NANOMATERIALS RESEARCH

The U.S. Army Research Laboratory (ARL) is pursuing an aggressive research program that applies advances in materials designed and engineered at the nanometer and molecular level to enable significant enhancements in military capabilities. ARL's research in nanomaterials is achieved by an outstanding staff of scientists and engineers with laboratory facilities that provide a unique capability in research and characterization of emerging technologies. Experimental capabilities include chemical synthesis and consolidation, comprehensive microscopy, ion-beam deposition and surface modification, composites processing and prototyping, mechanical and thermomechanical characterization, laser spectroscopy, and combustion diagnostics and burn-rate characterization.In-house research efforts are supplemented by extensive outreach and partnership programs that support scientific research in nanotechnologies pursued in academia and the commercial sector. These relationships foster collaboration and scientific exchange between ARL researchers and faculty and students at sponsored universities, as well as industrial partners.

Nanotechnology for Chemical and Biological Defense

ARL's Nanotechnology for Chemical and Biological Defense Program is focused on developing and transitioning novel nanomaterials technologies to protect our military forces against chemical and biological warfare threats. Principal application areas include chemical and biological detection, decontamination, and individual and collective protection systems. ARL's research in these areas is sponsored by system development agencies — the U.S. Army Soldier and Biological/Chemical Command (SBCCOM), the U.S. Army Medical Research Institute for Chemical Defense (USAMRICD), and the Joint-Service Agent Water Monitoring Program (JSAWM). Three successful program transitions include a nanoreactor-based reactive topical skin protectant sponsored by USAMRICD, a dendrimer-based handheld immunochromatographic assay for improved point detection of biological agents sponsored by SBCCOM, and molecularly imprinted polymer-based chemical-agent sensors sponsored by JSAWM. Mild, non-toxic formulations are being developed for decontaminating both chemical and biological agents and will be tested at Dugway Proving Ground. Future ultralight protective clothing systems are being pursued that feature ultrathin layers of enzyme-based nanocapsules and polymer-based nanoreactors applied to the soldier's battle dress uniform (BDU).

Dendrimer-Based Hand-Held Immunochromatographic Assay for Biological Agent Point Detection

Ultralight Soldier Protection featuring Enzyme-Based Nanocapsules, Polymer-Based Nanoreactors, Nanoparticulates, and Perm-Selective Membranes

Nanoscience for Structural Materials

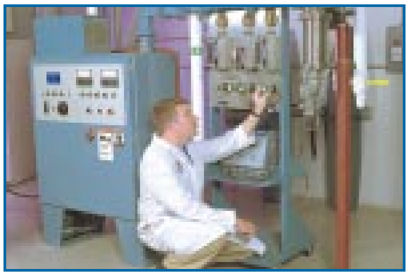
ARL's Nanoscience for Structural Materials Program is exploiting nanomaterials and synergistic effects in nanostructured systems for the design of ultralight material components with mechanical, thermal, barrier, and ballistic performance far superior to current capabilities. Polymer-based nanomaterials and inorganic nanoparticulate systems are being investigated to provide significant performance improvements at dramatic weight reductions in vehicle and personnel systems. Polymeric nanomaterials research is focused on building functional materials through the control of nanophase segregation and the dispersion of nanoparticulates into polymer matrices. Recent successes include the development of fiber-reinforced composite fabrication, bonding, and repair techniques using induction heating by magnetic nanoparticles dispersed in the matrix, the development of nanoparticulate-reinforced composite coatings that significantly improve ballistic performance of transparent-polymer faceshields for the individual soldier, and the development of novel processing methods for polymer nanofiber membranes.

Polymer-Silicate Nanocomposites for Soldier Eye/Face Protection

Nanoparticulate Materials

ARL's inorganic nanomaterials program examines the synthesis, consolidation, and characterization of nanoparticulates and structures made from nanoparticulates. The program is primarily focused on boron carbide and tungsten although other materials are examined as model materials and processing surrogates. The Small Business Innovative Research (SBIR) program has been heavily leveraged to provide additional avenues of investigation and development. These efforts have resulted in the development of the Nanogen, an R&D 100 Award winner, for the synthesis of nanoparticulates. The Nanogen device uses a microwave plasma to decompose precursor materials whose products are a nanoparticulate of the desired material and a waste gas. In the case of iron and nickel precursors, Nanogen produces particles as small as 5 nanometers at the rate of nearly 100 grams per hour. In the case of tungsten, it produces 50-nanometer particulates at a similar rate. The synthesis of tungsten-copper into nanocomposites through mechanical milling has been investigated. The lower limit of 200 to 500-nanometer grains was achieved using this process. Other synthesis efforts have examined the development of nanoparticulates of non-oxide ceramic materials such as boron carbide and silicon carbide. These efforts have resulted in boron carbide nanoparticles as fine as 50 nanometers, but more typically around 300 nanometers, consolidated with a sintering aid to full density and tested ballistically.

Consolidation of nanoparticulates to high densities without significantly changing the grain size is of critical importance. Process parameters require a rapid, high-pressure, and modest-temperature method. Since no existing process meets these requirements, a new process of plasma pressure compaction was developed under an SBIR contract. Plasma pressure compaction, an R&D 100 Award winner, meets these process requirements. In most instances, plasma pressure compaction holds materials at maximum temperature for less than five minutes and applies high pressure and Joule heating with a pulsed voltage that is believed to create a cleansing microplasma at particulate surfaces. The microplasma apparently removes surface oxidation and organic contaminants. Microwave sintering, using unconventional volumetric heating, for the consolidation of nanomaterials is also being examined. Microwave sintering provides a more even heating of the particulate bodies to allow lower processing temperatures and the sintering of net-shape components without the application of external pressure. Projected applications for consolidated nanomaterials include armor for personnel and light vehicles and refractory metals for anti-armor projectiles and devices.



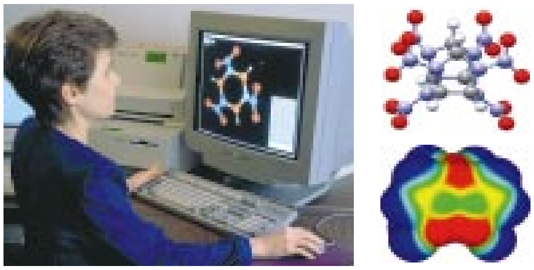
Nanogen

Plasma Pressure Compaction

Nanoparticulate Synthesis and Consolidation Research

Nanoenergetic Materials

Nanomaterials are also being investigated for application to insensitive high-energy munitions. Novel concepts have been developed that potentially can improve the burning rate and mechanical performance of charge designs for advanced munitions systems. Nanocomposite reinforcement of new solid propellants, such as extruded thermoplastic elastomers (ETPEs), is being investigated using an optimized nanocomposite structure that features intercalation strengthening of the molecular structure of the energetic material. These nano-ETPEs are tailorable to novel plasma ignition technologies currently under development at ARL and the U.S. Army Armament RDE Center for electrothermal-chemical gun systems. Nanomaterial-based energetic materials may also have future application in high specific-impulse rocket propellants under development at the U.S. Army Aviation and Missile RDE Center.



Nanocomposite Reinforcement of Advanced Energetic Materials for Novel Insensitive High-Energy Propellants

FOR FURTHER INFORMATION

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