ABSORPTION OF PHOTONIC CRYSTAL TEXTILE IN THE MID INFRARED FOR THERMOREGULATION

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ABSTRACT

A large part of the building energy consumption is attributed to temperature control using Heating, Ventilation and Air Conditioning (HVAC) systems. A decrease in this consumption, even slightly, will contribute to both environmental protection and costs saving. Toward this end, personal thermoregulation properties have been recently developed for the majority of people who spend their time in a sedentary state [1, 2]. Therefore, a tremendous effort is necessary to develop smart wearable thermoregulating textiles which can respond to the immediate temperature feeling of the wearer.

We theoretically investigate the effect of absorbance of a photonic membrane of low refractive index on the human body emission at 34°C in the MIR range. The photonic membrane, embedded in air, is made of Benzocyclobutene (BCB) and drilled following a triangular array of holes. We took into consideration the absorption of the BCB by using its complex refractive index. All numerical results have been performed with the help of the Finite Element Method (FEM).

We showed that the reflection and the transmission coefficients depend on the geometrical parameters of the membrane and found the occurrence of three peaks of reflection whose origin is due to the structuring of the membrane. One origin is due to the photonic guided modes inside the membrane, the second one comes from the local excitation of the electromagnetic field inside the air holes. The dependence of the geometrical parameters has been quantitatively highlighted through the definition of an efficiency coefficient. We found that, depending on the geometrical parameters, the BCB membrane can absorb up to 80% of the emission of the human body emissivity in the wavelength range [7.5, 11.5] µm. We are currently studying the effect of the physical parameters considering the behavior of the refractive index of both the membrane and the environment on the absorption rate. The estimation of the temperature of the membrane under the absorption modulation of the membrane is also under consideration, following the thermal balance calculation. This work paves the way for the design of a smart responsive photonic membrane. Integrated to a textile, such a membrane can greatly mitigate the energy demand for indoor heating and ultimately contributes to the relief of the climate issues.

[1] J. K. Tong, X. Huang, S. V. Boriskina, J. Loomis, Y. Xu, and G. Chen, "Infrared-Transparent Visible-Opaque Fabrics for Wearable Personal Thermal Management," ACS Photonics, vol. 2, no. 6, pp. 769–778, Jun. 2015.

[2] P.-C. Hsu et al., "Personal Thermal Management by Metallic Nanowire-Coated Textile," Nano Lett., vol. 15, no. 1, pp. 365–371, Jan. 2015.