THE PERFORMANCE OF ADVANCED III-V SOLAR CELLS †

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ABSTRACT

Test results show triple junction solar cells with efficiencies as high as 27% at 28C and 136.7 mw/cm^2. Triple junction cells also achieve up to 27.5% at -120C and 5 mw/cm^2, conditions applicable to missions to Jupiter. Some triple junction cells show practically no degradation as a result of Low Intensity Low Temperature (LILT) effects, while others show some; this degradation can be overcome with minor changes to the cell design.

INTRODUCTION

In the last decade solar cell efficiencies have increased by over 50% with significant improvements in the last year. This paper provides data for recently manufactured triple junction Gallium Arsenide (GaAs) based solar cells from three manufacturers: Emcore, Spectrolab, and Tecstar.

This data is from solar cell samples taken from production lots from each of the manufacturers. However, some differences may be expected between these cells and average production cells as the authors did not require the selection of cells representing the average of a production lot.

TEST CONDITIONS

Table I provides the intensity versus temperature matrix which defines the conditions under which the cells were tested. This matrix was devised to include three temperatures, 0C, 10C and 28C, common to all intensities. This was done to observe the effects of intensity change on cell output.

Table I
Cell Test Conditions

Intensity (mw/cm^2)	Test Temperatures (C)
5	-120, -100, -80, -70, -50, -30, -10, 0, 10, 28
58.4	-50, -30, -10, 0, 10, 28
136.7	0, 10, 28, 50, 70

CELLS TESTED

Tests were run on Emcore, Spectrolab, and Tecstar, bare, triple-junction solar cells. Protection diodes were present on the Tecstar cells, but were not connected. Protection diodes were not used at all on the Emcore and Spectrolab cells. Table II summarizes the cell characteristics.

Table II
Cell Characteristics

Manufacturer	Area in cm^2	Thickness in Microns
Emcore	27.48	140
Spectrolab	26.70	190
Tecstar	30.20	178

TEST DESCRIPTION

Prior to the characterization tests, the cells were electrically checked for low shunt resistance and visually examined for cracks to determine their condition. All were in good shape. Following the bonding of cells to copper test plates, they were similarly rechecked and were also checked for electrical isolation from the test plate. The cells still appeared to be in good condition and were well isolated from their test plates.

An additional inspection of the bonded Emcore cells under X-25 illumination showed that two of the cells appeared to have 0.5 cm long and wide "X" cracks that were barely perceptible and initially thought to be scratches. Electrical checks using the X-25 solar simulator and a Large Area Pulsed Solar Simulator (LAPSS) set to 136.7mW/cm^2 intensity and a cell temperature of 28C showed no particular difference in the performance of these cells and the other cells on the test plates.

Unfortunately, the LAPSS subjected the first Emcore cell tested to reverse bias that severely degraded it. This would not have happened had the cell had its protection diode connected.

During the testing that followed, which thermally stressed the cells somewhat, the cracks in the two

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Emcore cells mentioned above each propagated across the entire cell. This noticeably influenced cell performance. Cracks also occurred on an Emcore cell, a Spectrolab cell and a Tecstar cell. This established the number of good Emcore cells to four, Spectrolab cells to seven, and Tecstar cells to seven. The stresses the cells endured during these tests is expected to be higher than in space flight due to their mounting on a copper plate as opposed to a graphite face sheet substrate or similar. The adhesive used to fix the cells to the plate was NuSil CV-2568 Silicone Elastomer, which is similar to G.E. RTV-566 with small glass beads. NuSil SP-120 Clear Primer was also used sparingly. Some of the cracks were possibly in the cells at delivery, some were probably caused during the interconnect soldering, cell to plate bonding, or cell cleaning. It is difficult to conclude exactly when an individual cell was damaged. However, two things are clear. Care must be taken when handling these relatively thin cells and the thinner cells are more prone to damage.

Initial tests were used to compare results from the X-25 and the LAPSS. It was obvious that the LAPSS, which did not have the latest filtering available from Spectrolab, lacked sufficient infrared to adequately power the bottom, Germanium, junction. Therefore, all of the characterization tests used a modified Spectrolab X-25 solar simulator. The simulator modification refers to a set of adjustable filters used to correct the spectrum to simultaneously produce the proper calibration value from both the top and middle junction balloon standards of dual junction solar cells. A separate set of balloon-calibrated standards from each manufacturer was used to setup the X-25. In addition, I-V curves of the test cells were all obtained with an active load (bi-polar power supply) that had a diode circuit across its output to limit the reverse voltage across any test cell to 0.7 volts. The results of these tests are shown in Figure 1 below. The manufacturers are not identified by name because the authors are not certain about how each manufacturer selected cells from the production lots.

LILT EFFECTS

It is clear that the manufacturers represented by the squares and the diamonds suffer from LILT effects. Both of the manufacturers have stated that they can relatively easily eliminate these effects.

The LILT effects can be caused by at least two different defects, a diode in the contact metalization and a low internal shunt resistance. These tests show both defects.

Figure 2 shows a LILT effect in an I-V curve that results in a "flat" near the peak power point due to an diode in the metallization. Figure 3 below shows the LILT effect due to low internal shunt resistance which results in decreasing current as a function of increasing voltage in the curve's "constant current" region.

Figure 1
Efficiency of Triple Junction Cells from Three Manufacturers as a Function of Temperature at Intensities of 5, 58.4, and 136.7 mw/cm^2

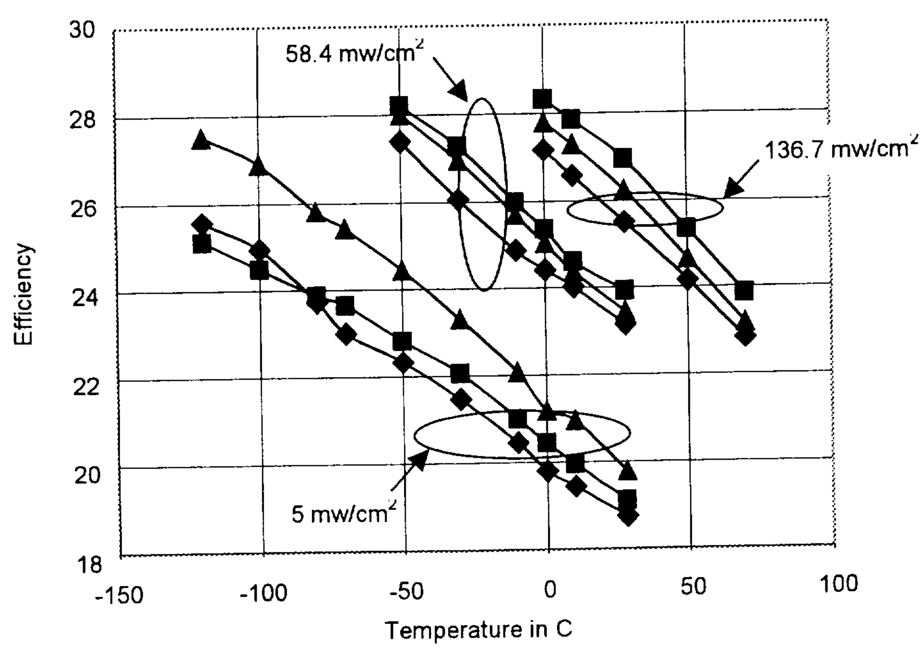

Figure 2
Solar Cell I-V Curve at –120C and 5 mw/cm^2 Showing the LILT
Effect Caused by a Diode in the Metallization

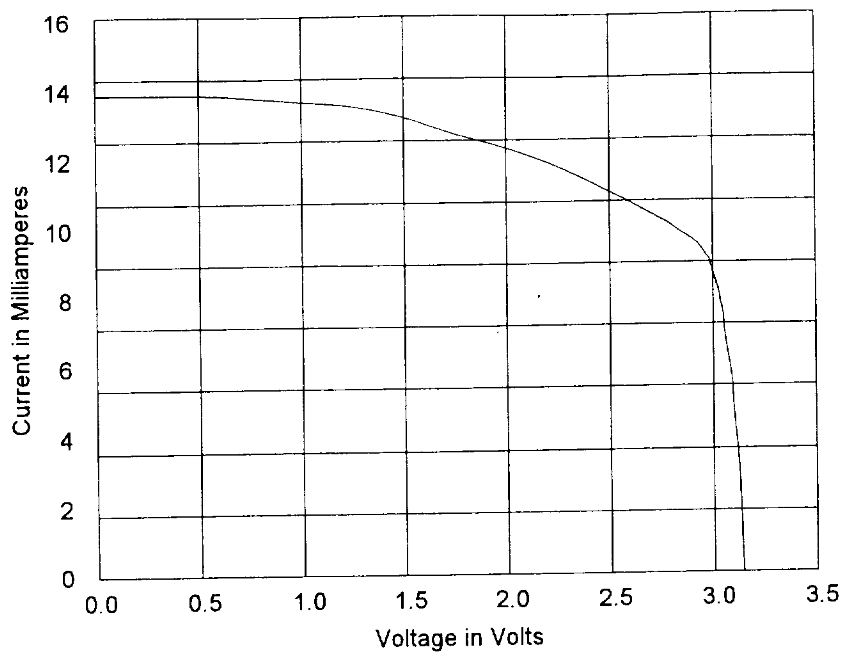

Figure 3
Solar Cell I-V Curve at –120C and 5 mw/cm^2 Showing the LILT
Effect Caused by Low Shunt Resistance

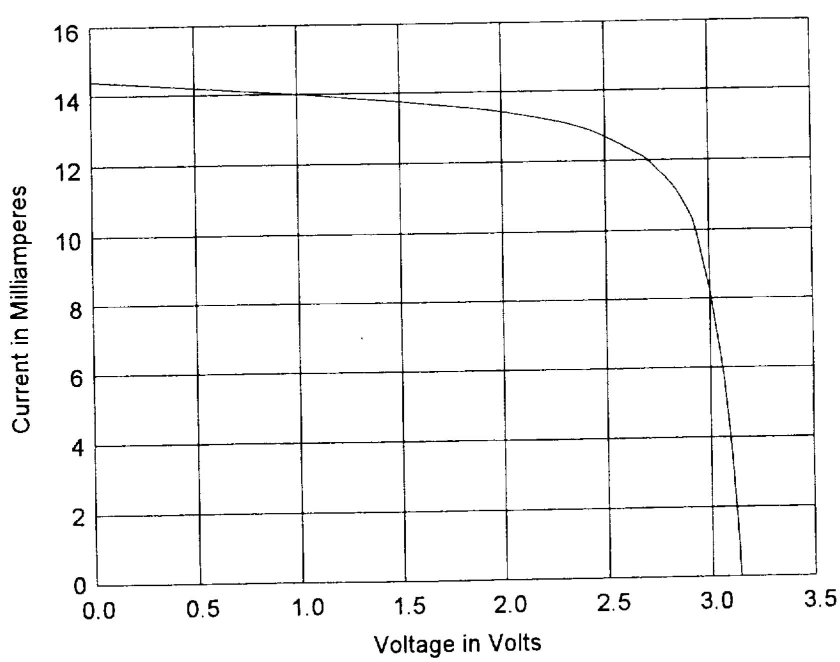

Figure 4
Solar Cell I-V Curve at –120C and 5 mw/cm^2 Showing Negligible LILT Effects

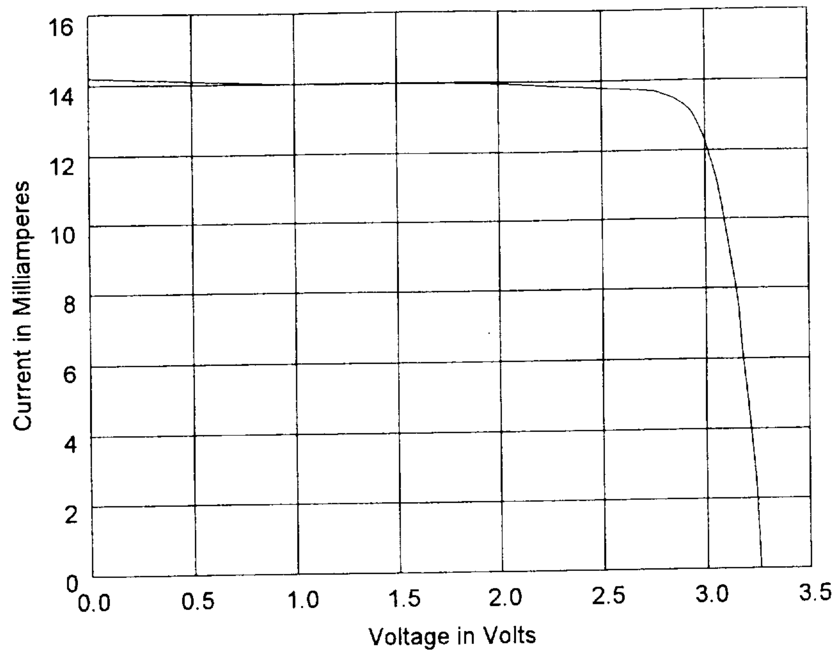

Figure 4 shows an I-V curve at –120C and 5 mw/cm2 that shows negligible LILT effects.

CONCLUSION

All the cells tested demonstrated efficiencies that were unobtainable even a short time ago.[1] While some triple junction solar cells exhibited LILT effects that were detrimental to cell efficiency, one manufacturer has shown that it is possible to fabricate cells that do not show LILT effects. All of the manufacturers have stated the causes of the effects are known and that they can be easily eliminated.

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[1] Paul Stella, Gregory Davis, Robert Mueller, Dmitri Krut, David Brinker, David Scheiman, The Performance of Advanced Solar Cells for Interplanetary Missions, *Twentieth IEEE PVSC*, 2000, pp. 1354 – 1357.

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