Transmission Electron Microscopy in Liquid Environments - a Powerful Tool for Dynamic Studies of Nucleation and Growth Phenomena of Nanomaterials

Sašo Šturm[1], Bojan Ambrožič[1,2], Nina Kostevšek[1,2], Marjan Bele[3], Kristina-Žužek Rožman[1]

1Jožef Stefan Institute, Department for Nanostructured Materials, Ljubljana, Slovenia
2Jožef Stefan International Postgraduate School, Ljubljana, Slovenia
3National Institute of Chemistry, Laboratory for Chemistry of Materials, Ljubljana, Slovenia

E-mail: saso.sturm@ijs.si

Significant advances in the development of novel functional nanomaterials can be achieved by using suitable microscopy methods that allow in situ dynamic investigations of nucleation and early growthstage of nanomaterialsfrom solutions [1]. For example, to achieve desired morphology and size distribution of nanoparticles, their nucleation and growth pathways need to be thoroughly understood. However, the mechanisms controlling the nucleation and growth of nanoparticles are often difficult to assess and are typically studied by indirect methods. On the contrary, in-situ transmission electron microscopy (TEM) combined with the specialized liquid cell offers both, unprecedented experimental and characterization tools for a direct study of nanoparticle's birth and early growth dynamics invarious solutions. The wealth of information that can be achieved from the so-called Liquid TEM will be demonstratedthroughthe nucleation and growth studies of yttria-based precursors, a model system for the development of up-conversion phosphor materials with great potential ranging from theranostics to photovoltaics. We will show how temperature controlled nucleation of yttria precursors by urea precipitation method can be facilitated inside the TEM when the temperature in the specialized liquid flow cellis raised above 90°C. Finally, the strategies to limit and control the effects of intense electron beam to the radiolytic decomposition of water, which can have serious detrimental effect on the nucleation and growth dynamics of the final products, will be emphasized.

1. Ross, F. M., *Science*,**2015**, 350 (6267), aaa9886-9.