# MULTI-METAL ELECTROHYDRODYNAMIC REDOX 3D PRINTING AT THE SUBMICRON SCALE: MICROSTRUCTURE – GEOMETRICAL GRADIENTS – CHEMICAL GRADIENTS AND THE RESULTING MECHANICAL PROPERTIES

Ralph Spolenak, Laboratory for Nanometallurgy, Department of Materials, ETH Zurich
ralph.spolenak@mat.ethz.ch
Lukas Hauser, Laboratory for Nanometallurgy, Department of Materials, ETH Zurich
Jeff W. Wheeler, Laboratory for Nanometallurgy, Department of Materials, ETH Zurich
Alain Reiser, Laboratory for Nanometallurgy, Department of Materials, ETH Zurich

Additive manufacturing, metals, gradient materials, nanoscale, microstructure control

An extensive range of metals can be dissolved and re-deposited in liquid solvents using electrochemistry. We harness this concept for additive manufacturing, demonstrating the focused electrohydrodynamic ejection of metal ions dissolved from sacrificial anodes and their subsequent reduction to elemental metals on the substrate. This technique, termed electrohydrodynamic redox printing (EHD-RP), enables the direct, ink-free fabrication of polycrystalline multi-metal 3D structures without the need for post-print processing. On- the-fly switching and mixing of two or more metals printed from a single multichannel nozzle facilitates a chemical feature size of <400 nm with a spatial resolution of 250 nm at printing speeds of up to 10 voxels per second. The additive control of the chemical architecture of materials provided by EHD-RP unlocks the synthesis of 3D bi-metal structures with programmed local properties and opens new avenues for the direct fabrication of chemically architected materials and devices. Mechanical properties can be locally controlled by alloying, dealloying (resulting in controlled porosity) and grain-size tuning via process control. The properties of EHD-RP are put into perspective by comparing with the most prominent current technologies for metal 3D printing at the nanoscale (Fig. 1).

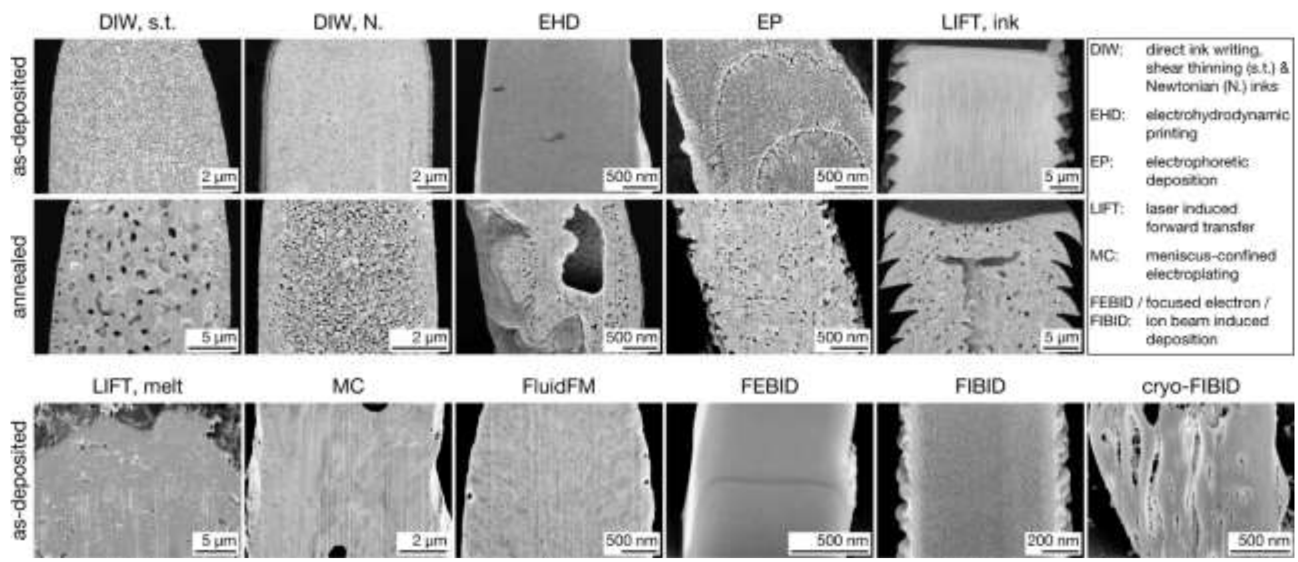


*Figure 1 – Comparison of the microstructures of metals deposited by all current processes to 3D print metals at the micron scale*