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DINGLE TEMPERATURE IN HgSe

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Abstract.—The low temperature collision broadening of electron states at the Fermi level (Dingle temperature) is calculated in the first Born approximation for ionized impurity scattering. The calculations take into account the conduction band nonparabolicity and wave function symmetry of small and zero-gap zinc-blende semiconductors. It is shown that Dingle temperatures in HgSe deduced from the present measurements and from previously reported measurements of the Shubnikov-de Haas effect are in agreement with calculation performed for single-ionized donor scattering.

1. INTRODUCTION.—The studies of quantum oscillations of transport coefficients and magnetic susceptibility are known to be a useful method for determining band structure parameters of semiconductors. It is also known that such studies when correlated with electron mobility measurements offer in addition a powerful tool for studying doping homogeneity and the predominant electron scattering mechanisms /1,5/.

The latter purpose is achieved through analysis of the oscillation damping temperature which in general is the sum of contributions resulting from the finite lifetime of electrons at the Fermi level (Dingle temperature, $T_D$) and of the semieperimentally introduced term usually attributed to the macroscopic fluctuations of electron concentration (inhomogeneity temperature, $T_i$).

In this paper we give a simple working formula for electron lifetime limited by ionized impurity scattering. We limit our considerations to zinc-blende semiconductors; however, since the quantum oscillation measurements are mainly performed on small-gap doped materials, we take into account the conduction band nonparabolicity and the properly mixed $s$-type and $p$-type electron wave functions. We then choose HgSe as a model material because of the great amount of experimental data that is available and because of its large dielectric constant which on-
follows now the general procedure of reference /6/, giving:

\[
\frac{1}{T_D} = \frac{2\pi e^2}{\hbar^2 k_F^2 B} \sum_{m} x \left( 1 - \frac{x^2}{2(\xi + 1)} \right) \left( 2[H_2 - (\xi + 1)] - 1 \right).
\]

Here \( Z \) and \( N_I \) are the charge and concentration of ionized impurities, \( \mu_0 \) is the static dielectric constant which in zero-gap materials includes the electron concentration dependent term arising from \( \Gamma_{\perp} \rightarrow \Gamma_{\parallel} \) excitations. The coefficient \( b \) and \( c \) describe the relative amount of p-type wave functions in the total electron wave function. Finally \( \lambda \) is the Thomas-Fermi screening radius.

3 EXPERIMENTAL.- The transverse magnetoresistance measurements (\( 1 \leq B \leq 10^5 \)) were performed at 2.2K and up to 7 T for two unannealed samples with electron concentrations 1.32 \( \times \) 10\(^18\) and 6.70 \( \times \) 10\(^18\) cm\(^{-3}\).

The latter sample was doped with Ga. The Dingle temperatures were obtained following the known (\( /1, 10,11/ \)).

The required values of the effective mass were calculated according to full Kane's formula and using \( B_{\parallel} \) parameters of Galazka et al. /7/. The same set of parameters together with \( B_{\perp} = 28.5 \) /8,9/ was used to compute \( T_D \) and \( T(\tau \) being the momentum relaxation time given explicitly in /6/).

4 RESULTS AND DISCUSSIONS.- The Dingle temperatures \( T_D \) and mobility temperatures \( T_m = eH/2nk_0 k_0 \), as measured by various authors, are plotted in figure 1. The solid lines represent calculated \( T_D = \hbar/2nk_0 \tau_D \) and \( T_m = eH/2nk_0 \tau \) assuming singly ionized donor scattering. We see that our calculations correctly account for the experimental magnitudes of the Dingle temperatures and for the difference between \( T_D \) and \( T_m \).

Thus we are led to the following conclusions:

First, the difference between \( T_D \) and \( T_m \) in HgSe, attributed in the literature /10,11/ to inhomogeneities in impurity distribution, actually results from the anisotropy of the ionized impurity scattering. Second, in contrast to the conclusions from the annealing properties of HgSe /13,14/, we see that at least the majority of donors in HgSe are singly ionized. Indeed, assuming that donors are doubly ionized one increases calculated \( T_D \) and \( T_m \) by the factor of two leading to disagreement with the experimental points.

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