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In-situ diffuse scattering experiment on stress-induced ferroelastic transformation in Ti-15Nb-2.5Zr-4Sn

Research to optimize the biocompatibility of titanium alloys for orthopaedic applications focusses on minimizing the Young's modulus of quenched, β-phase (Im-3m) titanium by adjusting the concentration of β-stabilizing elements. Ti-15Nb-2.5Zr-4Sn has the lowest Young's modulus yet measured in any forged titanium alloy of less than 50 GPa. This composition also possesses a controllable thermal expansion coefficient that is influenced by prior plastic deformation and it is superelastic over a very wide temperature range. There is pronounced non-linear elasticity and asymmetric response to strain, associated with the stress induced, ferroelastic transition between the bcc β-phase and α" (Cmcm) martensite phase. The potential to tailor these remarkable properties to specific applications, as well as further progress in superelastic alloy development require a clear microscopic understanding of the underlying physical effects. Therefore, to investigate these "pre-martensitic" phenomena and quantitatively explain the non-linear elastic responses we carried out in-situ measurement of β-phase Ti-15Nb-2.5Zr-4Sn single crystals on ESRF beamline ID15B, equipped with a large position-sensitive detector and rotating load rig, that allows single-crystal x-ray scattering measurements with crystals as thick as several millimetres with simultaneous application of compressive or tensile stress.
The results give a detailed picture of the large bcc crystal as it approaches and progresses through the structural transformation. Domains of ferroelastic α" and also ω instabilities form in response to the temperature and the direction and magnitude of the applied stress. We present these results and discuss some of the challenges of developing a quantitative interpretation of the data, an important one being how to properly treat coupling between elastic deformation and correlated structural distortions.

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