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.

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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.

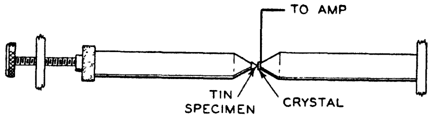

FIG. 1.

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

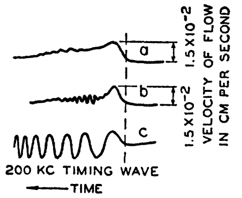

FIG. 2.

to side in the specimen. However, the magnitude of the displacement is about ten times larger than would be expected from the twinning of one pair of planes. The net volume contraction of the tin as viewed from the quartz is about 10^{-8} cm^3.

Somewhat similar experiments carried out with large aluminum crystals failed to give detectable signals.

On the Mechanism of Electron Emission at the Cathode Spot of an Arc

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THE experiments of Smith[1] on the thickness of the mercury arc cathode dark space show that the hypothesis of field emission fails to account for the high current densities (10^4 amp./cm^2) observed at the cathode spot.

The fact that the arc can be extinguished by a current interruption of less than 10^{-8} second,[2] together with evidence indicating a low cathode temperature even at the arc spot itself, shows that thermionic emission is also inadequate.

Smith's[3] theory ascribing the high current density to thermal excitation of the conduction electrons runs into the following difficulty, which applies to thermionic emission as well. Taking the diameter of an arc spot as 10^{-2} cm, the velocity of the spot in a magnetic field as 10^4 cm/sec.[3,4] the arc current as 1 ampere, and the cathode fall as 10 volts, we see that the cathode spot must be excited to full emission in 10^{-6} second by an energy of only 10^{-5} watt second. Furthermore, it is hard to conceive of any plausible mechanism for preventing the "hot" electrons in the cathode spot from losing their energy by interacting with other conduction electrons and even with the atoms of the cathode.

The hypothesis that the entire current is carried by positive ions[5] runs into difficulties such as communicating too much momentum to the cathode, accounting for the high temperature, and inability to explain why an interruption of less than 10^{-8} second should extinguish the arc.

A new theory is proposed that is applicable to the class of arcs characterized by relatively low spot temperature and relatively high spot mobility, e.g., liquid cathodes, Cu, Ag, Au, Fe, Ni. The mechanism may play a partial role in other cases as well. It is assumed that a region possibly 10^{-5} cm thick of very dense metallic vapor exists immediately adjacent the cathode spot. The high density perturbs the atomic fields so that the normally sharp energy levels are spread into bands, including conduction bands. Metallic conduction is then possible from the cathode to this region, which is at a sufficiently high temperature to emit thermionically into the plasma. The ions bombarding the cathode serve to maintain the high local density.

From the work of Birch[6] on the conductivity of Hg in the supercritical region, it appears that a particle density N equal to 10^{22} atoms per cc gives essentially metallic conduction. Consider the arc spot. If n atoms leave it per cm^2 per sec. with a velocity distribution $f(c)$, the particle density in a layer of thickness d outside it is given by

$$p=(1/d)n\int_0^\infty f(c)(\alpha/c)dc=n\int_0^\infty f(c)(dc/c)=N=10^{22}, \text{ say.}$$

To estimate n, we recall a current density of 10^4 amp./cm^2, about 10 percent of which is carried by ions, giving 6×10^{21} ions/cm^2/sec. bombarding the Hg arc spot. This is about ten times the net "evaporative" loss, so somewhat more than this number of atoms leave the cathode. The coefficient of accommodation is probably small, so many of them leave with large velocities giving small contributions to the integral. For want of a better choice at this time, we describe the low velocity fraction by a Maxwellian distribution corresponding to an effective temperature T. We have

$$p=\left[4n\Big/\left(\frac{\pi 2kT}{m}\right)^{\frac{1}{2}}\right]\int_0^\infty xe^{-x^2}dx=N,$$

whence

$$n/(T)^{\frac{1}{2}}\simeq 10^{-4}\ N.$$

Taking $N=10^{22}$, $n=10^{19}$ gives $T=100°K$, $n=10^{20}$ gives $T=10^4$. In view of experimental uncertainties, this can be considered satisfactory.

Additional evidence in favor of the conduction theory is afforded by Smith's[1] observation that a continuous spectrum originates within 10^{-3} cm from the cathode surface. As is well known, continuous spectra can be obtained from high pressure Hg lamps.

Mierdel's[2] work gives an independent estimate of the thickness of the dense region. If the arc conduction atoms are leaving with velocities of 10^4 or 10^5 cm per Mc and the source is cut off for 10^{-8} or 10^{-9} second, they can move 10^{-4} or 10^{-5} cm in this time. The fact that this extinguishes the arc indicates that the dense region is somewhere near this thickness or less.

A more detailed paper working out various refinements and consequences of the theory is in preparation.

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Hyperfine Structure in the Spectrum of Np^{237} *

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IN the course of numerous routine spectrographic analyses of very small samples of Np^{237} it was observed that many of the neptunium lines appeared very broad, even under moderate dispersion (5A/mm), suggesting the presence of wide hyperfine structure.[1] The widest neptunium line in the region investigated, at 3829.15A, was then photographed by use of the third order of a Baird