It appears that the results of the diffusion of antimony in CuZn, which can be explained in terms of the interstitialcy mechanism, require further experimental confirmation. At present, there are only three points in the ordered phase. It is also necessary to investigate the diffusion of other impurities before definite conclusions can be drawn as to the behavior of the impurity atoms in the ordered lattice.

It is therefore proposed that these experiments on beta brass constitute convincing evidence for the vacancy mechanism.

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Infrared Cyclotron Resonance in Bi, InSb, and InAs with High Pulsed Magnetic Fields*

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MICROWAVE cyclotron resonance in materials[1] other than germanium and silicon is not well defined because of large scattering or plasma effects. The use of infrared frequencies solves both problems, since $\omega\tau \gg 1$ even at room temperatures, and $\omega > \omega_p$ for semiconductors and semimetals. ω and ω_p are the frequencies of the electromagnetic field and the plasma, respectively, and τ is the scattering time. Infrared experiments, however, require high magnetic fields. The first successful results were obtained for InSb by Burstein, Picus, and Gebbie[2] with a Bitter magnet up to 60 000 gauss at 41.1 μ. Our experiments on InSb and InAs were performed from 10 to 22 μ with pulsed fields up to 320 000 gauss at room temperature, using both transmission and reflection techniques. The first direct observation of cyclotron resonance in a metal, Bi, was also made.

The samples were mounted in special coils[3] located between the infrared source and the monochromator. The detector,[4] a zinc-doped germanium cube maintained at 4.2°K, was located six feet from the coil to reduce electromagnetic pickup. The output signal from the high-impedance detector was fed to a cathode follower circuit specially designed to reduce the effective lead capacitance to give a time constant of 2 μsec. The output was recorded by photographing an oscilloscope trace, triggered by light from the spark gap switch of the pulse magnet.[3]

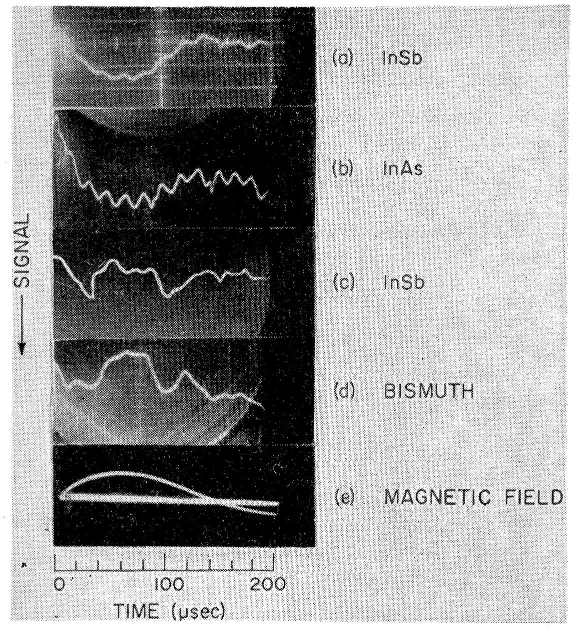

Fig. 1. Cyclotron resonance traces. Transmission signal through 200 μ samples at $\lambda = 12.7\ \mu$: (a) InSb, $B_{max} = 220$ kilogauss; (b) InAs, $B_{max} = 295$ kilogauss. Reflection signal at $\lambda = 18.3\ \mu$ and $B_{max} = 155$ kilogauss: (c) InSb, (d) bismuth. Magnetic field trace *vs* time is shown by curve (e).

The photograph in Fig. 1 shows traces of relative transmission of 200 μ thick InSb and InAs samples at 12.7 μ during a field pulse. The peak field for resonance was higher in InAs; the trace is modulated by periodic high-frequency noise. Even with fields up to 300 000 gauss, the resonance is not resolved in InSb, where the mass is presumably small. Two possible factors contributing to the excessive width of the resonance absorption are: (1) dimensional broadening due to the sample thickness exceeding the skin depth (10 μ) at resonance, (2) the apparent increase of the effective mass with increasing magnetic field. The first effect can be eliminated by using reflection techniques. A typical reflection trace for InSb is shown in Fig. 1(c). We interpret the resonance field as that corresponding to the point at which the rapid change of reflection passes through zero. By determining the resonance magnetic field from a calibrated trace shown in Fig. 1(e) for different wavelengths, a plot of effective mass *versus* magnetic field is obtained. This relation is shown for InSb in Fig. 2. Masses determined by Burstein *et al.*[2] and microwave cyclotron resonance at lower fields are also included. The increase of m^* for InSb is presumably related to decreasing curvature of the band with increasing energy, and correlates well with the data of Chasmar and Stratton[5] from thermoelectric power measurements. Reflection experiments were also performed recently on InAs, yielding $m^* \approx 0.03m_0$ between 150 000 gauss and 250 000 gauss. Further experiments

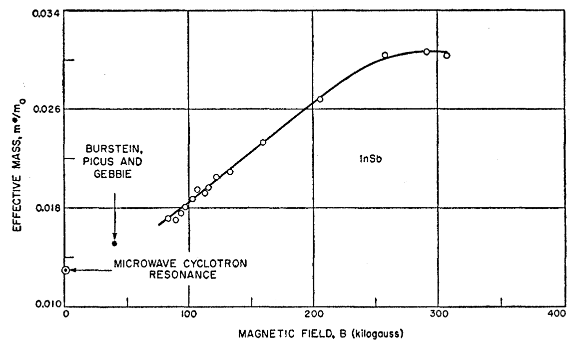

FIG. 2. Variation of effective mass with magnetic field in InSb from reflection experiments between $\lambda=10\,\mu$ and $\lambda=22\,\mu$. The magnetic field was perpendicular to the surface of the sample.

are planned to check this value and possible variation of effective mass with magnetic field.

A typical reflection trace for Bi is shown in Fig. 1(d), and m^* *versus* B is shown in Fig. 3. Two resonance peaks are observed when the magnetic field is along the [11$\bar{2}$0] direction; however, only one mass is observed along the [10$\bar{1}$0] direction. The mass values of Fig. 3 are identified with the values of $0.009m_0$ along [10$\bar{1}$0] and $0.008m_0$ and $0.016m_0$ along [11$\bar{2}$0] as calculated[6] from Shoenberg's de Haas-van Alphen data.[7] The observed increases in mass with B are again presumably due to changes in curvature of the bands with energy. The variation of the cyclotron resonance masses above and below these calculated masses probably represents transitions between Landau levels above and below the Fermi level at high and low magnetic fields, respectively. The de Haas-van Alphen masses correspond to those at the Fermi level.

Preliminary cyclotron resonance absorption effects have been observed in zinc and graphite. Further work is required before quantitative results can be obtained.

The samples of InSb and InAs were pure n-type material, with mobilities of ~75 000 and ~25 000, respectively, at 300°K, giving calculated values of $\omega\tau \approx 100$ at $10\,\mu$. These materials were generously provided by T. C. Harman of Battelle Memorial Institute.

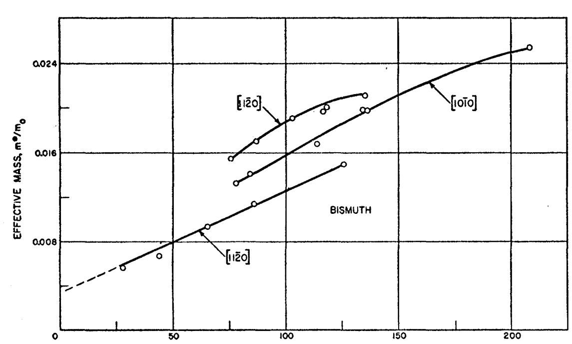

FIG. 3. Variation of effective masses with magnetic field in bismuth from reflection experiments. The magnetic field was perpendicular to the surface and parallel to the indicated crystal directions.

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Magneto-band Effects in InAs and InSb in dc and High Pulsed Magnetic Fields*

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IN a magnetic field semiconductors and semimetals with small effective masses have quantized Landau levels whose energy separations can become comparable to the energy gap or overlap of the bands, respectively. Displacement of the lowest conduction and highest valence band levels in a semiconductor would increase the energy gap. This magneto-gap effect was first

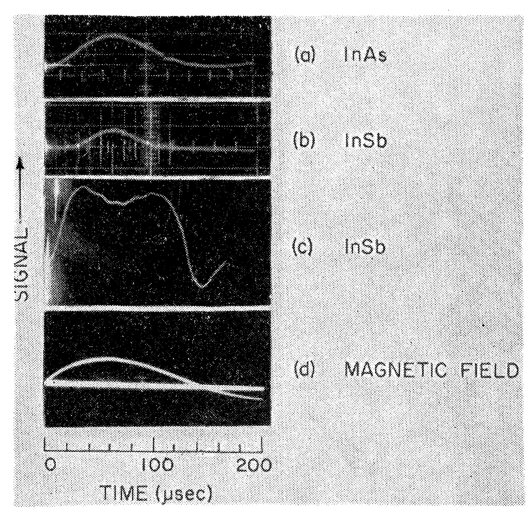

FIG. 1. Transmission signal in (a) InAs at $\lambda=3.55\,\mu$ and $B_{max}=150$ kilogauss, (b) InSb at $\lambda=5.99\,\mu$ and $B_{max}=220$ kilogauss, (c) InSb at $\lambda=7.55\,\mu$ and $B_{max}=220$ kilogauss, showing dip in trace due to onset of cyclotron resonance. The magnetic field trace *vs* time is shown in curve (d).

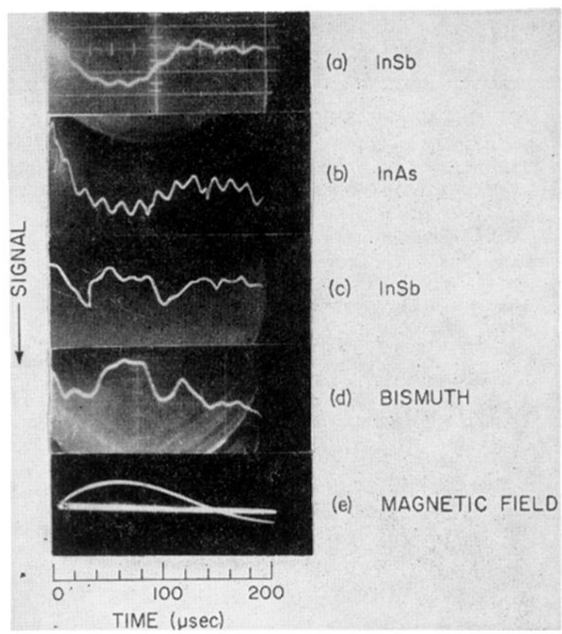

FIG. 1. Cyclotron resonance traces. Transmission signal through 200 μ samples at $\lambda=12.7\ \mu$: (a) InSb, $B_{\max}=220$ kilogauss; (b) InAs, $B_{\max}=295$ kilogauss. Reflection signal at $\lambda=18.3\ \mu$ and $B_{\max}=155$ kilogauss: (c) InSb, (d) bismuth. Magnetic field trace *vs* time is shown by curve (e).