STABILITY OF FERRITIC MA/ODS ALLOYS AT HIGH TEMPERATURES

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The oxide dispersion strengthened (ODS) MA957 alloy was commercially developed for liquid metal fast breeder reactors due to its excellent high-temperature creep and tensile properties The use of ODS ferritic steels is also attractive for fusion reactor applications because of their potential for higher operating temperatures and for trapping helium at the dispersed oxide particles. Some similar tungsten-containing mechanically-alloyed ODS ferritic alloys (designated 12YWT (Fe-12.3 wt% Cr-3% W-0.39% Ti-0.25% Y_2O_3 [Fe-13.3 at. % Cr, 0.92% W, 0.46% Ti, 0.13% Y and 0.19% O])) have shown remarkable improvement in their creep properties at temperatures up to 850°C compared to the molybdenum-containing MA957 alloy. The purpose of this study was to investigate the microstructure of the MA957 alloy with atom probe tomography to determine whether this molybdenum-containing alloy also exhibited similar ultrafine Ti-, Y- and O-enriched particles and to determine the stability of the nanometer size particles during high temperature annealing treatments close to the melting point of the alloy.

The commercial MA957 alloy had a nominal composition of Fe- 14 wt % Cr, 0.9% Ti, 0.3% Mo, 0.1% Al and 0.25% Y_2O_3 [Fe-14.8 at. % Cr, 0.17% Mo, 1.0% Ti, 0.2% Al, 0.13% Y and 0.19% O] and contained trace levels of Mn, Si, B and C. This MA957 alloy was characterized in the as-received condition and after high temperature isothermal heat treatments at temperatures up to 1300°C (~0.85 T_m) for times up to 24 h.

Atom probe tomography revealed the presence of a high number density of 2-4 nm diameter titanium-, yttrium- and oxygen-enriched particles. These ultrafine particles were found to be extremely resistant to coarsening during isothermal aging at 1300°C. Significantly high oxygen levels were measured in the ferrite matrix in the as-received and isothermally aged materials. After high temperature annealing at 1300°C, transmission and scanning electron microscopy revealed partial recovery of the dislocation structure and the formation and coarsening of cavities. However, no significant grain growth was evident.

The solute distribution in the intragranular regions and the formation of the ultrafine Ti-, Y- and O-enriched particles in this MA957 alloy are similar to those found previously in 12YWT alloy indicating that the molybdenum or tungsten additions do not significantly change the intragranular precipitation. However, the Ti-, Y- and O-enriched particles had coarsened slightly more in this MA957 alloy as compared to the 12YWT alloy. This trend is consistent with the free energies of formation of the molybdenum and tungsten oxides. In addition, the molybdenum content in the MA957 alloy (0.17 at. %) is lower than the tungsten content (0.92 at. %) in the 12YWT alloy thereby providing a lower number of less efficient trapping sites. Therefore, the molybdenum addition may not be as effective as tungsten in retarding the coarsening process of the ultrafine particles. This difference in coarsening rate may also contribute to the inferior creep properties of the MA957 alloy compared to the 12YWT alloy.

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