The nanomanipulation of metal nanoparticles inside oxide nano-tubes, synthesized by means of the Kirkendall effect, is demonstrated. In this strategy, a focused electron beam, extracted from a transmission electron microscope source, is used to site-selectively heat the oxide material in order to generate and steer a metal ion diffusion flux inside the nanochannels. The metal ion flux generated inside the tube is a consequence of the reduction of the oxide phase occurring upon exposure to the e-beam. We further show that the directional migration of the metal ions inside the nanotubes can be achieved by locally tuning the chemistry and the morphology of the channel at the nanoscale. This allows sculpting organized metal nanoparticles inside the nanotubes with various sizes, shapes, and periodicities. This nanomanipulation technique is very promising since it enables creating unique nanostructures that, at present, cannot be produced by an alternative classical synthesis route. Additionally, temperature dependent in-situ TEM experiments were carried out yielding a controlled morphological transformation of the Kirkendall oxide nanochannels.

References

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Fig. 1: Morphological evolution of an oxide nanotube upon exposure to an electron beam. (a) TEM image of the as-grown oxide nanotube. (b-e) formation of Cu nanoparticles inside the oxide nanotube upon exposure of several regions to the e-beam for different subsequent shots. The time of each shot was 2 s. Scale bar: 100 nm.