'Nanocrystal doping' enhances semiconductor nanocrystals

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This is professor Uri Banin of the Center for Nanoscience and Nanotechnology at the Hebrew University of Jerusalem. Credit: Hebrew University photo

Researchers at the Hebrew University of Jerusalem have achieved a breakthrough in the field of nanoscience by successfully altering nanocrystal properties with impurity atoms -- a process called doping – thereby opening the way for the manufacture of improved semiconductor nanocrystals.

Semiconductor nanocrystals consist of tens to thousands of atoms and are 10,000 times smaller than the width of a human hair. These tiny particles have uses in a host of fields, such as solid-state lighting, solar cells and bio-imaging. One of the main potential applications of these remarkable materials is in the semiconductor industry, where intensive miniaturization has been taking place for the last 50 years and is now in

the nanometer range.

However, these semiconductors are poor electrical conductors, and in order to use them in electronic circuits, their conductivity must be tuned by the addition of impurities. In this process, foreign atoms, called impurities, are introduced into the semiconductor, causing an improvement in its electrical conductivity.

Today, the semiconductor industry annually spends billions of dollars in efforts to intentionally add impurities into semiconductor products, which is a major step in the manufacturing of numerous electronic products, including computer chips, light emitting diodes and solar cells.

Due to the importance of doping to the semiconductor industry, researchers worldwide have made continuing attempts at doping nanocrystals in order to achieve ever greater miniaturization and to improve production methods for electronic devices. Unfortunately, these tiny crystals are resistant to doping, as their small size causes the impurities to be expelled. An additional problem is the lack of analytical techniques available to study small amounts of dopants in nanocrystals. Due to this limitation, most of the research in this area has focused on introducing magnetic impurities, which can be analyzed more easily. However, the magnetic impurities don't really improve the conductivity of the nanocrystal.

Prof. Uri Banin and his graduate student, David Mocatta, of the Hebrew University Center for Nanoscience and Nanotechnology, have achieved a breakthrough in their development of a straightforward, room-temperature chemical reaction to introduce impurity atoms of metals into the semiconductor nanocrystals. They saw new effects not previously reported. However, when the researchers tried to explain the results, they found that the physics of doped nanocrystals was not very well understood.

Bit by bit, in collaboration with Prof. Oded Millo of the Hebrew University and with Guy Cohen and Prof. Eran Rabani of Tel Aviv University, they built up a comprehensive picture of how the impurities affect the properties of nanocrystals. The initial difficulty in explaining this process proved to be a great opportunity, as they discovered that the impurity affects the nanocrystal in unexpected ways, resulting in new and intriguing physics.

"We had to use a combination of many techniques that when taken together make it obvious that we managed to dope the nanocrystals. It took five years but we got there in the end," said Mocatta.

This breakthrough was reported recently in the prestigious journal *Science*. It sets the stage for the development of many potential applications with nanocrystals, ranging from electronics to optics, from sensing to alternative energy solutions. Doped nanocrystals can be used to make new types of nanolasers, solar cells, sensors and transistors, meeting the exacting demands of the semiconductor industry.

Provided by Hebrew University of Jerusalem