Extra strengthening and work hardening in gradient nanotwinned metals

With the support by the National Natural Science Foundation of China, a collaborative study by the research groups led by Prof. Lu Lei (卢磊) from the Institute of Metal Research, Chinese Academy of Sciences and Prof. Gao HuaJian (高华健) from Brown University demonstrates an extra strengthening and work hardening in the gradient nanotwinned metals, which was published in *Science* (2018, 362(6414): 559).

The gradient structures exist ubiquitously in the natural materials such as shells, bones and trees, and exhibit a high strength and a good toughness to help creatures survive from the natural damages. These ingenious gradient structures shed a light on developing the high performance metals through tailoring their microstructures, considering that the high strength and good ductility are usually mutually repulsive through the conventional strengthening strategies, such as cold deformation, grain refinement and solid solution. However, it has been a big challenge to introduce gradient structures, especially with a large structural gradient, into materials and understand the structural gradient-related strengthening mechanism.

The authors synthesized the gradient nanotwinned (GNT) Cu samples with a wide range of structural gradients (in both the twin thickness and grain size that span across the entire thickness of the sample) by means of direct-current electrodeposition. Their findings indicate that simultaneous enhancement in strength and work hardening can be achieved by solely increasing the structural gradient in GNT Cu. The maximum structural gradient leads to both improved strength and work hardening that can even exceed the strongest component of the gradient microstructure, an unusual phenomenon that has never been reported in the existing literature on gradient metals and alloys. The extra strengthening is attributed to the unique patterning of geometrically necessary dislocations in the form of bundles of concentrated dislocations uniformly distributed in grain interiors with the help of the combination of both microstructural characterizations and parallel large scale atomistic simulations.

The GNT strengthening concept proposed in this work provides insights into combining structural gradients at different length scales in order to push forward the strength limit of materials and may be essential to creating the next generation of high strength-ductility metals.

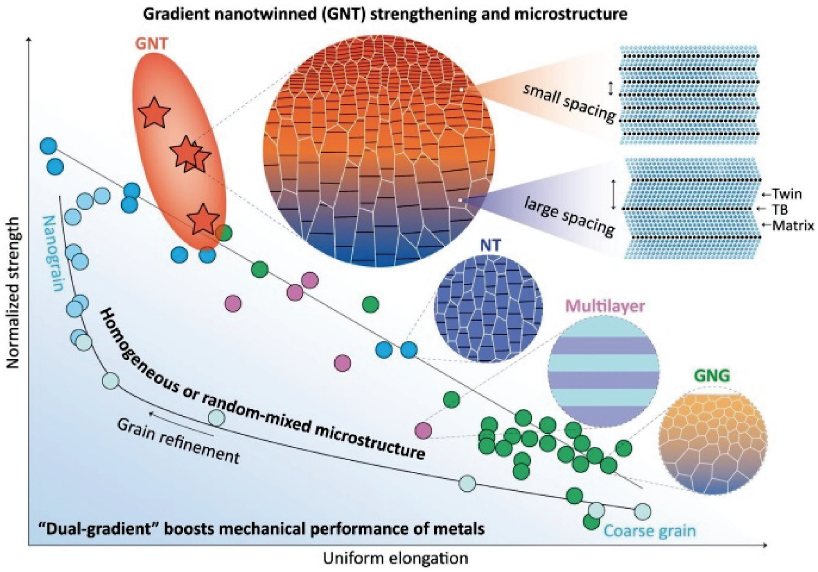

Figure Highly tunable structural gradient for extra strengthening and ductility in metals.