Phase transforming cellular materials

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ABSTRACT

A phase transition is the transformation of a thermodynamic system from one phase to another. This transformation occurs in a wide range of structure and systems by the deformation of the crystal into a new structure changing the packing arrangement of the atoms in the unit cell. The different phases exhibit distinct properties and this change in the properties is exploited by technological innovations. Shape memory alloys are materials that present phase transformation alloys where martensitic phase transformation occurs by the deformation of the crystal into a new structure. A characteristic feature of the phase transformation in memory alloys is a periodic saw tooth pattern in the stress plateau of the stress–strain curve. Many biological components present behaviors that resemble the phase transformation of shape memory alloys; e.g., certain structural proteins exhibit saw tooth patterns when switching from a folded to unfolded configuration. In addition, researchers have shown that nacre achieves its remarkable toughness, without sacrificing its strength and stiffness, from its wavy brick-and-mortar-like microstructure. The wavy bricks, in conjunction with the mineral bridges and the organic glue, activate a very unique compression-tension behavior that leads to irreversible bistable mechanisms resulting in an efficient process of energy dissipation and spreading of damage. In this article, we propose to extend this notion of diffusionless solid-state phase transformations to cellular solids, where we define a phase transformation to represent a change in the geometry of the unit cell. This is achieved by utilizing either bistable or metastable mechanisms as base for the unit cells of the cellular material. The phase transformation is due to a progressive change of configurations from cell to cell leading to a serrated force displacement behavior. The cells are designed in such way that the deformations remain in the elastic regime making the process reversible. Analytical and computational micromechanics based models will be presented and used to estimate the effective properties of the phase transforming cellular material in each of its phases. In addition, initial studies on the characterization of the material moduli, energy absorption, volume change, self-excited dynamic response associated with the phase transformation and effect of phase change on the wave guiding properties of the material among other properties will be presented.