of the magnetoresistance in heavily doped n- and p-type germanium from 1.6°K to 4.2°K, also advances the hypothesis that the positive and negative effects arise from the same physical mechanism.

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OBSERVATION OF OSCILLATORY MAGNETOSTRICTION IN BISMUTH AT 4.2°K

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We have observed the longitudinal magnetostriction in bismuth at 4.2°K up to 25 kG in a direction 58° from the trigonal axis and 34° from the bisectrix, and have found the oscillatory effect recently predicted by one of us.[1] With the sensitivity available, the effect is relatively large; features can be clearly observed which correspond closely to the de Haas–van Alphen effect.

The largest strain observed was 1.2×10^{-6} and occurred at 25 kG. Nine full periods of the oscillation were unambiguously identified, the smallest occurring at 1.4 kG with a strain amplitude of 1.5×10^{-9}. Three smaller periods are suggested in the data. The period is indeed constant in reciprocal magnetic field with a value of 7.3×10^{-5} G^{-1}.

The existence of the effect is readily apparent from Fig. 1, in which the relative change in length of the specimen is plotted against time while the magnetic field decays exponentially in time. This is thus equivalent to a plot of strain versus $\log(1/B)$. The curve shown is a tracing of the strip chart record produced in this way beginning at about 6 kG. The time constant of the decay of field was 325 sec, although the curve is rather closely reproduced by other data taken point by point under conditions insuring thermal equilibrium of the sample.

The measurement was made by White's capacitance method[2] which exploits the extraordinary

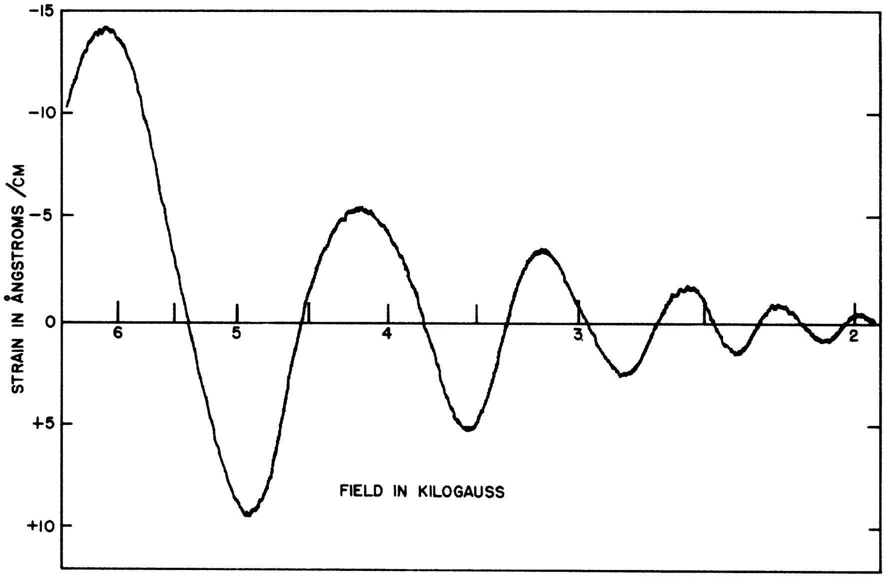

FIG. 1. Strain in bismuth crystal at 4.2°K versus magnetic field plotted during exponential decay of field from about 6 kG to about 2 kG.

precision of three-terminal capacitance measurements made possible by the use of the transformer-ratio bridge developed by Thompson.[3] The sample was a single crystal of 99.999% pure bismuth 5 cm long and 6 mm in diameter, centered along the axis of a superconducting solenoid 20 cm in length and 5 cm in inside diameter. Its free end carried a flat electrode 1.9 cm in diameter separated from another fixed electrode 1.3 cm in diameter by a gap of about 70 microns. This formed a capacitance of about 15 pF which varied with changes in the length of the sample. The drift rate obtained at 4.2°K with no current in the solenoid was about 2×10^{-7} pF/min, corresponding to a strain rate of 2×10^{-11} pF/min, and the electrical noise in the detection system represented less than 10^{-11} in strain.

Susceptibility measurements on this bismuth sample are not available, but the period of the oscillations is in agreement with the de Haas–van Alphen period measured by Dhillon and Shoenberg[4] in the following sense. In Fig. 1 of their paper, these authors show a maximum period for bismuth of 8.4×10^{-5} G^{-1}. We associate this period with the maximum cross section of one of the ellipsoids of the Fermi surface normal to its principal axis. The field direction in our sample makes an angle of 29° with this axis. Thus the cross section normal to our field direction is larger by the factor sec29°, and the period should be smaller by the factor cos29°, which yields 7.35×10^{-5} G^{-1}. We observe a period of 7.3×10^{-5} G^{-1}. It may be remarked here that the orientation of our crystal is close to the direction in which, as Dhillon and Shoenberg showed, a single period is dominant. This is consistent with our results. Figure 2 is a plot of reciprocal field at minima and maxima versus the half-integers and demonstrates the constancy of the period in reciprocal field.

The field dependence of the amplitude is rather closely proportional to $\exp(-\mathrm{const}/B)$ over the entire range of field in which oscillations could be detected.

Above 5 kG, the magnetostriction is quite reversible. Below this limit there is a small nonoscillatory contribution observed in increasing fields which is absent in decreasing fields. This hysteresis may be due, at least in part, to the well-known hysteretic behavior of superconducting solenoids at low fields, since we have in all cases measured currents, not fields, and have assumed linearity of the relation between the two. If the decreasing-field measurements are taken as the more reliable, then there is no detectable steady magnetostriction corresponding to the B^2 effect usually found.[5] This may be a coincidental result of the crystal orientation used, since Kapitza found that the magnetostriction at 77°K changes sign as a function of orientation with a zero at about 50° to the trigonal axis.

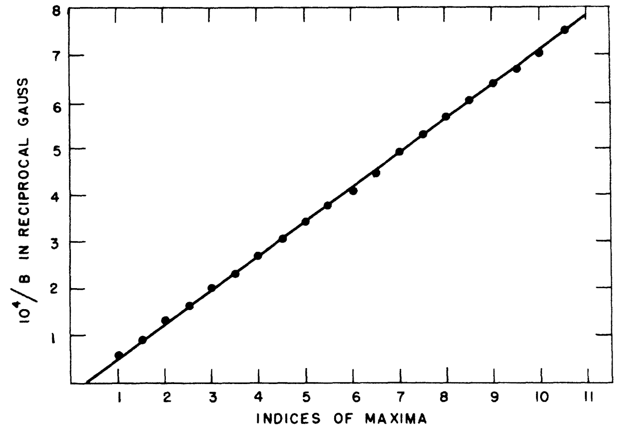

FIG. 2. Values of $10^4/B$ for maxima and minima plotted against successive half-integers for bismuth oscillations. Integers represent maxima.

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