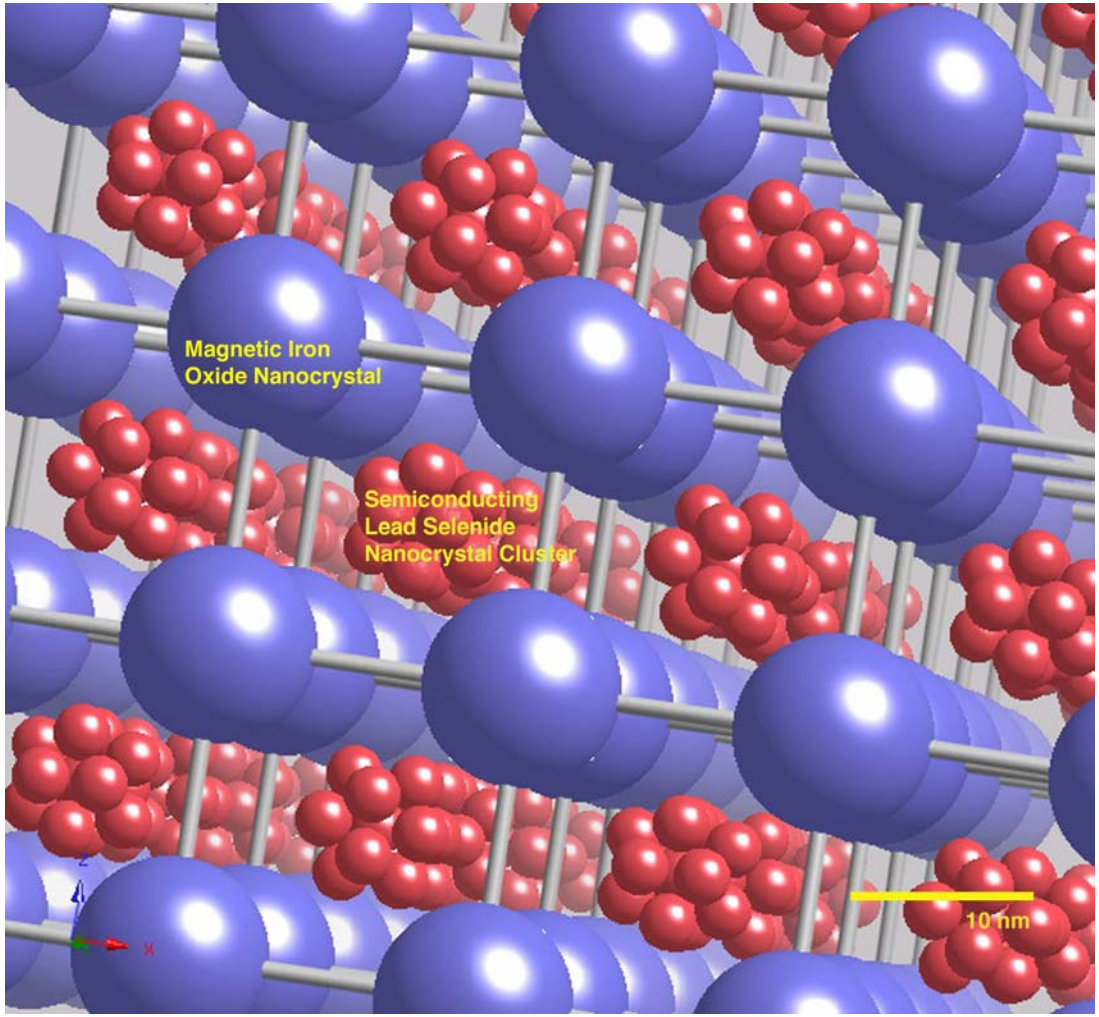
Assembly of Magnetic and Semiconducting Nanoparticles

Irving Herman, Columbia DMR-0213574

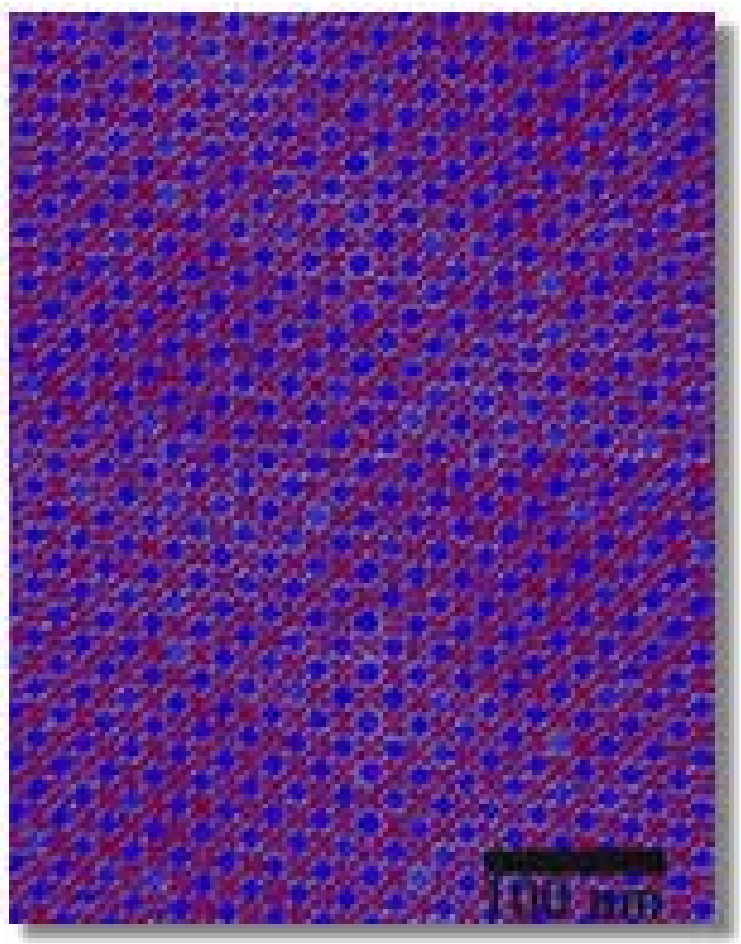


Sketch of a self-assembled bimodal superlattice of nanocrystals. The superlattice is composed of superparamagnetic iron oxide nanocrystals (blue) in a cubic array, with an icosohedron of 13 semiconducting lead selenide crystals (red) at the center of each cube. (The thirteenth lead selenide nanocrystal is at the center of the icosohedron.)

Credit: Franz Redl, Kyung Sang Cho, Christopher B. Murray and Stephen O'Brien, IBM T.J. Watson Research Center and Columbia University MRSEC

Assembly of Magnetic and Semiconducting Nanoparticles

Irving Herman, Columbia DMR-0213574



This electron microscopy image has been colorized to highlight the positions of the magentic iron oxide particles (blue) and the semiconducting lead selenide quantum dots (red).

Assembly of Magnetic and Semiconducting Nanoparticles

Irving Herman, Columbia DMR-0213574

Designing new materials with otherwise unattainable properties, sometimes referred to as "metamaterials," is one of the promises of nanotechnology. Two-dimensional patterns had previously been created from gold nanoparticles of different sizes and mixtures of gold and silver. Extending this concept to three dimensions with more diverse types of materials demonstrates the ability to bring more materials together than previously realized.

The scientists chose the materials for the experiments specifically because of their dissimilar, yet complementary properties. Lead selenide is a semiconductor that has applications in infrared detectors and thermal imaging and can be tuned to be more sensitive to specific infrared wavelengths. The other material, magnetic iron oxide, is best known for its use in the coatings for certain magnetic recording media.

The combination of these nanoparticles may have novel magneto-optical properties as well as properties key to the realization of quantum computing. For example, it might be possible to modulate the material's optical properties by applying an external magnetic field.

The first step was to create the nanoparticles. The particle sizes were calculated from the mathematical ideal of the structures they wanted to create. In addition to fine-tuning the sizes, the particles had to be very uniform, all within 5 percent of the target size. They settled on iron oxide particles 11 nanometers in diameter, which were created by Redl, and lead selenide particles 6 nanometers in diameter, created by Cho. There are approximately 60,000 atoms in one of the iron oxide nanoparticles and approximately 3,000 atoms in the lead selenide particles.

Next, Redl assembled the nanoparticles—or more to the point, had the particles assemble themselves—into three different repeating 3-D patterns by tailoring the experimental conditions. Forming these so-called "crystal structures," as opposed to random mixtures of nanoparticles, is essential for the composite material to exhibit consistent, predictable behaviors. Various other materials are known to assemble spontaneously into these structures of close-packed particles, but none has been made of two components in three dimensions and at these length scales.