NASA Solar Array Demonstrates Commercial Potential

Advanced cells exhibit energy-conversion efficiencies approaching 23 percent.

Dryden Flight Research Center, Edwards, California

A state-of–the-art solar-panel array demonstration site at NASA's Dryden Flight Research Center provides a unique opportunity for studying the latest in high-efficiency solar photovoltaic cells. This five-kilowatt solar-array site (see Figure 1) is a technology-transfer and commercialization success for NASA. Among the solar cells at this site are cells of a type that was developed in Dryden Flight Research Center's Environmental Research Aircraft and Sensor Technology (ERAST) program for use in NASA's Helios solar-powered airplane. This cell type, now denoted as A-300, has since been transferred to SunPower Corporation of Sunnyvale, California, enabling mass production of the cells for the commercial market.

Figure 1. This **Solar-Panel Array Demonstration Site** at NASA's Dryden Flight Research Center is a facility for testing the most advanced solar photovoltaic cells commercially available for terrestrial applications. *NASA photo by Tom Tschida.*

High efficiency separates these advanced cells from typical previously commercially available solar cells: Whereas typical previously commercially available cells are 12 to 15 percent efficient at converting sunlight to electricity, these advanced cells exhibit efficiencies approaching 23 percent. The increase in efficiency is due largely to the routing of electrical connections behind the cells (see Figure 2). This approach to increasing efficiency originated as a solution to the problem of maximizing the degree of utilization of the limited space available atop the wing of the Helios airplane. In retrospect, the solar cells in use at this site could be used on Helios, but the best cells otherwise commercially available could not be so used, because of their lower efficiencies.

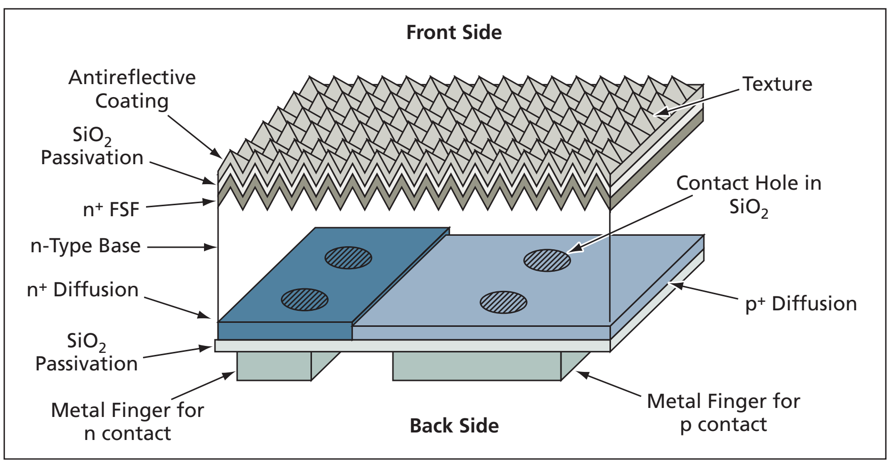


Figure 2. This **Rear-Contact Solar Cell** has an n-type base and features innovative routing of electrical connections for high efficiency. The basic design is equally applicable to a p-type base.

Historically, solar cells have been fabricated by use of methods that are common in the semiconductor industry. One of these methods includes the use of photolithography to define the rear electrical-contact features — diffusions, contact openings, and fingers. SunPower uses these methods to produce the advanced cells. To reduce fabrication costs, SunPower continues to explore new methods to define the rear electrical-contact features.

The equipment at the demonstration site includes two fixed-angle solar arrays and one single-axis Sun-tracking array. One of the fixed arrays contains typical less-efficient commercial solar cells and is being used as a baseline for comparison of the other fixed array, which contains the advanced cells. The Sun-tracking array tilts to follow the Sun, using an advanced, real-time tracking device rather than customary pre-programmed mechanisms. Part of the purpose served by the demonstration is to enable determination of any potential advantage of a tracking array over a fixed array. The arrays are monitored remotely on a computer that displays pertinent information regarding the functioning of the arrays.

The process for production of the advanced cells is more complex than is the process for producing typical previously commercially available cells. When laminated under glass in rigid framed modules, the advanced cells are robust enough to last outdoors for more than 20 years. Once the cells have been installed in the modules, the protective glass is coated with a dirt-repellent material. The demonstration is providing the opportunity to verify the effectiveness of the repellent, and to determine the effect, if any, of dust and dirt on the arrays.

NASA Headquarters funded a site-feasibility study for the demonstration. The study was performed by the U. S. Department of Energy's Idaho National Engineering and Environmental Laboratory in Idaho Falls, Idaho. The laboratory is also supporting Dryden Flight Research Center's public-outreach planning for the demonstration. Among the planned activities is the establishment of a Web site that will enable the public to view real-time information on the functioning of the arrays at the site.

This project can be characterized as part of a full-circle process of development of technology, transfer of the technology to private industry, and return of the technology to NASA ("spin-in") from industry to assist NASA programs. This project has been part of the Innovative Technology Transfer Partnerships effort under NASA's Aerospace Technology Enterprise.

Other solar-array sites are planned for construction in Hawaii and Arizona. A larger solar farm that may be constructed at Dryden Flight Research Center in the future might supply as much as one-third of the electric power consumed by the Center.

This work was done by Gray Creech of **Dryden Flight Research Center**. *Further information is contained in a TSP (see page 1).* *DRC-04-21*

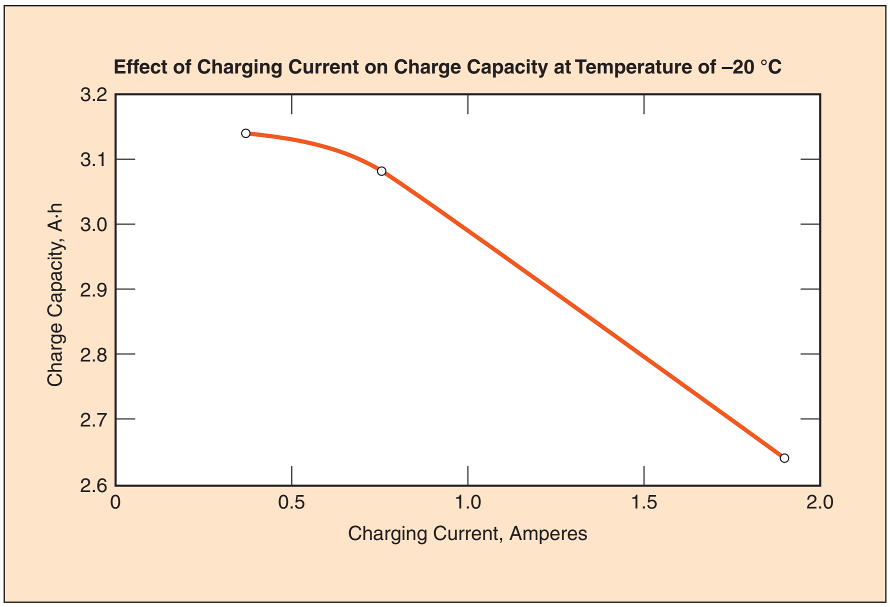
Improved Control of Charging Voltage for Li-Ion Battery

Charging potential would be increased by the internal resistive voltage drop.

NASA's Jet Propulsion Laboratory, Pasadena, California

The protocol for charging a lithium-ion battery would be modified, according to a proposal, to compensate for the internal voltage drop (charging current × internal resistance of the battery). The essence of the modification is to provide for measurement of the internal voltage drop and to increase the terminal-voltage setting by the amount of the internal voltage drop.

Ordinarily, a lithium-ion battery is charged at constant current until its terminal voltage attains a set value equal to the nominal full-charge potential. The set value is chosen carefully so as not to exceed the lithium-plating potential, because plated lithium in metallic form constitutes a hazard. When the battery is charged at low temperature, the internal voltage drop is considerable because the electrical conductivity of the battery electrolyte is low at low temperature. Charging the battery at high current at any temperature also gives rise to a high internal voltage drop. In some cases, the internal voltage drop can be as high as 1 volt per cell. Because the voltage available for charging is less than the terminal voltage by the amount of the internal voltage drop, the battery is not fully charged (see figure), even when the terminal voltage reaches the set value.



The **Charge Capacity** attainable by charging a representative Li-ion battery at constant current decreases with increasing current if the end-of-charge battery-terminal voltage is limited to a nominal full-charge value, because of internal ohmic voltage drop.

In the modified protocol, the charging current would be periodically interrupted so that the zero-current battery-terminal voltage indicative of the state of charge could be measured. The terminal voltage would also be measured at full charging current. The difference between the full-current and zero-current voltages would equal the internal voltage drop. The set value of terminal voltage would then be increased beyond the nominal full-charge potential by the amount of the internal voltage drop. This adjustment would be performed repeatedly, in real time, so that the voltage setting would track variations in the internal voltage drop to afford full charge without risk of lithium plating. If the charging current and voltage settings were controlled by a computer, then this method of charge control could readily be implemented in software.

This work was done by Paul Timmerman and Ratnakumar Bugga of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL, (818) 354-7770. Refer to NPO-20481.