## Note on the Photo-Conductivity of Cadmium Sulfide Crystals*

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THE photo-current in CdS crystals irradiated with alpha-, beta-, or gamma-rays or light is 100 to $10^4$ times larger[1] than the total charge brought up per second to the conduction band by the radiation. The carriers of this excessive current must enter the crystal from the metal electrodes, but must be prevented from passing through the crystal in the dark. To explain this effect we assume that in CdS the energy $E_0$ of the lowest empty level lies already sufficiently low to allow electrons to enter before irradiation. These electrons are trapped and give rise to a negative space charge which raises the empty band until in the dark further electrons are prevented from entering.[2] By irradiation, however, this space charge is reduced and the crystal becomes conducting.[3] Since thus the main effect of the irradiation is to regulate the flow of electrons, the current can exceed by far the number of electrons lifted to the conduction band per second. The effect is very similar to the increase of current in an amplifier tube when the space charge is reduced by a positive grid.

In order for irradiation to reduce the negative space charge, a fixed positive charge must remain in the insulator under irradiation while electrons leave. For this it is sufficient to assume that there are normally filled traps at an energy $E_2$, below the empty band, where $E_0-E_2>300°K$, and the electrons from these traps can fill the holes produced by irradiation in the filled bands. Since at room temperature the current under irradiation rises without delay, we conclude that electrons from the conduction band are lifted up by the irradiation and are trapped in states of an energy $E_1$, which is also below $E_0$ but much closer to it than $E_2$.

At a temperature sufficiently below $(E_0-E_1)/k$, electrons should be prevented from leaving the crystal until most of the upper traps are filled.

The resulting delay in the rise of conductivity can be observed at liquid air temperature. A crystal of CdS which has been kept in the dark for a sufficiently long time reached a resistance $\gg 3\cdot 10^{13}$ ohms if cooled to $-189°C$. If at $t=0$ irradiation starts with a constant intensity of gamma-rays, the resistance is lowered at $t=3$ sec. to $3\cdot 10^{12}$ ohms. With continued irradiation it then stays constant to $t=36$ sec. After this delay it drops very fast, reaches $4\cdot 10^{10}$ ohms at $t=72$ sec. and a saturation value of $2\cdot 10^8$ ohms after one hour. In these experiments the field strength applied to the crystal was always small (2.9 volts/mm) in order to avoid ionization effects in the surroundings of the crystal.

The current during the delay period can be considered as the primary current. (Its magnitude and the duration of the delay are compatible with reasonable assumptions for the "Schubweg" and the number of traps.) During the delay time the net result of the irradiation is the transfer of electrons from the lower traps to the upper traps, a process which does not produce any change of the space charge. If the irradiation is interrupted at $t=36$ sec., the crystal can be kept in this "metastable state" at $-189°C$ for a long time. A crystal in this state is similar to an excess semiconductor, and, without further irradiation, it becomes strongly conducting for a short time if it is heated to room temperature. After this experiment the crystal has returned to its normal state and the above-mentioned delay experiment can be repeated. However, if the crystal is not warmed and thus remains in the metastable state, the delay does not occur, but with further irradiation (even after a long intermission) the current rises instantaneously.

If the crystal in its metastable state and without applied voltage is heated on one side, we find the expected sign of the thermoelectric e.m.f. (i.e., positive on the hot junction).

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[1] R. Frerichs and R. Warminsky, Naturwiss. **33**, 251 (1946); R. Frerichs, Phys. Rev. **72**, 594 (1947), Table I; H. Kallman drew the attention of Frerichs to this fact in 1947. Recently Kallman and Warminsky have studied this amplification in a paper in print in Ann. d. Physik. The model here proposed is entirely different from the one used by these authors.
[2] N. F. Mott and R. W. Gurney, *Electronic Processes in Ionic Crystals* (Oxford University Press, London, 1940), p. 169.
[3] Similar to the mechanism proposed by N. F. Mott and R. W. Gurney, see reference 2, pp. 186–188.

## Diurnal Variations of Meteor Trails

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METEOR trails have been observed by means of radar equipment operating on 27 megacycles.

The diurnal variation in the distribution of meteor occurrence with time of day has been established by visual observations and by radio observations of Appleton and Naismith[1] and of Hey and Stewart.[2] The seasonal change in the nature of this distribution as specified by these authors, however, differs significantly from the present observations which were made between April 17 and June 19, 1948 (Fig. 1), which correspond closely to the

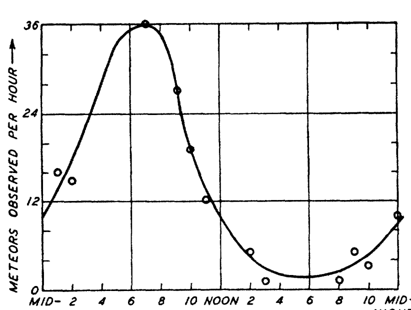


FIG. 1. The distribution of meteor occurrence over a 24-hour period.