Transformation induced inhomogeneity and its effects on creep, fatigue and deformation of titanium alloys

Rui Yang

Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, China

The nature and pattern of inhomogeneity determine the mechanical behavior of alloys to a large extent, and design of structural materials usually centers on optimizing the size and distribution of these inhomogeneities so as to control the critical stress and pace of plastic deformation under load. Understanding how these inhomogeneities form and evolve is part of the microstructural frontier. The theme of this talk is how plastic deformation interacts with and is interrupted by inhomogeneities that are already present or formed during loading, drawing examples from titanium alloys.

Gamma titanium aluminides are beginning to be used to make aircraft engine blades and future engines require increased creep strength. Nb addition is very effective in strengthening TiAl but for a long time the predominant mechanism is not clear. Recent first principles computation suggests the switch of sublattice occupancy of Nb, with increasing content, from the Ti- to Al-sublattice, forming short range order in addition, thus improving creep resistance. The sublattice short range order also provided embryos for a range of omega type transformations. Electronic modeling helps to clarify the relative stability of these phases and to understand why the addition of Mo hinders their formation, thus playing an important role in the design and optimization of next generation, creep resistant titanium aluminide alloys.

Near alpha titanium alloys for high temperature application experience significant drop in fatigue life under cold dwell condition. It has long been known that microstructure, microtexture and stress level are the main factors influencing dwell sensitivity, but it was revealed only recently how the microtexture was influenced by microstructure and why two commercial alloys, which differ only by 4 wt.% Mo, exhibited drastically different dwell sensitivity. While several crystal plasticity modeling investigations have been conducted on this subject, the atomistic mechanisms of crack initiation are still elusive. A first attempt at molecular dynamics simulation of the crack nucleation at twin boundaries will be presented and its relevance to dwell fatigue discussed.

In beta type titanium alloys several metastable phases, often stress-induced and therefore reversible, may compete to form and grow during loading, markedly changing elastic properties and modifying stress-strain behavior. The stability of these phases can be estimated by first principles computation. By ignoring the nucleation of multiple martensitic phases at the nano scale and by employing the mean field concept and the embedded-atom method, an interatomic potential was constructed for a typical alloy. Molecular dynamics simulations showed that the potential is capable of reproducing various manners of plastic deformation, e.g., dislocation nucleation and propagation, deformation twinning, and phase transformation. Regarding high strain rate deformation, a new mechanism of twin nucleation, facilitated by the reversible transformation from the omega to the bcc phase in beta titanium alloys, was proposed and supported by both experimental observation and results of first principles computation.