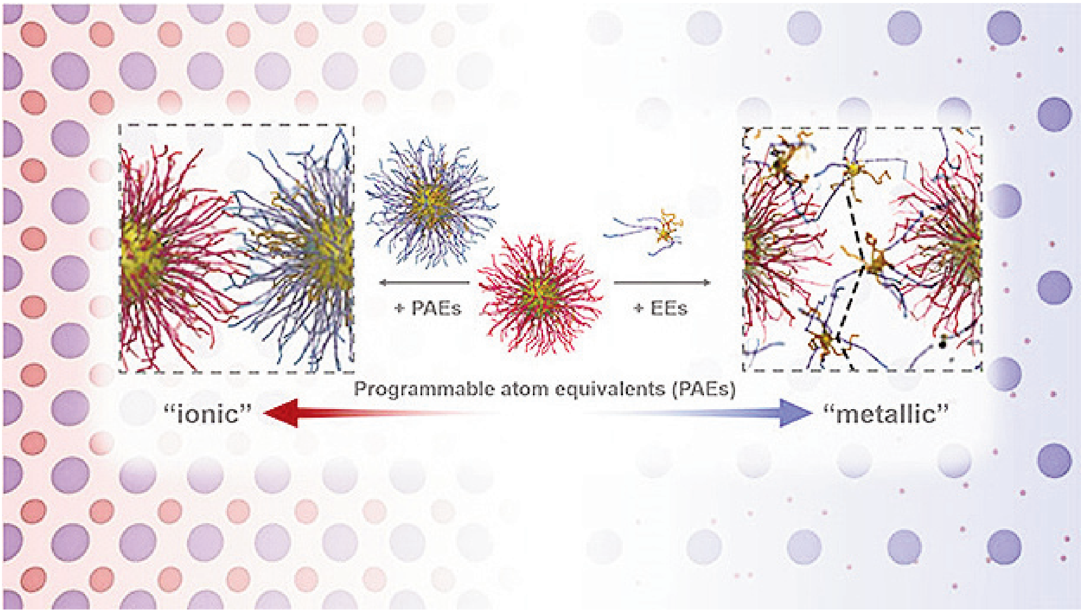
The Advanced Photon Source

Electron-behaving Nanoparticles Rock Current Understanding of Matter



Electron equivalent metallicity.

It's not an electron. But it sure does act like one.

Northwestern University researchers using a number of experimental resources, including the U.S. Department of Energy's Advanced Photon Source (APS), an Office of Science user facility at Argonne National Laboratory, have made a strange and startling discovery. Nanoparticles engineered with DNA in colloidal crystals — when extremely small — behave just like electrons. Not only has this finding upended the current, accepted notion of matter, it also opens the door for new possibilities in materials design.

With this discovery, the researchers introduced a new term called "metallicity," which refers to the mobility of electrons in a metal. In colloidal crystals, tiny nanoparticles roam similarly to electrons and act as a glue that holds the material together.

The paper was published in the journal Science.

Researchers in the group of Northwestern's Chad Mirkin previously invented the chemistry for engineering colloidal crystals with DNA, which has forged new possibilities for materials design. In these structures, DNA strands act as a sort of smart glue to link together nanoparticles in a lattice pattern.

Over the past two decades, they figured out how to make all sorts of crystalline structures where the DNA effectively takes the particles and places them exactly where they are supposed to go in a lattice.

In these previous studies, the particles' diameters are on the tens of nanometers length scale. Particles in these structures are static, fixed in place by DNA. Computational simulations, however, found that when the particles were reduced down to 1.4 nanometers in diameter, new behavior emerged.

The bigger particles have hundreds of DNA strands linking them together. The small ones only have 4 to 8 linkers. When those links break, the particles roll and migrate through the lattice holding together the crystal of bigger particles.

Mirkin's team's experiments, including small-angle x-ray scattering characterization at the DuPont-Northwestern-Dow Collaborative Access Team x-ray beamline 5-ID at the APS, agree with computational observations made by the team led by Northwestern U.'s Olvera de la Cruz's. Because this behavior is reminiscent of way electrons behave in metals, the researchers call it "metallicity."

A sea of electrons migrates throughout metals, acting as a glue, holding everything together. The tiny particles become the mobile glue that holds everything together.

Olvera de la Cruz and Mirkin next plan to explore how to exploit these electron-like particles in order to design new materials with useful properties. Although their research used gold nanoparticles, Olvera de la Cruz noted that metallicity applies to other classes of particles in colloidal crystals.

See: Martin Girard[1], Shunzhi Wang[1], Jingshan S. Du[1], Anindita Das[1], Ziyin Huang[1], Vinayak P. Dravid[1], Byeongdu Lee[2], Chad A. Mirkin[1**], Monica Olvera de la Cruz[1*], "Particle analogs of electrons in colloidal crystals," Science **364**, 1174 (21 June 2019).
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Call for APS General-User Proposals

The Advanced Photon Source is open to experimenters who can benefit from the facility's high-brightness hard x-ray beams.

General-user proposals for beam time during Run 2020-1 are due by Friday, October 25, 2019.

Information on access to beam time at the APS is at http://www.aps.anl.gov/Users/apply_for_beamtime.html or contact Dr. Dennis Mills, DMM@aps.anl.gov, 630/252-5680.

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