U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

DEVELOPMENT OF ISOCYANURATE-BASED SUPER INSULATION AT ATMOSPHERIC PRESSURE (SIAP)

WITH TARGET RESISTANCE R-12 hr·ft^2·°F/BTU·in

Performing Organizations: Fraunhofer USA Center for Sustainable Energy Systems (CSE), Virginia Commonwealth University (VCU)

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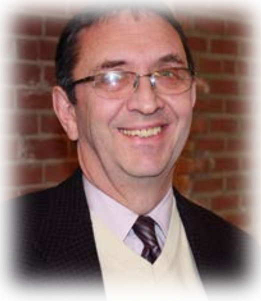
Project Team:



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Problem Definition:

1. Relatively expensive and troublesome production process:
   a. Currently-used close-cell plastic foams require a usage of expensive blowing agent technologies
   b. Some blowing agents are highly flammable and may cause explosion, which require an application of special safety measures
2. In sales/designing, it is challenging to accurately specify R-value of currently-used close-cell plastic foams, because they exhibit time-dependent degradation of thermal characteristics (foam aging)
   a. Caused by escape of the blowing agent from the foam cells
   b. Caused by ingress of the water vapor into the foam cellular structure
3. In low-temperature applications, some close-cell plastic foams may likely exhibit substantial degradation of thermal performance characteristics due to condensation of water vapor and sometimes blowing agent on the internal foam cell surfaces
4. An application of blowing agent may often increase foam's environmental impact

Challenge/Competition:

1. A new generation of non-flammable, high-performance hydrofluoroolefin (HFO) blowing agents is still waiting for a wide-scale adoption by the building foam insulation industry
2. Silica aerogles are already used in different niche applications, including buildings and industry
3. Despite superiorly low thermal conductivity, nanoporous thermal insulations are still not fully adopted by the building market, mostly due to high prices (due to an application of the supercritical CO_2 drying)
4. First, commercially available nano-foam technology has already arrived on the international markets (Europe).

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Proposed Solution

Theoretical Guidance:

1. Increase foam R-value and eliminate foam aging effect
   a. By reduction of the foam cell sizes below 70 nm, utilize the Knudsen Effect in the foam design; target surface area 300-400 m^2/g, density 0.1 to 0.3 g/cm^3
   b. Open-cell nanoporous foam will not require trapping blowing agent in close cells for attaining high R-value
   c. Lack of blowing agent will eliminate the foam aging process
2. Utilize polymeric chemistry to improve mechanical strength characteristics, comparing to silica aerogels
3. Keep production cost competitive
   a. Produce foam without a need for costly blowing agent and use well-established and cost-competitive PIR chemistry
   b. Don't use supercritical CO_2 drying in production of nano-foam. Instead utilize significantly less-costly freeze drying technology (lowers capex by ~10 times, and overall production cost reduced by 40%-65%)

Approach and Expected Results:

1. We propose the development of a nano-porous Super Insulation at Atmospheric Pressure (SIAP) that:
   a. Can attain thermal conductivity of 12×10^{-3} W/m/K (R-12 hr·ft^2·°F/Btu·in)
   b. In cost per R-value comparisons, the PIR SIAP is cost-competitive to the existing close-cell foam board products
2. PIR-based SIAP will have several benefits over conventional plastic foams:
   a. Will use a well-known and widely used PIR chemistry – so, now disadvantage in processing and supply materials
   b. Will show up to twice as low apparent thermal conductivity, over conventional plastic foams
   c. Since, it will not require a use of blowing agent, it will not exhibit thermal aging, and
   d. Its thermal conductivity will not increase in low temperatures due to the water and blowing agent condensation
3. When compared to currently produced silica aerogel products, the proposed PIR-based SIAP will be mechanically stronger, more elastic, significantly less expensive, and dust free

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Advantage, Differentiation, and Impact:

1. Proposed PIR SIAP uses well-established PIR chemistry, which will allow:
   a. Quick adoption of the new technology by industry and
   b. It's out-of-shelf source materials will be cost competitive relating to plastic foams

2. The proposed PIR SIAP, with target ~R-12.0 hr·ft^2·°F/Btu·in, will exhibit almost double R-value, compared to the "in-service R-value" of today's PIR foams (which is only R-5.7)

3. The proposed PIR SIAP does not require a use of the blowing agent:
   a. It's chemistry will be less expensive and it will not show "thermal aging"
   b. It will have lower environmental impact than today's plastic foam insulations

4. Because of a usage of a cost-effective freeze drying method, the price of the proposed PIR SIAP will be significantly lower comparing to other nanoporous insulations produced using supercritical CO_2 drying

5. Primary energy saving technical potential of PIR SIAP is about 0.7 quad *(=20%*[2.5 quad for residential sector + 2 quad for commercial sector - BTO Market calculator and a conservative estimate of 20% reduction in energy consumption with the PIR SIAP were used, compared to PIR foam of the same thickness*)

6. PIR SIAP will have the ability to improve the overall R-value of building envelopes between 30% to 50%, without changing the dimensions of the structural components or insulating sheathing.

Thank You

Fraunhofer USA

CENTER FOR SUSTAINABLE ENERGY SYSTEMS CSE

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