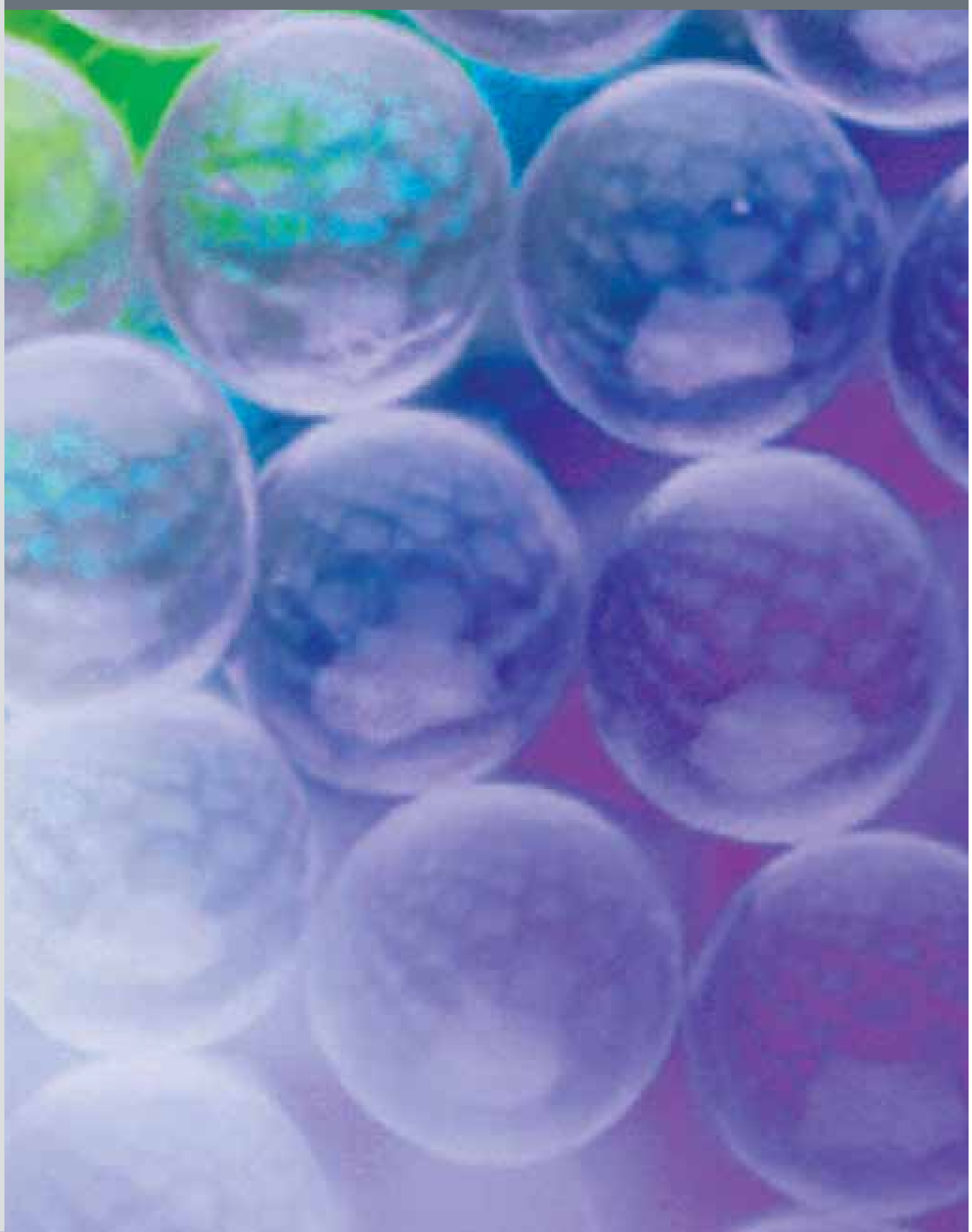
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

INDUSTRIAL TECHNOLOGIES PROGRAM

Nanomanufacturing Portfolio:

Manufacturing Processes and Applications to Accelerate Commercial Use of Nanomaterials



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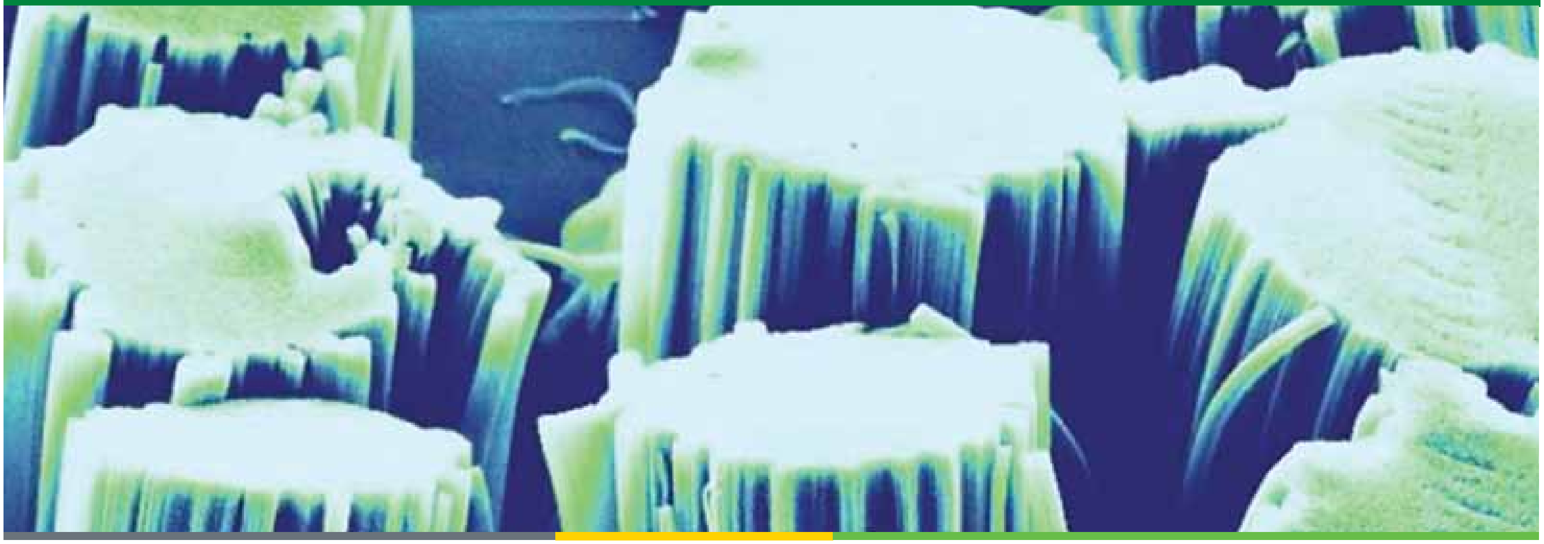


Introduction

Nanotechnology is an important pathway for reducing the energy and carbon intensity of manufacturing processes to advance national goals. Applications in the chemicals, refining, maritime, and automotive sectors alone may save up to 1.1 quadrillion British thermal units (Btu) and avoid more than 60 million metric tons of carbon dioxide emissions each year. Enabling the use of nanotechnology to improve U.S. manufacturing processes and products will also open global markets for nano-enabled solutions in energy generation, storage, and use.

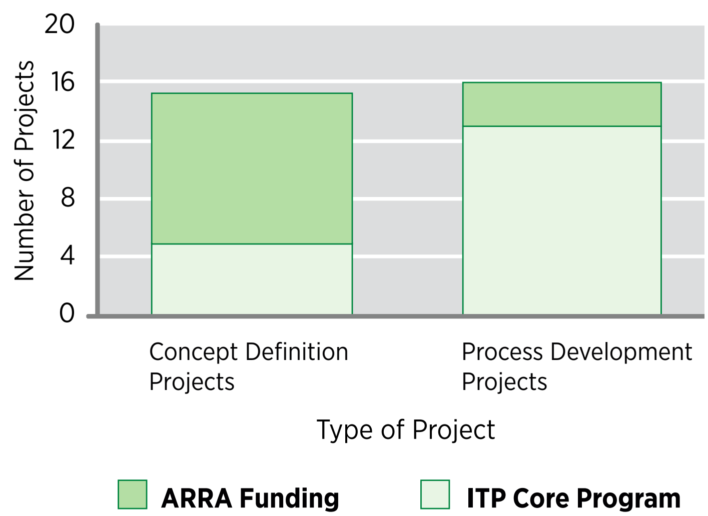
Countries around the globe are investing heavily in nanotechnology to address some of the world's toughest energy and environmental challenges. In 2009, nanotechnology investments by governments, corporations, and investors around the world totaled $17.6 billion.[1]

The U.S. government has made major investments in basic nanotechnology research for the past decade. To build on this research and accelerate the use of nanotechnology, the U.S. Department of Energy's (DOE's) Industrial Technologies Program (ITP) is now teaming with industrial partners and national laboratories to develop the following:

- Manufacturing processes to deliver high-volume, reliable, and consistent supplies of nanomaterials
- Scalable unit operations that enable nanomaterials to be incorporated into products

Commercial-scale nanomanufacturing will deliver performance-enhancing nanomaterials to U.S. and global markets, help U.S. industry maintain its global competitiveness, and support climate and energy initiatives.

Nanomanufacturing Portfolio by Project Type and Funding Source



[1] Lux Research, "Ranking the Nations on Nanotech: Hidden Havens and False Threats The Authority of Law," (August 2010).

ITP supports research, development, and demonstration activities that focus on the development and deployment of technologies to produce uniform nanomaterials and cost-effectively incorporate them into manufactured goods that save energy. ITP's nanomanufacturing portfolio focuses on the following objectives:

- Develop low-cost manufacturing processes to expand the near-term commercial use of innovative nanomaterials in 1) industrial processing and 2) energy-saving and energy-producing products
- Develop technologies that enable the expanded use of nanomaterials 1) directly as a material to enhance material performance and 2) indirectly as an intermediate device (e.g., nanosensors for thermal management)

Projects in the portfolio seek to make revolutionary improvements in a broad range of energy production, storage, and consumption applications that will reduce energy and carbon intensity in industrial processes. The projects are funded through ITP's core program and the American Recovery and Reinvestment Act.

In 2010, the ITP nanomanufacturing research and development portfolio supported 31 projects in two technical areas: concept definition studies and process development projects. A list of the projects by topic area and a description of each project follows.

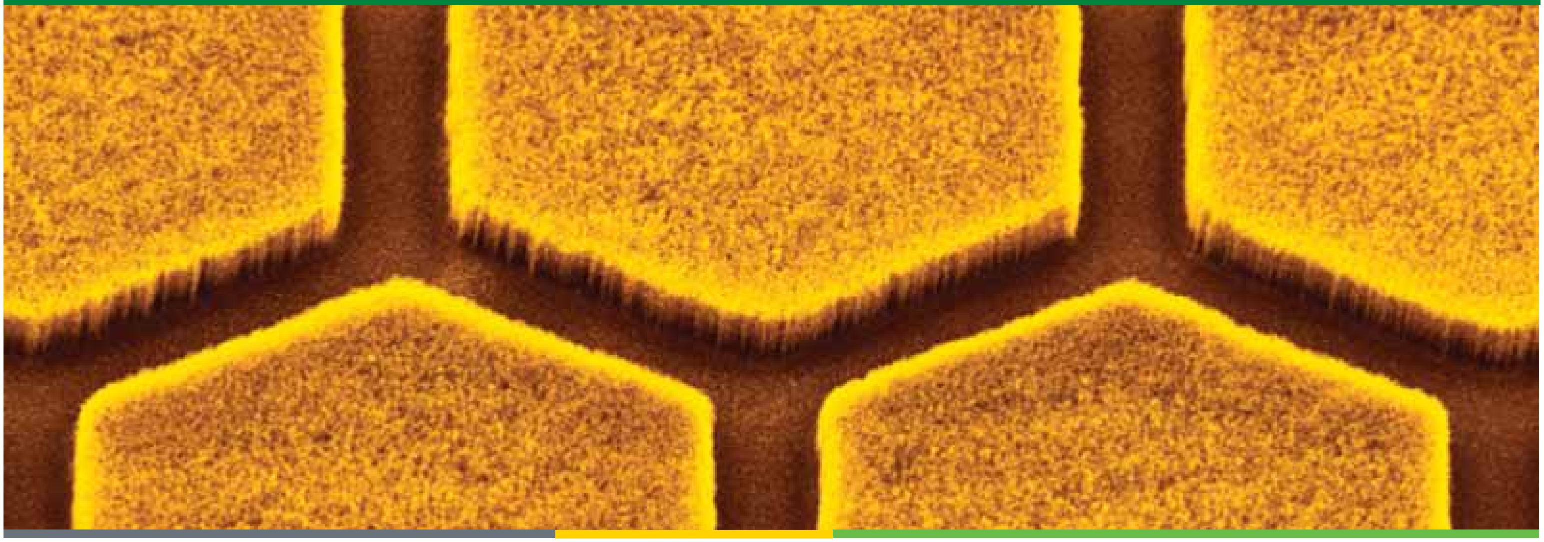
Nanomanufacturing Portfolio by Technology Category and Type of Project

Technology Categories	Number of Projects by Type	
	Concept Definition	Process Development
Catalysts	4	3
Nanocoatings and thin films	4	5
Nanofluids/suspensions	0	2
Separation media	2	0
Nanomaterials for energy and sustainability	3	4
Nanomaterial fabrication	2	2

List of Projects in the Nanomanufacturing Portfolio

Concept Definition Studies	Process Development Projects
High Power Impulse Magnetron Sputtering of Ultra-Hard and Low-Friction Nanocomposite Coatings	Nanostructured Superhydrophobic Coatings
Microwave and Beam Activation of Nanostructured Catalysts for Environmentally Friendly, Energy-Efficient Heavy Crude Oil Processing	Erosion-Resistant Nanocoatings to Improve Energy Efficiency in Gas Turbine Engines
Transformational, Large Area Fabrication of Nanostructured Materials Using Plasma Arc Lamps	Nanocatalysts for Diesel Engine Emission Remediation
Nanocrystallization of $LiCoO_2$ Cathodes for Thin Film Batteries Utilizing Pulse Thermal Processing*	Accelerated Deployment of Nanostructured Hydrotreating Catalysts
Oxide-Nanoparticle Containing Coatings for High Temperature Alloys*	Large-Scale Manufacturing of Nanoparticulate-Based Lubrication Additives
Highly Dispersed Metal Catalyst for Fuel Cell Electrodes	Microchannel-Assisted Nanomaterial Deposition Technology for Photovoltaic Material Production
Self-Assembled Biomimetic Nanostructured Anti-Reflection Coatings for Highly Efficient Crystalline Silicon Solar Cells*	Self-Assembled, Nanostructured Carbon for Energy Storage and Water Treatment
Mesoporous Carbon Membranes for Selective Gas Separations*	Ultratough Thermally Stable Polycrystalline Diamond/Silicon Carbide Nanocomposites for Drill Bits
Nanocatalytic Conversion of Biomass into Second-Generation Biofuels*	Modular Hybrid Plasma Reactor and Process for Low Cost Nanoparticle Production*
Large Scale Nanofermentation of Quantum Dots	Application of Wear-Resistant, Nanocomposite Coatings Produced from Iron-Based Glassy Powders
Filled Carbon Nanotubes: Superior Latent Heat Storage Enhancers*	Development and Application of Processing and Process Control for Nanocomposite Materials for Lithium Ion Batteries*
Pulsed Thermal Processing of Self-Assembled Quantum Dot Structures*	Process Development for Nanostructured Photovoltaics*
Architectured Nanomembranes for In-Situ Energy Conversion Technologies*	Development and Demonstration of Nanofluids for Industrial Cooling Applications
Infrared Absorbing Nanoparticles for Reducing Cure Temperatures in Industrial Coatings*	Manufacturing of Superhydrophobic Surfaces with Nanoscale and Microscale Features
Synthesis of Highly Ordered TiO_2 Nanotubes Using Ionic Liquids for Photovoltaics Applications*	Nanoparticle Technology for Biorefinery of Non–Food Source Feedstocks
	Nanostructured Materials for Renewable Energy

*** Funded through the American Recovery and Reinvestment Act**



Concept Definition Studies

Concept definition studies are early-stage, laboratory-scale research studies that explore and define technical concepts or answer a specific technical question. The studies will include technical and economic feasibility analyses as well as a complete life-cycle analysis for a proposed nanotechnology—from synthesis to disposal. The studies focus on promising nanotechnologies such as catalysts, coatings and thin films, separations media, nanocomposites, and other nanodevelopments.

High Power Impulse Magnetron Sputtering of Ultra-Hard and Low-Friction Nanocomposite Coatings

High Power Impulse Magnetron Sputtering (HIPIMS), a revolutionary coating method for industrial-scale deposition systems, can overcome nanocoating delamination by enabling super-toughness and super-strong adhesion and cohesion. HIPIMS seeks to achieve extremely high levels of adhesion (>40 newtons) between super-hard (>30 gigapascals [GPa]) nanocomposite coatings and the surfaces of tools or other mechanical parts. HIPIMS of ultra-hard and low-friction nanocomposite coatings could prevent wear, cracks, and delamination that commonly occur under harsh operating conditions, significantly lowering friction and wear losses in rolling, drilling, milling, and forming operations across multiple industrial sectors.

Project Partner

Argonne National Laboratory
Argonne, IL

Microwave and Beam Activation of Nanostructured Catalysts for Environmentally Friendly, Energy-Efficient Heavy Crude Oil Processing

Researchers are evaluating and developing energy-efficient processes activated by microwave, radio frequency, or radiation beams in order to take advantage of nanostructured catalysts. Microwave activation is expected to lower required process energies by selectively heating catalyst surface sites, rather than heating the bulk of the material being processed. The microwave-activated catalyst technology used in heavy crude oil processing will enhance catalytic cracking, reforming, and hydrotreating—with up to 50 times improvement in catalysis rates—in the chemical, biorefinery, and petrochemical processing industries, while operating at temperatures approximately 100°C less than conventional methods.

Project Partners

Oak Ridge National Laboratory
Oak Ridge, TN

Mach I, Inc.
King of Prussia, PA

Materials Technology Institute
St. Louis, MO

Transformational, Large Area Fabrication of Nanostructured Materials Using Plasma Arc Lamps

Critical steps are needed to synthesize nanostructured materials over large areas and dramatically reduce the processing costs of the solid-state lighting and photovoltaic materials. Focusing specifically on a zinc oxide system for light-emitting diode applications, this nanomanufacturing

Project Partner

Oak Ridge National Laboratory
Oak Ridge, TN

concept study employs high-density plasma arc lamp (PAL) technology to perform critical processing steps. The use of PAL technology incorporates nanostructure features into actual materials over large areas (as large as 1,000 cm^2) with the desired phase and/or morphology.

Nanocrystallization of $LiCoO_2$ Cathodes for Thin Film Batteries Utilizing Pulse Thermal Processing

Nanostructured architectures will increase the performance of energy-storage devices by 10 times; and improve capacity, charge time, and cycle lifetime; and augment overall battery energy efficiency. Researchers are studying and evaluating the nanocrystallization of lithium cobalt dioxide ($LiCoO_2$) cathode thin films as a function of Pulse Thermal Processing (PTP) conditions in order to enable thin film batteries. PTP's high power densities, short processing time, and large processing area allow for rapid fabrication of thin-film and nanoparticle material systems on temperature sensitive flexible substrates. PTP's characteristics permit thin film annealing temperatures of 550°C–700°C without thermal degradation of the underlying substrate (maximum operating temperature of 150°C) or other material system. PTP can also influence other thin film and nanoparticle material systems, including magnetic media, photovoltaics, solid-state lighting, thermoelectrics, and thin film transistors.

Project Partners

Oak Ridge National Laboratory
Oak Ridge, TN

ITN Energy Systems
Littleton, CO

Oxide-Nanoparticle Containing Coatings for High Temperature Alloys

In an effort to develop advanced high-temperature materials, researchers are examining the feasibility of using electromagnetic stirring techniques to disperse oxide nanoparticles uniformly within liquid steel. Desirable characteristics of these advanced materials include good high-temperature strength, oxidation resistance, and creep resistance (the ability to resist time-dependent elongation or distortion under loading). Oxide-dispersion-strengthened ferritic steels provide improved mechanical strength and creep resistance at temperatures exceeding 1,000°C, which can be several hundred degrees higher than conventional steels. These advanced materials could be useful in heat exchangers, radiant burner tubes, hydrogen reforming tubes, and other applications.

Project Partner

Oak Ridge National Laboratory
Oak Ridge, TN

Highly Dispersed Metal Catalyst for Fuel Cell Electrodes

This project utilizes finely dispersed platinum as an active component in fuel cells (as single atoms or monolayers) throughout the electrode to increase electrocatalytic activity. By increasing the electrocatalytic activity of a fuel cell, smaller amounts of the noble metal are required to retain electrical output. This project seeks to increase electrocatalytic activity by improving metal dispersion in electrode systems by 1–2 orders of magnitude (10–100 times) compared to current dispersion methods, thereby significantly reducing the total cost of the fuel cells.

Project Partner

Savannah River National Laboratory
Aiken, SC

Self-Assembled Biomimetic Nanostructured Anti-Reflection Coatings for Highly Efficient Crystalline Silicon Solar Cells

Anti-reflection coatings (ARC) for solar cell technology can reduce reflective losses and increase the efficiency of silicon-based photovoltaics. This research aims to enable economically feasible and more efficient silicon-based photovoltaic (PV) technology while testing the coating stability in simulated environments. Evaluating the conversion efficiency and material stability of silicon cells with templated ARCs in earth- and space-like environments is critical for the new nanofabrication platform to increase energy efficiency. This project is developing new ARCs with reflectivity values of less than 35% for wavelengths of 400–1,100 nm in order to increase the efficiency of solar cell technology.

Project Partners

Savannah River National Laboratory
Aiken, SC

University of Florida
Gainesville, FL

Mesoporous Carbon Membranes for Selective Gas Separations

Separation processes that combine low energy consumption with high selectivity and high throughput can reduce overall production costs in the petrochemical industry. This project targets the fabrication of nanostructured materials with pore sizes between 4 and 10 nm, which will enable the easy separation of select gases such as oxygen, carbon dioxide (CO_2), and alkanes. These materials will allow the separation of CO_2 from exhaust stacks and enable CO_2 sequestration at various industrial plants.

Project Partners

Oak Ridge National Laboratory
Oak Ridge, TN

Georgia Institute of Technology
Atlanta, GA

Nanocatalytic Conversion of Biomass into Second-Generation Biofuels

Investigators are exploring the use of clay-based nanocatalysts to facilitate the breakdown of refractory organics, such as those from lignin and bitumen, to enable the use of biomass as a biofuel. Advances in the use of clay minerals as economical catalysts will be coupled with the advantages posed by nanomaterials to greatly enhance the efficiency and economics of refractory organics processing, and will be compared with homogeneous catalysis technologies. In particular, the project seeks to use nanotechnology in order to achieve lower-temperature conversions and more rapid processing.

Project Partner

Oak Ridge National Laboratory
Oak Ridge, TN

Large Scale Nanofermentation of Quantum Dots

This project is quantifying bacteria-synthesized materials for their potential in photovoltaic and solid-state lighting materials. The thermophilic anaerobic bacteria under investigation excrete copious amounts of functional materials outside their cells. With the addition of chemical control agents that allow control over particle size and shape, these bacteria can synthesize a variety of candidate materials for quantum dots (QD). This project aims to demonstrate the feasibility of scaling up bacteria-synthesized materials for QDs from 10-milliliter (mL) to 30-liter (L) batches, and to assess deposition and transformation of the QDs as a thin-film.

Project Partner

Oak Ridge National Laboratory
Oak Ridge, TN

Filled Carbon Nanotubes: Superior Latent Heat Storage Enhancers

Demonstrations of the feasibility of filled carbon nanotubes (CNT) as latent heat storage enhancers are focusing on high-rate heat transfer and thermal energy storage. This project seeks to show significant thermal conductivity improvements compared to existing capabilities. Nanotube uniformity in planned thermal experiments is critical for accurate data interpretations, and a simple and effective method has been developed to fully control the diameter, length, and packing density of CNTs. Potential applications for this technology include next-generation thermal management fluids for microelectronic cooling, manufacturing, power generation, transportation, and solar energy storage.

Project Partners

Argonne National Laboratory
Argonne, IL

University of Illinois at Chicago
Chicago, IL

Pulsed Thermal Processing of Self-Assembled Quantum Dot Structures

This study focuses on the chemical synthesis and processing of various quantum dots (QD) nanocrystals for solid-state lighting applications. Some of the developed nanocrystals may be of use in additional applications, such as photovoltaics. A chemical synthesis process for the mass production of QD enables the manufacture and distribution of nanomaterials in quantities sufficient to realize benefits on a meaningful scale. Ultimately, this project may develop a QD manufacturing system for roll-to-roll thin film deposition and processing, characterization of QD thin films, and demonstration of scalability toward commercial nanocrystals production and film nanofabrication.

Project Partner

Oak Ridge National Laboratory
Oak Ridge, TN

Architectured Nanomembranes for In-Situ Energy Conversion Technologies

This project has synthesized composite membranes with unique architectures that contain parallel, cross-membrane nanochannel arrays, and is evaluating the membranes for large-quantity production for specific energy applications. This orientation of nanochannels could produce membranes with superior performance (upwards of 200 times greater capabilities in ionic conductivity when compared to conventional means) in energy production or conversion processes, such as fuel cells, solar cells, catalytic membrane reactors, and thermoelectric devices. Researchers are assessing the technical and economic impacts of the nanomembrane platforms in these applications and conducting life-cycle analyses.

Project Partner

Oak Ridge National Laboratory
Oak Ridge, TN

Infrared Absorbing Nanoparticles for Reducing Cure Temperatures in Industrial Coatings

Researchers are examining the ability of infrared (IR)-absorbing nanoparticles to reduce cure temperatures for industrial coatings at the laboratory scale. The IR additives improve the energy efficiency of drying coatings and softening resins for molding, which enables these materials to reduce cure temperatures or bake cycles in thermoset coating formulations. Incorporating nanoparticles with the required IR-absorbing characteristics specifically benefits applications that require visible light transparency, such as transparent coatings. This study seeks to reduce cure temperatures for a coating process from 400°F to 350°F through the addition of transparent IR-absorbing nanocoatings.

Project Partners

National Energy Technology Laboratory
Pittsburgh, PA

PPG Industries
Pittsburgh, PA &
Longmont, CO

Synthesis of Highly Ordered TiO_2 Nanotubes Using Ionic Liquids for Photovoltaics Applications

Researchers are developing highly ordered titanium dioxide (TiO_2) nanotube arrays using ionic liquids-based electrolytes. The effort includes synthesizing highly ordered TiO_2 nanotubes using ionic liquids, nanostructural characterization, understanding of synthesis mechanisms, and evaluation of photovoltaic (PV) characteristics. Promising photoelectric performance was previously observed in a proof-of-concept project. Compared to nanotubes grown in conventional organic electrolytes, TiO_2 nanotubes produced in ionic liquids show a light absorbance two times higher for ultraviolet (UV) light, a much-increased light absorbance for visible and infrared light, and more than double the photocurrent density in water splitting. Potential applications include TiO_2-polymer hybrid cells, dye-sensitized solar cells (DSSC), water splitting, waste decomposition, photocatalysis, and gas sensoring.

Project Partner

Oak Ridge National Laboratory
Oak Ridge, TN

Nanomanufacturing Process Development Projects

Nanomanufacturing process development projects focus on enabling processes for nanomaterials production or nanomaterial use in industrial processes. DOE national laboratories partner with industrial companies to 1) design production systems that will generate uniform material in production-scale quantities or 2) identify and modify promising processing techniques to handle nanomaterials at one-tenth of the smallest scale in use in industry today.

Nanostructured Superhydrophobic Coatings

Nanostructured superhydrophobic (SH) silica-based coatings that substantially reduce friction between water and a given substrate's surface result in surfaces that are more water-repellent and durable than anything found in nature. The new class of nanostructured SH coatings will extend equipment lifetimes, improve productivities, and generate substantial energy savings for various industrial, transportation, and consumer products. These oxide-based powders contain grains that have porous nanotextured properties that trap a layer of air on the coating's surface, making it remarkably water-repellent. The contact angles for the Oak Ridge National Laboratory (ORNL) powders approach 180º (non-wetting) under laboratory conditions. ORNL can now reproducibly create highly water-repellent surfaces that are both well bonded and durable when coated on steel and aluminum substrates. This project seeks to replicate these performance results when the technology is scaled up and implemented on component surfaces.

Project Partners

Oak Ridge National Laboratory
Oak Ridge, TN

Stevens Institute of Technology
Hoboken, NJ

Ross Technology Corporation
Leola, PA

Ross Technology Oak Ridge
Oak Ridge, TN

Erosion-Resistant Nanocoatings to Improve Energy Efficiency in Gas Turbine Engines

This project is optimizing and validating erosion-resistant (ER) nanocoatings to reduce the erosion of compressor airfoils in gas turbines, which are used in power plants and aircraft engines. The ER nanocoatings are applied using a cathodic arc physical vapor deposition process, and the number of coating layers and their individual thicknesses will vary according to each compressor airfoil's erosion pattern. Reducing compressor airfoil erosion extends component life and operational efficiency while reducing engine emissions and fuel costs. The application of these robust nanocoatings may double the lifetime of aviation and power plant turbine components.

Project Partners

National Energy Technology Laboratory
Pittsburgh, PA

MDS-Coatings Technologies Corporation
Slemon Park P.E., Canada

Calpine Corporation
Houston, TX

Delta Airlines
Atlanta, GA

Nanocatalysts for Diesel Engine Emission Remediation

This project is developing a zeolite-based nanocatalyst system that can perform in extreme environments, which will enable its use with urea selective catalyst reduction (urea-SCR) technology, a leading approach in diesel engine exhaust treatment for the removal of nitrogen oxide (NOx) emissions. The project is modifying the zeolite catalyst's nanostructure and widening its operating temperature window, allowing it to operate at both lower and higher temperatures than conventional catalysts and improving lifetime functionality. Improved catalyst performance will enable wider deployment of diesel systems, which are approximately 30% more fuel efficient than gasoline engines.

Project Partners

Oak Ridge National Laboratory
Oak Ridge, TN

John Deere Power Systems
Waterloo, IA

Accelerated Deployment of Nanostructured Hydrotreating Catalysts

This project targets improvements in hydrotreating catalyst reactivity in the removal of sulfur and other contaminants from crude oil fractions. An atomic layer deposition (ALD) system is being designed and deployed to manufacture hydrotreating catalysts that reduce energy use and improve hydrotreating performance for oil recycling or "re-refining." About 70% of used oil is recoverable base oils; these catalysts will reduce the required re-refining temperature and enable refiners to recycle more oil. The new nanostructured catalyst product will potentially provide energy savings of at least 20% by lowering operating costs as well as by lowering process temperatures, which will also increase the catalyst's lifetime. In addition, the new nanostructured catalyst will decrease byproduct formation and reduce greenhouse gas and other emissions compared to conventional hydrotreating processes.

Project Partners

Argonne National Laboratory
Argonne, IL

Universal Lubricants, Inc.
Wichita, KS

Chemical Engineering Partners
Irvine, CA

Large–Scale Manufacturing of Nanoparticulate-Based Lubrication Additives

The large-scale production of boron-based nanoparticulate lubrication additives can drastically lower friction and wear in a wide range of industrial and transportation applications. This project is focusing on nanocolloidal versions of boron-based lubricants, such as boric acid. Researchers are also investigating hybrid lubricants, such as boric acid with molybdenum disulfide (MoS2). Improved lubricant performance plays a vital role in extending machine life, augmenting performance, reducing friction and wear, and preventing component failure. This project seeks to reduce boundary friction by as much as 80% through the formation of slick boundary films for applications in the transportation and industrial sectors.

Project Partners

Argonne National Laboratory
Argonne, IL

Primet Precision Materials, Inc.
Ithaca, NY

Valvoline
Lexington, KY

University of Arkansas
Fayetteville, AR

Microreactor-Assisted Nanomaterial Deposition Technology for Photovoltaic Material Production

Researchers are developing energy- and materials-efficient manufacturing processes for greener, low-cost production of solar cells in order to improve photovoltaic (PV) production. Microreactor-Assisted Nanomaterial Deposition (MAND™) demonstrates a new, scalable pilot platform for the production of solution-phase synthesis, purification, functionalization, and deposition of nanomaterials for PV applications. Enhancing PV manufacturing practices will reduce costs, lower processing temperatures, and improve solvent usage and materials utilization. This project seeks to improve manufacturing efficiency and at least double the materials utilization rates of cadmium sulfide in Gen II PV and quantum dots in Gen III PV.

Project Partners

The Microproducts Breakthrough Institute (Pacific Northwest National Laboratory & Oregon State University)
Corvallis, OR

CH2M HILL
Portland, OR

Voxtel, Inc.
Beaverton, OR

Self-Assembled, Nanostructured Carbon for Energy Storage and Water Treatment

The development and implementation of reliable, scalable, cost-effective processes for manufacturing self-assembled nanostructured carbon materials is supporting new solutions to pressing problems in energy storage and water treatment. In energy storage, the development of carbon nanomaterials for improved ultracapacitors can enhance the commercial viability of renewable energy technologies. In water treatment, the development and implementation of carbon nanomaterials can improve capacitive deionization (CDI) systems for water treatment processes. This project is producing two forms of material: an unconsolidated form to displace activated carbon in current capacitor production, and a sheet form for CDI applications. To ensure successful device performance, it is important that the materials between the electrode surfaces and the electrolyte have high surface areas and pores accessible for ions. The project aims to reliably produce materials with nanometer-scale pores in order to provide sufficient charge/discharge rates and capacitance for the desired applications.

Project Partners

Oak Ridge National Laboratory
Oak Ridge, TN

Honeywell Specialty Materials
Morristown, NJ

Campbell Applied Physics
El Dorado Hills, CA

Ultratough Thermally Stable Polycrystalline Diamond/Silicon Carbide Nanocomposites for Drill Bits

Researchers are developing and producing novel superhard and ultratough thermally stable polycrystalline diamond nanocomposites for drill-bit applications and multiple industrial functions. Industrial drilling, mining, cutting, and grinding require superhard materials with superior wear resistance. This project is applying a novel nanosynthesis technique of high-pressure and temperature-reactive sintering to synthesize diamond/SiC nanocomposites that offer superb hardness (>50 GPa), enhanced yield strength comparable to that of a diamond (~16 GPa), and a 200% improvement in fracture toughness.

Project Partners

Los Alamos National Laboratory
Los Alamos, NM

U.S. Synthetic Corporation
Orem, UT

Modular Hybrid Plasma Reactor and Process for Low Cost Nanoparticle Production

This project 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. An energy-efficient, one-step, low-cost nanomaterial bulk production method that produces desirable surface properties will enable manufacturers to take advantage of enhanced properties from composite systems by utilizing nanoparticles blended with raw materials. This project is evaluating and optimizing a chosen modular hybrid plasma reactor concept to produce nanomaterial with consistent particle morphology and particle 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, before pre-commercial pilot-size scale-up consideration.

Project Partners

Idaho National Laboratory
Idaho Falls, ID

PPG Industries
Allison Park, PA & Longmont, CO

Application of Wear-Resistant, Nanocomposite Coatings Produced from Iron-Based Glassy Powders

This project targets the development of standard, high-yield, low-cost, and scalable manufacturing processes that optimize wear-resistant nanocomposite coatings for steel components used in engineering, mining, and construction applications. Laser fusing of the coatings provides a metallurgical bond that prevents spalling and debonding between the coating and substrate. The coatings are designed to improve wear resistance by more than 20% and could be used on any steel substrate and other components in a wide range of markets.

Project Partners

Oak Ridge National Laboratory
Oak Ridge, TN

Carpenter Powder Products
Wyomissing, PA

Development and Application of Processing and Process Control for Nanocomposite Materials for Lithium Ion Batteries

Researchers are developing large-scale nanomanufacturing capabilities for nanomaterial systems in order to enhance battery technology for energy-efficient transportation and stationary storage applications. Nanocomposite materials used with lithium-ion (Li-ion) batteries improve the performance of high-power and high-energy applications. This project seeks to provide a 30% improvement in power delivery, breakthrough high-temperature durability, and lower cell costs. Improving the cycle life, high-temperature durability, and power characteristics of batteries will lead to the implementation of effective, energy-efficient transportation vehicles and grid stabilization technologies.

Project Partners

Oak Ridge National Laboratory
Oak Ridge, TN

A123 Systems
Ann Arbor, MI

Process Development for Nanostructured Photovoltaics

The high-temperature manufacturing of conventional silicon-based photovoltaics is extremely energy intensive. In contrast, nanostructured solar cells, which use a monolayer of organic dye to harvest solar energy, can be manufactured using low-temperature and low-energy processes. Researchers are developing low-cost fabrication methods for manufacturing these nanostructured photovoltaics by developing and scaling-up supercritical drying and atomic layer processing manufacturing steps. This project will scale-up the size of the nanostructured photovoltaic devices by a factor of 100x while maintaining power efficiencies above 5%. Successful completion of this project will accelerate the deployment of cost-effective solar cells.

Project Partners

Argonne National Laboratory
Argonne, IL

Northwestern University
Evanston, IL

Innosense LLC
Torrance, CA

Batterson Cross Zakin Venture Partners
Chicago, IL

Development and Demonstration of Nanofluids for Industrial Cooling Applications

This project targets improvements in the thermal properties of nanofluids for use as industrial-grade coolants. Nanofluids contain unique thermal properties, made possible by suspending nanometer-sized particles (such as silicon carbide) in conventional heat transfer fluids (such as water or ethylene glycol). These nanoparticles augment the properties of thermal fluids with enhanced heat transfer coefficients and strong temperature-dependent thermal conductivity, which improves heat transfer rates and energy efficiency in heat transfer systems. This project seeks to develop nanofluids that achieve thermal conductivity enhancements of 10%–50% compared to traditional fluids and develop the chemistry to scale up from one liter to the pilot-production scale of 100 liters.

Project Partners

Argonne National Laboratory
Argonne, IL

Saint-Gobain Corporation
Valley Forge, PA

Manufacturing of Superhydrophobic Surfaces with Nanoscale and Microscale Features

This project is developing a high-volume process for manufacturing superhydrophobic (SHP) nanostructured surfaces to enhance water repellency, boiling heat transfer, and condensation heat transfer. A biomimetic approach will use nanopatterned/micropatterned molds and dies to image these features onto surfaces. The image transfer can be achieved via plastic injection molding, stamping, forging, die casting, and pressing. Hydrophobic, or water-repelling, surfaces are increasingly important in applications to reduce corrosion, drag, biofouling, and other undesirable effects of water exposure. Based on geometrical features that consist of an array of bumps and pillars, this project is developing hydrophobic surface features that give rise to a pronounced SHP effect. Optimized designs will be fabricated onto a master pattern using silicon etching, bulk micromachining, and laser micromachining methods, and similarly structured surfaces will be produced to enhance heat transfer in boiler tubes and dropwise condensation. The method developed will be viable for mass production.

Project Partners

Idaho National Laboratory
Idaho Falls, ID

General Electric Global Research
Niskayuna, NY

Nanoparticle Technology for Biorefinery of Non–Food Source Feedstocks

Mesoporous catalytic solid (MCS) nanoparticles are being used to develop microalgae-produced biodiesel fuel, ultimately leading to commercial scale. A mesoporous material will selectively isolate fuel-relevant hydrocarbons from live microalgae, and then convert microalgae-based hydrocarbons and waste oils into biodiesel in a single step, using a mesoporous mixed-metal-oxide catalyst. The MCS approach speeds up the reaction, requires less thermal input, uses less water, and eases recovery and reuse. This project seeks to deliver biodiesels with a cetane number that is optimal for engine performance while ensuring at least an 80% microalgae cell survival rate, leading to a faster turnaround time for microalgae oil production and extraction. Current methods of oil extraction from microalgae lead to 100% microalgae cell death.

Project Partners

Ames Laboratory
Ames, IA

Iowa State University
Ames, IA

Catilin, Inc.
Ames, IA

Nanostructured Materials for Renewable Energy

Researchers are developing novel techniques, materials, and devices to enable the low-cost production of high-efficiency organic/hybrid photovoltaic (PV) and photoelectrochemical (PEC) cells, which are relatively easy to manufacture at high throughputs. A laboratory site will develop, fabricate, test, and evaluate the PV and PEC systems. Advances will focus on expanding the knowledge of the design, synthesis, assembly, analysis, and modeling of novel molecular (and other nanoscale) systems using atomic layer deposition and physical vapor nanoevaporation. One focus is on fabricating arrays of well-defined nanostructured photoelectrodes with highly conformal nanoscale thin film coatings. This includes TiO_2 coatings on nanofibers for high-efficiency PV cells, and iron oxide (Fe_2O_3) nanoneedles for optimized photoabsorbance for low-cost water photo-dissociation.

Project Partners

North Carolina State University
Raleigh, NC

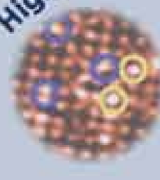
NC State Nanotechnology Initiative
Raleigh, NC

Advances in Cost-Effective Nanomanufacturing Can Deliver Diverse Energy Benefits— An Overview

Energy Supply


- Efficient and cost-effective solar cells
- Improved wind turbine efficiency
- Improved heat transfer
- Magnetic liquid coolants for higher transformer loads

High-Efficiency Manufacturing



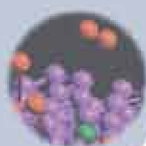
- Low-friction materials
- Anti-fouling surfaces

- Chip fabrication
- Highly selective separation membranes
- Efficient filters
- Advanced sensors


- Low-cost, effective catalysts for chemical manufacturing

Energy Storage

- Improved fuel cells
- Super capacitors
- Novel electrodes to boost battery efficiency and longevity
- Reversible hydrogen storage materials



Energy Efficient Products

- Window coatings
- Efficient insulation
- Solid-state lighting



- Ultra-fast computing
- Better electrostatic protection
- Improved thermal management for electronics
- Catalysts to boost engine performance
- Lightweight materials for cars and airplanes

What is Nanotechnology?

Nanotechnology is the purposeful engineering of matter at the nanoscale, which ranges from 1 to 100 nanometers. Materials at this scale can be manipulated to achieve unique properties and functions.

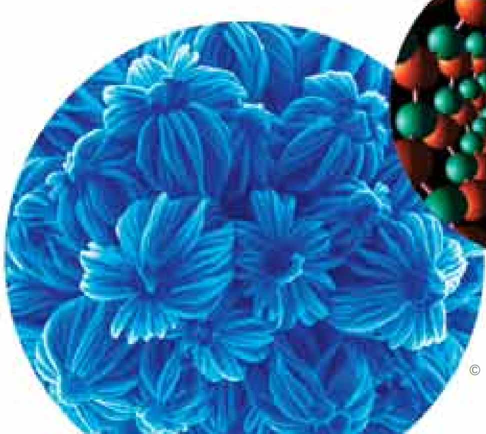
How Small is a Nanometer?

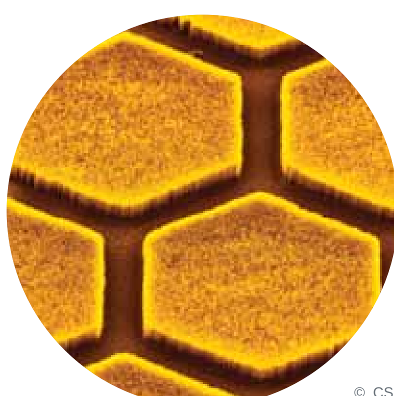
A typical human hair is around 80,000 nanometers wide.

Why the Excitement?

A nanoparticle is so tiny that its total volume is dominated by its surface area. This surface dominance increases interactions with surrounding materials, which can contribute to new and different properties in a material containing the nanoparticles.

Scientists and engineers have been learning to manipulate nanoscale materials in order to manufacture materials with different or improved properties, such as greatly enhanced strength, magnetism, or thermal conductivity.





The Industrial Technologies Program (ITP) is the lead government program working to increase the energy efficiency of U.S. industry—which accounts for about one-third of U.S. energy use. In partnership with industry, ITP helps research, develop, and deploy innovative technologies that companies can use to improve their energy productivity, reduce carbon emissions, and gain a competitive edge.

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