Tight limits to the Hall effect and other nonreciprocal effects in 3D composites

Christian Kern[1*], Rasmus E. Christiansen[1], Graeme W. Milton[2], Ole Sigmund[1]
[1] Department of Mechanical Engineering, Technical University of Denmark,
Nils Koppels Allé 404, 2800 Kgs. Lyngby, Denmark
[2] Department of Mathematics, University of Utah,
155 S 1400 E, Salt Lake City, UT 84112, USA
E-mail: chrke@dtu.dk

While it is well known that composite materials can exhibit unusual effective properties going beyond those of their constituents, the extent to which this applies to nonreciprocal composites is presently not well understood. In this talk, I will report on our recent progress on this problem: First, I will present new bounds on the effective material properties of composites that are made from at least one constituent material exhibiting a nonreciprocal effect. It is assumed that the underlying equations are those of the conductivity problem and that the antisymmetric contribution to the tensor describing the constituent material properties is small. Emphasis will be given to the Hall effect. However, as many other non-reciprocal effects take the same form in the mathematical description, our results are more generally applicable. Second, I will discuss the attainability of our new bounds. In particular, I will show that in the important high-contrast regime many of our new bounds are attained by hierarchical laminate microstructures. While these laminates show optimal behavior, their structure involves several separated length scales, which renders their practical realization difficult or even infeasible. Using topology optimization, we obtained much more realistic microstructures. These topology optimized microstructures show a performance that generally approximates their multi-scale counterparts well.