

# Background – First attempt of making Third Generation of Thermal Insulation

1992-1995 NIST ATP award: US\$ 4.5 million R&D

	Thermal Conductivity (k)	Thermal Resistance*(R)
Fiber Glass	45 mW/M°K	R-3.2-per-inch
Plain Silica Aerogel	23 mW/M°K	R-6.27-per-inch
Aerogel with Layered Silicates	16 mW/M°K	R-9-per-inch
Inverse-Emulsion Composite	20 mW/M°K	R-7.2-per-inch
Emulsion Polymer with Aerogel	18 - 23 mW/M°K	R-(6.3 - 8.6)-per-inch
Inorganic-Organic Copolymerized Aerogel with Opacifier	15 mW/M°K	R-9.6-per-inch

Nanopores were created by sol-gel, solution process; It could not compete with the more efficient foaming process.

Process Characteristics	Gelation and Drying (Aerogel, Hydrogel)	Direct gas foaming (Gas Blown Polymer Foams)
a. Porosity is created by	Solvent	Gas Bubbles
b. Weight % needed for a 95% porosity	2000 %	5~10 %
c. Processing speed	Fluid diffusion, depending on sample thickness ( $\delta$ ), $\propto \delta^2$ , slow	Gas blown, instantaneous
d. Pore size control	10 nm, needs special processing care to preserve the nanopores	100 $\mu$ , difficult to control
e. Environmental concern	Large quantity of solvent, VOC	HCFC, Hydrocarbons

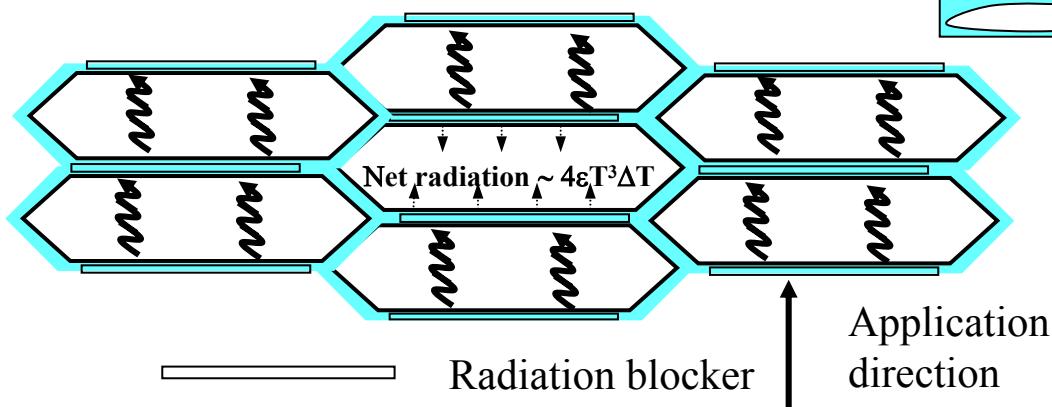
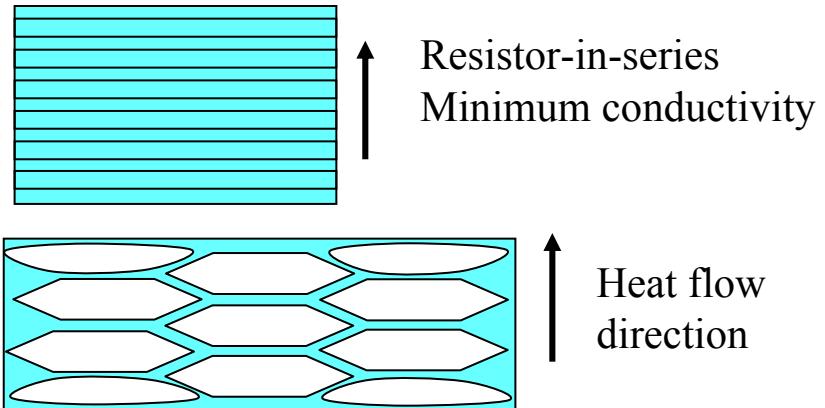
# Program Goals – Affordable Super Building Insulation by CO<sub>2</sub> foaming process

- Advanced building insulation without HFC and with higher R value
- Program budget – Total \$2.7 M, DOE \$2M, ISTN \$0.7M
- Processing cost must be competitive to the current insulation materials – low-cost Supercritical CO<sub>2</sub> foaming technology
- Developing innovations in addition to pore size reduction to further reduce the heat transfer through the foam – ISTN Patent pending innovations – four steps to improve R value:
  - (a) Create oblate pore structure
  - (b) Align oblate pores against heat flow direction
  - (c) Layers of reflecting surfaces to block radiation
  - (d) Secondary nanostructure within oblate pores

*Illustration on the  
following slide*

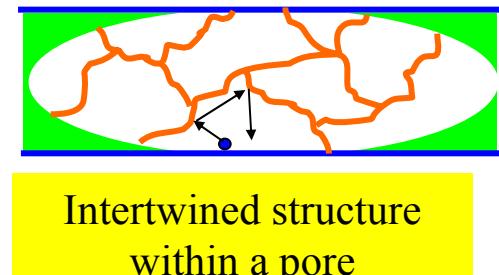
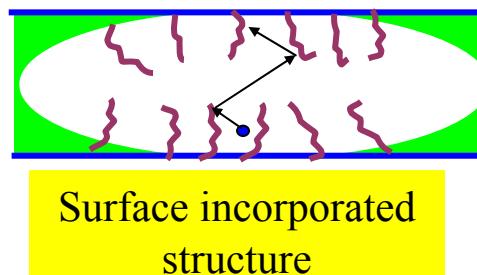
# ISTN Technology Innovations

(1) Aligning oblate (disk-shape) pores against heat flow direction to reduce thermal conductivity in application direction – increasing R **from R-4.2/inch to R-5.5/inch.**



(2) Adding reflective or absorptive radiation blockers in a layered structure can minimize radiation loss – increasing R **from R-5.5/inch to R-7/inch.**

(3) Secondary nanostructure (< **100 nm**) to enhance collisions with air molecules – increasing R **from R-7/inch to R-10/inch.**



# Program Status and Following Progress

	Expected Results	Current Status	Next Step
<b>(1) IR blockers &amp; pore control in 100% CO<sub>2</sub> foam extrusion</b>	HFC free R-5/inch insulation	Completed tests on pilot scale	Full factory tests are scheduled in July
<b>(2) Creating and Orienting oblate pore structure in foaming</b>	Enhance insulation value to R-6~7/inch	Designing new die for pilot line	Modifications of foam extrusion die
<b>(3) Secondary nanostructure to reduce heat transfer of entrapped air</b>	Enhance insulation value to R-7~10/inch	Hollow silica nanopore particles in the laboratory	Clay-Silica particle composite & SEBS

- Producing R-5/inch building insulation without HFC is expected to annually reduce global warming effects equal to ten million tons of CO<sub>2</sub>
- Creating and Aligning oblate pore structure in CO<sub>2</sub> foam extrusion process is a platform technology applicable to many insulation products
- Cost-effective technology to create nanopores or a secondary nanostructure within pores is the ultimate goal of reaching super thermal insulation property

# Outlook of Future Technology Progress

- Progress of Material Nanotechnology would inevitably lead to the 3<sup>rd</sup> generation of thermal insulation material with much reduced heat transfer from entrapped air
- The new generation of thermal insulation, no matter how much superior than current products, must still compete with them on the basis of cost per R-value
- Improved foaming and polymer processing technologies ought to lead to new materials replacing polystyrene in the building insulation market; the most promising candidates are PET foam and cellulose composite foam
- Developing high-temperature thermal insulation technology is one of the most important and urgent task of future