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Nanophotonics and Plasmonics for Solar Energy Harvesting and Conversion

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Highly efficient and low-cost solar energy harvesting and conversion devices are now in demand as renewable electricity and fuel sources emerge as necessary components of our energy future. In that regard, nanoscale light management is expected to enable new generations of thin-film inorganic and organic photovoltaic devices, compact and lightweight solar concentrators, more efficient photocatalytic processes for solar-to-fuel conversion, and novel solar thermoelectric devices. In particular, as photovoltaic active layers have become thinner, a reduction in the size of light-trapping structure has become necessary. As a result, a host of dielectric, semiconductor, and metallic nanostructures are under development to minimize surface and interface reflections and to in-couple light into thin-film active layers with thicknesses below the diffraction limit of light.

Examples of structures with nanophotonic and plasmonic light harvesting and trapping capabilities include arrays of dielectric or metal nanospheres and nanorods, semiconductor quantum dots, and metallic nanowires, gratings, and nanostructured electrodes. These structures typically facilitate strong light trapping due to their high scattering cross sections, intense near-field light localization, and/or thin-film in-plane guided-mode coupling ability. Further development of high-throughput, large-area nanofabrication methods are necessary to enable integration of nanophotonic or plasmonic structures in practical solar energy applications. Additionally, a comprehensive understanding of how integration of nanostructures affects electrical and morphological properties of absorber layers, as well as optical properties, is needed to ensure the optimal function of solar energy devices that include light-trapping nanostructures.

Ongoing research into the design and development of new nanophotonic and plasmonic materials or phenomena may enable unconventional solar harvesting and conversion approaches that further reduce the volume, embodied energy, and cost of materials required to harvest sunlight. This special section includes papers on theoretical or experimental research into the design, fabrication, and characterization of nanostructured dielectric, semiconductor, and metallic structures and materials with unique photonic properties that could be employed to improve solar energy harvesting and light trapping.

Deirdre M. O'Carroll has been an assistant professor in materials science and engineering and chemistry at Rutgers University since 2011. She received her PhD degree in microelectronic engineering from University College Cork in 2008. From 2007 to 2009, she was a postdoctoral researcher in plasmonics at California Institute of Technology, and in 2010 she completed an International Marie Curie Fellowship at University of Strasbourg and CNRS. She specializes in photonic nanostructures, plasmonics, photonics for energy, conjugated polymers, and organic optoelectronics.