COMMENTARY

Nature-inspired aerogel fiber

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With the continuous upgrading of science and technology, people's demand for thermal insulation materials is increasing. The advent of advanced insulation materials should not only improve insulation capacity, but also pay attention to environmental protection and sustainability. Since their invention in the 1930s, aerogels are recognized as the best thermal insulation materials.[1] Aerogels are even less dense than air, where air makes up more than 90% of the total volume. The large amount of air encapsulated in aerogels inhibits heat conduction and convection, thereby reducing heat loss. However, aerogels are greatly limited in thermal fabric applications because an ideal garment not only needs to be warm and lightweight, but also needs to be resistant to stretching and washing.[2] Unfortunately, either coating aerogels on the surface of fabrics or spinning directly into fibers containing aerogels cannot simultaneously solve the technical challenges of thermal insulation, lightness, flexibility and durability.[3-4] Therefore, developing

Figure 1. Biomimetic encapsulated aerogel fibers (A) Schematic diagram of thermal insulation principle of polar bear hair. (B) Schematic diagram of thermal insulation principle of EAFs and comparison of corresponding fabric property with traditional down jacket. (C-D) SEM images of polar bear hair and EAFs.[5] Reproduced with permission. Copyright 2023, American Association for the Advancement of Science.

knittable aerogels remains a challenge.

Polar bear hair is composed of a porous core and a dense shell, where hollow core effectively locks in air to ensure excellent thermal insulation, while dense shell provides effective mechanical protection, thus achieving a balance between thermal insulation and mechanical robustness. Inspired by core-shell special structure of polar bear hair, now, writing in Science, Weiwei

Gao, Hao Bai and colleagues[5] developed advanced encapsulated aerogel fibers (EAFs) composed of an aerogel core and a thermoplastic polyurethane (TPU) elastomer shell, realizing functional decoupling of thermal insulation and mechanical robustness (Figure 1). Specifically, aerogel fibers were firstly obtained by freezing spinning. Subsequently, frozen fibers were freeze dried to preserve lamellar porous structure within the fibers. Finally, EAFs with biomimetic core-shell structure were yielded by coating TPU solution on aerogel fibers.

In EAFs, the core is responsible for warmth, and the shell is responsible for toughness and durability, which synergistically solve the long-standing application bottleneck of incompatible thermal insulation and mechanical robustness of aerogel fibers. TPU shell not only provides sufficient mechanical strength to EAFs, but also protects their thermal insulation property without significant sacrifice when they are cyclically stretched. In detail, EAFs can be stretched up to 10 times their length without breaking, and their elongation is nearly 3 orders of magnitude higher than that of conventional aerogel fibers.

Interestingly, thanks to the robust TPU layer that ensures fiber integrity, EAFs maintains stable thermal insulation after 10,000 cyclic stretching at 100% strain. The sufficient strength and flexibility make EAFs suitable for knitting and weaving into textiles. Resultantly, the thermal conductivity (26.9±1.8 mW/m·K) of sweaters made of EAFs is much lower than that of nylon (91.2±1.6 mW/m·K), polyethylene terephthalate (98.3±1.9 mW/m·K) and wool (38.9±1.1 mW/m·K) textiles. A thin sweater knitted with EAFs is only around one-fifth the thickness of down jackets when equally insulated. Additionally, this EAFs-knitted thin sweater also exhibits excellent washability and dyeability without significantly impairing its warmth, which is essential for scale-up. Further, the authors also used an industrial rapier loom to weave EAFs into 40 cm × 25 cm textiles, reflecting the potential of EAFs to produce scalable textiles with excellent thermal insulation and mechanical robustness.

To sum up, advanced biomimetic encapsulated aerogel fibers solve the long-standing application bottleneck of incompatible thermal insulation and mechanical robustness of aerogel fibers. EAFs are able to cope with heat radiation, heat convection, and heat transfer in a multi-pronged manner, thus boosting thermal insulation capacity by a big step. If the industrialization process can be scaled up and costs reduced as quickly as possible, these major breakthroughs are expected to enable us to get rid of bloated down jackets in the near future, braving extreme cold environments like polar bears and upgrading the quality of life.

REFERENCES

1. Feng, J., Su, B.-L., Xia, H., et al. (2021). Printed aerogels: Chemistry, processing, and applications. Chem. Soc. Rev. **50**: 3842–3888. DOI: 10.1039/C9CS00757A.
2. Sheng, Z. and Zhang, X. (2023). Mimicking polar bear hairs in aerogel fibers. Science **382**: 1358–1359. DOI: 10.1126/science.adm8388.
3. Wu, J., Zhang, M., Su, M., et al. (2022). Robust and flexible multimaterial aerogel fabric toward outdoor passive heating. Adv. Fiber. Mater. **4**: 1545–1555. DOI: 10.1007/s42765-022-00188-x.
4. Li, G., Hong, G., Dong, D., et al. (2018). Multiresponsive graphene-aerogel-directed phase-change smart fibers. Adv. Mater. **30**: 1801754. DOI: 10.1002/adma.201801754.
5. Wu, M., Shao, Z., Zhao, N., et al. (2023). Biomimetic, knittable aerogel fiber for thermal insulation textile. Science **382**: 1379–1383. DOI: 10.1126/science.adj8013.

DECLARATION OF INTERESTS

The author declares no competing interests.