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THE ADVANCED SOLAR CELL ORBITAL TEST

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The motivation for advanced solar cell flight experiments is discussed and the ASCOT flight experiment is described. Details of the types of solar cells included in the test and the kinds of data to be collected are given.

INTRODUCTION

During the past 30 years, silicon solar cells have provided power for virtually the entire range of satellite missions. The requirements for these missions have included electrical power loads as high as several kilowatts and radiation fluences high enough to require the use of thick coverglasses. Nonetheless,it is only recently that the need for advanced solar cells has become sufficiently compelling that many Air Force programs are seriously considering their use.

The primary characteristics of advanced cells which are of interest include increased areal power density (W/m^2), specific power density (W/kg), and reduced degradation at end of life. Increased areal power density allows more power to be obtained from an existing array area, so that the same launch vehicle shroud can accommodate the spacecraft and no redesign of the solar array structure is needed. Increased specific power allows more power to be obtained without increasing the vehicle weight beyond an existing launch capability, or the same amount of power to be obtained at a lower weight, thus allowing additional payload. Reduced degradation allows mission extension or flight in very high radiation orbits There are many programs which are considering advanced solar cells for one or more of these reasons.

One reason for the limited acceptance of new solar cell technologies is the lack of proven on-orbit performance. Spacecraft customers and contractors are acutely aware of the consequences of power subsystem failure, and therefore use a conservative approach to new technologies. Clearly a successful flight demonstration is the most convincing evidence of the readiness of a new technology for application. The lack of on-orbit failures and the observation of the expected level of performance is persuasive to potential users.

The importance of a flight demonstration goes beyond the observation of expected performance. The quantitative behavior of solar cells in the actual space environment can also be used to validate the ground test models and procedures used for design and analysis of advanced cells. The most important of these ground tests is the radiation degradation analysis. In these tests, a few sample solar cells are irradiated with 1 MeV electrons and low energy protons. Typically the dose rate in these exposures is such that the cell receives a year's fluence in an hour or so. In addition the flux is often unidirectional, rather than omnidirectional as the space environment is. Finally, each solar cell is irradiated with only a single particle type and energy, rather than with the true orbital spectrum. All of these limitations may give rise to inaccuracies in the prediction of solar cell performance.

In order to use the information from these tests to predict the on-orbit performance of cells, the equivalent fluence concept is invoked. In this theory, 1 MeV electrons are chosen as a reference particle. The fluence of 1 MeV electrons which cause the same degradation as a test particle is referred to as the damage equivalence for that particle. This equivalence is established by experiment for a variety of electron and proton energies. Based on this information, the degradation due to an arbitrary space spectrum can, in principle, be computed. The validity of the equivalent fluence concept has been verified for silicon solar cells through many years of comparison between flight and ground test data. It has not been well established for any of the advanced materials.

THE ASCOT FLIGHT EXPERIMENT

The purpose of ASCOT is to flight test six advanced solar cell types in a high radiation, proton dominated space environment. Although the details of the host spacecraft, its orbit, and its launch date are proprietary, most of the significant details can be presented. One year in the ASCOT orbit results in a 1 MeV electron equivalent fluence of $1.5E15/cm^2$ into a silicon solar cell fitted with a 6 mil cover. This is about the same dose as accumulates in 50 years in a geosynchronous orbit. This orbit is therefore especially good for flight testing of hardened solar cells, because it accumulates radiation in a very short time. The experiment is designed to survive for at least three years. On-board dosimeters will provide an accurate measure of the actual flight environment.

The experiment consists of twenty four modules. Since there are six solar cell types, there are four identical modules populated with each cell type. Each module consists of a series string of five identical solar cells. A schematic of a typical 3x6 inch module assembly is shown in Figure 1. The cells are electrically isolated from the aluminum plate with a dielectric, and wired in series with silver mesh interconnects. Each module has a dedicated thermistor mounted directly under the cell string. The modules are designed to maintain a preselected temperature which corresponds to the expected operating temperature of the specific solar cell type when installed on a rigid panel array. Accomplishing this requires the judicious use of optical solar reflectors (OSR) because the flight experiment never experiences sun angles less than 45 degrees from normal. The OSR covers a fraction of the total module area which produces the desired temperature. In addition, the design is required to maintain a temperature gradient across a given module of less than 1°C.

The concept of the experiment is to measure 33 points along the IV curve of each module under known conditions of illumination and temperature. This is accomplished by using a programmable current sink, which is controlled with a Read Only Memory (ROM) system. The ROM is programmed before launch with the characteristics of each cell type, so that the spacing of the measurement points gives good definition to the IV curve both at the beginning and end of the 3 year mission. Analysis predicts that the accuracy of the voltage measurements will be approximately 0.5% of full scale. The use of a current sink, as opposed to a current generator, ensures that the cell strings cannot be reverse biased into failure under unexpected conditions. The telemetry system scans the 33 points in all 24 modules in approximately 5 minutes, so that the environmental conditions are not expected to change significantly. In order to minimize the telemetry requirements, only the voltage component of the IV curve is down-linked. The current sink values and calibration signals are interspersed in the voltage data.

The solar cell types included in the ASCOT experiment are listed in the following table. All cell sizes are 2x2 cm and are fitted with 12 mil coverglasses. The BOL and EOL efficiencies are given, where EOL is defined as 10 years with a 12 mil cover in the ASCOT orbit. The application column indicates the principal benefit of the cell type.

Table 1: Beginning and end of life efficiencies for solar cells in the ASCOT flight experiment.

Cell type	BOL (28°C)	EOL (28°C)	Application
8 mil Si	12%	7.3%	Reference
2 mil Si	13.5%	7.4%	Low cost
GaAs/Ge	18.5%	10.2%	Improved efficiency
GaAs/Ge thin emit	18.5%	11.8%	Hardened
AlGaAs	17%	11.1%	Tandem component
GaAs/CIS	22%	14.1%	High efficiency

Note: The GaAs and CIS cells are measured independently.

The silicon cells were purchased from Applied Solar Energy Corporation (ASEC). The 8 mil cells are BSR type, while the 2 mil cells are BSF/R. The standard GaAs/Ge cells were purchased from Spectrolab, Inc. Thin (0.25um) emitter GaAs/Ge cells were grown by Research Triangle Institute, contacted and interconnected by ASEC, and provided at no cost. The homojunction AlGaAs cells were also prepared by RTI and ASEC, but provided courtesy of Mr. Steven Cloyd of WRDC who funded the development effort which produced these cells. The GaAs/CIS cells were purchased from Boeing.

CONCLUSIONS

ASCOT will be the first flight test of recently developed solar cells intended for high radiation environments. The orbit will expose the cells to a sufficiently high radiation dose that useful degradation data will be obtained in the first year. This data will guide future development of concepts such as thin emitter cells, AlGaAs cells, and tandem cells. In addition, the radiation ground test procedures for advanced materials will be verified.