N86-17864

TESTING OF GALLIUM ARSENIDE SOLAR CELLS ON THE CRRES VEHICLE*

Terry M. Trumble
Air Force Wright Aeronautical Laboratories
Aero Propulsion Laboratory
Wright Patterson AFB, Ohio

A flight experiment has been designed to determine the optimum design for gallium arsenide (GaAs) solar cell panels in a radiation environment. Elements of the experiment design include, different coverglass material and thicknesses, welded and soldered interconnects, different solar cell efficiencies, different solar cell types, and measurement of annealing properties. This experiment, designated AFAPL-801, is scheduled to fly on the Combined Release and Radiation Effects Satellite (CRRES) to be launched in July of 1987 (Fig. 1). This satellite will simultaneously measure the radiation environment and thus, for the first time, provide engineering data on solar cell degradation that can be directly related to radiation damage.

INTRODUCTION

The initial portion of this flight will be in low earth orbit (LEO). The LEO portion of the flight will be a circular orbit at an altitude of 358 km inclined at an angle of about 28.5 degrees. During this ninety day orbit NASA will conduct their experiments and the AFAPL-801 experiment will be turned on. The CRRES vehicle will then be boosted into geosynchronous transfer orbit (GTO) for a 3 year mission. The GTO will be elliptical with an apogee of 35,000 km and a perigee of 400 km. The angle of inclination will be about 18 degrees. It is in this orbit that both the AFAPL-801 experiment and the SPACERAD experiments will be conducted. The SPACERAD experiments are a group of experiments designed to accurately measure the earth's trapped radiation belts (Fig. 2).

EXPERIMENT DESIGN

The design of an experiment of this type will take into account the different types and ranges of efficiencies of GaAs solar cells available. It will also provide a fiducial from which to judge the state-of-the-art of radiation resistance in solar cells. To accommodate these requirements, both liquid phase epitaxy (LPE) and metal organic chemical vapor deposition (MOCVD) GaAs solar cells will be used. Additionally, a string of K 4 3/4 silicon solar cells will be used as a reference. The K 4 3/4 silicon cells have been the workhorse of the industry and the wealth of data on these cells provides an excellent data base for comparisons. Finally, to round out the experiment one string of the thin silicon cells has been included on the test panel.

* Development of this experiment is being accomplished under AF Contract #F33615-79-C-2039 by the Space and Communications Group of Hughes Aircraft Co., Los Angeles CA.

The AFAPL-801 experiment consists of two flight panels, an ambient panel (Fig. 3), and an annealing panel (Fig. 4). Each panel is 6" x 12". The ambient panel will be aluminum honeycomb and will have 12 cell strings mounted on it. Different cell strings will use welded and soldered interconnects. Coverglass thickness will vary from about 2.5 mils to about 30 mils. Both microsheet and quartz coverglasses will be used. The LPE GaAs solar cells will have 16%, 17% and 18% beginning of life (BOL) efficiencies. The MOCVD GaAs cell string will be 16% efficient, BOL. The thin silicon solar cell string, A K 7 3/4 cell will also be about 13.5% BOL. All of these efficiencies are quoted at a temperature of 25°C.

The annealing panel is a glasscloth polyimide core honeycomb. This panel will only use the LPE GaAs solar cells. There are four pairs of cell strings. The first pair of cell strings are for temperature reference and to evaluate the effect coverglass thickness on annealed versus unannealed cells. These cell strings are designed to run at 70°C. The second pair of cell strings will be continuously heated at 150°C to evaluate the advantages of continuously annealing in space. A special heater has been designed to provide a continuous 150°C temperature over the lifetime of the flight experiment. The third pair of cell strings will be heated to 150°C for two hours a week to evaluate intermittent annealing properties of cell strings. The fourth and final pair of cells will be forward biased once a week and also will be run at 250°C for two hours a week. This experiment will complement the intermittent experiment and will determine the practicality of using intermittent heating to anneal radiation damage in space.

DATA MATRIXING

The unique feature of the design of this experiment is to matrix the data from different cell strings. Each of the total of twenty cell strings can be compared to each of the other cell strings. Of course some of the comparisons are of more value than others. The following is a list of the cell strings and the variations associated with each cell string. The cell strings are given in no particular order.

<u>Ambient panel</u>

Cell Type	Efficiency	Interconnect	Coverglass Thickness	Material
1. GaAs	16%	Solder	2.5 mils**	Quartz
2. GaAs (MOCVD)	16%	Solder	6 mils	Quartz
3. GaAs	16%	Welded	4 mils	Quartz
4. GaAs	17%	Solder	4 mils	Microsheet
5. GaAs	16%	Solder	6 mils	Quartz
6. Si (Thin)	13.5%	Solder	12 mils	Quartz
7. GaAs	16%	Welded	12 mils	Microsheet
8. GaAs	18%	Solder	12 mils	Quartz
9. Si (ref)	13.5%	Solder	12 mils	Microsheet
10. GaAs	16%	Solder	20 mils	Quartz
11. GaAs	16%	Welded	20 mils	Quartz
12. GaAs	16%	Welded	30 mils	Quartz

Annealing Panel

13. GaAs	16%	Welded	6 mils	Quartz
14. GaAs	16%	Welded	12 mils	Quartz
15. GaAs	16%	Welded	6 mils	Quartz
16. GaAs	16%	Welded	12 mils	Quartz
17. GaAs	16%	Welded	6 mils	Quartz
18. GaAs	16%	Welded	12 mils	Quartz
19. GaAs	16%	Welded	6 mils	Quartz
20. GaAs	16%	Welded	12 mils	Quartz

**Note: 1 mil = .001 inch
Note: All GaAs solar cells are made by the LPE process unless noted otherwise.

The current (I) and the voltage (V) will be measured at 16 loads and an IV curve generated. The temperature of the ambient panel will be taken and the temperature of each string on the annealing panel will be taken. The IV curves will be taken at a relatively slow data rate thus there will probably be some data slewing, requiring that several data sets be taken for analysis to ensure accuracies of at least 3% or better. There are two different load banks, one for the silicon cells and the other for the gallium arsenide solar cells. This ensures accurate measurements of both types of cells at the knee of the curve even after three years of operation.

A few examples of how the matrix will be used are as follows. If cell string #7 is used as a reference, the matrix is based upon the use of a 12 mil coverglass on a 16% efficient cell. The temperature of the cell is monitored and the IV points taken. The string is now compared to cell string #14 on the annealing panel. A correction for temperature is made and the data from the 16% cells compared. The only difference between the two strings is that string #7 has a microsheet cover and strings #14 has a quartz cover. A better example is what effect coverglass thickness has on the degradation of the cells. The comparison uses strings #1, #5, #10, #13 and #14. All cells are 16% efficient, use soldered interconnects and have different coverglass thicknesses. The thicknesses in mils; 2.5, 6.0, 20, 6.0 and 12 makes it possible to generate a radiation damage curve after a single data pass from the CRRES satellite.

DESIGN CONCERNS

Experiments conducted in the past on the NTS-2 and the LIPS-2 satellites have left a number of things unanswered. The NTS-2 used the older LPE GaAs solar cells. These cells were deep junction cells (1 micron) which were apoxied down. Although their performance was very good, opening the door for further development work, the degradation of the cells in the first 30 days of flight time was unexplainable. The LIPS-2 used the newer half micron junction depth cells, however, in a less than optimum fashion. This was due to the very short time period allotted between the initiation of the program, the production of GaAs solar cells and the subsequent panel fabrication. Cell selection was from a limited number of cells and the procedures for cell laydown had to be developed. Both flight experiments, however experienced the same type of power losses in the first 30 days of their flights. It is during this infancy period that we want to identify the cause of the problem. The CRRES flight will begin in low earth orbit (LEO) where the anticipated radiation environment will be low. The AFAP:-801 will be turned on in this orbit as soon as possible to measure the infancy problem. This requirement, as well as several others, mandated that a data matrix type of experiment be established. This ensures that data taken on as little as one pass will provide valid radiation damage data to aid in the identification and quantification of the source of cell degradation.

EXPERIMENT HARDWARE

The design of the experiment has been completed. Prototypical panels have been built and laboratory tested under contract. The electronics portion of the experiment has been breadboarded and tested and the final printed circuit boards are being delivered for assembly into the housing.

CONCLUSIONS

The results of this experiment will provide much needed information on the performance of solar cells in a high radiation environment with radiation measurements that are traceable recognized laboratory standards. The comparison of the four key types of solar cells either in use or planned for use in the near future will make it possible for satellite designers to have a high degree of confidence in their design margins and will make it possible for them to design with a high degree of accuracy. These four key types; GaAs (MOCVD), GaAs (LPE), Si (K4 3/4) and the Si (thin cell) will be responsible for providing the major portion of space electrical power for several years to come. The optimum hardware configuration for this particular orbit can be chosen from the results of the flight and the optimum combination of coverglass, adhesive, cell efficiency and interconnects can be projected for uses in other orbits. It is possible, that as a result of this experiment, that it can be proven that a thinner coverglass may be used to afford the level of radiation protection required for orbits lasting between 5 and 10 years.

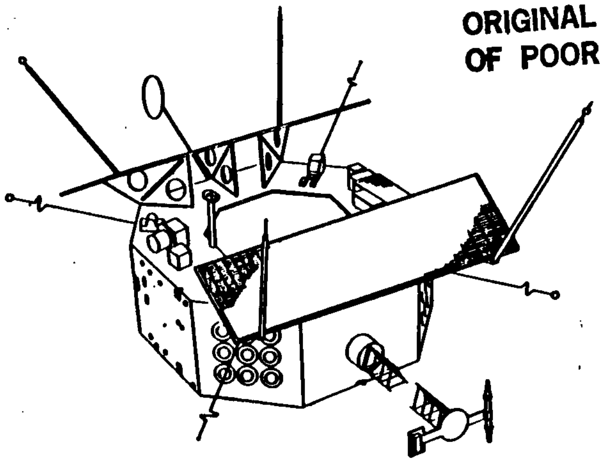

Figure 1 - CRRES Vehicle

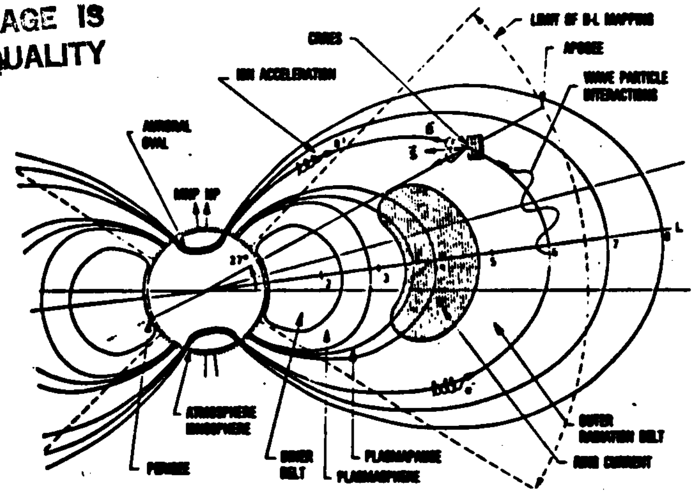

Figure 2 - Space Radiation

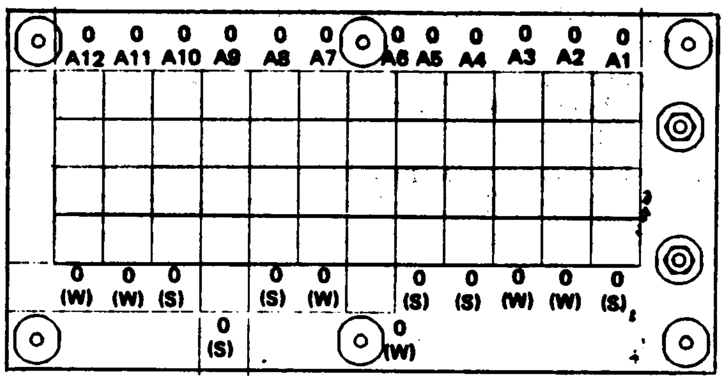

Figure 3 - Ambient Panel

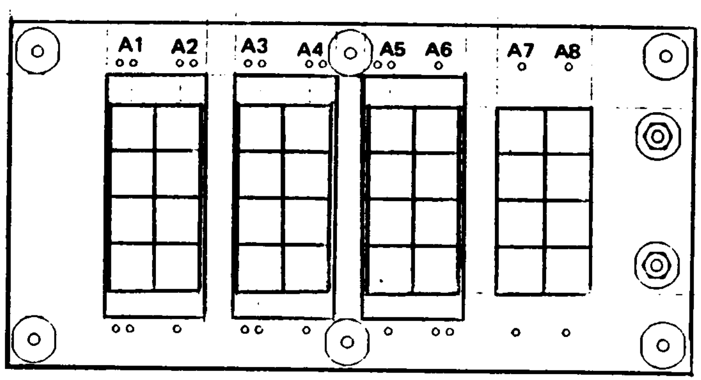

Figure 4 - Annealing Panel