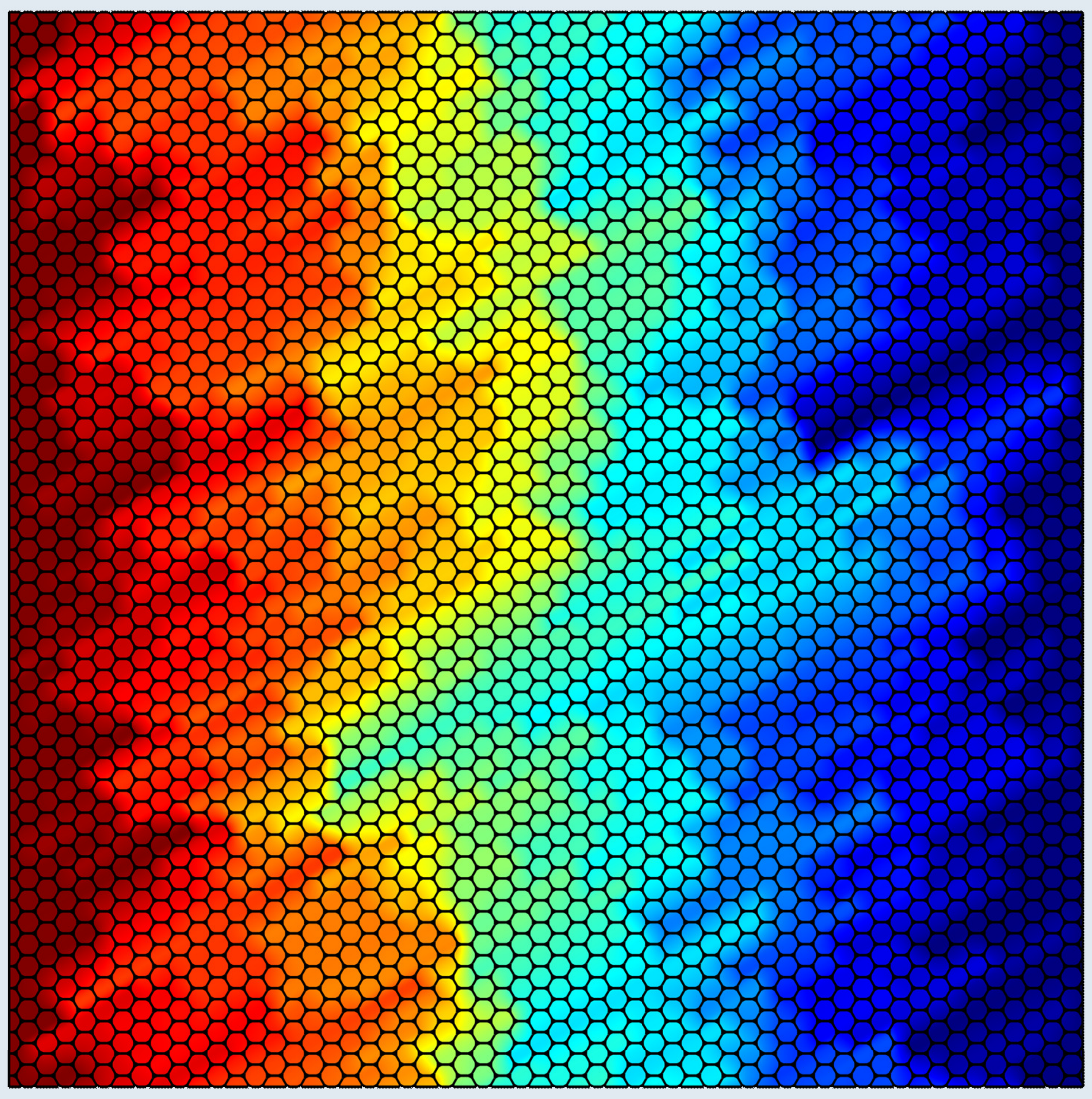

Thermal Conduction in Anisotropic Granular Mixtures

Introducing thermally anisotropic components in granular assemblies drastically changes the nature of heat transfer inside the material!

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Introduction

With the ongoing electrification of vehicles and rapid digitalization, thermal management is on everyone´s lips. This includes the use of ever-better materials. To fine-tune the thermal conductivity of a material, composite materials with specified volume contents are used. However, many additives to improve thermal conductivity exhibit a certain degree of anisotropy. This leads to unexpected and counterintuitive effects.

Here, we combine two approaches: composite materials with a certain amount of thermally anisotropic constituents allow us to maintain thermal anisotropy as well as the ability to adjust the resulting thermal conductivity to specific applications. We show that introducing thermal anisotropic components in granular matter drastically changes the way of heat transfer inside the material.

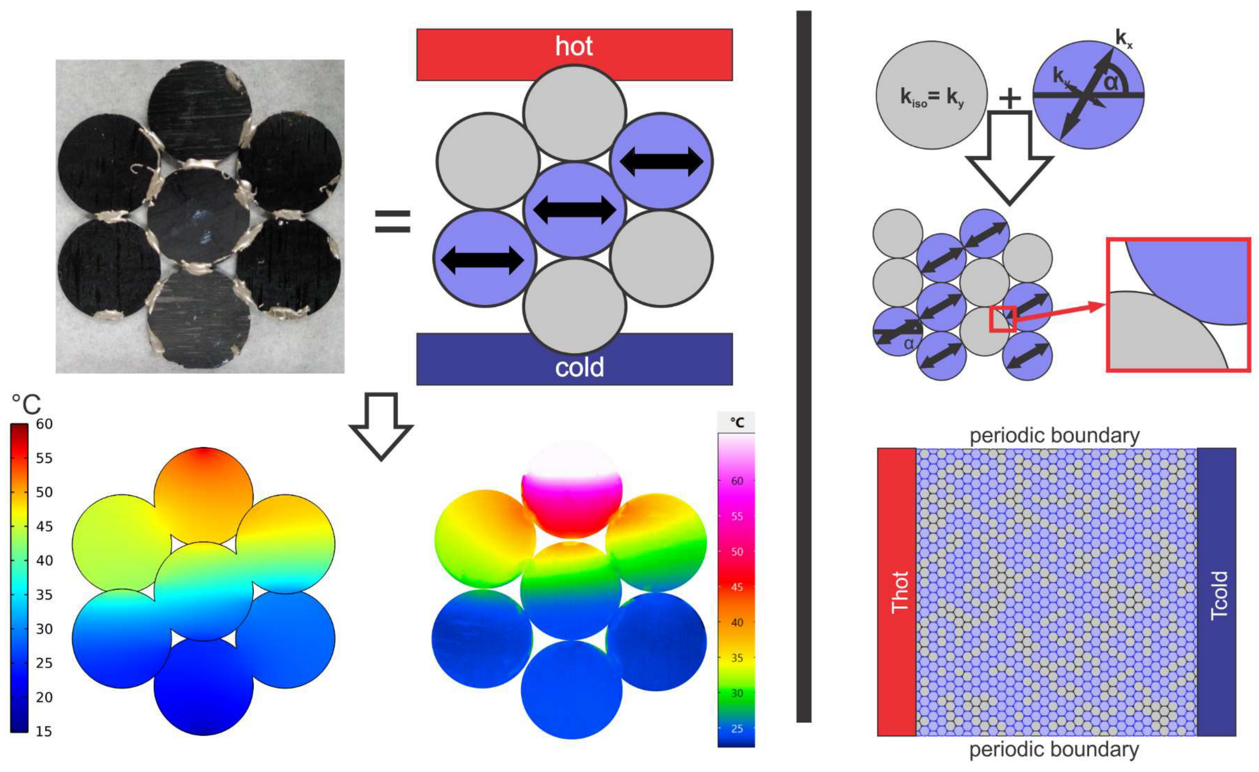

FIGURE 1: a) Verification of the simulations with IR thermography of thermally anisotropic laminates. b) Simulation setup made of hexagonal packed particles, isotropic: grey, anisotropic: blue.

Methodology

Specifically, our geometry in the 2D case represents a hexagonal array of particles. A newly developed Java® method in the Application Builder is used to assign the material properties of interest to the granules (isotropic and anisotropic with certain orientations). The code allows for either random distribution of material properties or clustering for given area fractions. The effective thermal conductivity is calculated out of the normal total heat flux.

The COMSOL® simulations are confirmed by IR thermography on small model structures made of thermally anisotropic laminates.

Results

The prediction of the thermal conductivity of anisotropic composites is not possible based on classic percolation theory, which only holds for the case of composites with isotropic constituents. However, the use of anisotropy enables us to even better control the effective thermal conductivity via the number and orientation of anisotropic constituents in the composite. Anisotropy does not only affect the macroscopic thermal properties. The admixture of anisotropic constituents gives rise to sharp local temperature gradients. The conscious use of thermal anisotropy in composite structures can be a great enhancement of tailoring materials for thermal management.

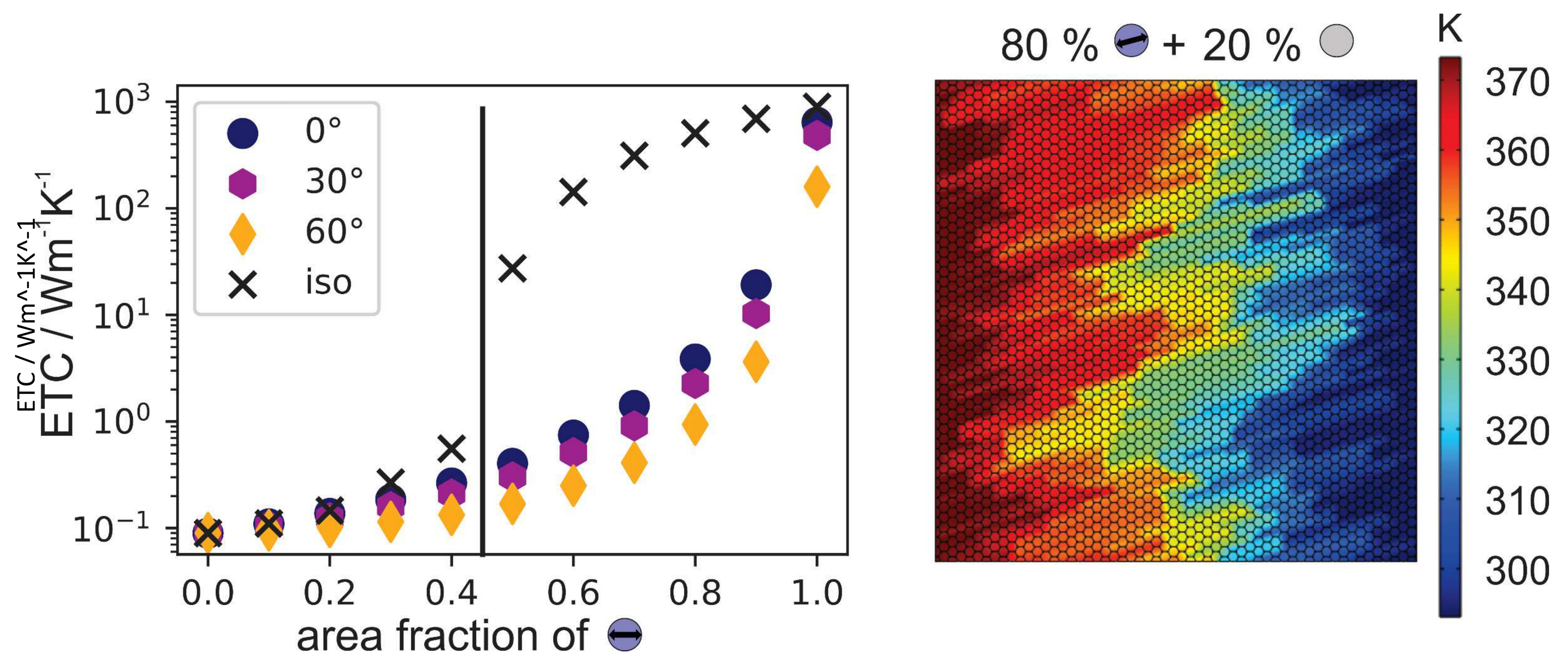

FIGURE 2: Increase in effective thermal conductivity differs from isotropic mixtures. Further, strong internal temperature gradients occur, visualized in the temperature distribution on the right.

REFERENCES

1. Ruckdeschel, P.; Philipp, A.; Kopera, B. A. **F.; Bitterlich**, F.; Dulle, M.; Pech-May, N. W.; Retsch, M. "Thermal transport in binary colloidal glasses: Composition dependence and percolation assessment" *Physical Review E* (97), page numbers (pp.), 2018.
2. Senis, E. C.; Golosnoy, I. O.; Dulieu-Barton, J. M.; Thomsen, O. T. "Enhancement of the electrical and thermal properties of unidirectional carbon fibre/epoxy laminates through the addition of graphene oxide" *Journal of Materials Science* (54), 8955-8970 (pp.), 2019.

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