SI traceable characterization of nanomaterials by X-ray spectrometry

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The development of new materials and the assessment of nanomaterials require the correlation of the materials' functionality or toxicity with their chemical and physical properties. To probe these properties, analytical methods that are both sensitive and selective at the nano- and microscales are required. The reliability of most analytical methods is based on the availability of reference materials or calibration samples, the spatial elemental composition of which has to be as similar as possible to the matrix of the specimens of interest. However, there is a drastic lack of reference materials in particular at the nanoscale. PTB addresses this challenge by means of a bottom-up X-ray analytical method where all instrumental and experimental parameters are determined with known contributions to the uncertainty of the analytical results. This *first-principle based approach* does not require any reference materials but a complete characterization of the analytical instruments' characteristics and, in addition, knowledge on the X-ray fundamental parameters related to the elements composing the sample. SR based X-ray spectrometric methods allow for the variation of the analytical sensitivity, selectivity, and information depth needed to effectively reveal the spatial, elemental, and chemical specimen parameters of interest. Examples of particle characterization, interfacial speciation, elemental depth profiling, as well as layer composition and thickness characterizations in advanced materials will be given. Recent instrumental achievements provide access to liquids, liquid-solid interfaces as well as the *in-situ* and *operando* elemental analysis and chemical speciation of nanoscaled battery materials. X-ray spectrometry under grazing incidence is capable to reveal analytical and dimensional information from layered systems and particles deposited on surfaces.

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