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## Application of graphene and aerogel in winter running shoes products

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# Application of graphene and aerogel in winter running shoes products

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**Abstract.** In view of the functional requirements of winter running shoes, the characteristics of graphene and aerogel materials, the preparation process, and the feasibility of their application in products are explored. The results show that the application of new materials in winter running shoes products will make winter running shoes have better heat preservation, breathability, skid-proof, wind-proof, water-proof, deodorant, durability, wear-resistance, encapsulation, and so on, which greatly improves the overall performance of winter running shoes products.

## 1. The functional requirements of the inter running shores

Winters running shores is a necessary equipment for runners to run in winter or in other cold weather. The winter temperature is low, the temperature of the road surface is usually lower than 0 degrees, and there is often freezing of the road surface. Snow and ice remained on the upper of the shoe easy to melt, winter monsoon cold, early morning and evening light dim, set above the situation, Winter running shoes must have the function of keeping warm, anti-skid, wind-proof and waterproof, reflecting light. When runners wear running shoes for long periods in winter, the feet are lined with the shoes, and the insole produces friction, heat, sweat or moisture. Winter running shoes needs to remove excess heat and moisture in a timely manner, so as not to cause stuffy heat, bacteria, and foot health. In order to prevent snow particles, ice slag from the structural gap into the shoe, so the porosity of winter running shoes fabric needs to be greater than water vapor less than water droplets, and the irregular pores can also ensure the function of windproof, waterproof, and breathable at the same time. At the same time, running shoes should also have good encapsulation, stability and anti-skid performance when they encounter road slippage in winter.

## 2. Research status of winter running shoes

German brand PUMA is a running shoe designed for winter running \_ PWRWARM (Figure 1). In order to reduce the weight of running shoes, multi-layer ultra-thin and ultra-light mesh cloth and traditional synthetic leather heat were used to fit the support, and the running shoes could not provide sufficient support when the actual weight of winter runners increased, and the running shoes could not provide sufficient support in the event of gravel or ice and snow on the road, and the upper of the shoes would strain quickly. In order to keep warm, a large number of fleece materials are used to make the air fluidity in the running shoes worse, so that the constant temperature technology of PWRWARM running shoes is the main part of the running shoes.——In terms of actual feelings, you will soon feel sweltering when you wear the ComfortTemp.





Figure 1: PWRWARM running shoes    Figure 2: ComfortTemp thermostat technology in shoe tongue

Although the Japanese brand ASICS's GT-1000 7 SOLAR SHOWER running shoes (figure 3) can withstand the cold better, its use of multilayer mesh cloth and a large amount of towel materials increase the weight of the shoes.



Figure 3: GT-1000 7 SOLAR SHOWER running shoes

The use of traditional materials will inevitably increase the weight and breathability of running shoes when ensuring winter running shoes windproof, rain-proof, snow-proof and wear-resistant conditions. In pursuit of lightweight running shoes, the winter running shoes support strength is inevitably reduced, and under the premise of the pursuit of breathability, the performance of winter running shoes is often reduced. Therefore, some new materials need to be used to meet the necessary performance of winter running shoes at the same time.

### 3. Characteristics of graphene and aerogel

#### 3.1 Characteristics of graphene

3.1.1 Graphene is a two-dimensional carbon nanomaterials with hexagonal honeycomb lattice composed of carbon atoms in  $sp^2$  hybrid orbitals, which can be kept strong in a light and thin structure; Graphene has good thermal conductivity and good light transmittance;<sup>[6]</sup> In addition, it has excellent chemical stability and electrical conductivity, as well as wear resistance, graphene is plastic, can curl into a cylindrical shape, become one-dimensional carbon nanotubes, can also be made into spherical or ellipsoidal ball, to obtain zero-dimensional fullerene (figure 4).<sup>[6]</sup> Graphene blended with ordinary fiber can produce new yarn with antibacterial, antistatic, UV-resistant, low-temperature and far-infrared emission.; Add graphene to running shoe rubber to enhance outsole strength, elasticity, and wear resistance<sup>[11]</sup>.

Compared with the materials in the above two cases, the upper made of graphene blended fiber is not easy to be damaged, it not only has good heat dissipation performance, but also has antibacterial property.

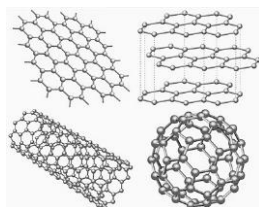


Figure 4: Structure of the graphene structure

#### 4. Characteristics of aerogel

Aerogel is the world's lightest solid, with the characteristics of high specific surface area and low thermal conductivity, known as "one of the top 10 magical materials that change the world." At present, aerogel mainly refers to a solid material (figure 6), which is composed of nanometer-sized ultrafine particles. It has three-dimensional reticular structure, high porosity, large surface area and low density, and has the characteristics of high porosity, large surface area and low density.<sup>[4]</sup> The greatest advantage of polymer-

based organic aerogel in organic aerogel is its flexible molecular design, which makes it easier to control its performance. For example, flexible polyimide aerogel can be more convenient for shoes, clothing, fabric industry, easy transportation, cutting, sewing.

Aerogel is an environment-friendly material, does not contain toxic substances such as chloride, and is soft, easy to cut, difficult to deform and less in loss during the cutting process.<sup>[1]</sup> At the same time, aerogel belongs to ultra-light and ultra-thin material, and it needs thinner thickness when it reaches the same insulation effect as ordinary insulation material.<sup>[4]</sup>

Thanks to the development of textile-specific aerogel composite super-heating materials by the S.kistler team in 2017, aerogel has been used in the garment industry. The textile-specific aerogel composite binds each aerogel particle with no powder loss, softness, washability, breathability, and so on (figure 6).



Figure 5: aerogel

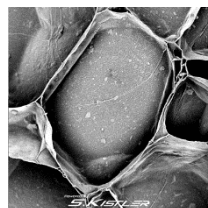


Figure 6; S.Kistler is a special aerogel composite for textile industry.

This material can achieve very strong thermal insulation performance, it is only 3mm thick, can resist-196 °C liquid nitrogen injection.

Compared with the previous two cases, the liner made of aerogel is lighter in weight, better in heat preservation and better in air permeability, and it is non-toxic and pollution-free.

## 5. Manufacturing process of graphene and aerogel

### 5.1. Graphene manufacturing process

The preparation method of transforming graphite oxide particles into graphene is as follows: firstly, carbon materials are obtained, and the carbon materials are rolled to form dispersed and comminuted graphite particles; Secondly, graphite particles are oxidized at high temperature above 600 °C to form graphite oxide particles. Then, use the graphene preparation system for microwave irradiation and tremor of graphite oxide particles, and then form the required graphene, for collection. The invention has the advantages of fast preparation speed, fast collection of graphene, avoiding deformation and warping of peeled graphene, and improving the efficiency of graphene preparation and the quality of graphene.<sup>[9]</sup>

### 5.2. Manufacturing process of aerogel

5.2.1 In 1931, Stanford University Kistler was prepared by ethanol supercritical drying using water glass as raw material.<sup>[4]</sup> In 1966, Peri synthesized SiO<sub>2</sub> aerogel by sol-gel chemical method.<sup>[3]</sup> Organic aerogel was originally synthesized from American l'ekala by high temperature carbonization of resorcinol and formaldehyde as raw materials.<sup>[4]</sup> Natural cellulose can be mechanically, ultrasonic, high-pressure homogeneous or chemically treated to form cellulose on a micron or nano-scale basis. These separated cellulose usually have a large specific surface area, and the groups on the surface can drive the micro-/ nano-fiber to self-assemble into a network structure by some interaction to achieve the prerequisite of preparing aerogel materials. By modifying other groups on cellulose, the interaction between cellulose molecules or cellulose microfibrils can be further increased, and then cellulose aerogel with good properties can be obtained.<sup>[5]</sup>

### 5.3. Graphene aerogel manufacturing process

The Chinese Academy of Sciences aerogel team spun oxidized graphene liquid crystals into a specific coagulation bath by wet spinning. After chemical reduction and supercritical drying, graphene aerogel

fibers with regular, continuous and porous structure can be obtained. Then, organic phase change materials (such as paraffin wax, polyethylene glycol, advanced fatty acids, etc.) were introduced into the porous network structure of aerogel fiber by impregnation. Graphene-aerogel phase change composite fibers were obtained: finally, fluorocarbon hydrophobic coating was coated on the composite fibers. A flexible graphene-aerogel intelligent fiber with self-cleaning function and multi-stimulus response behavior is obtained. <sup>[2]</sup>

## 6. Complementary characteristics of graphene and aerogel

Flexible graphene-aerogel intelligent fibers developed by the aerogel team of the Chinese Academy of Sciences achieve multi-functional integration in response to multiple stimuli, which can achieve fiber twist yarns and woven fabrics that cannot be achieved by single graphene and aerogel materials. <sup>[2]</sup> Aerogel materials have low strength, strong permeability, poor thermal conductivity, unable to provide support and high graphene strength, good thermal conductivity and release of far-infrared rays, graphene can be used in the intensity, heating and use. In addition, aerogel can also play a strong role in air permeability, heat preservation, the use of both materials can achieve complementary properties, such as the release of far-infrared graphene fiber, aerogel material locking heat to keep warm, a single graphene fiber thin. And aerogel can provide psychological thickness and aerogel can fill the crevice of graphene fabric and block the cold wind. Graphene fabric can avoid aerogel delamination, strengthen the solidity of upper, and increase the service life of composite materials. Graphene can also be prepared by hydrothermal reduction method as a three-dimensional cross-linked network structure, which has the characteristics of high elasticity, anti-fatigue, adsorption and so on. <sup>[12]</sup>

## 7. The advantage analysis of graphene and aerogel application in winter running shoes.

In the aspect of upper fabric, the preparation of Si/ cellulose composite aerogel, from cellulose and methoxytrimethylsilane precursors can provide good hydrophobic and adiabatic properties, which can enable winter running shoes to achieve the functions of keeping warm, preventing wind and waterproof. The blend of graphene and elastic fiber can provide good encapsulation and elasticity at the same time, and does not restrict the movement of the foot at the same time. For winter running shoes stability requirements, where running shoes need to provide support such as uppers, the use of graphene material to replace the traditional TPU material can enhance the support strength and reduce the weight of running shoes; Graphene material can also replace the traditional carbon plate, reducing weight while ensuring the original carbon board function. According to the requirements of winter running shoes comfort, the pores of aerogel are complicated and irregular, and the pores are larger than sweat steam. Combined with cotton or other skin-friendly material layer, the effect of absorbing sweat, keeping warm and breathable can be achieved. While keeping the feet warm, it can remove excess moisture and absorb excess sweat to make the running feet dry and comfortable. Graphene can also be prepared into graphene-aerogel, with high elasticity, fatigue resistance and adsorption characteristics, which can greatly enhance the life of aerogel, and absorb the smell inside the shoe bin to ensure the health of the user's feet. Dr. Aravind Vijayaraghavan, a material scientist at the University of Manchester, and the team added graphene to the rubber of the Invo-8G series of running shoes. This increases the strength, elasticity and wear resistance of its outer base by 50% compared to industrial standard rubber, and that graphene rubber can bend and control more effectively on all surfaces, greatly reduce wear efficiency, and make grip more reliable and robust. Lasting. <sup>[11]</sup>

The synthetic gel materials have the functions of moisture absorption and air permeability, compressive water retention, heat preservation and cold storage. The aerogel fabric has the characteristics of water absorption and swelling, dehydration, deswelling, and a large number of pores on the aerogel under dry conditions can ensure the hot gas evaporating from the runner's feet. <sup>[4]</sup> It can provide a "breathable" function for winter running shoes products, if wet by water, the surface gel layer quickly swelling, the pores closed, the outside water can not soak through the aerogel material, thus "waterproof" or "anti-immersion" performance. Optimal solution for waterproofing and air permeability in ready-to-use shoes: "several microholes in the front palm of the outsole, and air-permeable waterproof

cloth on the upper part of the opening...." It can replace breathable waterproof cloth with aerogel material, in addition to satisfying the function of breathable and waterproof, it also provides insulation and heat preservation function. Aerogel materials can reduce weight and thickness, reduce excess consumption during running, improve exercise efficiency, and aerogel materials are environmentally friendly materials, while achieving the same heat preservation effect as common winter running shoes, and it can reduce weight and thickness, reduce excess consumption during running, improve exercise efficiency, and aerogel materials are environmentally friendly. When the winter running shoes product is scrapped, the aerogel material can be directly landfill. Hydrophobic SiO<sub>2</sub> / aerogel, polyimide aerogel has the advantages of lightweight, high strength, flexibility, durability and excellent high temperature resistance. The greatest advantage of polymer-based organic aerogel in organic aerogel is its flexible molecular design, which makes it easier to control its performance. For example, flexible polyimide aerogel can be more convenient for shoes, clothing, fabric industry, easy transportation, cutting, sewing.

At the same time, there is no winter running shoes among the world-famous shoe companies to use these two materials at the same time, if the two materials are used in a shoe at the same time, consumers will pay attention to the two materials at the same time.

## 8. Conclusion

The use of graphene and aerogel in winter running shoes products has great feasibility and commercial value. Its products can greatly enhance the elasticity, encapsulation, windproof, waterproof and breathability of winter running shoes upper, and enhance the winter running shoes shoe lining to keep warm and deodorize. Reduce the weight and service life of winter running shoes, enhance the strength of winter running shoes shoe body, wear resistance, enhance the wear resistance of winter running shoes outsole, toughness, anti-skid, which can improve the overall performance of winter running shoes. At the same time, graphene and aerogel belong to the environmental protection material, even if the product is scrapped, the recycling value of the waste is high, even if the waste can not be recycled and reused, it can also be directly landfill, which accords with the idea of green design of the product.

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