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IT-6-IN-2314 Atomic structure and reactivity in catalysis studied by electron microscopy

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Developing efficient technologies for the production of fuel and chemicals as well as for reducing environmental harmful emissions are among the largest challenges for our modern society. As their solutions depend on catalysis, research and innovation in this field is mandatory to realize the vision of a clean and sustainable society. In recent years, new opportunities for catalysis research have opened up with remarkable progress in transmission electron microscopy (TEM). On one hand, advancements in aberration-corrected electron optics and data acquisition schemes enable TEM delivering images of catalysts with sub-angstrom resolution and single-atom sensitivity [1,2]. On the other hand, parallel developments of differentially pumped electron microscopes and of gas cells enable time-resolved observations of catalysts in situ during the exposure to reactive gas environments at pressures of up to the one-atmosphere level and temperatures of up to several hundred centigrade [3-5]. In this contribution, I will outline how such instrumentation and methodologies can advance in situ studies of surface structures and reactivity in catalysis. Specifically, the concept of using low electron dose-rates in TEM, in conjunction with in-line holography and aberration-correction, is introduced to allow maintaining atomic resolution and sensitivity during non-invasive in situ observations of catalysts [3,6]. Moreover, a novel nanoreactor concept is demonstrated for directly correlating time-resolved, high-resolution TEM images of catalysts with concurrent measurements of their catalytic functionality under reaction conditions at the ambient pressure level [4-5,7]. These competences expand the applicability of TEM in catalysis and build a foundation for “live” observations of structure-sensitive functional behavior at the single–atom level and in catalytically meaningful environments. Extraordinary benefits are illustrated by in situ studies in e.g. water splitting, hydrotreating and automotive emission abatement catalysis [1-10].

References

[1] C.F. Kisielowski et al, Angew. Chemie. Int. Ed. 49, 2708 (2010)

[2] L.P. Hansen et al, Angew. Chem. Int. Ed. 50, 10153 (2011)

[3] J.R. Jinschek, S. Helveg, Micron 43, 1156 (2012)

[4] J.F. Creemer et al, Ultramicroscopy 108, 993 (2008)

[5] S.B. Vendelbo et al, Ultramicroscopy 133, 72 (2013)

[6] S.Helveg, C.F. Kisielowski, J.R. Jinschek, P. Specht, G. Yuan, H. Frei (2014)

[7] S.B. Vendelbo, C.F. Elkjær, H. Falsig, I. Puspitasari, P. Dona, L. Mele, B. Morana, B.J. Nelissen, R. van Rijn, J.F. Creemer, P.J. Kooyman, S. Helveg (2014)

[8] Z. Peng et al, J. Catal. 286, 22 (2012)

[9] S.B. Simonsen et al, J. Am. Chem. Soc. 132, 7968 (2010); J. Catal. 281, 147 (2011)

[10] L.P. Hansen, M. Brorson, E. Johnson, S. Helveg (2014)