New imaging technique reveals the atomic structure of nanocrystals

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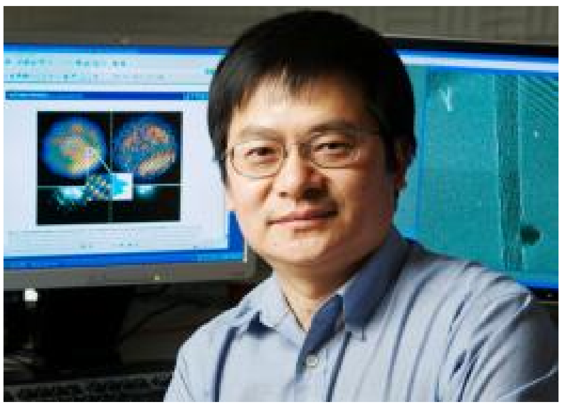

Jian-Min (Jim) Zuo, a professor of materials science and engineering, has developed a new imaging technique that can reveal the atomic structure of a single nanocrystal with a resolution of less than one angstrom (less than one hundred-millionth of a centimeter). Photo by L. Brian Stauffer

(PhysOrg.com) -- A new imaging technique developed by researchers at the University of Illinois overcomes the limit of diffraction and can reveal the atomic structure of a single nanocrystal with a resolution of less than one angstrom.

Optical and electronic properties of small assemblages of atoms called quantum dots depend upon their electronic structure - not just what's on the surface, but also what's inside. While scientists can calculate the electronic structure, they need to know where the atoms are positioned in order to do so accurately.

Getting this information, however, has proved to be a challenge for nanocrystals like quantum dots. Mapping out the positions of atoms requires clues provided by the diffraction pattern. But quantum dots are so small, the clues provided by diffraction alone are not enough.

By combining two sources of information - images and diffraction patterns taken with the same electron microscope - researchers at the U. of I. can achieve sub-angstrom resolution of structures that were not possible before.

"We show that for cadmium-sulfide nanocrystals, the improved image resolution allows a determination of their atomic structures," said Jian-Min (Jim) Zuo, a professor of materials science and engineering at the U. of I., and corresponding author of a paper that describes the high-resolution imaging system in the February issue of Nature Physics.

Images from electron microscopy can resolve individual atoms in a nanocrystal, but the atoms soon suffer radiation damage, which limits the length of observations. Patterns from X-ray diffraction can be used to determine the structure of large crystals, but not for nanocrystals, which are too small and don't diffract well.

To achieve sub-angstrom resolution, Zuo and colleagues developed a reiterative algorithm that processes and combines shape information from the low-resolution image and structure information from the high-resolution diffraction pattern. Both the image and the diffraction pattern are taken with the same transmission-electron microscope.

"The low-resolution image provides the starting point by supplying missing information in the central beam and supplying essential marks for aligning the diffraction pattern," said Zuo, who also is a researcher at the university's Frederick Seitz Materials Research Laboratory. "Our phase-retrieval algorithm then reconstructs the image."

To demonstrate the technique, the researchers took a new look at cadmium-sulfide quantum dots.

"We chose cadmium-sulfide quantum dots because of their size-dependent optical and electronic properties, and the importance of atomic structure on these properties," Zuo said. "Cadmium-sulfide quantum dots have potential applications in solar energy conversion and in medical imaging."

Using the reiterative algorithm, the smallest separation between the cadmium and sulfide atomic columns was measured at 0.84 angstroms, the researchers report.

"Since low-resolution images can be obtained from different sources, our technique is general and can be applied to non-periodic structures, such as interfaces and local defects," Zuo said. "Our technique also provides a basis for imaging the three-dimensional structure of single nanoparticles."

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