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VIEWS AND NEWS

Making Passive Daytime Radiative Cooling Metafabrics on a Large Scale

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Abstract
Cooling is pervasive in modern society and contributes significantly to global energy use. A hierarchical-morphology metafabric has been recently reported to show efficient passive daytime radiative cooling ability and may be also easily scaled up by industrial textile manufacturing technology. The above study represents an important advance in personal thermal management through the use of intelligent garments.

Temperature plays a vital role on Earth. Shifting the temperature a few degrees can disrupt the ecosystem, and even kill some organisms. However, the global annual temperature has obviously been increased since the Industrial Revolution. Moreover, the rate of increase has showed a growing trend. Global warming has already harmed weather patterns and ecosystem. Body temperature is crucial for human health, which must be maintained within a very narrow range so that the body function can be normally performed. Hence, cooling plays a key role in human life, especially for the outdoor work under the impact of global warming. Unfortunately, traditional cooling technologies, such as air conditioner, consume a lot of energy, which usually brings carbon footprint.

Personal thermal management, a technology that regulates the microclimate of the human body to realize individuals for thermal comfort [1]. Radiative cooling, as an attractive cooling technology, radiates heat to the cold outer space via the atmospheric transparent spectral window [2]. It is energy-free and eco-friendly. Cloth, an interface between human body and ambient, plays a vital role in thermal exchange between body and surroundings. Undoubtedly, integration of radiative cooling technology into cloth is a promising method for its practical applications.

Writing in *Science*, Guangming Tao, Yaoguang Ma and their collaborators report a hierarchical-morphology metafabric with passive daytime radiative cooling function, which is easy for large-scale production by advanced textile technology [3]. The hierarchical-morphology system in metafabric is reflected in a spatial structure of fabrics, single fiber structure, and inner nanostructure of fibers. Thanks to the hierarchical-morphology system with macroscopic order and microscopic randomness, a broad spectrum of ultraviolet, visible-near infrared and middle infrared bands can be accurately regulated (Fig. 1a). The metafabric showed a double layer structure, in which a thin polytetrafluoroethylene (PTFE) clothing film was laminated onto a piece of titanium oxide-polylactic acid (TiO_2-PLA) composite woven metatextile. The fabrication process includes four steps: (1) melt spinning of TiO_2-PLA metafibers; (2) twisting of metafibers to form yarns; (3) weaving of yarns; (4) lamination of PTFE film onto metatextiles to form metafabrics (Fig. 1b).

The researchers tested the outdoor radiative cooling performance of metafabrics via thermal measurement under clear sky conditions. The temperatures of metafabric were 5.0, 5.8, 6.8, 7.0 and 10.2 °C lower than those of cotton, linen, spandex, chiffon and bare skin simulators, respectively. Importantly, the metafabric shows efficient cooling results in practical application scenes. For example, the researchers designed a vest by sewing a metafabric and a commercial cotton fabric together. A volunteer wearing this special vest reclined under direct sunlight while temperatures of the vest and the volunteer were recorded for

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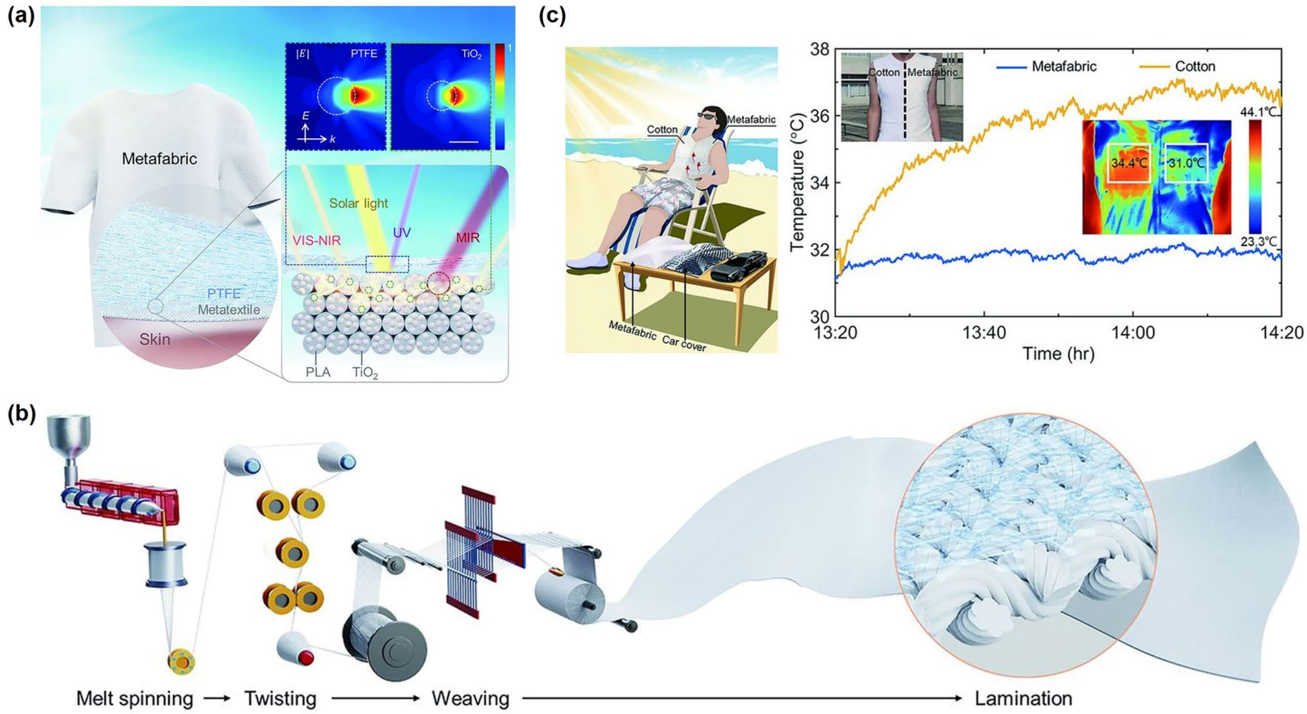

Fig. 1 **a** Schematic of the hierarchical-morphology metafabric for daytime radiative cooling. Dashed boxes in different colours (blue, green and red) highlight the three-level hierarchical structure in response to ultraviolet (UV), visible-near infrared (VIS–NIR) and middle infrared (MIR) bands. The insets show the calculated scattering fields of 300 nm and 550 nm light by PTFE particles (500 nm in diameter) and TiO_2 particles (400 nm in diameter). Scale bar, 400 nm. **b** Fabrication process of the metafabric. **c** Schematic of the fabric cooling test on human body and model cars (left) and recording of temperature of skin under metafabric and cotton in direct sunlight (right)

comparison (Fig. 1c). There was a large difference in temperature between two sides of the vest (34.4 and 31.0 °C). Temperature difference between the parts of body covered by different fabrics (metafabric and cotton fabric) is approximately 4.8 °C. In addition, the metafabrics also showed superior cooling performance in other application scenarios, i.e., as a vehicle cover. In addition to superior radiative cooling performance, this novel metafabric is green, breathable, washable, waterproof, and low-cost.

The hierarchical-morphology metafabric may arouse more researchers to study radiative cooling clothes. Nevertheless, there is still plenty of room for further improvement. For example, the color-compatible radiative cooling system is necessary for daily clothing. In short, this study provides a new avenue for personal thermal management.

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Declarations

Conflict of interest The authors declare no conflicts of interest

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