Modification of the Electron-Phonon Interactions in GaAs-GaAlAs Heterojunctions

Recently Brummell *et al.*[1] reported interesting results from cyclotron and magnetophoton resonance experiments on GaAs-$Ga_{0.7}Al_{0.3}As$ heterojunctions as a function of temperature. From the cyclotron resonance measurements they observed that the cyclotron effective mass shows an anomalous decrease as the temperature falls below about 100 K. This reduction in the mass enhancement with decreasing temperature was attributed by those authors to temperature-dependent screening of the electron-optical phonon interaction.

The purpose of this Comment is to discuss some aspects of these experimental results which we hope can help to clarify the electron-phonon interaction in GaAs-GaAlAs heterojunctions. In order to understand the qualitative behavior of the cyclotron effective mass we have applied the Feynman path-integral formalism for the polaron problem to calculate the polaron effective mass as a function of temperature. In the calculation we have assumed that the electron was restricted to movement in the interface plane and interacted with the GaAs LO bulk phonons in the case of zero magnetic field. The results we have obtained are plotted in Fig. 1 along with those for the corresponding three-dimensional GaAs. As we can see from this figure, the polaron mass shows the same behavior as that experimentally observed for the cyclotron effective mass. However, no screening effects were taken into account in the calculation. This comparison between theory and experiment must be regarded as qualitative since we have assumed a purely 2D electron system interacting with LO bulk phonons only. Inclusion of the finite extent of the electron wave function as well as screening by free carriers will reduce the strength of the electron-phonon interaction.[2,3]

The explanation for the observed behavior of the cyclotron mass can be in our opinion better interpreted as due to the polaronic effect itself. Then the anomalous increase with temperature of the cyclotron mass in GaAs-GaAlAs heterojunctions we prefer to attribute to the nonparabolicity of the polaron dispersion relation instead of screening of the electron-optical phonon as stated by Brummell *et al.*[1] The fact that the reduction in the observed cyclotron mass (1.8%, 2.1%, and 2.8%) increases with increasing electron density can be understood in terms of the coupling to the interface phonons. The larger the density, the closer the electrons will be to the interface and consequently, the larger the strength of the interaction with the interface phonons will be, even when we consider screening effects.

From Fig. 1 we also note that a maximum in the temperature-dependent polaron mass enhancement for bulk GaAs is predicted, in contradiction to the experimental observations by Brummell *et al.*[1] However, cyclotron resonance experiment performed at lower temperature[4] gave a measured cyclotron mass of $m^* = 0.0671m$, which is smaller than the value extrapolated from the experimental results shown in Ref. 1.

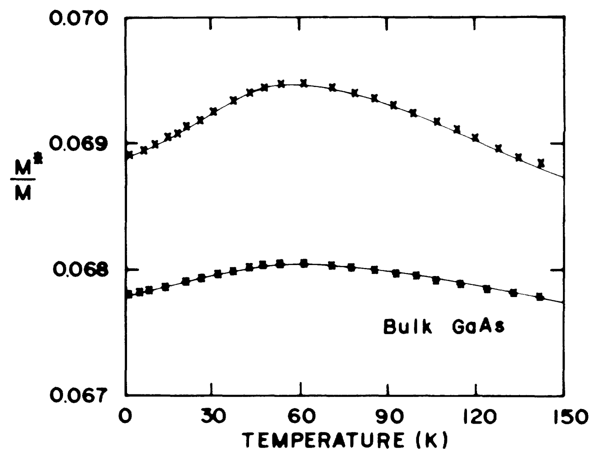

FIG. 1. The temperature dependence of the polaron effective mass in GaAs-GaAlAs heterojunctions and in bulk GaAs. Points are the numerical results and lines are guide to the eyes.

On the other hand, recent simultaneous observations of photoconductivity at 5 K and absorption at 20 K both gave an effective mass value of $m^* = 0.0676m$, once corrections have been made for nonparabolicity,[5] which is very close to $0.06761m$ earlier obtained at 30 K.[1] Although the discrepancy between these two experimental results could be due to the calibration of the magnetic field, we hope that new experiments could be performed to confirm or disprove the theoretical prediction.

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