Dr. Robert Fox examining vials of nanoparticle solutions made by processing single-source precursors with supercritical fluids.

Changing the World's Energy Future

Idaho National Laboratory

Precision Nanoparticles

Manufacturing transformative materials uniformly

Technological Marketing Summary

Nanoparticles — specks of matter thousands of times thinner than the width of a human hair — are showing tremendous potential in the development of new, transformative materials.

Just as a grain of salt has a higher percentage of its atoms on the surface than a block of salt, nanoparticles are so small that most of their atoms reside on the surface. This means atomic surface interactions dominate their behavior, giving them remarkable properties. The high surface interactions make nanoparticles exceptional for transmitting energy, which can be used for applications such as making transistors faster and more efficient. Nanoparticles are also of interest for solar energy applications, where particles of varied sizes could be layered, allowing energy movement from multiple wavelengths, improving viability and functionality.

The challenge with nanoparticles has been consistently creating them at prescribed specific and uniform sizes. A team of researchers from Idaho National Laboratory and Idaho State University were attempting to produce nanoparticles using the traditional method in which a supercritical fluid is used as a solvent to dissolve source material. The supercritical carbon dioxide failed to break down the organometallic material, instead producing a coagulated yellow "goo" in the reactor vessel, and the team assumed the experiment had failed. Then a member examined the material under an electron microscope and discovered nanoparticles smaller and more uniform than anything they'd seen.

After deconstructing the process, researchers were able to duplicate and formalize the supercritical fluids-based technique, which can now produce affordable, uniform (+/- 0.2 nm) particles in a designated diameter and a wide range of sizes (less than 1 to 100 nm). The process does not require special handling such as clean rooms and is extremely cost-effective. For instance, a gram of copper indium disulfide nanoparticles – until now difficult to produce in quantities of consistently high quality – can be made for just dollars.

Vials of nanoparticles that can be distributed in a spray to produce uniformity and consistency on surfaces and in materials.

Technology Description

Supercritical fluid extraction offers a more environmentally friendly, cost-competitive process for producing nanoparticles than traditional methods, which include attrition, pyrolysis and hydrothermal synthesis. A supercritical fluid is any substance at a temperature and pressure above its critical point, where distinct liquid and gas phases do not exist. Supercritical fluids can diffuse through solids like a gas, and dissolve materials like a liquid. By exposing single-source precursors — molecules containing elements connected by a single chemical bond — to carbon dioxide in a supercritical state, INL and ISU researchers have been able to form nanoparticles at set sizes. Instead of using high temperature, the process takes place at around 65 degrees Celsius, saving significant amounts of energy. While the patented method using supercritical fluids was originally conceived as a process for making nanomaterials for cost-effective and high-efficiency photovoltaic cells, nanoparticles have also been recognized for their possibilities in pharmaceuticals, electronics and magnets, and as catalysts in the advanced manufacturing of platform chemicals.

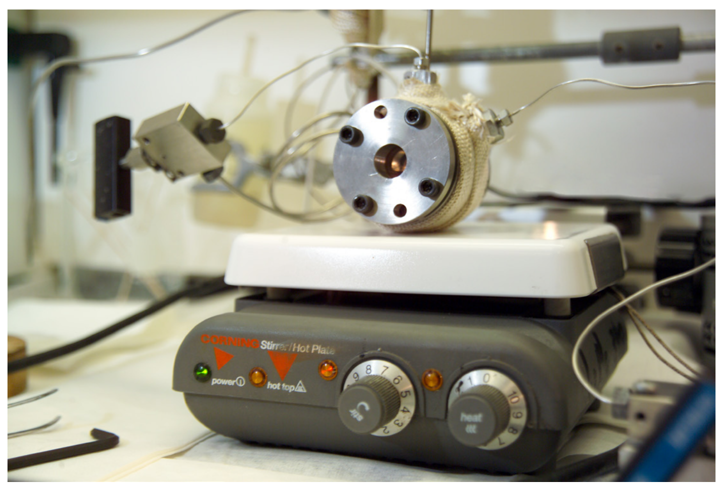
The promise of this breakthrough technology was recognized in 2009 with an R&D 100 Award.

Technological Benefits

- Uniform, microengineered material for advanced manufacturing
- Environmentally friendly technology for production
- Lower energy manufacturing costs
- Reduced overall production costs

Potential Applications

Pharmaceuticals, catalysts for advanced chemical manufacturing, high-efficiency nanoprocessors for electronics, and next-generation photovoltaic energy cells are among potential applications.



The laboratory apparatus used to generate nanoparticles by keeping carbon dioxide in a simultaneously liquid and gaseous state.

For more information

Technical Contact
Robert V. Fox
208-526-7844
robert.fox@inl.gov

General Contact
Ryan Bills
208-526-1896
ryan.bills@inl.gov

www.inl.gov

Additional Information

U.S.Patent No 8,829,217, "Methods of Forming Single Source Precursors, Methods of Forming Polymeric Single Source Precursors, and Single Source Precursors Formed by Such Methods."

A U.S. Department of Energy National Laboratory