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Microstructural evolution by heating at 1673-2373K in ultra-fine grained W-(0.25-1.5)%TiC consolidates

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Ultra-fine grained (UFG) W-TiC consolidates with nearly full densification are expected to be very promising for their use as divertors and structural materials exposed to irradiation environments because they exhibit good resistance to irradiations with fast neutrons, helium-ions and hydrogen-ions. In view of exposure to high heat loading on divertors, it is necessary to examine microstructural evolution due to high temperature heating in UFG W-TiC consolidates, which is closely related to recrystallization embrittlement. The objective of this study is to clarify how the microstructures in UFG W-TiC consolidates change with annealing at 1673-2373K, with emphasis on the effects of TiC additions and nano-sized Ar bubbles retained in UFG W-TiC consolidates fabricated by mechanical alloying (MA) in an Ar atmosphere.

UFG W-(0.25, 0.5, 0.8, 1.1, 1.5)%TiC (in wt%) consolidates were fabricated by powder metallurgical methods utilizing MA with 3MPDA (three mutually perpendicular directions agitation) ball mill in an atmosphere of purified H\textsubscript{2} (MA-H\textsubscript{2}) or Ar (MA-Ar), followed by hot isostatic pressing (HIP) at 1623K. Thin foils for transmission electron microscopy (TEM) observations were prepared from each of the as-HIPed consolidates and subjected to annealing in vacuum at temperatures from 1673 to 2373K for 3.6ks by radio-frequency induction heating. TEM examinations and EDX analyses were made using a JEM-2000FX and JEM-4000FX operating at 200 and 400kV, respectively.

It is shown that the as-HIPed specimens exhibit equiaxed grain sizes of 40 to 200 nm which decrease with increasing TiC addition, but the grain size tends to saturate around 1 wt% TiC addition. The nano-sized Ar bubbles in W-TiC with MA-Ar are observed in approximately half of the grains and provide a significant grain refinement effect: The grain size in W-TiC with MA-Ar is approximately half of that with MA-H\textsubscript{2}. Such Ar bubbles are retained even after heating at 2273K, indicating that they are very stable. It is also shown that as the TiC addition increases, the degree of microstructural changes is significantly suppressed. Such microstructural resistance to heating in UFG W-TiC is compared with that in the previously reported fine-grained W-(0.2-0.5)wt%TiC that was fabricated with MA-Ar and HIP processes at 2273K.

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