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Nanostructure Surfaces for Photovoltaic Cells

Photovoltaic (PV) cells are typically formed from semiconductor absorber layers. These absorber layers exhibit absorption of light with photon energy above their bandgap energy to generate electron-hole pairs. The absorber layers can also exhibit non-radiative recombination in the bulk of the absorber material. However, the absorber semiconductor materials can be expensive and time-consuming to grow such that thicker layers add cost to the manufacture of the PV cell. Thinner absorber layers can increase flexibility of PV cells but, with less semiconductor volume available for light absorption, can reduce the photogenerated current density and efficiency of the PV cells.

The optical path length of light in an absorber layer of a given thickness can be increased by light trapping. Light trapping has been accomplished for relatively thick (50-300 microns thick) PV cells with crystalline silicon absorbers by etching relatively large (1-10 micron wide) structures into the silicon absorber material. However, many thin-film PV cells have relatively thin (0.5-3 micron thick) absorber layers and it is difficult to form light trapping nanostructures on these layers. There is a need to achieve light trapping and greater photogeneration in PV cells with thin absorber layers for affordability, flexibility, and higher efficiency.

Researchers at Arizona State University have developed photovoltaic (PV) cells with nanostructure surfaces for wavelength-selective light trapping. The nanostructure surfaces allow the use of thinner semiconductor absorber layers that operate with reduced recombination and heat generation to more efficiently convert monochromatic light into electricity. Nanostructures may be on front and/or back surfaces of the photovoltaic cells.

Wavelength-selective light trapping provides various advantages, such as reduced heat generation in thermophotovoltaic cells and extreme light trapping for photonic power converters, resulting in increased device efficiency.

Potential Applications:

- For PV cells used in a wide range of applications, including the following:
  - Photonic power converters
  - Solar cells for earth-based electrical power generation from concentrated or nonconcentrated sunlight
  - Solar cells for outer space-based electrical power generation from concentrated or nonconcentrated sunlight
  - Thermophotovoltaic cells for conversion of light radiated by a thermal emitter to electrical power

Benefits and Advantages:

- Wavelength-selective light trapping in PV cells

- Reduced heat generation in thermophotovoltaics
- Extreme light trapping for photonic power converters (e.g., ~ 16% increase in device efficiency)
- Efficiently turn monochromatic light into electricity