nearly resemble the spectral distribution shown in curve *A*. It may be noted that the relative positions of the two groups in curves *B* and *C* are about the same as that given by the results of Walker and McDaniel.

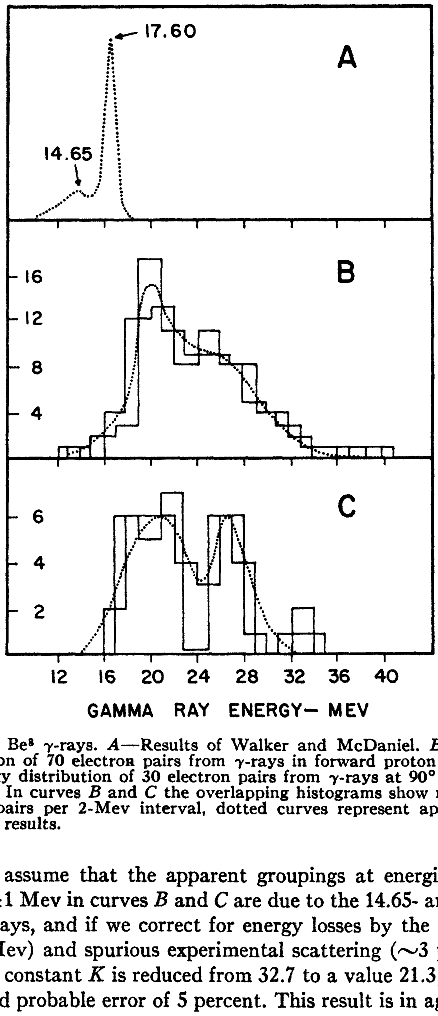

FIG. 2. Be^8 γ-rays. *A*—Results of Walker and McDaniel. *B*—Energy distribution of 70 electron pairs from γ-rays in forward proton direction. *C*—Energy distribution of 30 electron pairs from γ-rays at 90° to proton direction. In curves *B* and *C* the overlapping histograms show number of electron pairs per 2-Mev interval, dotted curves represent approximate smoothed results.

If we assume that the apparent groupings at energies 21 ± 1 and 26 ± 1 Mev in curves *B* and *C* are due to the 14.65- and 17.60-Mev γ-rays, and if we correct for energy losses by the electrons ($\sim$0.4 Mev) and spurious experimental scattering ($\sim$3 percent), then the constant K is reduced from 32.7 to a value 21.3, with an estimated probable error of 5 percent. This result is in agreement with recent measurements by Corson[9] on 115-Mev electrons.[10] Thus it would appear that energy values obtained by this scattering method using $K=32.7$ may be too high by about 35 percent.

It will be of interest to test the scattering of particles other than electrons. Further work will be done on the Be^8 electron pairs to investigate the apparent asymmetry of the spectrum and to establish the resolution of the multiple scattering method.

We are indebted to Mr. E. H. McLaren for the H.T. set irradiations and to Miss S. W. Young for searching the emulsions for electron pairs.

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[1] Camerini, Fowler, Lock, and Muirhead, Phil. Mag. **41**, 413 (1950); E. Pickup and L. Voyvodic, Phys. Rev. **80**, 89 (1950). Camerini, *et al.* used $K=32.7$ determined from a proton calibration and we used their value.

[2] P. H. Fowler, Phil. Mag. **41**, 169 (1950).

[3] E. J. Williams, Proc. Roy. Soc. **169**, 531 (1939).

[4] B. Rossi and K. Greisen, Revs. Modern Phys. **13**, 240 (1941).

[5] This was calculated using a radiation length of 2.86 cm of emulsion.

[6] R. L. Walker and B. D. McDaniel, Phys. Rev. **74**, 315 (1948).

[7] The γ-ray orientation in reference 6 was not specified.

[8] S. Devons and M. G. N. Hine, Phys. Rev. **74**, 976 (1948) observe a small asymmetry (near resonance) in the Be^8 γ-radiation and mention that observations on this asymmetry, as a function of γ-energy, indicate that the 17-Mev component is mainly responsible.

[9] D. R. Corson, Phys. Rev. **80**, 303 (1950).

[10] It is also in fair agreement with the detailed statistical theory of Williams (reference 3) as will be discussed in a subsequent note.

Electron Bombardment Induced Conductivity in Germanium Point Contact Rectifiers

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December 7, 1950

ELECTRON bombardment experiments on insulators and semiconductors using electrons in the kev range have been reported. Some of this work dealt with the currents induced in the solid by the electron beam.[1–4] This is called electron bombardment induced conductivity (EBIC). Some workers have employed α-particles of several Mev energies, and were principally interested in the corresponding current pulses in insulators or semiconductor rectifiers as crystal counters.[5,6] This is a report of preliminary experiments on the bombardment of germanium rectifiers with electrons of several kev energy.

The technique employed here involves scanning the surface of the germanium crystal with an electron beam magnetically deflected in a standard 525 line television raster. The ac component of the current flowing in the probe circuit is used as a video signal which either modulates the grid of a kinescope which is being synchronously deflected, or modulates the vertical deflection of an ordinary oscilloscope. In the first case a two dimensional plot of the EBIC is obtained which shows immediately the effects of nonhomogeneity on the surface; in the second case a quantitative measure of the diode current is obtained.

The diodes studied consisted of 2.5×2.5×0.5 mm pieces of Ge, large area heavily gold-plated base electrodes, and phosphor bronze probes inclined 45° to the Ge surface and to the beam, which strikes normally.

Figures 1a and b show the result on the kinescope of bombarding an *N*-type crystal biased in the back and forward direction respectively. The black level signal corresponds to an electron current from the probe into the Ge in the diode circuit; the white signal is the reverse. Thus the effect of the electron beam is always to increase the conductivity for both directions of bias. The sensitive region in the neighborhood of the point can be measured with accuracy by the scanning method, and a suitable scale is shown. The diameter of this sensitive region increases with increasing positive or negative bias. The size shown on the figure agrees with the rough estimate made by McKay[6] using α-particles and negative bias.

The magnitude of the EBIC effect can be seen from Fig. 2. Here δ is the ratio of the change of crystal probe current to beam current, given as a function of bias for three different beam voltages. The values plotted are maximum currents, obtained when the beam sweeps within 0.001″ of the point contact. Note that δ reaches saturation in the forward and reverse directions, but the values of δ_{sat} are not the same. Table I gives the ratio of $\delta_{-\text{sat}}$ (back direction) to $\delta_{+\text{sat}}$ (forward direction) for the beam voltages of Fig. 2. The ratio $\delta_{-\text{sat}}/\delta_{+\text{sat}}$ is constant within experimental error. Since the barrier at the contact is present in the back but not in the forward direction, $\delta_{-\text{sat}}/\delta_{+\text{sat}}$ has been tentatively interpreted as the current multiplication at the barrier, analogous to the "excess" values of α obtained in transistor experiments.[7] However, it is not yet certain whether some of this factor of 10 must be assigned to the normal current gain accompanying hole injection.

TABLE I. Saturation values of δ.

Beam voltage	$\delta_{+\text{sat}}$	$\delta_{-\text{sat}}$	$\delta_{-\text{sat}}/\delta_{+\text{sat}}$
5 kv	0.54×10^3	0.55×10^4	10.2
7.5	1.5	1.5	10.0
10	1.9	1.8	9.5

The advantage of the scanning technique in uncovering surface or subsurface effects as well as evidence for the motion of holes can be seen in Fig. 1c. The *N*-type crystal under bombardment

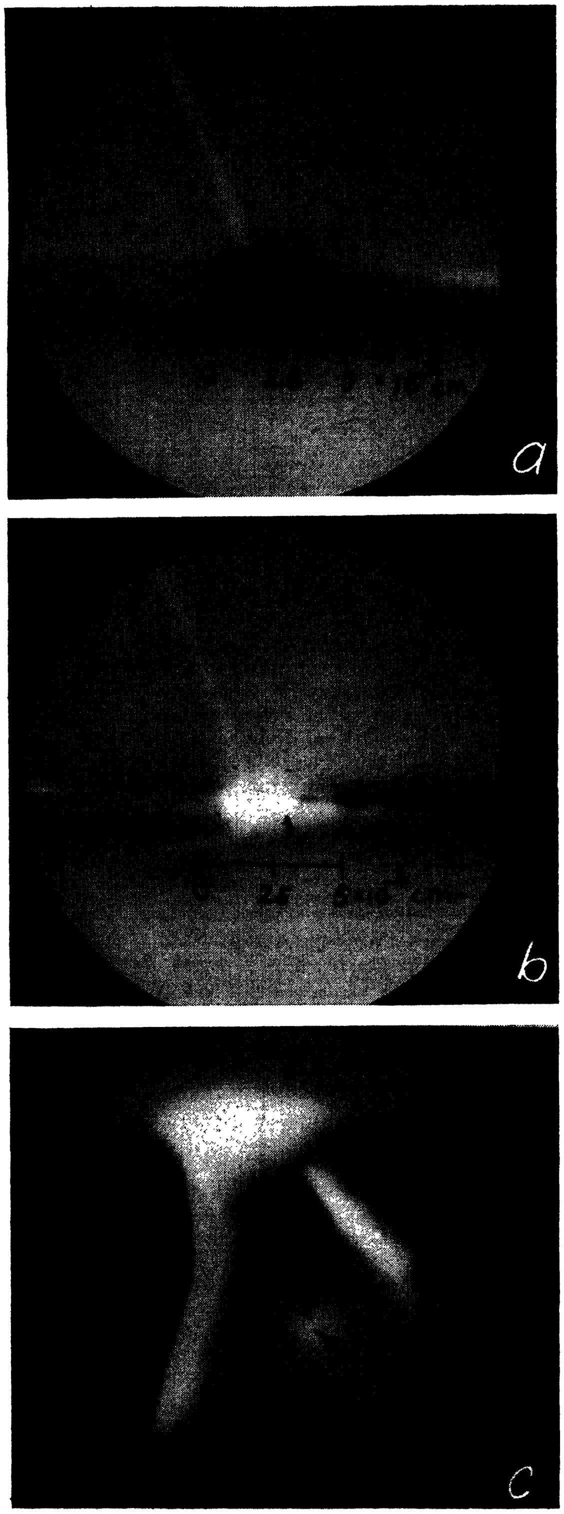

FIG. 1. Kinescope photographs of EBIC. (a) *N*-type crystal, biased −1 volt in back direction. (b) Same crystal, biased +0.2 volt in forward direction. Electron beam 10 kv for both cases. (c) *N*-type crystal, biased +0.1 volt, showing grain boundary effects. Electron beam 14 kv.

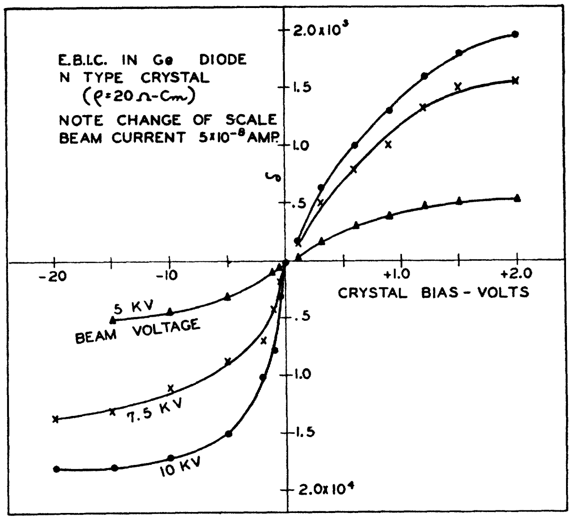

FIG. 2. Magnitude of the EBIC in *N*-type Ge *vs* crystal bias.

had a grain boundary in the shape of an obtuse angle (135°) easily visible under an optical microscope. This boundary is readily identified on the kinescope photograph, in which the crystal is biased in the forward direction and most of the applied bias appears across the spreading resistance of the bulk Ge. The arrow indicates the point contact. Note that only the edge of the grain boundary away from the point contact appears sharply defined. This is interpreted to mean that holes generated by the beam travel in the direction of the field until stopped by the grain boundary. Were electrons the current carriers, the sharp edge would be on the other side of the boundary.

In the upper right corner of the field another barrier of some sort is observed, although no grain boundary was visible under the light microscope.

Additional evidence of hole flow has been obtained by confining the scanning raster to the sensitive area around the point and then blanking the electron beam for 1 μsec during each scanning line. As successive scanning lines move away from the point contact a progressive increase in the delay time of the crystal probe signal corresponding to the blank with respect to the horizontal synchronizing pulse can be easily measured. The values are in satisfactory agreement with the delay calculated from known values of the hole mobility in Ge.

[1] E. S. Rittner, Phys. Rev. **73**, 1212 (1948).
[2] K. G. McKay, Phys. Rev. **74**, 1606 (1948).
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[6] K. G. McKay, Phys. Rev. **76**, 1537 (1949).
[7] W. Shockley, Phys. Rev. **78**, 294 (1950).

Photo-Disintegration of Copper*

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December 11, 1950

THE protons ejected from a copper foil irradiated with the bremsstrahlung from a 24-Mev betatron were observed in nuclear emulsions. In the process of determining the photo-proton energy distribution, several anomalies suggested the possibility of the presence of photo-deuterons. By grain counting the end of the tracks, it was possible to differentiate deuterons from protons and a considerable number of deuterons were found. Using this identification, the energy, angular distribution and relative numbers of protons, deuterons, and also alpha-particles were

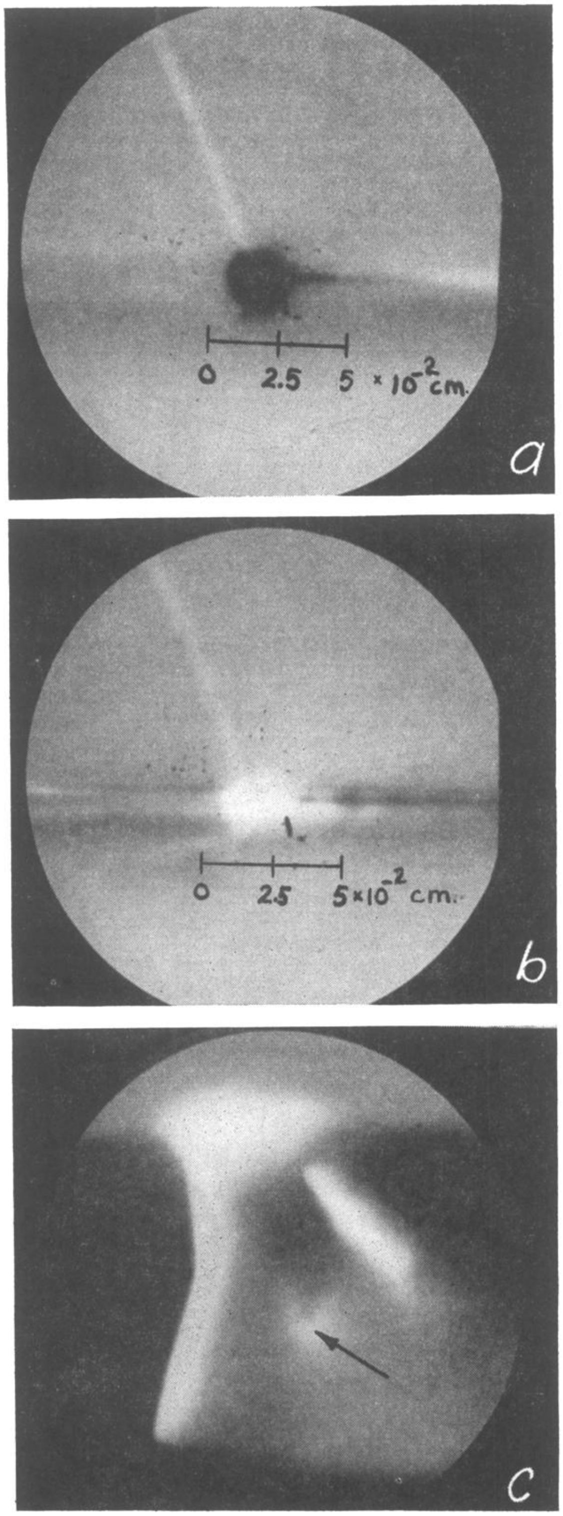

FIG. 1. Kinescope photographs of EBIC. (a) *N*-type crystal, biased −1 volt in back direction. (b) Same crystal, biased +0.2 volt in forward direction. Electron beam 10 kv for both cases. (c) *N*-type crystal, biased +0.1 volt, showing grain boundary effects. Electron beam 14 kv.