한국전기전자재료학회 춘계학술대회 논문집, 1995.

태양전지의 효율측정
Characterization of Solar Cells

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ABSTRACT

A solar cell *I-V* (current-voltage) *characteristic measurement facility* is crucial for the characterisation of solar cells. The solar cell I-V tester, "Solar SAIT" has been designed and fabricated to characterize the solar cells at SAIT.

I. Introduction

"Solar SAIT" measures basic solar cell output parameters such as short-circuit current, I_{sc}, open-circuit voltage, V_{oc}, maximum power-point current, I_{mp}, maximum power-point voltage, V_{mp}, current density, J_{sc}, efficiency, E_{ff} and fill factor, *FF* as well as sweeping through the entire illuminated I-V curve.

II. Measurement Techniques

There are two techniques of measuring the solar cell characteristics. First technique is to measure the power in the incident sunlight using a pyranometer and the electrical power when the cell is generating at the maximum power point. However, this technique has the difficulty in that the performance of the cell measured in this way will heavily depend on the precise spectral content of the sunlight. The other technique is to measure the characteristics of a cell with calibrated reference cells. The reference cells are calibrated by a central test authority under standard illumination conditions. The characteristics of test cell is measured relatively to the reference cell. In this paper the technique using reference cell is used as a measurement method. The reference cell was calibrated at Sandia National Laboratory, U.S.A. and the University of New South Wales, Australia. The measured calibration error is within 1.0 - 2.0 % from the two centers.

III. Characterization of Solar Cells

Four parameters - I_{sc}, V_{oc}, FF and E_{ff} are usually used to characterize solar cell outputs. The short-circuit current, I_{sc} means that the generated current from a solar cell without any load. It is ideally, equal to the light-generated current I_L.

$$I_{sc} = I_L = I_0 (e^{qVoc/kT} - 1) \qquad (1)$$

The open-circuit voltage, V_{oc} means that a solar cell has an infinite load ($R=\infty$) or just simply it is open-circuited ($I=0$). Setting I to zero in Eq.(1) gives the ideal value

$$V_{oc} = \frac{kT}{q} \ln \left(\frac{I_L}{I_0} + 1 \right) \qquad (2)$$

where I_0 is the diode saturation current given as below

$$I_0 = A\left(\frac{q D_e n_i^2}{L_e N_A} + \frac{q D_h n_i^2}{L_h N_D} \right) \qquad (3)$$

For maximum V_{oc}, I_0 needs to be as small as possible. One possible way to calculating upper limits on V_{oc} is to assign favorable values to the semiconductor parameters in Eq.(3) while still keeping them within the range which expected to be required to produce good solar cells[1].

The fill factor, *FF*, is defined as

$$FF = \frac{V_{mp} I_{mp}}{V_{oc} I_{sc}} \qquad (4)$$

It is a measure of how "square" the output characteristics are. Ideally, it is a function only of the *open-circuit voltage*, V_{oc}. Defining a normalized voltage, v_{oc}, as $V_{oc}/(kT/q)$, an empirical expression describing this relationship to about four significant for $v_{oc} > 10$ is below[2].

$$FF_0 = \frac{v_{oc} - \ln(v_{oc} + 0.72)}{v_{oc} + 1} \qquad (5)$$

The energy-conversion efficiency, E_{ff}, is given by

$$E_{ff} = \frac{V_{mp} I_{mp}}{P_{in}} = \frac{V_{oc} I_{sc} FF}{P_{in}} \qquad (6)$$

where P_{in} is the total power in the light incident on the cell(Here, the power density content of AM1.5 one sun is 1000 W/m^2 which is scaled up by the photovoltaic program of the U.S. government in 1977.)[3].

IV. Development of system

The I-V tester,"Solar SAIT" system consists of an illumination source, a simulator block, a DC power source, a measurement instrument and a 486-PC (GPIB installed).

The system is provided with a temperature regulated, copper susceptor plate to which the cells are held using a vacuum. This results in good electrical contact and reduces the increase in cell temperature during measurement to less than 0.1 %

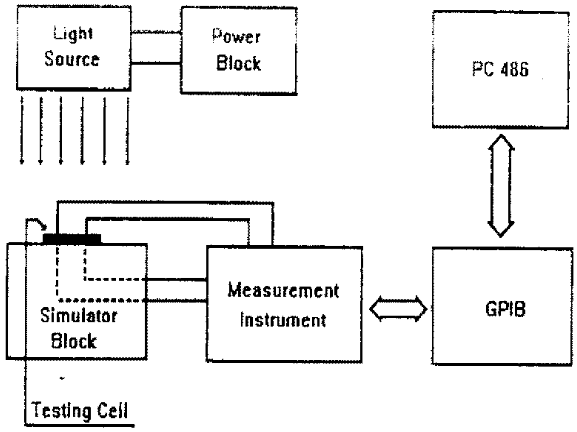

Fig.1 Schematic diagram of I-V tester

The illumination source consists of four ELH lamps. The ELH lamp is a tungsten-halogen projector lamp that has a dichroic multi-mirrored reflector which allows infrared wavelength to pass out the rear of the lamp. This effect enhances the visible content of the output light beam, lamp's spectral content is then reasonably close to sunlight. In order to have an accurate measurement, a four-point probe scheme is used. Current and voltage are measured separate through each of two probes. This reduces the series resistance of the measurement leads and associated contact resistances.

The operating software of the I-V tester is programmed using a virtual instrument tool, "Lab View". The software can plot the I-V characteristics curve and display all the measured and calculated parameters immediately after measurement[Fig.2].

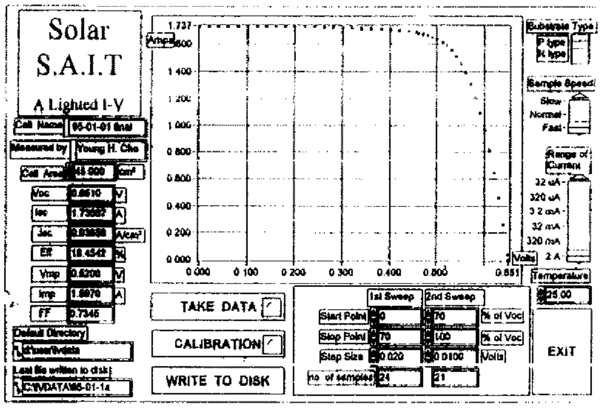

Fig.2 The displayed measurement result of the Solar SAIT

V. Performance result

To find out the performance of the measurement, a BCSC(Buried Contact Solar Cell) cell was measured and compared at the University of New South Walse and SAIT. The result showed that the "Solar SAIT" is in good agreement in the accuracy of measurement with the I-V tester at the University of New South Wales[Fig. 3, Table 1].

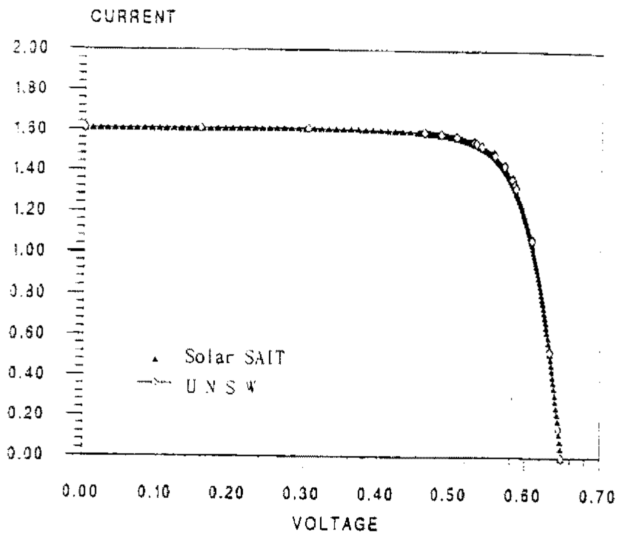

Fig.3 Comparison of the BCSC cell

Parameter	U N S W	Solar SAIT	Difference
Area (cm^2)	45.71	45.71	0.00%
V_{oc} (mV)	648.49	647.85	0.09%
I_{sc} (mA)	1610.79	1610.65	0.0086%
P_m (mW)	825.38	819.73	0.69%
FF	79.03	78.56	0.60%
Eff	18.05	17.93	0.67%

Table 1.Comparison of cell parameter

VI. Conclusion

The solar cell I-V tester,"Solar SAIT" which can characterize solar cells has been designed and fabricated at Samsung Advanced Institute of Technology. It's accuracy of the measurement is in good result. It has only less than 0.7 % of overall measurement difference with the I-V tester of UNSW.

Notation

q	electronic charge
k	Boltzmann's constant
T	absolute temperature
D_e	electron diffusion constant
D_h	hole diffusion constant
n_i	intrinsic concentration
L_e	diffusion length for electrons
L_h	diffusion length for holes
N_A	densities of acceptors
N_D	densities of donners
A	cross sectional area
R	resistance

References

1.H.J.Hovel, Solar Cells, Vol.11. Semiconductor and semimetals Series (Academic Press, New York, 1975)

2.M.A.Green, Solar Cells Operating Principles,Technology and System Applications, pp.79-81, (University of New South Wales,1992)

3.Terrestrial Photovoltaic Measurement Procedures,Report ERDA/NASA/1022-77/16, June 1977.