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Synthesis and characterization of single phase solid solution HfNbTaTiZr

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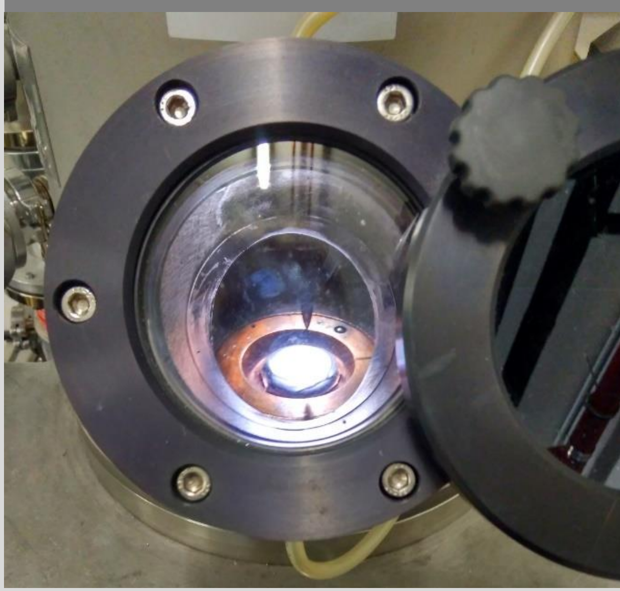
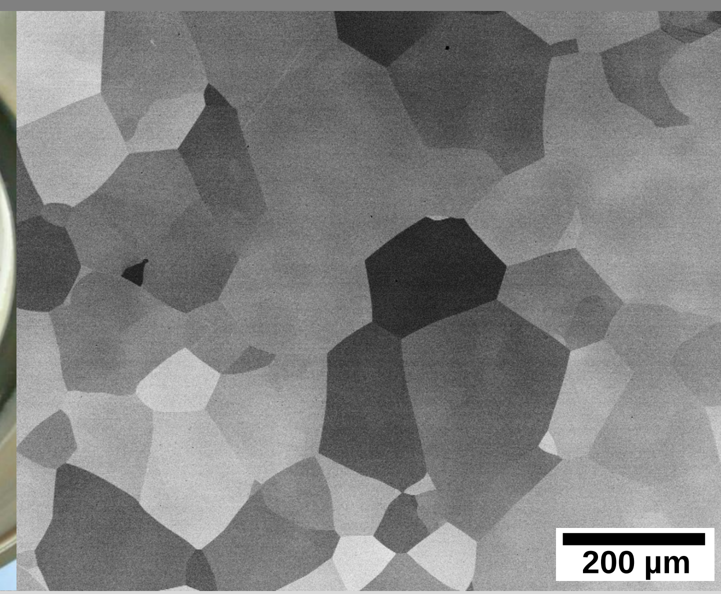
Institute for Technical Physics (ITEP)

SPP-Subgroup meeting HEA mech. Properties, Dresden, 09.11.2018



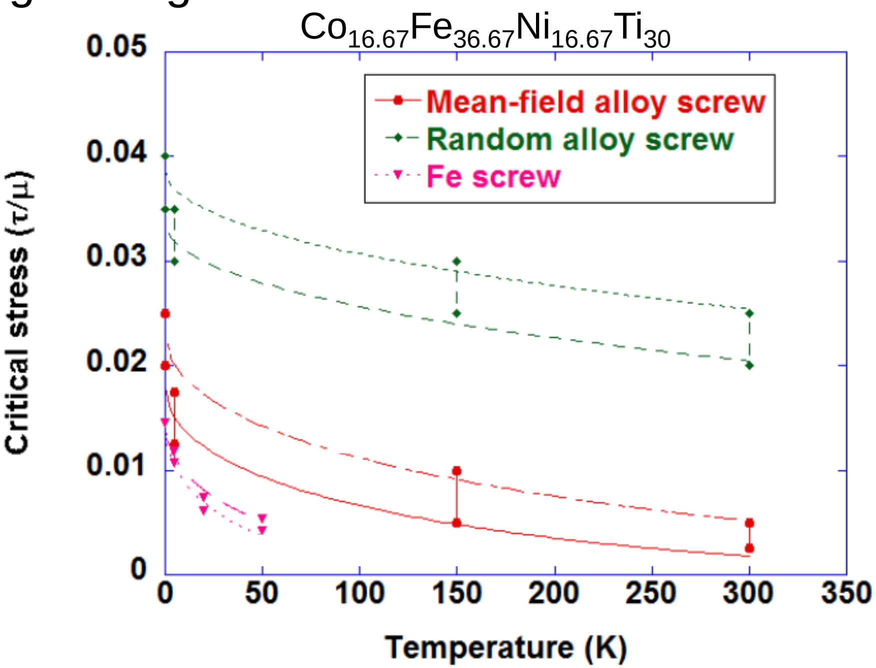


Background and Motivation

- Investigate deformation behavior of bcc HEAs

  → HfNbTaTiZr as model system (RT ductility, cold workability)

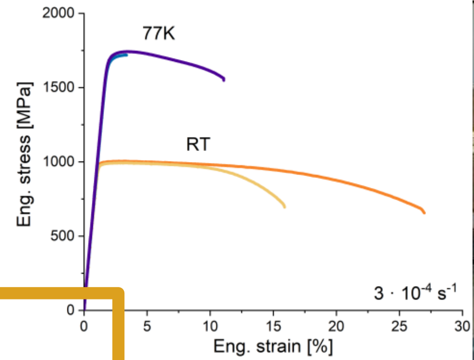
- Special emphasis on solid solution strengthening
  - Interaction of dislocations with local atomic arrangement
  - Influence on deformation mechanisms, e.g. twinning



[Rao et al., Acta Mat. 125, 2017]

→ Single phase solid solution
→ Reproducible initial microstructure

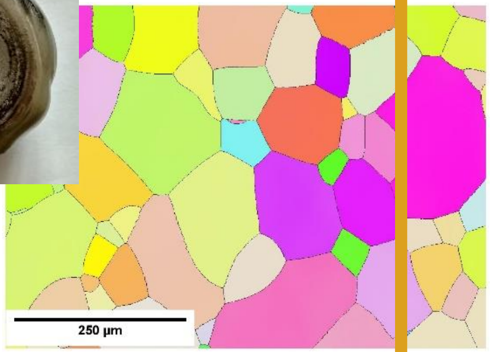
Project context

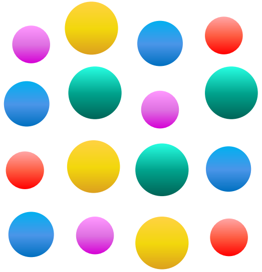


Materials synthesis/ characterization of initial state

Mechanical Testing RT – 4.2K

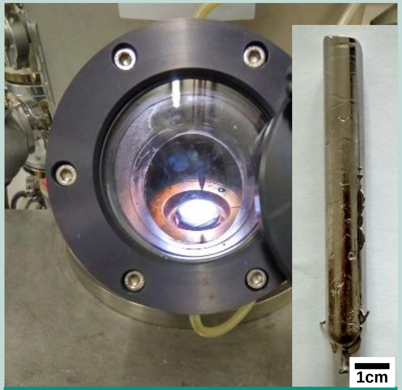
Comparison with deformation theories





$$\delta = \sqrt{\sum x_i (1 - \frac{r_i}{\bar{r}})^2}$$

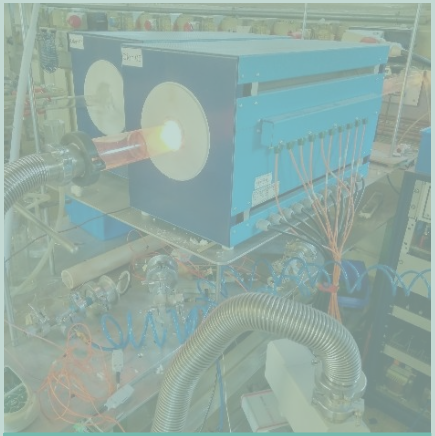
Material synthesis



Arc melting

Homogenization

Rotary swaging

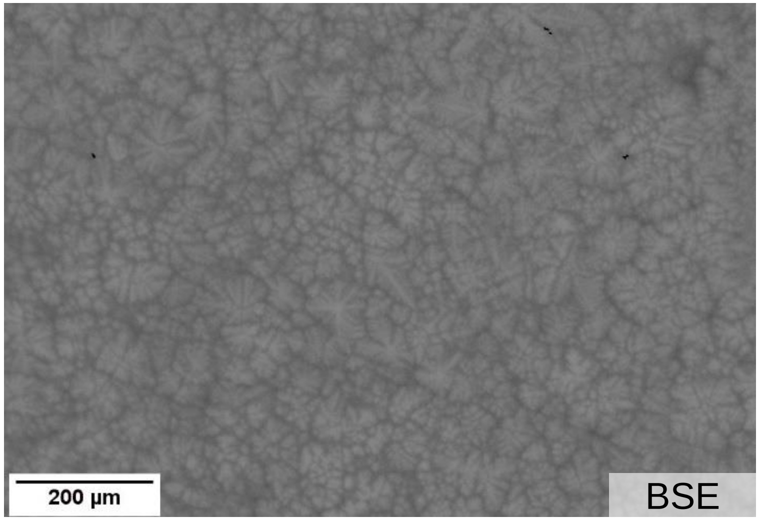


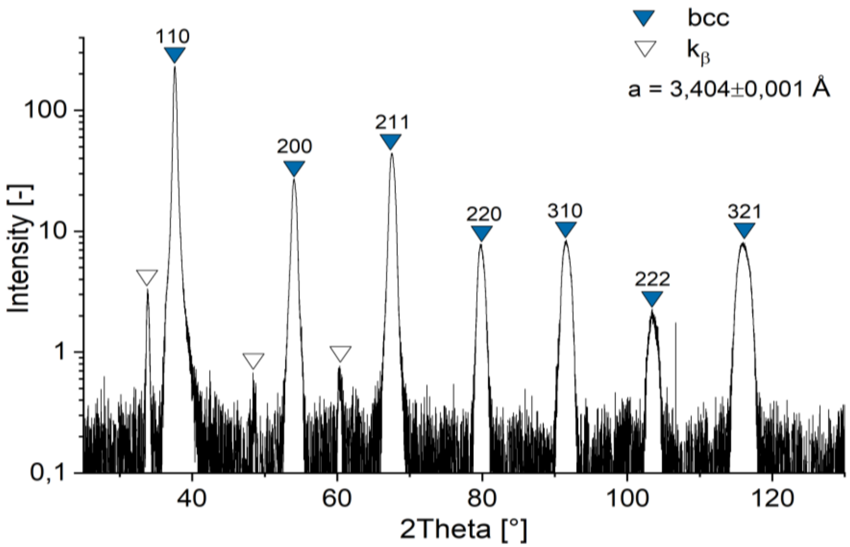
Recrystallization

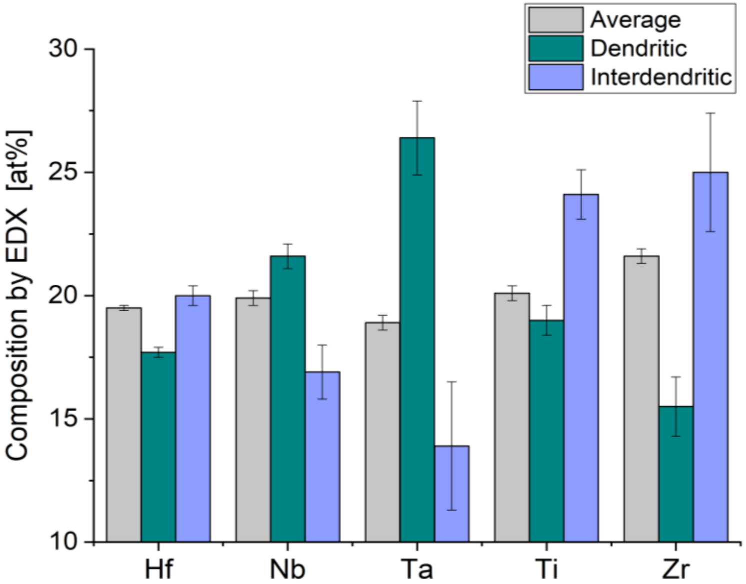
Microstructure - ascast

- Single phase bcc structure
- Inhomogeneous distribution of elements between dendritic and interdentritic regions

→ **Homogenization**







Material synthesis

Arc melting

Homogenization

Rotary swaging

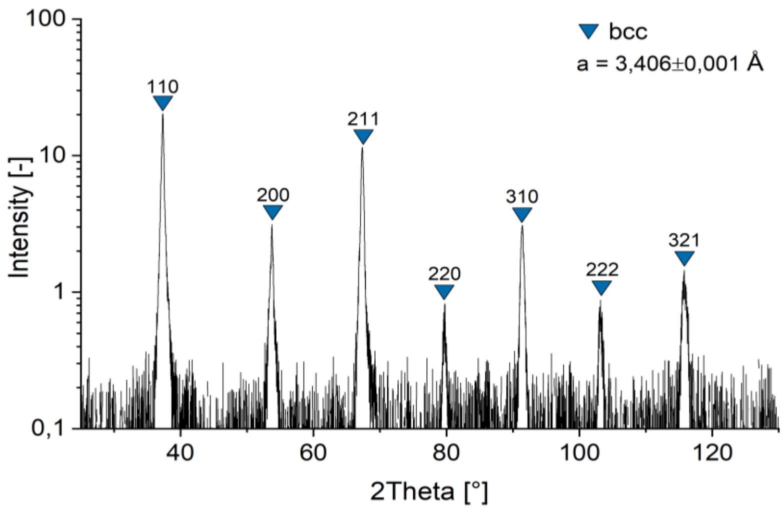
Recrystallization

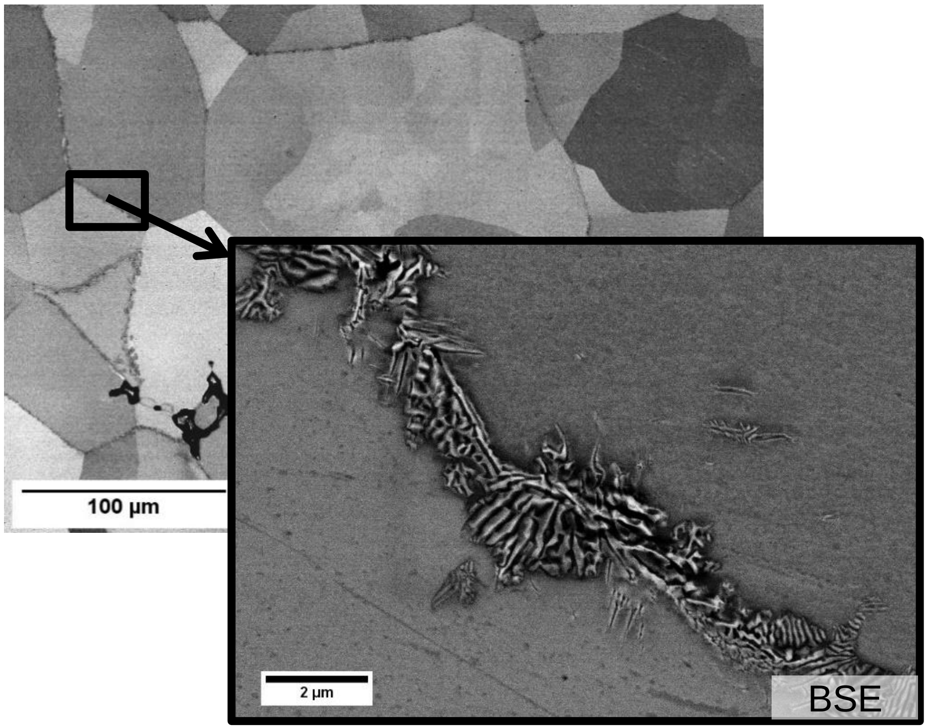
Set1:
1100°C, 48h,
fused silica,
furnace cooling

Set2:
1200°C, 48h,
fused silica,
water quenching

Microstructure - Homogenized

- Set1: 1100°C, 48h, fused silica, furnace cooled

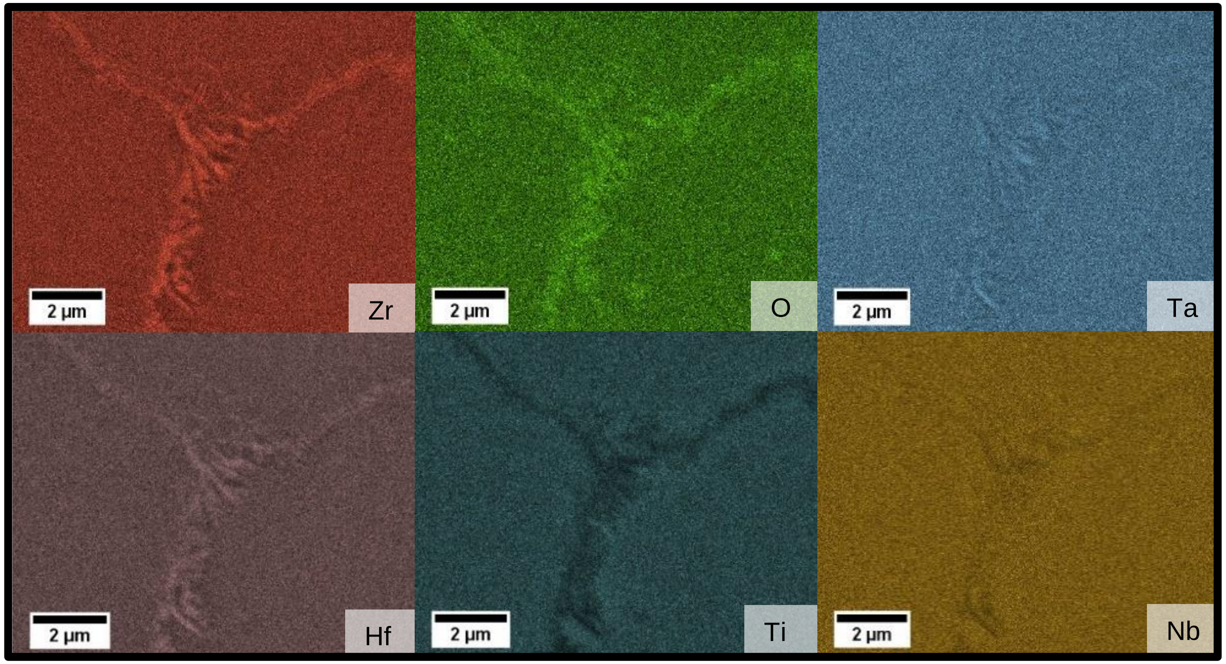


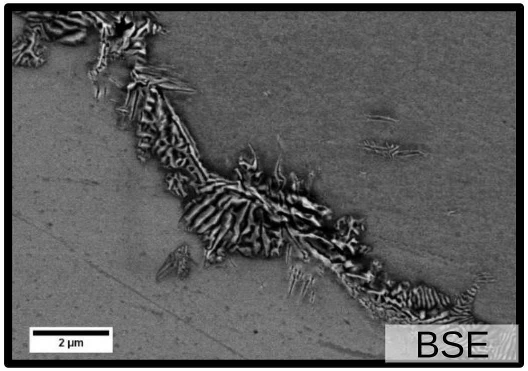


- Single phase bcc by XRD
- Grain boundary phase in BSE

Microstructure - Homogenized

- Set1: 1100°C, 48h, quarztube, furnace cooled

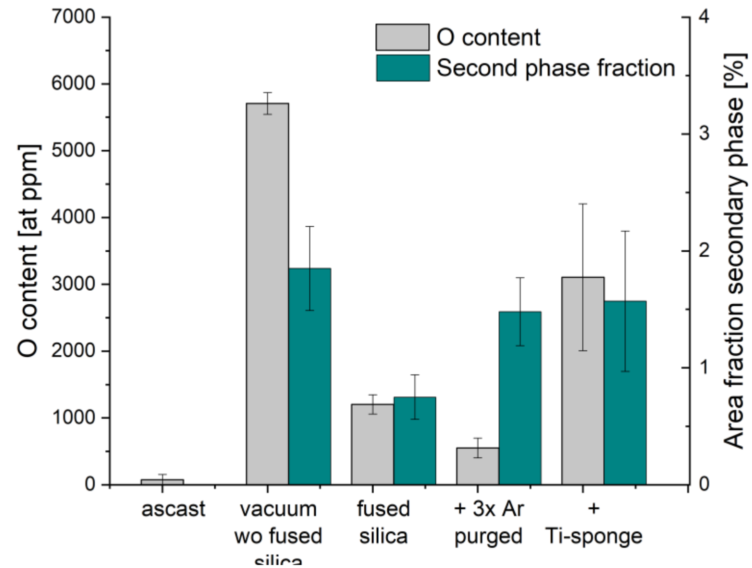




- Single phase bcc by XRD
- Grain boundary phase in BSE → Zr/Hf/O-enriched

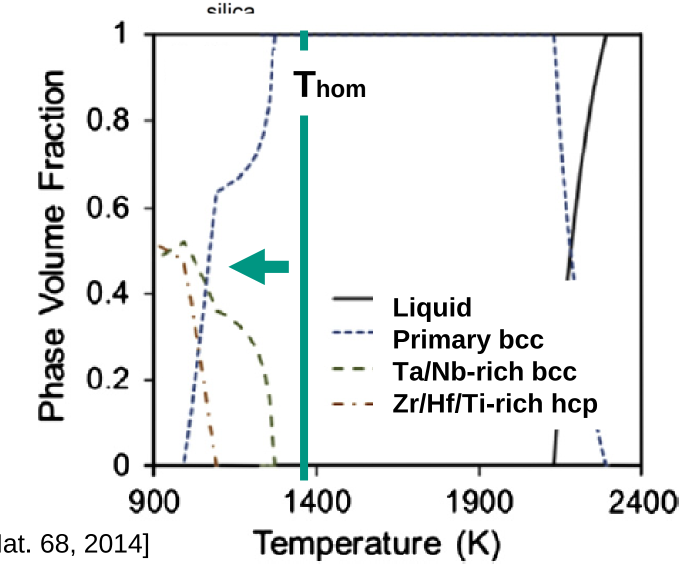
Explanations for secondary phase formation

1. Stabilization of Zr/Hf-rich phase by oxygen:
   - Increased O-content after homogenization
   - No clear correlation between second phase and O-content



2. Decomposition of solid solution during slow cooling:
   - Homogenization at single phase field
   - Decomposition at T < 985°C

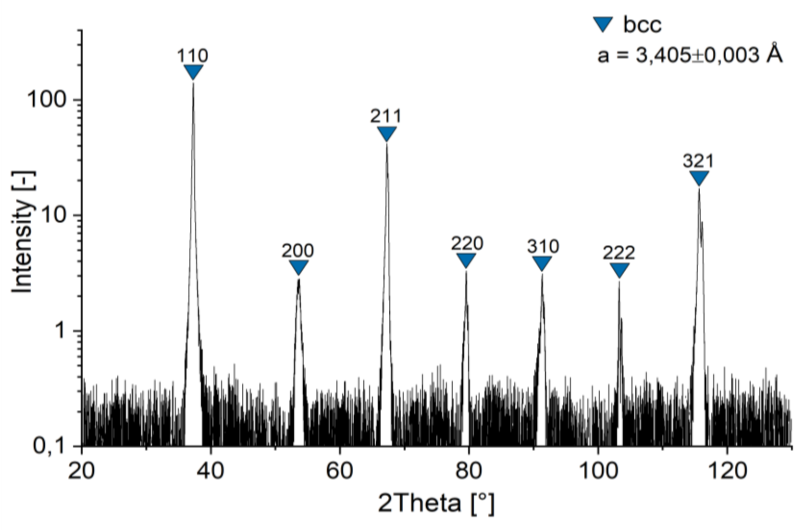
→ **water quenching**

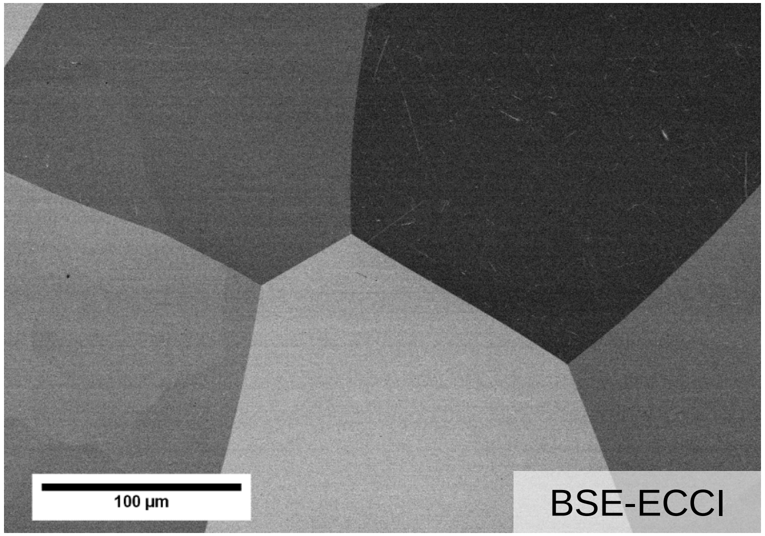


[Senkov et al., Acta Mat. 68, 2014]

Microstructure - Homogenized

- Set2: 1200°C, 48h, fused silica, water quenched





→ Single phase bcc by XRD and BSE

Material synthesis

Arc melting

Homogenization

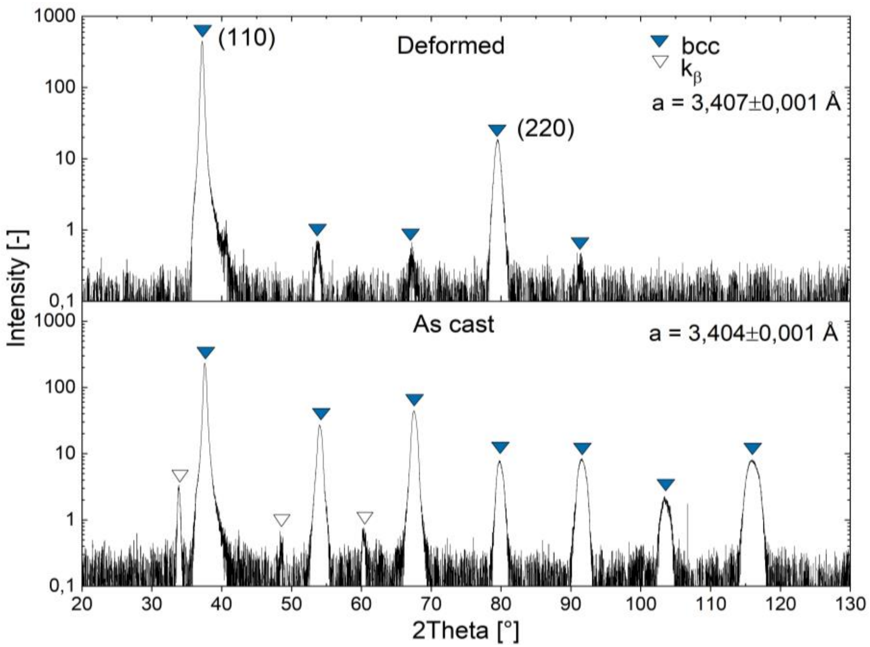
Rotary swaging

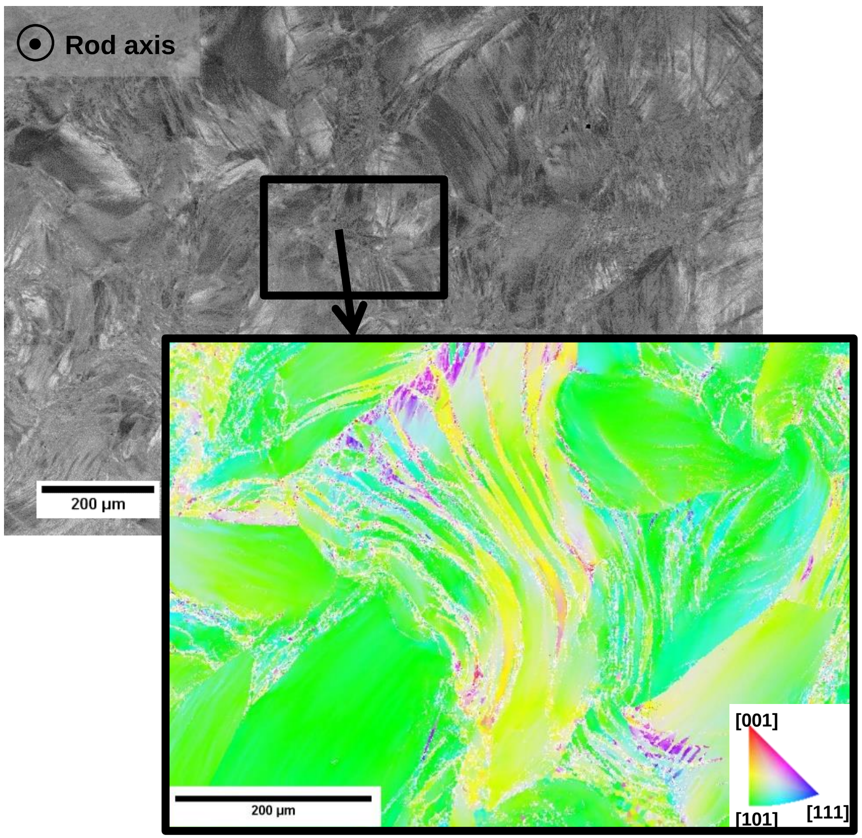
Recrystallization

Set1:
1100°C, 48h,
fused silica,
furnace cooling

Set2:
1200°C, 48h,
fused silica,
water quenching

Microstructure – Rotary Swaged





- Deformation to φ=1.39
- Evolution of <110> texture

  → expected for bcc

Material synthesis

Arc melting

Homogenization

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Set2:
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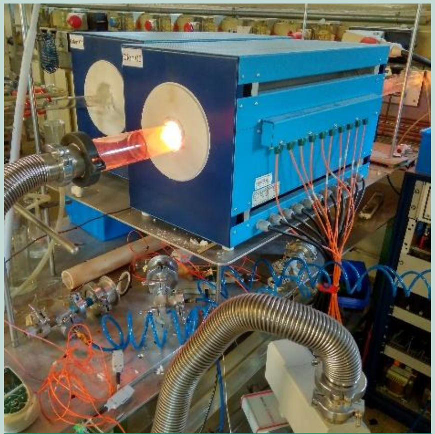
Rotary swaging



Recrystallization

?

Summary

- Cooling rate after heat treatment in single phase field critical for single phase retention → water quenching

- Necessity of microstructural investigation on different length scales

Outlook

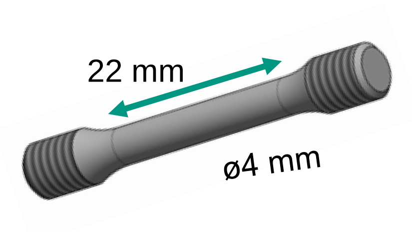
- Investigation of chemical homogeneity on smaller length scales

  → e.g. APT

- Complete standard material synthesis route

  → Reproducibility?

- Mechanical tests at RT down to 4.2K



Thank you for your attention

Many thanks to:

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