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Complex Nanostructured Materials

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Today's advanced materials are coined by structural, chemical and functional properties that require combined approaches of cutting-edge methods for their characterization. In order to determine the structures on multiscales several techniques have to be combined synergistically, e.g. atomic resolution transmission electron microscopy (TEM), X-ray- and Synchrotron-based analyses. In this contribution several complex nanostructured materials will be discussed in respect to their real structure – property relationships. In case of multilayer materials the design of sensor devices is enabled via tuning of their layered components. For instance, ultra-thin films of FeCo have been magnetically decoupled by layers of TiN to ensure high thermal stability, soft magnetic behavior and a coercive field strength scaling with the individual FeCo layer thickness. In the field of thermoelectrics, chalcogenide-based multilayers are known as the materials of choice for achieving ultralow thermal conductivity. Moreover, these materials are of great interest for fundamental research as demonstrated by the discovery of novel transition metal based heterostructures. In case of telluride based phase change materials, the interfaces between the nanolayered components themselves are establishing the device function. Via *in situ* TEM the atomic processes and defect dynamics interrelated to switching can be examined, enabling the characterization of switching mechanisms. More complex nano-architectures can be produced by dedicated syntheses as demonstrated for spark plasma sintered chalcogenides and the laser ablation synthesis of bimetallic core-shell nanoparticles. In the latter case the bimetallic particles, e.g. for the system Au-Fe, can be used as templates for etching experiments thus enabling the preparation of highly porous Au nanoparticles with well-defined porosity distribution.