Janus-yarn based dual-mode fabric for radiative heat management

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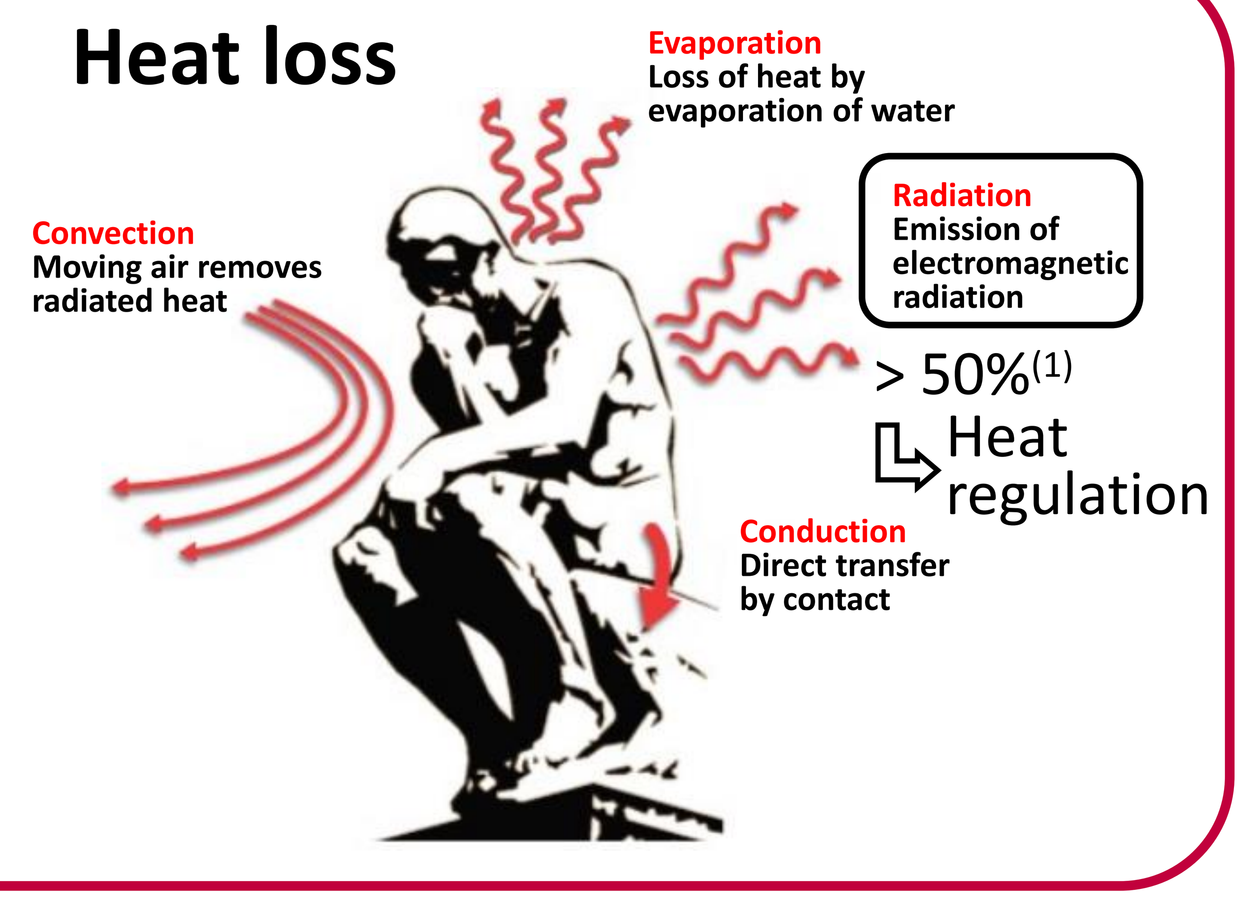
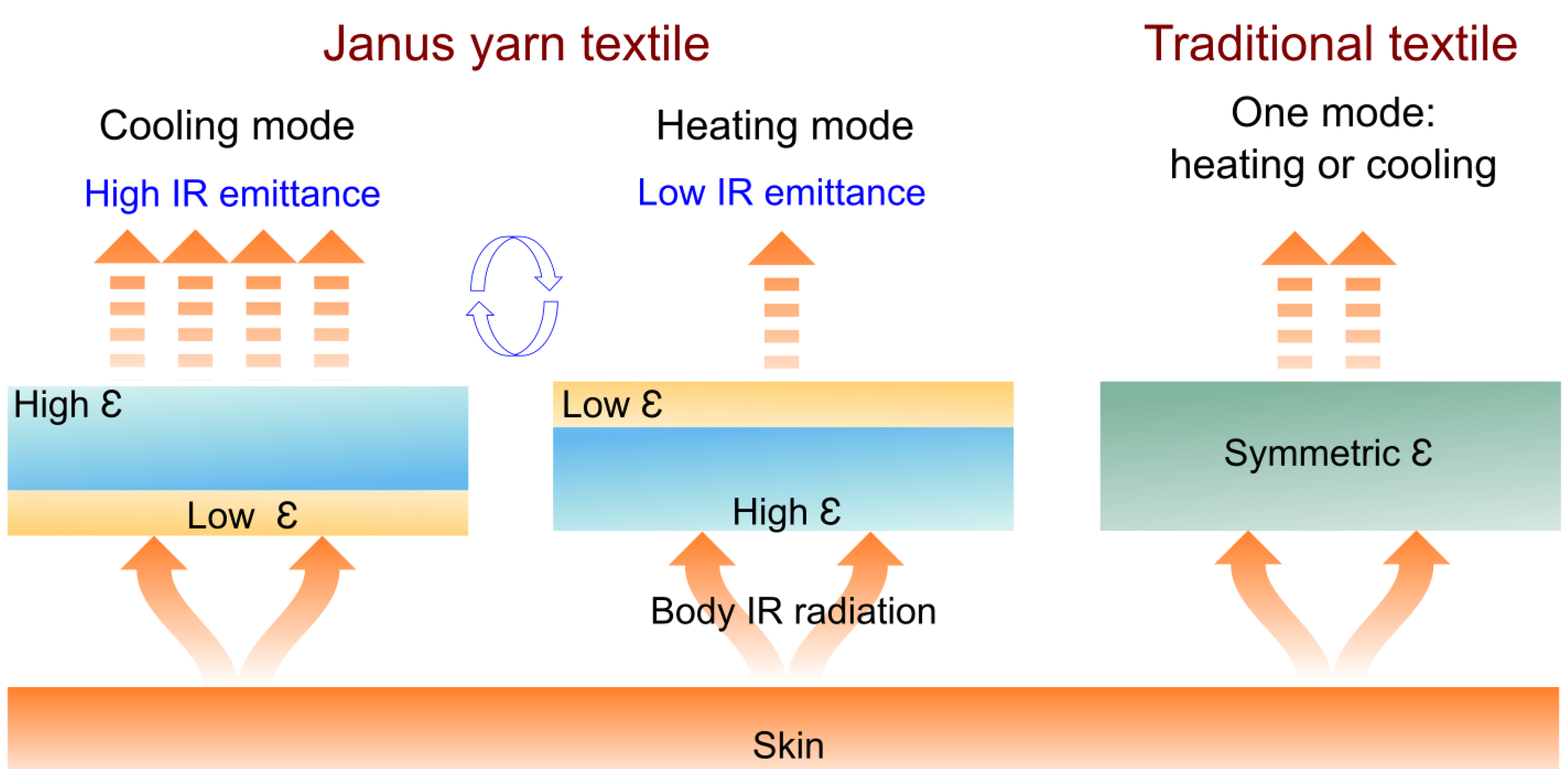
Personal radiative heat regulation by photonic engineered textiles can help contribute to a more sustainable cooling and heating energy consumption in buildings by expanding the range of comfortable ambient conditions. Here, we propose a **Janus-yarn structure for a dual-mode thermoregulating textile** that provides both passive cooling and heating functions by flipping. Using metallic and dielectric fibers within the yarn creates a strong emissivity contrast, benefitting from a plasmonic gap on the one hand, and Fabry-Perot and multipole localized modes on the other hand. By tailoring the yarn structure, an emissivity contrast Δε = 0.72 was achieved resulting in a significant 13.1°C setpoint temperature window, with the wearer staying comfortable between 11.3 and 24.4°C.

Heat loss

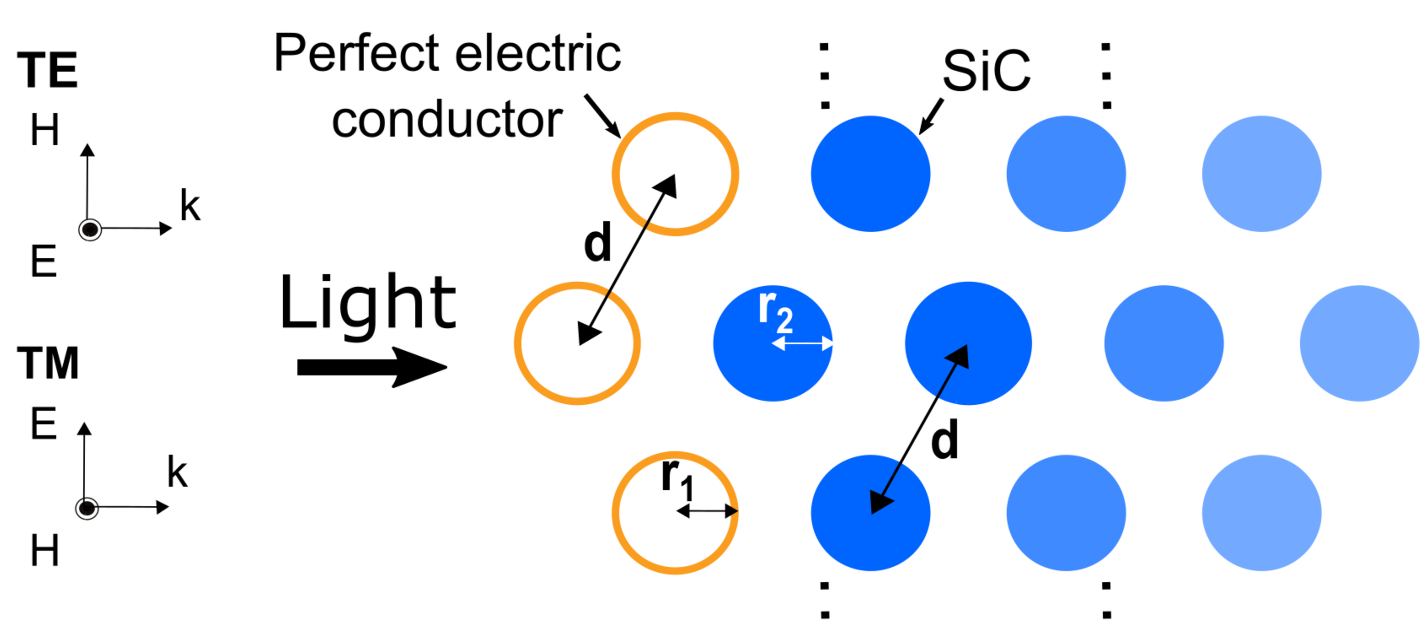


Design principle



Dielectric fibers on one side, metallic fibers on the other side
⇒ High or low IR emittance ⇒ Two heat transfer modes.

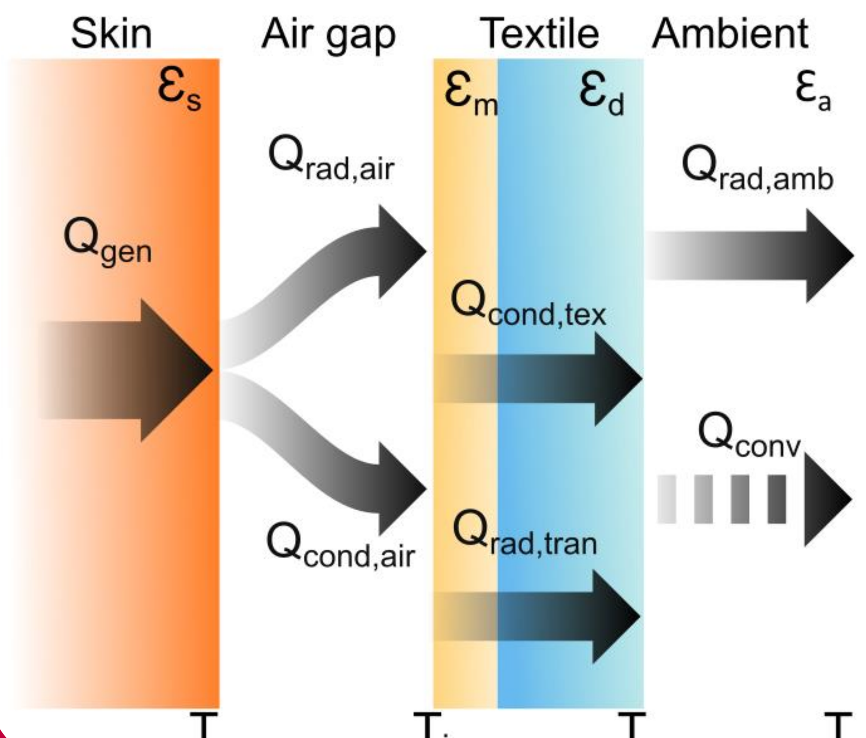
Electromagnetic modelling



- Finite Element modelling is used to investigate the radiative properties of the design.
- Results for TE and TM polarized light are averaged to get unpolarized properties.

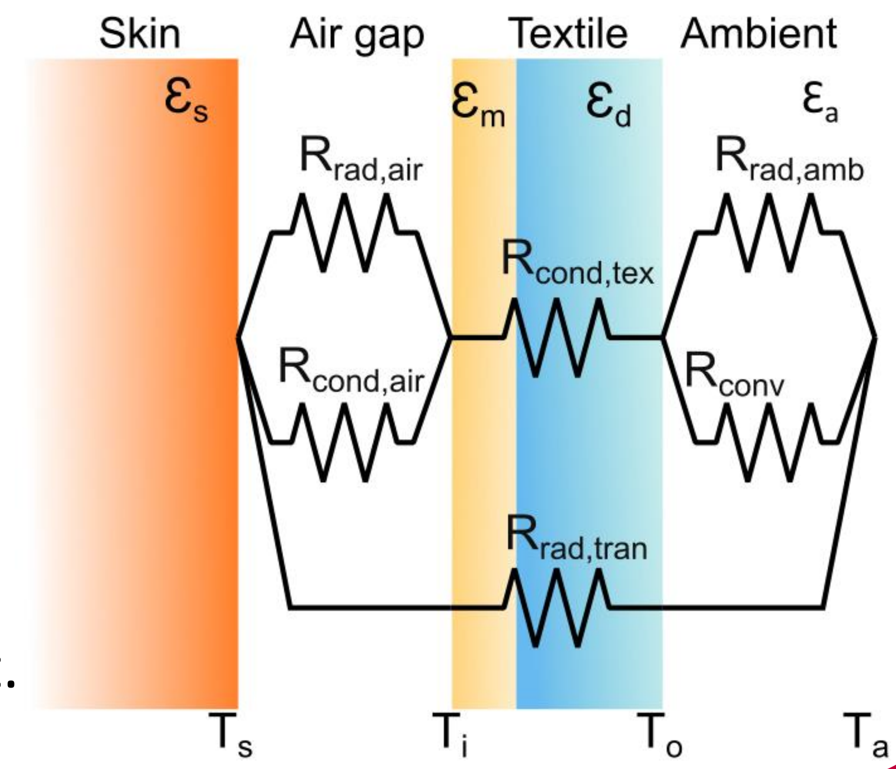
Thermal modelling

Heat transfer contributions

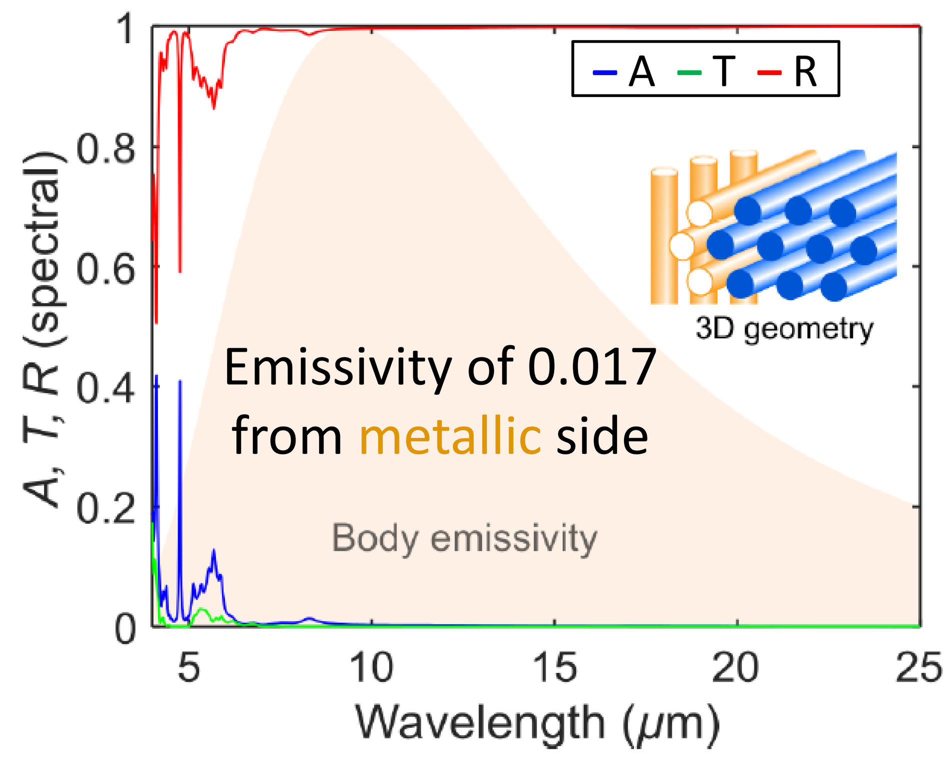


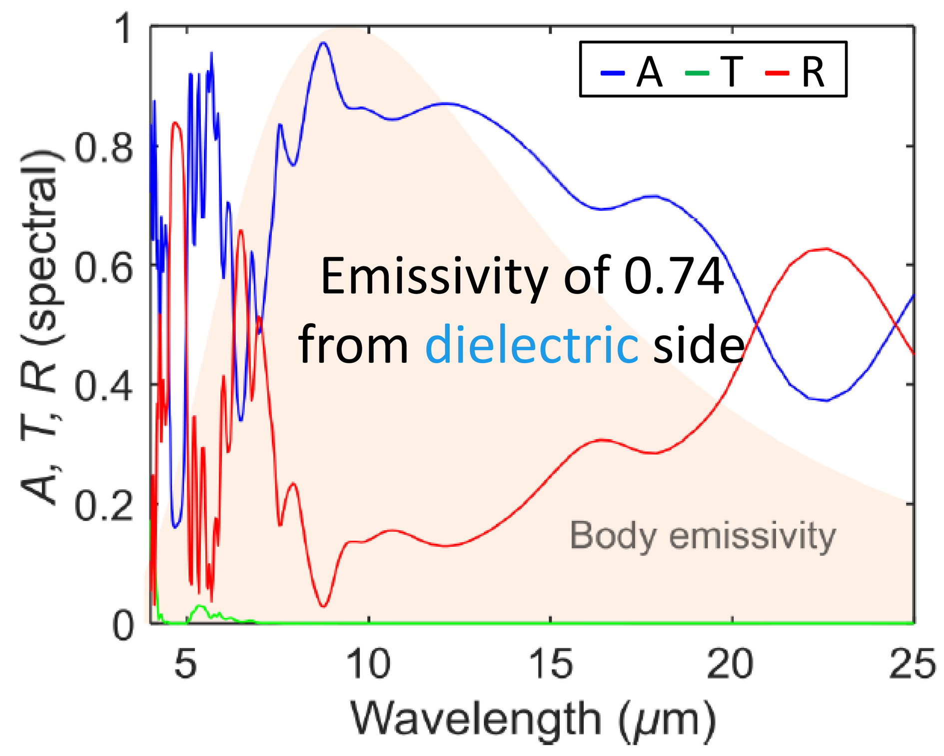
- Thermal comfort is defined as the equality between heat generation and total heat loss.
- By controlling the emissivity of the outer fabric surface, a different net radiative heat transfer can be achieved.
- For both modes, a thermal circuit model is used to calculate the ambient temperature that ensures comfort.

Thermal circuit model

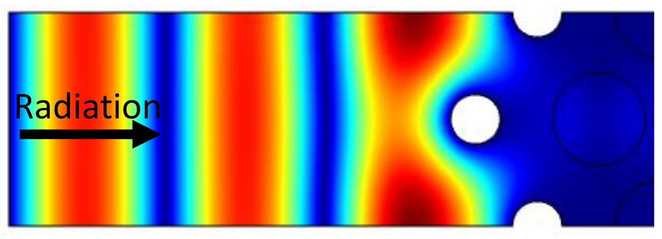


Radiative behaviour

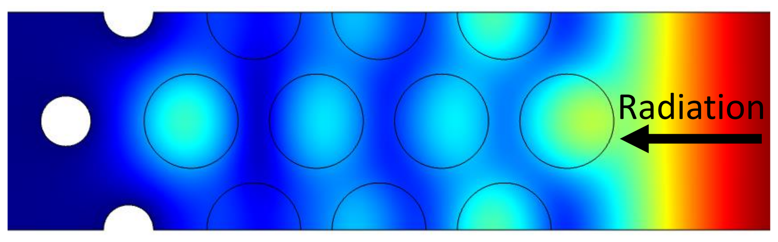




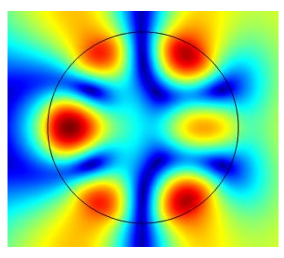
Large emissivity contrast ($\Delta\varepsilon = 0.72$) due to photonic resonances:



Plasmonic gap

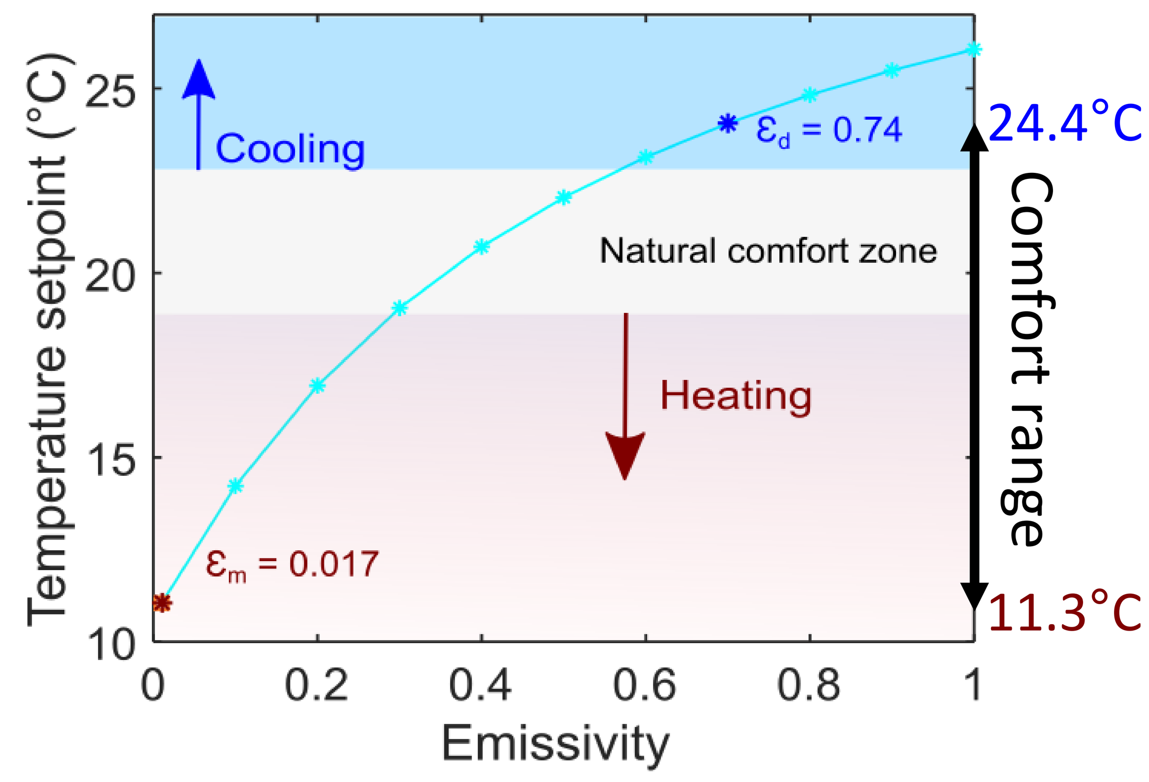


Fabry-Pérot mode



Multipole

Thermal results



The textile user is comfortable between ambient temperatures of 11.3 °C (heating mode) and 24.4°C (cooling mode):

Vast comfort range of 13.1°C.

(1) J. D. Hardy and E. F. DuBois, "Regulation of heat loss from the human body", Proceedings of the National Academy of Sciences of the United States of America 23, 624, 1937.
(2) M. G. Abebe, A. De Corte, G. Rosolen, and B. Maes, "Janus-yarn fabric for dual-mode radiative heat management", Phys. Rev. Applied, Accepted Sept. 2021.

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