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Ultrastiff Elastic Composites via Negative Stiffness Inclusions, and Material Stability Implications

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Composite materials of extremely high stiffness, far higher than that of either phase and exceeding that of all standard bounds (e.g., those of Voigt and Hashin-Shtrikman), can be produced by employing one phase of appropriately-tuned negative stiffness. We show this via several exact solutions within linearized and also fully nonlinear elasticity, and via the overall modulus tensor estimate of a variational principle shown to be valid in this case. The specific type of composite considered is a matrix-inclusion composite in which the matrix material is positive-definite, and this contains a very small volume fraction of negative-stiffness (non-positive-definite) inclusions. The composite stiffness can exceed that of the bounds because the usual assumption of positive-definiteness of all the components is relaxed. A negative-stiffness component is unstable by itself, but we argue that a composite material containing negative-stiffness inclusions can have overall stability under appropriate conditions.

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