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Monitoring the dynamics of Kirkendall effect in Cu nanoparticles

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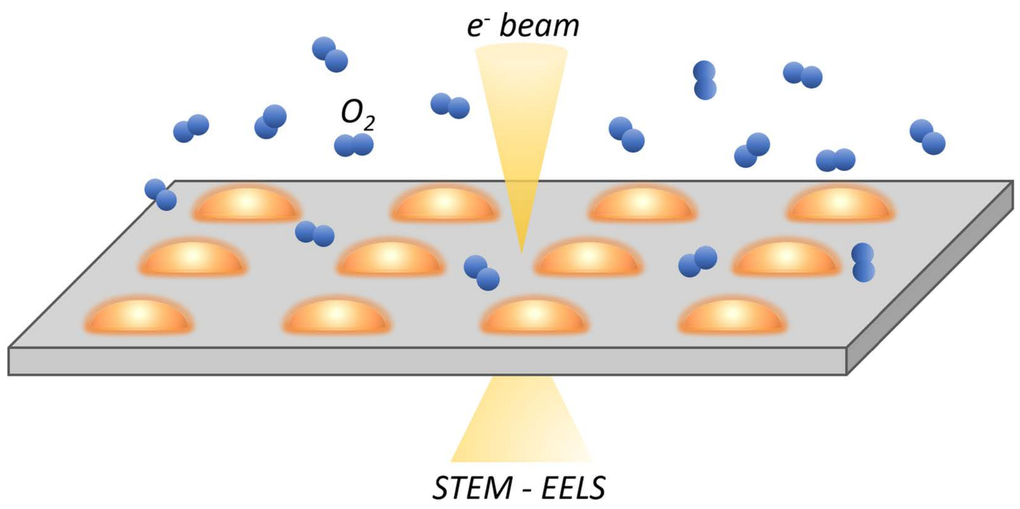
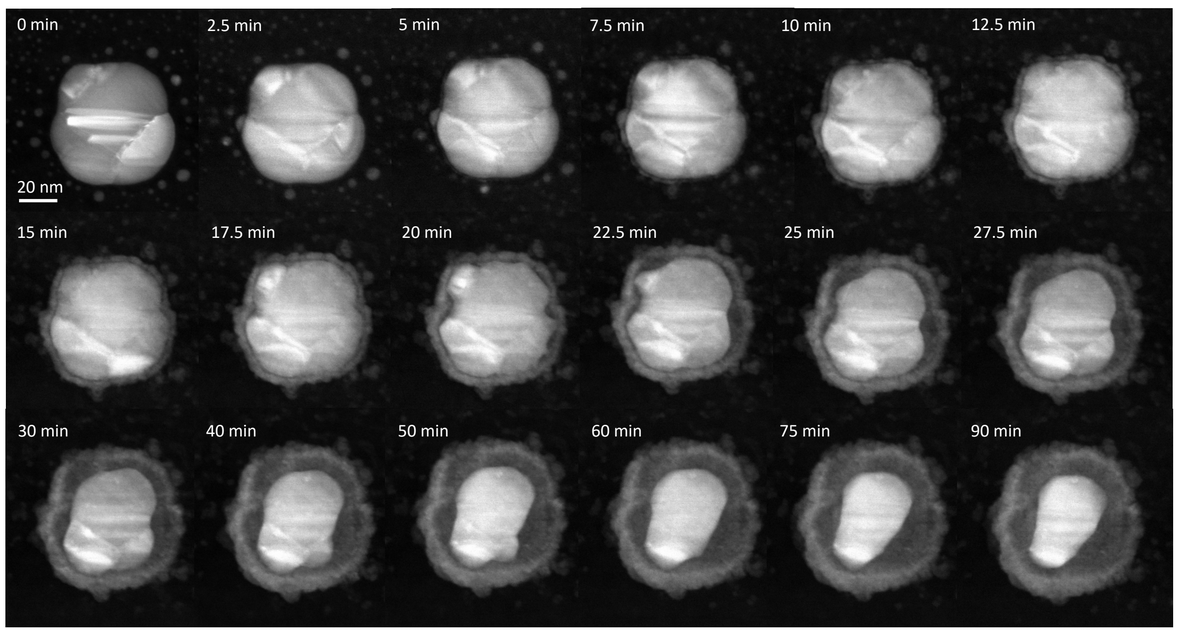
Studying the oxidation process in Cu nanoparticles is relevant for a number of applications, including microelectronics, catalysis, plasmonics and photovoltaics. Here we use environmental transmission electron microscopy (ETEM) to monitor *in-situ* the changes occurring to Cu nanoparticles and their localised surface plasmons (LSPRs) during oxidation. Annular dark-field scanning TEM (ADF STEM) imaging is employed to closely examine the dynamics of metal to oxide conversion and electron energy-loss spectroscopy (EELS) is employed to follow the evolution of the LSPRs of the particles.

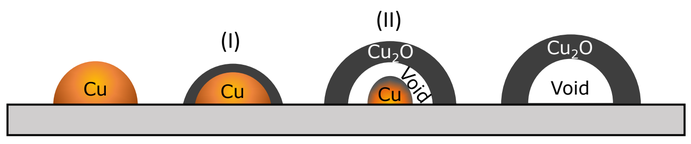


Particle 1:

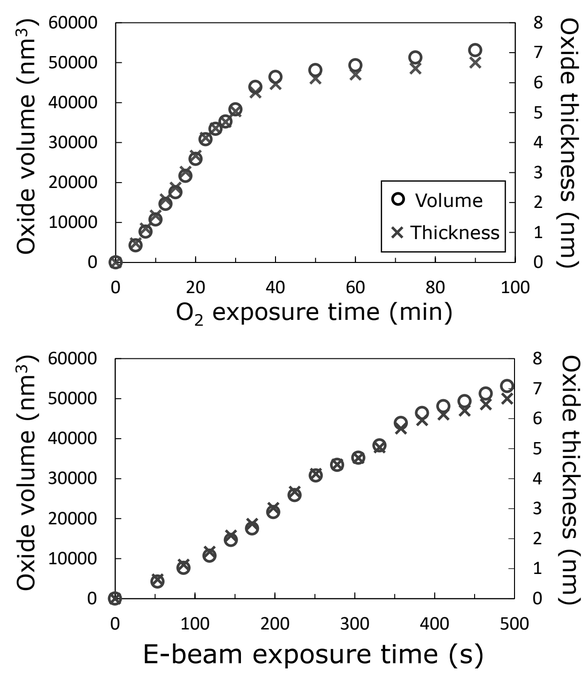
Top view ADF STEM images
e-beam 300 kV, 3 mbar O_2, T = 100 °C



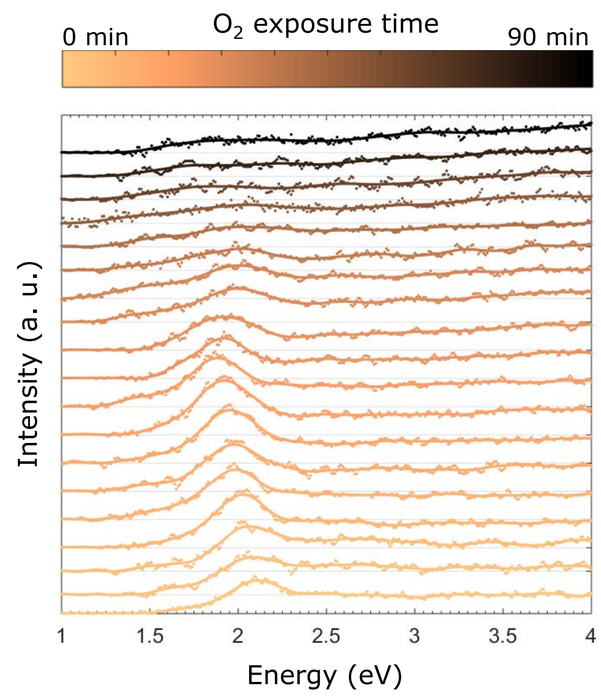
(I) Valensi-Carter model
(II) Nano Kirkendall model



Metal to oxide conversion

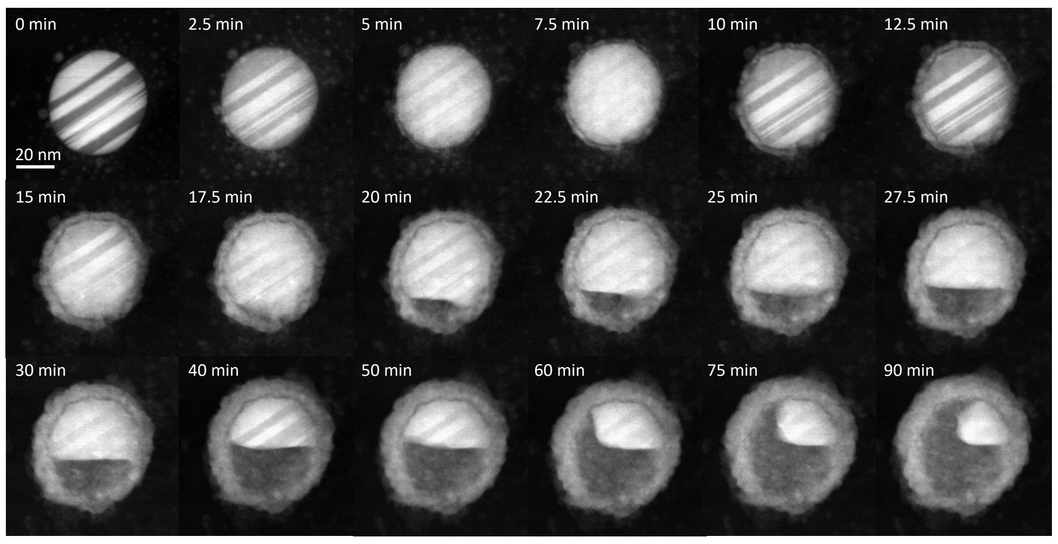


LSPR of nanoparticle probed by EELS



Particle 2:

Top view ADF STEM images
e-beam 300 kV, 3 mbar O_2, T = 100 °C



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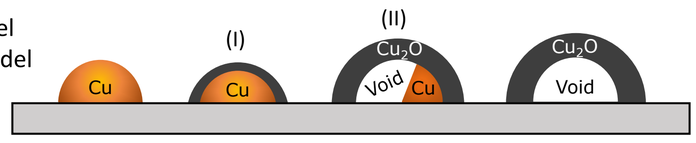
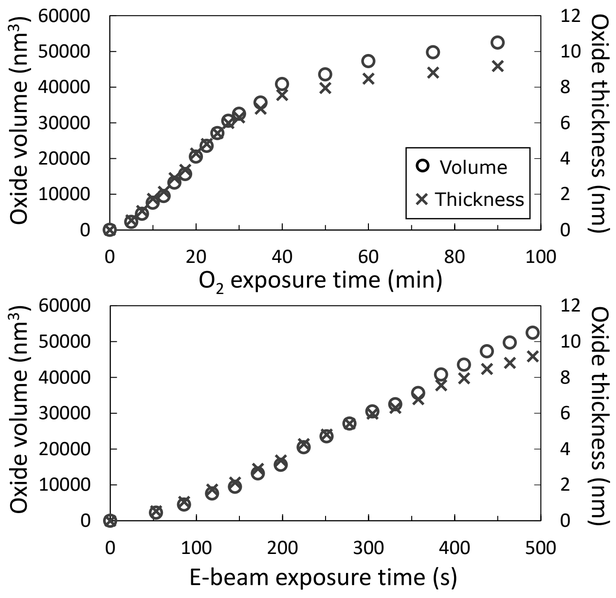
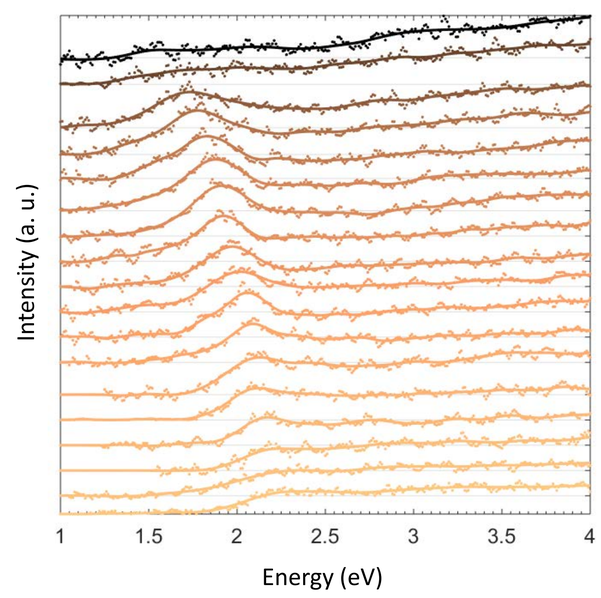


Metal to oxide conversion



LSPR of nanoparticle probed by EELS



Summary and future work

- *In-situ* STEM imaging of Cu nanoparticles during oxidation reveals a combined Valensi-Carter and Kirkendall oxidation mechanism.
- *In-situ* monitoring of the LSPR shows a continual red-shift of the peak energy followed by broadening and splitting of the LSPR into two peaks before complete loss of the signal at the final stage of oxidation.
- The electron beam significantly accelerates the oxidation process. Additional experiments will be carried out to better understand the role of the electron beam.