Advanced Thermal Insulator Using Inorganic-Organic Hybrid Porous Materials

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1 Abstract

With the growth of superconducting technology and the spread of liquefied natural gas and hydrogen in recent years, the use of cryogenic liquid is increasing rapidly. Generally, vacuum multi-layer insulation materials called “Super-Insulation” are applied for keeping ultra-low temperatures in these fields and further insulation performance is urgently required. We focused on nano-porous materials which are suitable for insulation layers of Super-Insulation and developed inorganic-organic hybrid porous materials which realize ultra-low thermal conductivity and flexibility. The developed Super-Insulation using these hybrid porous materials for insulation layers shows the superior heat-insulating property under a vacuum condition on a liquid nitrogen tank.

2 Characteristics of the development product

・Excellent heat insulating properties compatible with flexibility.
・Heat insulating material can be thinned down.
・Excellent workability by integration of reflective layer and heat insulating layer.

3 Background of the development

Evacuated multi-layer insulation called “Super-Insulation” is used to keep cryogenic liquid such as liquid nitrogen, helium and hydrogen cold. Super-Insulation usually consists of reflective layer (such as aluminum foil and deposited aluminum film) and heat insulating layer constituted of resin mesh or non-woven fabric; these layers are laminated alternately and used under a vacuum condition. In response to current trends toward reduction of energy losses and narrowing available space, we are required to further improve heat insulating properties of Super-Insulation and make it thinner.

We focused its attention on nanoporous material that has lower thermal conductivity than resin mesh or non-woven fabric as a heat insulating layer for Super-Insulation. Heat insulating properties of inorganic nanoporous material can be significantly improved by controlling porosity and nanostructure; however, its brittleness made film formation and handling difficult. Given such a situation, we tried and developed inorganic-organic hybrid porous materials having both high insulation capabilities and flexibilities; we eventually incorporated them into Super-Insulation.

4 Technical details

Characteristics of inorganic-organic hybrid porous material are shown in **Table 1**. Internal structure of inorganic-organic hybrid porous material observed by scanning electron microscopy is shown in **Figure 1**.

Developed inorganic-organic hybrid porous material has an average fine pore diameter of 20 nm and forms 3D-nanonetwork structure. Also, by incorporating flexible skeleton into this hybrid porous material, its thermal insulating properties become compatible with flexibilities that were impossible for conventional inorganic nanoporous materials or composite materials.

Table 1 Characteristics of hybrid porous materials

Item	Unit	Characteristic value
Porosity	%	80-90
Average pore diameter	nm	20
Thermal conductivity	W/(m・K)	0.020
Compressive modulus of elasticity	MPa	0.1-0.4

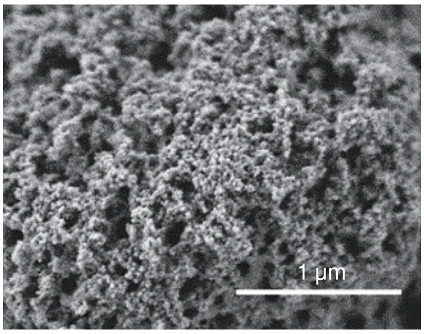


Figure 1 SEM image of hybrid porous materials

Structure of Super-Insulation using inorganic-organic hybrid porous material as a heat insulation layer is shown in **Figure 2**. Our developed Super-Insulation has a structure integrating both reflective and heat insulating layers wherein inorganic-organic hybrid porous material was coated on deposited aluminum film and shows good workability. It also has an excellent flexibility and will not cause cracks in the heat insulating layer during fabrication. Measured results of heat insulating properties using vertical liquid nitrogen tank (-196°C) under the vacuum condition are shown in **Figure 3**. By using our developed Super-Insulation, the thickness of heat insulation layer and the heat flux can be reduced by 50% or more compared to conventional materials using resin mesh for heat insulation layer while maintaining the same number of layers.

Our developed inorganic-organic hybrid porous material can be formed into a coating film on any substrate other than aluminum and processed into powder form (**Figure 4**). Thus, this material can be used in applications including not only cryogenic equipment but also a wide variety of applications requiring high heat insulating capability.

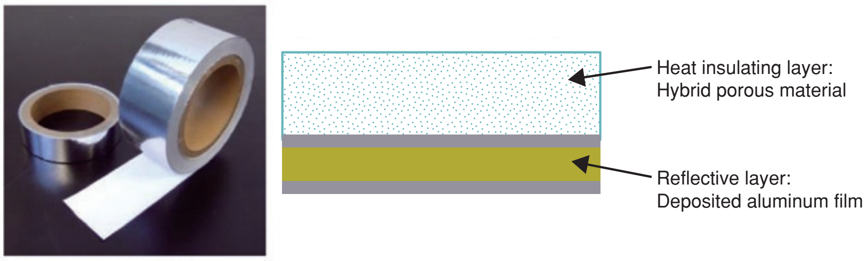
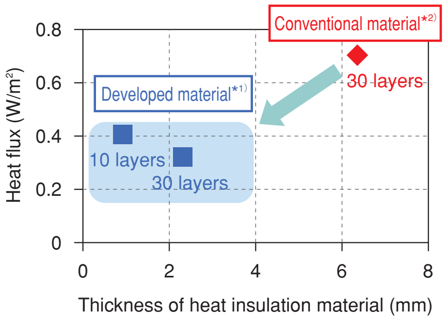


Figure 2 Components of our Super-Insulation



*1) Heat insulating layer: Hybrid porous material
*2) Heat insulating layer: Resin mesh

Figure 3 Heat insulating properties under a vacuum condition on a liquid nitrogen tank

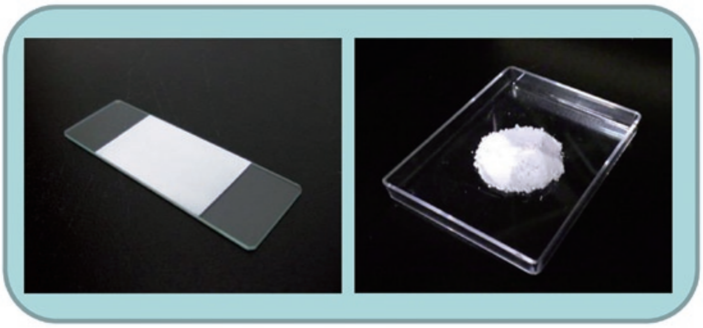


Figure 4 Appearance of coating and powder

5 Future Business Development

・Sales promotion of newly developed products
・Find new applications for inorganic-organic hybrid porous material

【References】

1) NEDO Commentary (2010) *Superconducting Technology*

2) NEDO (2014) *White Paper on Hydrogen Energy*