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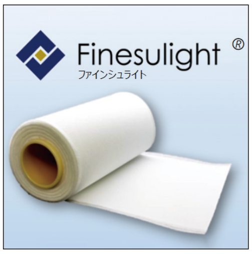

High Performance Heat Insulation Finesulight

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Sumitomo Riko Company Limited has successfully developed a water-soluble coating material with a high filling of "silica aerogel," a highly insulating material, and created a thin film high insulation material. This material has the highest level of insulation performance through air insulation and can exhibit its performance even when the thickness is 1 mm or less. In recent years, there has been a growing trend of increasing heat generation density in electronic devices and batteries due to their high integration and miniaturization. Therefore, we are considering applying this material to contribute to thermal management. Additionally, it is attracting attention as a product that can enhance the thermal efficiency of factory facilities and contribute to the reduction of energy consumption such as fuel and electricity, thanks to its easy application. It has already been adopted in the manufacturing industry.

Keywords: thin-film high-performance heat insulation material, silica aerogel, lightweight heat insulation material

1. Introduction

Recently, electronic devices have been increasingly integrated in line with higher communication speeds, and their size, weight, and thickness have been reduced for mobile applications. Accordingly, the heat generation density of electronic devices has been increasing year after year.

Meanwhile, heat generation of electronic devices is likely to cause various problems. Specific examples are as follows:

1. Functional problems: shorter service life of parts; temporary suspension of functions due to activation of safety functions; damage to functionality
2. Mechanical problems: changes in dimensions due to thermal expansion; deterioration and damage to parts
3. Energy problems: increasing power consumption due to heat loss
4. Health problems: burns due to contact with high-temperature parts

Thus, various measures are implemented for electronic devices that generate heat, depending on their design.

In general, measures against heat generation include heat dissipation, cooling, and heat insulation. For example, for heat dissipation, heat is transferred to the cooling surface of an enclosure, or heat dissipation materials are used. For cooling, heat sinks and cooling fans are used. For heat insulation, arrangements are made to avoid contact with the heat source, and heat insulation materials are used.

We have developed products for energy management to contribute to the creation of a sustainable society. Key products that we have marketed are Refleshine, heat shielding and heat insulation films for residential windows, and Magnetic Induction Forming(MIF), heat-dissipating sound absorbing materials for vehicles (Figs. 1 and 2).

To develop new energy management products, we focused on heat insulation from the viewpoint of implementing measures against heat generated in electronic devices and promoting energy-saving activities toward

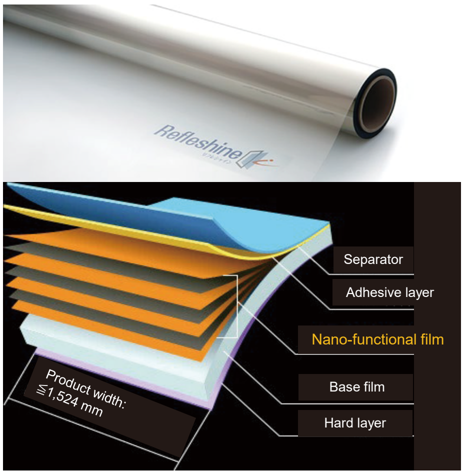

Fig. 1. Refleshine: highly transparent, heat-reflective, and heat insulation films for windows

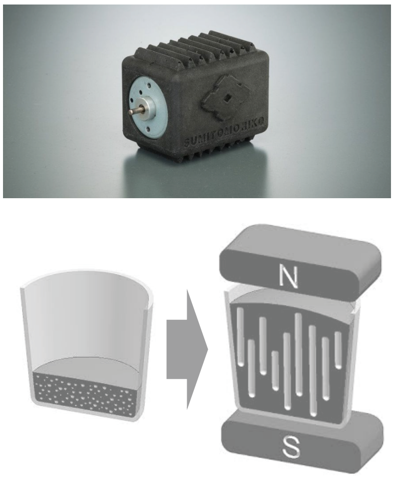

Fig. 2. MIF: heat dissipating and sound insulation materials

conservation of the global environment, in anticipation of growing demand for such applications. We started the development in 2016.

Because various types of heat insulation materials were already available in the market, we considered ourselves a latecomer. To survive in the market, we needed a clear-cut product concept to develop a competitive advantage. We conducted a thorough investigation of heat insulation materials on the market, and established a concept of a heat insulation material that would create new value. Specifically, we set the following targets:

1. To attain top-class insulation performance by air insulation (equivalent to still air)
2. To demonstrate the heat insulation function, even if the thickness is 1 mm or less (the thickness of ordinary heat insulation materials for housing is 4 mm or more)
3. To be available as flexible sheets that can be easily bent and be offered in rolls (for ease of handling for installation and transport)
4. To ensure ease of installation (ease of cutting with scissors)
5. To offer a product lineup that can be used in a high-temperature range where it is difficult to apply organic materials (e.g., heat resistance of 150°C or higher)

2. Silica Aerogel, a High Insulation Material

We considered that selection of an appropriate material was the key “to attain top-class insulation performance by air insulation (equivalent to still air),” which is the most important target in our product concept. We studied various insulation materials and selected silica aerogel.

Silica aerogel is a material made from silica, an inorganic substance, and consists of a microscopic network. It is a porous material with a pore structure on a nanoscale in the aggregate, which comprises primary particles of silica. It was invented by S. S. Kister in 1931 (Fig. 3).

Silica aerogel is very light with a specific gravity (ρ) of 0.13 to 0.17 g/cm^3, since air accounts for 90% or more of its volume. It also contains many pores (voids in silica particle aggregates). Because the pores are very small, no thermal convection occurs. Specifically, the pore diameter is 10 to 50 nm, which is smaller than the mean free path of air (65 nm). Thus, air is trapped in pores to reduce heat exchange due to collisions between air molecules and heat transfer due to air convection. The thermal conductivity is 0.012 to 0.020 W/m•K, which is superior to the 0.024 to 0.026 W/m•K of still air, demonstrating high heat insulation performance.

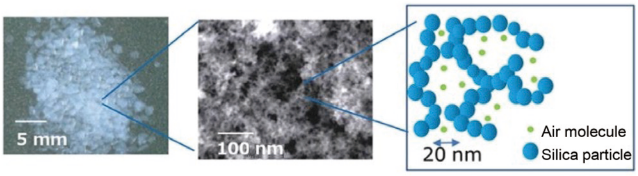

Fig. 3. Structure of the silica aerogel, a heat insulation filler

The pore diameter of general-purpose heat insulation materials, such as urethane and styrene, is considered to be approximately 50 to 800 µm. Thus, the pore diameter of silica aerogel is 1/1,000 of the size.

In general, thermal conductivity is inversely proportional to thickness. Notably, with general-purpose heat insulation materials, the thinner the material, the lower the insulation performance, following a quadratic curve. In particular, when the thickness of a heat insulation material is 1 mm or less, the pore diameter is close to the thickness. This results in damage to pores, making it difficult to demonstrate the heat insulation effect. In contrast, silica aerogel, which has microscopic pores, maintains the structure necessary to ensure heat insulation performance, and prevents thermal conductivity from decreasing even when the thickness of the heat insulation material is 1 mm or less. This is another major characteristic (Fig. 4).

In addition, the melting point of silica aerogel is about 1,200°C. The material is thus characterized by thermal stability.

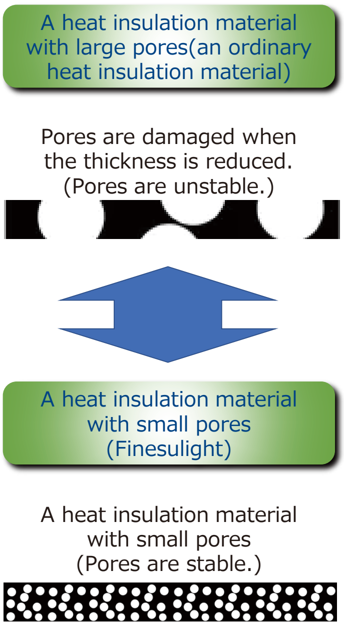

Fig. 4. Influence of pores in heat insulation materials

3. Development of Paint Using Silica Aerogel

In general, silica aerogel is handled as powder. Companies and research institutes that study the applications of silica aerogel work on various initiatives to create new value through secondary processing, such as mixing and kneading this powder into paints and resins, in addition to using it in powder form. However, it is necessary to overcome several issues in the development process. Specific issues that we tackled are discussed below.

Silica aerogel is a bulky powder material, making it extremely difficult to handle. We faced challenges in commercializing it in powder form. To address this, we focused on transforming the material into paint for ease of handling. Notably, to realize the product concept of thinness (thickness of 1 mm or less) and high heat insulation performance, we considered it most effective to coat the base material with the silica aerogel transformed into paint. This was deemed optimal in attaining the target thickness, and from the viewpoint of the manufacturing method.

To transform silica aerogel into paint, the powder must be made miscible and dispersed in a solvent. From the viewpoint of environmentally friendly manufacturing in particular, we conducted a study on the assumption that silica aerogel should be transformed into water-based paint.

Through the development of rubber and resin materials, we have refined various material formulation technologies and surface treatment/modification technologies in the course of handling poorly miscible and dispersible materials and additives. In this development project, we succeeded in making silica aerogel miscible and dispersible by using our technological expertise (Photo 1).

Photo 1. Silica aerogel transformed into paint

The developed paint demonstrated high insulation performance of 0.020 W/m•K (performance of the paint film only), which is superior to the thermal conductivity of still air (0.024 to 0.026 W/m•K), without undermining the insulation performance of silica aerogel (based on thermal conductivity measurement compliant with JIS A 1412) (Fig. 5).

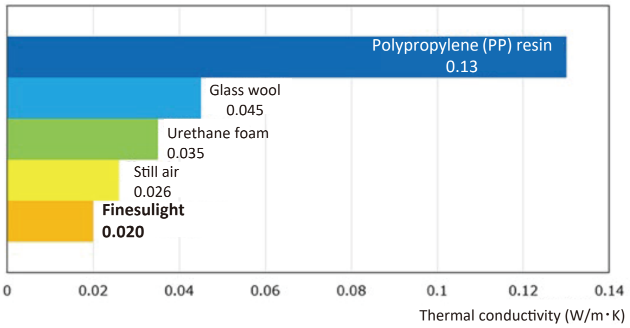

Fig. 5. Thermal conductivity of heat insulation materials

Thus, paint for thin-film, high-heat-insulation materials was completed with the high packing density of silica aerogel of 90% or more.

4. Study of Commercialization Using High-heat Insulating Paint

Toward commercialization using the new high-heat insulating paint, we realized a thin film by coating a thin-film base material (nonwoven cloth) with the paint (Photo 2).

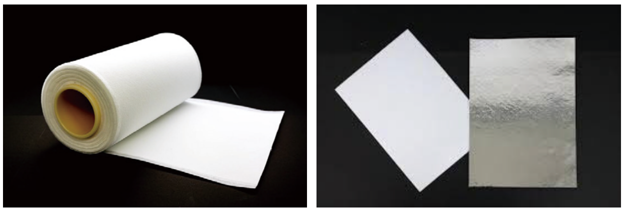

Photo 2. A roll (left) and a strip (right)

We registered "Finesulight," which was coined by combining "Fine," "Insulate," and "Light," which are the characteristics of this thin-film, high-heat-insulating material, as a trademark for the product.

The current product lineup is explained below. We sell three types depending on the function. One more type is planned to be released. The total thickness for all the types is 1 mm or less (Table 1).

Table 1. Product lineup of Finesulight (rolls)

		Standard product		Medium-heat-resistant product (under development)	High-heat-resistant product
		-	Heat shielding type		
Specifications		Organic heat insulation material Polyester-based nonwoven cloth	Aluminum deposition film Organic heat insulation material Polyester-based nonwoven cloth	Aluminum glass cloth Heat-resistant organic heat insulation material Nonwoven glass cloth	Inorganic heat insulation material Nonwoven glass cloth
Heat-resistant temperature		≤120°C	≤120°C	≤200°C	≤500°C
Thickness		About 0.5 mm	about 0.6 - 0.7 mm	About 0.8 mm	About 0.5 mm
Layer structure	Heat shielding layer	-	(Aluminum deposition film)	(Aluminum glass cloth)	-
	Heat insulation layer	Silica aerogel (+ organic binder)	Silica aerogel (+ organic binder)	Silica aerogel (+ heat-resistant organic binder)	Silica aerogel (+ inorganic binder)
	Base material	Nonwoven PET cloth	Nonwoven PET cloth	Nonwoven glass cloth	Nonwoven glass cloth

The standard type with the simplest configuration is a product whose nonwoven cloth is coated with the heat insulation paint.

The heat shielding type, with an aluminum deposition film added to the standard type, is also available.

We have also prepared a high-heat-resistant product for the high-temperature range of 150°C or higher, in which organic material-based heat insulation materials, such as urethane and styrene, are difficult to apply.

The medium-heat-resistant type, which is currently under development, is a new product that we started to develop in response to many requests from customers who wanted to promote energy conservation of plant equipment, including large continuous drying furnaces. Notably, there are many customers who need composite products with an aluminum glass cloth. We plan to deploy the product quickly.

5. Basic Features (1)

5-1 Configuration of the standard type (heat shielding type)

This section explains the standard type (heat shielding type) in the product lineup.

The basic configuration consists of three layers: a polyester-based nonwoven cloth, a heat insulation material, and an aluminum deposition film (Fig. 6).

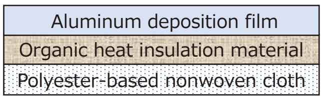

Fig. 6. Configuration of the standard product (heat shielding type)

The polyester-based nonwoven cloth is lightweight (ρ0.15 g/cm^3) compared to a general resin film (ρ1.0 g/cm^3). It can be made thinner (thickness ≤ 1 mm), and is characterized by excellent flexibility. Thus, we used it as a base material. The use of a nonwoven cloth allowed the heat insulation paint to impregnate the pores of the nonwoven cloth during coating, leading to improved adhesion.

The silica aerogel-based heat insulation paint (using an organic-based binder) was applied to the base material and was dried to form a heat insulation layer, which was made from a lightweight, thin film.

Subsequently, an aluminum deposition film was applied to the heat insulation layer as a material to reflect infrared rays entering from outside. The aluminum deposition film also prevents the heat insulation material from being delaminated by sandwiching the heat insulation material between the polyester-based nonwoven cloth and the aluminum deposition film.

5-2 Evaluations of high-temperature heat insulation

To verify the high-temperature heat insulation effect of the heat insulation sheet, the heat insulation sheet was placed on a hot plate at 85°C, and the surface temperature was measured. The details are described below (Fig. 7).

As an evaluation sample, we prepared a heat insulation sheet with a total thickness of around 0.7 mm, comprising three layers: a polyester-based nonwoven cloth (thickness: 0.4 mm), a heat insulation material (thickness: 0.3 mm), and an aluminum deposition film (thickness: 0.025 mm).

Evaluations were conducted in an environment of 25°C. A hot plate was prepared for the test and was set to 85°C. Subsequently, a heat insulation sheet with dimensions of 10 cm by 10 cm was placed on the hot plate, with the polyester-based nonwoven cloth in contact with the hot plate. After the sheet had been left on the hot plate for two minutes, the surface temperature of the heat insulation sheet was measured using a contact thermometer. Evaluations were conducted using a single heat insulation sheet and with two to four sheets stacked. The evaluation results are presented below. When the surface temperature of the hot plate was 85°C, the surface temperature was 66°C (-19°C) with one heat insulation sheet, 55°C (-30°C) with two sheets, 51°C (-34°C) with three sheets, and 48°C (-37°C) with four sheets. As the thickness of the heat insulation sheet increased, the surface temperature gradually approached normal temperature (Fig. 8).

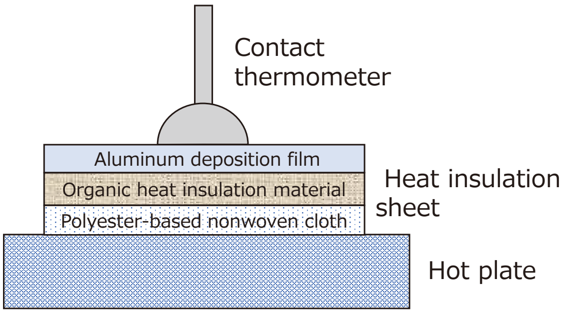

Fig. 7. Heat insulation performance test method (heating)

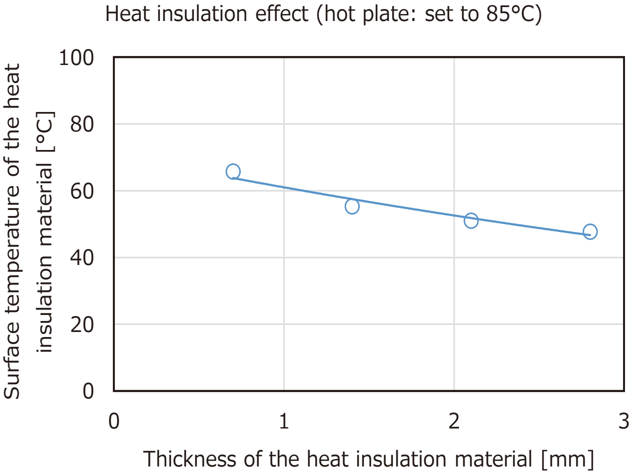

Fig. 8. Evaluation result of the heat insulation performance (heating)

5-3 Evaluations of low-temperature heat insulation

To verify the low-temperature heat insulation effect of the heat insulation sheet, the heat insulation sheet was placed on a cool plate at 0°C, and the surface temperature was measured. The details are explained below (Fig. 9).

As an evaluation sample, we prepared a heat insulation sheet with a total thickness of around 0.7 mm comprising three layers: a polyester-based nonwoven cloth (thickness: 0.4 mm), a heat insulation material (thickness: 0.3 mm), and an aluminum deposition film (thickness: 0.025 mm).

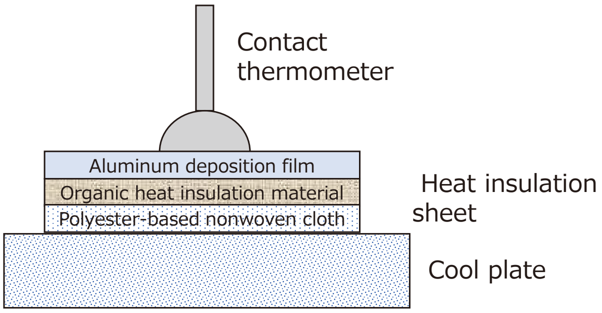

Fig. 9. Heat insulation performance test method (cooling)

Evaluations were conducted in an environment of 25°C. A cool plate was prepared for the test and was set to 0°C. Subsequently, a heat insulation sheet measuring 10 cm by 10 cm was placed on the cool plate, with the polyester-based nonwoven cloth in contact with the cool plate. After the sheet had been left on the cool plate for two minutes, the surface temperature of the heat insulation sheet was measured using a contact thermometer. Evaluations were conducted using a single heat insulation sheet and with two to four sheets stacked.

The evaluation results are discussed below.

When the surface temperature of the cool plate was 0°C, the surface temperature was 9°C with one heat insulation sheet, 12°C with two sheets, 15°C with three sheets, and 17°C with four sheets. As the thickness of the heat insulation sheet increased, the surface temperature gradually approached normal temperature (Fig. 10).

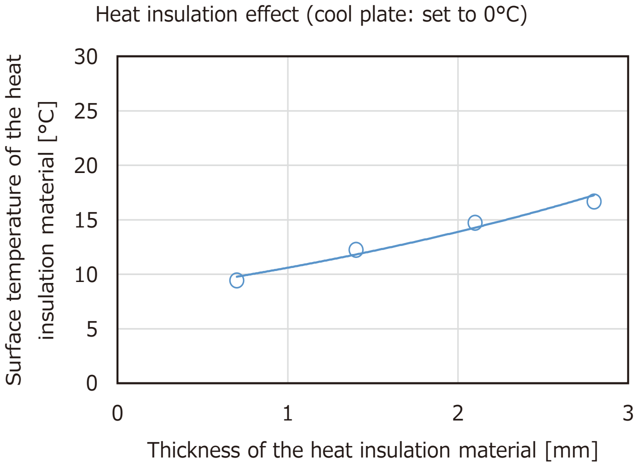

Fig. 10. Evaluation result of the heat insulation performance (cooling)

6. Basic Features (2)

6-1 Configuration of the high-heat-resistant type

The high-heat-resistant type in the product lineup is explained below.

The basic configuration consists of two layers: a nonwoven glass cloth and a heat insulation material (Fig. 11).

Fig. 11. Configuration of the high-heat-resistant product

The polyester-based nonwoven cloth used for the standard type is characterized by low heat resistance, and is unsuitable for use in a high-temperature atmosphere. We selected a nonwoven glass cloth as an alternative material. The nonwoven glass cloth was used as the base material because it was 0.2 mm thick and highly flexible. The use of a nonwoven cloth allowed the heat insulation paint to impregnate the pores of the nonwoven cloth during coating, leading to improved adhesion.

A silica aerogel-based heat insulation paint (using an inorganic binder) was applied to the base material and was dried to form a heat insulation layer, which was made from a lightweight, thin film.

6-2 Evaluations of high-temperature heat insulation

To verify the high-temperature heat insulation effect of the heat insulation sheet, the heat insulation sheet was placed on a hot plate at 200°C, 300°C, 400°C, and 500°C, and the surface temperature was measured. The details are presented below (Fig. 12).

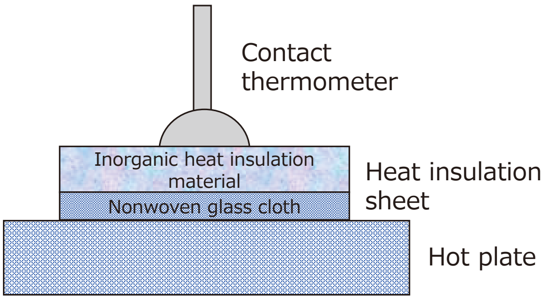

Fig. 12. Heat insulation performance test method (heating)

As an evaluation sample, we prepared a heat insulation sheet with a total thickness of around 0.5 mm comprising two layers: a nonwoven glass cloth (thickness: 0.2 mm) and a heat insulation material (thickness: 0.3 mm).

Evaluations were conducted in an environment of 25°C. A hot plate was prepared for the test and was set to 200°C, 300°C, 400°C, and 500°C. Subsequently, a heat insulation sheet measuring 10 cm by 10 cm was placed on the hot plate with the nonwoven glass cloth in contact with the hot plate. After the sheet had been left on the hot plate for five minutes at each temperature, the temperature stability was checked, and the surface temperature of the heat insulation sheet was measured. Evaluations were conducted using a single heat insulation sheet and with two to six sheets stacked.

The evaluation results are discussed below. As a representative example, when the surface temperature of the hot plate was 500°C, the surface temperature was

395°C (-105°C) with one heat insulation sheet, 352°C (-148°C) with two sheets, 307°C (-193°C) with four sheets, and 264°C (-236°C) with six sheets. The larger the number of heat insulation sheets stacked, the higher the heat insulation effect (Fig. 13).

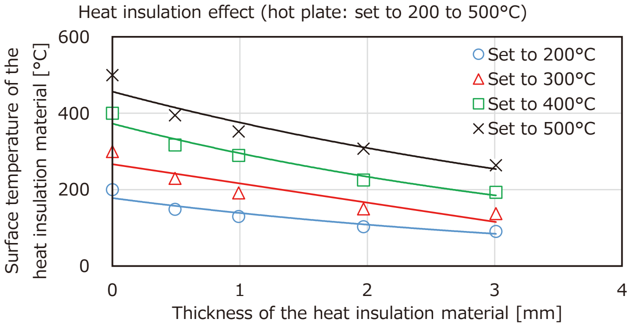

Fig. 13. Evaluation result of the heat insulation performance (high-temperature heating)

6-3 Flammability evaluations

We conducted flammability tests to confirm that the heat insulation sheet could be used safely in high-temperature environments. The details are described below. As an evaluation sample, we prepared a heat insulation sheet with a total thickness of around 0.4 mm comprising two layers: a nonwoven glass cloth (thickness: 0.2 mm) and a heat insulation material (thickness: 0.2 mm). The sheet was cut into strips measuring 13 × 125 × 0.4 mm thick.

Evaluations were conducted in conformance with ASTM D3801 (UL 94 vertical burning test). Specifically, a strip cut from the heat insulation sheet was vertically set to a clamp. Subsequently, it was brought into contact with a 20 mm flame twice for 10 seconds each, and the burning behavior was observed in order to make judgments (Fig. 14).

When a strip of the heat insulation sheet was brought into contact with the flame, it turned red, but no flame or dripping was observed. The result showed that the flammability of the heat insulation material was equivalent to V-0 of the UL 94 vertical test.

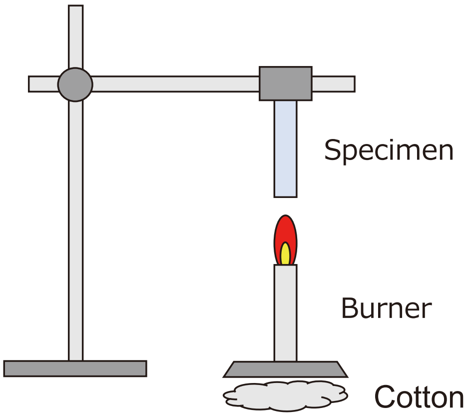

Fig. 14. Flammability evaluation: UL 94 vertical burning test

7. Conclusion

We succeeded in transforming silica aerogel, a material characterized by high heat insulation performance, into water-based paint with high packing density, and developed a thin-film, high-heat-insulating material. This heat insulation material is characterized by thermal conductivity of 0.020 W/m•K, which is superior to that of still air (0.024 to 0.026 W/m•K) and demonstrates high heat insulation performance even with a thickness of 1 mm or less.

In recent years, to cope with global climate change, even higher energy conservation performance has been required for houses and buildings through legal requirements to meet energy conservation standards and measures to promote low-carbon buildings. Changes in global energy procurement, including renewable energy, have caused energy prices to surge, leading to the spread of energy-saving products. The trend toward higher performance is also observed in foreign countries. Notably, technologies for thin, highly functional insulation materials have been developed in various fields with a view to improving their heat insulation performance.

At present, we are studying the possibility of applying mainly the high-heat-resistant type to electronic devices, such as for heat generation in electric home appliances that incorporate heating parts (e.g., heaters) and lithium-ion batteries (including measures against fire through the enhancement of flame retardance).

To spread the scope of application of the product, we have been working on the following development projects below in addition to the heat insulation sheet, whose polyester-based nonwoven cloth and nonwoven glass cloth are coated with the paint:

1. Development of paint that can be directly applied to enclosures of electronic devices (Fig. 15)
2. Development of paint for textiles with superb flexural durability and launderability
3. Development of paint that can be molded

The establishment of such technologies will enable applications, that previously found conventional sheet products difficult to use and expand the scope of application of the product.

We will further promote technology development for heat insulation materials using silica aerogel, thereby meeting market needs.

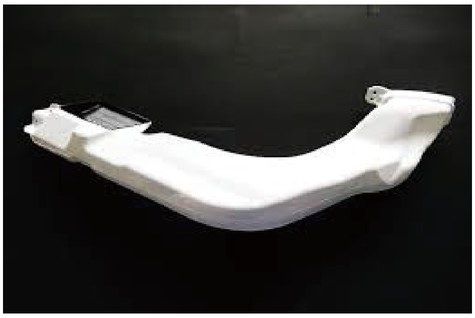

Fig. 15. An item coated with the heat insulation material

- Finesulight, Refleshine, and MIF are trademarks or registered trademarks of Sumitomo Riko Company Limited.

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