Advanced TEM techniques : 3D and operando views of the materials at the nanoscale

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Research on nanomaterials is burgeoning because of their numerous and versatile potential applications in the domains of catalysis, energy storage, environment. Optimizing their properties requires in-depth analysis of their structural, morphological and chemical features at the nanoscale. In a transmission electron microscope (TEM), combining the various imaging and spectroscopic modes with the 3D approach as well as with the possibility to perform in-situ analysis, provides a complete fundamental insight on the relationship between their nanoscale features, their properties of interest and their dynamical behavior. A special focus is put here on three techniques: in-situ electron microscopy (EM), quantitative 3D tomography and operando environmental TEM and their interrelations. The in-situ TEM is a powerful technique adapted for assessing the evolution of complex systems in real time, the electron tomography (ET) gives access to quantitative measurement of specific parameters in nano-objects such as specific surfaces, porosities, specific volume, and even their 3D chemical composition, whilst the latter offers an elegant solution for assessing materials behavior in given environments and under realistic reactions conditions. In the field of the heterogenous catalysis, the analysis of the reaction products by a RGA (Residual Gas Analyser) system simultaneously to the in-situ environmental TEM study allows us to correlate the microstructural changes in the catalysts with the catalytic activity and selectivity. In this general context, it is the aim of this contribution to explore through highlighting examples the potential of TEM techniques and the recent progress in the use of TEM to fulfill the gap between the development of new nano-architectures, their characterization as well as their subsequent properties.