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AEROGEL APPLICATIONS IN TEXTILE MATERIALS

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ABSTRACT

The production of materials that will provide the high-performance properties required by today's technology is important for many sectors. Apart from meeting clothing and shelter needs, there is a direct or indirect rising need for the use of advanced textile materials in many different areas. Compared to the conventional materials, aerogel materials attract attention due to their ultra-lightweight structure with superior properties such as high specific surface area, high porosity, low density, low dielectric constant, excellent sound, and heat insulation. In addition, for the functional use of aerogel materials in the industry, mechanical properties such as modulus of elasticity, tensile-compressive strength, shear modulus, and impact strength are also important. When the literature on aerogel since the early 1930s is examined, it is seen that the studies mostly focused on application areas and more economical production ways. Although the most established application of aerogels in textiles is to improve thermal insulation, it is seen that they are also used in water repellency, air and water permeability, acoustic insulation, prevention of electromagnetic radiation, protection against chemicals, flame retardancy and treatment of textile process wastes. In this article, besides general information about aerogel, current aerogel application examples in textile materials are also included.

KEYWORDS

Aerogel, textile, organic, inorganic, functional materials.

INTRODUCTION

Aerogels are nanoporous lightweight structures with great sound and heat insulation, as well as high specific surface area, high porosity, low density, and low dielectric constant. Samuel Stephen Kistler discovered aerogel in the 1930s while attempting to demonstrate that it was feasible to make a solid gel of the same size and shape without collapsing the gels' structure. Kistler succeeded in generating the first aerogels in 1931 by separating the liquid from the wet gel using the supercritical drying method without altering the porosity or skeletal structure. Even though aerogels were discovered early when compared to standard materials, the macroscopic forms of aerogel materials have minimal usage since they lack acceptable properties for specific textile application areas, such as apparel fabrics. The use of various precursors, the production of composites with aerogel additives, the production of new types of aerogels other than silica, and the modification of aerogel structures by adding chemicals have all been studied to provide the desired functional properties and mechanical strength to the aerogel [1–3].

Although the area where aerogels are most used in textiles seems to be thermal insulation, it seems that they are also used in water repellency, air and water permeability, acoustic insulation, electromagnetic radiation prevention, chemical protection, flame retardancy and treatment of textile process wastes [4].

LITERATURE REVIEW

The most suitable method for the preparation of aerogels is the Sol-Gel method. This method is also the most suitable method for obtaining inorganic and organic-inorganic hybrid polymers. First, the sol (solution) is obtained by forming colloidal particles and polymers. As a result of the subsequent reactions, a gel is formed. Gel formation is followed by aging and drying steps. The most challenging process encountered during the preparation of aerogels has remained unchanged since the discovery of the aerogel. In this context, drying is one of the most important steps to remove the liquid solvent from the gel without disturbing the nanoporous aerogel structure, thus preventing subsequent shrinkage and cracking of the dried gel. Four basic approaches used to dry wet gels or remove solvent from the gel are drying by supercritical fluid extraction, freeze-drying, drying under atmospheric pressure, and drying by evaporation. Depending on the drying method and drying conditions of the wet gels, the density can be changed systematically and by changing the drying conditions; aerogel, xerogel, cryogel and ambigel structures can be produced [1–3].

When the existing textile applications of aerogels are examined in the literature, it is frequently encountered that the inclusion of aerogels in melt polymer structures in granular form, thin-film coating on fabric surface by adding aerogels in powder form to resins, and organic/inorganic hybrid material studies. Production of aerogel yarn and structures called blankets to draw attention in current studies. Wet reaction spinning, extrusion/injection, freeze spinning, and wet coaxial spinning methods can be used to produce aerogel fibers. Some examples of these applications are briefly summarized below [2,5–9].

Polypropylene Foam/Silica Aerogel composite sheet was developed in the study performed by Sotashi et al. Due to the skin layers of the polymer-foam composite, silica aerogel flaking, which has been a concern in practical applications, is very low in this composite. A supercritical drying technique for rolled sheets of the material is also detailed for large-scale manufacture. Simulations of 2-propanol extraction from a silica alcogel demonstrated that rolled composite sheets with small gaps between the sheets can dry in an acceptable amount of time. Despite the inclusion of a large volume of silica aerogel (97%), the composite showed high flexibility. In addition, it was stated in the study that it showed a thermal conductivity of 0.016 W/(m·K) at 298 K, similar to the monolithic aerogel [6].

In firefighting apparel, phase change material (PCM) improves both safety and comfort. Wearing protective equipment containing PCM while battling a fire provides a direct risk to the user because most PCMs are combustible. Shaid and colleagues attempted to solve the problem by combining aerogel with phase-change materials. The weight of the aerogel-containing lining fabric was less than the PCM-containing lining, the flame spread was less than the just PCM-containing fabric, and the aerogel-coated lining had higher heat resistance, according to the results of the study [10].

Lee and colleagues created a hydrophobic halochromic aerogel sensor impregnated with complicated halochromic dyes in a hydrophobic porous silica aerogel that is stable even when exposed to varied external environments and responds to acids and bases in another work. In the security and industrial domains, a halochromic sensor that can visibly and swiftly monitor information regarding human body exposure to dangerous substances is useful [11]. Textiles using halochromic dyestuffs can be used in a variety of applications. They can be used as protective clothing in the presence of acid vapor in the environment, to observe color changes in the healing process of wounds, to control the pH value of the soil during plant growth, or to determine the effect of the pH level of the water when determining the filter performance [12].

Glass fiber was employed to improve the weak mechanical characteristics of silica aerogels in a work by Huang et al. The glass fiber reinforced aerogel blanket has a modulus of elasticity of 12 MPa and thermal conductivity values of 0.026 W/(m·K), according to the study. In terms of performance, the high modulus of elasticity compared to silica aerogels and low thermal conductivity values compared to typical thermal insulation materials are both good developments [13].

In the domains of adsorption, filtration, catalysis, and sensing, porous materials having a high specific surface area are required. Due to the numerous advantages of fiber materials, such as increased surface areas, it is expected that their working would be improved when they are translated into fibers. Wet reaction spinning was used by Meng et al. to create hollow and hierarchical silica aerogel fibers. Because of their unique architectures, silica aerogel fibers generated using this method have at least 25% more adsorption capacity and ultra-high adsorption rates than other commercial adsorbents, according to the study. According to the findings, silica aerogel fibers, which have a stable chemical structure, a large specific surface area, and good mass transport capabilities, can be employed in catalysis and sensing [14].

Bhuiyan et al. investigated the effect of PU/Silica Aerogel coating on cotton fabric surfaces in order to develop a protective covering with increased breathability, chemical and water resistance. As indicated by the water contact angle and water repellency results, the Aerogel/PU coated fabrics outperformed the PU coated fabrics alone in terms of protective performance and water resistance. Without entering the clothes, the liquid chemicals were absorbed by the porous aerogel layer. The overall findings of this study point to the potential use of silica aerogel particles with PU covering as a new strategy to manufacturing protective apparel that is both breathable and chemically resistant [15].

In the textile industry, wastewater recycling is becoming a growing environmental concern. To improve colorfastness in textile reactive dyeing, dyed materials must be rinsed numerous times in the wash-off process. As a result, repeated washing operations significantly increase freshwater consumption while also producing large waste rinsing effluents. Hu et al. suggested a novel approach to recycling wastewater to reduce the amount of freshwater used in the washing process. The researchers created a carbon aerogel (CA) containing a bimetallic hybrid material ($Ag–Fe_2O_3$@CA) and employed it as a catalyst in ozonation operations to degrade dyes left in waste rinse wastes. When the study's findings are evaluated, it is discovered that adding $Ag–Fe_2O_3$@CA to the mix raises the percentage of chemical oxidation demand removed by 30%. In addition, after catalytic ozonation with $Ag–Fe_2O_3$@CA, the effluent was successfully recovered. It is also acknowledged that, in terms of color difference and colorfastness, the matching materials can be reused without losing color quality to reduce the consumption of freshwater during the washing process [16].

CONCLUSION

Research on the use of aerogels in the production of textile materials that will provide the high-performance properties demanded by today's technology has increased especially in the last 20 years. Most of them seem to be limited to inorganic aerogels. We think that it will be possible to produce hybrid membranes to be used in heat and acoustic insulation, and purification applications; flame retardant materials and textile materials with many admirable functional properties in the industry, thanks to the transfer of aerogels to textile materials while preserving their superior properties and existing skeleton structure. The primary issue we should focus on for the future research should be the improvement of mechanical properties such as modulus of elasticity, tensile-compressive strength, shear modulus, impact resistance, in addition to specific properties for the functional use of aerogel materials in the textile industry. Two critical issues also need to be investigated in the production process that prevents large-scale production; these are ageing and drying processes. The fact that the process is long in those steps and the inability to make large-scale production causes an increase in production costs. It is also known that the specific properties of the aerogel dramatically change with the chosen drying method, and therefore aerogel structure types are named according to the drying method. Solvent selection and matrix compatibility are the critical points in the ageing process step. It is believed that it will be soon possible to shorten the ageing process by emphasizing the studies on this research field. It is necessary to create large-scale systems by making necessary developments with performing basic research on the thermodynamics and kinetics of the drying process. In addition, testing substances with lower critical temperatures and pressures can be an improvement in the drying step. As a result, the use of aerogels may answer the demands of industries for not only today's but also the future's high-performance materials, in a sustainable eco-friendly way. Within the scope of this project, monolithic and hybrid aerogels will be applied to the textile material and their thermal and acoustic insulation performances will be investigated.

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