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Fracture strength testing at the micron-scale on an ultra-fine grained WCr10- Ti2 alloy

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The fracture strength of a W-Cr10-Ti2 alloy, manufactured through mechanical alloying and subsequent hot isostatic pressing, has been measured through means of micro-cantilever testing at the Culham Materials Research Facility. The material is a product of ongoing work into self-passivating Tungsten alloys at CEIT, Spain [1] and was chosen for this work due to its fine micro-structure (average grain size <500nm) and embrittling alloying elements. The fine micro-structure allowed the measurement of test volumes encompassing several thousands of grains. Whilst the fracture strength of conventional pure Tungsten has not previously been possible to measure at the micro-scale due to extensive plasticity, the increased brittleness of this alloy allowed un-notched micro-cantilever fracture testing. For this purpose un-notched, pentagon shaped cantilever beams with a width of 6-7μm and a depth of 3-4μm were milled in a FIB and tested with a load applied 23μm from the support. All tested beams failed spontaneously and catastrophically and showed a trangranular fracture surface. The average fracture strength from a set of 11 cantilever beams was measured as 6.4 GPa. The fracture strength shows a clear size effect at the micro-scale, with a decrease in strength measurement of 35% for a factor of three increase in the beam cross-sectional area.

Heavy ion implantations to a depth of 3.5μm and an average damage of 0.7 and 7dpa were conducted at RBI, Zagreb in order to assess the effects of nuclear fusion relevant irradiation damage on the fracture strength of the material. Nano-indentation with pile-up correction showed an increase in hardness of 10% and 15% respectively. Results from micro-cantilever testing showed an apparent increase in the elastic modulus with implantation. This is not yet fully understood but similar effects have been reported in work on pure Tungsten previously [2]. A decrease in fracture strength by 10% was observed after implantation to 0.7dpa. For the 7dpa implanted material a slight increase in fracture strength was measured. This however changes to a decrease of 15% when normalized to the nano-indentation measured elastic modulus. Explanations for both the increase in the elastic modulus as well as the proportional effect on fracture strength measurements will be discussed.

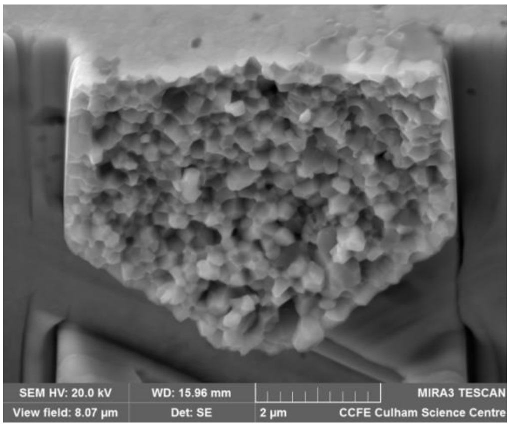

Figure 1 – Typical fracture surface

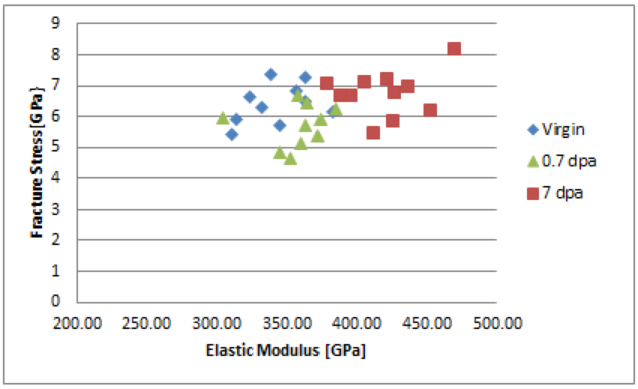

Figure 2 – Scatter plot showing increase in elastic modulus with implantation damage

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