Rate-dependent compressive properties of 3D printed copper microarchitectures with tunable microstructure

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Abstract

3D printed metallic microarchitectures have the potential to be applied in lightweight packaging to protect sensitive components for micro-/nanoelectromechanical systems or microelectronics. The recently developed localized electrodeposition in liquid (LEL) technique enables printing copper microarchitectures with high precision and 3D geometrical freedom. The LEL technique utilizes a silicon based hollow microcantilever with an orifice to deliver metal ions under controlled pressure into an electrochemical cell. The metal ions are locally reduced and microscale metal dvoxels are deposited with high spatial resolution on a conductive substrate. Complex metal geometries such as micropillars, microlattices, and microsprings have been successfully fabricated using this technique. Here, we present the effect of printing parameters (pressure and voltage) on the microstructure of 3D printed metal microarchitectures. The microstructure characterization by electron backscatter diffraction (EBSD) unveils the correlation between grain size and the printing parameters. The key focus of the presentation will be on the mechanical performance of metallic microarchitectures and their dependence on both the architecture and microstructure. The micromechanical properties of the microarchitectures were analyzed using *in situ* compression testing inside a scanning electron microscope (SEM). Copper micropillars printed using LEL with microcrystalline and ultrafine-grained (UFG) microstructure exhibit significant differences in strength and deformation mechanism (1). Specifically, the UFG copper micropillars show a strain rate sensitivity that's three times higher than the microcrystalline counterparts and show a unique saturation in yield stress beyond a strain rate of 0.1/s. More complex copper microlattices with octet and honeycomb architectures with UFG microstructure show excellent energy absorption properties under compression at a wide range of strain rates (0.001/s till 100/s) and temperatures (-150 ∘C till 25 ∘C) (2). Finally, the impact of our current study on utilizing metallic microarchitectures as highly localized lightweight packaging for protecting sensitive micro/nanocomponents will also be discussed.

References:

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2. Kang, S.-G., et al., *Fabrication and extreme micromechanics of additive metal microarchitectures.* arXiv preprint arXiv:2311.14018, 2023.