with $\epsilon = 0.0909$ (for air), $Re_M = 0.2$ and 1.0, and Q varying from 0 to 4. ($\epsilon = \rho_\infty/\rho$; $Q = (\sigma\alpha^2 c)/\rho_\infty U$; and $Re_M = \sigma\mu c U$). For this range of Q, a body that is consistent with the analysis is a sphere concentric with the shock. The theoretical stand-off distance, $\Delta \equiv (c - r_b)/r_b$, increases with increasing Q but is relatively unaffected by Re_M for the range of Re_M considered.

The experimental investigation of the effects of an applied magnetic field on the bow shock stand-off distance was performed in a 3 in. diameter electromagnetic shock tube of the tapered tube type.[2] The shock wave was driven by the discharge, through a spark gap, of six 1-μf capacitors at 20 kv. The model was a 2.0-cm diameter cylinder with a faired nose with a radius of 1.2 cm. Magnetic field strengths of up to 35 kilogauss were produced by a pulsed 6.3-mm i.d. coil contained in the nose with its axis parallel to the model axis. The magnet current was supplied by two 100-μf capacitors charged to voltages up to 1500 v. A pickup coil was used to trigger and synchronize the discharge through an ignitron circuit. The stand-off distance was scaled from image converter camera photographs of the bow shock taken with an exposure time of 110 millimicroseconds.

The shock tube tests were made in air at an initial pressure of 70 microns with a primary shock Mach number of 22. About 15 μsec. of steady flow were obtained, providing during this time free-stream conditions of $U = 6890$ m/sec, $M = 4.5$, $\rho/\rho_0 = 1.22 \times 10^{-3}$, and $T = 6450°$K, as determined from the thermodynamic properties of air.[3] The resulting conditions in the shock layer were $\rho/\rho_0 = 1.93 \times 10^{-2}$, $T = 17000°$K, and $\sigma = 130$ mho/cm.

The stand-off distance was measured for various strengths of the applied magnetic field and was found to increase with increasing field strength as shown typically in Fig. 1. To facilitate comparison with experimental data, the theoretical parameter Q was converted to $Q^* \equiv \sigma B_0^2 r_b/p_\infty U$ in which B_0 is the field strength at the stagnation point on the body and r_b is the nose radius. The theoretical curve and the experimental data are shown in Fig. 2 and are seen to correlate quite well for the range of Q^* investigated.

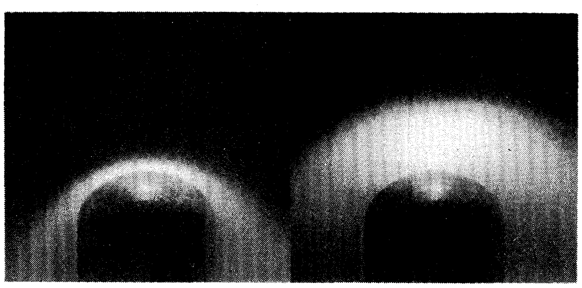

FIG. 1. Typical picture of bow shock without (left) and with applied magnetic field.

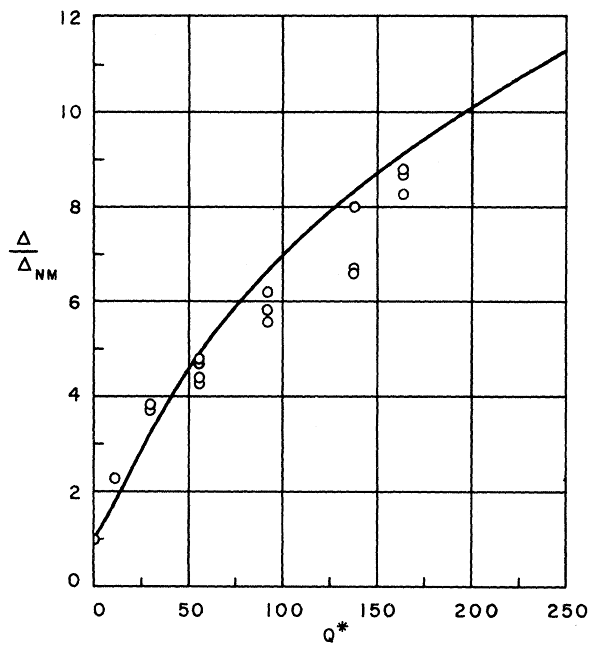

FIG. 2. Experimental data and theoretical curve for the variation of stand-off distance with Q* for air. Free stream conditions are $\rho/\rho_0 = 1.22 \times 10^{-3}$, $T = 6450°$K, $U = 6890$ m/sec and $M = 4.5$.

Work is now in progress which will extend the experimental data to variations in free-stream density and velocity and to other gases.

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OBSERVATION OF MICROWAVE CYCLOTRON RESONANCE BY CROSS MODULATION*

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A new method of observing microwave cyclotron resonance in semiconductors has been developed. The sample (~3 mm in maximum dimension), with leads attached, is placed in the high E field region of a microwave cavity, in a conventional K-band bridge. The static magnetic field is slowly swept through resonance, as in the usual technique, but the resonance peaks are observed by detecting changes in dc resistance of the sample. The phenomenon is in some ways similar to the Luxembourg effect.[1] A convenient method of operation has been amplitude modulation of the microwave power at 260 cps, and observation of the 260-cps component of the sample resistance. The technique seems to yield a significantly better signal-to-noise ratio than the conventional method of observing cyclotron resonance by detecting microwave power absorption.

This "cross-modulation" phenomenon was first observed in a sample of very pure germanium ($\omega\tau$ ~22) at 4°K. Low intensity light illumination was necessary to excite carriers in the sample. Cross modulation was observed by applying a small dc voltage (~0.2 v) across a sample, and detecting the 260-cps resonance signal across a small series resistor. Subsequently, we found that cross modulation could be just as easily observed in germanium by detecting the signal directly across the sample leads with no external dc voltage applied. This is perhaps due to a modification of a photoelectromagnetic effect[2] by the cyclotron resonance. The cross-modulation phenomenon in germanium is mainly due to the "heating" of carriers by microwave resonance, and the change in dc mobility associated with this heating, though other effects may be important.

Figure 1 shows a recorder trace of cyclotron resonance cross modulation in germanium, as a function of magnetic field, with no external dc voltage applied. To indicate the complexity of the phenomenon, it should be mentioned that the appearance of a resonance as an increase or decrease in signal may be reversed by a small rotation of the sample, or even a slight change in light intensity. In addition to the usual resonances in germanium, several new ones, of somewhat lower intensity, have been detected. Some of these may be related to the quantum transitions discussed by Luttinger[3] and observed by Fletcher *et al.*[4]

Cyclotron resonance cross modulation is also being studied in p-type InSb ($p \sim 4\times10^{14}$/cc). Indication of resonance has been observed. However, the peculiar magnetoresistance behavior of InSb at low temperatures introduces a complication in observing cyclotron resonance cross modulation.

An understanding of the spectra observed in germanium and in p-type InSb will require further careful experimental study, including anisotropy measurements. Experiments are also planned in other semiconductors. A simplified theory of the cross-modulation phenomenon has been developed and will be reported, along with more experimental details, in a later publication.

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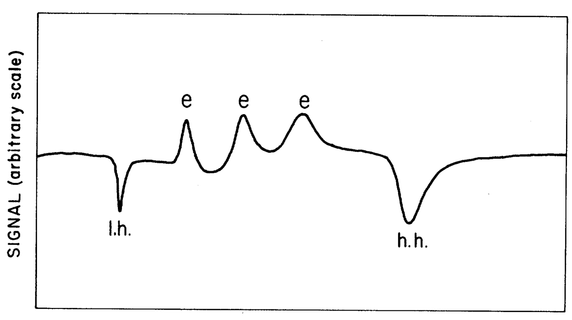

CROSS-MODULATION IN Ge

FIG. 1. Cyclotron resonance cross-modulation in germanium. *lh* is the light hole, and *hh* is the heavy hole. The three peaks marked *e* are electron resonances.

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