Integrated Phase Array Antenna/Solar Cell System For Flexible Access Communications (IA/SAC)

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Abstract

This paper describes recent efforts to integrate advanced solar cells with printed planar antennas. Several previous attempts have been reported in the literature, but this effort is unique in several ways. It uses Gallium Arsenide (GaAs) multi-junction solar cell technology. The solar cells and antennas will be integrated onto a common GaAs substrate. When fully implemented, IA/SAC will be capable of dynamic beam steering. In addition, this program targets the X-band (8 – 12 GHz) and higher frequencies, as compared to the 2.2 – 2.9 GHz arrays targeted by other organizations. These higher operating frequencies enable a greater bandwidth and thus higher data transfer rates. The first phase of the effort involves the development of 2 x 2 cm GaAs Monolithically Integrated Modules (MIM) with integrated patch antennas on the opposite side of the substrate. Subsequent work will involve the design and development of devices having the GaAs MIMs and the antennas on the same side of the substrate. Results from the phase one efforts will be presented.

Introduction

Recently, several attempts to integrate printed planar antennas onto solar cells have been reported in the literature. The first work reported in 1995 involved attaching solar cells to the surface of a single micro-strip antenna for a micro-satellite application [1]. Measured data from this study showed very good antenna performance with the solar cells having very little impact on the radiation pattern and return loss at S-band. In 1999, JPL attempted to combine antenna and solar cells for a Mars rover application at 400 MHz [2]. These early works attempted to demonstrate feasibility using commercial solar cells and a single antenna. Integrating multiple antenna elements and solar cells on the same surface, was first reported by a group in Europe [3-4]. Two small antenna arrays integrated with solar cells were demonstrated. The first was an 8-

element (4x2) array with 9 solar cells strips connected in series and superimposed on the antenna elements. The second was a 4x4 array of circularly polarized slot dipoles co-located on the same surface of the solar cells array. Amorphous silicon solar cells with about 5-12% efficiency were used in both demonstrations.

Compared to prior work, the GRC proposed integrated phased array/solar array cell (IA/SAC) concept is technologically more advanced, and is unique in several ways. As stated previously, the earlier work used silicon cells with a maximum efficiency of about 15%. This effort uses GaAs based monolithically integrated module (MIM) technology, which has a greater efficiency and can be easily tailored to produce a desired voltage. In addition, IA/SAC modules will be integrated on a common substrate as opposed to the previous efforts that developed the components on separate surfaces then combined them post processing. Finally, when fully implemented, IA/SAC arrays will be capable of dynamic beam steering in the X-band (8-12 GHz) or higher frequencies. To the best of our knowledge, in all prior developmental efforts, the antennas are passive arrays capable of only fixed point-to-point communications operating in the 2.2 – 2.9 GHz range.

Experimental Procedure

In the first phase of the project, we designed and developed single junction 2x2cm GaAs MIM devices. MIM devices are grown on semi-insulating substrates and have both the positive and negative contacts on the top-side of the device (figure 1). Elimination of the contacts on the back surface allows the semi-insulating substrate to act as the dielectric layer between the ground plane and radiating elements of the antenna.

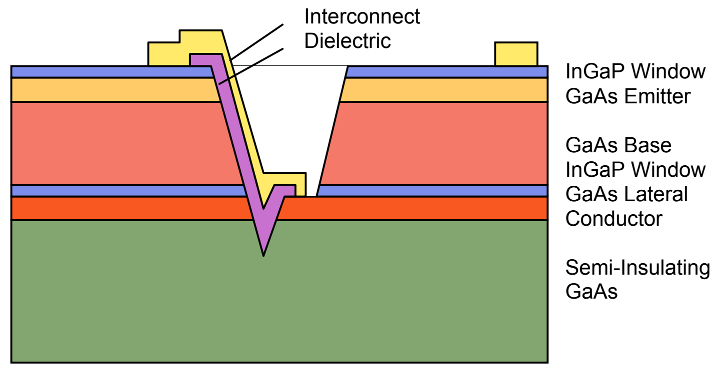

Figure 1. Diagram of a GaAs MIM device showing the device layers and interconnect.

The use of MIM technology was a crucial step towards the ability to integrate the solar cell and antenna on a common substrate. The Photovoltaic and Space Environments (PVSE) Branch of NASA Glenn originally developed the MIM concept for thermophotovoltaic (TPV) energy conversion. This device has been the focus of a multi-million dollar, multi-year development by Bechtel Bettis, Inc [5, 6, 7]. One of the main goals in the first phase of this effort was to increase the size of the GaAs MIMs to 2cm x 2cm. This is significantly larger than previous devices and it is anticipated that these MIM devices will have a conversion efficiency comparable to GRC produced GaAs solar cells (~20% efficiency). The initial devices will have a structure similar to figure 2 but will be optimized for the IA/SAC project.

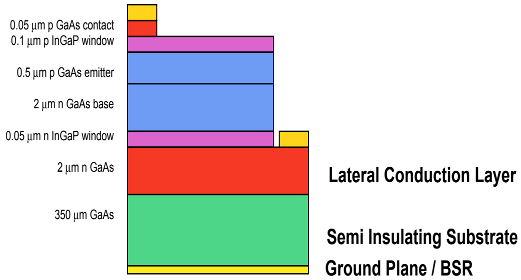

Figure 2. GaAs single junction IA/SAC MIM device structure.

The GaAs MIMs were grown on 2 inch, double side polished GaAs wafers by Organometalic Vapor Phase Epitaxy (OMVPE) at 620^{0}c and 190 torr. The specular films were then processed into 1cm x 1cm MIMs. After AM0 current-voltage (IV) measurements were taken, patch antennas were deposited on the opposite side of the wafer by E-beam evaporation. After deposition of the antenna, AMO IV measurements were repeated to determine whether there was any degradation to the solar cells.

Results and Analysis

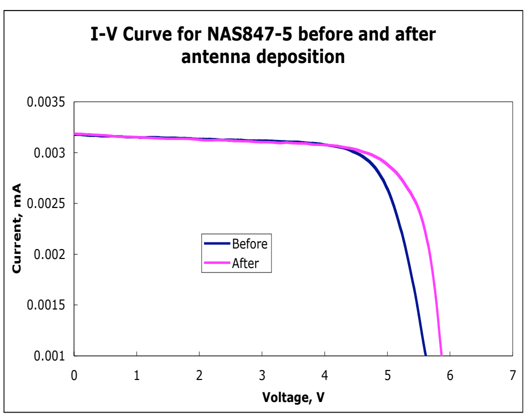

Figure 3. Pre- and Post antenna deposition AM0 IV measurements.

The IV measurements in figure 3 show that there was no degradation in the performance of the solar cells due to the deposition of the antenna. In fact, an increase in the cells performance is noted. This is most likely due to additional contact annealing that occurs during the deposition of the antenna. At the time of this writing, the results of the testing performed in the Microwave Antenna Range at NASA GRC were unavailable.

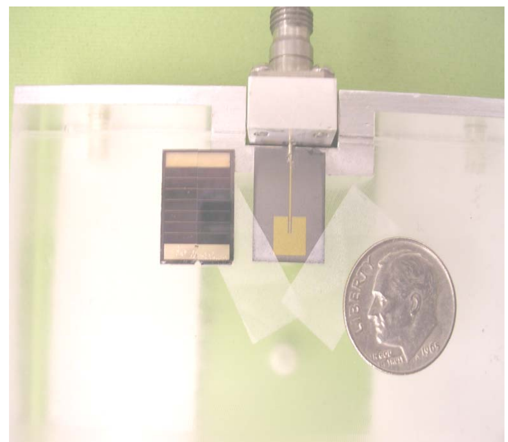

Figure 4. IA/SAC module being mounted for testing in antenna range.

Conclusion

We have demonstrated the feasibility of combining advanced solar cells with RF antenna technology on a common substrate with no degradation to the solar cells. Future phase one work will focus on characterizing the antenna and increasing the size of the MIM to 2cm x 2cm.

References

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