Enhancing Personal Thermal Comfort: Radiative Cooling Smart Textiles for Efficient Thermal Management

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Abstract: Smart textiles with passive radiative cooling (PRC) characteristics possess the ability to reflect sunlight and dissipate heat to the outdoor environment without requiring additional power input. The development of smart cooling textiles with enhanced performance, cost-effective production technology, and scalable manufacturing has garnered significant attention. In this study, we present the development of a PRC smart textile using state-of-the-art electrospinning technology. Firstly, the polyacrylonitrile (PAN) concentrations were optimized, followed by the incorporation of alumina nanoparticles (NPs) into the spinning solutions. Our results demonstrate that the addition of alumina NPs during the electrospinning process significantly improves the solar reflectivity of the optimized PAN from 93% to 97%. Furthermore, the developed smart textiles exhibit a remarkable midinfrared (MIR) emissivity of 95% with 8 to 13 μm wavelength. The results unequivocally indicate that smart textile has the capability to effectively mitigate heat stress of the human body across a wide range of scenarios. This substantiates its potential to significantly enhance the cooling effect, thereby validating its feasibility for widespread implementation on a global scale. With exceptional optical and cooling characteristics, as well as favorable mechanical and wearable features, the developed PRC textile shows great potential for commercial applications and contributes to a sustainable economy.

Keywords: *Sustainable manufacturing, cooling, smart textiles, personal thermal management, optical characteristics, nanofabric.*

Background: The desire to enhance personal thermal comfort has led to the development of smart fabrics incorporating PRC properties. These fabrics possess unique capabilities to reflect sunlight and disperse heat to the surrounding environment without requiring additional power input. The scientific community has shown significant interest in advancing intelligent cooling fabrics, focusing on improving performance, cost-efficiency, and manufacturability [1, 2]. This work specifically aims to create a PRC smart clothing material using advanced electrospinning technology (Figure 1a-c). The physical photographs of the developed smart clothing material is shown in Figure 1a, morphological image in Figure 1b, and a field test set up in Figure 1c (entailing bare skin, commercial textile, and the developed electrospun clothing). Notably, remarkable results were achieved by optimizing the concentrations of PAN and introducing alumina nanoparticles into the spinning solutions. The incorporation of alumina NPs during electrospinning significantly enhanced the solar reflectance of the optimized PAN material. Moreover, the developed smart fabrics exhibited impressive MIR emissivity of 95% within the wavelength range of 8 to 13 μm. These findings unequivocally demonstrate the fabric's ability to effectively reduce heat stress in various scenarios, underscoring its potential for widespread global use. With exceptional optical and cooling properties, as well as desirable mechanical and wearable attributes, the created PRC textile holds great promise for commercial applications and contributes to the establishment of a sustainable economy.

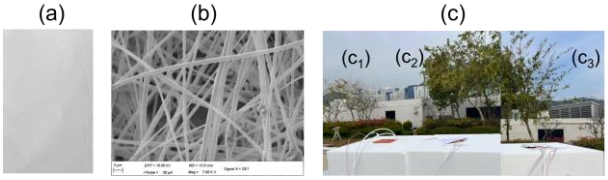

Figure 1: Radiative cooling smart textiles: (a) physical photograph, (b) morphological photograph, and (c) field test set up: (c_1) dummy bare skin, (c_2) commercial textile, and (c_1) developed smart textiles.

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