THE JPL SPACE PHOTOVOLTAIC PROGRAM*

John A. Scott-Monck
Jet Propulsion Laboratory
California Institute of Technology

SUMMARY

A brief overview of the JPL activities in space photovoltaic research and development is presented. Work that is being performed at JPL, as well as external programs directed by JPL for the NASA Office of Aeronautics and Space Technology are described.

INTRODUCTION

JPL has as its primary charter, interplantary exploration. Many missions, due to environment or solar distance, have in the past precluded employment of photovoltaics. Those JPL missions that use solar cells for power often operate at other than 1 AU. Therefore, a significant amount of our effort is involved in evaluating solar cells under rather novel conditions of temperature, solar intensity and radiation.

The JPL activities in array design and development are oriented to high performance goals such as extremely high specific power or increased radiation resistance. The need for advanced cells to support these efforts has been the main stimulus for the work in pilot cell development of advanced silicon solar cells such as the OAST thin cell.

Future requirements will demand that solar cell panels deliver even more power per unit area without sacrificing mass. Radiation resistance, which has always been an important parameter in panel design, will become even more critical as NASA begins to develop a new generation of satellites for operation in geosynchronous orbit. For these reasons, JPL has had an active internal program in GaAs solar cells. This material has already demonstrated superiority to silicon with respect to power per unit area and radiation resistance.

CELL PILOT PRODUCTION

JPL is in the process of bringing the OAST thin cell to flight readiness by demonstrating that this advanced silicon solar cell can be produced in

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quantity at a cost which is competitive with present state-of-the-art space solar cells. This activity is the culmination of a four year program that has resulted in a silicon solar cell which is only 50μm thick, yet can produce the equivalent power of silicon cells which are four to five times thicker.

It is anticipated that within a year the pilot production effort being carried out by the Solarex Corp. for JPL will demonstrate an average AMO conversion efficiency of 13 percent at a production rate of ten thousand 2x2 cm cells per month. In addition, the pilot line will be capable of producing up to one thousand 5x5 cm OAST thin cells with an average efficiency of greater than 11 percent.

This pilot line effort serves two critical purposes, demonstration of production readiness and support of other JPL programs involved in incorporating these cells into high performance arrays. This should act as a stimulus to array designers to seriously consider implementing this advanced silicon solar cell for future space missions.

CELL EVALUATION

This work is divided into two general categories; parametric studies of the electrical performance of solar cells as a function of temperature and solar intensity, and investigation of the influence of radiation and subsequent thermal annealing on the electrical behavior of cells.

The first mentioned effort has been actively pursued by JPL for many years. A great variety of state-of-the-art production cells and mature laboratory devices have been evaluated at JPL. This data has been used by JPL and other organizations involved in flight projects to design suitable solar cell arrays for a great number of missions.

During the past year, evaluation of candidate wraparound contact solar cells for use on SEP type missions has been performed. OAST thin cells from the pilot line have been evaluated. A number of new, high efficiency production cells employing back surface fields, multiple anti-reflection coatings, back surface reflectors and textured surfaces are being examined. In addition there are plans to begin a preliminary characterization of GaAs solar cells, as they become available.

As the interest in such missions as Comet Rendezvous or new array technology such as concentrator enhancement grows, the need for this type of information becomes even more critical. In addition, JPL is beginning a preliminary screening of the new cells being produced for DOE in hopes that some aspects of this emerging technology will demonstrate applicability for space applications.

JPL has placed a strong emphasis on studying radiation damage effects in solar cells, since this is a critical parameter for array design. The JPL Dynamitron facility has been the main tool for this work, but often other facilities are used to provide data on proton effects. During this year approximately fifty types of production, advanced development and research cells have been tested at the Dynamitron. Wraparound contact, tandem junction, vertical junction, dendritic web, cast silicon, and OAST thin solar cells are just a few examples of what has been done in silicon. Also a number of AlGaAs and GaAs solar cells have been tested.

This year has seen the JPL work extend into the field of annealing. The main stimulus for this activity is the concept of using on-panel annealing of solar cells as a means of either extending mission lifetime or enabling certain mission classes such as orbital transfer to use photovoltaics. However, annealing studies also can be used as a tool to understand those mechanisms which control the radiation damage properties of solar cells. JPL is investigating the annealing behavior of both silicon and AlGaAs solar cells using electron and proton irradiation. Although this is a recent activity, JPL has already begun to produce a significant body of data on the annealing characteristics of solar cells.

GaAs RESEARCH AND DEVELOPMENT

This area represents the commitment of JPL to high technology which will ultimately benefit the NASA space program. JPL has been involved in GaAs solar cell research for a number of years with the emphasis placed on thin film cell types such as the AMOS (Antireflecting Metal-Oxide-Semiconductor) cell. With the recent advances in liquid phase epitaxial grown AlGaAs devices and the chemical vapor deposited GaAs cells, JPL has reoriented its research approach to capitalize on this new technology.

Recognizing that such pragmatic considerations as cell cost and mass will ultimately determine whether GaAs is used for space applications, the JPL effort is focused on an approach that will minimize these factors. The basic thrust of the program is to use organo-metallic chemical vapor deposition methods to grow GaAs on relatively low cost and low mass substrates.

This approach uses silicon as a substrate, thus reducing the cost and mass when compared to other substrate candidates such as germanium or gallium arsenide. The key technology problem now being addressed is to develop a thin interface material layer that will allow a uniform transition between the differing lattice constants of silicon and the CVD grown GaAs. At this point it is not known whether p or n-type base homojunction GaAs cells are the more radiation resistant. Thus, techniques for controlling the resistivity of both types of GaAs over a wide range are being developed. Once these various pieces of technology are assembled, work will begin on developing reliable contacts and anti-reflection coatings.

It is anticipated that the GaAs solar cell developed by JPL will demonstrate marked improvement in output power and radiation resistance when compared to silicon and also be more than competitive with respect to specific power at the array level. These factors combined with the high temperature properties of GaAs will offer a unique opportunity to demonstrate a solar cell array which under certain conditions will meet the specific power and stability goals of an SPS type mission.