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Transformation thermotics and the manipulation of thermal energy

Xiangfan Xu[1,2]* and Baowen Li[1,2]

[1] Center for Phononics and Thermal Energy, School of Physics Science and Engineering, Tongji University, Shanghai 200092, China; [2] China-EU Joint Lab for Nanophononics, School of Physics Science and Engineering, Tongji University, Shanghai 200092, China

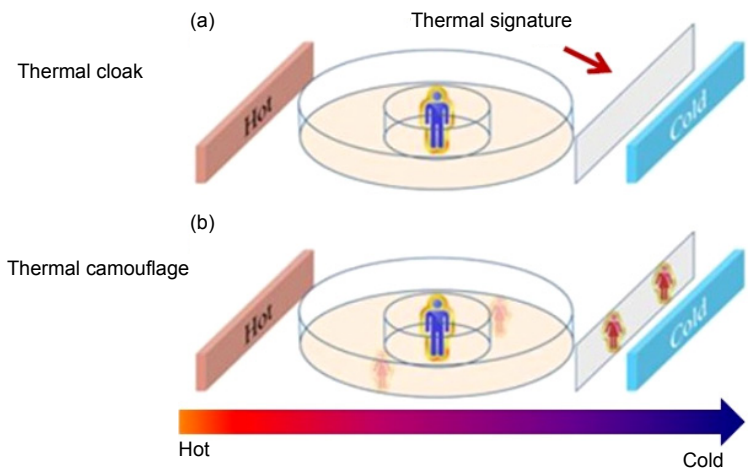

Illustration of thermal cloak (a) and thermal camouflage (b). Figures reprinted from reference [*Adv. Mater*, 2014, **26**: 1731–1734].

Abstract: Thermal energy has been proposed to have ever greater potential for human beings if the heat carriers, phonons can be controlled in micron-scale as easy as its counterpart, electrons in solid. However, it is a challenge to control phonons due to its relatively short wavelength, which is in the order of a few nanometers to a few tens of nanometers. Alternatively, in macroscopical scale, functional thermal materials are used to control thermal energy. The transformation of macroscopical thermal diffusion equation is proposed to obtain the asymmetrical thermal conductivity in real space. This new type of thermal functional materials helps to control heat flow and to realize thermal cloak and thermal camouflage. In this review, we summarize the recent advances in constructing thermal functional materials (also called thermal metamaterials). In Sec Ⅰ, we discussed the history of functional materials and the principles of constructing thermal functional materials , special focus was given to the thermal cloak, followed by the realization of thermal cloak in Sec Ⅱ.Thermal camouflage, based on the realization of thermal cloak, was discussed in Sec Ⅲ, which is proposed to have great potentials in military usage. We stressed both the principle and practical based challenges in thermal cloak and thermal camouflage in Sec Ⅳ, in which outlooks were also given.

It is worth noting that thermal transports consist of thermal conduction, thermal convection and thermal radiation. Recent progresses on thermal functional materials are based on the transformation of thermotics, i.e. spacial distortion of thermal conducting path, leaving thermal convection and thermal radiation untouched. We hope, though this review paper, to encourage more researchers in China to engage in this field, and to accelerate the practical usage of thermal cloak and thermal camouflage.

Keywords: manipulation of thermal energy; transformation of thermotics; thermal cloak; thermal camouflage

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