Perfecting Bone Implants: A Novel Method to Create Lighter and Stronger Porous Materials Using Nanorod Reinforcements

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Maintaining the strength and stiffness of a material while decreasing its density remains a fundamental challenge in materials science because it is a crucial requirement for biological implants. The mismatch in density and stiffness between current implant materials and their surrounding bones leads to bone degradation: a problem solved by implants that are stronger, three times less dense, and as stiff as bone. A novel solution is to reinforce lightweight but weaker porous materials(metal foams) with stronger nanorods. This hypothesis of whether nanorods can prevent pore collapse and increase strength in metal foams was investigated with a porous copper foam model reinforced with silver and niobium nanorods. The three-step methodology included testing pore architectures, nanorod reinforcements, and then extending these studies to irregular porous systems that are more prevalent in nature. Deformation characteristics of systems under tension and compression were systematically compared using Large-scale-Atomic/Molecular-Massively Parallel-Simulator(LAMMPS). During the first stage, simple rearranging of pore architecture affected the properties of the system and improved strength by 13% when pores were moved outward into an unsymmetrical distribution. Reinforcing the pore geometry with a niobium nanorod increased the strength back to their pre-porous values and increased stiffness by 44%. In the third stage, strength increased with nanorod thickness and these niobium atoms kept pores from collapsing, indicating that nanorods strengthened the irregular geometries. These results support the hypothesis that reinforcing metal foams with nanorods is an effective way to engineer stronger and exceedingly light alloys whose stiffness can be selectively tuned to desired values.