Letters to the Editor

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High-Voltage Photovoltaic Effect*

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VACUUM evaporated films of cadmium telluride have been prepared that show unusually high photovoltages across their ends. The effect is independent of the electrode material and the voltage is proportional to the length of the film. A value of one hundred volts/cm has been obtained in sunlight. Since the photovoltage of a single junction is limited by the band gap of the material (1.45 ev), it is concluded that the films consist of large numbers of junctions (or other photovoltaic elements) whose individual voltages add to produce the observed values. Photovoltages greater than band gap have been reported for films of PbS,[1,2] but with a maximum of 3 volts and only after some post-evaporation processing. No such processing is required for the CdTe films.

The presence of the effect depends on the angle, θ, of deposition of the vapor onto the substrate as shown in Fig. 1. Lines of constant θ are found to be equipotentials for photovoltage. No photovoltage exists in material deposited with $\theta=0$. The photovoltage increases rapidly with θ up to about 10 degrees and then very slowly up to 60 degrees, above which no measurements were taken. A second requirement for the effect is that the substrate be held at a temperature between 100 and 250°C during deposition. The pressure during evaporation, $\sim 10^{-5}$ mm, is maintained by an oil diffusion pump.

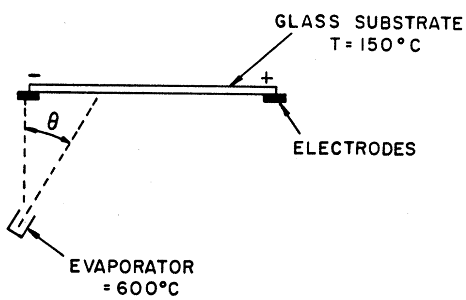

FIG. 1. Schematic diagram of evaporation arrangement for producing the high-voltage photovoltaic effect in films of CdTe. Polarity of the film is as indicated.

The rate of film formation is about 1000 A per minute. The films become photovoltaic when the thickness is sufficient to absorb some light, and the voltage increases to a maximum at approximately one micron. The effect occurs with Pyrex glass, fused quartz, and other substrate materials. The only requirement is that the substrate be more insulating than the films which, in the dark, have a resistance of the order of 10^{13} ohms per square at room temperature.

The electrical properties of the films and their response to light and temperature are reported in a following letter. Optical transmission measurements show that the fundamental absorption edge is 8300 A, the expected value for CdTe. X-ray studies by J. G. White of this Laboratory are consistent with the view that the films consist of crystallites whose size is comparable with the film thickness ($\sim 1\ \mu$). The crystallite (111) planes have a preferred orientation parallel to the substrate, regardless of the angle of deposition.

Although the effect has been found in every film made, the magnitude has not been reproducible within a factor of 10. An explicit model for the mechanism of the effect has not yet been established. An effect of comparable magnitude has been found in single-crystal zinc sulfide by another group in this laboratory. Further studies of the effect in both materials are under way.

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[1] Starkiewicz, Sosnowski, and Simpson, Nature **158**, 26 (1946).
[2] Berlaga, Rusmach, and Strakhov, Zhur. Tekh. Fiz. **25**, 1878 (1955).

Properties of Photovoltaic Films of CdTe†

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THIS letter describes some of the basic properties of a representative photovoltaic film of CdTe.[1] The film was deposited onto a Pyrex substrate: it was one-half cm long, one cm wide, and about one micron thick. The open-circuit voltages were measured with a bucking circuit and null detector.

Both the open-circuit photovoltage and the short-circuit photocurrent of the film cut off sharply at 8300 A. The photovoltage is strongly temperature-dependent as shown in Fig. 1. Figure 2 shows the light intensity dependence of the open-circuit photovoltage at four temperatures for a light source and filter combination which transmits light of wavelengths less than 6500 A. Analysis of these data has shown that the photovoltage has many of the important characteristics exhibited by that of a well-behaved *p-n* junction. The photovoltage saturates with light intensity at low temperatures, while at higher temperatures it follows