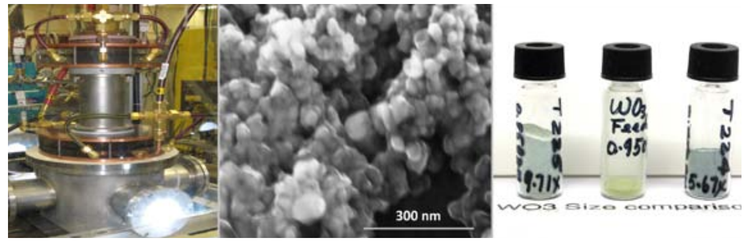
Novel, Low-Cost Nanoparticle Production

A Modular Hybrid Plasma Reactor and Process to Manufacture Low-Cost Nanoparticles



The 5th-generation modular hybrid plasma system (left). Researchers will complete a pre-pilot scale development of this system during the project. Tungsten oxide nanoparticles produced with the system (center). Comparison of feed and product powders (right).

Photos courtesy of Idaho National Laboratory.

Introduction

Nanotechnology offers the ability to work at or near the atomic level to create structures with fundamentally new and beneficial physical properties and behaviors. Successful application-based, large-scale manufacturing of nanomaterials will enable the development of diverse products that can solve long-standing problems and facilitate unprecedented materials innovation. However, to fully realize the economic benefits of nanomaterials, a robust understanding of the fundamental scientific principles operating at the nanoscale level is required. Such an understanding will unlock the ability to synthesize and scale-up production of nanomaterials and allow producers to focus on designing with application in mind.

Currently, production of nanoparticles generally falls into three categories: solid phase particle size reduction, liquid phase synthesis, and gas phase synthesis. In addition to economic considerations, each process suffers from limitations ranging from poor property control to the introduction of outside contaminants into the product.

To address these limitations, the project team is researching and developing new approaches—such as plasma reaction processes and new plasma reactor designs—to produce low-cost, high-performance nanoparticles from inexpensive solid feedstocks. Specifically, this project is evaluating and optimizing a modular hybrid plasma reactor (MHPR) to produce nanomaterials with consistent particle morphology and size (> 95% of nanomaterial less than 100 nm), desirable surface chemistry, and reduced contaminants (> 99.5% purity). The plasma reactor system must be able to run continuously with feed materials for a minimum of eight hours, which is several times longer than current technologies.

Benefits for Our Industry and Our Nation

Successful manufacturing of nanoparticles using the proposed MHPR will result in greater energy, environmental, and economic benefits relative to current technologies used for nanomaterial production. The primary economic benefit is the ability of the MHPR to accept multiple feedstocks with few or no process changes and little operational downtime for the production of multiple products. This makes the MHPR economical for large-scale production processes. In addition, the MHPR is environmentally friendly and energy efficient, and produces nanoparticles without any unwanted waste or emissions.

Applications in Our Nation's Industry

Successful development of MPHR technology would support the synthesis of nanoparticles that could be used in a wide range of applications, including:

- Catalysts for chemical, petroleum, and energy processes
- Coatings and thin-films for low-friction drag, wear, corrosion-resistance, dispersion aid, thermal, and energy applications
- Nanocomposites for strong, lightweight industrial, automotive, and energy products
- Functional materials for environmental, medical, sanitary, energy storage, optical, memory storage, and carbon management applications
- Stronger, lightweight body armor for soldiers and other defense and homeland security applications

Project Description

The goal of this project is to develop a pre-pilot scale MHPR and demonstrate high-yield, low-cost production of nanomaterials from inexpensive feedstock. This goal is being achieved by using solid raw materials and oxidizing neutral or reducing environments in the proposed plasma reactor to create a flexible synthetic method of economically producing a wide variety of inorganic nanoparticle compositions including oxides, mixed oxides, non-oxide ceramics, and metals. Ultimately, the technology will be scaled-up and transferred for commercial deployment.

Barriers

- Achieving controlled generation of monodispersed nanoparticles with size variance too small to necessitate size selection by centrifugal precipitation or mobility classification
- Developing continuous processing techniques that enable the economical scale-up production of nanoparticles

Pathways

The first phase of the project involved defining several hybrid plasma system concepts, each with uniform high-temperature processing zones and long residence time. Next, researchers design, construct, test, and evaluate the capabilities of these systems and select one for optimization and use in bench-scale, cost-effective nanoparticle production. Finally, researchers will construct and demonstrate a pilot-scale production system. This is the final phase before the technology is transferred to the industry partner for commercial deployment.

Milestones

Work on this project commenced in September 2009.

- Complete model materials property assessment with industrial partner. The research team chose tungsten oxide as the model material. (Completed)
- Conduct preliminary runs of chosen material to demonstrate 100% optimization. (Completed)
- Finalize production process and system optimization.
- Complete scale-up modeling and validate the 300 kW size requirements.

Commercialization

PPG Industries, the initial customer and primary industrial partner for the proposed technology, is a large, diversified manufacturer of specialty materials such as paints, coatings, chemicals, optical products, glass, and fiberglass with a long history of novel product development. As the primary industrial partner, PPG is providing cost sharing and will be responsible for the commercialization strategy of the technology. The company's primary interest is in the nanoparticles that the MHPR technology can produce and how these nanoparticles will enhance and expand the range of PPG products.

Once the 300 kW pilot reactor is completed, the technology and its products will be tested and implemented by PPG. To supply larger markets, the technology may be scaled up to 2 to 3-MW commercial units. Commercial production of a nanoparticle product can be initiated with one such unit and then, as market acceptance grows, ramped to a full commercial-scale plant. Eventually, PPG may engage other companies with a core competency in the manufacture, sale, installation, distribution, and servicing of plasma arc systems in industrial applications, either as partners or as licensees.

Project Partners

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