Microarchitectured polymer materials designed by topology optimization and fabricated using 3D printing

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The aim of this presentation is two fold. First to complete a design cycle for several auxetic materials where the cycle consists of three steps (i) the design of the microarchitecture, (ii) the manufacturing of the material and (iii) the testing of the material. Second we aim to help the representation of the optimzed microstructures in the space of anisotropic elastic moduli.

In more precise terms, we aim to obtain domain microarchitected materials with a prescribed elasticity tensor and Poisson's ratio. In order to reach this goal we use topology optimization via the level set method for the material design process, see [6] for details and based on methods proposed initially by [1, 2]. The theoretical problem of reachable elasticity tensors has theoretically been solved using laminates in the seminal paper of Milton & Cherkaev [5] starting from two isotropic materials with arbitrary Young moduli. Given geometric and materials constraints that 3D printing introduces we are not certain that all targets of elastic moduli can be attained. In other words, the definition of the set of elastic moduli determined by all printable designs is a priori not know. The realizable space of Poisson's ratio can be obtained, at a first step, from direct stability constraints i.e. positive definitiveness of the effective elastic tensor or by the use of variational bounds [3], [4]. Since the celebrated work of Hashin & Shtrikman [3] where they characterized all possible *isotropic* effective material tensors by mixing *two isotropic* materials in specified proportions, many other works have appeared that generalize their work to *anisotropic* effective material tensors [7, 4]. Here we compute the bounds obtained by Milton & Kohn [4], which only involve the volume fractions of the components, to show that certain optimally designed, *orthotropic*, auxetic microstructures can attain them.

The structures are manufactured using a desktop stereolithography 3D printer and then tested on a uniaxial tensile machine. Insight into the local mechanical fields is obtained using digital image correlation.

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