InGaP/InGaAs-on-Ge Concentrator Solar Cell for Space Power Generation

Contract—

NAS3-99174

Author—

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Contractor—

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WORK PERFORMED THIS PERIOD

TASK 1.—Grow and characterize a lattice-matched passivating window for InGaP

$Al_{0.33}In_{0.67}P$ has been chosen as the lattice-matched passivating front and back window layer of the 1.62 eV InGaP top cell. High-resolution X-ray diffraction (HRXRD) studies of this material grown by metal organic vapor phase epitaxy (MOVPE) in our laboratory show it to be of excellent crystalline quality. Hall effect measurements show that the $Al_{0.33}In_{0.67}P$ films can be doped n- type (Si) up to $2x10^{19}/cm^3$ and p-type (Zn) to mid-$10^{18}/cm^3$ level. Secondary electron mass spectrometry (SIMS) analysis of the films revealed that the oxygen concentration in these films was in the low to mid-$10^{17}/cm^3$ level. Although the oxygen level is slightly higher than that found in non-aluminum containing III-V alloy layers, it is not believed to be high enough to be detrimental to the performance of the InGaP top cell. However, we are continuing process improvement studies to reduce the oxygen level further.

TASK 2.—Fabricate and test passivated InGaP top cells

We have completed the fabrication and processing of the initial InGaP top cell. The epilayer structure is shown in Figure 1.

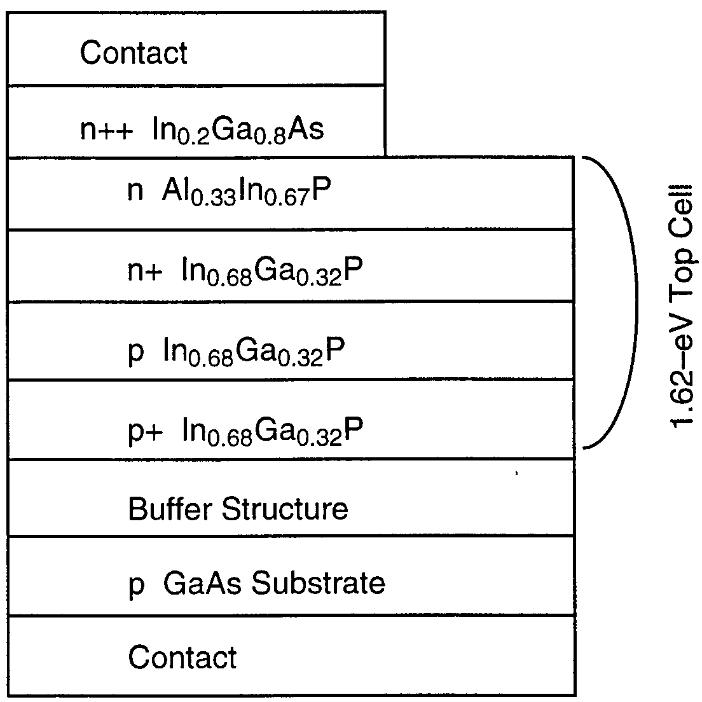

Figure 1.—Epilayer structure of the 1.62–eV n/p InGaP top cell.

The current-voltage (I-V) characteristic of a 1.62-eV n/p $In_{0.68}Ga_{0.32}P$ solar cell is shown in Figure 2. The air-mass zero (AM0), one-sun efficiency (η) of 11.56%, the open-circuit voltage (V_{oc}) of 1.13 V, the short-circuit current density (J_{sc}) of 17.0 mA/cm^2, the grid shadow (G.S.) of 5%, and the fill factor (FF) of 82.4% represent the best cell performance on this particular wafer. However, 50% of the devices had AM0, one-sun efficiencies in excess of 11%. We expect that this cell will demonstrate an AM0, one-sun efficiency of 15.7% and a J_{sc} of 22.4 mA/cm^2 with an optimized anti-reflective (AR) coating.

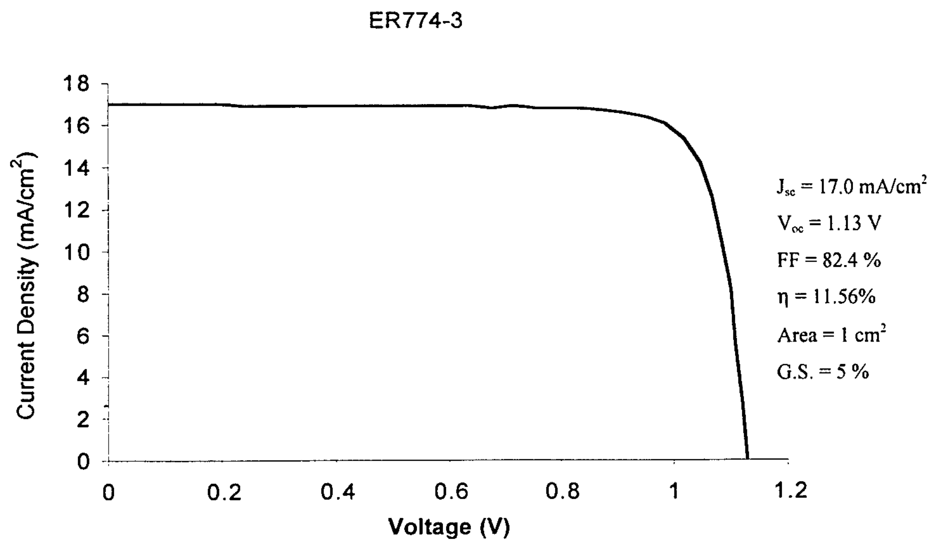

Figure 2.—Current-voltage characteristic of a 1-cm^2 1.62-eV n/p InGaP solar cell under AM0, one-sun illumination.

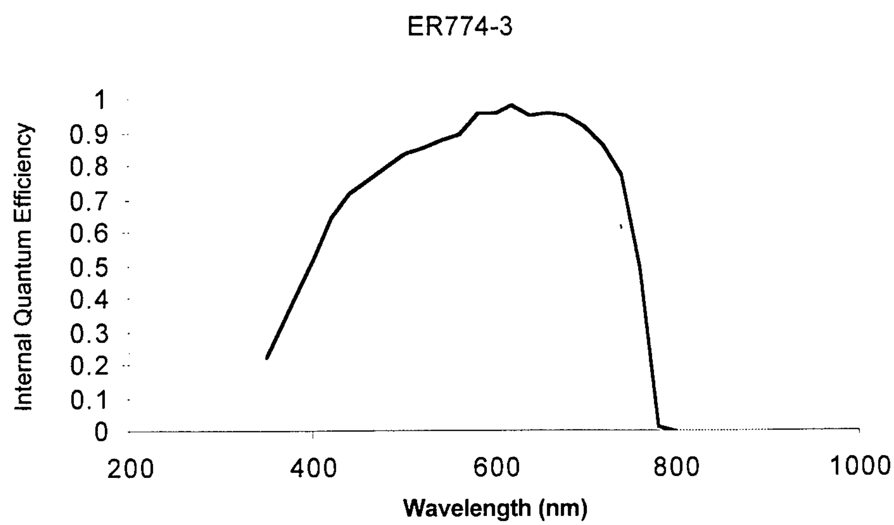

Figure 3.—Quantum efficiency of a 1-cm^2 1.62–eV n/p InGaP solar cell.

Note that all tests were done under AM0, one-sun conditions as a first step towards evaluating this cell. Large area pulse solar simulator (LAPSS) tests under 1- to 20-sun concentrations will follow.

TASK 3.—Grow and characterize an InGaAs tunnel junction.

We have successfully demonstrated an InGaAs tunnel junction by degenerately p- and n-doping successive thin (0.025 μm) layers of InGaAs on our standard buffer layer on a GaAs substrate, and then testing the tunnel diode characteristics. We have not yet performed any dopant diffusion studies in these tunnel diode structures.

TASK 4.—Fabrication and testing of two-terminal InGaP/InGaAs monolithic tandem cells on GaAs substrates.

We are currently in the process of fabricating and testing InGaP/InGaAs dual-junction cell structures. The initial epilayer structure of the dual–junction cell grown on GaAs (100) substrate with a 6° offcut towards the <111>B direction is shown in Figure 4. Tests are being performed under AM0, one-sun conditions for initial optimization purposes.

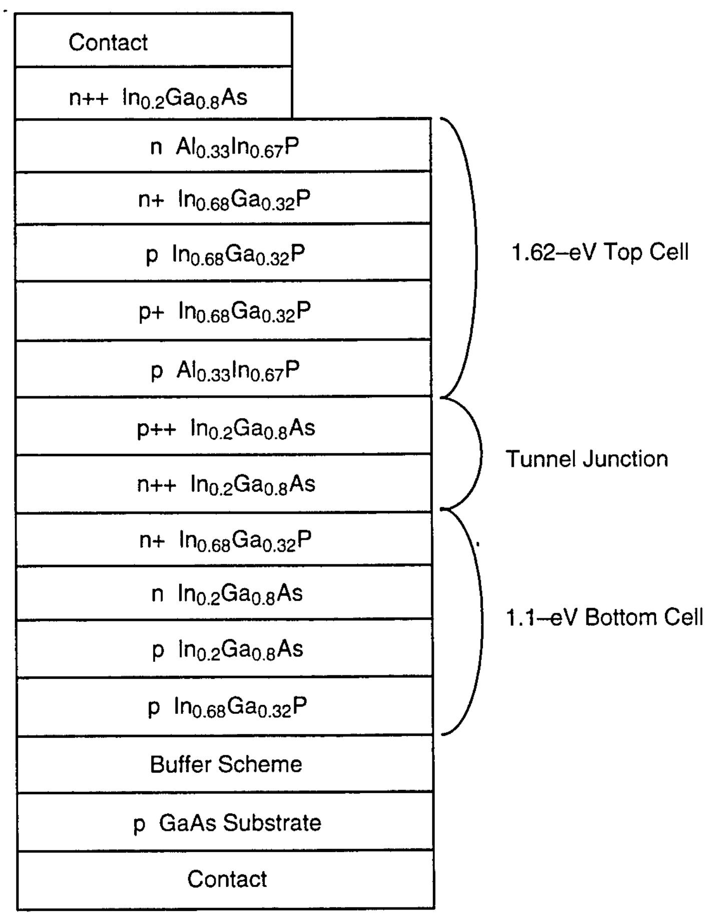

Figure 4.—Epilayer structure of the 1.62-eV InGaP/1.1-eV InGaAs dual-junction cell.

CURRENT PROBLEMS AND PROPOSED CORRECTIVE ACTION

No major problems are envisioned towards the fulfillment of program objectives. However, several test experiments and optimization of materials structures will be required. It is not sure at this point what effect if any, the presence of oxygen in the AlInP window layer (Task 1) will have on the performance of the top cell. Initial results indicate that the oxygen content is not large enough to affect the cell performance. Efforts will continue to reduce the oxygen content in the AlInP layer. In the case of the tunnel junction (Task 3), some loss is expected within the junction region because the material is of the same bandgap as the bottom cell. However, we are making the tunnel junction layers very thin to minimize this loss. We are also considering the possibility of replacing the InGaAs tunnel junction with a higher bandgap material such as InGaP, which will eliminate the absorption problem completely. Another potential problem related to the tunnel junction is the possibility of dopant diffusion. We are planning to perform a SIMS analysis of the complete dual junction cell structure to investigate this further.

WORK TO BE PERFORMED DURING THE NEXT PERIOD

During the next reporting period, the emphasis will be on LAPPS testing the individual InGaP and InGaAs cells under 1- to 20- sun concentrations. The cell structures and processing parameters will continue to be optimized to realize the highest possible efficiency values under these conditions. For the dual-junction cell, initial efforts during the next reporting period will be limited to optimizing the structure and processing to obtain the highest efficiency values under AM0, one-sun conditions, until the individual cell structures are optimized for higher concentrations.

COST AND COMPLETION ESTIMATES

The March costs have been calculated and the estimates are as follows:

- Total Costs (cumulative) through March 22, 2000 .... $ 34,593
- Estimated costs for the following quarter.. $ 25,000
- Estimated costs to the contract completion .... $ 265,393
- Estimated physical completion through March 22, 2000 .... 10%

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