

Ultra-warm artificial aerogel fibers: a biomimetic material based on polar bear hair

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•Commentary•

Ultra-warm artificial aerogel fibers: a biomimetic material based on polar bear hair

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Aerogels are widely recognized as the premier thermal insulation materials due to their high porosity and exceptionally low thermal conductivity [1, 2]. Regrettably, their widespread application in thermal insulation textiles is significantly limited by their fragility and poor processability. Although many aerogel fibers made with silica [3], graphene [4, 5], carbon nanotube [6], titanium oxide [7], and cellulose [8] have been prepared through various methods, including wet spinning [9], reaction spinning [10], and sol-gel confined transition [11] over the last decade, they still face challenges in strength and flexibility for extensive textile applications. Furthermore, these aerogel fibers struggle in practical use, as they are unable to withstand machine washing and are prone to losing their thermal insulation properties when exposed to water or humid environments. In response, the exploration of biomimetic strategies for the design and manufacture of materials with superior insulation performance and multifunctionality, inspired by animals' specialized hair for cold environment adaptation, has become a significant area of research.

In the recently published article "Biomimetic, knittable aerogel fiber for thermal insulation textile" in *Science* [12], Bai's group drew inspiration from the "core-shell" structure of polar bear hair to develop a polymer-shell-encapsulated aerogel, termed Encapsulated Aerogel Fiber (EAF), boasting enhanced insulation and mechanical properties. Under scanning electron microscopy (SEM), researchers observed the polar bear hair's "core-shell" structure, characterized by a dense outer shell and a porous inner core. This structure enables the core to provide thermal insulation while the shell contributes to mechanical strength and core protection. Ad-

opting this methodology, researchers independently engineered the shell and core components of EAF, effectively decoupling thermal insulation from mechanical functionality to avoid performance compromise. The EAF core, made from a polymer aerogel, blocks heat loss through conduction, convection, and radiation. The shell, crafted from thermoplastic polyurethane (TPU), enhances mechanical strength and elasticity, merging insulation with durability. Textiles made from EAF demonstrated a thermal conductivity of $(26.9 \pm 1.8 \text{ mW/m}\cdot\text{K})$, significantly surpassing that of conventional textiles. Comparative insulation performance evaluations between EAF and down, using infrared (IR) imaging on a heated stage, revealed EAF's thickness to achieve the same warmth was only about one-fifth that of down. Furthermore, when EAF was knitted into sweaters, the surface temperature of a volunteer wearing the EAF sweater and a down jacket in -20°C conditions was measured at 3.5°C and 3.8°C , respectively, demonstrating the superior thermal protective performance of EAF. In addition, EAF can fully recover after being stretched to 1000% strain, showing no change in length or insulation quality—a nearly threefold improvement over traditional aerogel fibers. EAF also boasts excellent washability and dyeability, presenting additional benefits.

In conclusion, this study developed a biomimetic material based on polar bear hair, addressing the longstanding challenges that have hindered the practical application of fragile aerogel in creating strong, thermally insulating textiles. However, the path toward real-life application of aerogel fibers faces several challenges. A primary concern is the development of rapid EAF spinning technology, as there is currently a significant gap between the spinning rate of EAF and that of traditional fibers used industrially. Optimizing the EAF preparation process to narrow this disparity remains a critical area for further research, aiming to broaden its applic-

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ability in practical settings. Additionally, the abundant pores within aerogel fibers present a unique opportunity. Leveraging these pores to integrate medical materials could fulfill specific healthcare requirements, marking a significant stride in medical textiles. In addition, the poor solubility of TPU poses a challenge in enhancing encapsulation efficiency, a factor crucial for the practical application of EAF.

The natural world, with its vast diversity of species, is an invaluable source of biomimetic materials. Effectively exploring, utilizing, upgrading, and transforming these materials, alongside developing advanced biomimetic materials and innovative preparation techniques, represents a crucial research avenue. This approach not only aims to enhance human life and its quality but also offers a viable pathway for the development of green technologies.

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