Investigation on different oxides as candidates for nano-sized ODS particles in reduced-activation ferritic (RAF) steels

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- Production of ODS alloys
- Mechanical tests
- EBSD measurements
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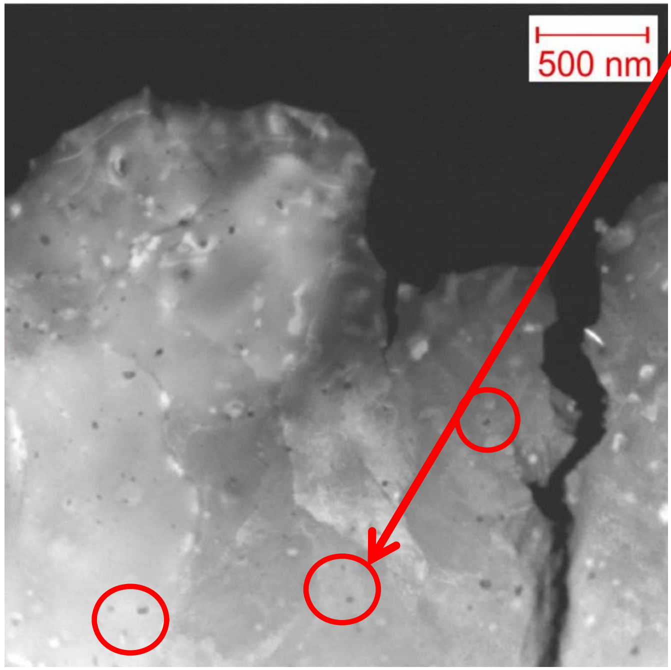
Introduction

- What are ODS alloys?

Oxide **D**isperions-**S**trengthened alloys



(TEM High-Angle-Annular-Dark-Field Image)

Nano-sized oxide-particles 10-20nm

+ good corrosion-resistance

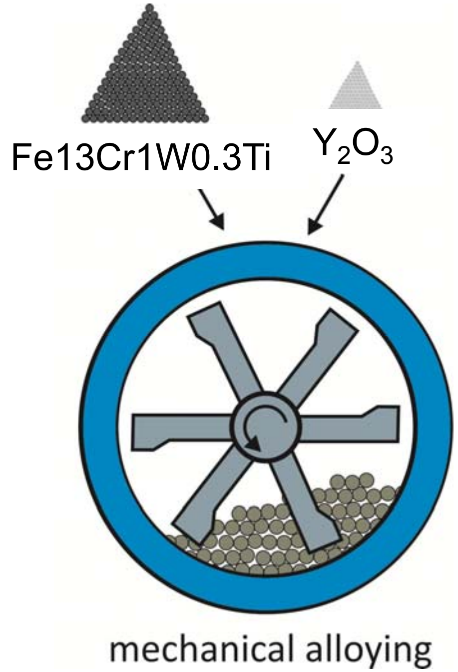
+ excellent high-temperature properties

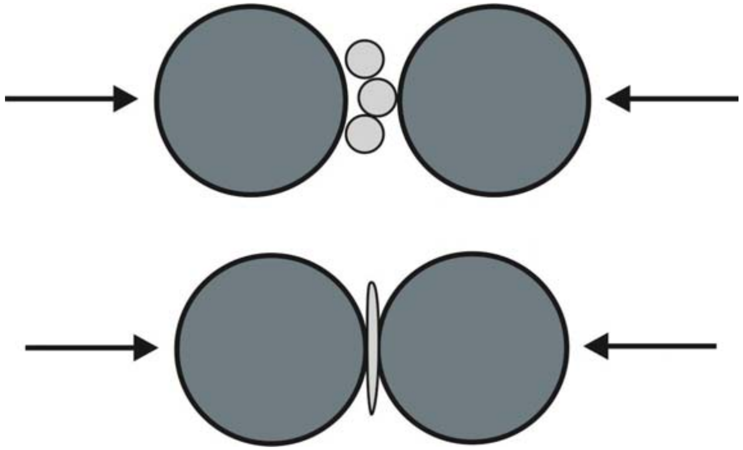
++ improved creep-strength

- material tends to be brittle

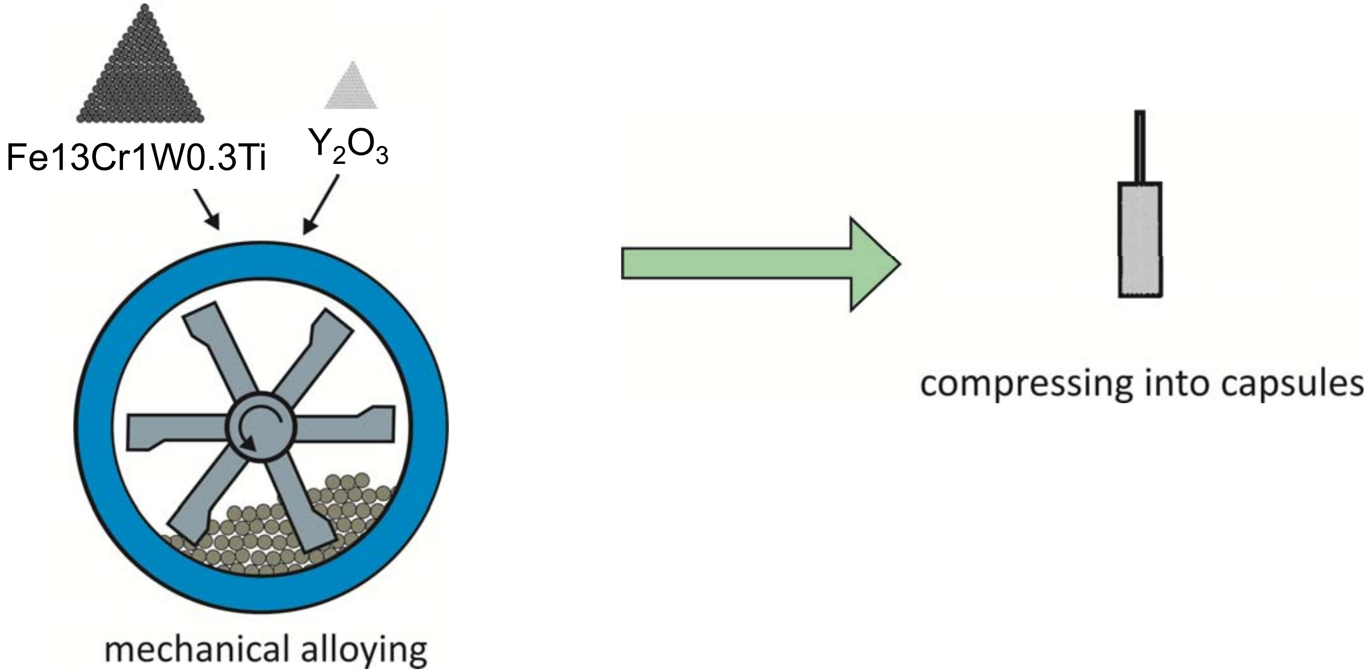
- high production costs

Production of ODS alloys

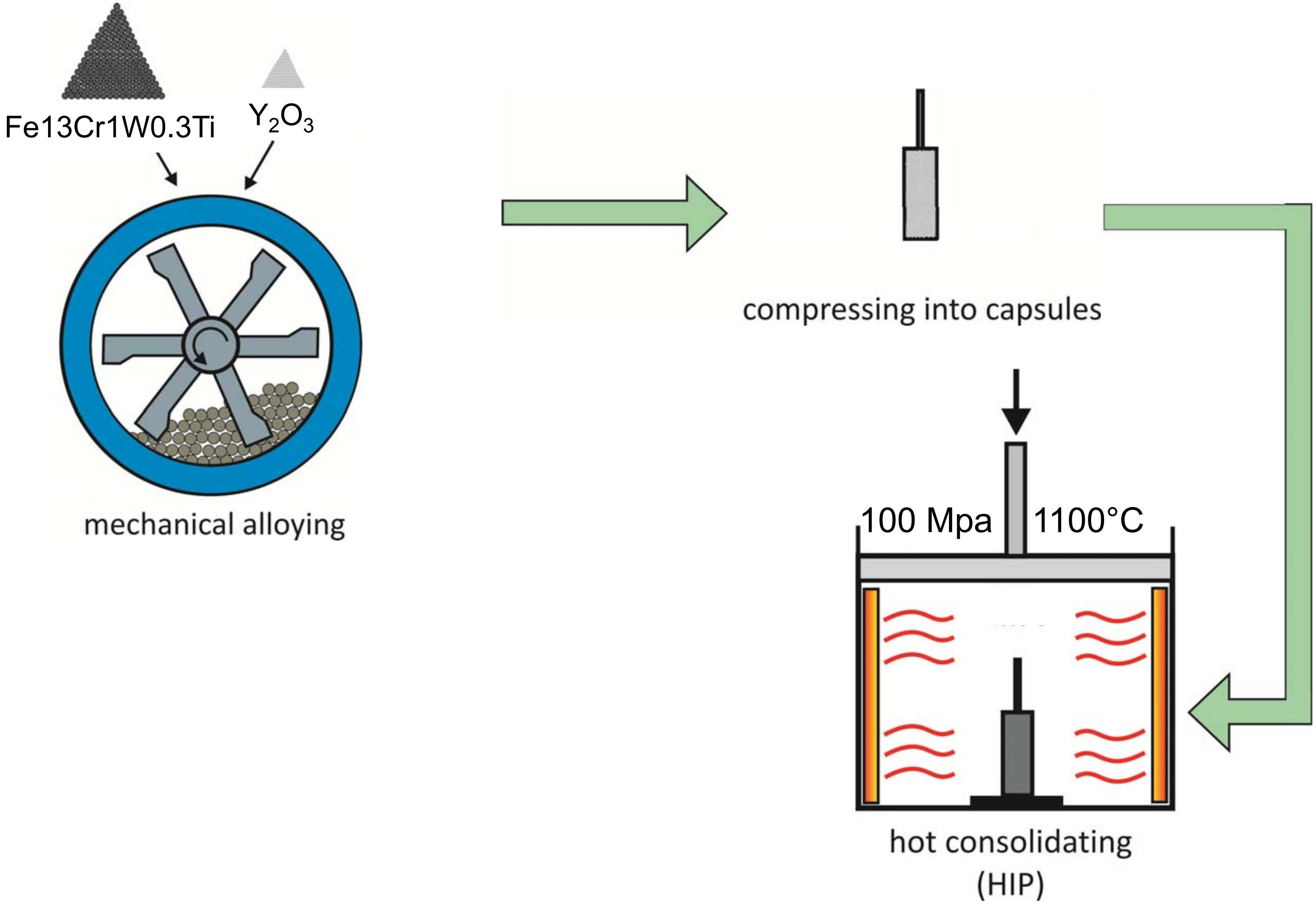




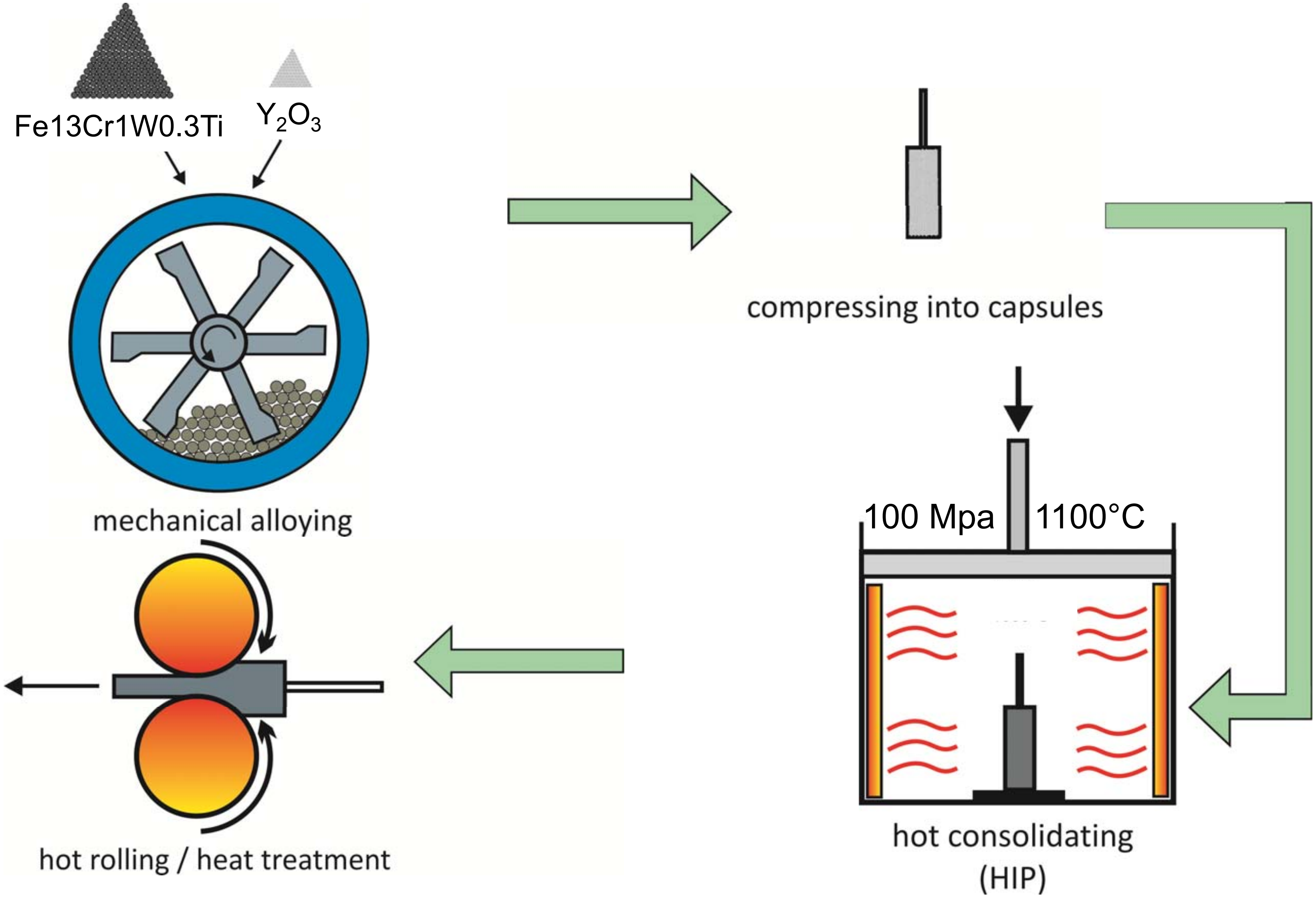
Production of ODS alloys



Production of ODS alloys



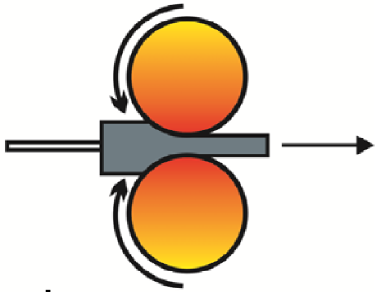
Production of ODS alloys



Production of ODS alloys

Compacting of the powders containing the different oxides:

- HIP at 1100°C / 100 MPa for 2 hours
- Hot-rolling at 1100°C
- Reduction from 45 mm diameter to 6 mm thickness
- 5 passes needed for final shape, with reheating after each pass



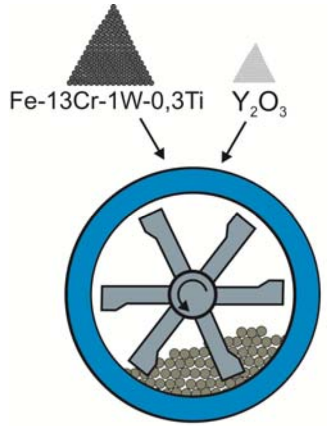
TU Clausthal

Production of ODS alloys

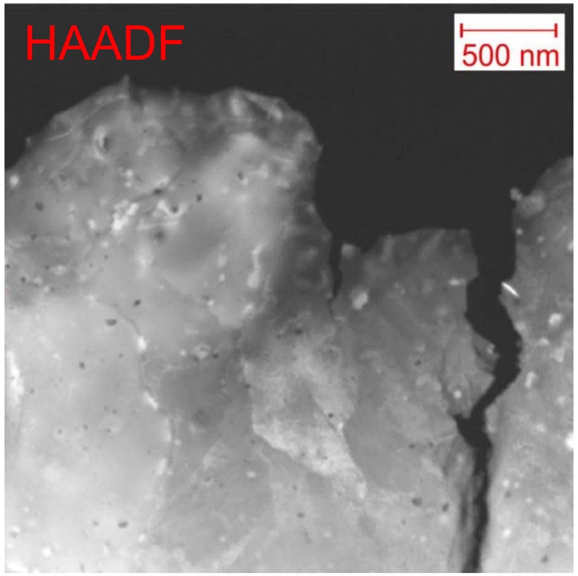
Production-parameters:

No.	composition	milling-speed	milling-time
1	$Fe13Cr1W0.3Ti + 0.3La_2O_3$	1200 / 800	80h
2	$Fe13Cr1W0.3Ti + 0.3Ce_2O_3$	1200 / 800	80h
3	Fe13Cr1W0.3Ti + 0.3MgO	1200 / 800	80h
4	$Fe13Cr1W0.3Ti + 0.3ZrO_2$	1200 / 800	80h
5	$Fe13Cr1W0.3Ti + 0.3Fe_2Y$	1200 / 800	80h
Ref.	$Fe13Cr1W0.3Ti + 0.3Y_2O_3$	1200 / 800	80h

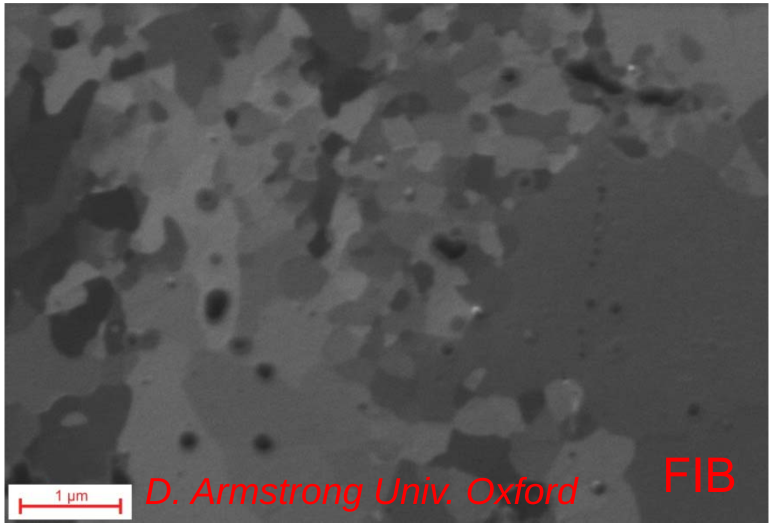
- milling in argon-atmosphere
- ball to powder ration 10:1 (2000g : 200g)
- complete produktion in argon (glove-box)

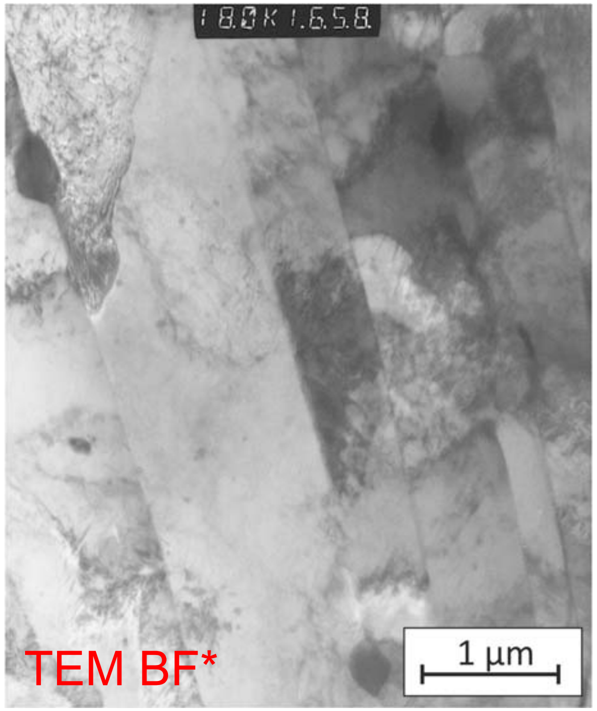


Characterization (FIB/TEM)



Fe13Cr1W0.3Ti + **Y_2O_3**

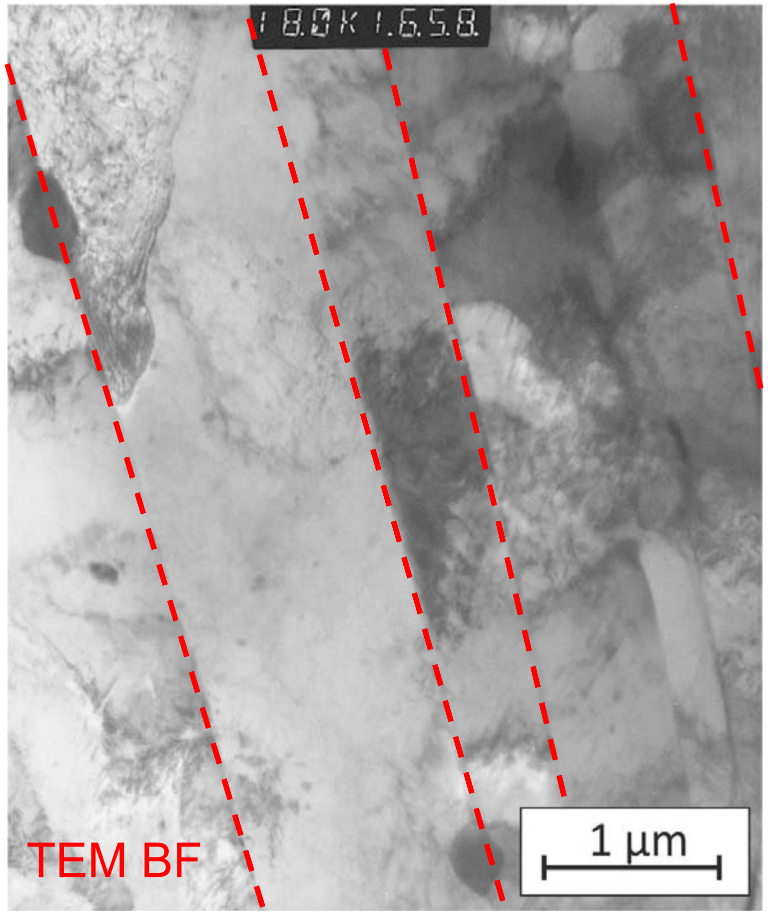




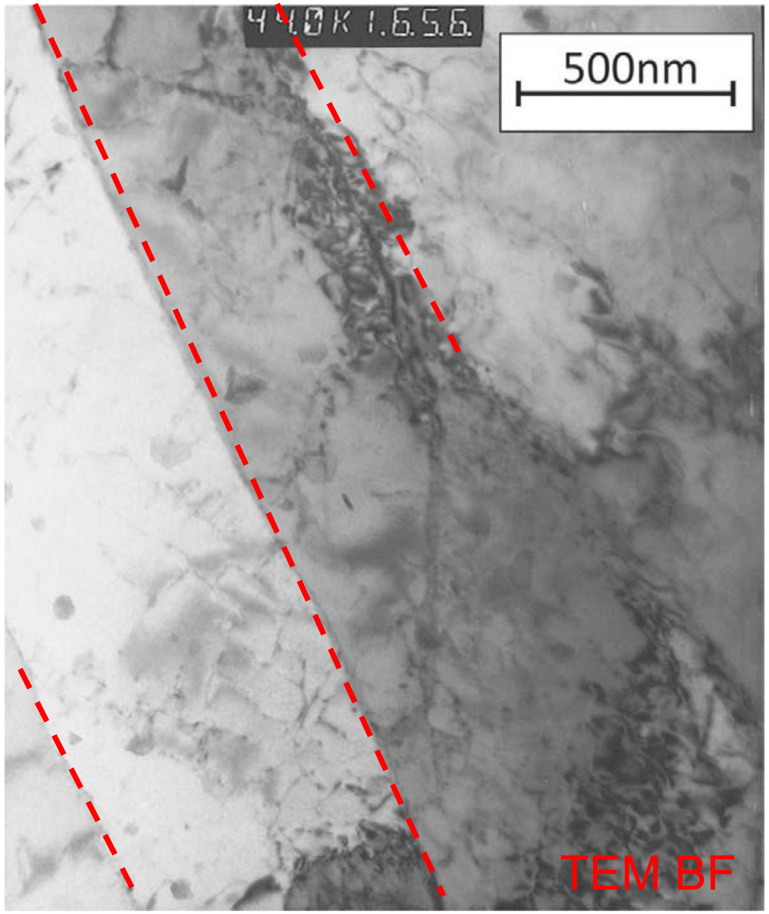
Fe13Cr1W0.3Ti + **La_2O_3** rolled

*GRC - Physical Metallurgy 2011, August 3., Boston, USA

Characterization (microstructure)

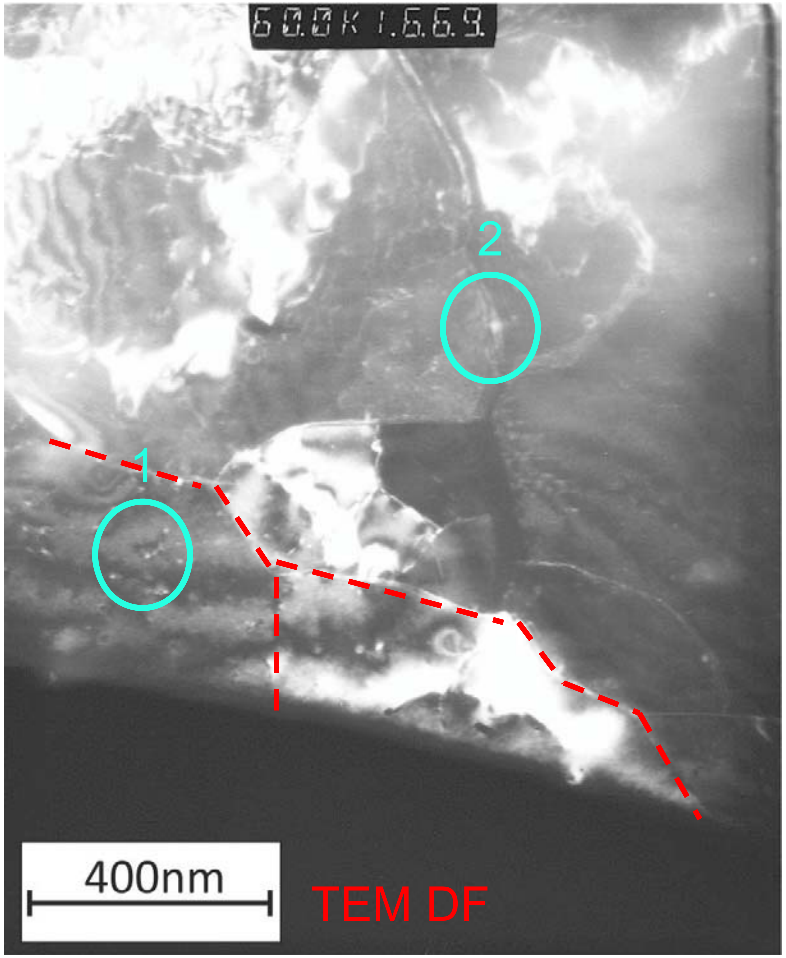


90°RD

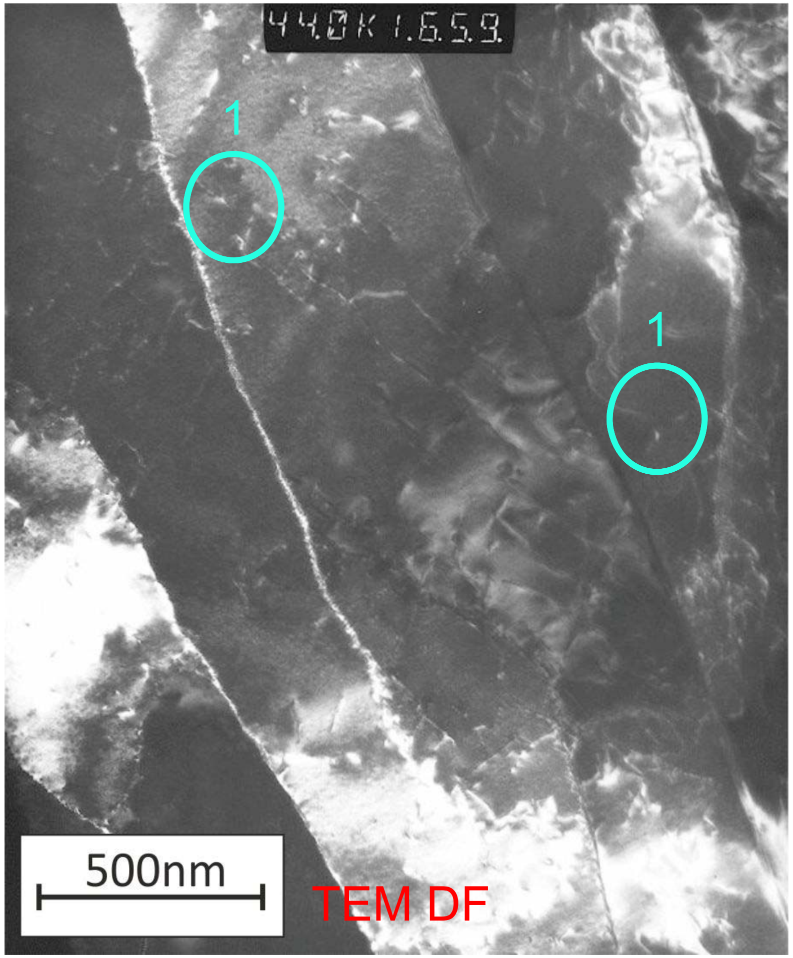


- clearly visible rolling texture
- grain size approx. 400 to 800 nm width, but micrometer-sized length

Characterization (oxides)

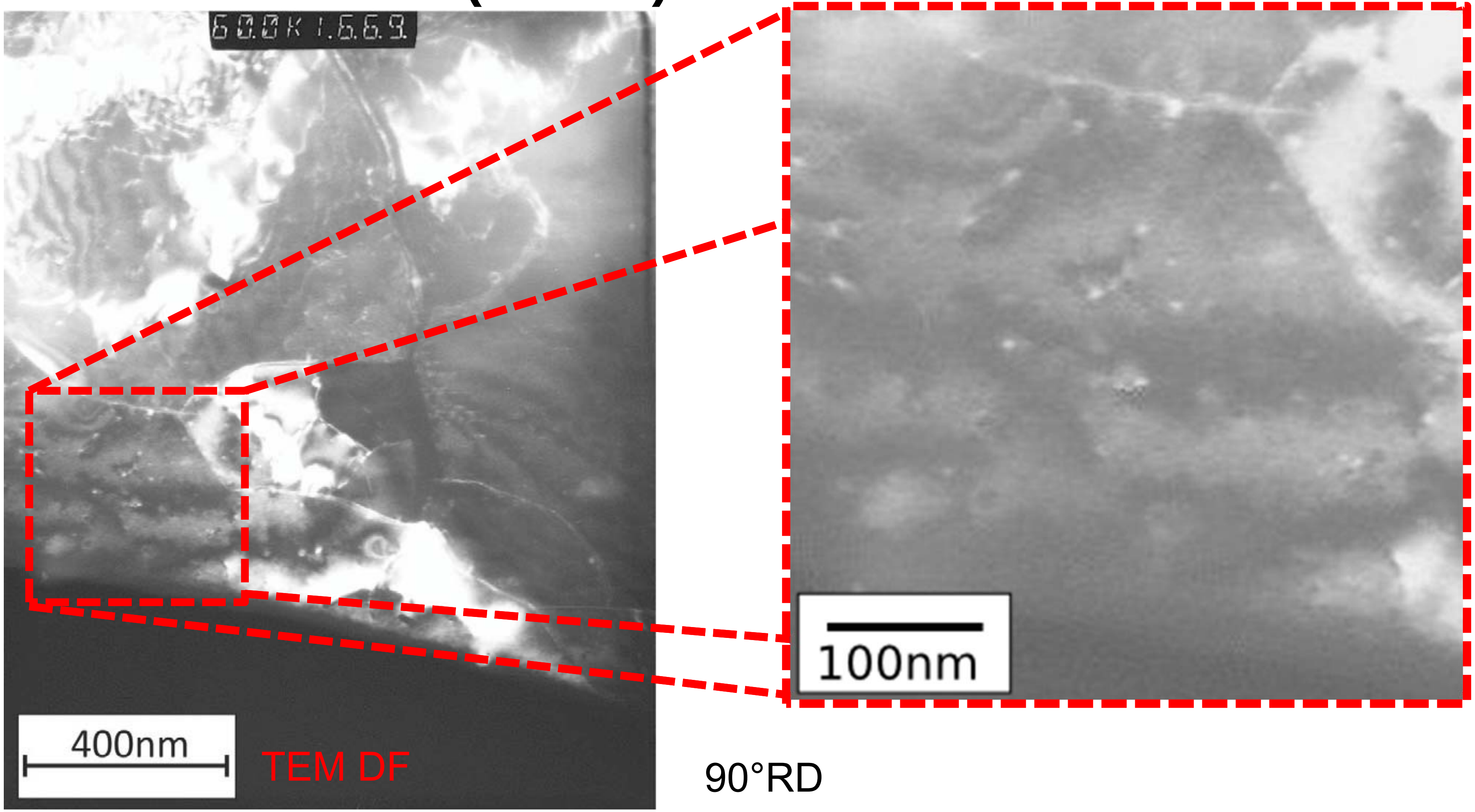


90°RD



- formation of ODS particles with La_2O_3
- fine distribution of the oxides (inside grains[1] and on GB[2])

Characterization (oxides)



90°RD

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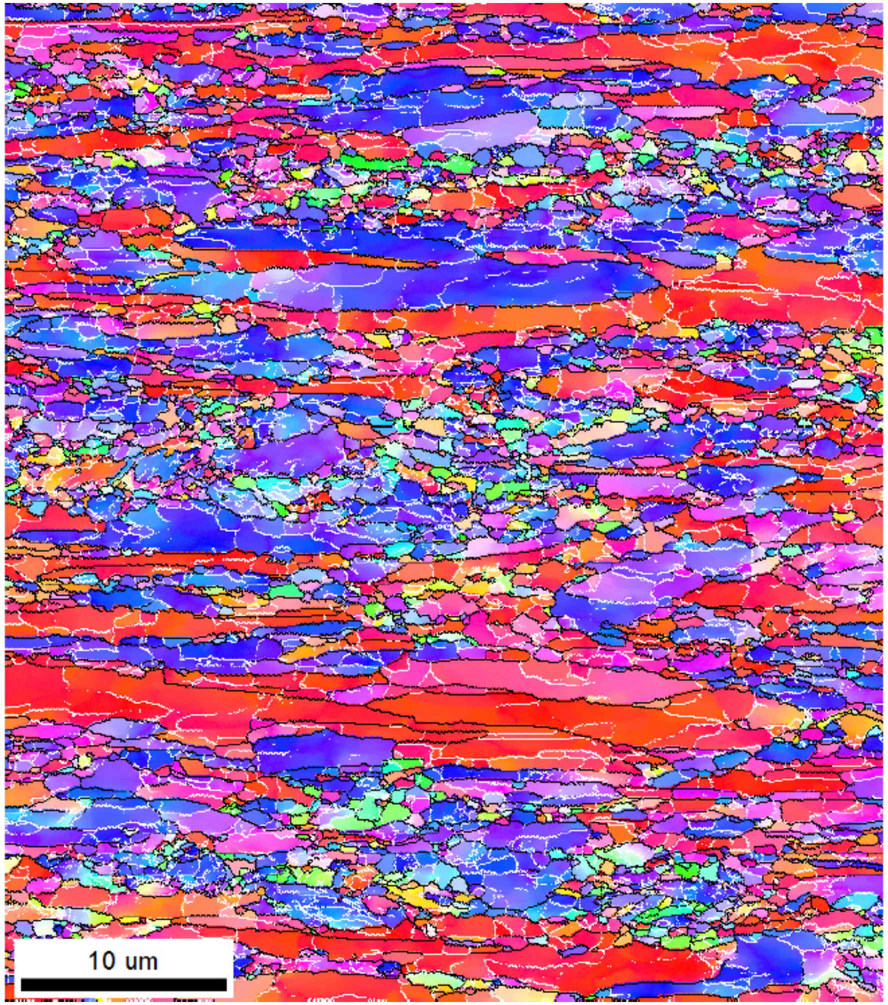
EBSD Measurements

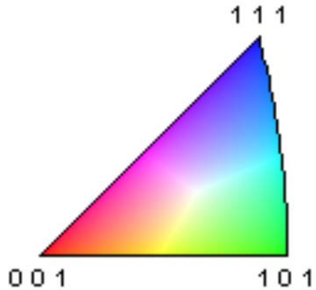


RD

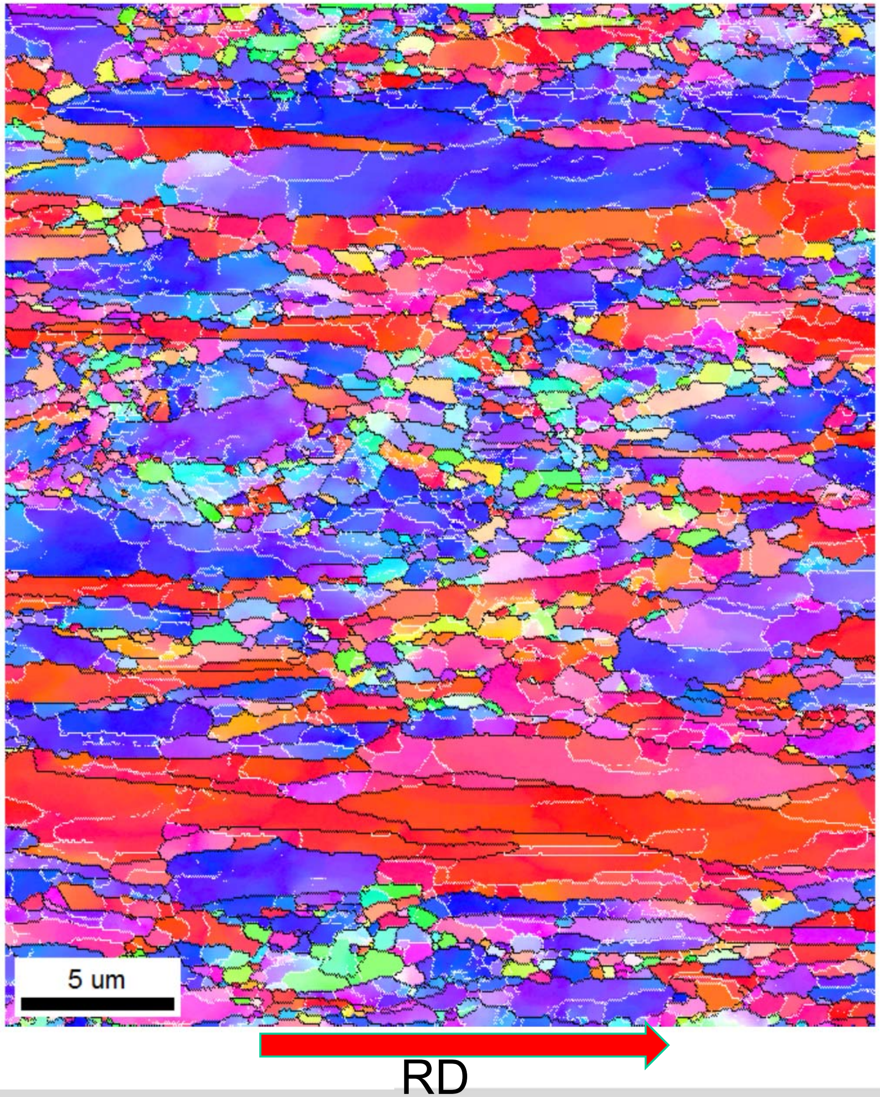
$Fe13Cr1W0.3Ti + \mathbf{Y_2O_3}$

Color Coded Map Type: Inverse Pole Figure [001]

Iron - Alpha



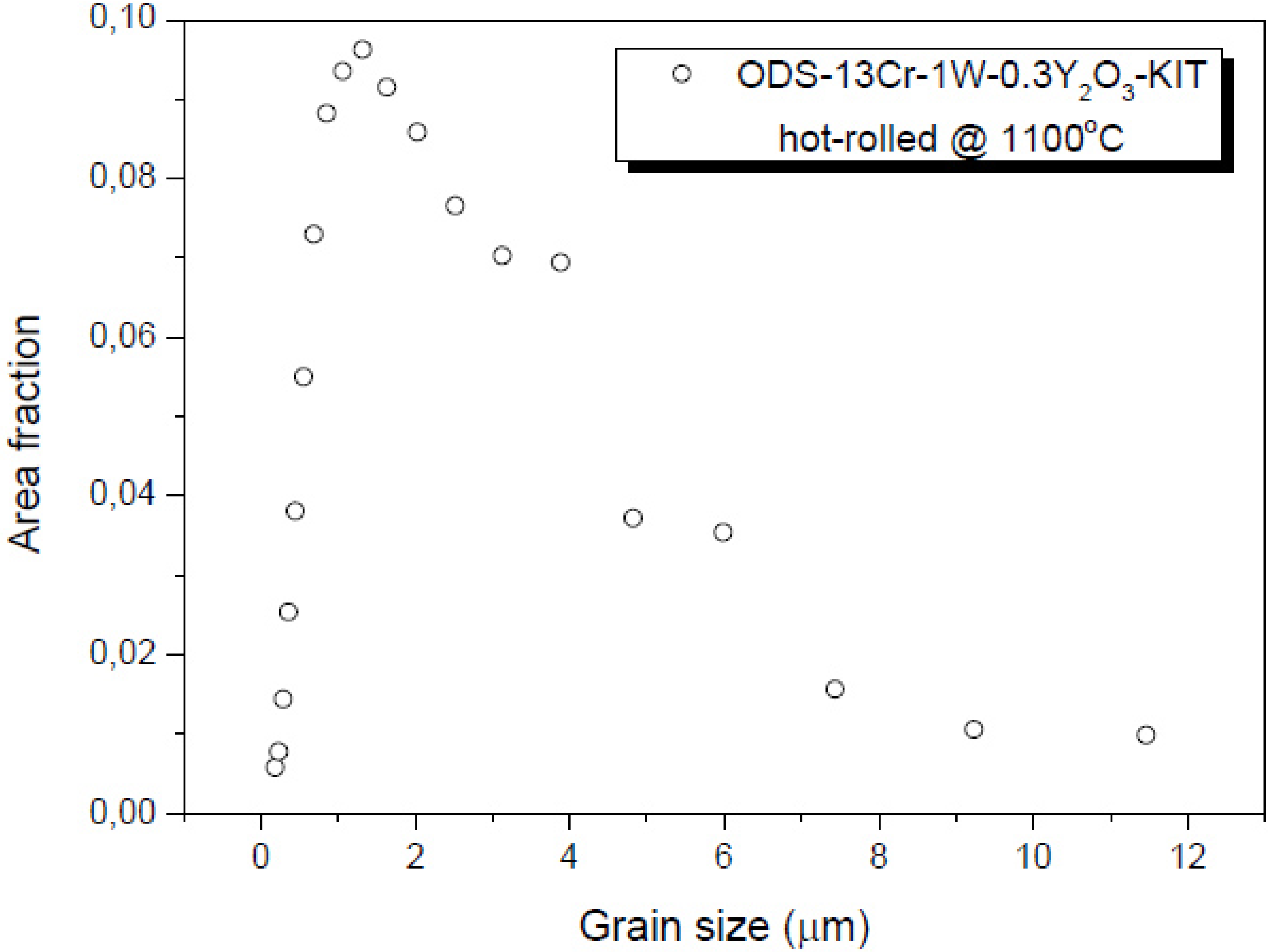
EBSD Measurements



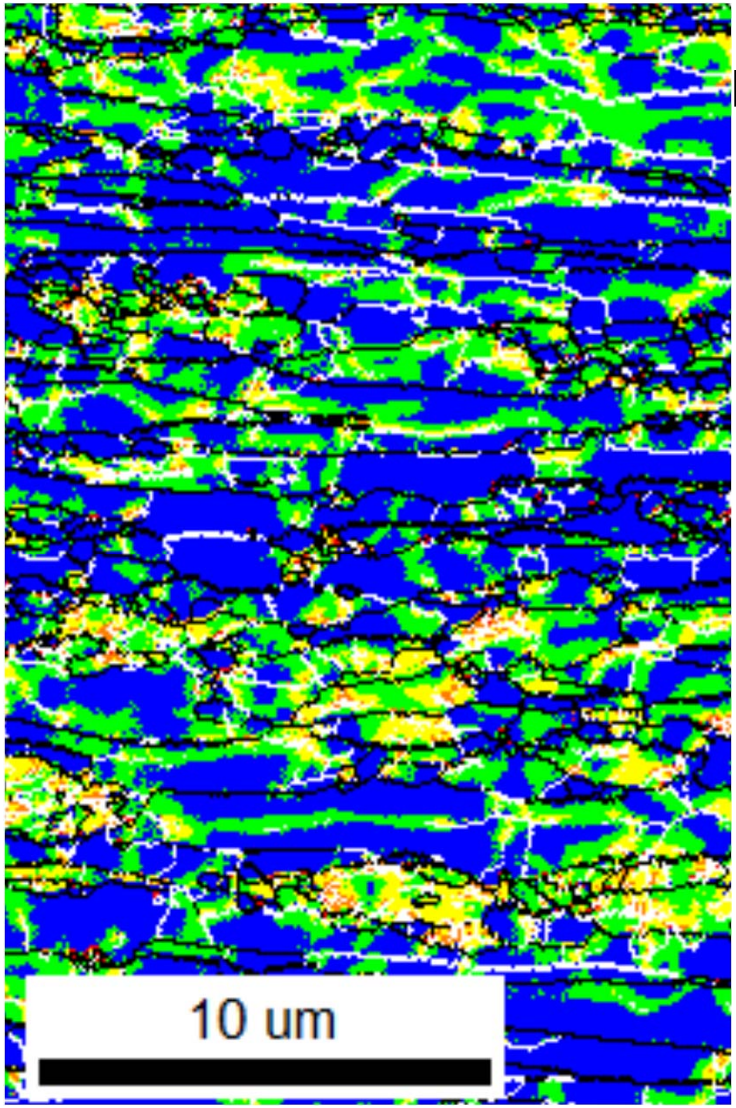
Results from EBSD Measurements

- A bimodal grain size distribution is visible
- Grains with <110> parallel to the rolling direction
- Predominance of {001} <110> rotated cube (α-fiber) (typical texture in bcc metals)

EBSD Measurements



EBSD Measurements

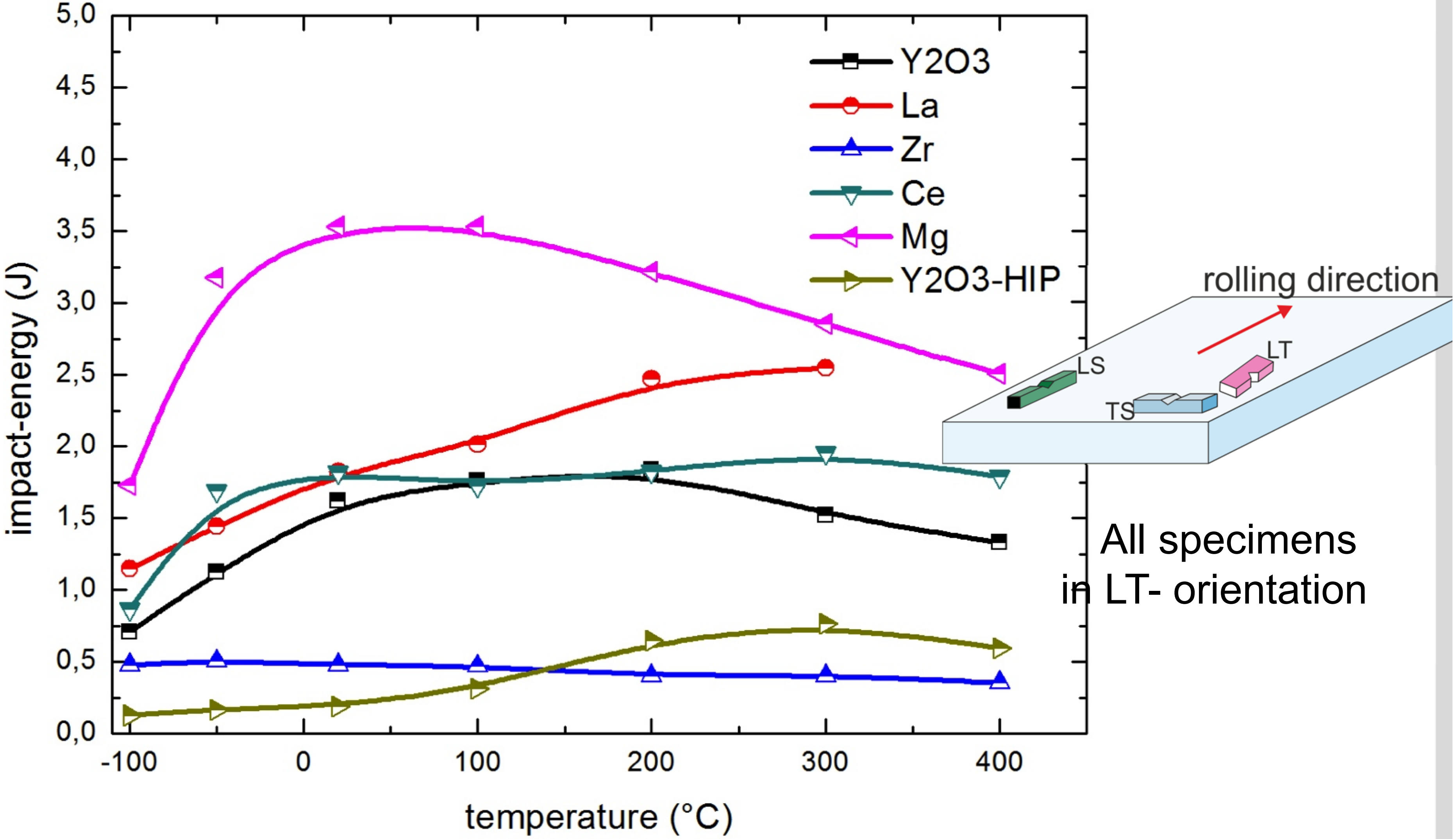


KAM – Kernel Average Misorienation Map

	Min	Max	Total Fraction	Partition Fraction
Blue	0	1	0.463	0.463
Green	1	2	0.341	0.341
Yellow	2	3	0.148	0.148
Orange	3	4	0.034	0.034
Red	4	5	0.015	0.015

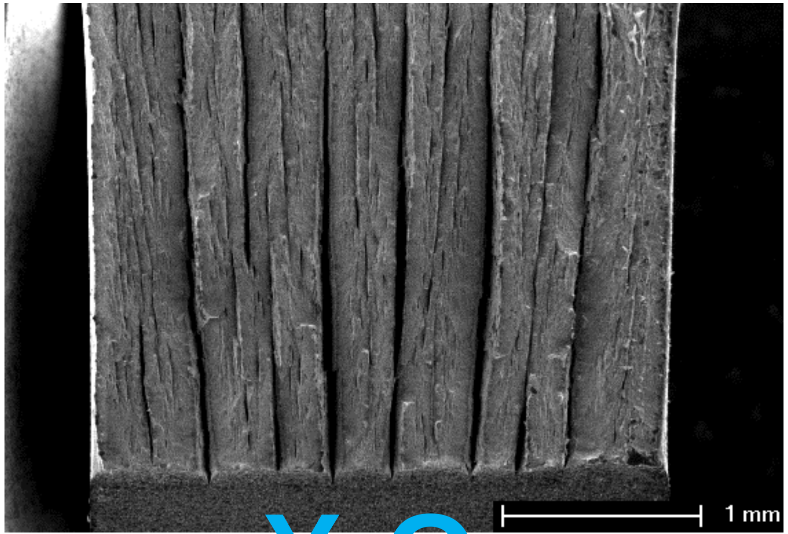
Fine recrystallized grains are surrounded by coarser elongated ones

Mechanical tests (charpy-impact test)



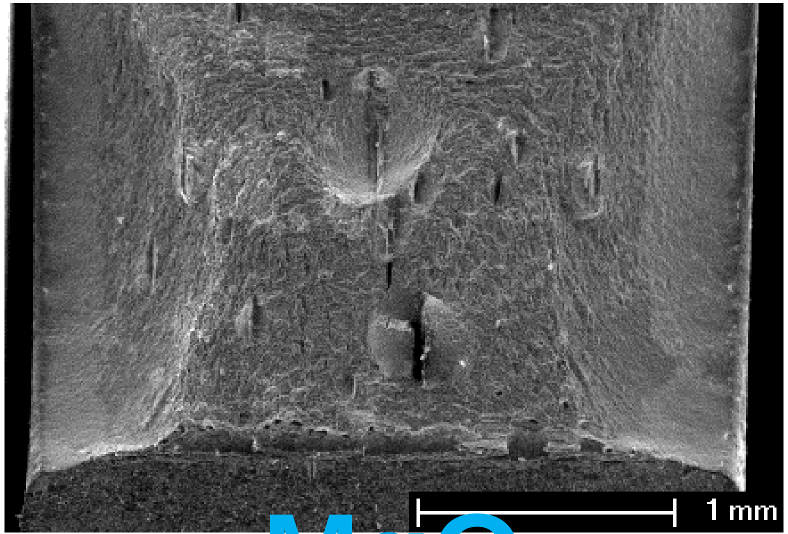
All specimens in LT- orientation

Mechanical tests (charpy-impact test)



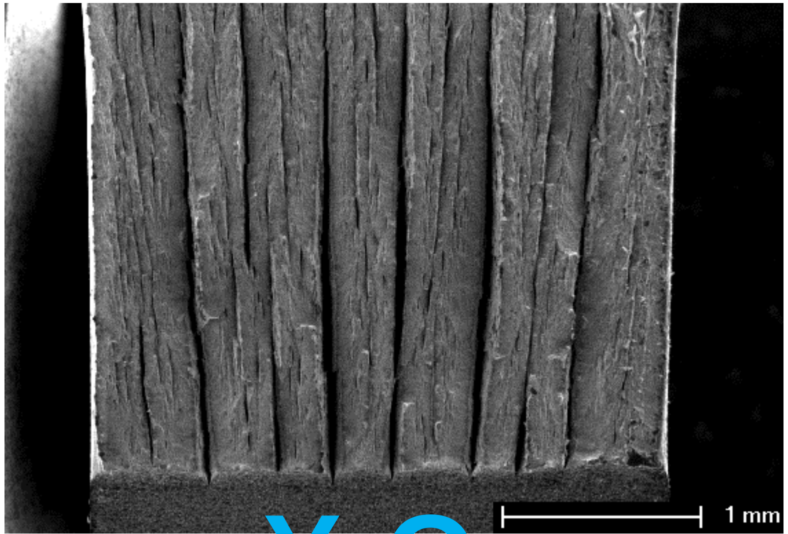
Y_2O_3

RT

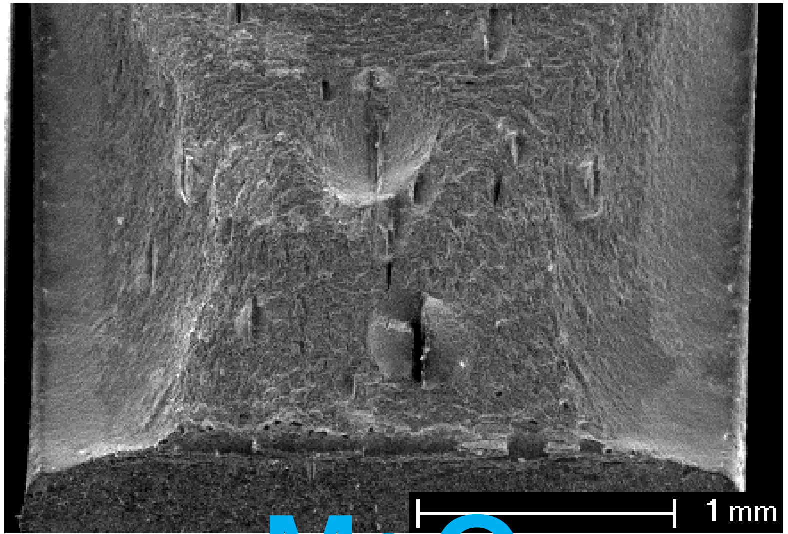


MgO

Mechanical tests (charpy-impact test)

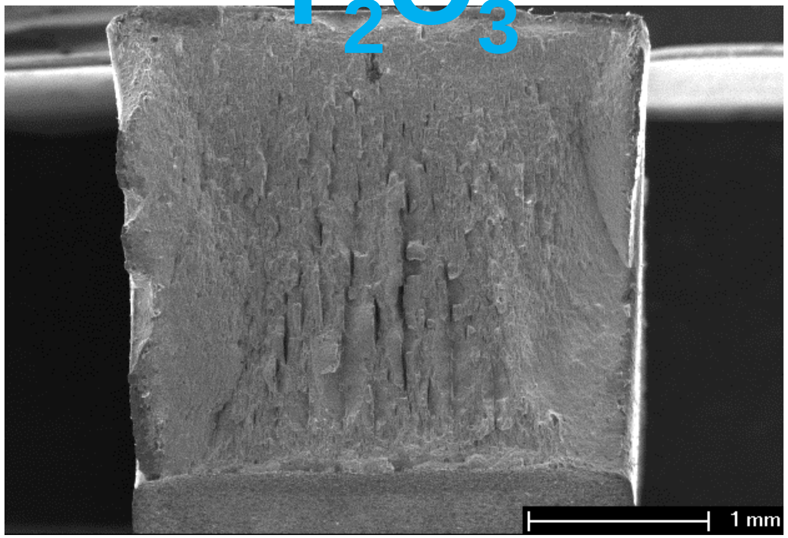


RT

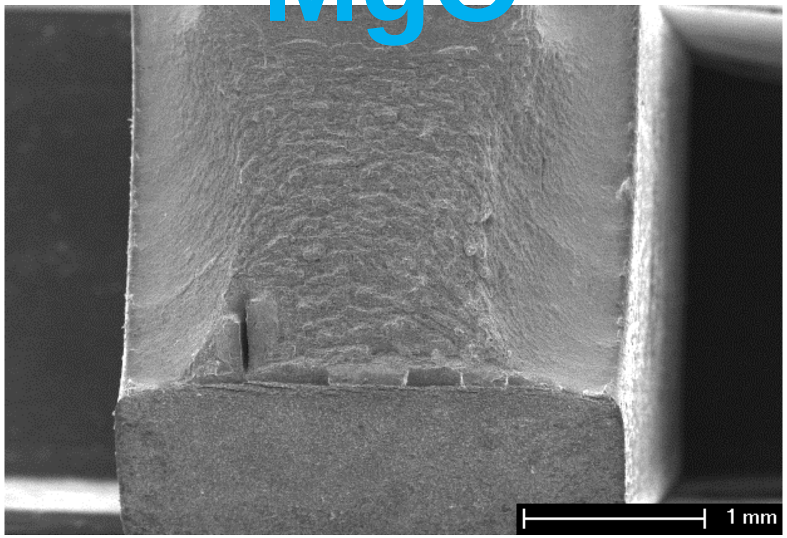


Y_2O_3

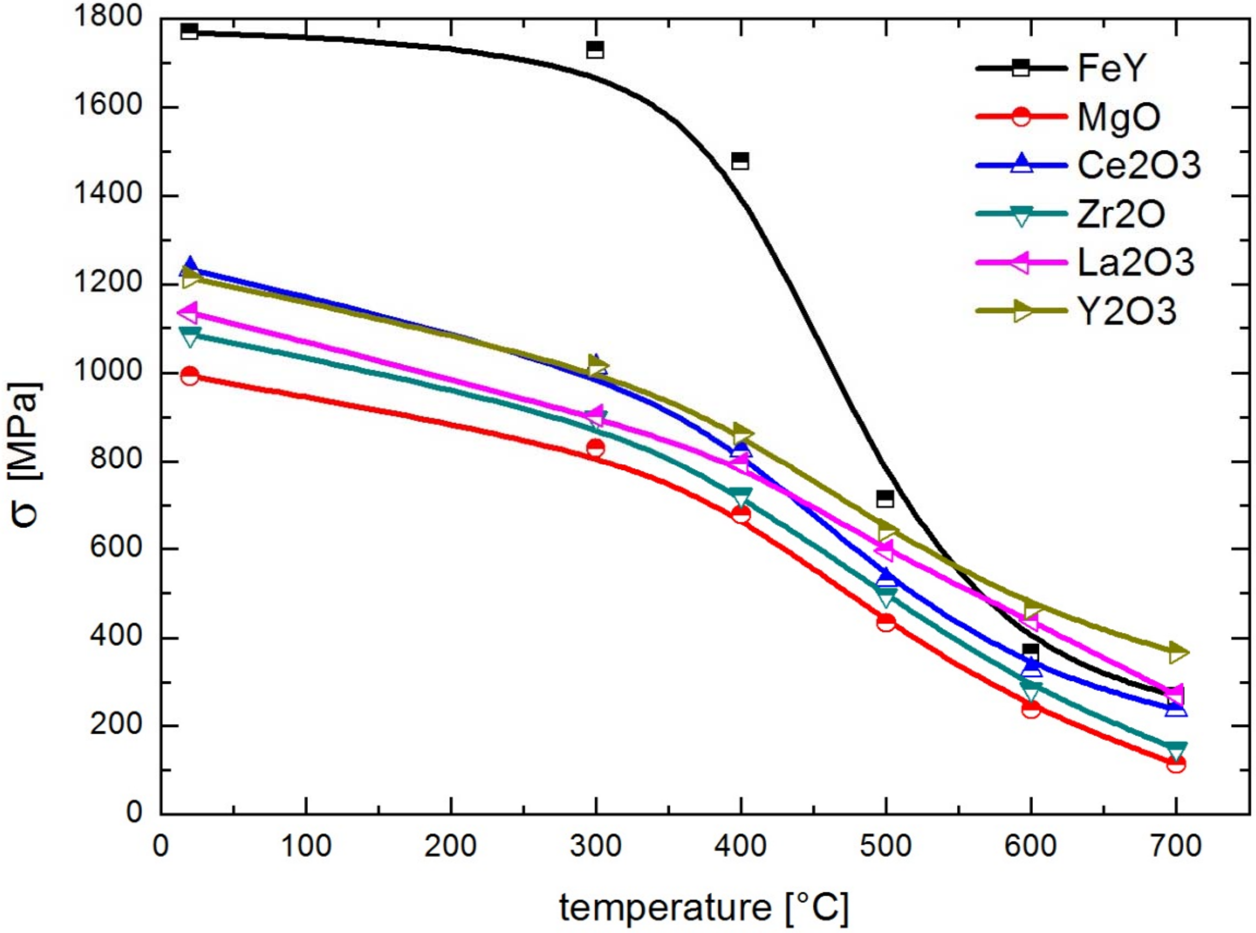
MgO



300°C

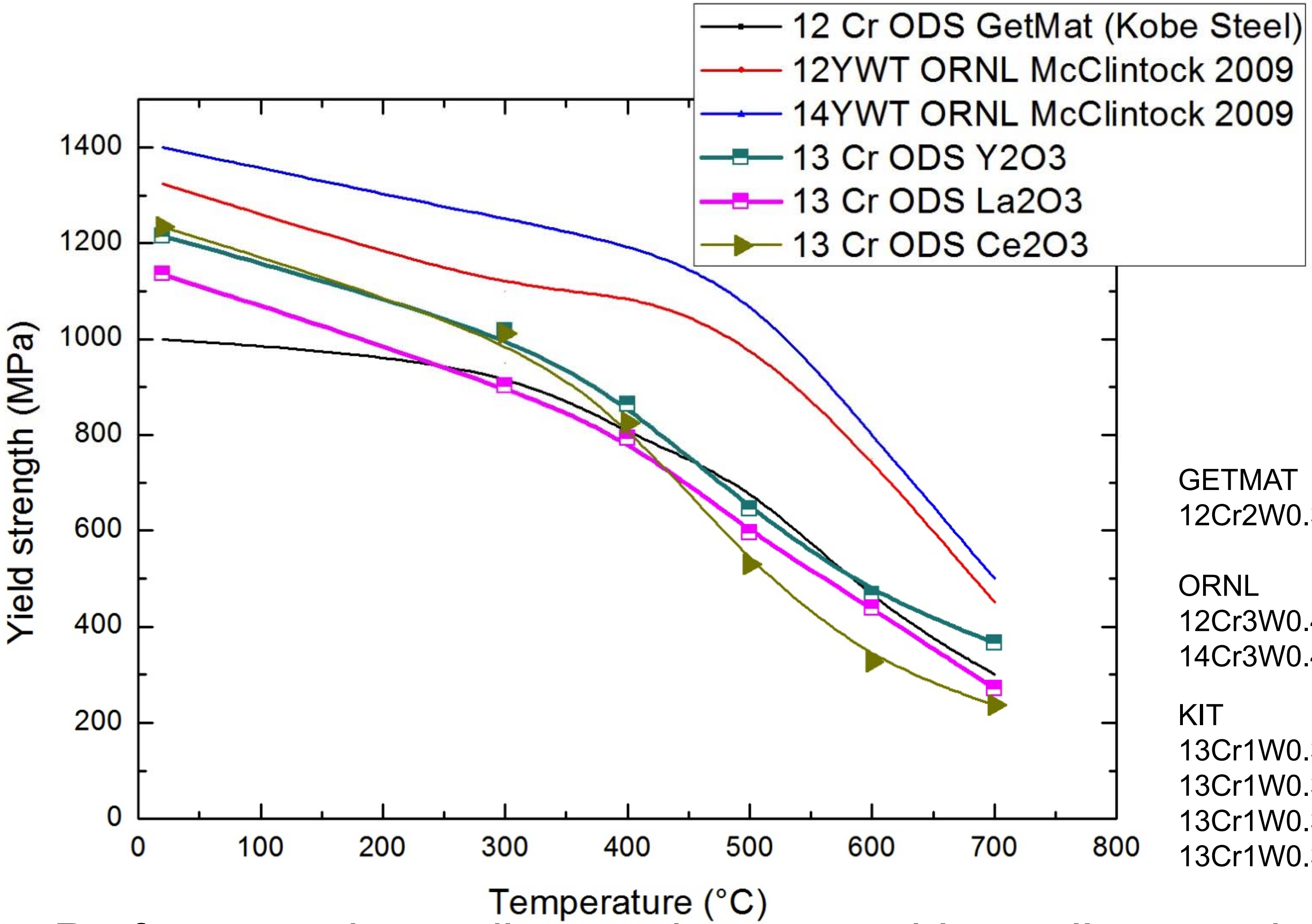


Mechanical tests (tensile tests – yield strength)



- Y-containing alloys show the best results
- Most alloys perform in a similar way

Comparison of 12Cr, 13Cr and 14Cr ODS



GETMAT
12Cr2W0.3Ti 0.2 Y_2O_3

ORNL
12Cr3W0.4Ti 0.25 Y_2O_3
14Cr3W0.4Ti 0.25 Y_2O_3

KIT
13Cr1W0.3Ti 0.3 Y_2O_3
13Cr1W0.3Ti 0.3 La_2O_3
13Cr1W0.3Ti 0.3 Ce_2O_3
13Cr1W0.3Ti 0.3 Fe_2Y

- Performance in tensile tests is comparable to alloys produced at other facilities

Conclusion and Outlook

Alternative oxides for ODS steels

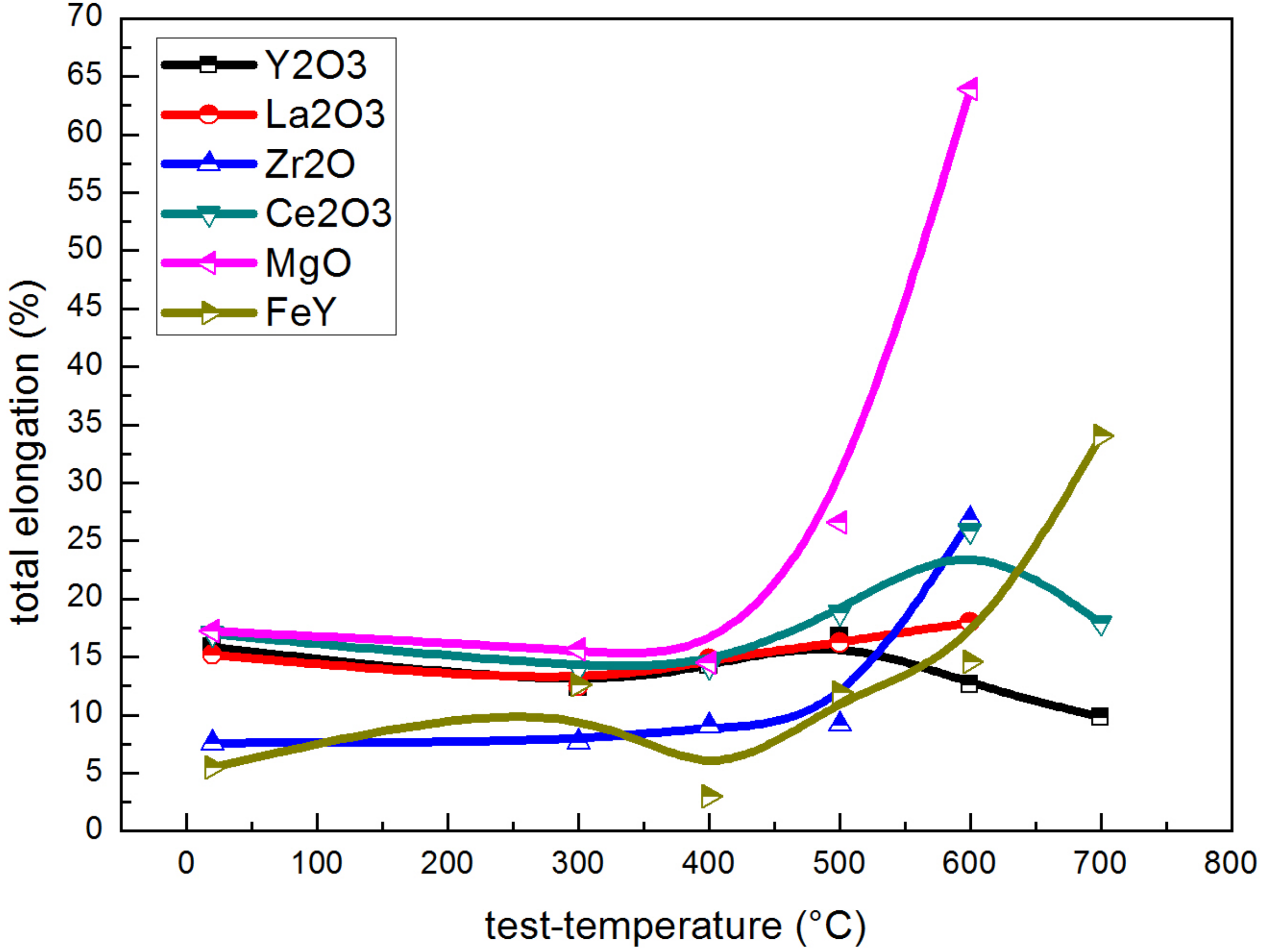
- Formation of nano-oxides is possible with alternative oxides
- Tensile properties of different oxides are comparable to yttrium-alloys
- Improved charpy-impact properties for Ce_2O_3 and MgO

Outlook

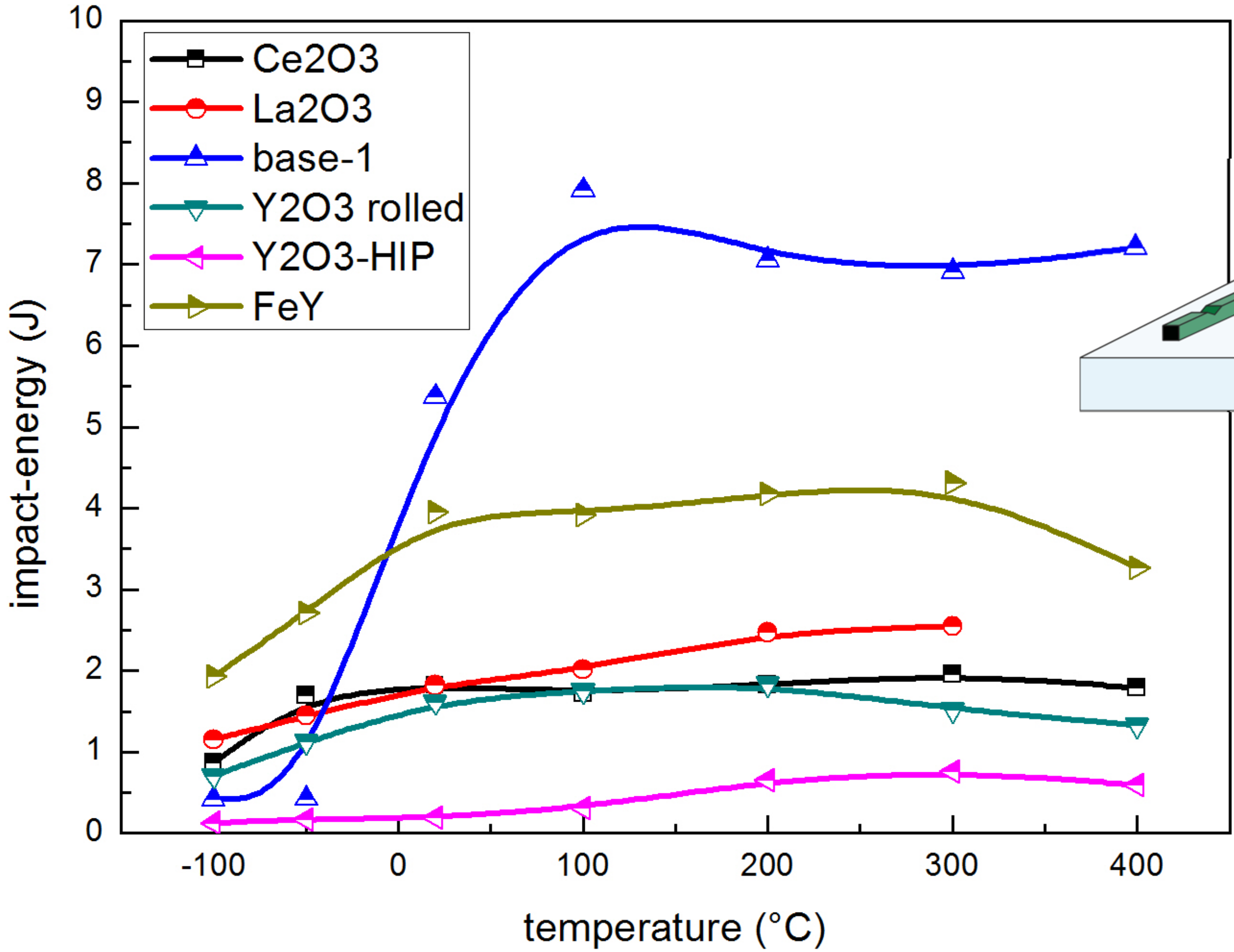
- Detailed TEM Characterization of nano-oxides is still in progress
- EBSD mappings of selected oxides (other than Y_2O_3)

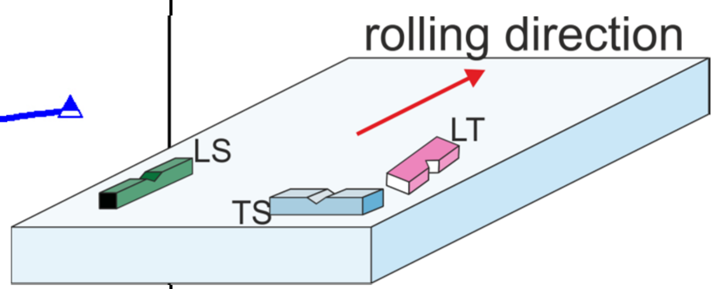
Thank you for your attention!

Mechanical tests (tensile tests – total elongation)



Mechanical tests (charpy-impact test)





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