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FAILURE ANALYSIS OF THIN-FILM AMORPHOUS-SILICON SOLAR-CELL MODULES

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Failure Analysis

PURPOSE:

- PROVIDE INFORMATION AND DATA FOR APPROPRIATE CORRECTIVE ACTION THAT CAN RESULT IN IMPROVEMENTS IN PRODUCT QUALITY AND RELIABILITY.

APPROACHES:

- EXPAND EXISTING TECHNIQUES AND CAPABILITY IN ORDER TO EVALUATE AND CHARACTERIZE DEGRADATIONAL PERFORMANCE OF A-SI SOLAR CELLS.
- INVESTIGATE IN DEPTH MICROSCOPIC AND MACROSCOPIC DEFECTS AND FLAWS THAT SIGNIFICANTLY CONTRIBUTE TO PERFORMANCE DEGRADATION.
- DEVELOP NEW ANALYTICAL TECHNIQUES.

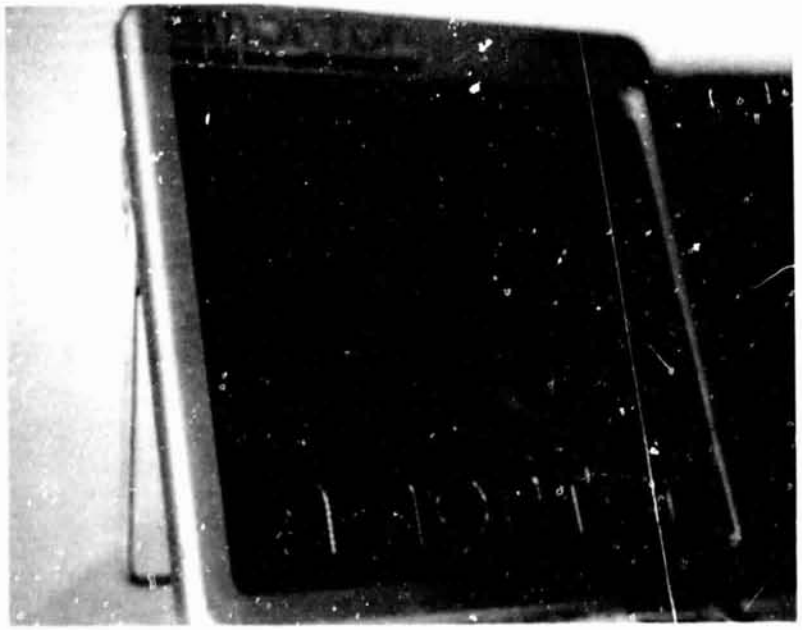
State of the Art of α-Si Solar Cells

TABLE 1. PERFORMANCE OF BEST REPORTED SINGLE JUNCTION p-i-n AMORPHOUS SILICON SOLAR CELLS

STRUCTURE	V_{oc} mV	J_{sc} mA/cm^2	FF %	EFF. %	AREA cm^2	
GLASS/TCO/p (a-SiC:H) - i - n (a-Si:H)/Me				10.1	1.09	RCA
p-i-n	836	16.7	66.0	9.2	0.05	ECD
GLASS/TCO/p (a-SiC:H) - i - n (a-Si:H)/Me	845	13.03	74.0	8.15	0.04	SANYO
GLASS/TCO/p (a-SiC:H) - i - n (a-Si:H)/Me	880	15.21	60.0	8.04	0.033	OSAKA
GLASS/TCO/p (a-SiC:H) - i - n (a-Si:H)/Me	832	14.00	67.6	7.87	1.09	RCA
TCO/n (mC-Si) - i - p (a-Si:H)/SS	860	13.90	65.2	7.80	1.20	FUJI
GLASS/TCO/p (a-SiC:H) - i - n (a-Si:H)/Me	900	14.60	58.0	7.62	0.09	SUMITOMO
TCO/n (mC-Si) - i - p (a-Si:H)/SS	889	13.80	60.0	7.36	0.09	TEIJIN
TCO/n - i - p (a-Si:H)/Me	839	13.80	64.0	7.40	0.06	SIEMENS
BEST INDIVIDUAL PARAMETERS	950	16.70	74.0	(11.70)		

- HIGH CONVERSION EFFICIENCY: 7.4 – 11.7%
- DIFFERENT DEVICE STRUCTURES: p - i - n
  n - i - p
- DIFFERENT FABRICATION PROCESS: GLOW DISCHARGE
  REACTIVE SPUTTERING
  CHEMICAL VAPOR DEPOSITION

Solar Battery Charger (NC-AM1), Sanyo Electric Co. Lt



Some Test Results

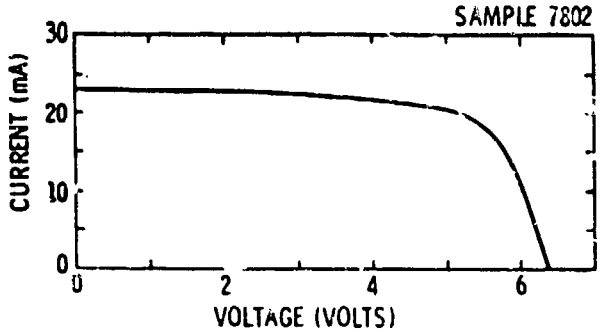


FIGURE 1. IV CHARACTERISTICS

AFTER ANNEALING (160°C FOR 1/2 HR IN AIR)

J_{SC}	= 2.973 m A/cm^2	η = 1.68%	
V_{oc}	= 0.798 V	SHUNT RESISTANCE:	1.495 K Ω
P_{max}	= 1.58 mw/cm^2	SERIES RESISTANCE:	4.163 Ω
FF	= 0.709	THERMAL ACTIVATION ENERGY:	0.14 eV
CELL AREA	= 7.738 x 8 cm^2		

PRACTICAL CONSIDERATIONS

- LARGE DIFFERENCES IN η SUGGESTS A NEED FOR AN IN-DEPTH EVALUATION OF DEGRADATIONAL MECHANISMS
- MANY OF THE MECHANISMS ARE LIKELY TO BE PROCESS PARAMETER SENSITIVE ON WHICH THERE IS SOME LIMITED INFORMATION
- EFFECT OF ENVIRONMENTAL STRESS ON OTHER MECHANISMS APPEAR TO BE LESS UNDERSTOOD

Amorphous-Silicon Solar Cell

- VERY SHORT DIFFUSION LENGTH (< 1 / 1000 x C-Si)
- VERY HIGH ABSORPTION COEFFICIENT (> 10 x C-Si)
- CARRIER TRANSPORT BY DRIFT

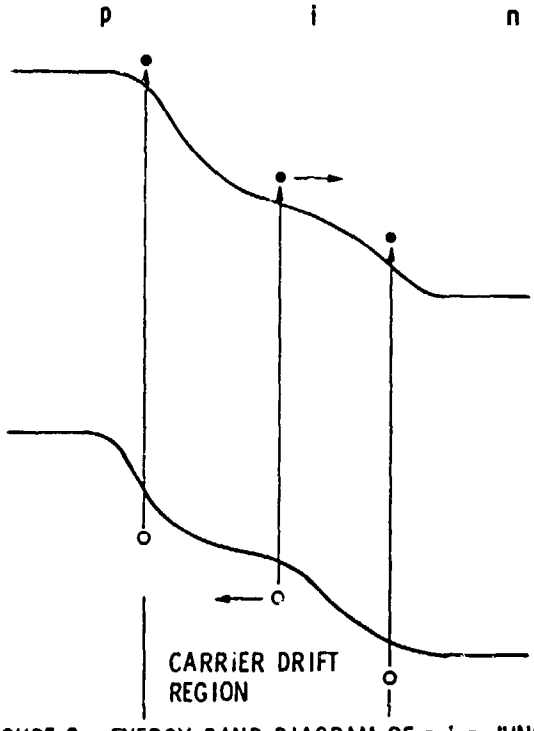
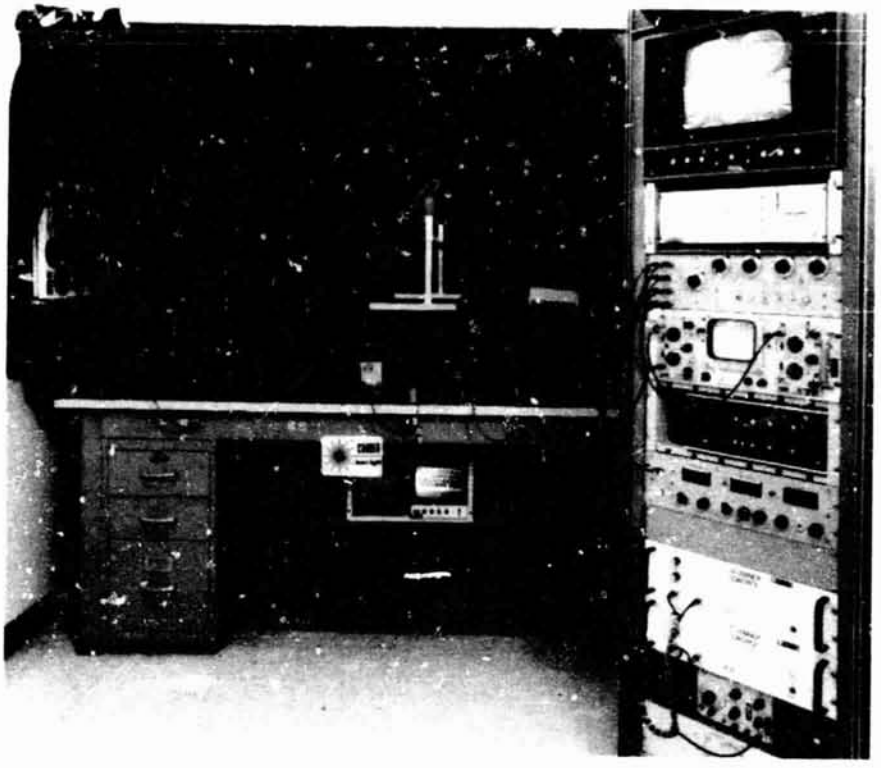


FIGURE 2. ENERGY BAND DIAGRAM OF p-i-n JUNCTION

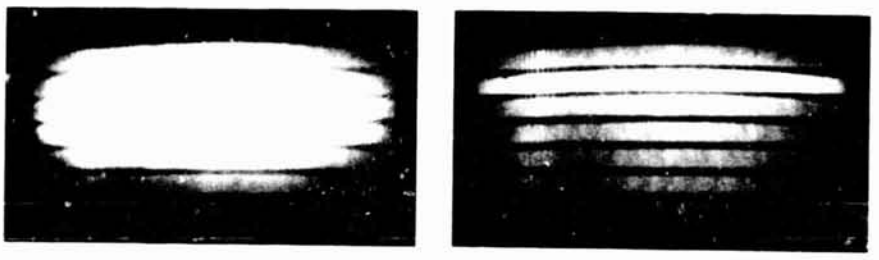
- OPTIMIZE ABSORPTION AND I-LAYER INTERNAL ELECTRIC FIELD BY ADJUSTING THE THICKNESSES AND FILM CHARACTERISTICS

Current Activity

- o INVESTIGATING DEGRADATIONAL MECHANISMS ON COMMERCIAL A-SI SOLAR CELL PRODUCTS.
  - o THESE CELLS ARE TYPICALLY LOW EFFICIENCY BUT PROVIDE AN OPPORTUNITY FOR CONTRIBUTING DIRECTLY TO THE IMPROVEMENT OF COMMERCIAL TECHNOLOGY.
- o EXAMINING DEVICE STRUCTURES, AND OPTICAL AND ELECTRICAL CHARACTERISTICS.
  - o POLARIZING MICROSCOPE, SEM, CURVE TRACER, SUN-U-LATOR SCLS, FTIR, CAPACITOR BRIDGE, HIGH PRECISION ELECTROMETER, ELLIPSOMETRY, ETC.



Solar-Cell Laser Scanner



(a) (b)

FIGURE 3. SCLS IMAGE OF SAMPLE 7703-1 BY TWO DIFFERENT MONOCHROMATIC LIGHTS (4880Å (a) AND 5145Å (b))

- IT ALLOWS FOR NON-DESTRUCTIVE EVALUATION AND FAILURE ANALYSIS OF ENTIRE SOLAR MODULE AS WELL AS INDIVIDUAL CELL
- IT MAKES IT POSSIBLE TO DISCRIMINATE BETWEEN ACTIVE AND PASSIVE (COSMETIC) DEFECTS
- IT MAY PROVIDE MEANS FOR ABSTRACTING INFORMATION ON DIFFERENT LAYERS OF THE THIN-FILM SOLAR CELL

Future Plans for α-Si Solar Cells

- Upgrade SCLS capability to probe photocurrent response in different layers of the device.
- Evaluate and characterize module degradational phenomena in thin-film amorphous silicon solar cells with particular emphasis on micro and macroscopic defects/flaws.
- Develop methods to analyze failure modes resulting from degradation due to environmental effects such as optical, thermal, mechanical and moisture.