

Materials Science & Engineering Doctoral Defense

Process-Structure-Property Relationships in The Synthesis and Nanoscale Welding of Nanoporous Metal Feedstocks

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Abstract

In recent years, the scientific community around the synthesis and processing of nanoporous metals is striving to integrate them into powder metallurgy processes such as additive manufacturing since it has a potential to fabricate 3D hierarchical high surface area electrodes for energy applications. Recent research in dealloying – a versatile method for synthesizing nanoporous metals – emphasized the need in understanding its process-structure relationships to independently control the relative density, ligament and pore sizes with good process reproducibility. In this dissertation, a new understanding of the dealloying process is presented for synthesizing (i) nanoporous gold thin-films and (ii) nanoporous Cu spherical powders with an emphasis on understanding variability in their process-structure-relationships and process scalability. First, this work sheds the light on the nature of the dealloying front and its percolation along the grain boundaries in nanocrystalline gold-silver thin films by studying the early stages of ligament nucleation. Additionally, this work analyses its variability by investigating new process variables such as (i) equilibration time and (ii) precursor aging and their impacts in achieving process reproducibility. The correlation of relative density with ligament size is contextualized with state-of-the-art data mining research. Second, this work provides a new methodology for large scale production of nanoporous Cu powder and demonstrates its integration with powder casting to fabricate porous conductive electrode. By understanding the influence of etching solution concentration and titration methodology on the structure and composition of nanoporous Cu, it was possible to fabricate precipitate-free powders at high throughputs. Further, the nature of oxygen incorporation into porous Cu powder was studied as a function of surface-to-volume ratio of powder in atmospheric conditions. To consolidate powders into parts via open-die casting, this work harvests Ostwald Ripening phenomena associated with thermal coarsening in nanoporous metals to weld them at low temperatures (approximately one-third of its melting temperature). This work represents a major step towards the integration of nanoporous Cu feedstocks into additive manufacturing.



September 16, 2022; 9:30 AM; PRLTA 302;
Zoom Link: <https://asu.zoom.us/j/89120260872>