Energetics and Power Generation

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Materials that are produced on the nanoscale have the promise for increased performance for energetics (such as propellants & explosives) and power generation devices (such as batteries & fuel cells). This lecture provides selected examples based on recent publications by the US Army (Ref. 1 and 2) and the US Navy (Ref. 3 and 4).

For **energetics** the focus is on solid propellants, where utilization of nanomaterials promises increased energy density, controlled energy release, reduced sensitivity, reduced environmental impact, and long-term stability. In the near-term novel propellants with nanoscale material will be used to reduce particle size dispersion (greater uniformity), reduce agglomeration of aluminum (increased combustion efficiency), and increase reaction rates (increased burning rates). In the long-term radical new propellant approaches will be explored to utilize 3-dimensional nanostructures that might yield controllable energy release and tailorable sensitivity.

Recent experiments have shown that the ignition sensitivity and burning rate of nano-aluminum particles can be significantly higher than micron-aluminum particles. This resulted in increased burning rates and improved combustion efficiency for conventional composite propellants. It was observed that the nanometer-sized aluminum powder significantly reduced aluminum agglomeration. The low agglomeration rate may be the result of a thin aluminum oxide layer on the aluminum particles as observed on transmission electron microscope images.

New efforts are directed towards coated nanometer-sized metal powder, which may yield controlled oxidation and improved storage lifetime. Encapsulation of aluminum particles in an oxidizer matrix has been successfully demonstrated as an example for the creation of a novel nanostructure using aerosol and sol-gel chemistry. The reactivity of the encapsulated aluminum increased by a factor of 10, when the structures were ordered through bipolar coagulation as compared to random structures with Brownian coagulation.

Future goals are 3-dimesional nano-energetics with a high degree of structure and order for controlled reactivity and improved manufacturability.

For **batteries** nanostructured materials are being explored to increase electrical capacity of the electrodes and to increase ion conductivity and long-term stability of the electrolytes. For lithium batteries anodes, templated nanostructures are being explored to fabricate nanoscale materials having the specific sizes and dimension needed for optimum performance. One example is an anode consisting of 110-nm-diamter SnO_2 nanofibers reduced to a Sn based nanocomposite to increase number of discharge cycles, improve discharge rates, and reduce capacity losses.

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For **fuel cells**, nanostructures are also being explored for electrocatalysts and hydrogen storage. One example is a nano-architectured Pt catalyst using sol-gel techniques. In this nanomaterial, carbon powder provides a continuous electronic network to the 2-nm carbon-supported colloidal Pt nanoparticles within the continuous nanoscale network of the SiO_2 aerogel. This 3-D porous pathway results in significantly enhanced catalytic activity.

For hydrogen storage there are many conflicting reports on the degree of hydrogen adsorption and desorption in nanocarbons (Ref. 5 and 6). However, results of around 4wt% storage in Single Wall Nanotubes and Graphite Nano Fibres have been recently achieved in reproducible tests, which is still below the US Department of Energy goal of 6.5 wt%. Hydrogen storage is also explored in nanostructured magnesium-related materials, which are manufactured through mechanical alloying and milling. These nanomaterials show acceptable hydrogen storage performance at elevated working temperatures, however the storage capacity drops down dramatically at temperatures below 200C.

In summary, nanomaterials have a high potential for energetics and power generations. Groundbreaking work has been started and has resulted in first successes. However, science at the nanoscale has to advance to fully exploit the potential of this emerging technology and to understand, control, and fabricate complex nanomaterial structures.

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