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[1] Anisotropy in the plastic flow properties of single crystal alpha Ti determined from micro cantilever beams J Gong and AJ Wilkinson, Acta Materialia, (2009), 57, 5693-5705 [2] A microcantilever investigation of size effect, solid-solution strengthening and second-phase strengthening for prism slip in alpha-Ti, J Gong and, AJ Wilkinson, Acta Materialia, (2011), 59, 5970-5981

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Ultra Small Scale High Cycle Fatigue Testing by Micro-cantilevers

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A new method has been developed for testing high cycle and very high cycle fatigue properties of materials at the micro-scale based on micro-cantilevers. Focused ion beam was employed to cut micro-cantilevers on the surface of a selected grain in a bulk polycrystalline commercial pure Titanium. The bulk specimen was pre-examined by EBSD, so the crystal orientation of all micro-cantilevers were known. The bulk sample with prepared micro-cantilevers was then attached to a high power ultrasonic generator, which can generate mechanical vibration at the frequency 20KHz. The bulk specimen moves with the ultrasonic generator, but the micro-cantilever lags somewhat behind. The resulting deflections generate cyclic stress in the micro-cantilevers. The high vibration frequency means it can easily test into the high cycle and very high cycle regime. The design challenge is to generate enough stress to cause fatigue in these ultra-small specimens because the stress amplitude achieved in vibration is inverse to the cantilever size. Previous finite element model and experiments had shown that the classic micro-cantilever with uniform cross-section [1,2] can only generate stress a few MPa, even with the acceleration was tuned up to 10^7m/s^2. Instead, we designed a new 'hammer' shape micro-cantilever as shown in Figure 1a to increase the inertia. This design now generates sufficient stress and enables fatigue testing even in Titanium, which is a challenging material due to the high strength to weight ratio (both high strength and low density require higher acceleration).

SN curves in the testing range from 10^5 to 10^8 cycles have been obtained for these micro- single crystal Ti samples using a step test protocol. The stress to failure decreases systematically as the number of cycles to failure increases. However, there is strong dependence on the crystal orientation with the fatigue strength at 10^7 cycles for test pieces cut along the <c> direction being approximately twice that of those cut in the <a> direction. The fatigue strength of micro-fatigue test is significantly lower than the static strength measured on micro-cantilevers of identical size using a nanoindenter. Due to the small specimen size, it is suggested that the results reflect the behavior of fatigue nucleation rather than propagation.

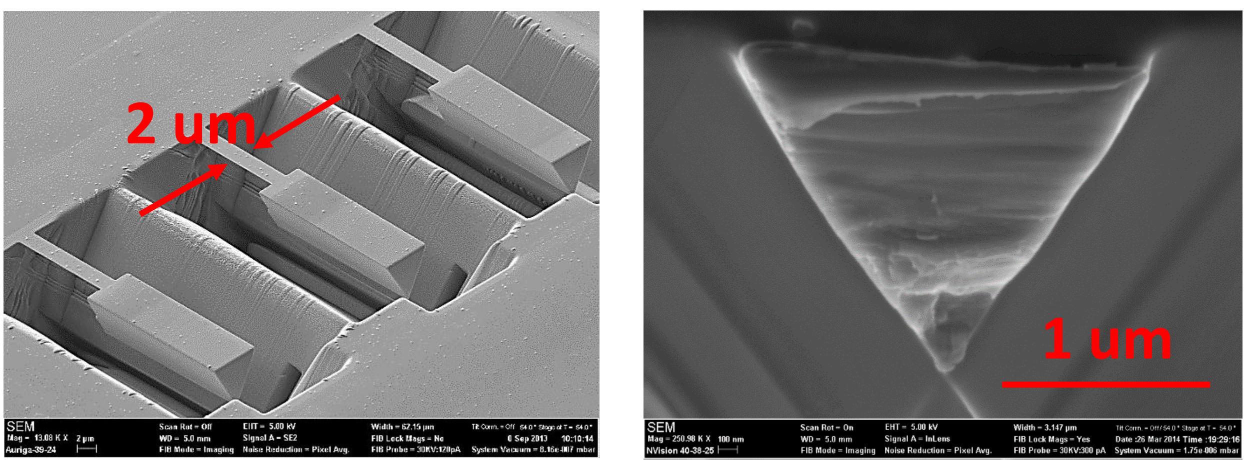

Figure 1 (a) Three micro-fatigue testing specimens prepared by focused ion beam; (b) fraction surface of one micro-fatigue cantilever after 10^6 cycles

References

[1] *Anisotropy in the plastic flow properties of single crystal alpha Ti determined from micro cantilever beams* J Gong and AJ Wilkinson, Acta Materialia, (2009), **57**, 5693-5705

[2] *A microcantilever investigation of size effect, solid-solution strengthening and second-phase strengthening for <a> prism slip in alpha-Ti*, J Gong and, AJ Wilkinson, Acta Materialia, (2011), **59**, 5970-5981