

# Mechanical Engineering Doctoral Defense

## Experimental Investigation and A Novel Packing Hollow Dodecahedron Model to Understand the Thermal and Mechanical Properties of Elastic Cellular Architectures

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### Abstract

Cellular metamaterials arouse broad scientific interests due to the combination of host material and structure together to achieve a wide range of physical properties rarely found in nature. Stochastic foam as one subset has been considered as a competitive candidate for versatile applications including heat exchangers, battery electrodes, automotive, catalyst devices, magnetic shielding, etc. For the engineering of the cellular foam architectures, closed-form models that can be used to predict the mechanical and thermal properties of foams are highly desired especially for the recently developed ultralight weight shellular architectures. Herein, for the first time, a novel packing three-dimensional (3D) hollow pentagonal dodecahedron (HPD) model is proposed to simulate the cellular architecture with hollow struts. An electrochemical deposition process is utilized to manufacture the metallic hollow foam architecture. Mechanical and thermal testing of the as-manufactured foams are carried out to compare with the HPD model. Timoshenko beam theory is utilized to verify and explain the derived power coefficient relation. Our HPD model is proved to accurately capture both the topology and the physical properties of hollow stochastic foam. Understanding how the novel HPD model packing helps break the conventional impression that 3D pentagonal topology cannot fulfill the space as a representative volume element. Moreover, the developed HPD model can predict the mechanical and thermal properties of the manufactured hollow metallic foams and elucidating of how the inevitable manufacturing defects affect the physical properties of the hollow metallic foams. This work will inspire new ideas in designing efficient cellular architecture for mechanical energy absorption, acoustic damping, stretchable/compressible conductors, heat exchangers, and among others. In addition, using our simple and viable modeling approach and polymer foam templated deposition method, many more complexed foam-based device can be realized with an accelerated designing process. Despite of the macro-scale stochastic foam architecture, nano gradient gyroid lattices are studied using Molecular Dynamics (MD) simulation. The simulation result reveals that, unlike homogeneous architecture, gradient gyroid not only shows novel layer-by-layer deformation behavior, but also processes significantly better energy absorption ability. The deformation behavior and energy absorption are predictable and designable, which demonstrate its highly programmable potential.



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Zoom Link: <https://asu.zoom.us/j/85424797381>