REPORT OF THE WORKSHOP ON NEXT-GENERATION SPACE PV: THIN FILMS

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A workshop on the future use of thin-film photovoltaic devices in space power was convened at the 16th Space Photovoltaic Research and Technology Conference held at the NASA Glenn Research Center in Cleveland, OH. This workshop began by addressing three questions pertaining to future use of thin film devices for space power systems. What follows is a summary of the discussion that transpired.

1. What are the leading impediments or technological challenges to be overcome with regard to the use of thin-film PV in space?

Higher efficiency large-area cells need to be developed. Efficiencies need to exceed approximately 13% before thin-films could realistically displace silicon cells. Thin film technology has many wonderful attributes (e.g., radiation tolerance, power to weight ratio, flexibility, etc.). There would be a tremendous market for high-efficiency light-weight non-degradable cells. Unfortunately, the space power community has yet to realistically evaluate this perceived potential.

Two separate sets of issues must be considered for space implementation:
1) Systems level issues, 2) Device level issues.

Systems level

A complete systems study is necessary to match power level versus size, mission time, array type, and thermal management requirements. Just because one could make a inexpensive thin-film array the size of a football field does not mean it would be useful. There are serious deployment and control issues that would have to be considered in the design stage. It is also not clear at this point if the good attributes such as the radiation tolerance are scalable.

In large-area cell development, the use of a light-weight flexible substrate such as Mo on Kapton or suitable polyimide is essential. However, the CIS processing temperatures are still to high. Either a higher temperature substrate material or lower processing temperatures must be developed.

Device Level

The is more to do to achieve higher efficiency thin-film cell than just adjusting the bandgaps. Questions such as: Why are CIS polycrystalline thin films are nearly as good as their single crystals counterparts? Can all this be explained with Zunger et. al.'s defect pairing mechanism? What is happening at the grain boundaries? What is the real nature of the so-called buried junction between the CdS and CIS? The limiting factors at the junction level need to be identified and addressed.

Many feel that the possibility of a multi-junction CIS – CIGS cell may work. However, a efficient top-cell is the biggest hurdle. As Ga or S is introduced to increase the bandgap or CIS, device performance and efficiencies degrade.

2. What is the status of organic based cells? Will they have a role in space PV, if so when?

Stability is a big problem. Difficult to produce a n-type materials that will not degrade. Absorption is still very low. However, if tunnel junctions could be made, you could stack say 10 to 20 junctions and still have a light-weight device.

3. What about an integrated PV/Li battery array – up and down sides?

People are already investigating the implementation of batteries in the honeycomb arrays etc. Thin film battery performance in space environments needs to be studied (temperature, radiation, etc.) Thermal management issues are still in question. These devices must operate in eclipse at very low temperatures, where batteries perform poorly.

A request was made to the conference organizers. As a result of this workshop, the participants would like to see a space thin-film PV workgroup established that could share information and ideas. They would also like to see a development of a space thin-film PV roadmap for the development of this technology. This would at a minimum get people thinking about and possibility working on the current impediments to the realization thin-film PV for space.

After the individual workshop was concluded, a joint meeting of all the SPRAT participants was held. Brief reports from the various workshops were made and comments were solicited from the entire group. What follows is a summary of the points of discussion.

Discussion Points

A multi-junction CIS-based cell with the ability to eclipse the 20% efficiency should be achievable with current materials. A CdTe top cell looks like a good possibility for a multi-junction thin-film cell with CIS.

Several people felt that development of thin-films space arrays has enormous potential, however it will never be realized unless a the government or a cell manufacturer is willing to invest the type of money necessary to develop the proposed materials. However, it was noted that NREL has invested multi-million dollars in CIS development. However, the development of cells for space has different problems that are not likely to be addressed by the terrestrial community. Although AM 1.5 testing on thin films has taken place, the AM 0 needs to be performed. Good numbers for temperature coefficients need to be measured. Questions pertaining to degradation and materials performance under space conditions need to be answered. Space qualification needs to be addressed.

Low efficiency cells although light do not necessarily give high power to weight in practice, for array weight scales with area. The larger the array, the more energy that must be expended to deploy the array and control the spacecraft. Also, as arrays size increases, more weight is required in the deployment mechanism. Air Force Research Labs and JPL are both working on new array technologies for light-weight blankets.

Space qualified arrays need much more inspection and tracability; this is a major organizational cost. Are the manufacturers willing to do this? Not likely since it is a long-term investment in a market which can be very volatile and unpredictable. Space areas need a total system engineering approach. This is not likely to happen until the development of a thin-film array becomes an enabling technology for a specific mission.

Cost is a perceived advantage for thin film cells. Terrestrial cell manufacturers claim manufacturing costs of under $2.00/watt presently and lower costs in the future. However, it is not clear if lower cell manufacturing costs translate into lower array costs, since much of the space array cost is due to space qualification requirements, that may be much higher than the actual manufacturing cost. However, one of the cost advantages of thin films comes in the integral interconnection of large-area blankets, which could translate directly into reduced costs for space arrays.

Since cost is such a critical point regarding the development of thin-film arrays, the question of what is the actual cost of a current PV array was posed.

> One cost example: A 500 watt array, cost at the panel level, not including substrate cost or deployment mechanism, came in at $1200/watt. The same array substituting 21.5% GaAs cells came to $1000/watt (no NRE cost). 60% of this cost is quoted as touch labor.
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> For comparison, JPL noted a cost of $1000/watt for a Si array of similar size, but costs can be five to six thousand dollars/watt, depending on engineering, for some arrays. This depends often on testing costs, which can be high for non-standard arrays.
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> For comparison, Goddard noted that the EOS-AM array, based on the JPL APSA design, had a final cost of $10,000/watt ($50,000 for a 5kW power system) at the completed array level (including structure and mechanisms). This price is unusually high, but shows that in some cases array costs can be extremely high.

It was pointed out that the same impediments to the development of GaAs cells, concentrator cells, and multi-junction cells for space are now being discussed with regard thin film cells. And on this note, the discussion on Next-generation Thin Film Space PV was concluded.