SOME RECENT ADVANCES IN THE PHOTOELECTRIC FIELD*

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THE photosensitive cell has assumed great importance of late as an indispensable constructional element in automation, regulation and measuring systems. An outline of the new developments in two particular sectors, (*i*) photoelectric emission, and (*ii*) barrier-layer-cells is of topical interest.

PHOTOELECTRIC EMISSION

Photo-cathodes with alkali-Sb layers have been known for some 20 years, particularly those of the type Cs-Sb and Li-Sb.[1] These so-called composite cathodes then competed with the Cs-oxide-cathodes. Excepting minor variations from these two basic conceptions, there is no further innovation on record as far as the construction of photo-cathodes is concerned. However, measurements of the spectral distribution of the sensitivity of photo-cathodes were extended into the extreme ultraviolet (Schumann-region) up to about 80 mμ.[2] The observed high sensitivities, especially of the alkali-Sb-cathodes also in the Schumann-region, permitted us to design photomultipliers of maximum sensitivity in the ultraviolet region, thus practically removing what obstacles may have been in the way of a complete experimental exploitation of the Schumann region—so far as the receiving end is concerned—for the investigation of photochemical reactions, optical transmission through thin media, etc.

With respect to the lowest dark-currents produced by thermionic noise, a value of 10^{-17} to 10^{-19} amp./cm.^{2} primary at the photo-cathode has been obtained for multipliers working in the visual region of the spectrum, and using Li-Sb-cathodes combined with an occasional low-temperature-cooling of these layers.[3] In precision photometry of lowest light-intensities and also for scintillation measurements, the importance of this result cannot be underestimated, more especially as the proportionality between the incident flux of light and the output current of the multiplier can be guaranteed in the range of some powers of ten.

At the same time, modern technology of photomultipliers has led to a usable arrangement for verifying the existence of ions in mass spectrometers. The secondary emission part of modern multipliers is generally insensitive to short-time influences of the atmosphere if an alkali-component in the secondary emission layer of the dynode stages is dispensed with, *i.e.*, the secondary emission factor of the single stages does not deteriorate by the above manipulations.[4] The above-mentioned multiplier dynode-systems are therefore of late used in mass spectrometers or in connection with vacuum-monochromators, *i.e.*, in all those cases in which ion currents are to be amplified by secondary emission and also where it becomes necessary to permit air to enter for a short time into the vacuum-apparatus between separate experiments. This is done in such a way, that electrons are liberated on the first dynode by the ion current which is to be amplified. These electrons are then further amplified in the dynode system in the same way as the secondary electrons liberated by photoelectric electrons.

In a recent manual on physics, Weissler[5] has given a very clear survey of the present state of our knowledge regarding the photoelectric emission of solids. This review could be supplemented with regard to the section on composite photo-cathodes as follows: recently it has become possible to draw certain conclusions with respect to the mechanim of composite photo-cathodes or to the actual structure of the layers themselves, if the whole phenomenon of discharge in gas-filled photocells, *i.e.*, including the independent discharge, is considered as a reciprocal action with the measurable changes of the cathode-layers. Whether or not the formulation or position of the question is similar to that of the Joshi effect, cannot be decided until an adequate amount of experimental data is available. Such investigations on composite photo-cathodes have already been initiated by Kluge and his collaborators.[6] In a dissertation suggested by us, but which has not been published so far, W. Telle has shown by experiment that, in the region of independent discharges of inert gases (under specified discharge conditions, and upon subsequent reproducable discharge phenomena) it will be possible to show increase or decrease of the sensitivity of composite cathodes as a function of these conditions, in particular, as regards their photoelectric yield. The obtained changes in sensitivity are also maintained if the filling gas is removed from the cell. Exhaustive investigations in this direction are likely to show good

* From a lecture given at the 44th Session of the Indian Science Congress, January 1957, dealing with the work done on the subject at Jena.

results in the above sense, unfavourable and intricate though the existing experimental conditions may appear.

There are various provinces where the industrial use of iconoscopes and the employment of the so-called industrial television assumes a steadily growing importance of late. There are possibilities now of visualizing images formed by rays from invisible spectral regions, of increasing the contrast and intensifying the light. The problems which arise from the above for photoelectric research consist in adapting the photo-sensitive imaging elements together with their electrical accessories to the specific applications as regards size, spectral distribution, mode of storage or amplification, choice of glass or material for windows, as well as the technology of photoelectric elements. As a result of these investigations, it may be necessary to envisage more extended photoelectric methods and the employment of image converters or image pick-up tubes in microscopy, as well as in astronomical research, in medicine, surveying, as also in taking photographs of rapid motions and in many other fields. Surprising results may occasionally be expected when using photosensitive imaging elements. For example, we have been able to show that the structure of thin sections of wolframite and manganite, if viewed microscopically in the infrared region (λ 913 or 850 mμ respectively) *via* an image-converter, displays a marked fine-crystalline texture while, if observed in the visible region (λ 506. 8 mμ) the same layers are completely opaque.[7] Also in astronomical research a tenfold extension of the radius of observation is anticipated in the linear scale if image pick-up tubes are employed, using the same telescope. This possibility has been pointed out of late by several astronomers.[8] Thus a modern pick-up storage tube, if used in connection with the 200 in. Hale-Telescope on Mount Palomar, would be likely to pick up stars of the 29th magnitude.[9]

Barrier-Layer Photocells

From the engineering point of view, the progress achievable with barrier-layer cells is of particular interest. The preferential employment of these cells in luxmeters, photometers and exposure-meters, particularly in portable instruments, is known to be attributable to the fact that they are operative without any outside source of power. Whereas selenium, as a semiconductor, received serious rivals in cupros oxide, silver sulphide and thallium sulphide, the selenium barrier surface cell maintains its leading position now as before. Yet, recent investigations on Cu_2O, especially by Dixit[10] leave room for the possibility of this type of cell being likely to again push to the foreground by changed methods of producing Cu_2O-barrier cells (as also of Cu_2O-photo-resistance cells).

Without our having been aware of the now prevailing views on *pn*-transitions we succeeded in effecting one such transition by depositing a Cd-Se-layer on the Se-semiconductor layer of a barrier cell and in this way we obtained in addition to the known Se-maximum of the spectral distribution at $\sim$ 580 to 600 mμ, another a red maximum at $\sim$ 710 mμ.[11] As a covering layer (conductor layer), a thin transparent metal film was sputtered or evaporated on the Cd-Se-surface (same as in the past on the pure Se-layer). Preston[12] eventually changed over to using covering layers of a semi-conducting nature, such as CdO-layers, for instance. Since then, investigators have been interested in obtaining a greater influence upon the spectral distribution in the red region by means of Cd-Se than was possible by a *pn*-transition. Such investigations are of interest also from a technical point of view, for there are many possibilities of applying highly red-sensitive Se barrier-layer cells: for instance, the important problem of the continuous supervision of the oxygen-content of blood during surgical operations, or for the purpose of studying the circulation, which can be solved with the aid of a red-sensitive cell for measuring the red absorption component ($\lambda \sim$ 805 mμ) and with a cell of suppressed red-sensitivity for measuring the absorption component at $\lambda \sim$ 650 mμ.[13]

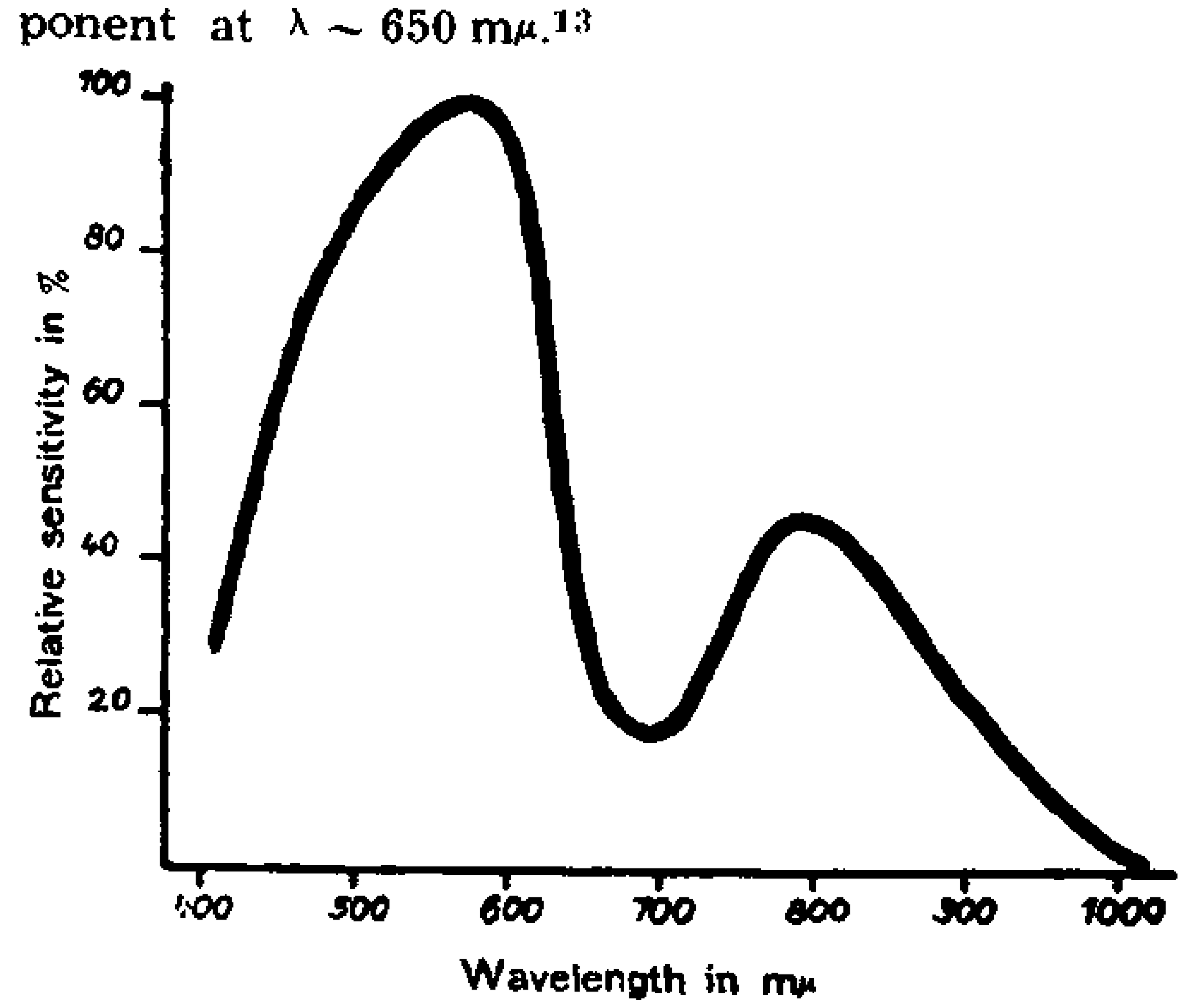

FIG. 1. Spectral distribution of an infrared photoolement.

The high sensitivity in the infrared which occur in resistance cells with thallium-sulphide, lead sulphide, lead selenide and lead telluride would seem to suggest that selenium surfaces should be treated with thallium or lead in order to obtain transitions between the thallium-selenides or lead-selenides, respectively, and the selenium for producing infrared maxima, also in barrier-layer cells. We actually succeeded in creating maxima[14] in the region of 800 mμ and, by treatment with lead, to shift the longwave limit far beyond 1 μ. By cooling down the lead-treated cells to a temperature of carbon-dioxide snow, we detected symptoms of infra-red excitation of the sensitivity and a diminution in the inertia-phenomena and in the dependence on frequency. Experiments with In-Se-intermediate layers, not published so far, show a very distinct maximum near 780 mμ (see Fig. 1). The effects of the above-mentioned modes of treatment on the spectral distribution in the near and far ultra-violet have not yet been fully analysed. Rough investigations, during which the Cd-treatment was effected by means of an electrolytic method, show that such influences must be strong. A distinct new maximum near ~ 380 mμ was thereby produced.[14]

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NEW TYPE NUCLEAR REACTION

THE observation of a new kind of nuclear reaction that yields energy and is akin to thermonuclear reactions was reported recently to the American Physical Society by scientists in the University of California Radiation Laboratory. The new phenomenon is described as a "catalyzed nuclear reaction". This adds to those reactions already known to science a new and third way of making a nuclear reaction take place. The older ways are either to induce thermonuclear reactions, in which two light nuclei fuse into a heavier one when the temperature is raised to roughly one million degrees, or else to bombard nuclei with other nuclear particles from accelerators like cyclotrons or nuclear reactors.

In order to make a nuclear reaction take place, two nuclei must touch. The new discovery is a way of pulling two nuclei together so that a proton and a nucleus of heavy hydrogen (a deuteron) can combine to form helium-3 with the release of 5·4 million volts of energy. This pulling together takes place in a mesic molecule.

In a normal molecule the nuclei of the component atoms are pulled together weakly by electrons. But the electron can be replaced by a much heavier particle, the negative mu meson. Because the mu is 210 times heavier than an electron, it circles the nucleus at only 1/210 of the distance of an electron, and thus binds the two nuclei correspondingly closer. The nuclei then have a good chance of touching, and the nuclear reaction can take place.

The reaction is termed a catalyzed reaction because the mu meson is not consumed by the reaction but may be ejected from the molecule by the energy released. The mu is then free to catalyze more reactions, in chain fashion.

It is however emphasized that at the present time the energy producing chain of catalyzed reactions cannot continue long enough to generate commercially useful amounts of power, because mu mesons decay into other particles after two-millionths of a second. Unfortunately, from the point of view of thermonuclear power mu mesons can be made only in high-energy nuclear collisions of particles accelerated by cyclotrons and other expensive machines. But the possibilities will be greater if a much longer lived particle, with properties similar to that of the mu meson, can be found.