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CHARACTERIZATION OF PLASMA-DEPOSITED AMORPHOUS Si:H THIN FILMS

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Semiconducting films prepared by plasma deposition from silane have been shown to possess some very desirable properties for large area thin film device applications. Long minority carrier lifetimes in undoped material have permitted the fabrication of 6% efficient Schottky barrier solar cells[1]. Doping in the plasma with diborane (B_2H_6) and phosphine (PH_3) has been demonstrated[2] and p-n junctions fabricated[1,3]. The material is also strongly luminescent and pin electroluminescent devices have been reported[4].

The major barrier to enhanced device performance is the presence of non-radiative recombination centers that limit the minority carrier lifetime. These centers are present in undoped material and doping seems to increase their density.

The first part of this characterization study has been to systematically map the structural and electronic properties of material produced by varying the deposition conditions in the plasma reactor shown in Fig. 1. The second part has been to find correlations between structural properties and those electronic properties that are sensitive to defect states. The third, and continuing part, is an attempt to provide models for the non-radiative recombination process and for the structural origin of the defect states.

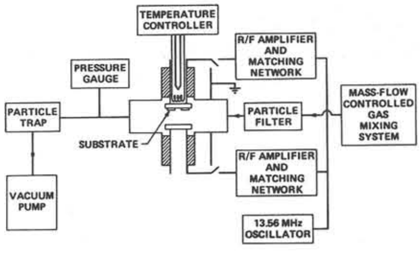

Fig. 1 Schematic of Plasma Deposition System.

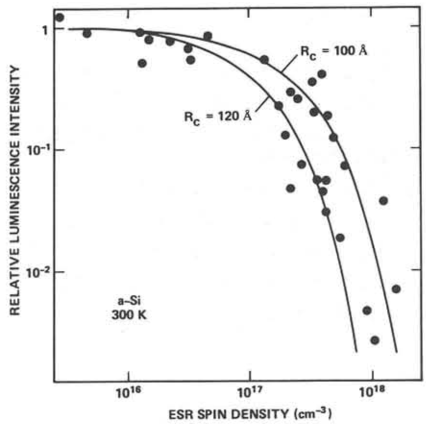

Fig. 2 Luminescence Intensity as a function of Electron Spin Density in a-Si:H

The findings of the first part of the study are that it is possible to produce material with a chemical formula varying from $SiH_{1.4}$ to $SiH_{0.05}$ - indicating that the material is a silicon hydride and not simply amorphous silicon. Three distinct hydrogen environments - SiH, SiH_2 and $(SiH_2)_n$ have been identified[5]. The relative proportion of hydrogen in these environments is a complex function of the deposition parameters and does not scale simply with hydrogen content. The density of defect states, as measured by ESR and luminescence (intensity and lifetime), is also a strong function of deposition parameters particularly substrate temperature, partial pressure of silane, and electrical bias on the substrate[6].

Correlations have been found between the density of defect states and the proportion of hydrogen in the different environments. A high proportion of SiH correlates with a low density of defects. A high proportion of $(SiH_2)_n$ correlates with a high density of defects. At present there is no apparent correlation between the proportion of isolated SiH_2 groups and defects.

Models for both the radiative[7] and non-radiative recombination processes have been developed[8]. That for the non-radiative process involves tunnelling from a band-tail localized state into a deep defect state associated with a spin. Fig. 2 shows the experimental relationship between the luminescence intensity and ESR compared to the model curves for two tunnelling radii. Models for the structural origin of the defect states are still under consideration but there are strong indications from refractive index and density measurements that the primary defects are associated with voids in the material that are in turn associated with $(SiH_2)_n$.

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