Hall Theory in n-Type Germanium*

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A STUDY of the galvanomagnetic properties of the eight-[111] and six-[100] ellipsoidal models, appropriate respectively for the energy surfaces in n-type germanium and silicon, has been in progress for some time in the Lincoln Laboratory.[1] Using the assumption of energy-independent scattering time τ which has already been employed to explain cyclotron resonance,[2] theoretical calculations have been carried out. Preliminary comparison of the angular and magnetic field B dependence of the magnetoresistance reveals essential agreement with the energy-dependent τ theories,[3,4] although admittedly the constant τ assumption is restrictive. The latter has the advantage, however, of greatly reducing the computational effort required in arriving at explicit results.

The behavior of the Hall coefficient R_H in n-germanium is as follows: Plots of R_H *vs* B have two asymptotic values which are independent of orientation—the saturation (high-field) limit is just $R_\infty = 1/Nqc$, while in the low-field limit $R_0 = [3K(K+2)/(2K+1)^2]R_\infty$. In between these limits, an orientation-dependent minimum occurs which becomes more pronounced as the current density J and magnetic field directions are chosen with higher Miller indices. The occurrence of such minima for τ characteristic of lattice scattering was pointed out earlier.[3] However, in the present description, it is easier to show this for diverse orientations; and moreover, for a given orientation of $\mathbf{J}$ and $\mathbf{B}$, a universal plot can be made for R_H *vs* $\omega\tau$, where

$$\omega = \frac{qB}{\bar{m}^* c} \cdot \frac{3K}{2K+1}, \quad K = m_1/m_2,$$

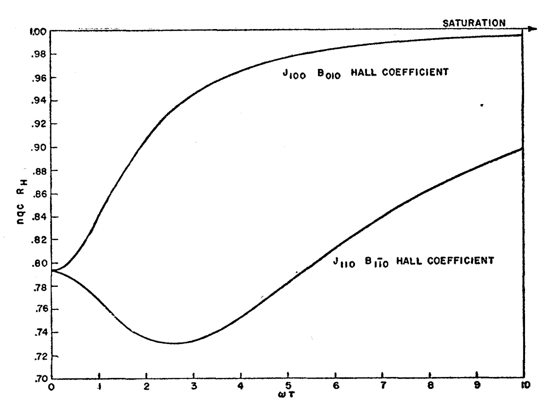

FIG. 1. Behavior of Hall coefficient plotted in terms of the universal parameter $\omega\tau$ which simultaneously depicts the effect of magnetic field and scattering time: (a) The case $\mathbf{J}_{100}$, $\mathbf{B}_{010}$; (b) the case $\mathbf{J}_{110}$, $\mathbf{B}_{1\bar{1}0}$.

$\bar{m}^*$ being the average effective mass defined in terms of the mass tensor components m_1 and m_2, by

$$3/\bar{m}^* = 1/m_1 + 2/m_2.$$

Favorable resolution of the minimum requires the proper combination of symmetry for $\mathbf{J}$ and $\mathbf{B}$ along with the proper range of $|B|$ and τ, being generally abetted by small τ associated with high temperatures and impure samples.

Figure 1 illustrates typical behavior of the universal plots. The arrangement $\mathbf{J}_{100}$, $\mathbf{B}_{010}$ exhibits the behavior shown in Fig. 1(a); the minimum here is coincident with the R_0 value. Experiment indeed indicates a minimum very close to $B=0$.[5] The situation for $\mathbf{J}_{110}$, $\mathbf{B}_{1\bar{1}0}$ is more amenable for the observation of the minimum which as Fig. 1(b) indicates occurs at $\omega\tau \sim 2.5$ with an R_H value a few percent below R_0. Again experiment seems to be essentially in line with this.[5] So far, it appears that the experimental data fall somewhere between the predictions of the constant and energy-dependent τ theories; the measured value at liquid nitrogen temperatures of R_∞/R_0 for $\sim$10 ohm-cm material at room temperature lies between 1.27 and 1.08 in these respective theories, for K about 19.[6]

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Measurement of Electron Momentum by Positron Annihilation*†

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IN order to explore the possibility of investigating electronic states in solids by means of positron annihilation we have measured, with good resolution, the angular distribution of gamma rays from two-quantum positron annihilations[1–4] in various metals. The experimental arrangement utilizes two scintillation counters placed behind vertical slits in lead blocks located two meters on either side of a vertical strip of the material being studied. This strip is bombarded by positrons from two Na^{22} sources which are placed on opposite sides of it and which are shielded from direct view of the fixed counter. The movable counter