Imaging the Nucleation and Growth of Nanoparticles in Solution

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Purpose

Develop high spatial and time resolution *in situ* tools for imaging the nucleation and growth of nanoparticles in solution.

Atomic-scale, millisecond time-resolution imaging will advance the understanding of particle nucleation and growth mechanisms. This will enable the controlled synthesis and study of nanomaterials of well-defined size, shape and exposed surfaces.

Expected Outcomes

Atomic-scale, millisecond time resolution *in situ* imaging capability for studying nanoparticle nucleation and growth in solution

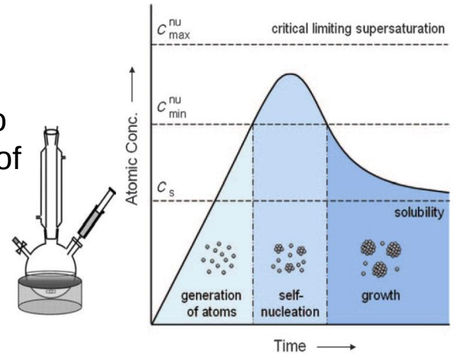
Developing a fundamental under-standing of nucleation and growth processes that will enable new material design and exploration

Enhanced chemical imaging and nanomaterials synthesis capabilities and expertise at PNNL

International visibility for the new imaging and synthesis capabilities

Nanoparticles Synthesis

A multi-step process involving: the nucleation and formation of metal seeds, growth of seeds to form nanoparticles and control of the growth, using a capping agent and/or quenching. Monitoring batch synthesis requires ultrafast spectroscopic and imaging techniques.

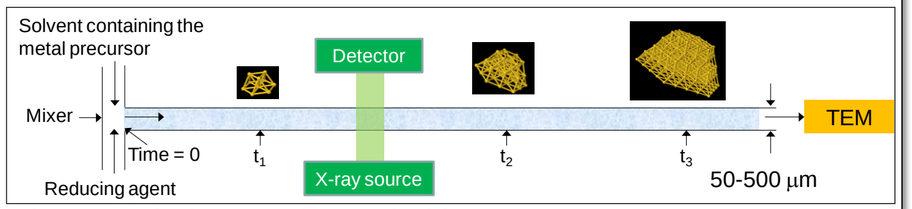


Angew. Chem. Int. Ed. 2009, 48, 60-103

Approach

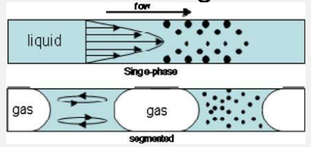
Combine microfluidics, x-ray absorption spectroscopy (XAS) and atomic-resolution aberration-corrected transmission electron microscopy (AC-TEM).

- Microfluidics
  - Convert the time scale to a length scale
  - Precise control of the synthesis conditions
- *In situ* XAS
  - Coordination number (size, shape)
  - Oxidation state
- AC-TEM (*ex situ* and *in situ* using a microfluidic cell)
  - Size and shape

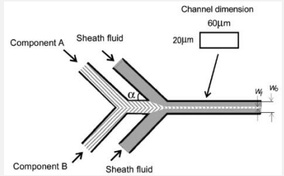


Time resolution can be varied by: channel dimensions, flowrate, and beam width

Task 1: Develop a micromixer and microreactor to achieve uniform synthesis conditions with minimal temperature and concentration gradients.

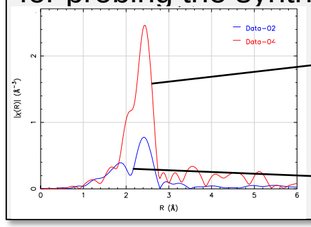


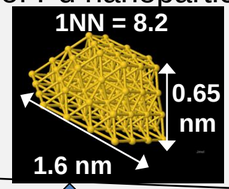
Adv. Mater. 2003,15, 1858–1862

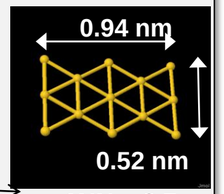


Biomicrofluidics 2008,2, 014101

Task 2: Develop x-ray absorption spectroscopy techniques for probing the synthesis of Pd nanoparticles.

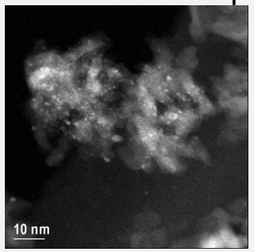


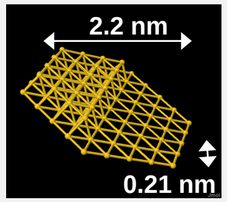




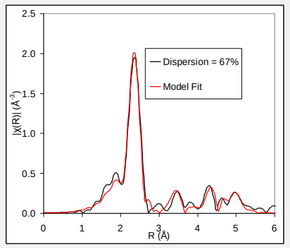
1NN = 3.7

Task 3: Image the synthesis of Pd nanoparticles using AC-TEM and develop methodology to correlate with XAS.





1NN = 6.1



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