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B—4—3 (INVITED) PHOTOVOLTAIC PROPERTIES OF DISCHARGE-PRODUCED AMORPHOUS SILICON

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Recently amorphous silicon (a-Si) produced from discharge decomposition of silane has been used to fabricate efficient thin film (~1 μm) solar cells. In these cells photogenerated currents around 10 mA/cm^2 are collected, using only the available junction voltage (~1 V). This paper discusses the properties of discharge produced a-Si that allow these requirements to be satisfied, even though the a-Si is a highly disordered and resistive material.

Discharge-produced a-Si, deposited at substrate temperatures, T_S,between ~200 and 400°C has an optical bandgap of ~1.7 eV, is n-type and has much lower density of deep gap states than the a-Si prepared by evaporation or sputtering. These low densities of gap states are attributed to the reduction in the density of dangling bonds by the several percent of bonded hydrogen present in the films. Such films have resistivities between ~10^5 and 10^{10} Ω-cm, and large photoconductivities. Electron lifetimes are as high as ~10^{-4} sec. Also at these substrate temperatures the a-Si can be doped both n^+- and p-type by incorporation of dopants into the discharge. As in the case of crystalline semiconductors, a wide variety of junctions can be used to produce photovoltaic structures. Of these the metal/undoped a-Si structures have been most extensively characterized and are used here to illustrate the physics of the photovoltaic effects in a-Si.

The characteristics of evaporated metal/a-Si Schottky barrier structures having n^+ ohmic contacts are discussed using the usual Schottky barrier concepts. The diode currents can be related to clearly defined barrier heights, ϕ, which depend on both the metal work function and the surface states of the a-Si. Significantly higher values of ϕ are obtained in a-Si than on crystalline Si, resulting in much lower values of saturation current density, J_o. The low density of gap states in discharge produced a-Si results in junction space charge densities which are 10^{15}-$10^{16}cm^{-3}$. Thus, the barrier regions extend over a significant fraction of structures ~1 μm thick. The barrier fields and the high optical absorption of the a-Si allow efficient collection of a large fraction of the carriers photogenerated by white light. The short-circuit currents, J_{sc}, and the open-circuit voltages, V_{oc}, found on illumination can be related to the nature of the incident illumination, the junction, and the bulk a-Si properties. A typical temperature dependence of J_{sc} and V_{oc} is shown in Fig. 1 for a Pd/a-Si Schottky barrier. The falloff in J_{sc} at the low temperatures results from the decreased photoconductivity of the bulk a-Si and the resultant increased series resistance.

The collection efficiencies of photogenerated carriers are presented for different a-Si Schottky barrier structures and their dependence on various physical parameters discussed. Also the dependence of the photocurrent-voltage (I-V) characteristics under load are considered. Major new parameters, not usually considered in the operation of crystalline photovoltaic structures, are found to be important. This includes the large effects due to photogenerated carriers which are not collected in the external circuit and the changes in the electric fields that occur under load. Despite hole diffusion lengths significantly smaller than 1 μm, fill factors (FF) on the order of 0.6 can be obtained with a-Si Schottky barrier cells. Such an I-V characteristic is shown in Fig. 2 for a Pd/a-Si Schottky barrier structure together with the I-V characteristic of a similar structure formed on n-type single crystal.

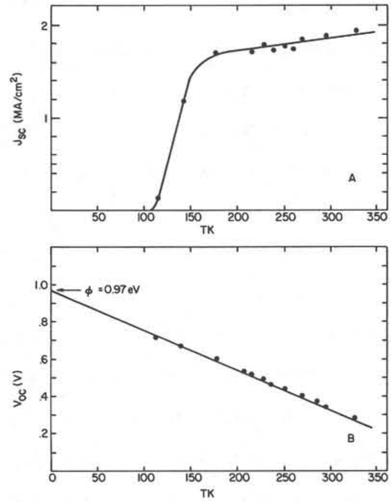

Figure 1. (a) The short-circuit photocurrent, J_{sc}, plotted as a function of temperature; and (b) the open-circuit photovoltage plotted as a function of temperature. ϕ is the Schottky barrier height. Illumination is ~100 mW/cm^2 of white light through ~20% transmitting Pd film.

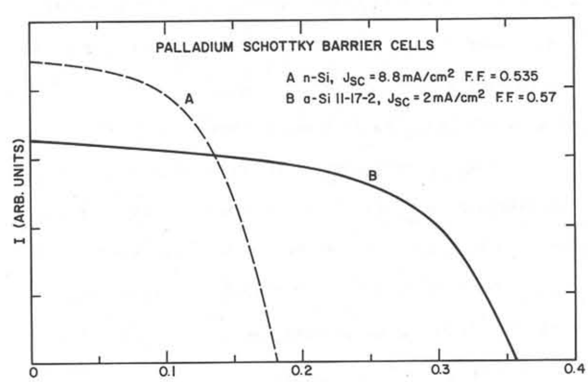

Figure 2. (a) I-V characteristic of Pd/n Si Schottky barrier structure; and (b) I-V characteristic of Pd/a-Si Schottky barrier structure. Illumination is ~100 mW/cm^2 of white light through ~30% transmitting Pd film.