Design of materials properties by microstructure and external fields

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The mechanical, physical and chemical properties of materials are determined by their microstructure. Modern materials science uses the complex interplay of defects, such as impurities, phases, point and line defects and interfaces, to tailor properties and obtain high-performance metallic alloys and ceramics. In this approach of materials design, properties can only be changed by modifying their microstructure, for example by initiating grain growth during annealing at elevated temperatures. Such a behavior, that fixes the properties irreversibly to the microstructure, is advantageous for many applications of materials, where long-term stability of the properties is required. Recent examples for designing materials properties will be presented, nanoglasses, cluster-deposited glasses and high entropy oxides.

In contrast, tuning using external fields, i.e., electric, offers completely new opportunities for the fully reversible control of materials properties. Such tuning of physical properties will be demonstrated for several nanostructures, i.e. (epitaxial) thin films, nanoporous, nanoparticulate structures and nanowires. Tuning can be either achieved using dielectric/ferroelectric gating, well known from semiconductor physics, or by electrolyte gating using liquid or solid electrolytes. Furthermore, using electrochemical ion intercalation, fully reversible properties with substantially larger effect magnitude can be achieved.

Finally, the concepts employed for tuning properties of nanostructures can be employed in applications as well. As an example, field-effect transistors based on inorganic nanoparticles as the channel material and solid electrolyte for the gating will be described.