A Sunny Future:

Demonstration Facilities and Basic Research Improve Photovoltaic Power

by JOHN TOON

Atop Georgia Tech's Aquatic Center, nearly 3,000 photovoltaic panels produce as much as 30 percent of the electricity needed by the building. Researchers Miroslav Begovic, Aleksander Pregelj and Christiana Honsberg are evaluating the long-term performance of the system, which was built as a test bed for large photovoltaic arrays.

PHOTO BY GARY MEEK

PHOTOVOLTAICS

As the summer sun rises over Atlanta, it begins converting nitrogen oxides and hydrocarbon compounds — the leftovers of electricity generation and vehicle operation — into ground-level ozone. It's the beginning of another bad air day for Atlanta.

But as the sun rises over the Aquatic Center at the Georgia Institute of Technology, it initiates an entirely different process. Photovoltaic cells covering the structure's roof — 342 kW of them — begin producing electricity, enough to provide 30 percent of the building's power needs — an amount sufficient to energize 70 average homes.

Built to house swimming and diving events at the 1996 Summer Olympics, the Aquatic Center now serves as a test bed for large-scale photovoltaic (PV) arrays. In the past six years, the facility has produced more than 2 billion watt hours of electrical energy — and a wealth of information about the reliability of large PV systems, how they should be connected to the utility grid and what architects should expect from the growing number of similar systems being integrated into new buildings.

"To see such a large system operating on campus every day and performing very close to what we had predicted is very heartening," says Ajeet Rohatgi, director of Georgia Tech's University Center of Excellence for Photovoltaics Research and Education (UCEP), operator of the array. "Based on the data we have collected, we are developing better models to predict the performance and reliability of this system over its projected 30-year life."

Beyond data on reliability and power output, researchers monitoring the system have also noted some factors that hadn't been figured into their initial predictions, such as the impact of the roof's curvature. That new knowledge will help designers of future systems improve their performance predictions.

Operationally, the facility has seen near-flawless performance from the PV panels and the electronic equipment that controls the system's interaction with the external power grid. But Rohatgi notes a few glitches in the power inverters

— electronic devices used to convert direct current (DC) from the 2,856 panels to AC power.

Researchers have also obtained data from a separate PV system built into a canopy over the nearby Student Athletic Center entrance. That system uses an alternative design, integrating inverters into each panel.

As the demonstration projects produce valuable information about operating PV systems, work under way in UCEP's labs produces advances in basic PV technology. UCEP researchers work to improve the efficiency of photovoltaic cells, lower their cost and devise more easily manufactured designs – part of efforts to make PV-generated electricity more competitive with other sources.

Photovoltaic cells, mostly based on silicon, absorb light energy from the sun. That boosts the energy level of electrons in the semiconductor material, freeing them to move about in the crystalline structure and produce a flow of electrical current. The percentage of light energy converted to electrical energy provides a measure of the efficiency of different PV cell designs.

"The goal is to get very high efficiencies while keeping production costs low," explains Christiana Honsberg, associate professor in the School of Electrical and Computer Engineering and a UCEP researcher. "We do this by using novel techniques and clever designs."

UCEP researchers have begun evaluating one such clever design: building cells on low-quality thin multi-crystalline silicon material that costs just a third as much as the material normally used.

They have developed a single silicon nitride processing step that simultaneously anneals the cells, applies an anti-reflection coating — and introduces hydrogen atoms to passivate defects in the lower-quality silicon. The resulting cells are nearly as efficient as those produced with higher-cost materials.

UCEP researchers have pioneered rapid thermal processing of silicon cells and have made cells with record-high efficiencies. They are also developing a rapid processing system that uses a continuous belt line to move cells through a high-temperature furnace. This technique may trim production costs by cutting diffusion time from two hours to as little as six minutes.

And they are pushing established limits on the thickness of cells — with thinner devices more forgiving of defects. The goal, notes Rohatgi, is to reduce the cost of PV through technology development and efficiency improvement.

"We are working on several approaches at the same time," he says. "If we can start with low-cost silicon, that holds down materials costs. If we can use rapid processing technologies, that reduces the processing cost and time. And if we can improve efficiency, that reduces the size of the entire PV module, which has an additional impact on the cost of the entire assembly or system. This way we can make PV competitive with the traditional energy sources."

Efficiency remains the goal of PV cell research. Most cells mass-produced today are just 12-15 percent efficient, while the best laboratory-produced silicon cells have efficiencies as high as 24 percent. An industry goal is to close that gap, increasing efficiency of manufactured silicon cells to 18-20 percent over the next 3-10 years by adopting innovations produced by UCEP and other research labs.

Beyond the research efforts aimed at efficiency and cost, Honsberg notes another key factor. As more architects incorporate PV arrays into new buildings, they increase the volume of cell production, creating economies of scale that will help drive down costs much like high-volume computer chips did before them.

Formed in 1992, UCEP now involves three faculty members, five full-time research professionals and ten PhD students. Funding comes from such agencies as the National Renewable Energy Laboratory and the Department of Energy. UCEP researchers also collaborate with leading PV companies such BP Solar, Evergreen Solar and ASE Americas, Inc.

Rohatgi sees a bright future ahead for the program and PV industry.

"Over the past five years, growth in the PV industry has been phenomenal," he says. "If the growth continues in this way, in 20 years PV could be contributing almost 15 percent of the new electrical capacity required each year. As the cost of PV continues to come down, a lot more applications will become favorable. We are doing our part here to make that happen." **RH**

■ For more information, you may contact Ajeet Rohatgi, School of Electrical and Computer Engineering, Georgia Tech, Atlanta, GA 30332-0250. (Telephone: 404-894-7692) (E-mail: ajeet.rohatgi@ece.gatech.edu)

"As the cost of PV continues to come down, a lot more applications will become favorable. We are doing our part here to make that happen."

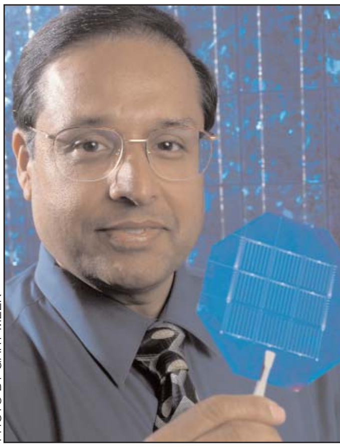

PHOTO BY GARY MEEK

Ajeet Rohatgi displays a low-cost, high-efficiency screen-printed multicystalline silicon solar cell fabricated at Georgia Tech's University Center of Excellence for Photovoltaics Research and Education (UCEP).