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. Some mechanically alloyed (MA), oxide dispersion strengthened ferritic alloys have exhibited dramatically improved high temperature creep properties compared to other ferritic alloys [1].

The ultrafine-scale microstructures of three MA/ODS ferritic alloys (12YWT, 14YWT and MA957) have been characterized by atom probe tomography and electron microscopy to investigate the reason for the improved properties in these highly deformed alloys. The 12YWT alloy had a nominal composition of 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]. The 14YWT alloy that was developed at Oak Ridge National Laboratory had a composition of Fe-14.2 wt% Cr-1.95% W-0.22% Ti-0.25% Y_2O_3 [Fe-15.0 at. % Cr, 0.6% W, 0.26% Ti, 0.13% Y and 0.19% O]. 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. These alloys were characterized in the as-received condition, after extended high temperature creep tests, and after high temperature isothermal heat treatments at temperatures up to 1300°C (~0.85 T_m).

Atom probe tomography revealed the presence of a high number density of 2-4 nm diameter titanium-, yttrium- and oxygen-enriched particles in all three alloys. These ultrafine particles were found to be extremely resistant to coarsening during creep and isothermal aging at 1300°C, as shown in the atom maps of the MA957 alloy in Fig. 1. Significantly high oxygen levels were measured in the ferrite matrix in the as-received, crept and isothermally aged materials. Solute segregation of the alloying elements to the dislocations [1] and grain boundaries, Fig. 2, was also observed. Transmission and scanning electron microscopy were used to study the dislocation structure and to determine whether recrystallization had occurred during the high temperature annealing treatment. After annealing the MA957 alloy at 1300°C, partial recovery of the dislocation structure and the formation and coarsening of cavities was observed. However, no significant grain growth was evident.

The ultrafine particles and the solute segregation to the dislocations act to pin the dislocations and the stability of these nanoscale features may explain the improved high temperature mechanical properties. The lower molybdenum content in the MA957 alloy was found to be less effective in trapping oxygen at solute atoms than the tungsten content in 12YWT alloys and therefore, was not as effective in retarding the coarsening of the Ti-, Y- and O-enriched particles during high temperature annealing [2].

[1] M. K. Miller, E. A. Kenik, K. F. Russell, L. Heatherly, D. T. Hoelzer and P.J. Maziasz, *Mater. Sci. Eng. A.*, **A353** (2003) 140-145.

[2] Research at the Oak Ridge National Laboratory SHaRE User Center was sponsored by the Division of Materials Sciences and Engineering and the Office of Nuclear Energy, Science and Technology (I-NERI 2001-007-F), U.S. Department of Energy, under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

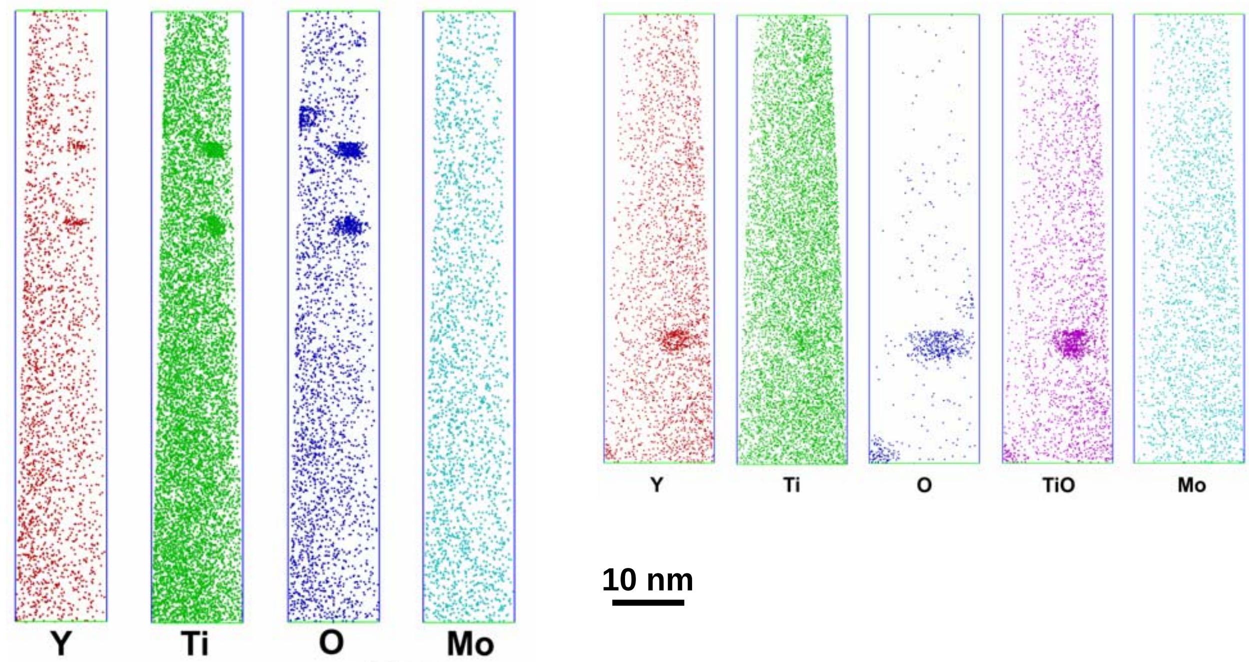

FIG. 1. Atom maps of ultrafine Ti-, Y- and O-enriched particles in MA957 alloy annealed for a) 1 and b) 24 h at 1300°C.

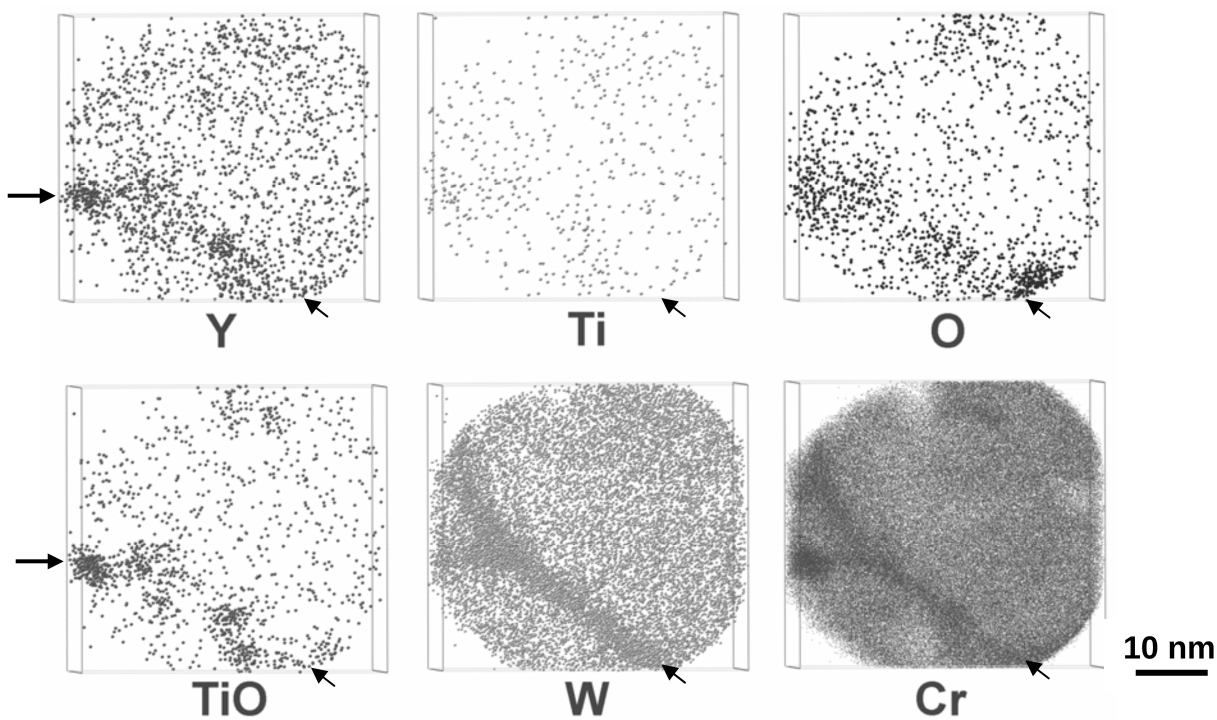

FIG. 2. Atom maps showing grain boundary segregation of chromium and tungsten and ultrafine Ti-, Y- and O-enriched particles in 14YWT extruded at 850°C.