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Creep and Recrystallization of Pure and Dispersion Strengthened Tungsten

Tungsten and selected W-alloys are considered to be the primary candidates for armour and structural materials of ITER and of even more ambitious DEMO divertor designs. But even dispersion strengthened W alloys could recrystallize during DEMO relevant exposure times in the temperature range where the structural material of advanced divertors must operate (up to about 1300 °C). A critical issue is the recrystallization of W-alloys and its interaction with aging time as well as elastic-plastic deformation during mechanical loading. To evaluate their applicability for the use as structural material, a special creep testing facility has been developed and implemented successfully (Fig.1). It allows for performing fully instrumented creep and creep rupture tests on selected reference W-alloys at typical temperatures of the divertor structural material. Pure tungsten and W-La_2O_3 (WL10) rods (Ø10 mm) were used for specimen fabrication. Aging tests and microstructural analysis of the materials as-delivered (Fig.2) have been performed. These have shown that pure tungsten rod material shows starting recrystallization at 1100 °C after 200 hours whereas the La_2O_3 dispersion strengthened tungsten material remains stable. Further, if not recrystallized, tungsten shows a very high plasticity at 1100 °C that leads to necking of more than 90 %. At the same condition WL10 shows less ductility (necking of only 20 %) but increased creep strength by about 10-20 % (Fig.3). At 1300 °C, creep strength of pure tungsten drops significantly (Fig.4) and shows severe recrystallization. First pores develop at grain triple points, and then cracks propagate along grain boundaries, which finally lead to inter-granular fractures (Fig.5). In conclusion one can say that oxide particles have only a slight strengthening effect (just 20 MPa for the case of La_2O_3 as shown in Fig.6) but they suppress recrystallization significantly by several hundred K.

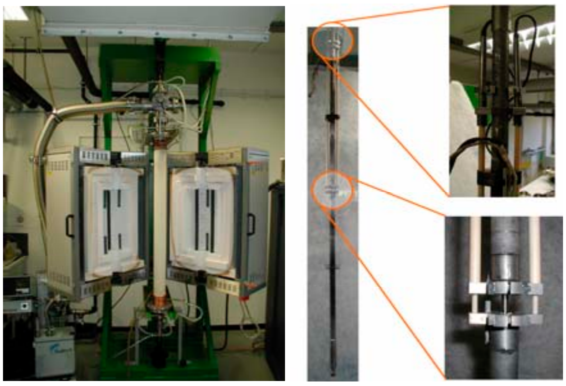

Fig.1: The high-temperature creep tests take place in a ceramics vacuum pipe. Elongation is measured by two strain sensors with help of ceramics rods.

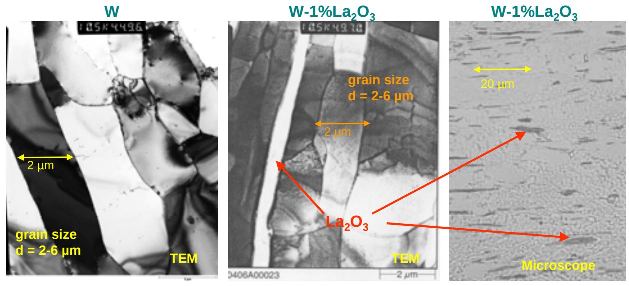

Fig.2: Microstructure of the materials as delivered by TEM and microscopic examination. Both materials show inhomogeneous grain size. The grains as well as the La_2O_3 particles are deformed along the rod axis due to forging during fabrication.

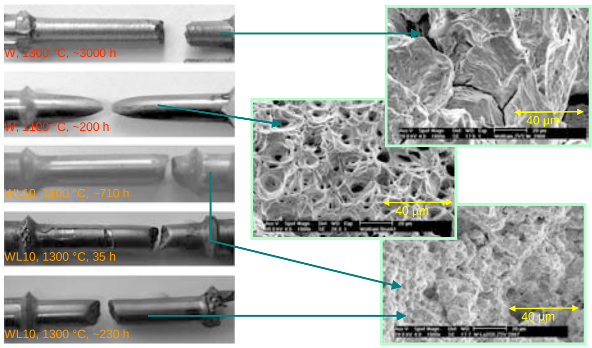

Fig.3: Only pure tungsten tested at 1100 °C shows the typical ductile behaviour (necking of more than 90 %). At 1300 °C after 3000 h tungsten is fully recrystallized. Therefore, the fracture looks quite different. Although the WL10 specimens show no recrystallization, the fracture surface seems to be different compared to that of pure tungsten at 1100 °C. But a closer look on the surface reveals also dimples. Therefore the different fracture appearance may be based on the La_2O_3 dispersoids, which reduce ductility and, therefore, lead to the different fracture surfaces.

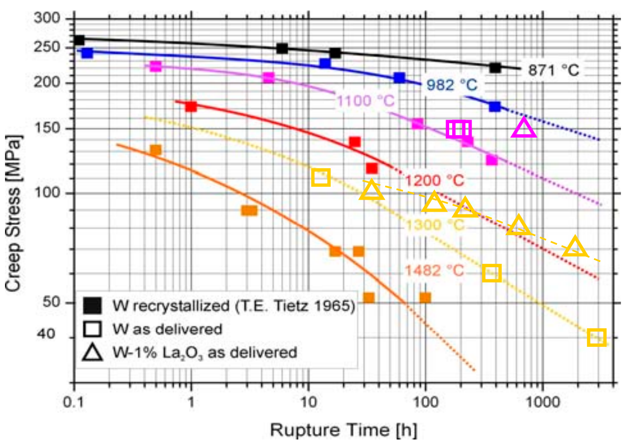

Fig.4: Own creep rupture test results (large open symbols) compared to those available from literature (small filled symbols). The dotted lines are highly speculative and have still to be confirmed by experiments

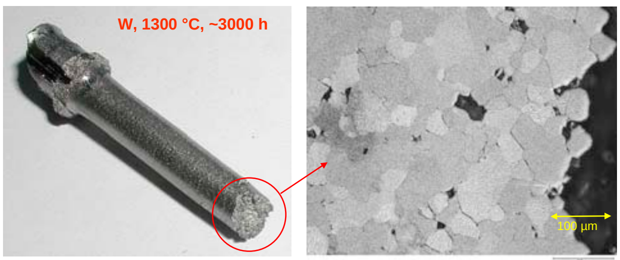

Fig.5: After about 3000 hours at 1300 °C the tungsten specimen is fully recrystallized. This is already visible to the naked eye due to the grainy surface appearance (left image). The fracture is initiated by pore formation at triple points and crack propagation along grain boundaries (right image).

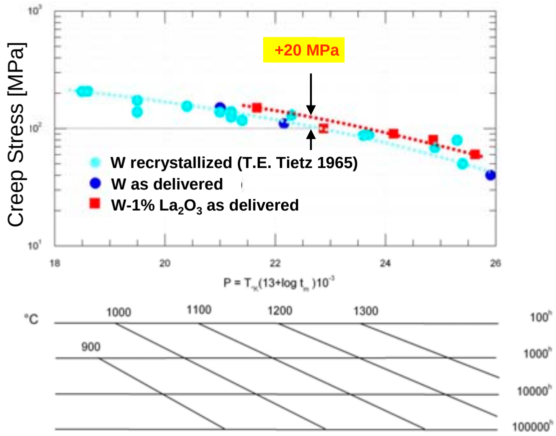

Fig.6: The Larson-Miller diagram shows clearly that oxide particles lead only to slightly improved creep properties. The gain in creep strength is just about 20 MPa.

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