Photonic Smart Coatings Unlock New Efficiencies in Solar Panels

Most photovoltaic (PV) cells are designed to harvest a small band of the solar spectrum, between 450 nm to 1,050 nm, which represents less than 30% of the full solar spectrum (that ranges from 290 nm to 2,400 nm). Hence, if conversion of photons at shorter and longer wavelengths can be achieved, an increase in power output of 15% or more is possible. Single-junction monocrystalline or polycrystalline silicon solar cells have captured the majority (>90%) of the market share of solar PV cells in the utility, commercial, and residential sectors. Enhancing the efficiency of these cells by accessing a wider range of the solar spectrum will unlock significant value.

SunDensity, a company based in Boston, MA, is creating photonic smart coatings (PSCs) that can be applied to solar glass to promote smart photon management and increase the power generation of single-junction silicon solar cells. With funding from the U.S. National Science Foundation (NSF), SunDensity has produced a few initial laboratory prototype coatings and demonstrated the efficacy of this concept.

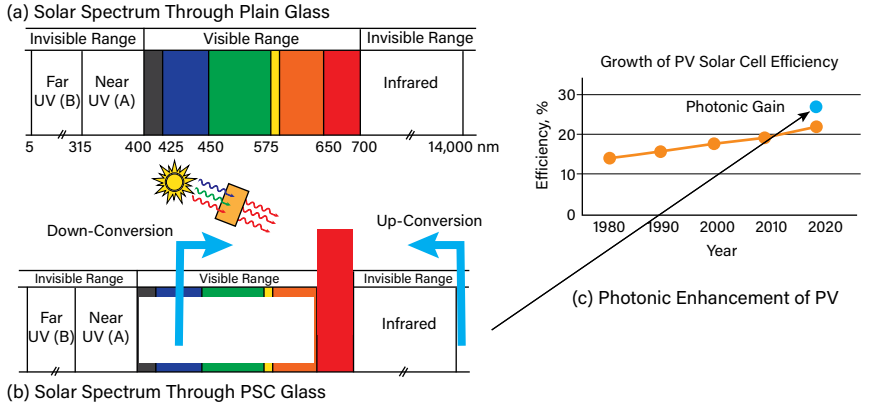
The PSCs are approximately 350 to 400 nm thick, contain metal nanoparticles, and are produced using a novel sputtering and annealing process. Within the PSCs, metal nanoparticles generate a plasmonic electrical field. High-energy ultraviolet photons (*i.e.,* blue photons) interact with the metal nanoparticles to create localized surface plasmonic resonance, which is indicated by absorption of blue photons. The absorbed blue photons are then converted into lower-energy near-infrared photons (*i.e.,* red photons) by a process called down-conversion by radiative relaxation. The red photons, which match the energy gap of solar cells, can be easily absorbed in the band gap to generate more electrons, thereby increasing the power output. The production process to create the PSCs can theoretically be scaled up to coat millions of solar glasses per year, helping to meet the growing demands of the solar industry.

For further development and manufacturing scale-up, SunDensity moved part of its operation to Rochester, NY. Leveraging Rochester's photonic ecosystem, with additional funding from NSF and venture capital, the company is developing a scalable version of the PSC product that can be made using in-line magnetron sputtering and ultrafast flash lamp annealing.

"Overcoming manufacturing scale-up is one of our major challenges and SunDensity is well on its way to accomplishing this," says Nish Sonwalkar, founder and president of the company.

In a recent evaluation at SolarPTL in Arizona, an outdoor test of coated solar cell samples with the scalable PSC product showed a power gain of 3.99% over the reference solar cell with plain glass. Although SunDensity's goal is to reach >15% power gain from its PV panels, the successful early testing has allowed the company to engage potential clients and a solar panel company. By the end of 2023, SunDensity plans to install a pilot coating production line capable of producing over 15,000 coated glass panels/yr (*i.e.,* 30,000 ft^2 of coated glass) in Rochester, NY.

Through collaborations with numerous solar panel manufacturing companies in the U.S. and Europe, the company seeks to help grow the solar PV sector with significant increases in the efficiency and capacity of commercial solar panels. For example, the company is collaborating with the Fraunhofer FEP research lab in Dresden, Germany. "This is a groundbreaking development in the thin-film coating area with the in-line generation of silver nanoparticles using flash lamp annealing in milliseconds, instead of a costly oven process," says Jörg Neidhardt of Fraunhofer FEP. CEP



▲ Most photovoltaic (PV) cells are designed to harvest a small band of the solar spectrum. SunDensity's photonic smart coatings (PSCs) are designed to access a wider range of the solar spectrum. (a) The transmission of the solar spectrum through plain glass is shown. (b) After the solar glass is coated with PSC, the down-conversion of UV photons to near-infrared photons and vice-versa allows for an increased number of red photons to generate more power from the single junction PV cell. (c) The plasmonic enhancement of the PV cell is predicted to result in power gains of 15% or more.

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