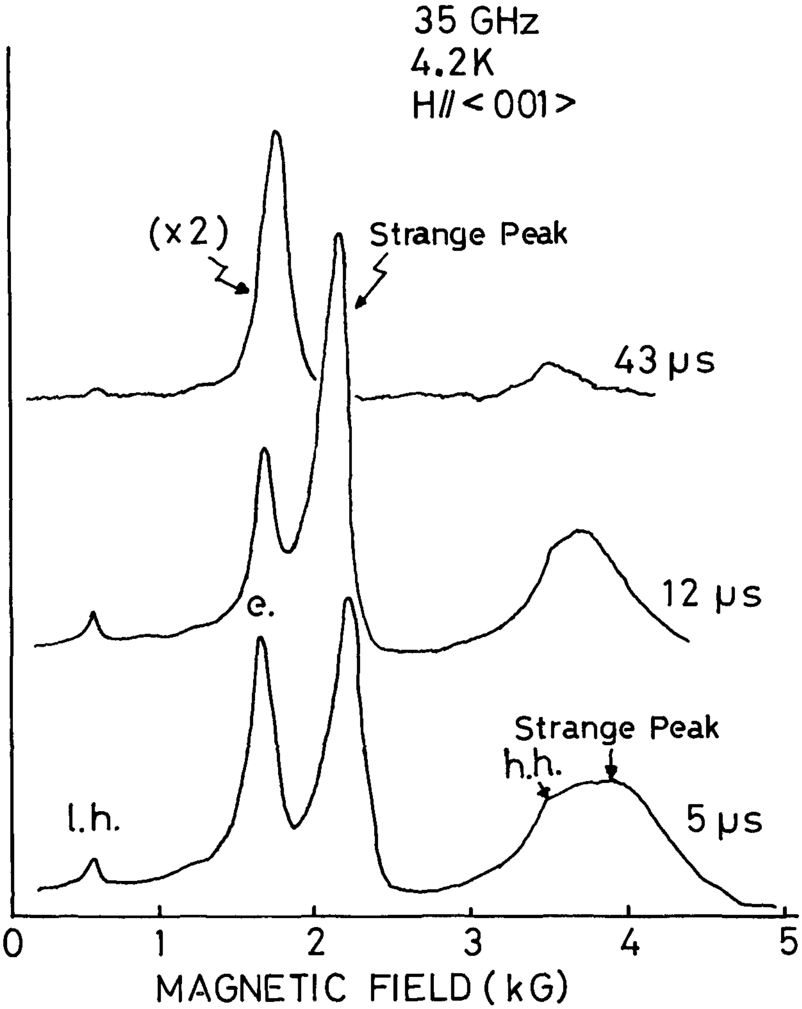


Fig.1. Some traces of time-resolved cyclotron resonance signals, indicating emergence and shift of the strange peak. The delay-times after photoexcitation are shown on the right.

having close resemblance with our experimental data at a fixed delay-time. It is true that, so long as one compares the experimental result with theory at a single time-profile, the agreement is exceedingly good. But the agreement is found only at one suitably chosen section of the time-resolution. If one watches the phenomenon through a passage of time, the theory of dimensional resonance confronts a difficulty.

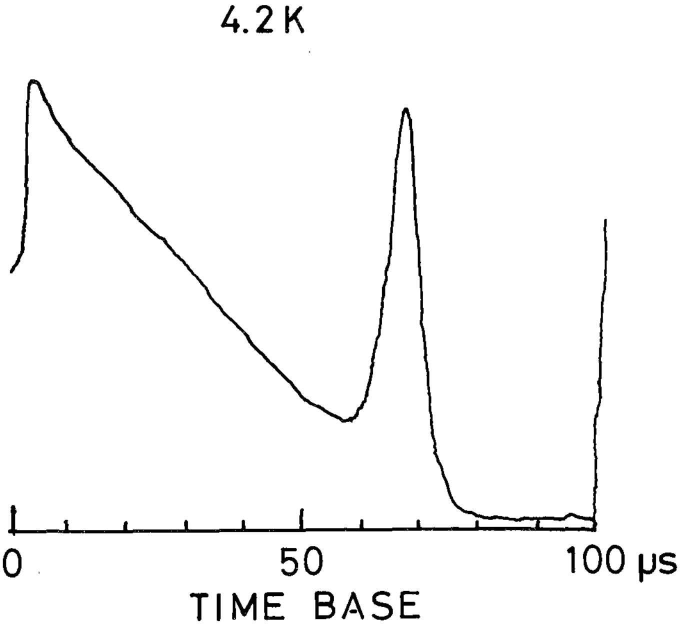
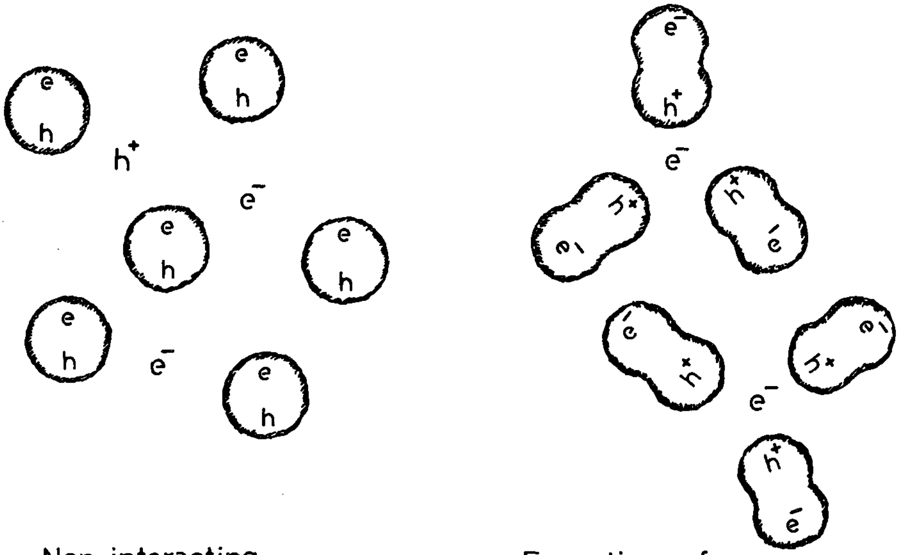


Fig.2. Microwave photoconductance trace under the application of a magnetic field. The field is set somewhat above the proper electron resonance field. It is characterized by the emergence of a striking overshoot on the tail.

Namely, the theory predicts a decrease in relative size of the strange peak with decreasing separation. That is contrary to the experimental observation.

The polaron model, on the other hand, has its own difficulty. It is hard to find any good reason why the electron interacts with a fixed number of excitons at a given instant of time (Fig. 3). Unless this condition is fulfilled, however, what we obtain would be just a smearing-out of the polaron peak. In other words, we have a distribution in polaron mass. The fact is the appearance of a definite peak during the passage of time.

Our original interpretation of the phenomenon through the idea of polaron had nothing to do with the presence of electron-hole drops. We find, however, some difficulty if we proceed by completely neglect-



Non-interacting carriers and excitons

Formation of excitonic polarons

Fig.3. Difficulty of the polaron model: At a given delay-time, each electron should be accompanied by an "equal" number of excitons.

ing the presence of drops. Figure 4 shows the time variation of the relative intensities of ordinary and extraordinary peaks. The ordinary resonance intensity falls exponentially with time. The extraordinary peak, or the polaron peak, grows with time for some time-interval at the beginning, saturates and then decays at last. Both the ordinary and extraordinary peaks correspond to electrons. The only difference is whether the electrons are coupled with excitons or not. The total intensity remains practically constant for a certain interval of time and then rapidly decays. Why does the total number of electrons not decrease for this initial period of time? There should be a source of producing electrons. When that source is exhausted, the observed number of electrons, coupled or not coupled with excitons, starts to decay. What is that source then? That must be electron-hole drops. Excitons, evaporated from the drop, will subsequently yield free

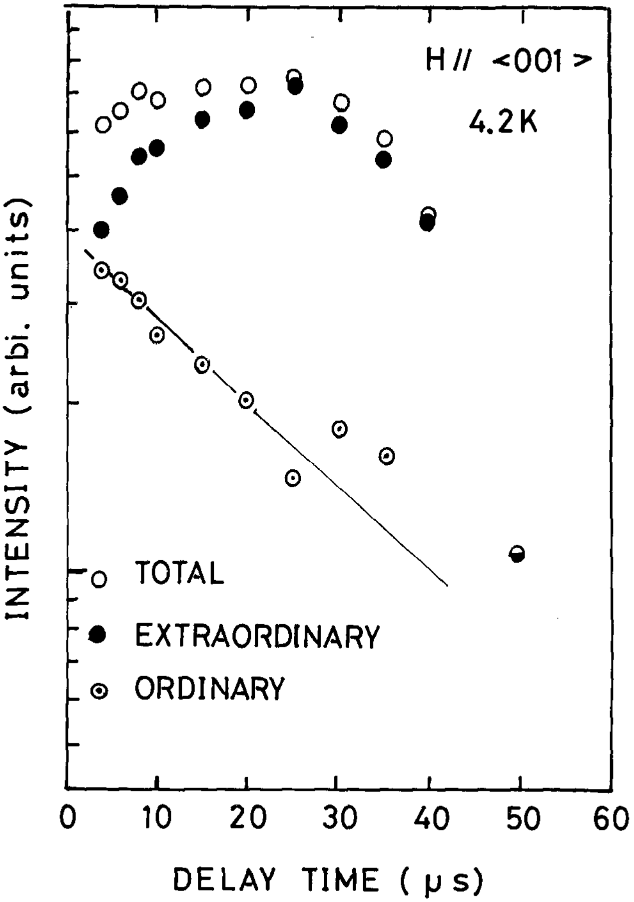


Fig.4. Intensities as a function of delay-time for ordinary, extraordinary and total electron resonances.

carriers on dissociation. One may expect a zone of uniform distribution of free carriers and excitons around an electron-hole drop. The uniformness is ensured by the uniform evaporation processes. If the distribution is uniform, there is no reason to denounce the uniform coupling between electrons and excitons. In other words, one can expect an average number of excitons with small fluctuation around an electron at a given instant of time. Even if, of course, the exciton evaporation is uniform around a drop, one has to expect a possible gradient in density along the direction perpendicular to the drop-surface. But the Auger processes due to exciton-exciton collisions would be more frequent near the surface and tend to make the density of excitons more uniform along that direction. In addition, if free carriers are produced dominantly through the Auger processes, one can forget the existence of the free carriers and hence the polarons in the region of less dense excitons. Thus we observe the cyclotron resonance signal arising only from the region of a high and "uniform" exciton density.

The sudden overshoot of the photoconductance signal at a proper delay-time as seen in Fig. 2 may correspond to the final exhaustion of drops or a single huge drop. Owing to the finite surface free energy, the unit volume free energy for the drop itself increases with decreasing drop size, eventually resulting in the small burst of the vapor pressure of the exciton gas.

REFERENCES

1) E. Otsuka, T. Ohyama and T. Sanada: Phys. Rev. Letters 31 (1973) 157.
2) E. Otsuka, T. Ohyama and T. Sanada: J. Phys. Soc. Japan 37 (1974) 114.
3) H. Numata: J. Phys. Soc. Japan 36 (1974) 309. See also Thesis, University of Tokyo, 1975.

Note Added in Proof.

Recently the authors have arrived at a conclusion that the strange peaks are not due to the polaron effect. They appear as a consequence of geometrical resonance, depending on the sample shape and the microwave frequency. The feature, however, is fairly complicated owing to the varying dielectric constant, which depends on the degree of excitation. More details will shortly be published elsewhere. The authors are indebted to Prof. C. D. Jeffries for suggesting the possbility in this direction.