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Using Light To Dope Quantum Dots

Materials Science: A simple photochemical process dopes semiconductor nanocrystals with electrons

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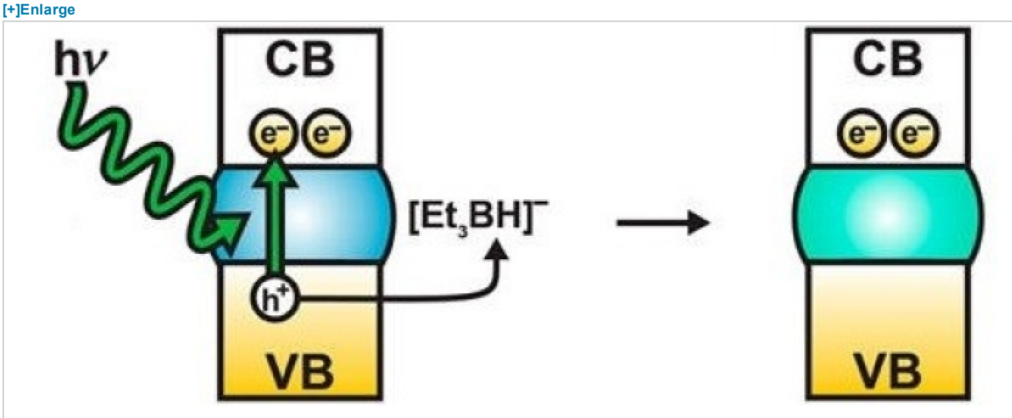

Splitting The Difference

A photon (hu, wavy green arrow) strikes a quantum dot, generating an electron (e^-) in the conduction band (CB) and a hole (h^+) in the valence band (VB). The hole is drawn off by a triethylborohydride ion ($[Et_3BH]^-$), leaving the surplus electron behind (right).

Credit: *J. Am. Chem. Soc.*

Quantum dots—bits of semiconductor materials a few nanometers in diameter—could help scientists create new types of batteries, solar cells, and field-effect transistors. Such nanoelectronics could take advantage of the fact that the electronic properties of quantum dots change with their size, allowing for easy selection of the wavelengths of light they'll absorb or emit, the voltage they respond to, and other characteristics. But it's difficult to add electrons to the dots, a process called doping, to further tune their properties; the usual methods require cryogenic temperatures or harsh chemicals that degrade the crystal's surface.

Now researchers at the University of Washington have come up with a soft chemistry approach to easily and reversibly dope nanocrystal materials (*J. Am. Chem. Soc.* 2013, DOI: 10.1021/ja410825c). They applied reactive lithium triethylborohydride to cadmium-selenide nanocrystals and exposed them to visible light. Photons striking the quantum dots create electrons and positively charged vacancies in the nanocrystal structures called holes. These holes move through the crystals and eventually encounter triethylborohydride ions. Lithium ions then replace the holes, leaving the photon-generated electrons nothing to recombine with. The process results in a negatively doped crystal.

Ordinary room lighting was enough to trigger the doping. The process can be reversed simply by exposing the crystals to air, giving scientists the ability to adjust the density of electrons in the quantum dots. By adding or removing electrons, researchers can customize nanocrystals to make conductive materials, diodes, and transistors.

Daniel R. Gamelin, the chemist who led the research, calls the method "very accessible chemistry" and says it can be applied to other quantum dot materials, including zinc oxide, cadmium sulfide, and cadmium telluride. It should allow researchers to use nanocrystals to make the same devices that they can make with bulk semiconductors—which are relatively easy to dope—but that have the tunability offered by quantum dots. For example, the method could allow scientists to design solar cells to absorb different wavelengths in different layers, rendering them more efficient, he says.

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