Cs-corrected STEM investigations of an ODS ferritic steel for fusion applications

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ODS steel in fusion reactors

Oxide Dispersed Strengthened (ODS) Reduced Activation Ferritic (RAF) steels emerged as one of the major material for fusion reactors. Despite the progress made in their technology, currently available properties still do not meet all the expectations. As a result these steels remain subject of extensive research, recently centred on the possible improvement due to their nano-metric engineering. In particular, technologies are developed for grain size refinement down to nanometres and strengthening by nano-oxides. This in turn calls for nano-scale investigations of the microstructures, which can be efficiently carried out only with the use of high resolution transmission electron microscopy and spectroscopy.

Ukai, S. and M. Fujiwara, Perspective of ODS alloys application in nuclear environments. Journal of Nuclear Materials, 2002. 307: p. 749-757.

$\langle \mathfrak{O} \rangle$ MATERIALS DESIGN DIVISION Manufacturing by mechanical alloying

Powders production High energy milling Hot isostatic pressing or hot extrusion

Rolling

Heat treatment

3/16



Microstructure

- Ferrite sub-micron grains with high density of dislocations
- Wide histogram of grain size
- Grain orientation texture = anisotropy of properties
- Oxide particles distribution homogeneity
- Wide range of precipitates size from 2 up to 300 nm
- Different composition of oxides Y₂O₃, Cr₂TiO₅, Y₂Ti₂O₇, ...
- Phase transitions



Microscope



Cs corrected dedicated Scanning Transmission Electron Microscope (STEM) equipped with EDX+EELS spectrometers. In the investigations Transmitted (BF TE, HAADF) and Secondary Electrons (SE), were employed together with CCD camera for capturing diffraction patterns.



© MATERIALS DESIGN DIVISION ODS RAF steel after hot extrusion 6/16 and annealing





ODS RAF steel after hot extrusion





Complex structure of big oxides and carbides





Unwanted impurities





ODS RAF steel after hot isostatic ^{10/16} pressing





Different size and composition





Mapping with EDX, Normal mode apt. nb. 2, Time 15 min. , res. 64x48



12/16





EELS mapping



HR STEM and nanodiffraction





Summary

- ODS RAF steel has complex structure consist different shape and size of ferritic grains with high density of dislocations which can hide the ODS particles on BF image
- Precipitates has different size and composition than the initial powder according to transformations during mechanical alloying
- Different contrast including diffraction and atomic mass contrast as well as the surface topography of the specimen is necessary for better understanding of ODS RAF steels microstructure
- By using complex spectroscopy, including EELS + EDS, we can investigate all kind of precipitates in ODS RAF steels



Thank You for Your attention

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