Sandia scientists' fabrication method could improve availability of large nanoparticle supercrystals

Sandia National Laboratories

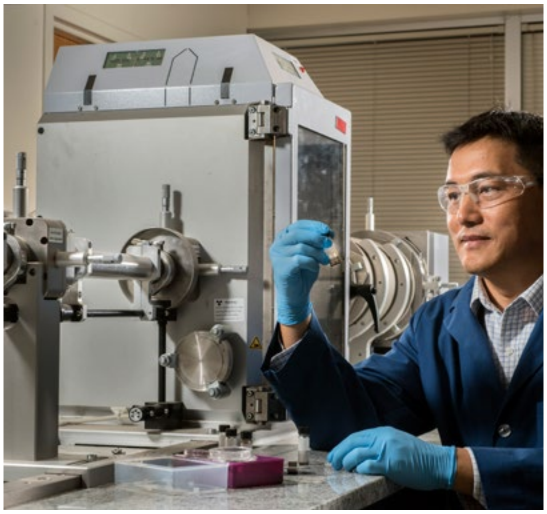
Researchers from Sandia National Laboratories have created a way to turn tiny amounts of gold into large, high-quality supercrystals with the potential to improve the chemical detection of drugs or explosives and the performance of sensors, lasers, and solar panels.

Metallic nanoparticles (a few millionths of a millimeter in diameter) such as gold and silver can self-assemble and crystallize into highly ordered arrays known as supercrystals. Highly ordered single supercrystals have critical applications in areas such as optics, electronics, and sensor platforms. However, the difficulty of obtaining high-quality supercrystals for production scale usage and device integration has limited their wide-scale adoption.

Sandia researchers' solution involves a method for fabricating unusually large (millimeter-sized) supercrystals containing millions of tightly packed gold nanoparticles. The method involves binary solvent diffusion (BSD), in which the nanoparticles are exposed to two types of liquids (solvents). A toluene solution containing gold nanoparticles is topped with isopropanol (IPA), forming a liquid–liquid interface. The IPA solvent then flows (diffuses) into the toluene solvent, and as the concentration of gold nanoparticles becomes too high for all of them to remain in the solution, they slowly emerge and form large nanoparticle supercrystals. These supercrystals have a hexagonal disk shape characterized by facets (similar to those seen in cut diamonds).

In addition to supercrystals made from gold nanoparticles, the scientists also successfully used the same method to create supercrystals from other nanoparticle materials such as semiconducting (e.g., cadmium selenide, lead sulfide, lead selenide) or magnetic (e.g., iron oxides, iron platinum).

The BSD method has several competitive advantages over conventional approaches to supercrystal fabrication and sensing (e.g., using single-nanoparticle or thin film substrates) that will enhance its potential for use in industry applications.



Above: Sandia National Laboratories researcher Hongyou Fan holds a container enclosing gold supercrystals in front of a small-angle X-ray scattering instrument. (Photo by Randy Montoya)

- It offers more systematic control of nanoparticle morphology and structure, which allows precise tunability of the shape, size, composition, and other functional properties. These advanced functional materials are of major interest for materials manufacturing companies.
- The facets of the nanoparticle supercrystals enable new facet-dependent chemical and physical properties. Some of these properties, for example, can be used to enhance a local electromagnetic field. This is important for a variety of applications in nanoelectronic and photonic devices, such as optical antennas for cellular media and photovoltaics.
- Sensors made from supercrystals are nine times more sensitive for chemical detection than nanoparticle in solution or thin film nanoparticle substrates. These sensors have practical applications in airport and drug screen testing, etc.
- It enables large scale fabrication and reproducible properties in applications at reduced cost. The bench-top sensors are surprisingly inexpensive despite the use of gold. The total materials cost of a sensor is roughly 50 cents, which makes them so inexpensive that they can be considered disposable.