

Excitonic Devices for Photovoltaics and Nanophotonics

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Excitons are a nano-sized energy packet that mediates the conversion between photons and electrons. Their roles become especially important in nanomaterials, such as organic molecules, quantum dots and 2D semiconductors. By controlling excitons in nanomaterials, I demonstrate two optoelectronic devices that enable functions that conventional semiconductors could not achieve.

The first device is a solar cell that doubles the electricity generated from the blue/green part of the sunlight. Conventional solar cells generate one electron for each absorbed photon, wasting a photon's excess energy above the bandgap. Exciton fission in organic molecules splits a high-energy exciton into a pair of low-energy ones. In solar cells, it promises to increase the photocurrent twofold for the blue/green solar spectrum. Using exciton fission, I show a photovoltaic cell that produces more than one electron per photon in the visible spectrum, which is the first-time demonstration for any kind of solar cell technology.

The second device is an electrically-controllable nanoscale light source. Photoluminescence of semiconductor nanocrystals is efficient and wavelength-tunable, finding applications in photonic communication, quantum information processing and optical probing of biological systems. I demonstrate electrical modulation of light emission from semiconductor nanocrystals by controlling excitonic interaction between nanocrystals and 2D semiconductors.