Janus-yarn based dual-mode textile for radiative heat regulation

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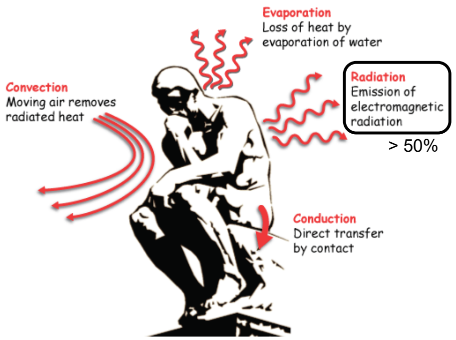
Abbreviated abstract: Radiative heat management for personal comfort using photonic engineered textiles can provide a substantial advantage for an energy-efficient and sustainable society. We propose a Janus-yarn design approach for a dual-mode, double-sided thermoregulating fabric: a passive radiative management textile using asymmetric yarn composition, leading to dual emissivity characteristics. The fabric provides both passive cooling and heating functions by wearing the textile inside-out. A tailored combination of reflective and absorptive structures leads to a substantial emissivity asymmetry between the two surfaces of the fabric.

Related publications:
[1]. M. G. Abebe *et al*, Dynamic thermal regulating textiles with metallic fibers based on a switchable transmittance, Physical Review Applied (14), 044030 (2020)
[2]. M. G. Abebe *et al*, Janus-yarn fabric for dual-mode radiative heat management, Physical Review Applied, accepted (2021)

Previous work, challenge, and approach

Heat loss in stationary situation



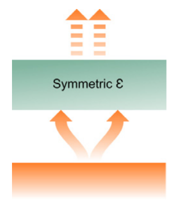
Comfort
Heat loss = Metabolic heat generation

Heat transfer regulation

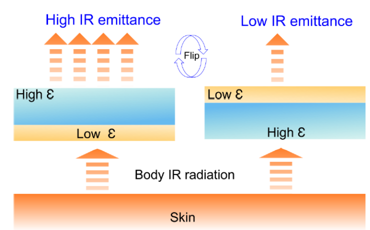
Design working principle

Traditional textile

One mode:
heating or cooling



Janus-yarn textile



One Mode
- Heating or cooling.
- Mainly controls thermal conduction.

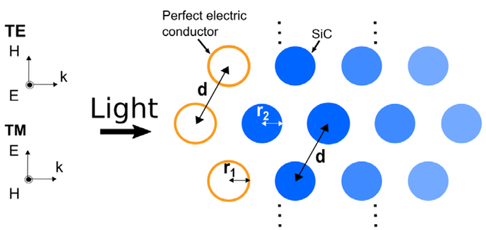
Cooling mode (hot)
- Dielectric fibers face the outside.
- High IR emissivity in human skin emission wavelength range.

Heating mode (cold)
- Metallic fibers face the outside.
- Low IR emissivity in human skin emission wavelength range.

Techniques and Methods

Electromagnetic modeling

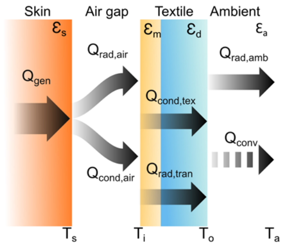
Simulated geometry



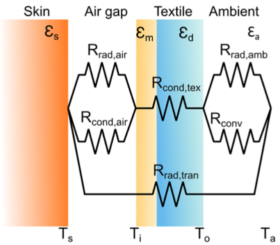
- Finite Element modeling is used for numerical simulation to investigate the radiative properties of the design.
- Simulations are conducted for incident light polarized parallel and perpendicular to the fiber axis at normal incidence.

Thermal modeling

Heat transfer contributions



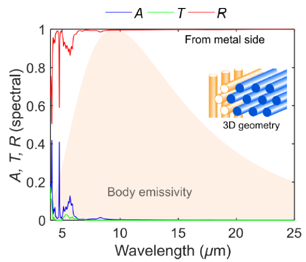
Thermal circuit model

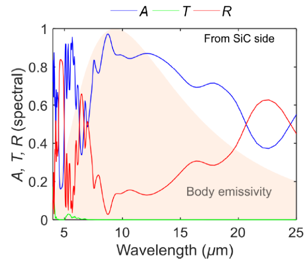


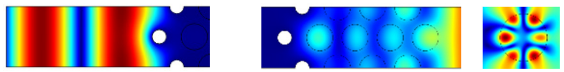
- The equality between heat generation and total heat loss defines thermal comfort.
- By controlling emissivity of outer fabric surface, a different net radiative heat transfer can be achieved.
- Thermal circuit model is used to calculate the ambient setpoint temperature.

Results and Conclusions

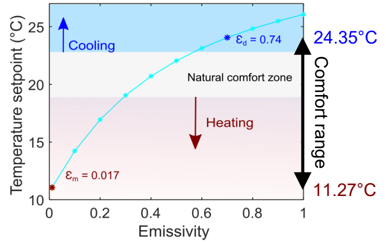
Large emissivity contrast of ~0.7 between metal and dielectric surfaces







Wide setpoint range



The textile user is comfortable between the lowest setpoint temperature of 11.27 °C and the highest setpoint temperature of 24.35 °C.

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