MICROSCALE ADDITIVE MANUFACTURING OF METAL – MECHANICAL PROPERTIES

Alain Reiser, Laboratory for Nanometallurgy, ETH Zurich, Switzerland
alain.reiser@mat.ethz.ch
Jeffrey M. Wheeler, Laboratory for Nanometallurgy, ETH Zurich, Switzerland
Ralph Spolenak, Laboratory for Nanometallurgy, ETH Zurich, Switzerland

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Additive manufacturing (AM) is transforming the way we design and fabricate structures on many scales. A main driving force of this movement is the ability of AM to overcome geometrical constraints imposed by subtractive manufacturing techniques. Because such design restrictions become increasingly limiting at small length scales, microscale AM has the potential to significantly expand the capabilities of microfabrication. Yet, for AM to become a beneficial addition to current microfabrication techniques, the properties of materials fabricated by AM have to be determined and quality standards have to be established.

Thus, a comparison was performed of the mechanical properties of metals deposited with most of the currently suggested microscale metal AM techniques [1]. The range of techniques studied includes well established approaches, e.g., focused electron beam induced deposition and laser forward transfer, as well as more novel methods, e.g., electrohydrodynamic printing and electrochemical deposition. The mechanical performance of structures deposited with these methods was evaluated using nanoindentation and microcompression (Fig. 1b), and the materials' microstructure was analyzed using cross-sectional electron microscopy.

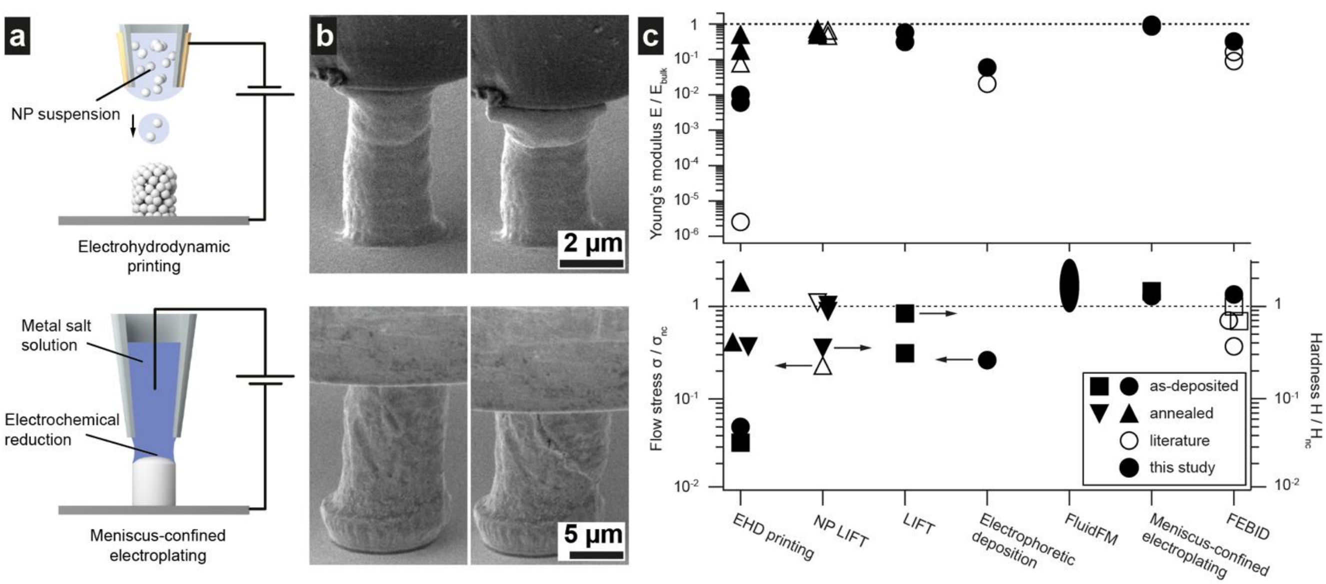

Figure 1 – a) Schematics of two out of seven microscale metal AM techniques studied [1]. b) In-situ microcompression of pillars fabricated with these two techniques. c) Young's modulus, flow stress and hardness of Au, Ag, Cu, Co, Pt and W deposited by different microscale metal AM techniques. The values are normalized by bulk values of polycrystalline (Young's modulus) and nanocrystalline (flow stress and hardness) metals.

Both the elastic and plastic properties were found to vary by orders of magnitudes between the individual techniques (Fig. 1c). These observed differences can be related to the large variations in microstructure in the deposited materials. Some microscale AM techniques were demonstrated to be already able to deliver materials with dense and crystalline microstructures with excellent mechanical properties, comparable to those of nanocrystalline thin films.

Knowing the microstructure and its influence on the mechanical properties of additively manufactured materials is the first step towards the engineering of their microstructure and the optimization of their performance. It is thus a key aspect for establishing AM techniques in microfabrication.

References

[1] A. Reiser, L. Hirt, R. Spolenak, T. Zambelli, Adv. Mater. 2017, 201604211, 1604211.