roundabout route to understanding

By F. C. Brown

IN 1905 the author became interested in selenium cells because of the unusual challenge to understanding which they presented. One of the best-known selenium cells of that time was the Giltay Cell —a thin soapstone plate around which two parallel wires were wound, with selenium melted and crystallized between the wire electrodes. There were other types, but all had the same remarkable capacity to increase in electrical conductivity when exposed to light. By comparison, a metal, such as a blackened platinum foil, decreased in conductivity when exposed to light. Because of the light sensitivity, selenium cells had proved useful in several kinds of machines and instruments; for example, in the Optiphone and phonopticon, which could enable the blind to read the printed page.

During the ensuing three years, the author conducted many experiments with selenium cells—measurements of the light of the moon in its different phases, made jointly with Joel Stebbins, and a comparison of the effects of the three forms of radiation emitted by radium, using a sample of radium loaned by E. Rutherford. Nevertheless, understanding the photo effect itself eluded the author not only during these experiments but through subsequent studies for a period of nearly forty years.

After an interruption of several years the study was taken up again, this time stemming from the author's determination that the effect of the light to which the selenium was exposed penetrated much more deeply than did the light itself. To corroborate this assumption, single needle-like crystals of selenium, slightly more than a centimeter in length, were grown. One end of these crystals was clamped between small metal electrodes. When the crystal was illuminated at any point, the effect was almost as great as when illuminated between the electrodes. Moreover, the wavelength sensibility curves were almost identical whether the illumination was on the electrodes or at some other point on the crystal. These phenomena were reported as the transmitted effect of light in selenium, and in one publication under the title "Action at a Distance". But such words did not explain the effect, they merely described it. How and why the effect existed remained a mystery.

World War I called, and the interval between the two wars passed without further experiments being made. Then, during World War II, while the author was assigned to the Radiation Laboratory at the Massachusetts Institute of Technology, a particularly good opportunity to work again on the problem presented itself. This came about because the laboratory possessed silicon crystals that were 5 centimeters in length, and, like selenium, were photosensitive. Furthermore, they showed the transmitted effect. Electrodes were placed across one end of a silicon crystal, and narrow bands of light illuminated the crystal between the electrodes and at another point on the crystal simultaneously. Using an MIT oscilloscope, which could measure even a fraction of a millisecond, the determination was made that the effect was transmitted at the speed of sound in silicon.

Next, a blackened metal plate was connected to the silicon, and it was illuminated without any light falling on the crystal. The effect was then as great as when the light had fallen on the crystal. Thus it seemed clear that the "action at a distance" was a heating phenomenon caused by the absorption of light by the crystal from the black metal plate. In other words, the so-called photo effect in selenium and silicon was actually a heat effect.

As a further test, the silicon at the electrodes was coated with an opaque insulating wax. When this was illuminated, the effect was observed to be even greater than when the light fell on the silicon, because the silicon reflected some of the radiation. This fact indicated that photo-sensitive devices can be more useful if they have a covering of selective absorption.

It has often occurred to me that the problem of the transmitted effect in selenium might have been solved in the matter of a few days or weeks—rather than the several decades that were actually taken—had an investigator been able to combine his interest and curiosity with the proper materials and facilities for experimentation. For me, both existed, but not in combination until a long period of time had passed. Chance then brought them together, permitting the problem to be solved. However, the tardiness of the discovery did not lessen the satisfaction that comes with understanding, particularly when such understanding can be useful to others. The following illustrates this point.

At the time the silicon experiments were under way at MIT, an investigator at the Bell Telephone Laboratories, who was also working with selenium, obtained results from his experiments which appeared to negate the so-called transmitted effect. The director of Bell Laboratories, O. E. Buckley, advised him to confer with the author in Cambridge. Soon after doing so, he reviewed his laboratory experiment and found that his setup permitted the heat from illumination to be dissipated into a conducting metal plate so that the temperature at the electrodes was not altered.

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