Symposium: Scalable micro/nanomanufacturing

Title: High Resolution 3D Printing of Copper with Tunable Porosity Through µCLIP and Nanoporous Copper Powders

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Abstract:

Manufacturing of micro-scaled metal features with optimal architectures for circuits and other micro-electronic applications has been of high interest in both industrial and academic communities. High complexity morphology can be obtained by additive manufacturing (AM) means, but the printing resolution and speed limitations of AM processes such as Laser Powder Bed Fusion (LPBF), Direct Energy Deposition (DED), Material Extrusion (ME), and Material Jetting (MJ) have hindered their potential to fabricate such parts. In this study, we overcome both barriers by the use of the novel Micro-Continuous Liquid Interface Production (µCLIP), a high-speed and high-resolution printing method[1] that, although resin based, presents outstanding potential to fabricate polymer matrix composites (PMCs) to 3D print green parts that are sintered to obtain metal parts. Along with µCLIP, this breakthrough in printing copper parts is made possible with the use of nanoporous copper (np-Cu) powders as fillers in the PMC, as their nanopores decrease the PMC's surface energy, resulting in a dispersible and stable resin and, in combination with the small amounts of oxides (< 10at.%), also enable increased light absorption during the print, minimizing printing energy requirements. Optimum metal content and other rheological properties were obtained during the PMC fabrication as well as optimum printing parameters, resulting in successful 5.8$\mu m \cdot pixel^{-1}$ resolution printed parts at 10$\mu m \cdot s^{-1}$ speed. Additionally, np-Cu's size-dependent properties allow reduced sintering temperatures, being as low as 46% to 64% of Cu's melting temperature, which also promote controlled tunability in the parts porosity levels that are inversely scaled with the sintering temperature, varying from 25.0% (at 500 °C) to less than 1.7% (at 750 °C) based on SEM image analysis, with electrical resistivities of $1.8\times10^{-3}\Omega\cdot m$ *(at RT)* and $9.01\times10^{-5}\Omega\cdot m$ *(at RT)*, respectively.

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[1] *ACS Materials Lett.* 2023, 5, 6, 1727–1737