Deformation-induced phase transformations in metastable β-Ti alloys

Pereloma E, Naseri R, Mitchell D. R. G., Casillas G., Ahemed M, Gazder A. A., Saleh A. A.

Metastable β-Ti (body centred cubic, bcc) alloys exhibit a unique combination of strength and ductility as they accommodate deformation via stress-induced phase transformation, twinning and slip. The matrix bcc β phase typically transforms during loading to α'' martensite (orthorhombic) and ω (hexagonal) phases. The relative activities of the operative deformation mechanisms depend on several factors including the stability of the β phase, loading path and deformation conditions (temperature and strain rate).

In the present ongoing research project, various in-situ and ex-situ experimental techniques are used to evaluate the effects of the β matrix characteristics, strain, loading path (tension, compression and cyclic tension-compression) and strain rate on the microstructure evolution and the associated deformation mechanisms in metastable β Ti-V-Fe-Al alloys. Detailed microstructural characterisation was undertaken using high resolution scanning transmission electron microscopy and electron back scattering diffraction. The electron microscopy studies revealed the formation of a relatively small fraction of ω phase within the β matrix, at β/α'' martensite interfaces and within deformation twins. At the same time, the formation of primary and secondary α'' martensite was much more prolific but its extent was affected by both the loading path and deformation conditions. It was found that with increasing β phase stability (by introducing increasing fractions of α (hexagonal close packed, hcp) phase in the initial microstructure), the deformation mechanisms during tension change from the dominant formation of α'' martensite + twinning in addition to slip to α'' martensite + slip. Contrarily, the formation of α'' martensite becomes more restricted during compression as the β phase stability increases. The effect of higher strain rates on the stress-induced phase transformation is similar to increasing the β phase stability with enhanced deformation twinning activity. The underlying reasons for the observed mechanisms will be discussed in detail. Lastly, in-situ neutron diffraction during cyclic tension-compression loading (±2% strain) of fully β microstructure revealed a significant tension-compression asymmetry (with the maximum stress in compression always higher than tension) along with a pronounced strain recovery during unloading. The former is associated with easier α'' martensite formation under tension than compression, whereas the latter suggests that reverse transformation of α'' martensite back to the β matrix could be occurring during load reversal.