

Ductilisation of tungsten (W)

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For tungsten (W), its tendency to fail at low temperatures by brittle fracture is a major limitation in its commercial exploitation. This raises the question of how to make tungsten ductile. The main challenges that need to be overcome are (i) lowering the brittle-to-ductile transition (BDT) temperature, (ii) improving the fracture toughness, and (iii) increasing the total elongation in a tensile test. Within this contribution we introduce our ductilisation approaches and present selected experimental results.

Our first ductilisation approach is the modification of microstructure through cold-rolling. By performing Charpy impact tests we were able to demonstrate that cold-rolling decreases the BDT temperature. The BDT temperature correlates with the grain size following a Hall-Petch-like equation. Our results suggest that the availability of dislocation sources (dislocation boundaries, grain boundaries; in particular IDBs and HAGBs) is the most important parameter responsible for the decrease of the BDT temperature (Fig. 1).

These results were confirmed by a study on the crack growth resistance (R) behaviour obtained by using the direct-current-potential-drop method: cold-rolling decreases the stable crack growth onset temperature. Stable crack growth is accompanied by crack bridging, which in turn is triggered by dislocation activity. The entire stable crack growth regime shows ductile intergranular fracture.

Furthermore we were able to reproduce the results presented by Wei and Kecskes [1]. Wei and Kecskes assessed the effect of low-temperature rolling (800°C (1073 K), 600°C (873 K), and 400°C (673 K)) on the room temperature tensile behaviour of pure tungsten. Their results show that the ductility (total elongation) increases with decreasing rolling temperature.

Severely cold-rolled ultrafine-grained (UFG) tungsten sheets possess even more exceptional mechanical properties (nearly no strain hardening, rate dependence of the flow stress above the knee-temperature, BDT at -196°C (77 K)). These issues will be focused on in the

contributions to this conference by S. Bonk et al. (Ductilisation of tungsten (W) through cold-rolling: Correlation of microstructure and mechanical properties in UFG-W sheets) and C. Bonnekoh et al. (Ductilisation of tungsten through cold-rolling: Fracture behavior of UFG tungsten sheets).

Our second ductilisation approach is the synthesis of a tungsten foil laminate. The motivation of the laminated composites is determine if a bulk material can be made that retains the ductility of the thin severe cold-rolled ultrafine-grained tungsten foils. Selected experiments displaying the Charpy impact properties and tensile properties (15.5 % total elongation at room temperature) will be discussed.

Tungsten foil laminates allow to assemble and to produce three-dimensional components such as pipes. The performance of tungsten laminated pipes in a high heat flux test is demonstrated (28 MW/m²). Finally we evaluate tungsten-copper laminates after irradiation in the High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory (ORNL), USA.

References:

- [1] Q. Wei, L.J. Kecskes, Effect of low-temperature rolling on the tensile behavior of commercially pure tungsten, Mater. Sci. Eng. A. 491 (2008) 62–69.

Figure:

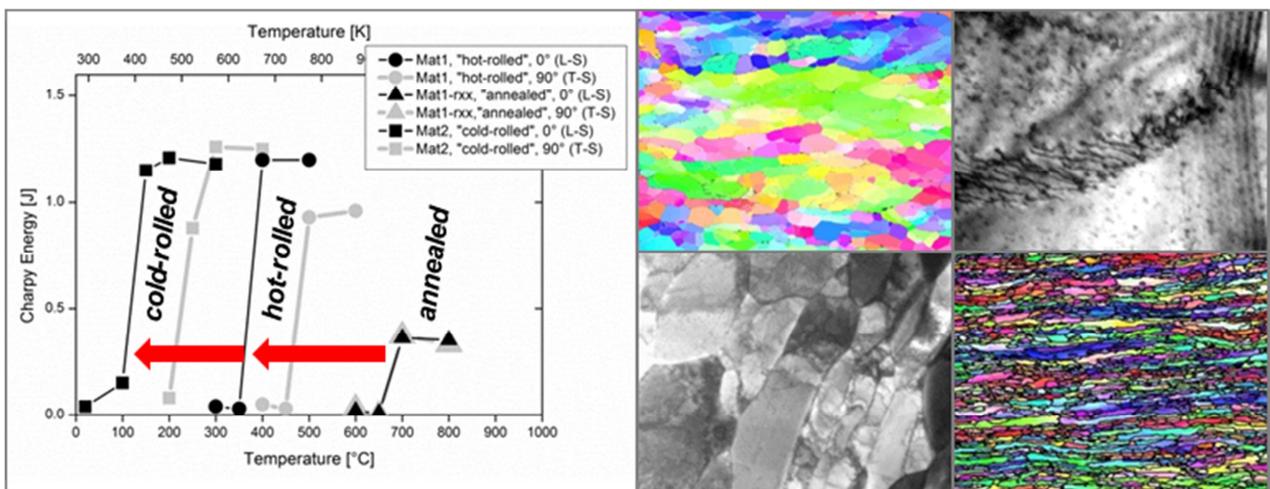


Fig. 1: The Charpy impact properties of tungsten plates can be improved by cold-rolling. A Cold-rolled tungsten plate possesses a lower brittle-to-ductile-transition temperature compared to its hot-rolled or recrystallised counterparts.