

RELIABILITY AND ENGINEERING OF THIN-FILM PHOTOVOLTAIC MODULES

JET PROPULSION LABORATORY

E. L. Royal

Research Forum

Title: Reliability and Engineering of Thin-Film Photovoltaic Modules
Date: March 20, 1985
 Washington, D.C.

Technical Sessions: 3

Session I Cell and System Characteristics Affecting Module Design
 Chairman L. Herwig, DOE HQ

Session II Thin-Film Module Developments Within U.S. Companies
 Chairman E. Royal, JPL

Session III Reliability Research and Performance Investigations
 Chairman R. Ross, JPL

Attendees: 68
Papers: 17

Research Forum Overview

The purpose of the Research Forum was to: (1) examine critically the attributes of thin-film cells that influence module performance and reliability, (2) explore the lessons and applicability of crystalline-Si module technology to thin-film modules, (3) review the current status of thin-film module technologies, and (4) identify problem areas and needed research. Another important objective was to accelerate the sharing of technical experience between solid-state device researchers and engineering reliability researchers. Forum arrangements were designed to encourage interaction and exchange of information among the wide range of researchers who attended.

The keynote address, presented by Dr. Charles Gay, Vice President, Research and Development, ARCO Solar, Inc., was titled "The Need for Thin-Film Reliability Research." In this address, Dr. Gay praised the work of JPL for its reliability research support as a key factor in the success of crystalline-silicon technology. He urged that a similar type and level of support be committed for thin-film cell and module reliability research.

PLENARY SESSIONS

Dr. Gay gave equal praise to SERI as a developing center of excellence in basic research studies and measurements. In addition to papers presented, two domestic private-industry photovoltaic companies used the Research Forum to announce new a-Si module designs. Both modules were shown and each was described in considerable technical detail.

Reversible Degradation Versus Non-Reversible Degradation

- **Concern**
 - **How to separate Staebler-Wronski-effect-related degradation from degradation incurred during Arrhenius-type reliability research investigations**
 - **Pros and cons on use of annealing**

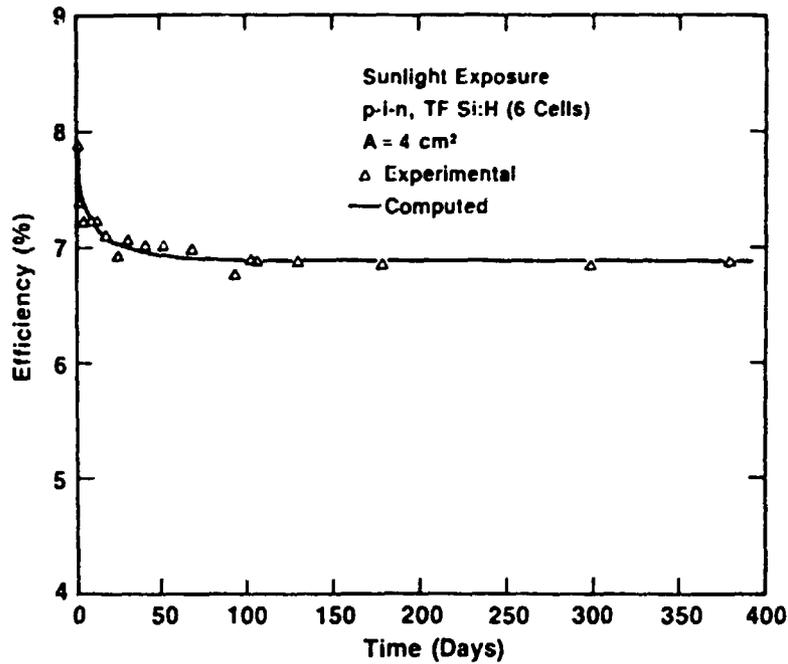
Staebler-Wronski Effect

LIGHT-INDUCED CHANGES:
GENERATION OF METASTABLE
DEFECT STATES THAT CAUSE DECREASES
IN BOTH DARK CONDUCTIVITY AND
PHOTOCONDUCTIVITY

Degradation

- **10% to 15% (from as-made, initial measurement)**
- **Major contributor: bulk**
- **Reversible**

Staebler-Wronski Effect



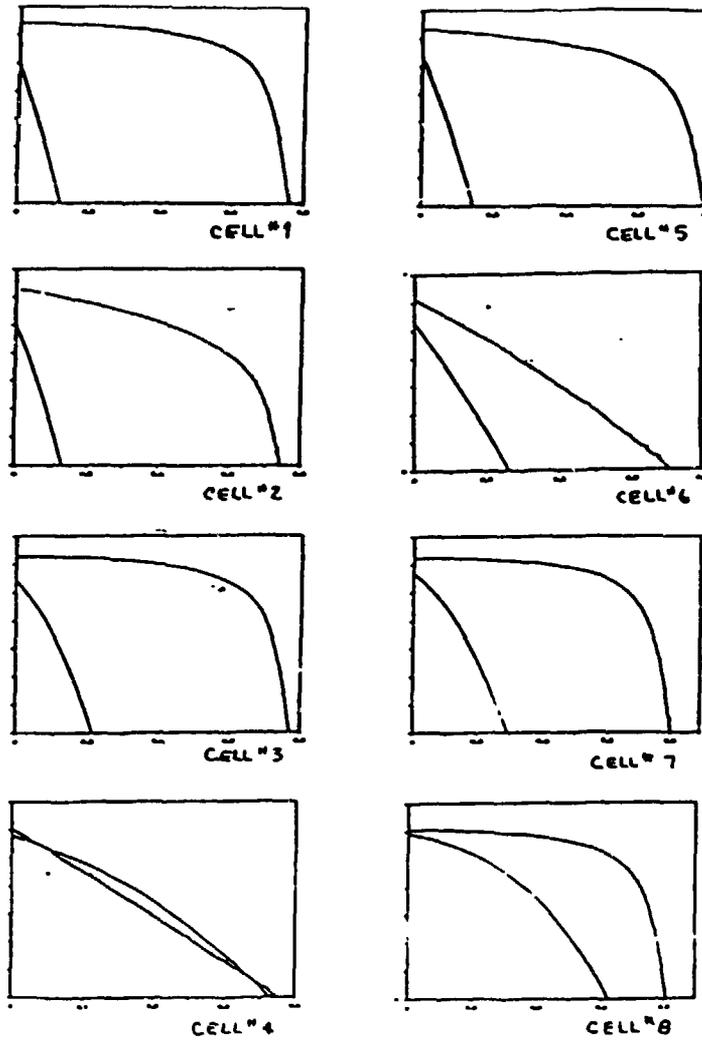
Ullal, Morel, Wilett, Kanani

Amorphous-Silicon Reliability Investigations (Clemson University)

- **Research areas: major focus**
 - **Exploratory research investigations**
 - **α -Si cell accelerated Arrhenius-type testing underway**
 - **α -Si cell real-time outdoor exposure testing**
 - **Cell failure analysis and failure mechanism research (includes new state-of-the-art Auger microprobe)**

- **Support activity**
 - **Device measurement research (major new development to be announced!)**

Eight Amorphous-Silicon Cells in Same Submodule Pre- and Post-Stress IV Curves (140°C Step)



Range of Amorphous-Silicon Reliability Data

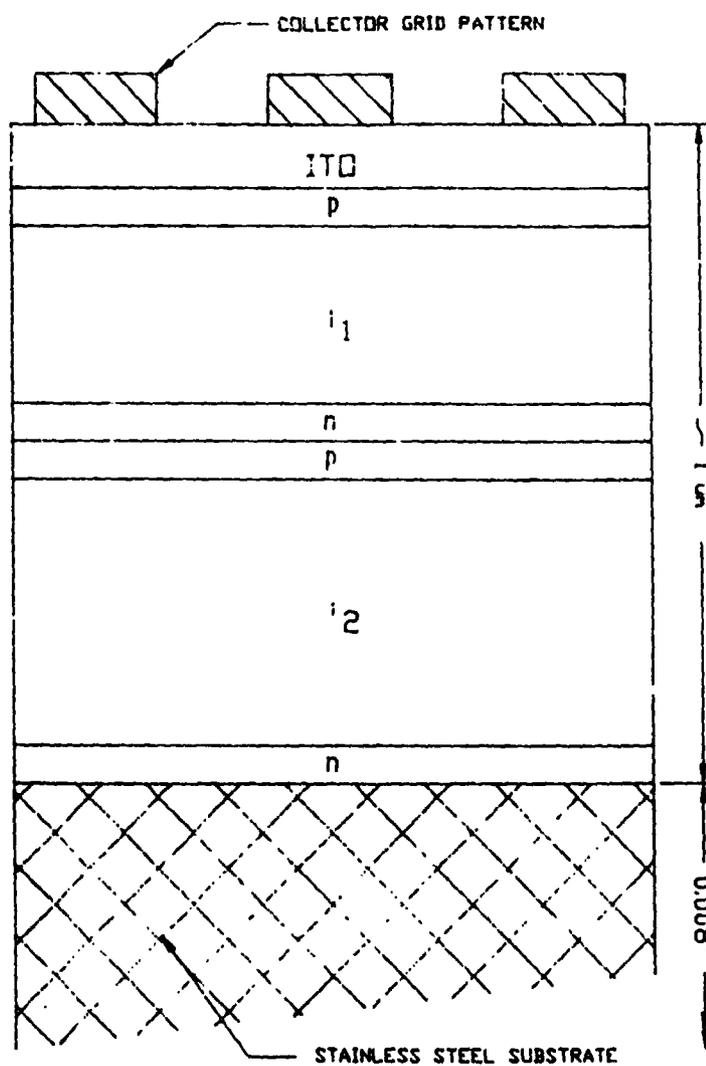
- o BIAS VS-OPEN CIRCUIT CONDITIONS
- o DARK-VS-ILLUMINATED DURING STRESS
- o MEASUREMENTS UNDER VARIABLE LIGHT INTENSITIES
- o ENCAPSULATED VS-UNENCAPSULATED
- o ELECTRICAL CHANGES CORRELATED WITH PHYSICAL CHANGES

PLENARY SESSIONS

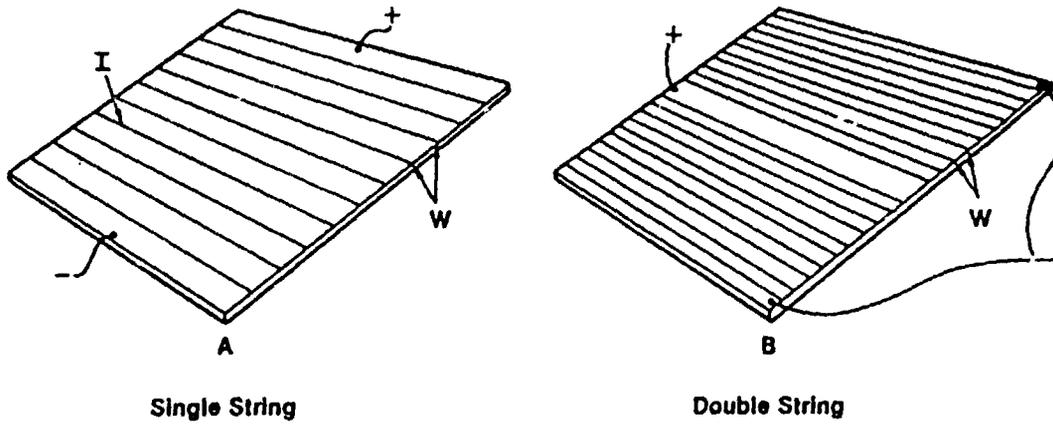
NEW DEVELOPMENTS REVEALED:

- Two unique a-Si module encapsulation approaches
 - All glass
Glass substrate, front cover
Glass backsheet (tempered), back cover
 - All polymer
Tedlar, front cover
PET/Tedlar, back cover
- New tandem (multijunction) a-Si cell

Amorphous-Silicon Tandem Cell Profile



Module Options



Glass Strength Research

- o STRENGTH REDUCTION STUDIED
 - o DURING HIGH TEMPERATURE DEPOSITION OF ITO
 - o DURING LASER SCRIBING
- o SAMPLES FROM A-SI CELL/SUBMODULE MANUFACTURERS
- o BURST PRESSURE TEST DEVELOPED
- o DATA ANALYSIS CONSIDERATIONS

Encapsulation Materials Developments

- o CONSIDERATION FOR FLEXIBLE THIN-FILM MODULES
- o UV STABILIZATION ADDITIVE RESEARCH
- o NOVEL OUTDOOR CONTROLLED TESTING

PLENARY SESSIONS

Expanded Needs for Reliability Research Data (Cells/Submodules/Modules)

- o EFFECTS OF ANNEALING PROCESS
- o ACTIVATION ENERGY OF REVERSIBLE PROCESS

Conclusions

- Crystalline-Si and thin-film modules are expected to have much in common with respect to reliability problems, methods and solutions
- New materials and processes in thin-film modules will require a diligent reliability program
 - Establishment of mechanism-specific reliability goals
 - Quantification of mechanism parameter dependencies
 - Prediction of expected long-term degradation
 - Identification of cost-effective solutions
 - Testing and failure analysis of trial solutions