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MAGNETIC BREAKDOWN AND THERMOELECTRICITY IN METALLIC TIN

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Large quantum oscillations are observed in the thermoelectric emf in metallic tin at 1.3°K. These are correlated with magnetoresistance structure due to magnetic breakdown.

We recently reported anomalous Shubnikov–de Haas amplitudes in metallic tin.[1] Extremely large amplitudes appeared at ±3° and at ±22° from [001] in the (110) and (100) planes. All oscillations were shown to be from the $3\delta_1^1$ section of the Fermi surface.[1,2] In the present Letter we report seeing these, and additional anomalies in the thermoelectric emf (Figs. 1 and 2). These anomalies are marked A, B, C, and A', B', C' in Figs. 1 and 2. All anomalies correlate with structure in the magnetoresistance as shown in Fig. 2.

In Fig. 1 the amplitudes of quantum oscillations in the thermo-emf are plotted against angle in the (110) plane. The large amplitudes at ±3° and ±22° are identical in structure to the anomalies found in the Shubnikov–de Haas effect.[1] For a discussion of the anomalies at ±3° see Ref. 1.

From the field dependence of the magnetoresistance, Anderson and Young show that magnetic breakdown can occur between zone $3\delta_1^1$ and zone four.[2,3] This occurs at ±32° and ±22° in the (110) plane. At ±22° we find giant quantum oscillations in the thermo-emf (Figs. 1 and 2). We conclude that the opening and closing of orbits on zone four is governed by phase coherence over the $3\delta_1^1$ section. This effectively introduces an oscillatory scattering time which causes the large oscillations seen at A and A'.

Anomalies B and B' (Figs. 1 and 2) are unusual in that they are strong dc emf's. That is, quantum oscillations at these angles do not have un-

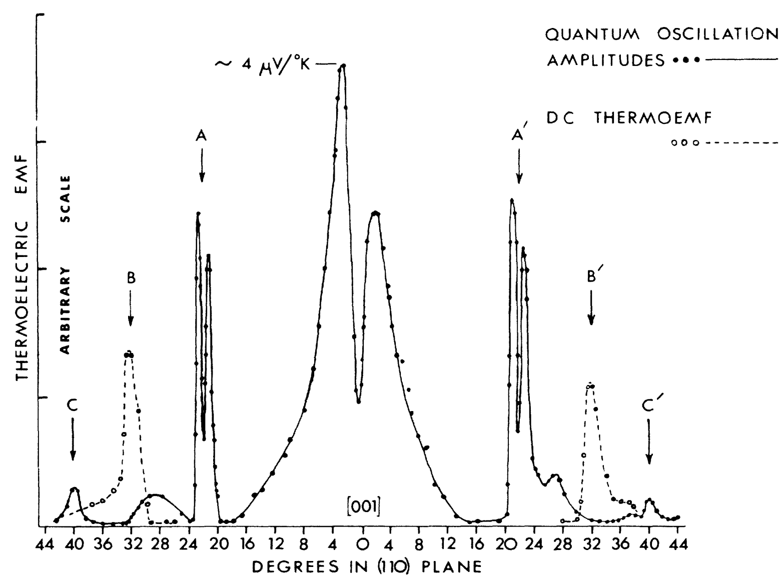

FIG. 1. Thermoelectric emf for the field H in the (110) plane of tin near 32 kG and 1.3°K. Solid lines are quantum-oscillation amplitudes. Dashed lines are nonoscillatory emf's. The adiabatic thermoelectric coefficient is proportional to the thermo-emf, and at B for example, has a value of 10 μV cm/W.

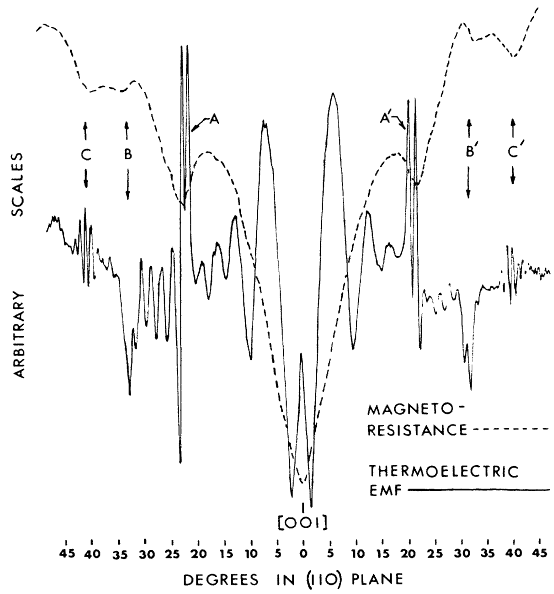

FIG. 2. Correlation of magnetoresistance structure with anomalies in the thermoelectric emf. The emf and resistance are plotted as a continuous function of angle at 32 kG and 1.3°K.

usually large amplitudes. The emf's grow linearly with field strength and appear at the angles where Anderson and Young found magnetic breakdown influencing the magnetoresistance. It isn't certain how magnetic breakdown could cause this anomaly. A large thermo-emf indicates a strong scattering mechanism.

Our anomalously large quantum amplitudes at C and C' in Figs. 1 and 2 are about 8° outside the region where Anderson and Young saw breakdown. The presence of these amplitudes suggests the existence of a mechanism similar to that causing A and A'.

Anomalies similar to the ones above occur in some nonsymmetry planes where the field passes near [001].[4]

Both thermoelectric and magnetoresistance voltages were measured with a dc amplifier. Temperatures ranged from 1.3 to 4.2°K, and fields ranged from 15 to 32 kG. The angles at which the anomalies occur are independent of temperature and field. All anomalies grow rapidly with field and decreasing temperature.

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MICROWAVE ACOUSTIC AMPLIFICATION IN n-InSb AT 9 GHz

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Amplification of 9-GHz longitudinal acoustic waves has been observed in n-InSb at 4.2°K on application of a pulsed electric field. The amplification results from a resonant transfer of energy between the conduction electrons and the acoustic wave since the mean free path is greater than the wavelength.

Acoustic amplification has been observed at 9 GHz on applying a pulsed electric field to n-InSb at 4.2°K. In these experiments we achieve $ql > 1$, where q is the acoustic wave vector and l is the electron mean free path. Hence the amplification results primarily from a resonant interaction of the conduction electrons with the acoustic wave, a process distinct from the collision-dominated process responsible for the familiar CdS acoustic amplification. In these experiments at 9 GHz, the momentum of the acoustic phonons $\hbar q$ is comparable with the mean thermal electron momentum mv_0. Therefore, the resonant electrons are not those traveling in synchronism with the wave, as in the classical Landau damping case, but rather electrons which travel much faster than the velocity of sound and which undergo Bragg scattering by the acoustic wave. The interpretation of the amplification for $ql > 1$ as resulting from a phonon maser process[1,2] remains valid for $\hbar q/mv_0 > 1$, although the regions of momentum space corresponding to initial and final states of the resonant electrons are considerably altered. This is the first observation of this res-