Pressure Induced Effects During in situ Characterization of Supported Metal Catalysts

Nielsen, Monia R.; Liu, Xi; Wagner, Jakob B.; Damsgaard, Christian D.; Hansen, Thomas W.; Schumann, Max; Jensen, Anker D.; Christensen, Jakob M.

Publication date:
2018

Document Version
Peer reviewed version

Link back to DTU Orbit

Citation (APA):
Pressure Induced Effects During in situ Characterization of Supported Metal Catalysts

Monia R. Nielsen¹, Xi Liu³, Jakob B. Wagner¹, Christian D. Damsgaard¹2, Thomas W. Hansen¹, Max Schumann⁴, Anker D. Jensen⁴ and Jakob M. Christensen⁴

¹Center for Electron Nanoscopy, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark
²Department of Physics, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark
³SynCat@Beijing, Synfuels China Technology Co., Ltd, Beijing, 101407, China
⁴Department of Chemical and Biochemical Engineering, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark

A combination of different in situ techniques were used to investigate the activation and deactivation processes of supported metal catalysts such as α-Fe₂O₃ for Fischer-Tropsch synthesis and Rh based catalysts for the synthesis of higher alcohols. The pressure was varied between a few millibars and atmospheric pressure.

Iron-based catalysts are typically used commercially for Fischer-Tropsch synthesis, as they are cheaper than their cobalt and ruthenium-based counterparts [1]. Therefore, looking at their activation process is critical for gaining further insight on the nature of the active sites in order to further enhance their performance. α-Fe₂O₃, used as precursor for Fischer-Tropsch catalysts, is typically activated in either H₂, CO or syngas before synthesis reaction. As CO or syngas activation lead to iron carbides and iron oxides we look at the unsupported α-Fe₂O₃ precursors exposed to hydrogen to gain information about their evolution in time under in situ conditions. The activation involve interaction between the precursor, α-Fe₂O₃, and the surrounding gas constituents, in this case hydrogen, which is not only altering the morphology and surface structure but eventually also the catalytic performance.

To better understand the gas-induced shape evolution of the α-Fe₂O₃ precursor, we look at the activation process at different pressures. First, we look at low pressure (a few millibars) using a Cs-corrected FEI Titan 80-300 environmental TEM and a DENSsolution Wildfire S3 MEMS based heating holder, see Figure 1. Under these conditions, the catalyst can be reduced from Fe₂O₃ to Fe₃O₄ and finally to metallic Fe. In order to further understand what happens at higher pressure, a DENSolutions Climate system was used. Here the catalyst can be exposed to the same gas composition at pressures up to 1 bar. While reducing α-Fe₂O₃ to Fe₃O₄ and further to α-Fe, we aim to look into the shape evolution of iron and to demonstrate the difference that occur at different pressures, which is an important result of the influence of pressure in terms of obtaining the real structure-activity correlation for nanoparticles in reaction condition. Furthermore, since the high electron energies and current densities typically used in HRTEM measurements often causes beam induced dynamic processes, we also want to address some of the effects that occur at higher pressures.

In order to further understand pressure effects under in situ investigations of supported metal catalysts, strong metal support interactions (SMSI) were investigated on Rh based catalysts for the synthesis of higher alcohols, see Figure 2.

Reference:

Figure 1. Iron oxide particles showing the general structure, currently in the Fe$_2$O$_3$-state.

Figure 2. Rh particles on a TiO$_2$ support illustrating the strong metal support interaction (SMSI).