Novel supercritical elasticity in NiCoFeGa single crystals

With the support by the National Natural Science Foundation of China, the research group led by Prof. Wang YanDong (王沿东) at the Beijing Advanced Innovation Center for Materials Genome Engineering, State Key Laboratory for Advanced Metals and Materials, University of Science and Technology Beijing, successfully designed a novel supercritical elastic alloy, which exhibits supercritical elasticity with nonhysteresis and small temperature dependence over a wide temperature range. The results were published in *Nature Materials* on March 16, 2020 (doi: https://doi.org/10.1038/s41563-020-0645-4).

Elastic components have wide applications ranging from daily life to aerospace field due to its large recoverable stain. Superelasticity, which refers to the ability to achieve much larger recoverable strains (~8%) than conventional metals and alloys, is known to appear in shape memory alloys possessing a first-order martensitic transformation (MT) when a uniaxial stress is applied. However, the nature of the first-order stress-induced MT implies a pronounced hysteresis between the loading and unloading processes. The hysteresis is detrimental to the recoverability of the mechanical energy, the stability of the functional behaviors and the precision of the displacement control. Eliminating the hysteresis is the real holy grail for the practical application of superelastic alloys.

In 2012, Wang's group introduced a lot of hexagonal cobalt in NiFeGa alloy; the thermally induced MT was completely suppressed, but the stress-induced superelastic hysteresis still existed (*Europhys Lett*, 2012, 98: 46004). Through data analysis and seasonable assumption, Wang's group proposed a novel design strategy to achieve a non-hysteretic superelasticity, which involves the key question that is the introduction of an atomic-level entanglement of ordered and disordered structures. The entangled structure will not just hinder the dislocation movement, but rather suppress the first-order MT. After ingenious alloy design and thermal treatment, the entangled state has been realized in NiCoFeGa alloy, which exhibits an unprecedented non-hysteretic superelsticity over a wide temperature range from 123 to 423 K. The *in-situ* synchrotron X-ray diffraction measurements demonstrate that the non-hysteretic elasticity originates form the stress-induced continuous lattice parameter change, rather than the jump-like first-order phase transformation strain. We denote this particular type of elasticity as supercritical elasticity.

The phenomenon of "supercritical elasticity" is similar to that of supercritical fluids. When the temperature and pressure of water are above its thermodynamic critical point, it enters a supercritical condition, where distinct liquid and gas phases do not exist. It can effuse through solids like a gas, and dissolve materials like a liquid. This supercritical phenomenon has been widely used in chemical and pharmaceutical fields. In the field of condensed matter physics, many important phenomena such as superconductivity and superfluidity are closely related to this supercritical transition. The discovery of supercritical elasticity in the NiCoFeGa alloy challenges the classic theory of martensitic transformation and has broadened the research area of superelastic alloys. Furthermore, the proposed design strategy, introducing atomic-scale entangled structures, may bring out other unexpected behaviors in condensed matter physics.

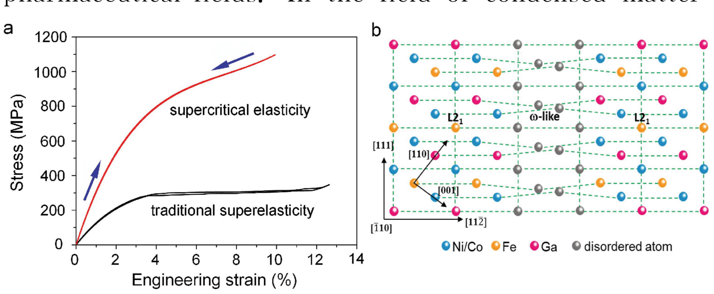

Figure (a) The comparison of the traditional superelasticity and the supercritical elasticity; (b) the schematic illustration of atomic-scale entangled structures.