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Fabrication and Properties of Nanometer Multilayer Compound Heat Insulation Material

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Abstract: This research focuses on the development of a nanometer multiple-layer compoundheat insulation material and its preparation procedure. The material consists of alternating layers of an infrared reflecting screen and a spacer. The infrared reflecting screen is made of metal foil or metal plated foil, while the spacer is a thermostability nanometer porous aerogel compoundheat insulation material. The layers are combined using thermostability adhesives or puncturing connection with thermostability sewing threads. The objective of this study is to investigate the properties and preparation procedure of the nanometer multiple-layer compoundheat insulation material. The material offers low density, favorable mechanical properties, and excellent high-temperature heat insulation performance. It reduces the vacuum requirements for vacuum insulation plate core materials and eliminates the need for getters. This material meets the high-efficiency heat insulation requirements of aviation, aerospace, and civil applications. Moreover, the proposed procedure enables the production of large-sized heat insulation material members with complex shapes.

Keywords: *nanometer compound, heat insulation, infrared reflecting screen, spacer, preparation procedure*

Introduction

In recent years, there has been a growing demand for advanced heat insulation materials with enhanced properties and improved efficiency. These materials play a crucial role in various industries, including aviation, aerospace, and civil fields, where effective heat insulation is essential for optimizing energy consumption and maintaining stable operating conditions. In response to this demand, researchers have been exploring innovative approaches to develop high-performance heat insulation materials(Sima et al. 2020).One such development is the nanometer multiple-layer compoundheat insulation material, which offers promising characteristics and potential applications in the field of heat insulation.

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This material is composed of alternating layers of an infrared reflecting screen and a spacer, providing a unique combination of heat insulation properties and mechanical strength. The infrared reflecting screen consists of a metal foil or a metal plated foil, while the spacer is a thermostability nanometer porous aerogel compoundheat insulation material. The layers are joined using thermostability adhesives or puncturing connection with thermostability sewing threads, resulting in a robust and efficient compound structure(Kuyuldar, Genna, and Burda 2019).The objective of this research is to explore the properties and preparation procedure of the nanometer multiple-layer compoundheat insulation material

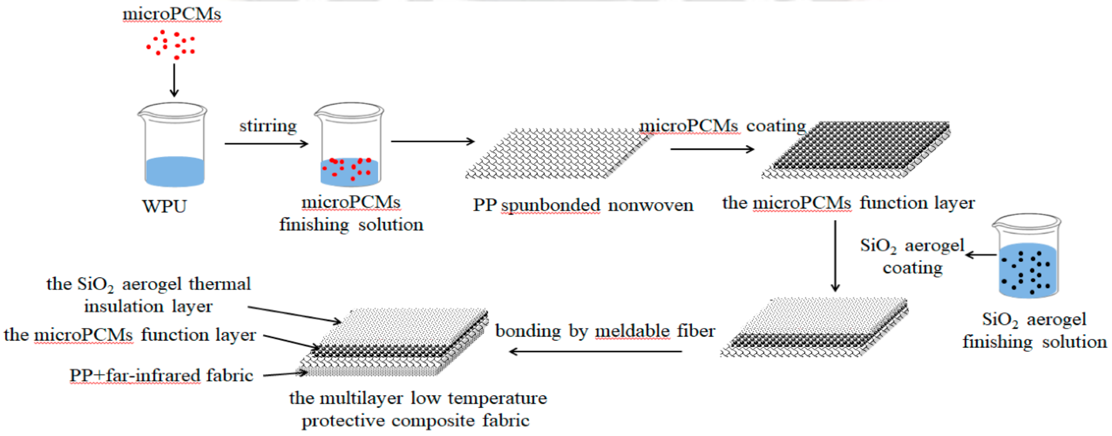

Figure 1. Fabrication Process for the Multilayer Cold-Resistant Composite Fabric

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Figure 1 illustrates a simplified schematic representation of the manufacturing process for the multilayer low temperature protective composite fabric (MPF). The process encompasses three main stages: (1) Production of the microPCM functional layer, (2) fabrication of the SiO2 aerogel heat-insulation layer, and (3) integration with the far-infrared fabric.

To evaluate the thermal insulation capabilities of the MPF in a cold environment, we devised the experimental apparatus with a structure as illustrated in **Figure 2**. The apparatus comprises the testing module, the data transmission adjustment module, and the data processing and output module (computer), which together facilitate the assessment of the MPF's thermal insulation performance at low temperatures.

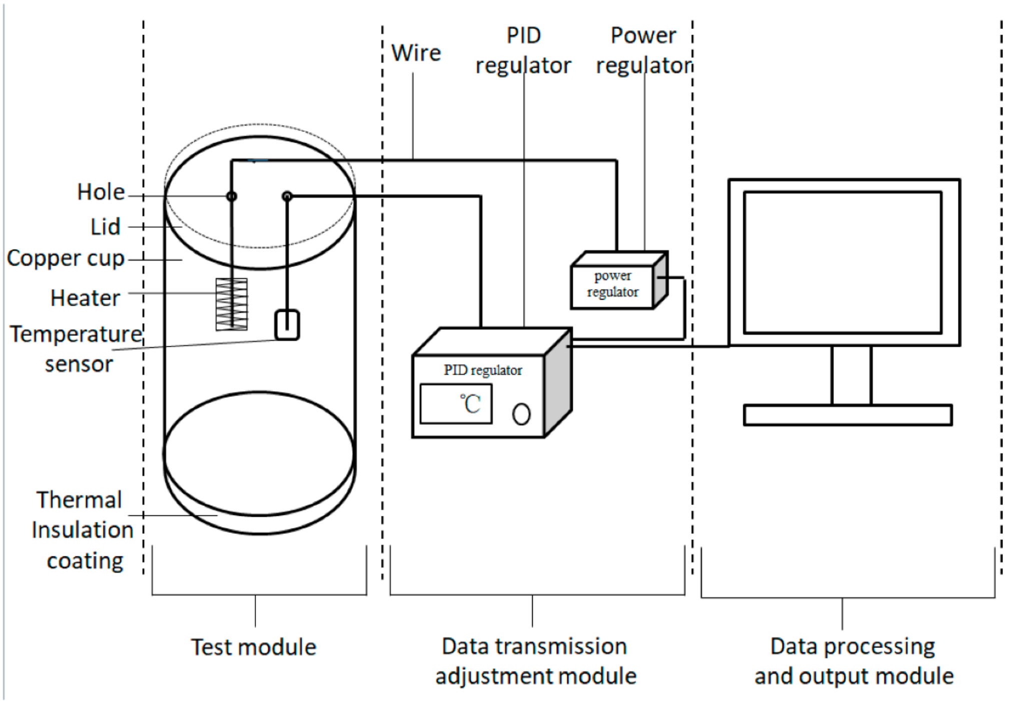

Figure 2 depicts the experimental setup used to evaluate the thermal insulation properties in a cold environment

By investigating its heat insulation performance, mechanical properties, and density, researchers aim to assess its suitability for various applications. Furthermore, the research aims to evaluate the effectiveness of the infrared reflecting screen and spacer in enhancing heat insulation, as well as the adhesion techniques and puncturing connection procedures employed to combine the layers(Hu, Wu, and Sun 2018).The development of such advanced heat insulation materials is driven by the need for more efficient and environmentally friendly solutions. Traditional structure contribute to its lightweight nature, which is particularly advantageous in applications where weight reduction is crucial, such as aerospace and aviation(Xu et al. 2019). Additionally, the material exhibits favorable mechanical properties, ensuring its durability and longevity in demanding environments.

Moreover, the nanometer multiple-layer compoundheat insulation material demonstrates excellent high-temperature heat insulation performance. By utilizing the infrared reflecting screen, which reflects and dissipates heat radiation, and the spacer with its heatly insulating properties, the compound material effectively minimizes heat transfer through radiation and conduction. This capability is vital in insulation materials often have limitations in terms of density, mechanical strength, and high-temperature performance.

The nanometer multiple-layer compoundheat insulation material offers a potential breakthrough in overcoming these limitations and achieving superior heat insulation properties.One significant advantage of the nanometer multiple-layer compoundheat insulation material is its low density. The use of nanometer-scale materials and the unique layering

applications requiring precise temperature control and protection against heat fluctuations(Guanhua et al. 2017).The research also aims to evaluate the material's suitability as a vacuum heat insulation plate core material.

Traditionally, vacuum insulation panels (VIPs) have been widely used for their outstanding heat insulation properties. However, VIPs often require high vacuum degrees and the inclusion of getter materials to maintain their performance. The nanometer multiple-layer compoundheat insulation material aims to reduce the vacuum requirements while eliminating the need for getters, simplifying the manufacturing process and enhancing overall efficiency.

The development of a nanometer multiple-layer compoundheat insulation material holds great potential for advancing heat insulation technology. Its unique composition, combining infrared reflecting screens and spacers, provides a balance of heat insulation, mechanical strength, and lightweight characteristics. The research objectives include investigating the material's properties, exploring its preparation procedure, and assessing its performance in various applications. By addressing the limitations of traditional insulation materials and offering superior heat insulation capabilities, the nanometer multiple-layer compoundheat insulation material paves the way for more energy-efficient and environmentally friendly solutions in the fields of aviation, aerospace, and civil engineering.

Related Work

In recent years, the global energy crisis has created a pressing demand for innovative heat-insulation and heat-preservation materials. One such material that has gained attention is the Vacuum Insulation Panel (VIP), which is a new type of low-temperature heat insulating material. VIPs are primarily composed of three main components: a core heat-protective material (insulating material), a gas absorption material (getter), and a trapping film (barrier). These components work together to effectively block the transmission of heat through air, resulting in a significant reduction in heat conductivity(Sima et al. 2020). In fact, the heat conductivity of VIPs is typically less than 0.004 W/mK, which is only about one-fourth to one-sixth of the heat insulating capability of commonly used materials like polyurethane rigid foam plastic. As a result, VIPs have found applications in various fields, including cold storage and aerospace.

However, conventional vacuum heat insulation materials require a high degree of vacuum (ranging from 10^-7 to 10^-5 KPa) to achieve optimal heat-shielding performance. Over time, the core of a vacuum heat-insulating plate may slowly emit small amounts of gas, while external gases can gradually enter the vacuum insulation layer through micro-pores in the trapping film. This leads to a decrease in internal vacuum and a reduction in the insulation effectiveness of the VIP. To maintain a high vacuum level, specific technical measures must be implemented, which increase the manufacturing cost(Luo et al. 2015; Zhang et al. 2018; Zou et al. 2020).Additionally, absorbent materials need to be added to absorb water vapor and other gases, further adding to the complexity and cost of production.

In the field of high-temperature insulation, there is a growing demand for materials that can withstand elevated temperatures while providing excellent heat insulation properties. The currently employed heat-protective materials can be broadly categorized into organic and inorganic types. Organic heat-protective materials, such as phenolic foam and urethane foam, are mainly used in lower temperature insulation applications for shorter durations(Ermeler and Pfeiffer 2002; Gunnarshaug, Metallinou, and Log 2020). However, these materials are unsuitable for high-temperature insulation. In contrast, inorganic heat insulation materials, including foamed ceramics, ceramic fiber blanket, and ceramic fiber paper, can be used in higher temperature environments. Nevertheless, most inorganic heat insulation materials exhibit significantly higher heat conductivity at elevated temperatures compared to room temperature. For instance, the heat conductivity of refractory fiber cotton produced by a leading heat ceramics company is 0.062 W/mK at 200 °C and 0.278 W/mK at 800 °C. Consequently, there is a continued demand for heat-protective materials that can maintain low heat conductivity under high-temperature conditions, particularly in industries such as high-end household appliances, industrial equipment, petroleum pipelines, and aerospace.

To address these challenges, researchers have explored various procedures to improve the high-temperature insulation properties of nanoporous silica aerogel materials. One approach involves introducing infrared light screening agents, such as TiO_2, Fe_3O_4, B_4C, carbon black, or short fibers, into the aerogel material(Luo et al. 2015; Zhang et al. 2018). These agents aim to enhance the high-temperature insulation performance. However, due to technological limitations, achieving uniform dispersion of infrared light screening agents within the aerogel matrix can be challenging, and the mechanical strength of the compound materials needs improvement.

Researchers, such as Lee et al. (Lee, B.Y., et al., "Effects of additives on the heat insulating and mechanical properties of nanoporous silica aerogel compounds," Journal of Sol-Gel Science and Technology, 2015), have investigated the effects of different additives on the heat insulation and mechanical properties of nanoporous silica aerogel compounds, with the aim of achieving better performance and practical applications.

In summary, the global energy crisis has led to an increased demand for advanced heat-insulation and heat-preservation materials. Vacuum Insulation Panels (VIPs) have emerged as a promising solution due to their low heat conductivity. However, maintaining a high vacuum level in VIPs and improving high-temperature insulation properties remain ongoing challenges. Researchers are exploring procedures to enhance the performance of aerogel materials, such as introducing infrared light screening agents, to achieve better heat insulation and mechanical strength. These advancements have the potential to address the needs of various industries requiring high-performance heat insulation materials.

Research Objective

The main objective of this research is to develop a nanometer multiple-layer compoundheat insulation material and investigate its properties and preparation procedure. The specific goals include:

Evaluating the heat insulation performance, mechanical properties, and density of the nanometer multiple-layer compound material.

Investigating the effectiveness of the infrared reflecting screen and spacer in enhancing heat insulation.
Examining the adhesion techniques and puncturing connection procedures for combining the layers.
Assessing the suitability of the material as a vacuum heat insulation plate core material and its performance without the need for getters.
Exploring the potential applications of the material in aviation, aerospace, and civil fields.

Nanometer Multilayer Compound Heat Insulation Material

The nanometer multiple-layer compoundheat insulation material is designed with a specific structure. It consists of alternating layers of an infrared external reflection screen and a Spacer. The infrared external reflection screen can be a metal foil or metal-plated paper tinsel, while the Spacer is a high-temperature resistant nano porous aerogel heat-insulation compound material. These layers are connected either by bonding or by using a high temperature resistant sewing thread or adhesive.The thickness of the high-temperature resistant nano porous aerogel heat-insulation compound material is between 0.3 to 2mm. The total thickness of the nanometer multiple-layer compoundheat insulation material is determined by the combined number of layers of the infrared external reflection screen and the Spacer, denoted as "n". The ratio of the total thickness of the material to "n" is in the range of 0.5 to 4.In simpler terms, the nanometer multiple-layer compoundheat insulation material is made up of several layers. Each layer alternates between an infrared external reflection screen (made of metal foil or metal-plated paper) and a Spacer (made of a special heat-insulating material). These layers are connected together using bonding, sewing thread, or adhesive that can withstand high temperatures.The thickness of the heat-insulating material is between 0.3 to 2mm, and the overall thickness of the insulation material depends on the number of layers. The ratio of the total thickness to the number of layers is between 0.5 to 4.

Conclusion

In conclusion, the developed nanometer multiple-layer compoundheat insulation material demonstrates promising properties for high-efficiency heat insulation. The material consists of alternating layers of infrared reflecting screens and spacers, providing low density, favorable mechanical properties, and excellent high-temperature heat insulation performance. By reducing the vacuum requirements and eliminating the need for getters, it offers advantages in various applications, including aviation, aerospace, and civil fields. The proposed preparation procedure allows the production of heat insulation material members with large sizes and complex shapes, further enhancing its versatility. The nanometer multiple-layer compoundheat insulation material represents a significant advancement in heat insulation technology and holds great potential for future applications.

References:

1. Ermeler, K., and W. Pfeiffer. 2002. *Influence of the Ambient Temperature on the Impulse Withstand Voltage Characteristics of Insulation Material Surfaces under Humidity Conditions*.
2. Guanhua, Jia, Zhu Li, Peng Liu, and Qiangshan Jing. 2017. “Preparation and Characterization of Aerogel/Expanded Perlite Composite as Building Thermal Insulation Material.” *Journal of Non-Crystalline Solids* 482. doi: 10.1016/j.jnoncrysol.2017.12.047.
3. Gunnarshaug, Amalie, Maria-Monika Metallinou, and Torgrim Log. 2020. “Study of Industrial Grade Thermal Insulation at Elevated Temperatures.” *Materials* 13:1–16. doi: 10.3390/ma13204613.
4. Hu, Feng, Siyu Wu, and Yugang Sun. 2018. “Hollow-Structured Materials for Thermal Insulation.” *Advanced Materials* 31. doi: 10.1002/adma.201801001.
5. Kuyuldar, Seher, Douglas Genna, and Clemens Burda. 2019. “On the Potential for Nanoscale Metal–Organic Frameworks for Energy Applications.” *Journal of Materials Chemistry A* 7. doi: 10.1039/C9TA09896H.
6. Luo, Zhengqian, Duanduan Wu, Bin Xu, Huiying Xu, Zhiping Cai, Jian Peng, Jian Weng, Shuo Xu, Zhu Chunhui, Fengqiu Wang, Zhipei Sun, and Han Zhang. 2015. “Two-Dimensional Materials Saturable Absorbers: Towards Compact Visible-Wavelength All-Fiber Pulsed Lasers.” *Nanoscale* 8. doi: 10.1039/C5NR06981E.
7. Sima, Wenxia, Jiahui He, Potao Sun, Ming Yang, Ze Yin, and Chuang Li. 2020. “Novel Nanostructure Composite Dielectric with High Insulation Performance: Silica-Based Nanometer-Sized Porous Composite Insulating Paper Reinforced by Ceramic Fibers.” *Scripta Materialia* 181:58–61. doi: 10.1016/j.scriptamat.2020.02.016.
8. Xu, Weiheng, Sayli Jambhulkar, Rahul Verma, Rahul Franklin, Dharneedar Ravichandran, and Kenan Song. 2019. “In-Situ Alignment of Graphene Nanoplatelets in Poly (Vinyl Alcohol) Nanocomposite Fibers with Controlled Step-Wise Interfacial Exfoliations.” *Nanoscale Advances*1. doi: 10.1039/C9NA00191C.
9. Zhang, Yuxia, Dazhi Lu, Haohai Yu, and Huaijin Zhang. 2018. “Low-Dimensional Saturable Absorbers in the Visible Spectral Region.” *Advanced Optical Materials* 7:1800886. doi: 10.1002/adom.201800886.
10. Zou, Jinhai, Qiujun Ruan, Xiaojin Zhang, Bin Xu, Zhiping Cai, and Zhengqian Luo. 2020. “Visible-Wavelength Pulsed Lasers with Low-Dimensional Saturable Absorbers.” *Nanophotonics* 9. doi: 10.1515/nanoph-2020-0022.