CLINT Catalysis at Liquid Interfaces CRC 1452

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GRK 1896 *in situ microscopy*

Guest Colloquium

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In-situ electron microscopy of dynamic processes and active catalysts

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Zoom Online Meeting

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Due to the worsened Corona situation, we ask those present in the auditorium to follow the 2G rule.

DFG Deutsche Forschungsgemeinschaft

FAU Friedrich-Alexander-Universität Erlangen-Nürnberg

In-situ electron microscopy of dynamic processes and active catalysts

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Abstract
Heterogeneous catalysis is concerned with the study of reactions and dynamics at interfaces. The active catalyst is involved in bond breaking and bond making and thus, experiences a constant change in surface coverage due to adsorption, reaction, and desorption of species. The transfer of charge, energy and chemical species at the surface of the catalyst induces a response that feeds back into the reaction. As a consequence, concerted dynamics can emerge in the interaction between reactive gas-phase and active catalyst. They can give rise to complex spatio-temporal dynamics, oscillatory behavior, and eventually, lead to sustained catalytic activity. Over the last years, we have investigated the dynamic behavior of catalytically active metals by a combination of in-situ and operando scanning- and transmission electron microscopy (SEM and TEM, respectively). This multi-scale approach allows both, the study of collective large-scale dynamics from the mm to the nm scale, as well as studies of atomistic processes on individual active metal nanoparticles. We have observed the propagation of chemical waves and formation of dissipative structures during hydrogenation of nitrogen dioxide on platinum foils (Figure 1a-c) [1], as well as complex transformations of metal catalysts in model redox reactions [2,3]. As a next step, we increased the complexity from simple metals to supported metal catalysts. Using the prototype titania supported platinum catalyst, we studied effects related to a strong metal-support-interaction (SMSI, Figure 1d-g). Starting with a description of the catalyst under oxidizing conditions based on a combination of in-situ TEM imaging and X-ray spectroscopy [4], we are now moving forward and hopefully, reveal the underlying atomistic interactions that are at play under reactive conditions and responsible for the superior catalytic activity of supported metal catalysts.
The aim of my presentation is to demonstrate the potential of In-situ and operando electron microscopy and highlight the importance of observing processes while they are happening.

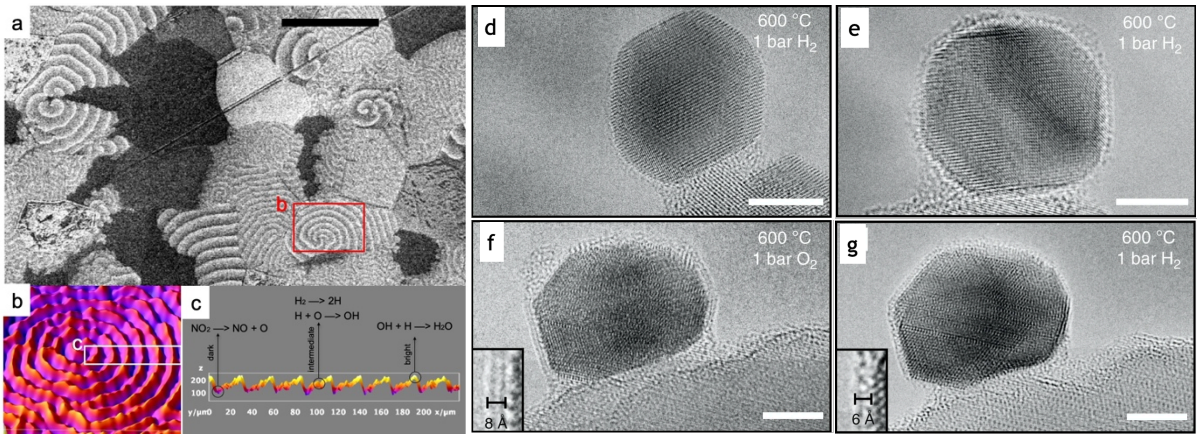

Figure 1: (a-c) Contrast variations caused by propagating chemical waves as revealed by in-situ SEM during NO_2 hydrogenation on a polycrystalline Pt foil [1]. Examples of in-situ TEM are shown in panels (d-g): A platinum particle on a titania support in the first exposure to H_2 at 600 °C, before (d) and after (e) encapsulation with a thin layer of reduced titania and the subsequent atmosphere change to O_2 at 600 °C (f), and back to H2 (g). Scale bar: 5nm [2].

References:

[1] Barroo, C. *et al.* Imaging the dynamics of catalysed surface reactions by in situ scanning electron microscopy. *Nat Catal* **3,** 30–39 (2020). https://doi.org/10.1038/s41929-019-0395-3
[2] Cao, J. *et al.* In situ observation of oscillatory redox dynamics of copper. *Nat Commun* **11,** 3554 (2020). https://doi.org/10.1038/s41467-020-17346-7
[3] Huang, X. *et al.* Phase Coexistence and Structural Dynamics of Redox Metal Catalysts Revealed by Operando TEM. *Adv. Mater.* 2021, 2101772. https://doi.org/10.1002/adma.202101772
[4] Beck, A. *et al.* The dynamics of overlayer formation on catalyst nanoparticles and strong metal-support interaction. *Nat Commun* **11,** 3220 (2020). https://doi.org/10.1038/s41467-020-17070-2