Electron Momentum Distributions in Single-Crystal Cd†

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(Received February 3, 1958)

The momentum distribution (distribution in p_z) of electrons in single-crystal Cd has been observed through measurement of the angular correlation of annihilation radiation. An anisotropy of approximately 1% was detected, the distribution along the c axis being broader than that perpendicular to the c axis.

THERE is at the present time a considerable amount of interest in determining the Fermi surfaces of various metals. The measurement of electron momentum through observation of the angular correlation of annihilation radiation is potentially valuable in such determinations. In a preliminary investigation in this direction we have made measurements on single-crystal specimens of Cd.

Cadmium has a c/a ratio which is larger than the ideal close packed ratio by about 15%. This extension of the material along the c axis results in a compression of the Brillouin zone. One would expect the Fermi surface to have, at least qualitatively, the same anisotropy. The gamma angular distribution[1] from polycrystalline Cd indicates the presence of a large broad component, presumably due to annihilations with d electrons of the atomic cores. In spite of the masking effect of the broad component, the chance of observing anisotropy in the conduction electrons was considered good, and the following experiment was performed.

Single crystals of Cd were grown from the melt, and their orientations were determined by the pin test and by Laue back reflection. Two slab-shaped specimens with 1-mm by 10-mm cross sections were cut out with an acid saw: the c axis lay in the plane of the slab in one case and perpendicular to it in the other case. Measurements were then made with the angular correlation apparatus[2] with counter openings of 2×10^{-3} radian. Coincidence counting rates were measured at counter positions ranging in steps of one milliradian up to 8 milliradians, and in steps of two milliradians from 8 to 20 milliradians on either side of a straight angle.

In a preliminary graphical comparison of the distributions, no differences could be detected. A numerical analysis of the data was therefore performed. The particular nature of the following analysis was dictated primarily by the need to minimize systematic errors.

A quantity W, which may be called a weighted first moment, was determined for each sample. The counting rates at angles 18 and 20 milliradians were averaged and treated as background; call this average n_b. The weighted moment was then determined by

$$W=\sum_\alpha|\alpha|\,(n_\alpha-n_b)/\sum_\alpha(n_\alpha-n_b);$$

$$\alpha=0,\pm1,\pm2,\pm3,\pm4,\pm5,\pm6,\pm7,\pm8,\pm10,\pm12,\pm14,\pm16,$$

where $|\alpha|$ is the absolute value of the counter displacement in milliradians, and n is the counting rate. The results for the two single-crystal specimens and for a polycrystalline specimen are as follows:

$$W_c=3.23\pm0.02,\quad W_\perp=3.19\pm0.02,\quad W_p=3.20\pm0.02.$$

Here W_c refers to the case where electron momentum along the c axis is being measured, $W_\perp$ refers to electron momentum perpendicular to the c direction, and W_p is the result for a polycrystalline sample. The weighting accentuates the effect of the central portion of the distribution, which is where the anisotropy should exist. The tabulated errors are somewhat larger than the standard deviations, and take into account various practical experimental factors.

The observed anisotropy is very small, almost within statistics. It is encouraging to note that it is in agreement, both as to sense and order of magnitude, with the results obtained by Stewart[3] in measurements on Zn and Sn. If one takes the view that compression of a system in a given direction expands its momentum distribution in that direction, the observed anisotropy is in the wrong sense. It is possible, however, that it could be accounted for in a detailed band calculation.

† This work was supported by the National Science Foundation.
[1] Lang, DeBenedetti, and Smoluchowski, Phys. Rev. **99**, 596 (1955).
[2] G. Lang and S. DeBenedetti, Phys. Rev. **108**, 914 (1957).
[3] A. T. Stewart (private communication).