Development of chromium for mid-flux region PFCs for DEMO divertor

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Introduction
Designing of plasma-facing components (PFCs) for DEMO divertor remains a challenge, leading to a high number of materials with improved mechanical properties. Both pure and Cr-10W alloyed materials were produced by Vacuum Arc Melter (VAM) and compared with commercial high purity Cr produced by PlanseeTM with sintering and mechanical treatment.

Objectives
The main objective was to test and investigate mechanical properties as well as microstructure of pure Cr and Cr-10W alloy produced in Vacuum Arc Melter and compare them with commercial high purity Cr produced by PlanseeTM with sintering and mechanical treatment.

Materials and methods
The Arc Melter
An innovative solution acquired by OCASTM which uses principles of an electric arc furnace in combination with induction furnace:
- Allows on to melt W and Cr in order to create solid solution, instead of sintering.
- Vacuum chamber significantly reduces oxidation.
- Induction furnace involved in a melting process helps to cool down material slower, ensuring homogeneity of microstructure and mechanical properties.

Results
Mechanical properties

![Mechanical properties](image1)

Microstructure

![Microstructure](image2)

Conclusions

- As-cast pure Cr (without any further treatment) produced by VAM has shown very similar mechanical properties to pure Cr of Plansee, which was produced by sintering and rolled into plate. The DBTT of VAM Cr is around room temperature.
- Further thermo-mechanical treatment applied to VAM Cr should considerably improve its properties in terms of strength increase and DBTT reduction.
- The vacuum arc melt producers enough volume of chromium to fabricate a monoblock.
- Due to the large grain size, the main fracture mechanism of VAM Cr is transgranular cleavage.
- As-cast Cr-10W produced by VAM has shown much higher strength than pure Cr, capacity for significant work-hardening and DBTT around 250°C.
- EBSD examination reveals the presence of W-rich particles, which implies that perfect solid solution was not reached.
- Fracture mode is a mixture of trans- and intergranular cleavage.

Materials investigated in this work are on the first stage of future improvements by thermo-mechanical treatments.

Chromium flakes and tungsten lumps were used to produce tested materials.

- Chromium flakes (99.97% purity)
- Tungsten lumps (99.99% purity)

Cr sample produced after melting (271 g)

- Avg. grain size ≈ 522.48 µm
- Expected DBTT derivation
- Nanoindentation
- Flexural stress vs flex. strain at RT
- Flexural stress vs flex. strain at 250°C
- Flexural stress vs flex. strain at 500°C

Chemical analysis by XRF and O contamination

<table>
<thead>
<tr>
<th>Material</th>
<th>Cr (%)</th>
<th>W (%)</th>
<th>Fe (%)</th>
<th>O (%)</th>
<th>O in raw material</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAM Cr</td>
<td>99.5</td>
<td>0.005</td>
<td>0.005</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>VAM Cr-10% W</td>
<td>99.5</td>
<td>9.1</td>
<td>0.1</td>
<td>0.07</td>
<td>0.003</td>
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<tr>
<td>Plansee Cr</td>
<td>99.8</td>
<td>0.078</td>
<td>0.05</td>
<td></td>
<td></td>
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</tbody>
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