The deHaas-van Alphen Effect in a Single Crystal of Zinc

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IN 1930 deHaas and van Alphen[1] observed that the diamagnetic susceptibility of bismuth, which is independent of the field strength at ordinary temperatures, becomes a complicated periodic function of the field at temperatures of liquid hydrogen (20°K) and below. This has come to be known as the deHaas-van Alphen effect. The field dependence occurs only in a plane perpendicular to the trigonal axis. In this plane the susceptibility is anisotropic at 20°K and below but is isotropic at higher temperatures.

Subsequently, this effect was studied in greater detail by Shoenberg and Uddin[2] with respect to the influence of temperature and impurities. Blackman[3] developed a theory based on the particular electronic structure of bismuth which agrees qualitatively with these experiments but does not account for the fact that any slight change in the electronic structure caused by impurities decreases the magnitude of the effect. Blackman's theory also fails to account for the fact that the effect is not observed in antimony which has an electronic structure very similar to that of bismuth.

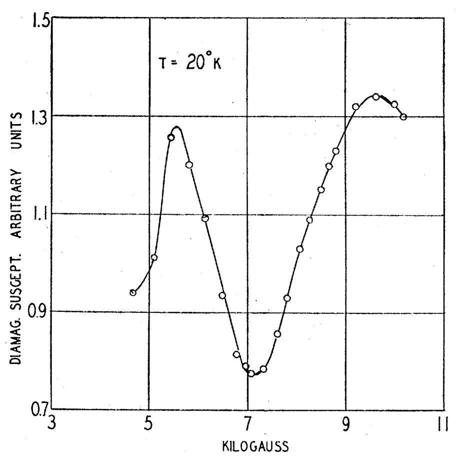

FIG. 1. Field dependence of the susceptibility parallel to the hexagonal axis of a zinc single crystal at 20°K.

In 1941 Nachimovich[4] reported an anomalous field dependence of the resistance of zinc at low temperatures. This suggested that the deHaas-van Alphen effect might occur in a single crystal of zinc since it was just such a resistance anomaly which led deHaas and van Alphen to investigate the magnetic susceptibility of bismuth.

Accordingly, the diamagnetic susceptibility of a single crystal of zinc has been measured from 20°K to 373°K in fields ranging from 4.5 to 10.5 kilogauss. It was found that at 20°K the susceptibility perpendicular to the hexagonal axis, $\chi_\perp$, is independent of the field while the susceptibility parallel to the hexagonal axis, $\chi_{\parallel}$, shows a marked field dependence. Figure 1 shows the variation of $\chi_{\parallel}$ with field strength at 20°K. At 64°K this variation was only slightly larger than the experimental error and at 79°K it was no longer detectable. Figure 2 shows the variation in susceptibility with temperature at a constant field of 8.25 kilogauss. The behavior of $\chi_\perp$ is normal, being independent of temperature below 100°K and decreasing almost linearly in numerical value from 100°K to 373°K. On the other hand, $\chi_{\parallel}$ shows anomalous behavior with pronounced maxima at

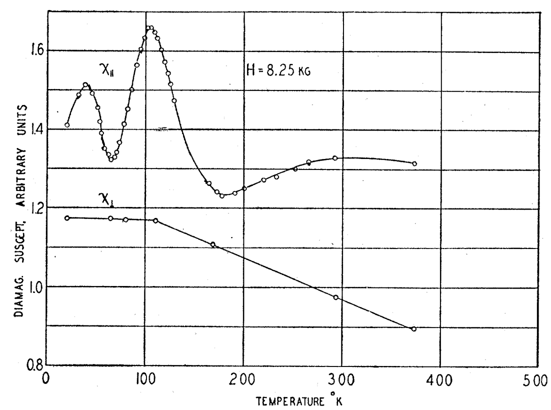

FIG. 2. Temperature variation of the susceptibility parallel and perpendicular to the hexagonal axis of a zinc single crystal at a constant field strength of 8.25 kilogauss.

approximately 40°K and 100°K and minima at 64°K and 180°K.

Considering the difference in electronic structure between zinc and bismuth and the large difference in magnitude of the susceptibility, the similarity in the field dependence for $\chi_{\parallel}$ in zinc and $\chi_\perp$ in bismuth is somewhat surprising. In relation to the absolute magnitude of the susceptibility at room temperature, the magnitude of the variation in $\chi_{\parallel}$ with field for zinc is approximately twice that of $\chi_\perp$ in bismuth, although the spacing between maxima and minima is about the same in both cases.

The temperature dependence exhibited by $\chi_{\parallel}$ for zinc does not seem to have been reported for any other metals. As the temperature variation of diamagnetism has not been worked out in detail, no comparison with theory can be made at present.

Further details of this research will be published at a later date.

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[2] D. Shoenberg, Proc. Roy. Soc. A170, 341 (1939).
[3] Blackman, Proc. Roy. Soc. A166, 1 (1938).
[4] N. M. Nachimovich, J. Physiol. 6, 111 (1941). I am indebted to Professor C. T. Lane for calling my attention to this article.