-Hill, New York, 1953.

73.

Journal of the Less-Common Metals
Elsevier Sequoia S.A., Lausanne – Printed in The Netherlands

The effects of strain rate and pressurization on the ductile–brittle transition temperature of polycrystalline sintered tungsten

The ductility of polycrystalline body-centred cubic transition metals is well known to be sensitively dependent on temperature and many physical and metallurgical factors such as purity, grain size, strain rate and, for iron, chromium[1] and molybdenum[2], pressurization. The transition with decreasing temperature, T, from ductility to brittleness, defined as an absence of detectable macroscopic plastic deformation, we[3] shall refer to as *the* transition temperature, T_T. It is generally found that T_T increases with increasing strain rate, $\dot{\varepsilon}$, but a satisfactory formulation of this dependence based on theories of yielding and fracture does not appear to exist. Recently[4], we have postulated a phenomenological correlation between T_T and $\dot{\varepsilon}$ for molybdenum in which the transition occurs at a constant stress, σ_C. To apply this model it is also required that the stresses for yield, σ_Y, and brittle fracture, σ_F, are approximately continuous, known functions of T and $\dot{\varepsilon}$ in the transition region. The principal aim of this investigation was to see whether this simple model was applicable to sintered tungsten.

A difficulty in the study of brittle fracture of this material is the occurrence of "low-stress failures[5]". These are sometimes avoided (quite frequently at temperatures not more than 50°K below T_T) and brittle fractures take place at stresses at which it is predicted the material would yield, if it were ductile. At the transition temperature brittle fracture thus occurs at the yield stress and it appears that immediately below T_T this is, at least, approximately so.

Another aim of the investigation was to determine the effects, if any, of pressurization at 14 kbars on the ductile–brittle transition temperature. If polycrystalline specimens of the other Group VIA b.c.c. transition metals, chromium[1] and molybdenum[2], are subjected to a hydrostatic pressure of the order of 15 kbars irreversible effects on the mechanical properties at atmospheric pressure, *e.g.* lowering of T_T, are sometimes found.

Tensile test pieces of $\sim$18 mm gauge length and $\sim$2 mm gauge diameter were ground from two batches of $\frac{1}{4}$ in. diameter Sylvania sintered tungsten rod. One batch of over thirty specimens was used to investigate the effects of pressurization on T_T, and the other of over fifty specimens to study in detail the effect of strain rate on T_T. All the specimens were recrystallized to a grain diameter of $\sim 50\,\mu$ by heat treatments of 1 h at $\sim$1750°C in vacua of 10^{-6} torr. Then, before testing, the specimens were electropolished in a 2% NaOH solution at $\sim$9 V.

In tungsten the important impurities are thought to be the interstitials and accordingly analyses were carried out for oxygen, nitrogen, hydrogen and carbon. The analyses figures are: N_2: 1–2 p.p.m., H_2: < 1 p.p.m. and O_2: 3–8 p.p.m. by mass spectrometry (A.E.I.'s MS 10); O_2: 26–87 p.p.m. by conventional vacuum fusion; and C $\sim$1 p.p.m. by neutron activation.

The investigation of the effects of pressurization at 14 kbars (carried out by Harwood Engineering Co.) was performed on one batch of specimens on an Instron testing machine at strain rates of approximately 10^{-4}, 4×10^{-4}, 10^{-3}, 2×10^{-3} and 10^{-2} sec^{-1}. Further tests, on the other batch of specimens which were all not pres-