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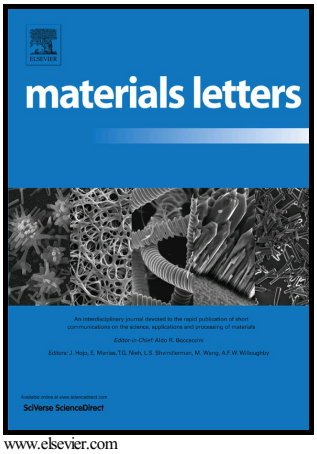

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A new fabrication method for hierarchical truss materials with millimeter-scale struts

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Abstract

Hierarchical truss materials with millimeter-scale struts have been fabricated using a three-dimensional printing and interlocking method. The limitation designs of hierarchical truss materials have been found in this short letter to show the imperfection of hierarchical materials. The analytical models and experimental work have been conducted to investigate the restriction mechanism of the hierarchical design. Polymer hierarchical truss materials with low relative densities (0.66% to 2.67%) have been fabricated for compressive tests. Euler buckling of hierarchical and first order truss materials has been observed in our experiments. Our conclusions are very useful for accurate comprehension of hierarchical construction and designing ultra-lightweight hierarchical truss materials with high specific strength at low density to avoid the deficiencies of this structural configuration.

Keywords: Hierarchical materials; Porous materials; Elastic properties; Three dimensional printing; Interlocking method.

1. Introduction

Honeycomb, foam and integrated woven materials are commonly used as core materials and they are one type of bionic design based on natural materials [1-4]. Efforts to develop lightweight and multifunctional structures have attracted extensive interests all over the world, such as man-made foam and lattice materials having been fabricated and their mechanical behaviors investigated [5-8]. Many natural and man-made materials also exhibit structure on more than one scale, in some materials, the structural elements themselves have smaller scale structures. This structural hierarchy can play a major part in determining the bulk material properties. Lattice truss [9-10], honeycomb [11-14] and corrugated [15-16] geometries with centimeter-scale elements were considered, and it was shown that a hierarchical material could be used in the design of their structural elements which, for a given compressive strength, are much lighter than first order (solid) elements.

Almost all of the previous papers have shown the superiority of a hierarchical design for lightweight sandwich structures due to larger size struts (centimeter-scale), while the relevant design limitations of such types of structures remains an open issue because of the fabrication difficulty. Hierarchical truss materials with small (millimeter-scale) struts cannot be fabricated and the hierarchical design cannot be fully implemented to provide it with higher structural efficiency. In our paper, a three-dimensional printing and interlocking method are used to manufacture this type of structures on a small scale. The analytical calculations have been derived to show the new limitation of hierarchical truss materials and experiments have been conducted. No similar research work has been found in the literature.