transitions to occur between the valence and conduction bands. (3) Various kinds of charged debris are created by and associated with the dislocations; as in the case of the α center, some of these imperfections would be effective in lowering the energy of the transition of the neighboring ions.

The absorption coefficient on the long-wavelength side of the fundamental absorption edge was calculated according to mechanism (1) for a crystal in which the energy contours in k space for the valence band are those for a p band, while those for the conduction band are for an s band. The calculation involved a summation over all k states in the two bands which could be evaluated only by means of simplifying assumptions which restrict the validity of the results to the region near the absorption edge. The length of the tail (measured from the absorption edge toward lower energies) cannot exceed the width of that branch of the valence band which bends upward.

For a dislocation density of 10^{12} lines per cm^2, a crystal with a valence band two volts wide, an energy gap of six volts, and with 0.4 taken to be the ratio of the effective mass of an electron in the conduction band to its mass in the valence band, an absorption coefficient of 20 cm^{-1} is calculated at 1 ev from the edge. In a crystal with a valence band one volt wide, an energy gap of nine volts, and 0.2 for the effective mass ratio, an absorption coefficient of 20 cm^{-1} is reached only 0.2 ev from the edge. The displaced oscillator strength per dislocation line intersection is about 0.2 in both cases. An alternative mechanism, considered by Bardeen and co-workers,[4] for obtaining nonvertical, or forbidden electronic transitions seems much more effective than that treated here for crystals of normal lattice disorder. (In the former mechanism, the transition occurs by the simultaneous emission of absorption of a phonon in order to conserve momentum.)

The shift in the absorption edge due to mechanism (2) was estimated by adopting the Heitler-London point of view and using deformation potential theory[5] to calculate the change in the absorption edge per atom as a function of the local density. This treatment shows that most of the absorption on the long-wavlength side of the edge occurs in the immediate vicinity of the edge and does not extend beyond about 0.5 ev beyond the edge. (This figure was obtained for a maximum dilatation of 0.1 and a reasonable value of 5 ev per unit dilatation for the deformation potential constant.)

It was concluded that neither mechanism (1) nor (2) can account for the long-wavelength tail extending into the visible as observed in the silver halides. However, in a cold-worked crystal, the vacancies, incipient vacancies, clusters, and other charged products of the moving dislocations represent regions of the crystal particularly effective in modifying the fundamental absorption edge. Measurements on the effects of cold working and annealing on good single crystals would be helpful in indicating the importance of mechanism (3).

* This paper was presented at the Bristol Conference on Defects in Crystalline Solids in July, 1954, and the details of these calculations will appear in the published proceedings of this meeting.

† Research supported in part by funds from the U. S. Air Force under a contract monitored by Headquarters, Air Research and Development Command, Baltimore, Maryland.

[1] N. F. Mott and R. W. Gurney, *Electronic Processes in Ionic Crystals* (Oxford University Press, London, 1948), p. 94.
[2] F. Seitz, Revs. Modern Phys. **23**, 328 (1951).
[3] H. Fesefeldt, Z. Physik **64**, 741 (1930); H. Fesefeldt and Z. Gyulai, Göttingen Nachr. **1929**, 226.
[4] Hall, Bardeen, and Blatt, Phys. Rev. **95**, 559 (1954).
[5] J. Bardeen and W. Shockley, Phys. Rev. **80**, 72 (1950).

Structure of the Intermediate State of Superconductors*

B. Serin
Rutgers University, New Brunswick, New Jersey
(Received August 6, 1954)

We have qualitatively verified the observations of Meshkosky and Shalnikov[1,2] on the discontinuous structure of the intermediate state of superconductors. We used lead rather than tin for the sample, and employed a different technique for observing the normal and superconductive regions.

The discontinuous magnetic field changes at the normal-superconductive interfaces were detected by using commercially available magnetic recording tape.[3] After the tape was magnetized at low temperatures, the details of the magnetization were revealed by making a magnetic powder pattern[4] on the tape after it had been warmed to room temperature. A similar technique was tried without success by Shalnikov and Meshkovsky,[1] who finally used the changes in the electrical resistance of an extremely small bismuth wire to detect the discontinuous magnetic field changes.

The sample consisted of two polycrystalline lead hemispheres of 0.25-in. radius cast from Johnson-Matthey and Company lead. Each hemisphere was mounted in a Plexiglass holder, and the two holders were bolted together with the tape in between them so that flat sides of the hemispheres were pressed against the two surfaces of the magnetic tape. The tape is 0.002 in. thick. A small patch of tape was also placed in the bottom of one holder so that it pressed against the outside surface of the hemisphere in the neighborhood of the pole. A bismuth wire was mounted in one of the holders near the equator. Suitable leads were attached so that the electrical resistance of the wire could be measured, and the magnetic field at the surface of the sphere thereby determined.

The sample was cooled in liquid helium to about 1.4°K. A uniform magnetic field was then applied in a direction passing through the poles, and thus transverse to the long direction of the tape between the hemispheres. The field was increased slowly and the resistance of the bismuth wire measured. The initial penetration of the magnetic field into the sphere was

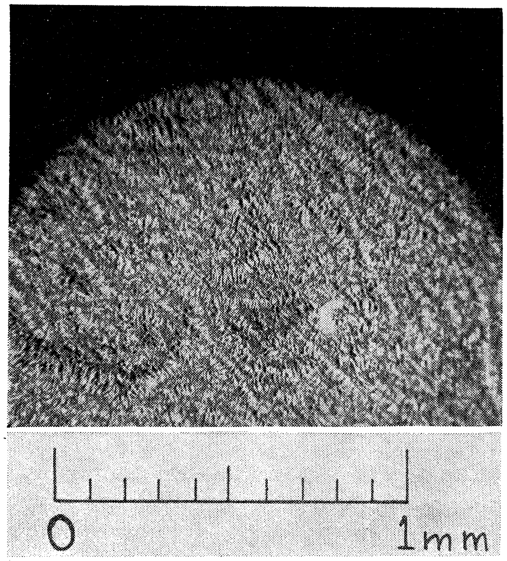

FIG. 1. Photomicrograph of powder pattern obtained on tape placed near the pole.

detected by the abrupt, large decrease in the slope of the resistance as a function of field. The field at which penetration occurs is $\frac{2}{3}$ of the threshold field value. The threshold field was thereby determined to be about 800 oersted. After initial penetration, the external field was further increased to about 0.8 of the threshold value, corresponding to a ratio of magnetic induction to critical field inside the sphere of about 0.4 The external field was then reduced to zero, and the apparatus warmed up.

Figure 1 is a photomicrograph of a powder pattern obtained on the tape placed at the pole on the outside of the hemisphere. The light areas are the magnetized regions where the iron powder has collected, and these correspond to the regions of normal phase in the sample. The pattern is complicated, but it is clear that the distances between the regions are about 0.05 mm. Similar patterns were obtained on the tape placed between the hemispheres, and qualitatively similar results were obtained with three different samples. The tape placed on the outside seems to become more strongly magnetized and thus exhibit clearer patterns, probably because the magnetic field at the outer surface has a component which lies in the tape as well as one transverse to it.

We hope that this extremely simple technique can be used to explore aspects of the intermediate state in which further investigations are needed.[5]

* This work has been supported by a joint program of the U. S. Office of Naval Research, the Rutgers University Research Council, and the Radio Corporation of America.

[1] A. Meshkovsky and A. Shalnikov, J. Phys. (U.S.S.R.) **11**, 1 (1947).

[2] For a review of the later work which is printed in Russian see D. Shoenberg, *Superconductivity* (Cambridge University Press, London, 1952), pp. 103–110.

[3] "Scotch" Brand Sound Recording Tape No. 111A, Minnesota Mining & Manufacturing Company, St. Paul, Minnesota.

[4] B. F. Murphy and H. K. Smith, Audio Engineering **33**, 12 (1949).

[5] *Note added in proof*.—Another technique, quite different from the one above, has been recently reported by Schawlow, Matthias, Lewis, and Devlin, Phys. Rev. **95**, 1344 (1954).

Magnetic Cloud Chamber Study of $V^{\pm}$ Events*

Y. B. KIM, J. R. BURWELL, R. W. HUGGETT AND R. W. THOMPSON

Department of Physics, Indiana University, Bloomington, Indiana

(Received August 16, 1954)

THE object of this note is to give a preliminary report of the $V^{\pm}$ events observed to date with the rectangular magnet chamber.[1]

The transverse momentum p_y has been measured for 31 cases[2] with an average uncertainty of ±5 percent.

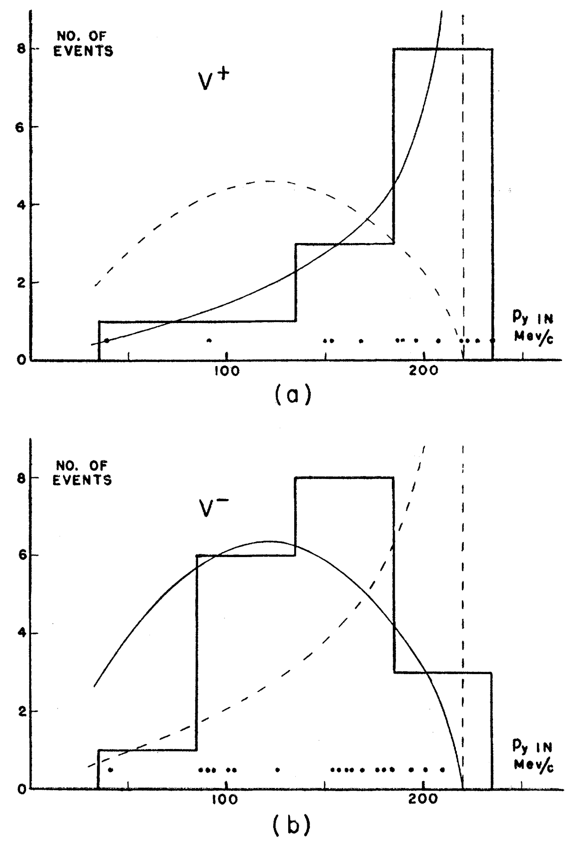

FIG. 1. The distributions of transverse momenta of $V^{\pm}$ events. The histograms give the number of events per 50-Mev/c interval. (a) is the distribution for V^{+} (13 events) and (b) for V^{-} (18 events). The values of the individual p_y's are indicated by the dots. Events with $p_y \leqslant 35$ Mev/c are omitted in order not to include possible π–μ decays. The theoretical distributions for a two-body decay (with $p'=220$ Mev/c) and for a three-body decay (with $p'_{\max}=220$ Mev/c) are shown by the solid line and by the dashed line in (a), and by the dashed line and by the solid line in (b). The average uncertainty in p_y is 5 percent and the errors are not folded into the theoretical distributions.

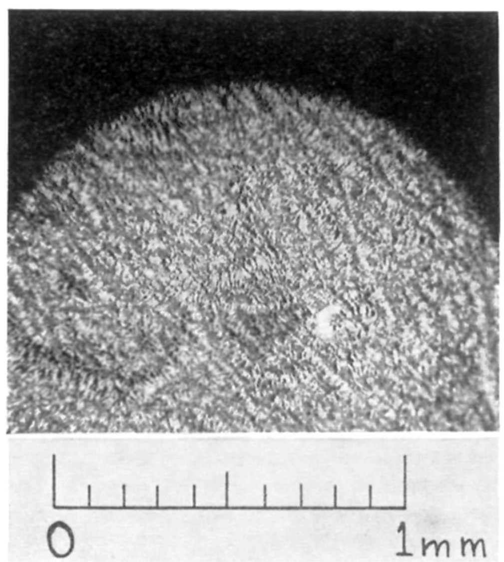

FIG. 1. Photomicrograph of powder pattern obtained on tape placed near the pole.