Three-Dimensionally Textured Photovoltaic (PV) Cells

A light-trapping solution to significantly increase absorption

These novel carbon nanotube (CNT)-based textured PV cells permit greater energy absorption—a significant advantage over traditional PV cells that offers multiple benefits for both terrestrial and space-based applications. Developed at Georgia Tech, these 3D PVs can be scaled to form large, periodic arrays of vertically aligned CNTs. Common thin-film PV materials (e.g., cadmium telluride [CdTe], copper zinc tin sulfide [CZTS], or perovskite) are deposited on the upper side of each array. These innovative materials act as a 3D scaffolding of sorts—a structure that provides a light-trapping effect that produces more power at off-normal angles without requiring additional sun-tracking machinery.

Specifically, the 3D geometry enables multiple photon impingements and therefore an increased number of interactions between a photon and a photoabsorber. The result is a greater likelihood of absorption and a resulting increase in photocurrent and power output as compared with similar planar cells.

For space-based applications in particular, the increased power output should yield an increased energy output as the sun subtends all zenith/beta angles. Such arrays are being tested for efficacy on the International Space Station as part of the Materials International Space Station Experiment (MISSE)-11, MISSE-12, and NanoRacks External Platform (NREP)-1 missions.

Summary Bullets

- **Powerful**: Improves probability of absorption via a novel light-trapping geometry
- **Practical**: Eliminates the need for heavy, complex, costly, and failure-prone mechanical systems required by traditional planar PV cells to track the sun
- **Reliable**: Improves photon absorption probability even at off-normal azimuth angles, leading to more predictable performance across all seasons for terrestrial applications

Solution Advantages

- **Powerful**: Improves probability of absorption via a novel light-trapping geometry
- **Practical**: Eliminates the need for heavy, complex, costly, and failure-prone mechanical systems required by traditional planar PV cells to track the sun

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Potential Commercial Applications

Georgia Tech’s technology is well suited to increasing the power and reliability of both space-based and terrestrial applications that benefit from solar-generated power, including:

- Earth-orbiting satellites
- Space missions within Mars’s orbit
- Specialty space-based power systems
- Solar vehicles
- Solar farms
- Concentrator photovoltaics

Background and More Information

Solar energy is the only renewable source that can provide the majority of the 10 TW deemed necessary for the global economy by 2035 (source: M.I. Hoffert et al., *Nature*, 395(6705): 881-884, 1998). While PV research has made tremendous strides since its introduction in the 1950s, an order-of-magnitude decrease in the PV price per watt is still needed in order to compete economically with conventional fossil fuels and other non-renewable power sources. Viable technologies will need to be highly efficient while minimizing PV cell production costs. Space-based applications for solar energy add the requirement of low weight to the mix, since spacecraft payload weight is of critical importance. Georgia Tech’s innovation addresses all of these needs with a method that significantly increases the energy absorption and power potential of PV cells while eliminating the need for heavy and costly sun-tracking machinery.

Inventors

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Publications

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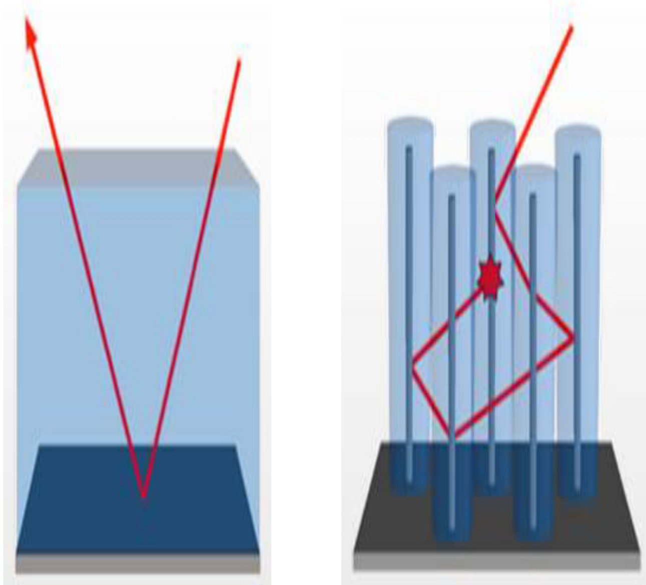
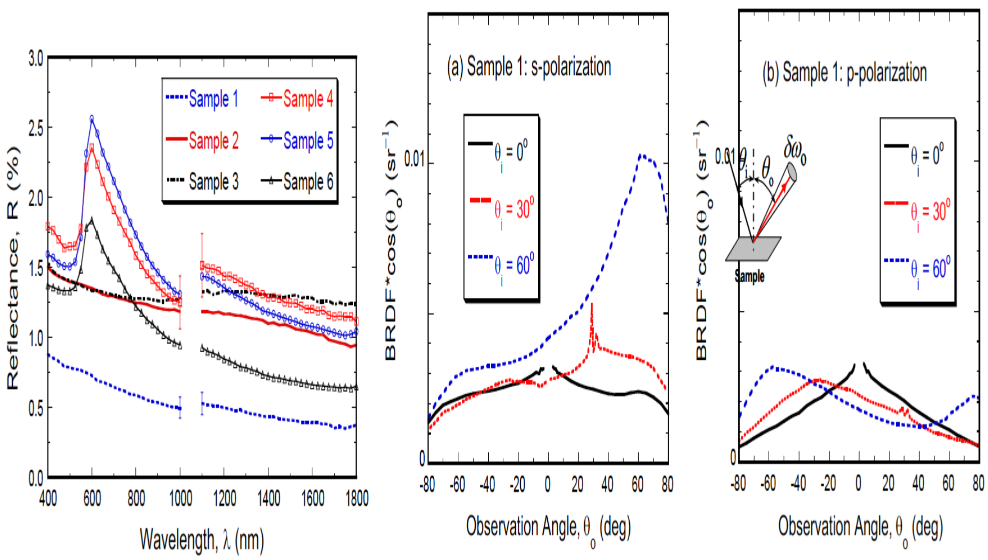
Images



Traditional planar PVs (left) allow for only a single impingement of the photon, which limits absorption. Anti-reflection (AR) coatings can improve upon this deficiency but only to a limited extent due to wavelength dependency of the AR coating. Georgia Tech’s CNT-based textured device (right) permits multiple wavelength-independent impingements of a single photon, which significantly increases absorption probability.



Light trapping is critical to the novelty of Georgia Tech’s technology. (left) Directional-hemispherical reflectance of six light-trapping PV samples measured with an integrating sphere in the spectral regions from 400 nm to 1,000 nm and from 1,100 nm to 1,800 nm, using different grating and detector combinations. (center and right) Bidirectional reflectance distribution function measurements of a sample at different incidence angles for both (center) s-polarization and (right) p-polarization. The inset of (b) shows the geometry of bidirectional reflection.

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