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


3rd ODISSEUS Workshop - Dresden

**Motivation**

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

**Expected Results**

- 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

<table>
<thead>
<tr>
<th></th>
<th>In wt. %</th>
<th>Fe</th>
<th>Cr</th>
<th>Ni</th>
<th>Ti</th>
<th>Y₂O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>FNC 14</td>
<td>Bal.</td>
<td>14</td>
<td>0.4</td>
<td>0.4</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>ANC 16/16</td>
<td>Bal.</td>
<td>16</td>
<td>16</td>
<td>0.4</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>ANC 25/20</td>
<td>Bal.</td>
<td>25</td>
<td>20</td>
<td>0.4</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

- Formation of oxide particles by addition of Y₂O₃
- Decreasing particle size by titanium additions
- Formation of Y-Ti-O-containing nanoclusters (~ 4 nm)

Processing

- Attritor or planetary ball mill
- Elemental powders + Y₂O₃
- Argon atmosphere

Mechanical Alloying

- 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**

- **Mechanical Alloying**
  - Attritor or planetary ball mill
  - Elemental powders + Y₂O₃
  - Argon atmosphere

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

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

**Composition (of ANC 25/20)**

Nominal: Fe-25Cr-20Ni-0.4Ti-0.25Y₂O₃ (in wt.%)

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

<table>
<thead>
<tr>
<th></th>
<th>Fe</th>
<th>Cr</th>
<th>Ni</th>
<th>Ti</th>
<th>Y</th>
<th>W</th>
<th>C</th>
<th>Co</th>
<th>O</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bal.</td>
<td>26.5</td>
<td>20.1</td>
<td>0.39</td>
<td>0.09</td>
<td>0.11</td>
<td>0.12</td>
<td>0.02</td>
<td>0.45</td>
<td>0.004</td>
<td></td>
</tr>
</tbody>
</table>

**Yttrium**
- 0.20 wt.% nominally expected
- Specimens to small

**Oxygen content in powders (in wt.%)**

<table>
<thead>
<tr>
<th></th>
<th>Fe</th>
<th>Cr</th>
<th>Ni</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>0.37</td>
<td>0.74</td>
<td>0.11</td>
<td>0.06</td>
</tr>
</tbody>
</table>
**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)

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**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: $1.2 \times 10^{23} \text{ m}^{-3}$

- Nanoclusters in ANC 25/20 larger, but lower number density
- Size and number density of clusters stable for annealing at 1000 °C