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Interfacial segregation and embrittlement in liquid-phase sintered tungsten alloys*

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When tungsten-rich W–Ni–Cu or W–Ni–Fe alloys are liquid-phase sintered the resulting microstructure consists of a continuous network of spheroidal tungsten single crystals embedded in a ductile f.c.c. Ni–Cu–W or Ni–Fe–W matrix. The mechanical properties of these particulate composites are controlled primarily by the relative strengths of the phases present and by the strengths of the interfaces developed between them. The impact strength of conventionally prepared material furnace-cooled from the sintering temperature (1430–1470 °C) may be approximately doubled by reheating to temperatures in the range 1150–1350 °C for 1–2 h and water quenching. Both optical and transmission electron microscopies have failed to reveal any significant change in microstructure accompanying this solution treatment and it seems likely that the inherent strengths of the tungsten–matrix and tungsten–tungsten interfaces are of major importance in controlling the impact properties. In brittle, furnace-cooled specimens fractured at ambient temperatures, failure occurs primarily along these interfaces and the fracture surfaces, particularly the areas of tungsten–tungsten impingement, have the smooth featureless appearance often associated with intergranular failure and commonly attributed to grain boundary segregation of impurity elements. The present study was thus initiated to investigate the possible contribution of interfacial segregation to the embrittlement of these alloys.

An Auger electron spectrometer equipped with fracture stage is being used to examine specimens fractured by slow bending at room temperature. The fresh fracture surfaces of specimens of a W–7.2 % Cu alloy (percentages by mass) furnace-cooled from the sintering temperature show strong phosphorus and sulphur Auger electron peaks. The impurity level has been confirmed to be the result of segregation by using argon ion sputtering to establish a profile of composition beneath the original fracture surface. A systematic study made of the effects of post-sintering heat treatment on the levels of contamination indicates that segregation is reversible and may essentially be eliminated by solution treating at 1350 °C for 2 h and water quenching. This treatment is accompanied by a noticeable change in fracture mode: a marked improvement in interfacial cohesion is evident, the matrix phase fails in a ductile manner and an increased fraction of the tungsten grains now fail by cleavage. Separation along the interfaces remains, however, the major component of failure and consequently enables an approximate comparison of the levels of impurity segregation to be made. A good correlation is observed between the improved impact properties and reduced levels of interfacial contamination and it seems likely that, in the absence of other detectable changes in microstructure, interfacial segregation of phosphorus and sulphur contributes significantly to embrittlement.

* Extended abstract.