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Designing Materials for Negative or Zero Compressibility Through Topology Optimization

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There has been considerable interest in materials exhibiting negative or zero compressibility as such materials are desirable for various engineering applications [1,2]. A number of models or mechanisms have been proposed to characterize the unusual phenomena of negative linear compressibility (NLC) and negative area compressibility (NAC) in natural and synthetic systems. In this study we propose a general design technique for finding metamaterials with negative or zero compressibility by using a topology optimization approach. Based on the bi-directional evolutionary structural optimization (BESO) method [3-5], we establish a systematic computational procedure and present a series of designs, obtained from BESO, of orthotropic materials with various magnitudes of negative compressibility, or with zero compressibility, in one or two directions. Shown in Figure 1 is a physical prototype of one of such metamaterials fabricated using a 3D printer and tested in the laboratory under uniform pressure from all directions. The material, originally of a cubic shape, expands in the vertical direction. The experimental results compare well with numerical predictions. This research has demonstrated the feasibility of designing and fabricating metamaterials with negative or zero compressibility and paved the way towards their practical applications.

Fig. 1. This material *expands* vertically when subjected to a uniform pressure in all directions.

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