Karlsruhe Institute of Technology

Institute for Applied Materials

Comparison of the microstructure and the mechanical properties of ferritic and austenitic ODS steels

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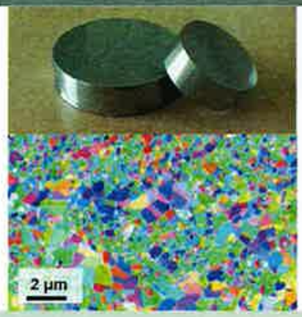
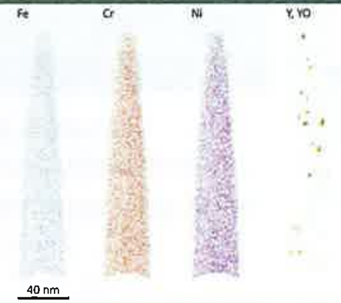
3rd ODISSEUS Workshop - Dresden

Institute for Applied Materials IAM–WK





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KNMF Karlsruhe Nano Micro Facility

Motivation

- Influence of microstructure on mechanical properties at high temperature
- Exclusion of thermally induced changes of the microstructure during experiments

Oxide particles ? Grain size

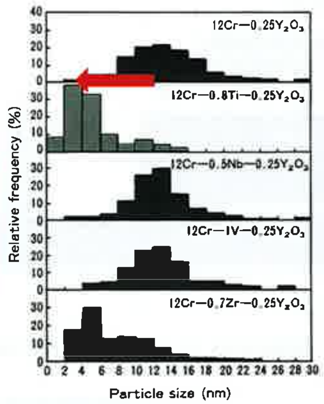
- Expections
  - High thermal stability of Y-Ti-O particles
  - Pinning of grain boundaries by particles
  - Low grain growth in temperature range of experiments

Materials

- Analysis of ferritic and austenitic ODS steels
- Improved high temperature properties of austenitic (fcc) ODS steel expected

In wt. %	Fe	Cr	Ni	Ti	Y_2O_3
FNC 14	Bal.	14		0.4	0.25
ANC 16/16	Bal.	16	16	0.4	0.25
ANC 25/20	Bal.	25	20	0.4	0.25

- Formation of oxide particles by addition of Y_2O_3
- Decreasing particle size by titanium additions
- Formation of Y-Ti-O-containing nanoclusters (~ 4 nm)



S. Ukai et al., J. Nucl. Mater. 307 (2002)

Processing

Zoz Simoloyer CM01
www.zoz-gmbh.de

Retsch PM400
www.retsch.de

Mechanical Alloying

- Attritor or planetary ball mill
- Elemental powders + Y_2O_3
- Argon atmosphere

Ferritic ODS steels

- Attritor
- 4800 cycles
- 45 s milling + 15 s cooling
- 1000 rpm

Austenitic ODS steels

- Planetary ball mill
- 240 cycles
- 60 s milling + 120 s cooling
- 200 rpm

Processing

Zoz Simoloyer CM01
www.zoz-gmbh.de

Retsch PM400
www.retsch.de

- Cylinders with very low porosity
- Diameter between 20 and 40 mm

Mechanical Alloying

- Attritor or planetary ball mill
- Elemental powders + Y_2O_3
- Argon atmosphere

FAST

- Field Assisted Sintering Technique
- Pressure of 50 MPa
- 5 min at 1000 °C
- Fast heating and cooling rate (100 K/min)

- SEM/EBSD
- APT
- Annealing
- Compression tests

Composition (of ANC 25/20)

Nominal: Fe-25Cr-20Ni-0.4Ti-0.25Y_2O_3 (in wt.%)

Measured by ICP-OES and hot gas extraction (in wt.%)

Fe	Cr	Ni	Ti	Y	W	C	Co	O	N
Bal.	26.5	20.1	0.39	0.09	0.11	0.12	0.02	0.45	0.004

Yttrium

- 0.20 wt.% nominally expected
- Specimens to small

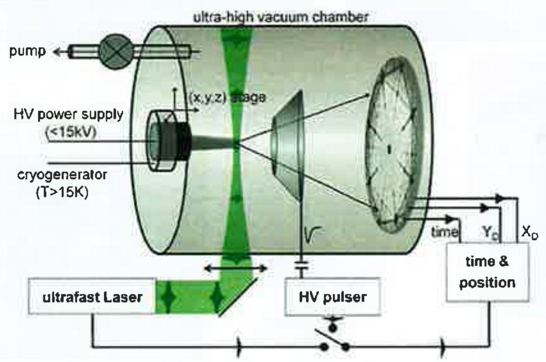
Oxygen

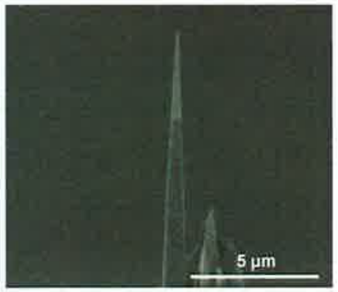
- Only 0.05 wt.% nominally expected
- Calculation of oxygen from powders: 0.40 wt.%
- Excess oxygen from powders

Oxygen content in powders (in wt.%)	
Fe	0.37
Cr	0.74
Ni	0.11
Ti	0.06

Analysis of nanoclusters

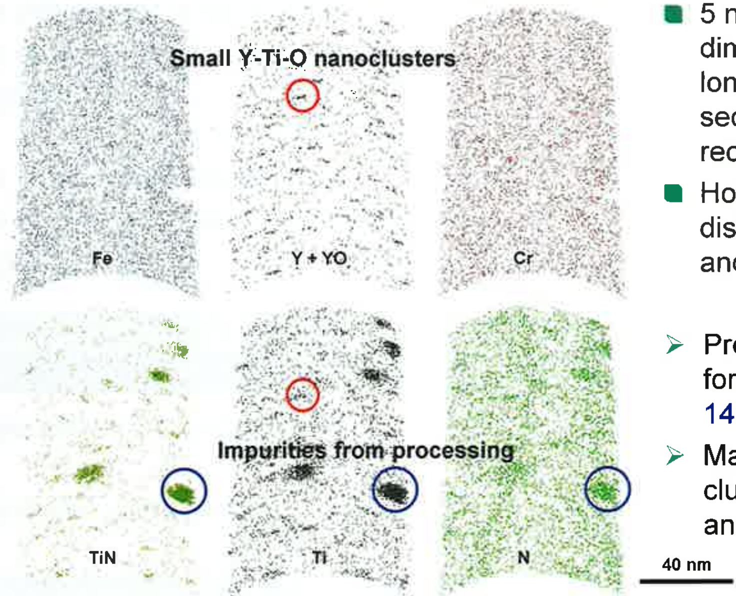
- Atom Probe Tomography (APT)
- Tips produced by lift out method at SEM/FIB dual beam microscope
- Tips measured with voltage pulses (pulse fraction = 20 % at 50 to 70 K)





Gault, B. et al.: Atom Probe Microscopy, Springer Series in Materials Science, Vol. 160, 2012

Reconstruction of a FNC 14 tip (FAST)



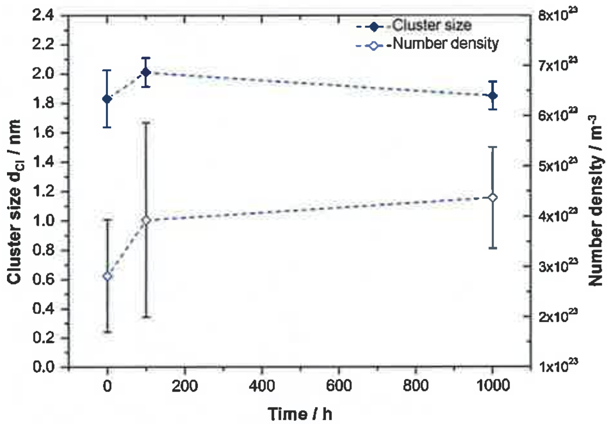
- 5 nm thick, 2-dimensional longitudinal section of the reconstruction
- Homogenous distribution of iron and chromium

➢ Proof of cluster formation in FNC 14 and ANC 25/20

➢ Main elements in clusters: Y, O, Ti and Cr

Cluster analysis

FNC 14 (annealed at 1000 °C)



ANC 25/20 (FAST)

- Diameter of clusters: 4.9 nm
- Number density of clusters: $1.2 \cdot 10^{23}$ m^{-3}

➢ Nanoclusters in **ANC 25/20** larger, but lower number density

➢ Size and number density of clusters stable for annealing at 1000 °C

Sascha Seils