Industrial Technologies Program

Advanced Nanoporous Composite Materials for Industrial Heating Applications

Improve Energy Efficiency with New Low-Cost Nanostructured Refractory Materials

Industrial process heat is associated with about 38% (approximately 12 x 10^{15} Btu per year) of the total industrial energy consumption in the United States. Refractory materials used in process heat technologies vary from conventional firebricks to highly specialized materials for particular environments. There is a significant heat loss associated with the refractories in industrial furnaces and heat treatment equipment that use conventional materials. The project team identified the opportunity to improve energy efficiency by enhancing materials for higher performance insulation. This project evaluated various nanostructured materials for their suitability for use in the insulation panels and refractory blocks. The search focused on materials that can be processed using currently available production methods and prepared from low-cost raw materials.

The project successfully developed a new type of low-cost nanoporous ceramic based on alumina, chromia, and silica. The material is aerogel-based ceramic derived from sol-gel processing. The small size of the pores and low solid content of the materials minimizes internal gas phase and solid energy conduction within the material. This material will provide better insulation in high-temperature furnaces and other industrial applications, and substantially reduce energy loss and enhance equipment life and operation.

A heat meter developed by Applied Science Laboratories was used for high-temperature thermal conductivity measurement of a large sample (15 by 15 centimeters).

Benefits for Our Industry and Our Nation

- Estimated energy savings of 100 trillion Btu
- Estimated cost savings of $750 million

Applications in Our Nation's Industry

Many industries involve processing of large quantities of material at high temperatures, therefore requiring specialty thermal protection systems. The project will benefit the following industries:

- Aluminum
- Chemical
- Glass
- Metal Casting
- Steel
- Refining

Project Description

The goal of this project was to develop nanoporous insulating and refractory materials for industrial heating applications based on sol-gel processing, supercritical drying, and advanced processing techniques.

Barriers

The technical hurdles included:

- finding new high-temperature materials with desirable insulating gel forming characteristics,
- reducing the high cost associated with starting materials based on gel forming alkoxide compounds,
- minimizing the tendency of nanostructured materials to sinter at high temperatures resulting in an increase in solid conductivity, and
- mitigating the increase in high thermal conductivities at high temperatures due to radiant heat transfer within the material.

Pathways

- Developed nanostructured insulating materials
- Developed low-cost processing methods
- Performed thermal conductivity measurements
- Performed high-temperature sintering tests
- Performed industry testing

Results

- Identified nanoporous material with a composition of aluminum oxide (Al_2O_3), chromium oxide (Cr_2O_3), and silica (SiO_2), referred to as ACS.
- Reduced the cost of the raw materials by nearly two orders of magnitude by synthesizing the material using inexpensive commodity chemicals as opposed to using conventional alkoxide precursors.
- Demonstrated about three times lower thermal conductivity in vacuum and lower conductivity than any of the firebrick samples studied - the ACS sample showed about half the conductivity of the lowest density firebricks.
- Demonstrated less than 3% shrinkage over nearly 2000 hours at 1000°C and only 4% shrinkage after 6300 hours after increasing the temperature to 1050°C at 3000 hours, indicating long-term stability of the material at high temperatures.
- Demonstrated that samples consistently retained about 15-20% of the volume of the original wet gel after both supercritical drying and baking at 1000°C.

Commercialization

The materials were tested directly in high-temperature industrial process heat applications. The project team plans to demonstrate the performance of ACS to the manufacturers of refractory and insulation materials in the industrial process heat market.

Project Reports

This project was completed in September 2005. The final report can be found on the Industrial Technologies Program Web site: http://www.eere.energy.gov/industry/imf/completed_rd.html.

Project Partners

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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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