Influence of the addition of Fe_2Y on the microstructure and tensile properties of ODS ferritic steels

J. Macías-Delgado[1], V. de Castro[1], T. Leguey[1], M. A. Auger[2], M. A. Monge[1], P. Spätig[3], N. Baluc[4] and R. Pareja[1]

[1]Departamento de Física. Universidad Carlos III de Madrid. 28911-Leganés, Spain
[2]Department of Materials. University of Oxford. OX1 3PH Oxford, United Kingdom
[3]Laboratory for Nuclear Materials-NES, 5232 Villigen PSI, Switzerland
[4]CRPP-EPFL, 5232 Villigen PSI, Switzerland

Abstract

Oxide dispersion strengthened reduced activation ferritic steels having Cr contents of ~14 wt% (ODS steels) are one of the leading candidates to become part of the structure of the first wall/blanket of future fusion reactors. In the case of ODS Ti-modified steels, it has been found that the (Y+Ti)-rich oxide dispersion formed is finer than the Y-rich induced in a Ti free steel. ODS steels have better creep resistance than their non-reinforced counterparts, but suffer from poor toughness. It is therefore vital to optimise the microstructure of ODS steels to achieve an improved mechanical behaviour. It has been shown that the use of intermetallic Fe_2Y powder particles instead of Y_2O_3 powder particles as precursor to the oxide nanodispersion in the reinforced steel, can improve considerably the impact properties[1]. However there exists little information about the mechanical behaviour of this material at high temperatures.

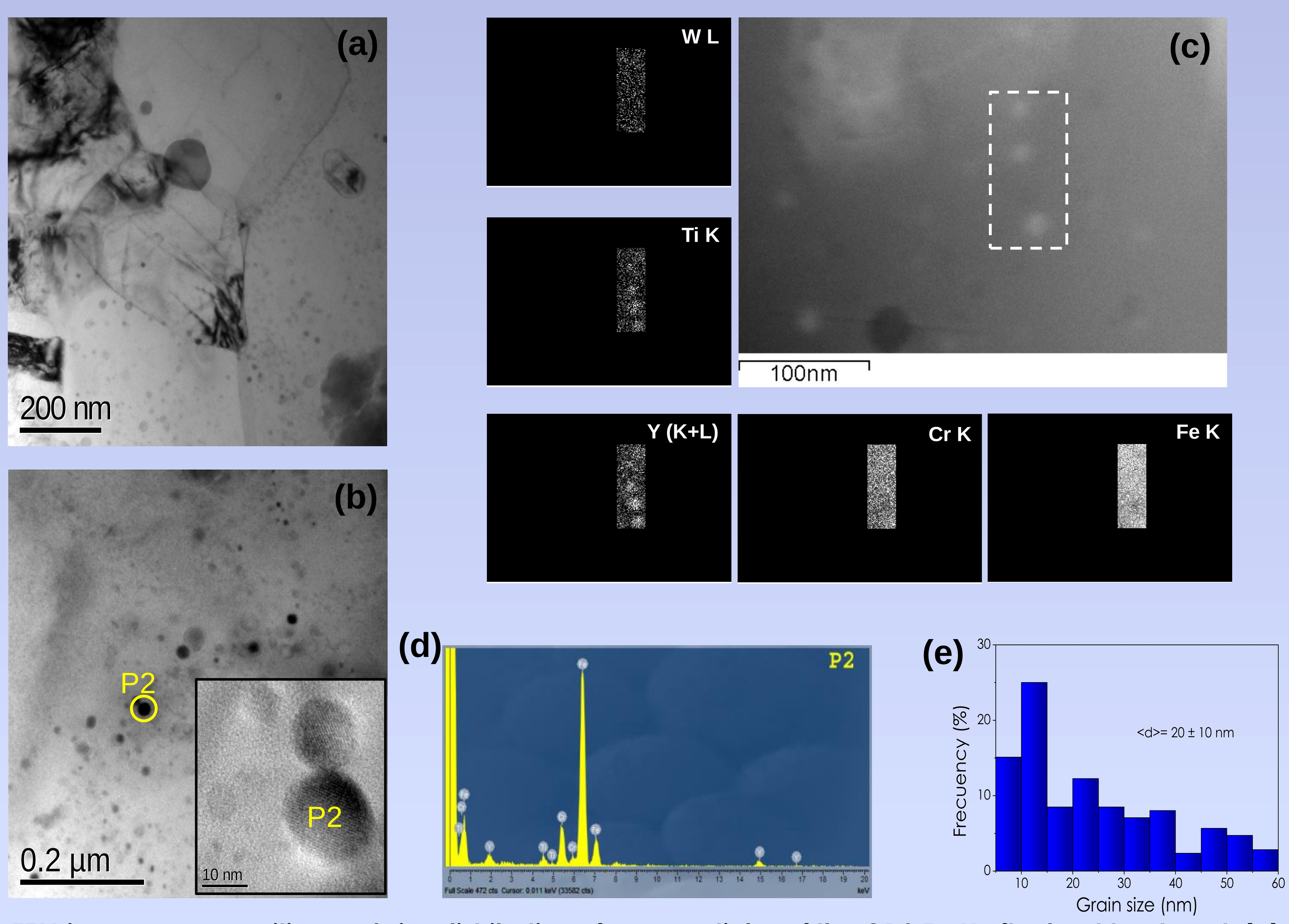
The aim of this work is the characterization of the microstructure and mechanical properties of an ODS ferritic steel with optimised oxygen content. An ODS ferritic steel has been produced by mechanical alloying of Fe–14Cr–2W–0.2Ti (in wt.%) prealloyed powder with 0.55% Fe_2Y intermetallic particles and consolidated by hot isostatic pressing (ODS Fe_2Y). Tensile properties and microstructural characteristics have been obtained and the results are discussed with respect to similar ODS ferritic steels produced using Y_2O_3 powder (ODS Y_2O_3)[2].

Experimental detail

The steel was produced by mechanically alloying Fe-14wt%Cr-2wt%W-0.3wt%Ti pre-alloyed powders and 0.55wt%Fe_2Y. Consolidation was performed by hot isostatic pressing (HIP). HIP samples were normalised for 30' at 1373 K and tempered for 2h at 1123 K. After heat treatment, the samples were analysed by Scanning Electron microscopy (SEM) and Transmission Electron Microscopy (TEM). The ODS steel was analysed using bright field TEM and high-angle annular dark field (S)TEM combined with X-ray dispersive spectroscopy (EDS). The desired homogeneous dispersion of Y-Ti-rich nanoparticles is attained. Microhardness was measured using a Vickers indenter with an applied load of 300 g for 15 s. Tensile tests in the temperature range 298-973 K at a constant crosshead rate of 0.1 mm/min were performed on flat tensile specimens. Above room temperature, the tests were performed with the specimens under a flow of pure Ar to minimize surface oxidation.

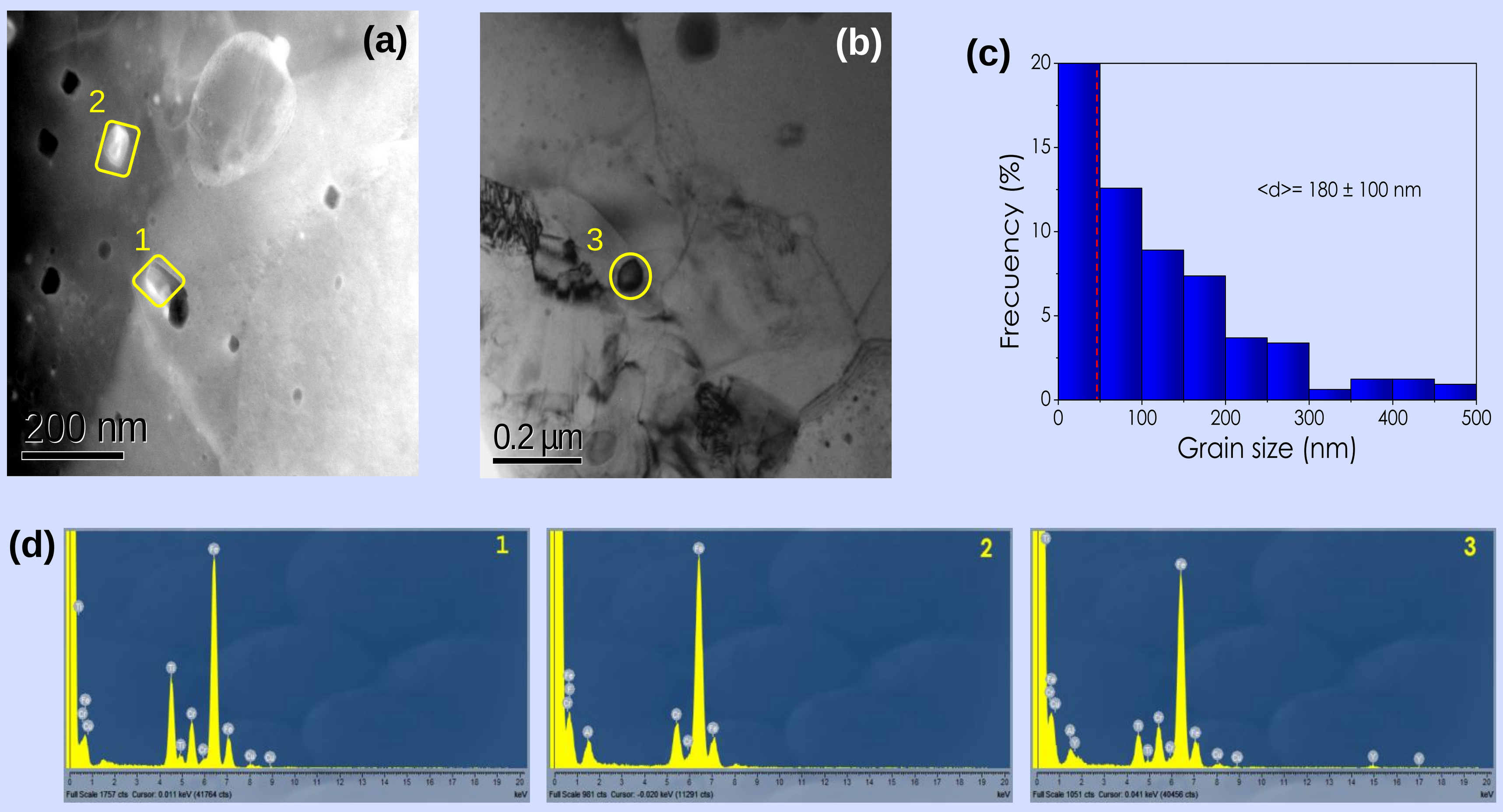
GENERAL MICROSTRUCTURE

DISPERSION OF NANOPARTICLES



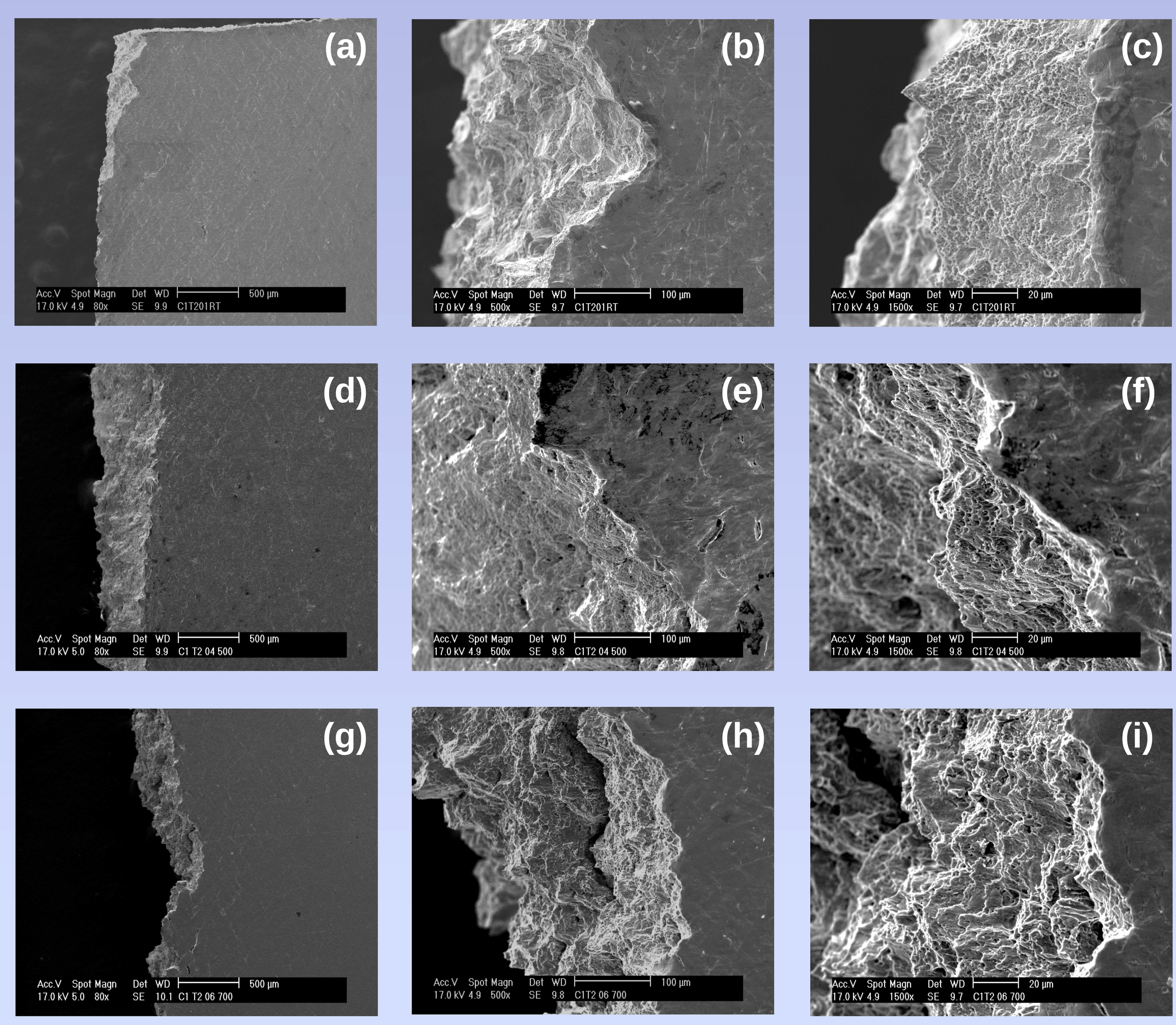
TEM images, composition and size distribution of nanoparticles of the ODS Fe_2Y after heat treatment. (a) BF low magnification image showing the dispersion of nanoparticles; (b) BF image of Ti-Y-rich nanoparticles, and in-set is HREM image of the particle encircled in yellow; (c) XEDS maps of nanoparticles; (d) Nanoparticle composition; (e) Size distribution.

DISPERSION OF LARGER PRECIPITATES

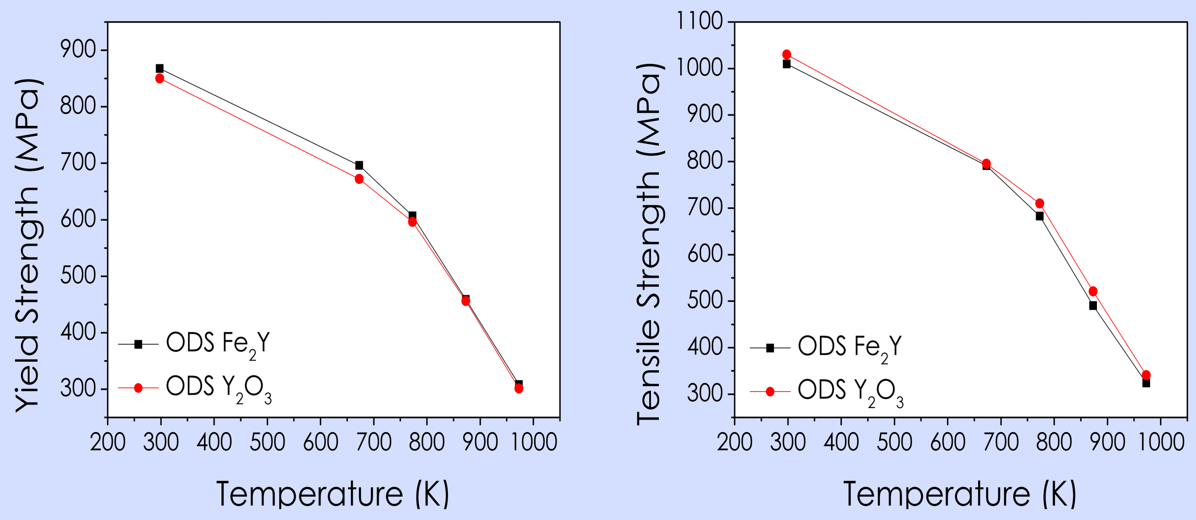


TEM images, composition and size distribution of precipitates of the ODS Fe_2Y after heat treatment. (a) Ti-rich and Al-rich precipitates (b) Ti-Y-rich precipitates (c) Size distribution (d) Precipitate composition.

MECHANICAL PROPERTIES

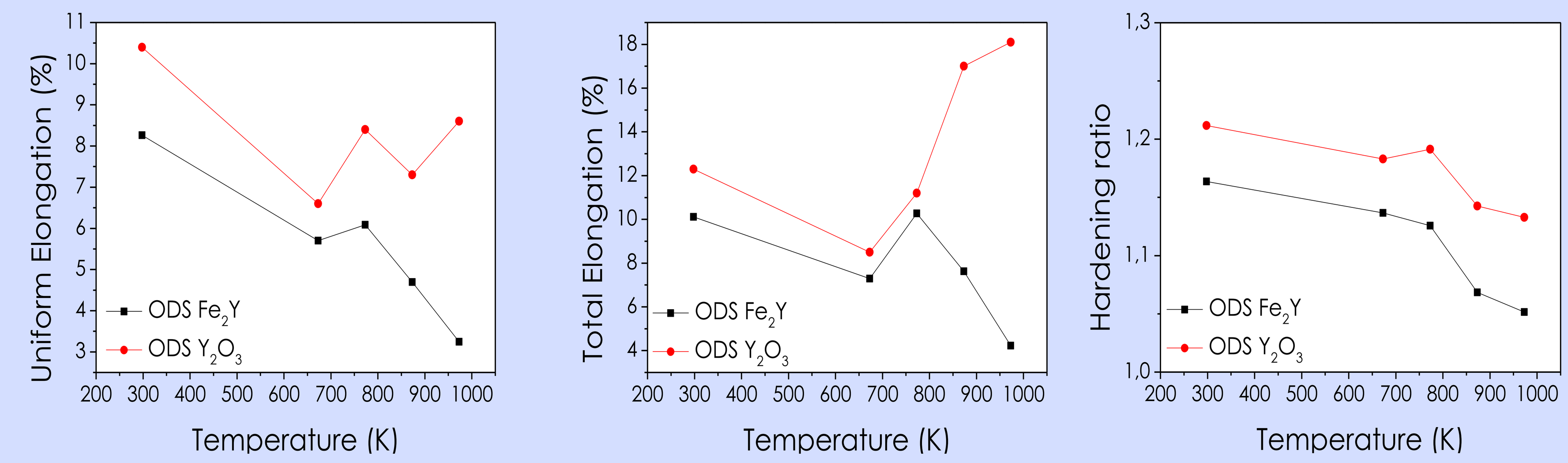


SEM fractographs showing ductile fractures in ODS Fe_2Y at (a, b and c) Room Temperature, (d, e and f) 773 K and (g, h and i) 973 K)



Sample	HV
ODS Fe_2Y	340
ODS Y_2O_3	380

Microhardness



Tensile properties as a function of temperature for the ODS Fe_2Y and ODS Y_2O_3.

CONCLUSIONS

- The microstructure characterization revealed Y-Ti-rich and Ti-rich nanoparticles (size between ~5 and 60 nm) distributed homogeneously in the alloy. Y-Ti-rich and Ti-rich precipitates (size between ~60 and 500 nm) also were found. Al impurity was observed in some large precipitates.
- Fractographs showing microvoid coalescence and transgranular fracture correspond to a ductile fracture and some flat fracture regions. These regions are probably due to the presence of hard second-phase particles.
- The yield strength and ultimate tensile stress obtained in all temperature range are similar for the ODS Fe_2Y and ODS Y_2O_3. However, the ODS Fe_2Y steel shows a lower ductility which drops strongly from 773 K. In addition, the ODS Fe_2Y Vickers hardness at RT is lower than the ODS Y_2O_3 one. These results can be due to the fact that ODS Fe_2Y was only was heat treated, while the ODS Y_2O_3 underwent a thermomechanical treatment, which would improve its mechanical properties.

UNIÓN EUROPEA
Fondos Estructurales

Acknowledgements
This investigation was supported by the Ministerio de Economía y Competitividad (project ENE2012-39787-C6-05), the Comunidad de Madrid through the program MULTIMAT (S2013/MIT-2862), the European Commission (EFDA) and the FP7-EU Program under Grant Agreement 312483 (ESTEEM2).

References
1. Z. Oksiuta *et al.* FED **86**. 2417 (2011)
2. M.A. Auger *et al.* JNM **442**. S142 (2013)

MultiMat Challenge