**Nanostructured bulk steels**

Dierk Raabe, Max-Planck Institut für Eisenforschung, Düsseldorf, Germany

Developing strong, damage-tolerant, and functional steels shapes the backbone for industrial innovations in manufacturing, energy, transportation, and safety. Examples are Fe-Cr steels for emission-reduced turbines; weight reduced and ultra-high strength Fe-Mn-Al steels for light-weight and safe mobility; magnetic Fe-Si steels for low-loss electrical motors and generators; or stainless steels for power plants. These examples document the necessity of developing improved high strength and yet ductile steels. Most traditional hardening mechanisms, however, such as enabled by solutes, dislocations, or precipitates, albeit leading to high strength, often reduce ductility rendering the material brittle and susceptible for failure. This phenomenon is sometimes referred to as the inverse strength-ductility problem.

Reduction the grain size offers a pathway for increasing both, strength and toughness. Here we develop this concept further in that we combine this strategy with the manipulation of individual interfaces by grain boundary segregation and even local phase transformation. More specific, we enable grain boundaries in steels not only as barriers against dislocation motion but also as regions where segregation and nanoscale phase transformation occur. Such locally transformed regions can act as compliance layers impeding for instance crack penetration among lath martensite lamellae.

* Duarte MJ, Klemm J, Klemm SO, Mayrhofer KJJ, Stratmann M, Borodin S, Romero AH, Madinehei M, Crespo D, Serrano J, Gerstl SSA, Choi PP, Raabe D, & Renner FU, II. Element-Resolved Corrosion Analysis of Stainless-Type Glass-Forming Steels. Science 2013; 341: 372-376.
* Raabe D, Sandloebes S, Millan J, Ponge D, Assadi H, Herbig M, & Choi P-P. Segregation engineering enables nanoscale martensite to austenite phase transformation at grain boundaries: A pathway to ductile martensite. Acta Materialia 2013; 61: 6132-6152.
* Herbig M, Raabe D, Li Y, Choi P, Zaefferer S, Goto S, Atomic-Scale Quantification of Grain Boundary Segregation in Nanocrystalline Material, Phys Rev Letters 112, 126103 (2014)

