# Dynamics at phase boundaries of active catalyst studied by multi-scale operando EM

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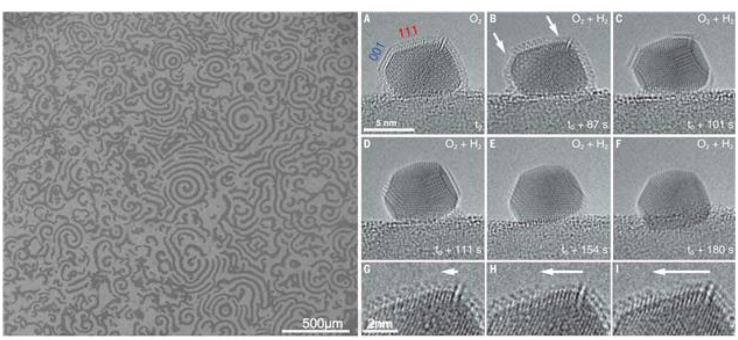
Catalysis is a highly complex phenomenon and intricately linked to the interplay between processes that dominate at different time and length scales. It is therefore impossible to understand the emergence of catalytic function solely based on the study of static atomic arrangements. Up to now, the full-scale complexity of catalysis is only poorly understood because the way in which atomic-scale processes influence the behavior and dynamics at larger scale is not well documented experimentally. The result is that we still, to a large extent, develop new catalysts on the basis of iterative trial-and-error approaches. Elucidating the link between atomic-scale structural dynamics, feedback mechanisms, and collective behaviour is the key to a deeper understanding and further optimisation of catalysts and processes. From imaging of quasi-static low- energy configurations through gas-phase-induced state switching to observation of complex non-equilibrium dynamics and oscillatory behaviour (Figure 1), electron microscopy has provided novel insights across several length and time scales and has meanwhile matured from a service tool for catalyst researchers to a driving force in catalysis research [1,2]. In my presentation, I will show that consideration of dynamics and processes taking place at different time and lateral scales as well as the consideration of non-linear and complex behaviour is essential for our understanding of working catalyst.

**Graphic:**




**Keywords:**

catalysis, non-equilibrium dynamics, multi-scale

**Reference:**

[1] Hansen, T.W., Willinger, M. From atomistic to collective dynamics: Bridging gaps in gas-phase electron microscopy for catalysis. MRS Bulletin 48, 842–851 (2023)
[2] H. Frey, A. et al., Science 376, 982-987 (2022).