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HIGH-EFFICIENCY DEVICE RESEARCH

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Progress reports on research in high-efficiency silicon solar cells were presented by 11 contractors. The presentations covered the issues of: heavy doping, bulk and surface recombination, and cell modelling.

The University of Florida's theoretical work on heavily doped silicon was described. Heavily doped polysilicon was used as a back-surface passivant replacing the usual back-surface field (BSF). Very good first results were achieved and there is the promise of a simple, low temperature deposition process. Short-circuit current-decay measurement methods were also covered.

A survey of bulk recombination measurement techniques was presented by the University of Pennsylvania. Classical methods were reviewed along with their limiting assumptions and simplifications. A moduated light measurement system was built and showed the large effects of junction capacitance. Techniques for extension of classical methods for measurement of multiparameter multiregression measurements were identified and analyzed.

Measurement of minority carrier transport parameters in heavily doped silicon was covered by Stanford University. The basic transport equations were used to define two independent parameters. Use of special vertical and lateral transistor test devices permitted the measurement of both parameters. Prior studies were normalized to show excellent agreement over the heavy doping region.

The State University of New York at Albany presentation featured oxygen and carbon related defects, both native and process-induced. A summary of oxygen processes in silicon versus process temperature was shown along with experimental results. The anamolous diffusion of oxygen was explained by the dissociation of the (V.O) center allowing O_i to move through the lattice.

Modelling and correlation studies of solar cells was discussed by the Research Triangle Institute. Recursive relationships were used to generate solutions at a number of mesh points within the emitter region. Photoexcited hole concentration and built-in electric field were calculated as a function of position. Simulated and experimentally determined I-V curves were shown to have good fit.

C. T. Sah Associates discussed loss mechanisms in high-efficiency solar cells. Fundamental limitations and practical solutions were stressed. Present cell efficiency is limited by many recombination sites: emitter, base, contacts, and oxide/silicon interface. Use of polysilicon passivation was suggested. After reduction of these losses, a 25% efficient cell could be built. A floating emitter cell design was shown that had the potential of low recombination losses.

Fabrication and characterization of high-efficiency metal insulator, n-p (MINP) cells was described by the University of Washington Joint Center for Graduate Studies. Particular attention was paid to development of measurement methods for surface recombination and density of surface states. A modified Rosier test structure has been used successfully for density of surface states. Silicon oxide and silicon nitride passivants were studied. Heat treatment after plasma enhanced chemical vapor deposition (CVD) of silicon nitride was shown to be beneficial. A more optimum emitter concentration profile was modelled.

Westinghouse Electric Corporation's Research and Development Center showed their work on high-efficiency dendritic web cells. The influence of twin planes and heat treatment on the location and effect of trace impurities was of particular interest. Proper heat treatment often increases efficiency by causing impurities to pile up at twin planes. Oxide passivation had a beneficial effect on efficiency. A very efficienct antireflective (AR) coating of zinc selenide and magnesium fluoride was designed and fabricated. An aluminum back-surface reflector was also effective.

Pennsylvania State University examined surface and bulk loss reduction by low-energy hydrogen doping. Hydrogen ions provided a suppression of space charge recombination currents. Implantation of hydrogen followed by the Spire anneal cycle caused more redistribution of boron than the Spire anneal which could complicate processing.