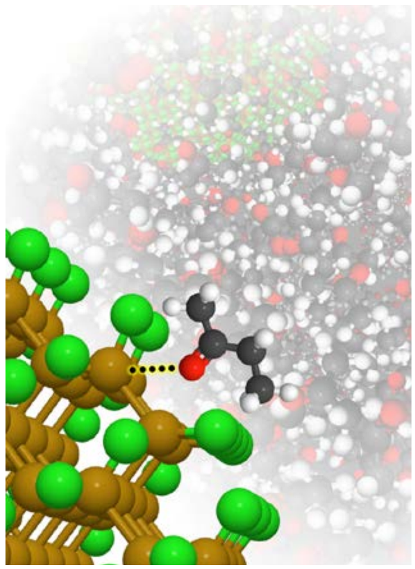
New Pathway Developed to Silicon Quantum Dot Devices

Highlights in Science

Researchers create a way to prepare doped nanocrystal solutions for solar thin films that are nontoxic and less expensive than heavy metal-based thin films.

Scientists at the National Renewable Energy Laboratory (NREL) and the University of Minnesota have developed a method for preparing doped colloids (solutions) of silicon nanocrystals (NCs) as potential nontoxic infrared-absorbing and -emitting alternatives to metal chalcogenide quantum dots. Significant progress in the methods for preparing thin films of semiconductor NCs has recently led to very promising results in which metal chalcogenide (cadmium selenide, lead sulfide, etc.) NC thin films are used as the photoactive layer in solar cells, photodetectors, light-emitting diodes (LEDs), and related technologies.



A molecule of 2-butanone interacting with a silicon quantum dot surface. Image by Lance Wheeler, University of Minnesota

The surface chemistry modifications that have allowed this progress in metal chalcogenide NC film research, however, are not possible with silicon NCs because this class of nanomaterials typically features strong bonds between surface atoms and insulating molecules at the NC surface. This dramatically impedes electrical conductivity. In addition, after a conductive film is achieved, doping the material—which can tune its electrical properties—has proven difficult.

Collaborating under the U.S. Department of Energy's Center for Advanced Solar Photophysics Energy Frontier Research Center program, the research team has discovered a method to get around this limitation by using the ability of surface silicon atoms to undergo hypervalent interactions with solvent molecules. These weak interactions facilitate both solubility and doping of the nanocrystals, which allow conductive films of silicon NCs to be cast from low-cost solution methods, potentially leading to lower-cost solar thin films.

Technical Contact: Nathan Neale, *nathan.neale@nrel.gov*

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Key Research Results

Achievement

A method has been developed to prepare doped group IV nanocrystal colloids (solutions) that are nontoxic infrared-absorbing and -emitting alternatives to lead- and cadmium-based quantum dots.

Key Result

Hypervalent interactions between molecular species and surface silicon atoms enable colloidal stability as well as doping of silicon nanocrystals. These "ligand-free" nanocrystal solutions can be cast into low-cost, conductive films applicable to a variety of optoelectronic devices.

Potential Impact

Nanocrystals and quantum dot assemblies have exhibited impressive results as the active layer in solar cells and related technologies. This discovery capitalizes on the weak interactions between surface silicon atoms and solvent molecules to provide a pathway for extending these breakthroughs to nontoxic, less expensive group IV nanocrystals.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

15013 Denver West Parkway
Golden, CO 80401
303-275-3000 | www.nrel.gov

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