Deep Learning-Assisted FIB Nanofabrication

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Deep learning – a neural network trained on the basis of prior manufacturing experience – can predict the post-fabrication appearance of structures manufactured by focused ion beam (FIB) milling with nanoscale accuracy: >96% over a range of ion beam current and dosage parameters, accounting for variations in beam focusing/scanning parameters and target medium characteristics. With predictions being generated in milliseconds, the methodology may be deployed in near real-time to expedite process optimization and enhance precision/reproducibility in FIB nanofabrication.

Focused Ion Beam (FIB) milling is a vitally important direct-write process for rapid prototyping and materials/device characterization in both fundamental research and industrial manufacturing of nano-/microtechnologies. However, establishing optimal process parameters for any given task relies upon time-consuming (and therefore costly) iterative trial-and-error. We demonstrate here that a deep learning network can simulate the FIB milling process for arbitrary 2D binary patterns etched into gold thin films - i.e. structures common to a range of nanophotonic/plasmonic applications, from metamaterial and metasurface devices to spectroscopy (e.g. SERS) and seeded nano-materials growth. A conditional generative adversarial network trained on a binary designs and corresponding electron microscope images of samples fabricated with a range of FIB process parameters is then able to accurately simulate process outcomes for previously unseen designs - specifically their appearance in SEM imaging, as a strong indicator of process accuracy and quality.

This artificial intelligence-enabled capability can markedly reduce the number of experimental dose-test iterations required for, and therefore time and cost of, developing and optimizing new FIB nanofabrication processes. The methodology may also be deployed for early fault (e.g. beam alignment, aperture damage) detection, and to maintain performance (i.e. consistency of outcomes from established processes) against ageing of the ion source and beam apertures.