

**ADMINISTRATIVE INFORMATION**

1. **Project Name:** Advanced Nanoporous Composite Materials for Industrial Heat Applications
2. **Lead Organization:** Lawrence Berkeley National Laboratory  
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3. **Principal Investigator:** Arlon Hunt  
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4. **Project Partners:** Applied Sciences Laboratory, Inc. Dr. Siu-Chun Lee
5. **Date Project Initiated** 8/1/2001,
6. **Expected Completion Date:** 9/30/2005

**PROJECT RATIONALE AND STRATEGY****7. Project Objective:**

The objective of this project is to develop new advanced nanoporous materials for high temperature industrial heating applications based on sol-gel processing, supercritical drying and advanced processing techniques. These new nanoporous materials provide better insulation for high temperature furnaces and other industrial applications that will substantially reduce energy loss, enhance equipment lifetime, and improve certain operations because of the more rapid heating possible because of their lower thermal mass.

**8. Technical Barriers Being Addressed:**

The technical barriers include 1) finding a new high temperature material with desirable insulating characteristics, 2) reducing the high cost associated with starting materials based on gel forming alkoxide compounds, 3) minimizing the tendency of nanostructured materials to sinter at high temperatures resulting in an increase in solid conductivity, and 4) mitigating the increase in high thermal conductivities at high temperatures due to radiant heat transfer within the material.

**9. Project Pathway:**

The objective was to find a new high temperature insulating material composition with a stable nanostructure at high temperature with a porous nanostructure to reduce gas conduction. Aerogel-based composites provide many of the desirable characteristics required for a new class of materials for industrial heating applications. The small size of the pores in this material quenches the gas conduction, the low density minimizes the solid conductivity and the intrinsic optical properties aggregates block the radiant heat transfer. Once the desired material was produced with the optimized composition and pore size using available alkoxide routes, alternative processing methods were sought to reduce the cost of production.

**10. Critical Technical Metrics:**

- Materials must withstand temperatures of 700-1000°C
- Thermal conductivity of 0.01 to 0.2W/m-K for insulation and < 0.5W/m-K for refractories
- Affordable, target is \$5-20 per board foot

## **PROJECT PLANS AND PROGRESS**

### **11. Past Accomplishments:**

Various nanostructured materials were evaluated for their suitability for use in the insulation panels and refractory blocks used by several industries in the IMF program. The physical characterization of the most promising candidates performed. Particular attention was placed on materials that can be processed using currently available production methods, and, especially, could be prepared from low-cost raw materials. After an extensive survey of various materials, Al<sub>2</sub>O<sub>3</sub>/Cr<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> (ACS) powder derived from a CO<sub>2</sub>-dried aerogel precursor met these criteria. This composition showed an excellent resistance to high temperatures, maintaining a surface area of 170 m<sup>2</sup>/g after heating at 1000 °C. The original preparations involved using alkoxide precursors. One of the most important technical barriers involved finding novel chemistry pathways that avoid the high costs associated with these alkoxide precursors. We have been successful in finding preparations that made use of commodity feedstocks, specifically, Al(OH)<sub>3</sub> and CrO<sub>3</sub> and a small amount of silica alkoxide. Once this preparation technique was discovered, it was scaled up from gram to kilogram quantities for thermal testing and evaluation. This proved to be a more difficult task than was anticipated. We have developed larger scale methods and performed thermal conductivity measurements on medium sized blocks of material in conjunction with our partner, Applied Science Laboratory. We are currently conducting sintering tests on the materials to determine their long term stability and analytically investigating the effects of package design.

#### **Significant milestones achieved:**

- Identified a material composition suitable for high temperature industrial insulation and refractory applications. The best composition was determined to be Cr<sub>2</sub>O<sub>3</sub> and Al<sub>2</sub>O<sub>3</sub> with a small amount of silica as a stabilizer.
- Produced gels using a variety of chemical pathways, initially using alkoxides of aluminum and chromium. Alkogels formulated using these starting compounds exhibited nanostructured properties after prolonged exposures to high temperatures.
- Discovered a non-conventional route to the ACS gels. This allowed the use of inexpensive commodity chemicals instead of expensive alkoxide precursors. Calculations showed that the raw material costs dropped from \$118 per pound to slightly over \$2 per pound.
- Fabricated blocks large enough for high temperature testing (15x15x1cm)
- Conductivity measurements using the heat flow method was performed at temperatures up to 1000 C by Applied Science Laboratories, Inc. showed that the thermal performance is superior to existing products in the same price range.

### **12. Future Plans:**

*Sintering Tests:*

We are preparing a series of samples of ACS for sintering tests. These samples will be placed in high temperature furnaces operating at several temperatures for periods of a month or more. Following the heat soak we will conduct shrinkage and volume measurements to determine the effects of exposure to prolonged high temperatures. The results will graphically depict the rates of sintering at various high temperatures to determine the long term stability of the material.

*Thermal Modeling:*

To assess the efficacy of additions/modifications of the aerogel structure and composition to further reduce the thermal conductivity, we will carry out calculations based on modeling heat flow in the aerogel in collaboration with Applied Sciences Laboratories. There are two aspects of this research. The effect of varying aerogel density in layers can optimize the mechanical strength and overall thermal properties. By using additives of particles and fibers the radiant component of the thermal conductivity can be further decreased. This is accomplished by optimizing the size and optical properties of the particles to increase the scattering of the infrared component of the heat transfer. We will do this in partnership with Applied Science Laboratories who have developed heat transfer algorithms for these types of materials. These calculations are complicated by the simultaneous presence of heat transfer by solid, gas, and radiation – that all interact with each other.

Date	Milestone/Deliverable	Partner Activities
8/15/05	Thermal modeling completed	ASL numerical modeling
9/15/05	Completion of sintering tests	
11/30/05	Final Report	

13. **Project Changes:**

We do not expect any changes from our earlier project plans.

14. **Commercialization Potential, Plans, and Activities:**

With the sintering tests, thermal measurements and cost estimates in hand, we will demonstrate the performance of ACS to the manufacturers of refractory and insulation materials in the industrial process heat market. We will apprise them of our work and provide them with technology transfer opportunities to carry out the commercialization of this new nanoporous insulating material. In particular we will expand the initial contacts with Johns Manville, and SEPR Group.

15. **Patents, Publications, Presentations:**

**Publications**

Michael R. Ayers, Ashley A. White, Xanyoun Song, and Arlon J. Hunt "Preparation and Characterization of Aerogels Derived from Al(OH)<sub>3</sub> and CrO<sub>3</sub> . J. Non-Crystalline Solids, 15 December 2003, pp. 173-184.

**Presentations**

Michael R. Ayers and Arlon J. Hunt "Advanced Nanoporous Composite Materials for Industrial Heating Applications" DOE/IHEA Materials Forum, Oak Ridge, Tennessee, February 5-6, 2003.

Arlon J. Hunt & Siu-Chun Lee, "Towards Low-Cost Nanostructured Refractory Materials" DOE-IMF Annual Program Review June 23, 2004