Researchers transform the properties of matter with tunable quantum dots

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Researchers at the University of Pennsylvania may not have turned lead into gold as alchemists once sought to do, but they did turn lead and selenium nanocrystals into solids with remarkable physical properties. In the October 5 edition of Physical Review Letters, online now, physicists Hugo E. Romero and Marija Drndic describe how they developed am artificial solid that can be transformed from an insulator to a semiconductor.

The Penn physicists are among many modern researchers who have been experimenting with a different way of transforming matter through artificial solids, formed from closely packed nanoscale crystals, also called "quantum dots."

"Essentially, we're forming artificial solids from artificial atoms – about 10 times larger than real atoms – whose properties we can fine tune on the quantum level," said Drndic, an assistant professor in Penn's Department of Physics and Astronomy. "Artificial solids are expected to revolutionize the fabrication of electronic devices in the near future, but now we are only beginning to understand their fundamental behavior."

Artificial solids, in general, are constructed by specifically assembling a number of nanocrystals, each composed of only a few thousand atoms, into a closely packed and well-ordered lattice. Previous researchers have demonstrated that quantum dots can be manipulated to change their physical properties, particularly their optical properties. In fact, the blue laser, which will soon be put into use into commercial products, was a result of early research in changing the colors of quantum dots.

"Many of the physical parameters of these crystals, such as their composition, particle size and interparticle coupling, represent knobs that can be individually controlled at nanometer scales," Drndic said. "Variation of any of these parameters translates directly into either subtle or dramatic changes in the collective electronic, optical and magnetic response of the crystal. In this case were able to adjust its electrical properties."

In their study, Drndic and her colleagues looked at the ability of artificial solids to transport electrons. They demonstrated that, by controlling the coupling of artificial atoms within the crystal, they could increase the electrical conductivity of the entire crystal. According to the researchers, this system promises the possibility of designing artificial solids that can be switched through a variety of electronic phase transitions, with little influence from the local environment. Their findings represent a key step towards the fabrication of functional nanocrystal-based devices and circuits.

Quantum dots are more than simply analogous to individual atoms; they also demonstrate quantum effects, like atoms, but on a larger scale. As a tool for research, quantum dots make it possible for physicists to measure, firsthand, some things only described in theory.

"It is this versatility in both experiment and theory that can potentially turn these quantum dot solids into model systems for achieving a general understanding of the electronic structure of solids," Drndic said. "Not only are we making strides in creating a future generation of electronics, but in doing so we are also getting a deeper understanding of the fundamental properties of matter."

Source: University of Pennsylvania