Growth Dynamics of Layered Carbon Studied by In Situ Environmental Transmission Electron Microscopy

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Nanostructured carbon materials are predicted to play a major role in future electronic applications. Cheaper and smaller components with improved or new functionality and lower power consumption are necessary, where conventional materials reach their limitations. Devices based on layered carbon materials, such as graphene or multilayer graphene, open for a giant technological leap in electro and optical performance. A cheap way to synthesize such materials on a large scale is chemical vapor deposition (CVD) growth on catalyst films like copper or nickel. However, the growth processes and the control of these is still not completely understood.

We present *in situ* transmission electron microscopy (TEM) experiments in a FEI Titan 80-300 Environmental TEM (ETEM) for studying the growth of layered carbon materials on these catalysts. The ETEM allows imaging with controlled gas environments around the sample up to a few mbar. In combination with a MEMS-based heating holder, growth of layered carbon materials is systematically studied at the atomic level.

NiO particles in the size range up to a few hundred nm are used as model material for the large-scale growth, as they provide a small surface curvature and mimic the native oxidized Ni surface found in conventional Ni thin films. The particles are reduced in the microscope under H_2 at 500-600°C in order to form a catalytically active Ni surface. Introducing carbon precursor gas at elevated temperature leads to growth of layered carbon. By following the appearance of carbon layers, the layer growth rate as well as the growth rate of individual graphene layers on the Ni surface can be determined directly from the ETEM observations.
These results add to a better understand the growth mechanism and help to control and optimize the formation process.