Sensitizing the photocell

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THE photo-electric effect was discovered shortly before 1890 by the director of the Physical Institute of the Dresden Technical High School, Wilhelm Hallwachs, who died in 1922. However, neither the discoverer himself nor the interested scientists had any idea that research, technical, and applied physics least of all industry as a whole had through this discovery been given the foundation for a device of almost numberless applications.

It has been determined that every material is sensitive to light regardless of the state of the material, whether it be a gas, a liquid, or a solid. It may be an electrical conductor or an insulator. It is only necessary to know which wavelength the light must have in order to release the electrons. Gaseous substances emit when subjected to X-rays. Fluids must be exposed to the very short wavelengths of ultra-violet light with a maximum wavelength of 180 milli-microns in order that electrons are released. Solids, especially metals, will emit under the influence of ordinary ultra-violet light. The upper limit of wavelength at which solids are still light-sensitive is about 300 milli-microns. In only a few cases is this upper limit exceeded so as to include the visible and infra-red spectrum. To these exceptions belong the alkali metals: sodium, potassium, rubidium, caesium, and lithium. These alkali metals can be extremely sensitive in the visible spectrum. Besides, their upper limit of sensitivity sometimes reaches far into the infra-red.

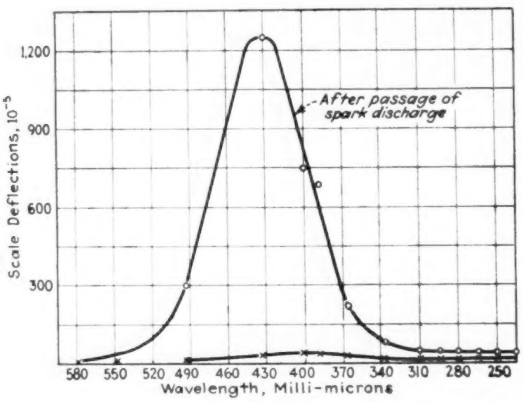

Fig. 1—Sensitivity changes of compact potassium surface

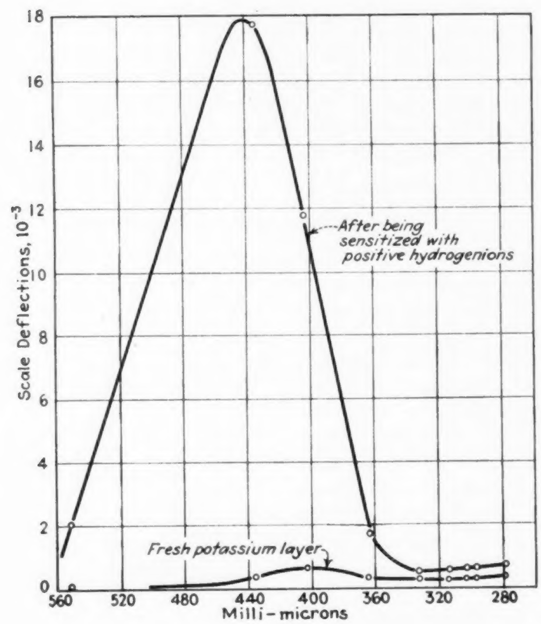

Fig. 2—Sensitization of fresh potassium layer after being loaded with positive ions. The increase in sensitivity is apparent

As practically applied the photo-electric effect represents nothing more than a variable resistance in the space between the cathode and the anode.

By merely placing a "collector" plate opposite the light-sensitive plate we have the simplest form of photo-electric apparatus. Since the effect is largely dependent upon the nature and pressure of the surrounding gas and the density of the adsorbed and absorbed gas, the light-sensitive system is incorporated in a vacuum tube. The characteristics of the gas may thus be controlled and the troublesome effects of these three factors may be greatly minimized.

Photo-electric cell properties

Two of the natural properties of the photo-electric effect are most important in determining its applications.

First is the practically instantaneous flow of electrons when light strikes the metal surface. The electronic current reaches maximum as soon as light strikes the cathode; the electronic current ceases to flow when the light is cut off. The speed with which the cell acts is limited by the time required by the electrons to pass through the space between the cathode and the anode.

The second important property is the simple relation between the applied light intensity and the resulting electronic current. The latter increases in proportion to the intensity of the applied light.

This linear dependence signifies particularly the ease with which the photo-electric effect may be applied to photometry. The following are given as examples:

Translated from the German by C. W. Loeber.

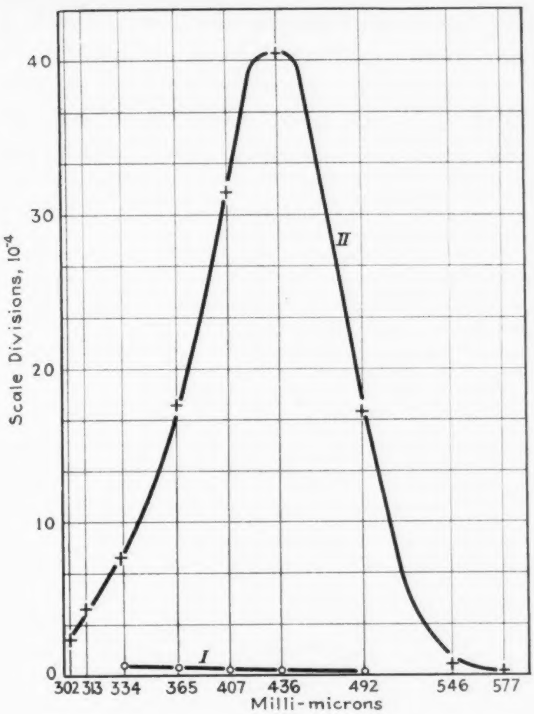

Fig. 3—Lower curve—potassium surface supersaturated with hydrogen. Upper curve—same surface after vaporization with fresh potassium layer

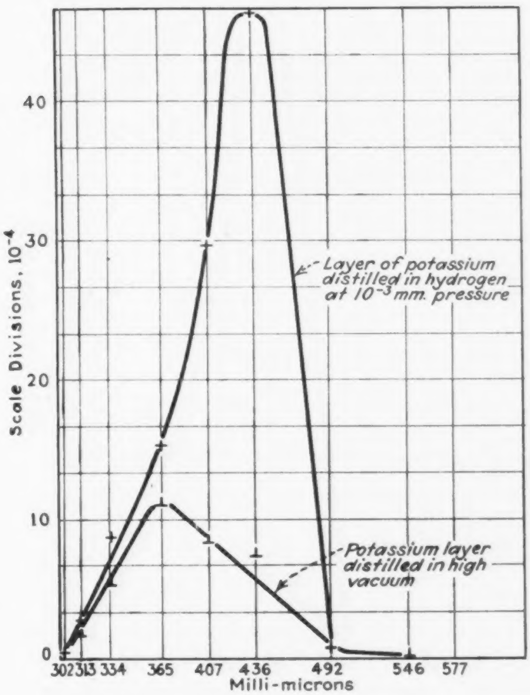

Fig. 4—Effect of sensitizing potassium layer in an atmosphere of hydrogen under a pressure of 10^{-3} mm. of mercury

measurement of the light intensity of stars, measurement of the light intensity of the heavens by day and by night, solar measurements, measurements of absorption, etc.

This sensitivity is important where for the various applications different values of sensitivity are required. The sensitivity of a cell used for solar measurements need not be as great as that of a cell used to make measurements of the heavens at night.

Aside from these two characteristics of the photo-electric effect two more demands are made upon the photocell in order that it may be a useful aid to research and technical science. These are the sensitivity of the cell in the visible spectrum of light and the constancy of the cell.

Sensitivity and constancy

Concerning the first requirements, nature has aided greatly by providing the alkali metals. These are sufficiently sensitive for short wavelength red, the visible spectrum, and long wavelength ultra-violet. The normal sensitivity of an alkali cell is generally sufficiently great for measurements in pure research when sensitive instruments are used (quadrant electrometer, reflecting galvanometer) or less sensitive instruments with one or more vacuum tube amplifiers.

The constancy of the cell depends mainly upon the condition of equilibrium between the gas and the photo-electrically sensitive metal, since it is recognized that the sensitivity is strongly dependent upon the nature and the pressure of the residual gas in the cell and the density of the gas which is adsorbed and absorbed by the metal. In addition, the constancy is also affected greatly by its insulation and by the formation of charges on the walls of the cell which give rise to field distortion. However, insulation difficulties and stray charges may be avoided by proper construction of the cell.

The four requirements mentioned above—instantaneous response, the linear relation between light intensity, sensitivity in the visible spectrum, and constancy—are of equal importance in the application of the photo-electric cell for research and technical purposes.

If a greater degree of sensitivity is required, it is necessary to employ a sensitizing process.

The process of sensitizing which is generally employed is that described by Elster and Geitel in 1910 (Phys. Z. 11,257, 1910). A spark discharge is produced in an alkali cell which is filled with hydrogen or some inert gas under low pressure. An increase in sensitivity is produced, as shown in Fig. 1. (Suhrmann and Theissing. Z. f. Phys., 52,453, 1928.)

The surface of the alkali cathode becomes discolored during the discharge. Hallwachs called this discolored, light-sensitive gas-metal surface colloidal alkali metal. It is seen from this designation that neither the condition of this more or less loose combination between the alkali metal and the gas nor the combination itself was clearly described.

It was Suhrmann who undertook this last problem again—the combination between the alkali metal and the gas. He established the fact that the great photo-electric sensitivity of potassium and especially the selective maximum at 436.8 milli-microns is caused by the presence of positive hydrogen ions. Figure 2 shows, according to Suhrmann, (Phys. Z. 29,811, 1928), the increase in photo-electric sensitivity of a potassium layer covered with hydrogen ions.

It is to be noted that when sensitizing by means of a

[*continued on page 530*]

Sensitizing the photocell

[continued from page 519]

spark discharge, first, the potassium is atomized, and secondly, the success of the process is dependent upon the gas pressure in the cell. The first observation indicates that during the sensitizing process potassium is present in the form of a vapor. The dependence upon gas pressure varies in the following manner: the simultaneous increase in sensitivity with the spark discharge occurs only when the pressure is approximately 0.1 mm. of mercury. If the gas pressure is about ten times less or still lower there will be no increase in sensitivity caused by the spark discharge. On the contrary, the sensitivity may be reduced. Only when a small drop of potassium is vaporized in any part of the cell will an increase in sensitivity take place. Several examples of this are given in the following table (R. Fleischer, Phys. Z. 30,320, 1929).

PHOTO-ELECTRIC CURRENT

Cell	Before Sparking	After Sparking	After Redistillation	Pressure
C	103 Div.	96 Div.	129 Div.	0.01
D	21 Div.	4 Div.	70 Div.	0.01
G	30 Div.	1 Div.	170 Div.	0.01

These examples indicate that in order to increase the sensitivity, the potassium, in the form of potassium vapor, must be brought into intimate contact with the hydrogen or inert gas which is present.

There still remains to determine, whether the hydrogen or the gas which is present produces highly sensitive potassium layers as an ion or as a neutral gas combined with the potassium vapor.

In this connection two investigations were undertaken at the Dresden Physical Institute. First, fresh potassium, which had been degassed as far as possible by distillation in a high vacuum, was vaporized and deposited under very low pressure upon a potassium layer which had been super-saturated with hydrogen.

Secondly, potassium, similarly prepared, was distilled upon platinum foil, which had been degassed by heating to incandescence, this distillation taking place in a high vacuum and also in an atmosphere of hydrogen under a pressure of 10^{-3} mm. of mercury.

Figures 3 and 4 show clearly the increase in sensitivity obtained in both cases. (R. Fleischer and H. Teichman, Z. f. Phys., 61,222, 1930.)

In the first case, the potassium vapor comes into contact with hydrogen which is adsorbed and absorbed by another potassium surface. In the second case, the potassium vapor has the opportunity to combine with the neutral hydrogen which is present in the cell.

Both investigations show that in order to obtain an increase in sensitivity of a potassium layer, the potassium, in vapor form, must be brought into contact with the gas which is present. This conception is not in disagreement with the sensitizing methods of Elster and Geitel and of Suhrmann, since in both cases potassium is vaporized by ionic bombardment.