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Polymer Nanocomposites for Lowering Heating and Cooling Loads in Buildings

Chaired by PROF. DR. ANTONIO PIZZI and PROF. DR. FRANK WIESBROCK
polymers MDPI

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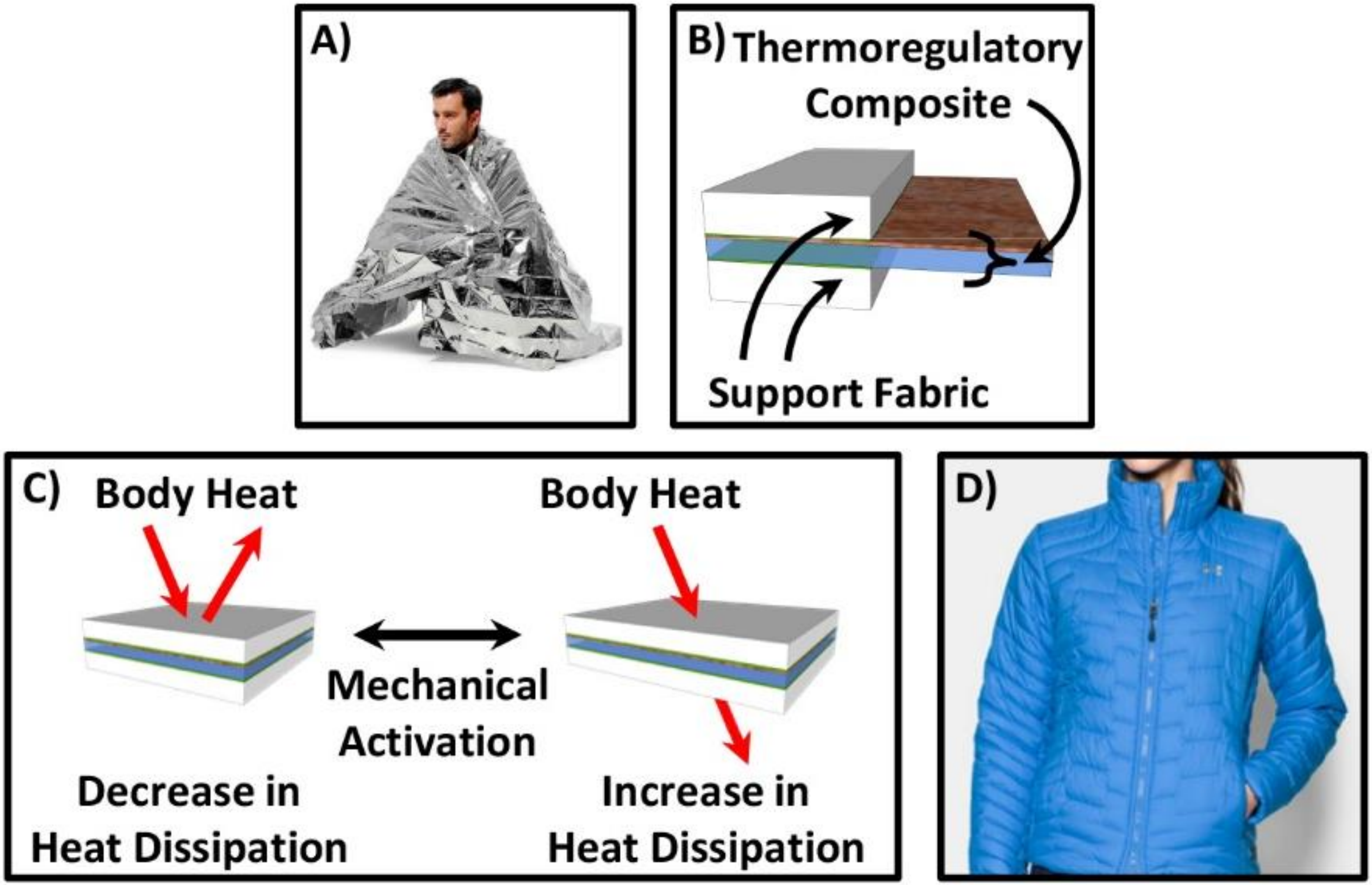
Abstract:
Worldwide, buildings consume over 40% of the total commercial energy, and 36% of this amount is dedicated to heating and cooling of buildings. Therefore, building environment control systems require efficient thermal management (Ürge-Vorsatz et al., 2015). An ideal thermal management that could lower the energy load for cooling and heating respectively would combine passive strategies for thermal control, which are characterized by low cost, straightforward implementation, and energy efficiency, with the on-demand control of heating and cooling, specific for active thermal management strategies.

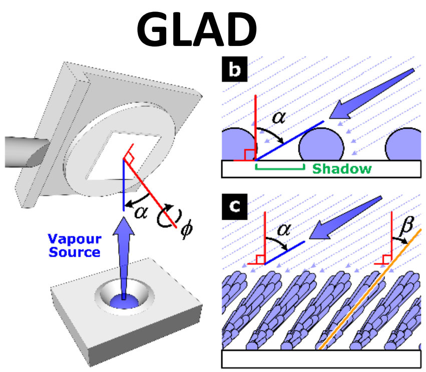
The scientific challenge of building an efficient platform for thermal control was addressed by using block copolymer materials in the development of nanocomposites with dynamically tunable thermal infrared properties. The polymer nanocomposites manage 60-70 % of the metabolic heat flux from sedentary individuals and can modulate changes in the individual body temperature within a setpoint temperature range of 8 °C. This increase in the setpoint temperature translates into use of air conditio cooling/heating with a significantly lowered load, which would translate into a 4.3 % decrease of global energy consumption.

Keywords: nanocomposite; polymer; thermal comfort; infrared radiation

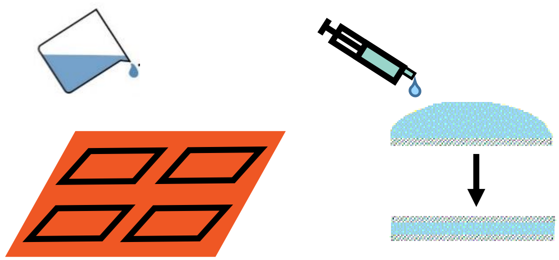
Activation Mechanism of Nanocomposite



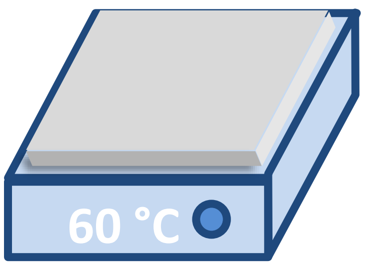
Steps for Preparation and Testing of Nanocomposite Material



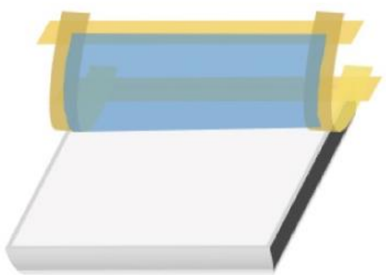
Deposition of Metal Layer



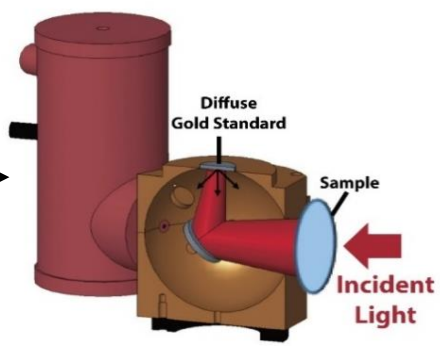
Deposition of Thin Polymer Film



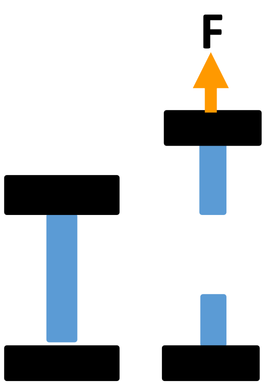
Film Aging



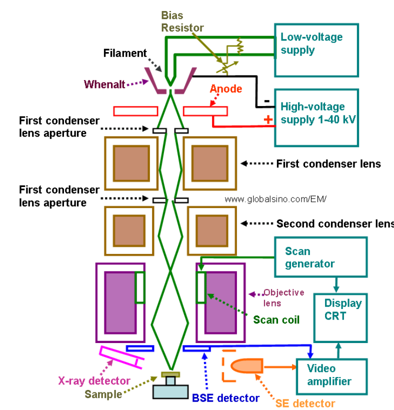
Delamination from Substrate



FTIR Spectroscopy



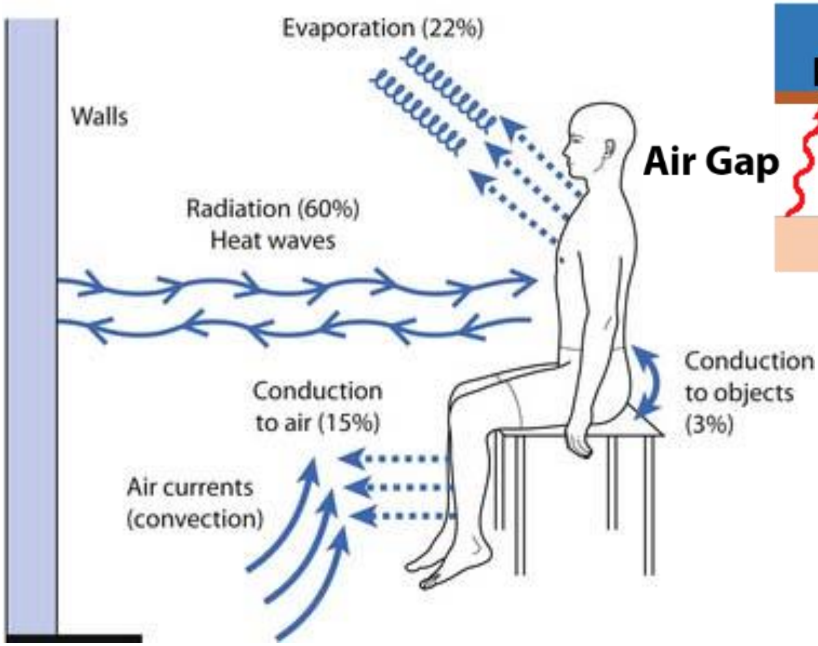
Mechanical Analysis

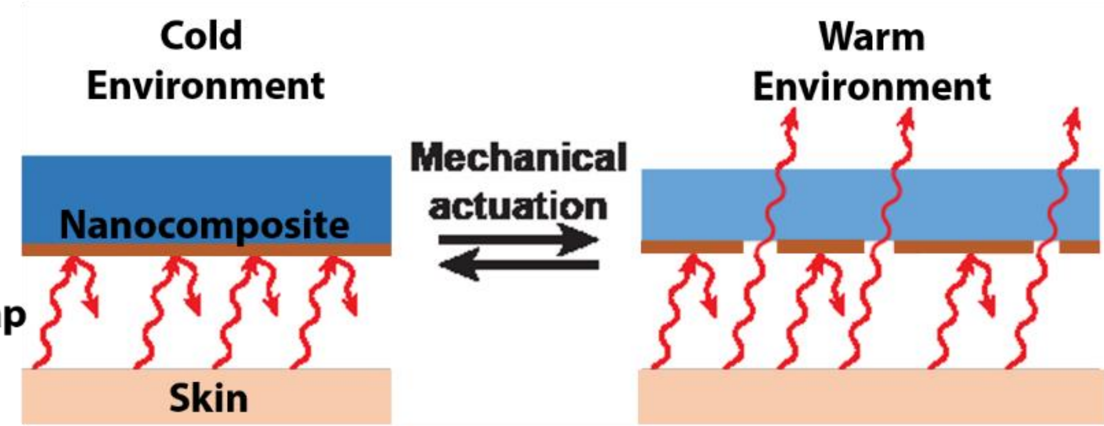


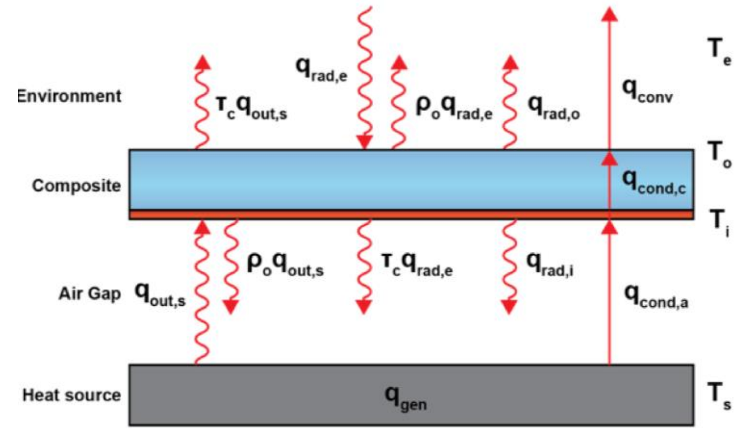
SEM Analysis

Thermoregulating Mechanism for Mechanically Actuated Nanocomposites

Mechanisms for Heat Exchange with the Environment







Michelle Tannam, Human Thermoregulatory Response to Infrared Radiant Heating, Ph.D. Dissertation, Department of Mechanical and Manufacturing Engineering, Trinity College Dublin, 2012.

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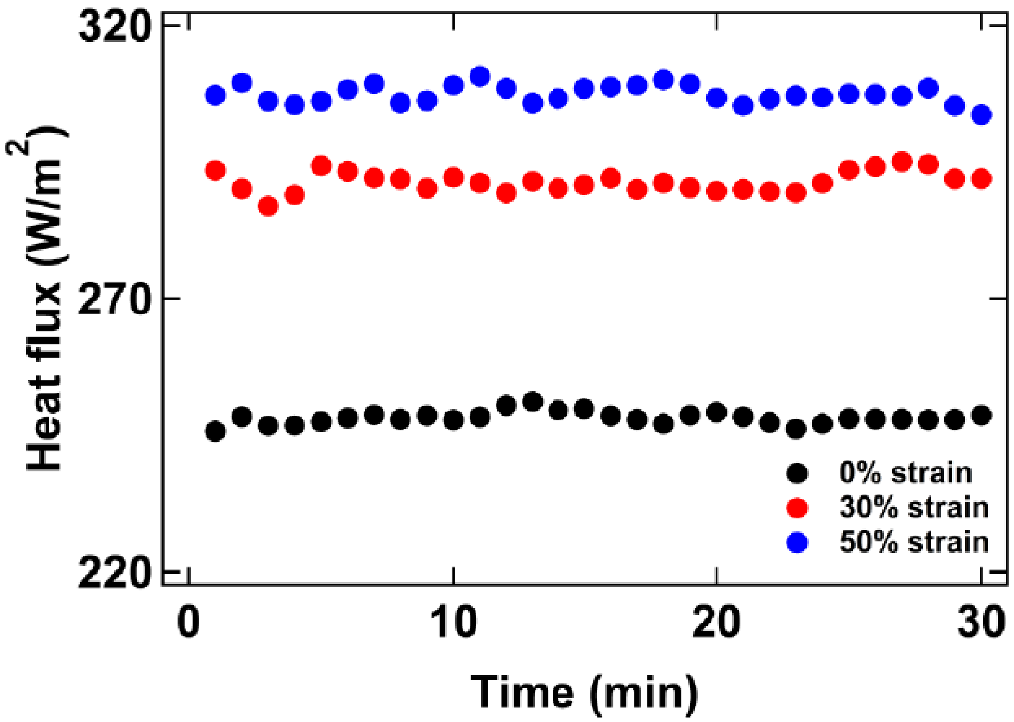
Dynamic Control of Thermal Flux Emitted by Human Skin

Heat Flow Regulation Using Mechanical Actuation of Nanocomposites



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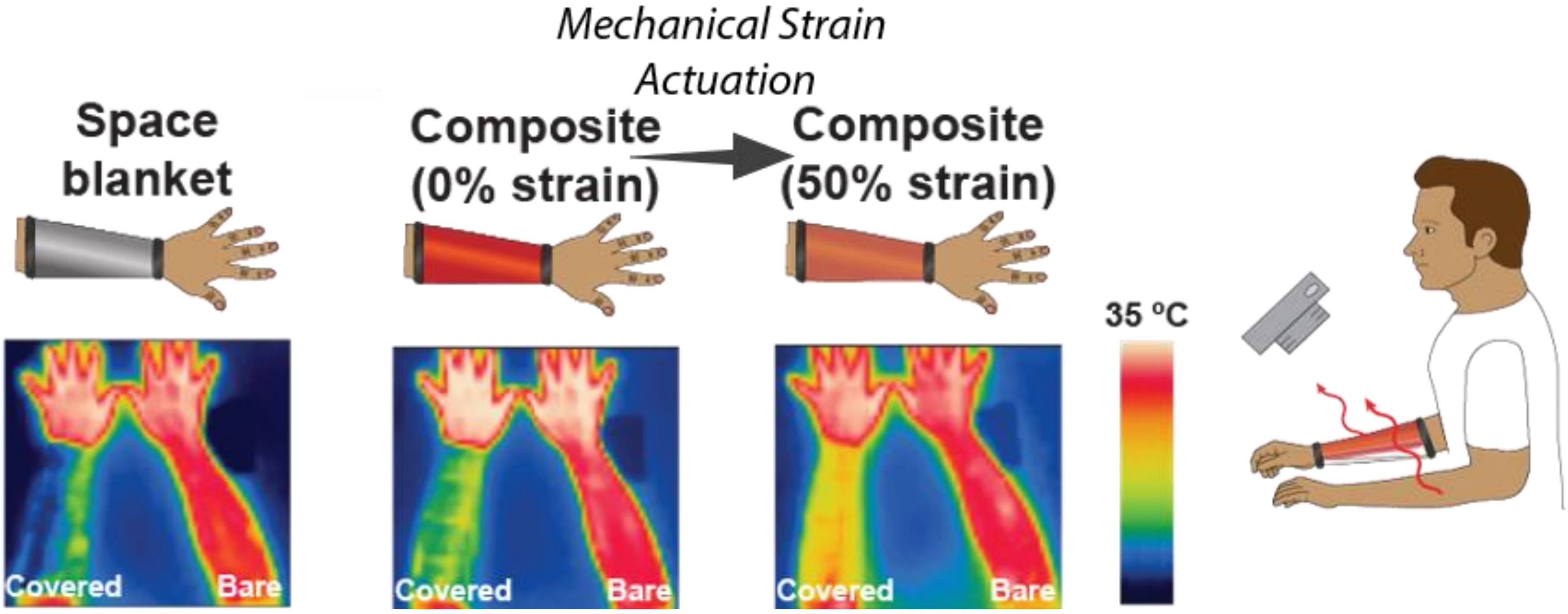
Comparison for Setpoint Temperature for Different Textile Materials



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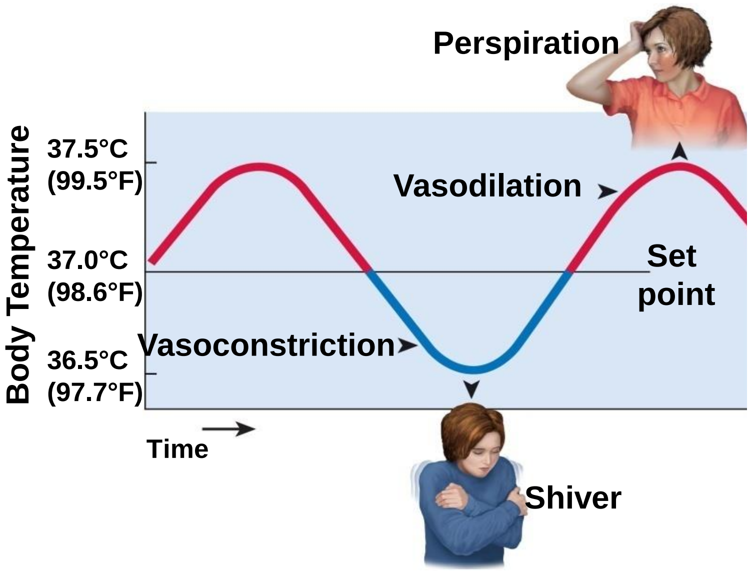
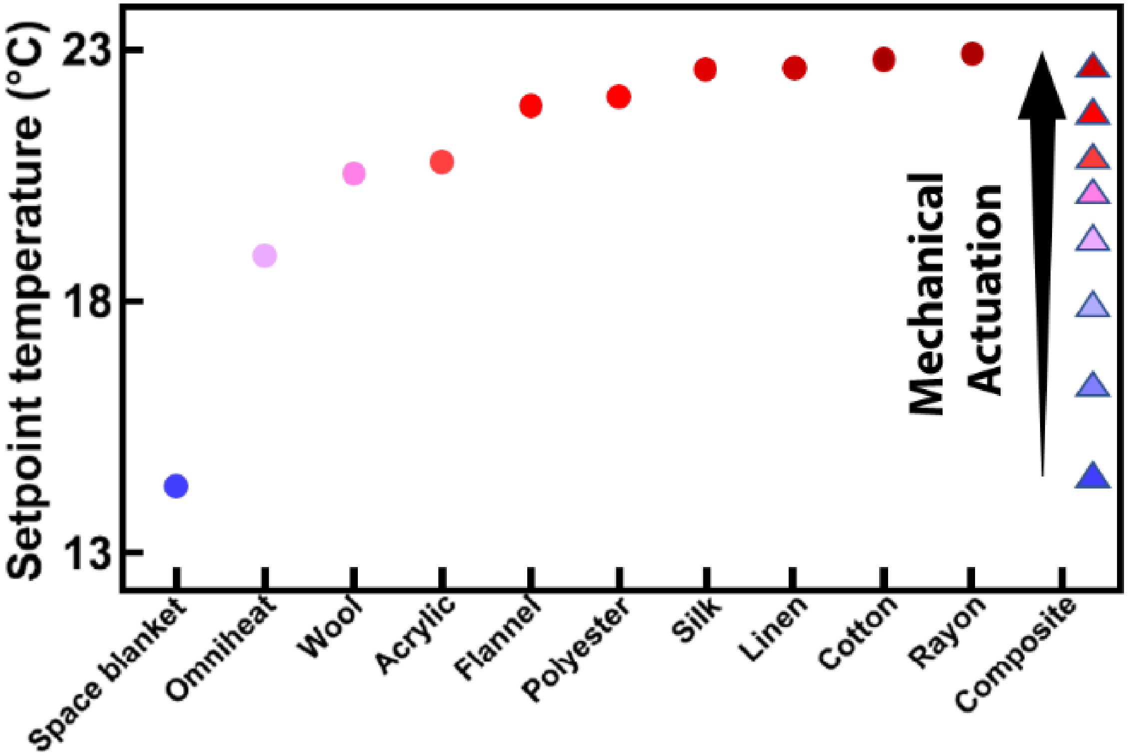
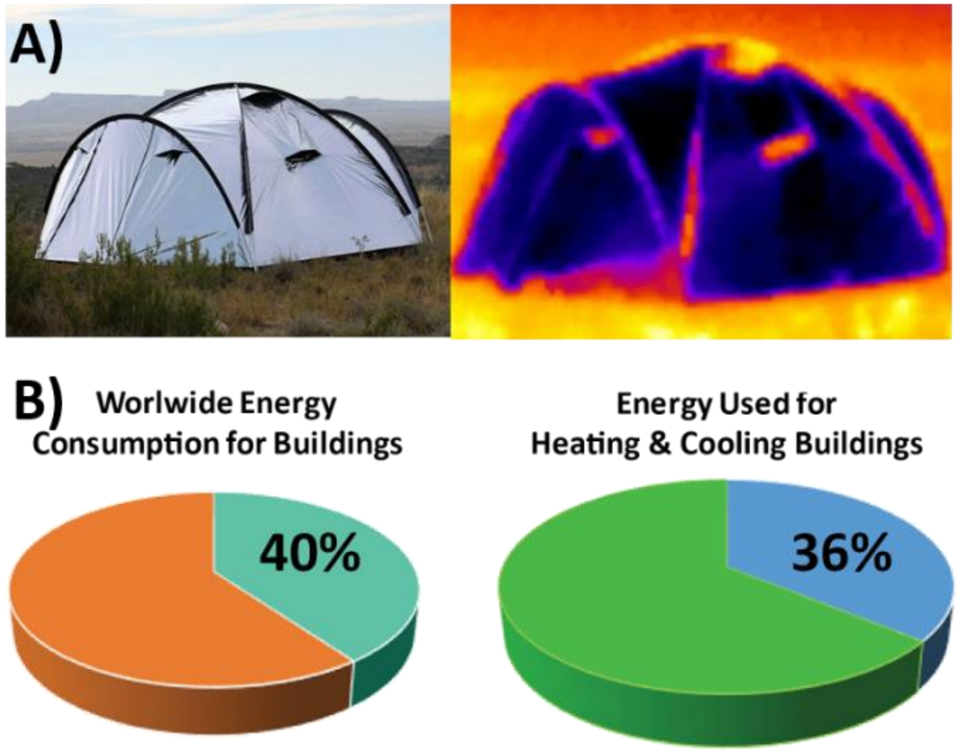




Leung, E. M., *et al.*, A Dynamic Thermoregulatory Material Inspired by Squid Skin, *Nat. Commun.*, 2019, 10, 1947

Potential for Global Energy Savings



Setpoint temperature from 22 °C to 16 °C (6 °C difference)

Reduction in global energy consumption: $\underbrace{0.30}_{1.} * \underbrace{0.36}_{2.} * \underbrace{0.40}_{3.} = 4.3\%$.

1. Reduction in energy consumed by buildings due to change in setpoint temperature
2. Energy used for heating and cooling buildings
3. Worlwide energy consumption in buildings

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Conclusions

The nanocomposite function via a unique mechanism that relies on reversible and mechanically-actuated changes in surface microstructure.

Such materials change their reflectance and transmittance in the infrared region of the electromagnetic spectrum and their thermoregulatory properties resemble those of common materials, such as the space blanket, fleece lining, wool, and cotton.

The nanocomposite behaves like radiative thermal switch with easy mechanical actuation method without hysteresis and can regulate skin temperature changes for consumers in real time.

The nanocomposites can be manufactured from low-cost commercially available starting materials using scalable processes.

The use of nanocomposite can lower the global energy use by up to 4.3%.

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