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The effect of dopant elements on the structure and high temperature creep behaviour of tungsten and molybdenum wires*

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The influence of minor additions of dopant elements on the recrystallization, grain growth and creep behaviour of both tungsten and molybdenum wires has been investigated. Microstructural examinations were conducted by light and by transmission electron microscopy and the creep behaviour evaluated through the use of resistively heated specimens possessing a helical coil geometry. The wires were processed from sintered ingots by swaging and drawing to the final size of 0.195 mm.

Tungsten and molybdenum were examined in the pure state, and also in wires doped with small additions of aluminium, potassium and silicon (AKS) and thoria. In the AKS materials the total dopant concentration was approximately 100 μg/g and in the thoriated tungsten 0.58 % by mass.

During thermo-mechanical processing the dopants are dispersed in such a way as to create linear arrays of dispersoids aligned parallel to the direction of working. In the thoriated metal the dispersoids existed as oxide particles (100–1000 nm), whereas in the AKS doped metals they took the form of small voids (5–100 nm) which originated from volatilization of the dopants, and potassium in particular. Microscopical evidence showed both the oxide and void arrays to be effective in pinning the grain boundaries, delaying recrystallization and thus extending the thermal stability of the ductile ⟨110⟩ fibrous grain structure within the as-drawn wires. At high temperatures, grain boundary depinning occurred but the arrays of dispersoids remained effective in promoting differential boundary migration rates and the development of non-equiaxed recrystallized grains. The morphology of the recrystallized grains was governed by the dispersoid size and spacing and the linearity of the dispersoid arrays. A small dispersoid size and spacing coupled with well defined arrays promoted recrystallized grains of high aspect ratio. Aspect ratios varied from about 1 in the dispersoid-free pure metals, to 5 for the thoriated tungsten, to 15 in the AKS-doped molybdenum and up to 30 for the AKS tungsten.

The creep performance was evaluated by conducting short-time constant-load tests on recrystallized specimens at temperatures between 1500 and 2500 °C. Creep strength and stress-sensitivity were significantly increased in both metals by the presence of the dispersoids and the generation of recrystallized grains possessing high aspect ratios. In the range 1500–2000 °C the stress dependence increased from $n < 2$ for pure molybdenum to $n = 3$–5 for the AKS doped metal. The pure tungsten exhibited a stress dependence of 3–5 in the range 1800–2500 °C, whereas for the thoriated tungsten $n = 12$ and for AKS tungsten n values as high as 38 were recorded. The high exponent values are in accord with data obtained with other dispersoid-strengthened systems.

The high creep strength of AKS doped tungsten and molybdenum was attributed to the combined effects of arrays of small voids and recrystallized grains of high aspect ratio. Both of these structural features appeared to retard dislocation creep and the diffusional creep processes.

* Extended abstract.