

## Fracture behavior of tungsten materials depending on microstructure and surface fabrication

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Present helium cooled DEMO divertor designs make use of the high temperature strength and good heat conductivity of refractory materials. In such outlines, structural parts of W-1%La<sub>2</sub>O<sub>3</sub> (WL10), for example, are used for operation temperatures between 600 and 1300 °C. Here the lower range is restricted by the transition to a steel part and the upper temperature limit is defined by the onset of recrystallization and/or loss of strength, respectively. The most critical issue of tungsten materials in connection with structural applications, however, is the ductile-to-brittle transition. But the microstructure of refractory alloys strongly depends on the manufacturing history. Therefore, the mechanical behaviour may be quite different, even if the chemical composition is the same.

A systematic screening study of impact bending properties of standard tungsten materials was performed to determine the influence of microstructure characteristics. Plansee provided five different tungsten rod materials: pure W, W-1%La<sub>2</sub>O<sub>3</sub> (WL10) in two different conditions, potassium doped tungsten (WVM), and WL10 with 1% Re. For comparison, plates of pure W, WL10, and WL10 with 1% Re were also used for fabrication of standard specimen (KLST type) and testing. Additionally, a molybdenum rod and plate, stabilized by Ti and Zr (TZM) was used as reference material.

It could be clearly seen that only specimens of the TZM rod show the classical embrittlement behaviour which is typical for most body-centred cubic structured metals: (1) there is a clear transition from brittle (at lower temperatures) to ductile (at higher temperatures) fracture (DBTT), and (2) there is an extended regime of ductile fracture (area of almost constant energy, the so-called upper shelf). But the results of the tungsten materials look quite different. Only specimens of pure and potassium doped tungsten show an upper shelf starting at about 900 °C. All other rod materials don't show pure ductile fracture within the whole test temperature range. However, all tested materials tend to brittle fracture at temperatures below 500 °C. But above that temperature, the specimens show cleavage fractures which propagate along the rod axis, that is, parallel to the specimen's long side and perpendicular to the notch.

Compared to the rod materials, two trends were recognizable after testing specimens of the plates: (1) the energies are lower by more than 50 %, and (2) there is a smaller but still significant difference in the specimen's orientation (parallel or perpendicular to rolling direction). Therefore, a distinct anisotropy of the microstructure can be assumed, even if it is not easily recognizable in the micrographs. The explanation for the severe reduction of charpy energy might also be found in the specific plate microstructure and, as a result, a specific fracture type which is called delamination.

In summary, there are four types of fractures (brittle, cleavage, ductile, delamination) while further examinations have shown that EDM fabrication produces microcracks at surfaces which certainly promote cleavage fracture.