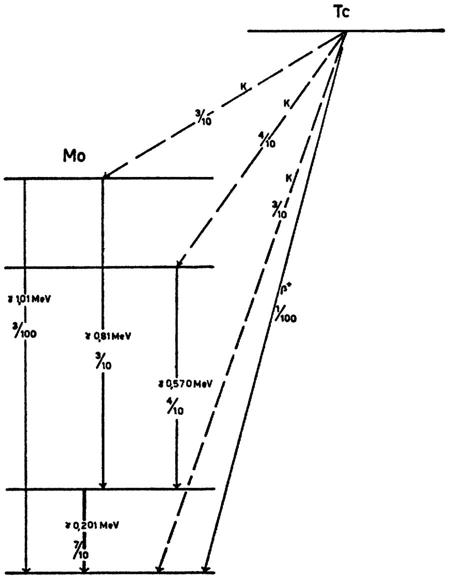

FIG. 1. Decay scheme of the 62-day Tc.

with the number of conversion electrons arising from the 201-kev radiation, as well as from the annihilation coincidence counting rate, we estimate that about 0.8 percent of the transitions take place by positron emission. The intensity ratios of x-rays and γ-rays show that one third of the electron capture transitions lead directly to the ground level. Summarizing these measurements, we propose a term scheme according to Fig. 1.

A detailed report will appear in Helv. Phys. Acta. We take pleasure in thanking Professor P. Scherrer for his stimulating interest in this work.

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Use of Photo-Conductive Semiconductors as Amplifiers

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March 29, 1948

RECENT studies[1] at the Bell Telephone Laboratories have revealed that diamond may be employed as an electron amplifier by virtue of its internal secondary emission. Current amplification factors as high as 500 have been observed by exposure to electrons of 15,000-ev energy. Because of deleterious space charge effects produced by the impingement of electrons on the insulator and by electrons trapped at imperfections in the crystal, the experiments were performed with a pulsed beam technique and with an alternating field across the sample.

There are several extremely important advantages to be derived from the employment of a photo-conductive semiconductor rather than an insulator in this application:

(1) the above-mentioned space charge effects which oppose the flow of current through the specimen in the case of insulators will be absent in the case of semiconductors;

(2) the number of internal secondary electrons released per incident primary electron will be proportional to the quotient (energy of primary electrons/energy gap between filled band and conduction band); this quotient will be greater in the case of semiconductors by a factor of the order of 5 to 10;

(3) in analogy with the secondary photo-effect, the total number of electrons flowing through the semiconductor circuit will, in most cases, far exceed the number of electrons internally released by the bombarding electrons;[2]

(4) the loss of electrons via external secondary emission will be less in the case of semiconductors;[3]

(5) the impedance of the semiconductor device will be of a more suitable magnitude for use in conjunction with usual electronic circuits, the "dark" current being entirely analogous to the no-signal plate current in a vacuum tube amplifier.

Optimum results will probably be achieved with thin specimens of the same order of thickness as the penetration depth of the primary electron beam. Single crystals, in general, present the advantage of extremely high charge carrier mobility relative to polycrystalline samples, although even the latter can be employed to great advantage.

The amplification factor will be proportional not only to the charge carrier mobility and the energy of the incident electrons but also to the field strength applied to the sample, limitations being imposed by the total power input, which will cause heating of the specimen. Care should be exercised to prevent the deflection of the incident beam to an electrode of the sample. For low primary beam intensities the increase in current through the semiconductor on bombardment will be a linear function of the beam intensity.

The main disadvantage of this type of amplifier is the fact that highest amplification factors can be obtained only at a sacrifice in frequency response.[4] The frequency response can be improved with an attendant reduction in amplification factor by exposure of the sample to steady background illumination, by raising the temperature of the sample, or by incorporation of the proper impurities into the photo-conductive layer.

Preliminary experiments have been carried out with a thin polycrystalline layer of selenium deposited on a glass base furnished with two tungsten wire electrodes 5 mm apart. Selenium was chosen because of the ease with which it can be fashioned into a photo-conductive cell. The data are shown in Table I.

These results are subject to improvement by factors of one or more orders of magnitude by changes in the geometry of the electrode configuration and in the tech-

Table I. Increased conductivity in selenium induced by electron bombardment.

D.c. voltage across photo-conductor	Electron accelerating voltage	Beam current, μa	Increase in current through photo-conductor, μa	Amplification factor
225	1000	0.015	0.95	63
225	2000	0.015	1.85	123

Notes
Sample resistance $=1.12\times 10^9\Omega$.
Cross-sectional diameter of primary beam $\cong$1 mm.

nique of preparing the photosensitive layer. Still further improvement of similar magnitude is possible by reverting to thin single crystals.

Further work on selenium as well as on other photoconductive semiconductors such as silicon, germanium, and lead sulfide is in progress.

The author wishes gratefully to acknowledge his indebtedness to various members of the staff of Philips Laboratories, Inc., particularly to G. A. Espersen for making available the equipment employed in making the measurements, to M. J. Lun for assistance in the measurements, and to R. H. Ahlert for aid in preparing the photoconductive layer.

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[2] A. von Hippel and E. S. Rittner, J. Chem. Phys. 14, 372, 373, 375 (1946).

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Ultrasonic Observation of Twinning in Tin

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At the suggestion of the last named writer some experiments have been performed with a view to observing the effects of individual moving dislocations. If a dislocation moves across a test specimen with a speed approaching that of sound, a displacement of the order of the lattice constant d should occur in a time of order of diameter of specimen divided by the speed of sound. This requires instruments capable of measuring displacements of about 10^{-8} cm occurring in times of 10^{-6} sec., values which lie in ranges already exploited in connection with ultrasonic delay lines.

The method of experimentation consists of pressing the metal specimen directly against a quartz crystal with a liquid seal, applying stresses which deform the metal, and observing the resulting motion imparted to the quartz. The mechanical arrangement giving the most satisfactory results is shown in Fig. 1. The tin specimen is prepared from 99.9 percent pure tin. The crystal grain size is about $\frac{1}{16}$ in. The specimen (a cone tapering from $\frac{1}{8}$-in. to $\frac{1}{16}$-in. diameter) presses against the quartz crystal on the right, and on the left is soldered to a silver paste baked on the tip of a long tapered glass rod. The quartz crystal (0.5 mm thick and $\frac{1}{8}$-in. diameter) is similarly attached to the other glass rod. The two glass rods are lined up in a V block and pressure is applied by a screw through a rubber pad. During the time of observation (described below) the ultrasonic disturbance does not have time to reach the ends of the glass rods; furthermore, the transient pressure wave developed on the quartz is less than 1 percent of the applied load. As a consequence of these facts, the deformation takes place essentially at constant load. Increasing the applied load by turning the screw provokes additional transient yielding. The tapering of the rods tends to eliminate transverse reflections.

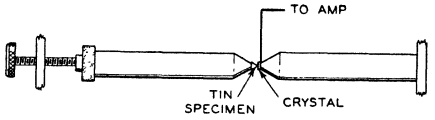

Fig. 1.

The voltage generated by the quartz crystal is amplified and split into two parts; one part actuates the trigger of a sweep circuit while the other is delayed 15 microseconds by a fused quartz delay line and then applied to vertical plates of the oscilloscope. Various electrical and mechanical tests indicate that crystal plus electrical circuits have an adequate band width for the effects studied. The sensitivity is such that a force of 1000 dynes gives $\frac{3}{8}$-in. deflection on the oscilloscope. Because of the nature of the mechanical impedances on either side of the specimen, voltages are proportional to velocity of yield with 1000 dynes corresponding to a rate of yield of 1.6×10^{-2} cm/sec. over the $\frac{1}{16}$-in. face of the tin specimen.

Observation of the voltage output on fast and slow sweeps shows that the noise generated consists of pulses lasting about 30 microseconds. Pantograph tracings of the photographs of two such pulses are shown in Fig. 2, together with a calibrating timing wave. Out of 15 photographs taken, 11 were similar to (a) and 4 to (b). The fine structure is not the same on any two traces, which suggests that it is characteristic of the twinning process rather than of some mechanical resonance in the specimen. The distance moved in one cycle of the fine structure is about 2A for (a) and about $\frac{1}{2}$A for (b). The period of the fine structure corresponds to 3 microseconds for (a) and 1 microsecond for (b), and the time for a compression sound wave to cross the specimen is 1 microsecond.

These results are in general agreement with passage at the speed of sound of twinning dislocations from side

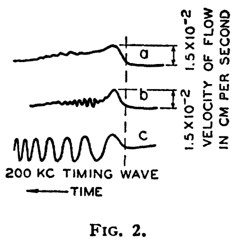

Fig. 2.