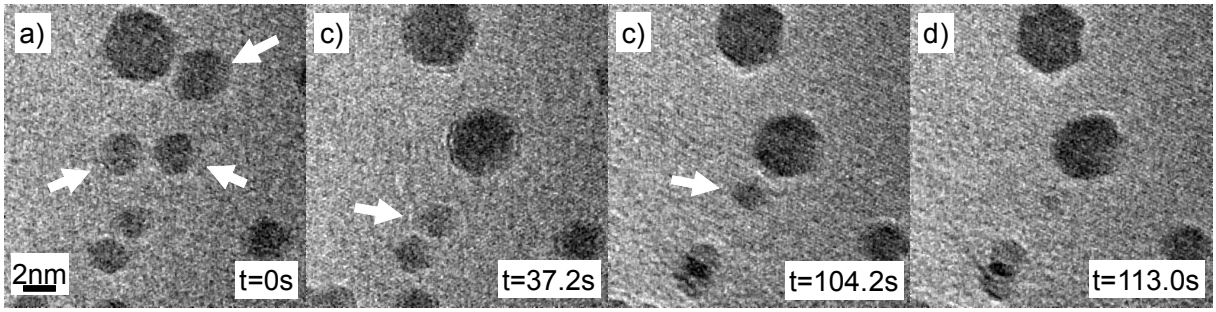
Environmental TEM of the Dynamics of Catalyst Particles

Thomas W. Hansen[1], Jakob B. Wagner[1], Linus D. L. Duchstein[1], Filippo Cavalca[1] and Rafal E. Dunin-Borkowski[1]
[1]Center for Electron Nanoscopy, Tech. University of Denmark, DK-2800, Lyngby, Denmark
twh@cen.dtu.dk

Abstract
Transmission electron microscopy (TEM) is used extensively in catalysis research [1]. Recent developments in instrumentation include monochromation of the electron source and aberration correction of both the condenser and the objective lens system. These developments are now also being introduced into the environmental TEM (ETEM). The improved spatial resolution and interpretability resulting from the implementation of aberration correctors are beneficial for imaging the surface structures and dynamics of catalyst nanoparticles.
Whereas conventional high-vacuum TEM provides important information about morphologies and atomic arrangements, ETEM capability allows materials such as catalysts to be investigated under gas exposure at elevated temperature. In this way, catalytic processes can be followed in a simulated working environment. Furthermore, phenomena such as sintering and growth can be observed dynamically [2].
In order to initiate a systematic study of the dynamics of nanoparticles, we exposed a model system of gold nanoparticles on boron nitride to 1.3 mbar of H_2 at 410°C in an image C_S corrected FEI Titan 80-300 ETEM. Image sequences were acquired at 2 frames/s. Mobility of the particles was visible, while maintaining lattice resolution of both the BN and the Au. Some particles remained immobile during observation, while others moved on the support (see figure) and sintered by migration and coalescence. Other particles were observed to shrink in size and disappear as neighbouring particles grew by Ostwald ripening. Fundamental insight into activation energies and energy barriers for sintering processes will be studied by quantifying these observations.



Frames extracted from an image sequence acquired in an environmental TEM in 1.3 mbar of H_2 gas at 410°C. Arrows indicate the positions of coalescence events and Ostwald ripening. The times are relative to the first frame shown.

References

[1] A. K. Datye, J. Catal. **216,** 144 (2003).
[2] P. Wynblatt and N. A. Gjostein, Prog. Solid State Chem. **9**, 21 (1975).