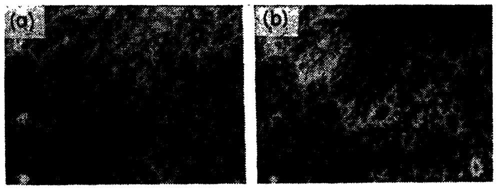

FIG. 2. Polarized light patterns showing change of domains in cobalt single crystal in response to a magnetic field. (a) Lower field. (b) Higher field.

of the magnetization at the reflecting surface. Thus, the rotation introduced by all the domains of like polarity can be compensated by a clockwise rotation of the compensator, for example, while those of the reverse polarity require a counter-clockwise rotation. Compare (a) and (b) in Fig. 1 of an electro-polished surface of a single cobalt crystal, approximately normal to the c axis. If the compensator is set to introduce no rotation, no distinction between the two sets of domains is observed [Fig. 1(c)], since the light intensity from each is dependent only on the amount of rotation of the plane of polarization and not on the sense of the rotation.

No magnetic field was applied when the pictures in Fig. 1(a), (b), and (c) were taken. However, when a magnetic field is applied, the patterns change with the field, as in Fig. 2(a) and (b), which were obtained for different values of a field applied normal to the surface. In Fig. 3, (a) and (b) show the effect of varying the applied field on a polycrystalline cobalt specimen which exhibits a different type of pattern. Figure 3(c) is a powder pattern[3] obtained with colloidal magnetite on the same surface at a later time. Slight changes in the domain structure may have occurred prior to this photograph.

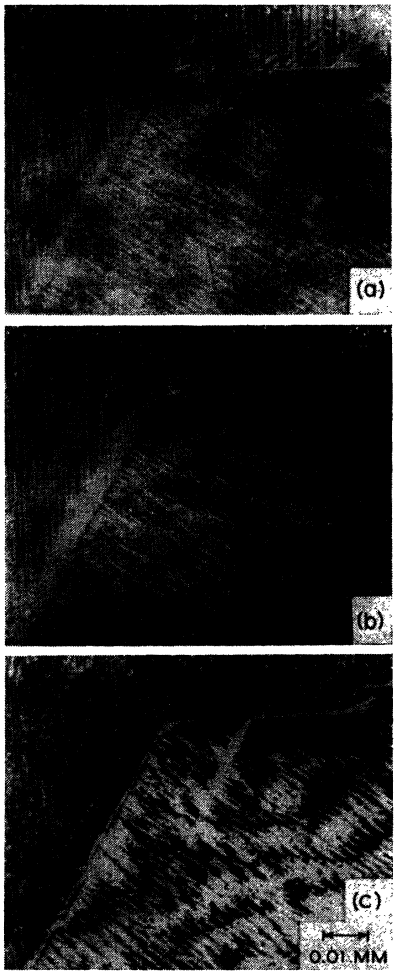

FIG. 3. Domains in polycrystalline cobalt. (a) and (b) Polarized light patterns showing change of domains in response to a magnetic field. (a) Lower field. (b) Higher field. (c) Pattern obtained with colloidal magnetite on the same region (dark field illumination).

A pattern like that shown in Fig. 1(a), though hardly visible, has also been observed by the authors with a Zeiss neophot type of metallographic microscope equipped with separate polarizer and analyzer. Photographs of the pattern were obtained with this equipment in collaboration with E. E. Thomas.

It should be mentioned that although it is comparatively easy to obtain photographs of polarized light patterns which have good contrast and show the details clearly, visual observation is difficult because of the very low intensity of the light and lack of contrast.

We are indebted to W. Shockley and C. Kittel for suggestions and discussions, and to J. Benford and Colin Alexander of the Bausch and Lomb Optical Company for making available to us their optical compensator so that we might explore its potentialities for work of this type.

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[2] L. V. Foster, J. Opt. Soc. Am. **28**, 124 (1938).
[3] Williams, Bozorth, and Shockley, Phys. Rev. **75**, 155 (1949).

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p—*n* Junction Rectifier and Photo-Cell

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THIS note[1] discusses briefly the electrical characteristics of two semiconductor devices made from $p-n$ junctions in single-crystal germanium by a process described by Teal, Sparks, and Buehler.[2] The two devices are quite similar in construction but differ widely in application.

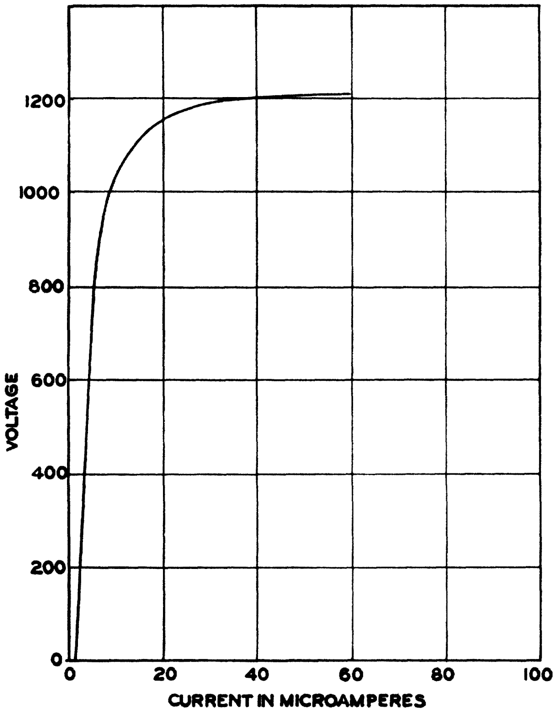

FIG. 1. $p-n$ junction rectifier reverse characteristic.

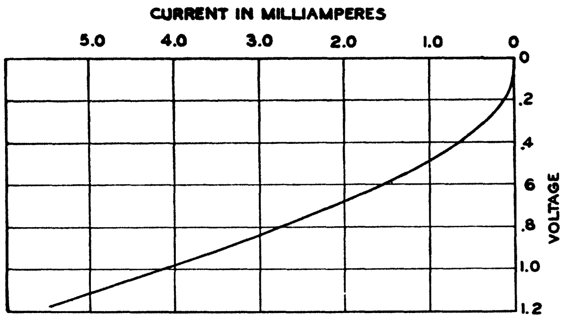

FIG. 2. $p-n$ junction rectifier forward characteristic.

The first of these is a $p-n$ junction rectifier. A typical reverse voltage-current characteristic is shown in Fig. 1, where one notes that the rectifier retains its high impedance to well over 1000 volts. From the static curve one can see that the dc resistance at 1000 volts is 117 megohms. The forward characteristic of the same unit is plotted in Fig. 2 on a much expanded scale. The curve shows the dc resistance at one volt to be 237 ohms, or an impedance ratio at 1000 volts reverse to 1 volt forward of 500,000:1. These characteristics were taken at 25°C, and the saturation current increases by about a factor of ten for an increase in temperature to 60°C. The frequency response of the rectifier makes it usable over and slightly above the audio range. Used in a rectification circuit feeding into a 50,000-ohm load in parallel with a 0.5-$\mu\mu$f condenser, the dc voltage output was down 3 db at 200 kc. The size of the unit described was roughly 0.4 cm in length with a cross section of 0.0025 cm². The $p-n$ junction lies perpendicular to the long dimension of the bar of germanium, and electrical contacts are made to each end. This junction differs from that reported by Dunlap[3] in method of preparation and in having higher reverse voltage.

The second device to be described here is a photo-cell which uses the photo-sensitivity of a $p-n$ junction. Figure 3 shows the characteristic curves of the cell as a function of light intensity. The $p-n$ junction responds to light of wavelengths up to $\lambda=1.9$ microns with a quantum efficiency of unity.[4] The sensitivity to a light source of 2900°K color temperature is about 0.01 ma/mlu. As can be seen, the dark impedance of the device is the order of megohms. If the junction is used with a load impedance of one megohm, a drop of 100 volts may be obtained with a hundredth of a lumen light flux. A $p-n$ junction with this flux incident on it is adequate to drive cold cathode gas triodes directly.

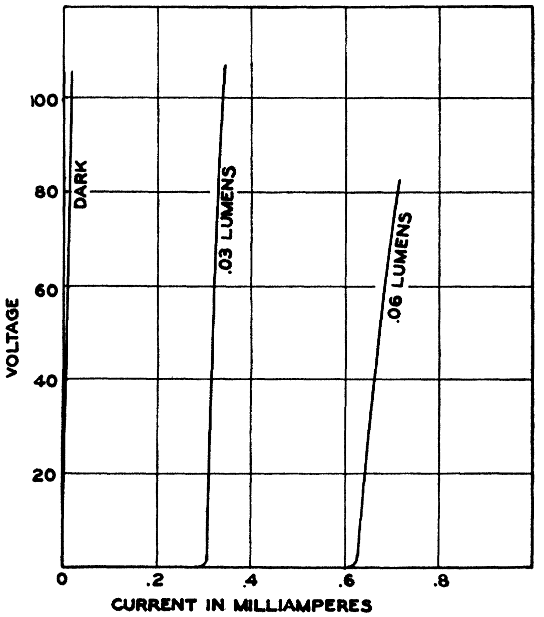

FIG. 3. $p-n$ junction photo-cell static characteristics.

The characteristics of both the $p-n$ junction rectifier and photo-cell described here are in agreement with the theory[5] of diffusion of current carriers to and from the junction discussed by Goucher *et al.*

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[1] Substantially, this material was presented orally by the author at the I.R.E. conference, Ann Arbor, Michigan, June 23, 1950.

[2] Teal, Sparks, and Buehler, Phys. Rev. **81**, 637 (1951).

[3] R. N. Hall and W. C. Dunlap, Phys. Rev. **80**, 467 (1950).

[4] F. S. Goucher, Phys. Rev. **78**, 816 (1950).

[5] F. S. Goucher *et al.*, Phys. Rev. **81**, 637 (1951). W. Shockley, Bell Sys. Tech. J. **28**, 435 (1949).

Scintillation Spectrum from Cosmic Rays at 30,000 Feet*

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THE cosmic-ray scintillation pulse distribution in anthracene has been obtained during experiments conducted in the decontaminated waist section of a B-29 circling at 30,000 feet and 50°N latitude (geomagnetic). The aircraft completed a 360° turn every five minutes, insuring that local absorption and azimuthal variations were averaged. The detector, enclosed in a housing of $\frac{1}{8}$-inch brass and $\frac{1}{16}$-inch Mumetal, was a $\frac{1}{2}\times\frac{1}{2}\times 1$ inch anthracene crystal viewed by a 5819 photo-multiplier operating at 900 volts. Pulses from the detector were fed to a cathode-ray tube differential analyzer[1] set for low resolution because of the low counting rate and short time available. Space limitations prevented the use of a multiple-channel analyzer.

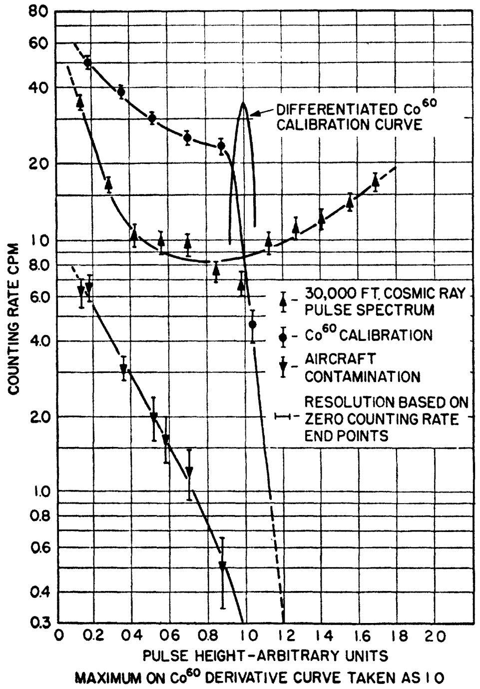

FIG. 1. Scintillation pulse distributions.