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HIGH-EFFICIENCY SILICON SOLAR CELL RESEARCH

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Progress reports on research in high-efficiency silicon solar cells were presented by eight contractors and JPL. The presentations covered the issues of Bulk and Surface Loss, Modeling, Measurements, and Proof of Concept.

The University of Florida's theoretical work on heavily doped silicon included an energy-gap model, which was compared with photoluminescent and transport data. A majority carrier screening model, originally published by C.T. Sah in 1966, was presented with modifications. Improvement in the short-circuit current decay and open-circuit voltage decay measurement methods were described.

The University of Pennsylvania described and compared various methods of measurement of L or τ and s, specially in the front region of the cell. Basic requirements, types of parameters and classification of the methods regarding various options were given. Sensitivity analysis of light-beam-induced current (LBIC) method was presented.

Cornell University described its work on dislocations and grain boundaries using the electron diffraction technique. Cornell's studies on EFG showed that low concentrations of oxygen introduced a higher density of twins. Distribution and location of precipitates in processed EFG were also studied, using TEM and EDX.

A comprehensive review of oxygen-related and carbon-related defects was presented by State University of New York at Albany. It was pointed out that oxygen is a bond-centered interstitial, which is mobile, whereas carbon is relatively immobile, being a substitutional impurity in silicon. Data on diffusion of oxygen and various oxide precipitate formations were described along with their bonding behavior. Other impurities react with oxygen and carbon-related defects during processing and are therefore important for silicon solar cells.

Research Triangle Institute described its effort on the comprehensive modeling of solar cells and elaborated on its analysis of the charge distribution in the quasineutral region by considering a Gaussian doping profile in the emitter region. Results of measurement on cells made by Spire Corp. were compared with the simulated analysis, and a 6.4% correspondence was shown for data taken at temperatures varying from 28°C to 150°C. Other simulation plots of photo-excited hole concentration and net charge distribution were also discussed.

Anant Mokashi of JPL described studies using Purdue Research Foundation's SCAP1D simulation program. A good match was obtained between his result and MINP solar-cell data published in the literature. The doping profile in the front region was then altered to show its effect on efficiency. Sensitivity analysis with S, τ, BSF and cell thickness was also described.

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The University of Washington described its study of the effects on SiN_x surface passivation of gas flow and temperature in the plasma enhanced CVD system. Special device structures for interface studies, along with a description of preparation techniques, were described. Surface-state density results were good for devices prepared using the RCA cleaning procedure and fabricated with a thin oxide and nitride layer and annealed at 450°C. The layers were fabricated with a substrate temperature of 270°C. Spectral response analysis was also given for these devices. Results of electrical characterization and theoretical analysis were described for an MINP cell. A procedure for preparing 25% cells was described.

C.T. Sah Associates described its study of important loss mechanisms for >20% and <20% cells. For <20% cells, dark currents below 10^{-13} A/cm^2 will be required. Present cells are limited both by emitter and base recombination mechanisms. To reach 25% efficiency, SRH and interband Auger recombination mechanisms will have to be reduced.

In its effort on high-efficiency solar cells made from silicon web, Westinghouse has investigated loss mechanisms and formulated an analytical model to study the effect of a twin plane on V_{oc}. It shows a fall of V_{oc} by 20 mV with a twin plane having an interface recombination velocity of 10^6 cm/s. Electrical activity of a twin plane is studied on bevelled web material with the LBIC method. Further, it was shown that some web samples showed increases in diffusion length with temperature cycling. These diffusion length data were compared with those from similar temperature cycling of FZ silicon material.