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COUPLE STRESS THEORY FOR MATERIALS WITH MICROSTRUCTURES

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ABSTRACT

Classical continuum theory (CCT) provides a mathematical model to study the mechanical response of materials under external effects. In the context of CCT, there is no material length scale, and a solid body is sub-dividable into an infinitesimal element with the same behavior as the bulk material, disregarding the fact that all materials are made of building blocks and have microstructures in different length scales. The lack of material characteristic length-scale in CCT prevents it from recognizing any size-effect. Additionally, even order material property tensors associated with this theory can only characterize the centrosymmetric behavior of the materials, and consequently, CCT overlooks the intrinsic chirality and polarity of materials. Although a handful of generalized continuum theories has been proposed in the last century to address the shortcomings of CCT, none has proved to be consistent and applicable, mainly due to a lack of knowledge about the introduced material coefficients in these non-classical theories. This study introduces a consistent and self-sufficient effective generalized continuum theory for advanced materials with microstructures. Assuming that CCT governs the base material's behavior, we implement a bottom-up approach based on an augmented asymptotic homogenization resulting in the couple-stress theory in 3D space Using the introduced continuum theory, we can accurately model the response of chiral mechanical metamaterial under different type of loads. The proposed model provides a benchmark for the rational design, classification, and manufacture of mechanical metamaterials.