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Ferritic and austenitic nanocluster containing ODS steels for high temperature applications

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Motivation

Steels for high temperature applications

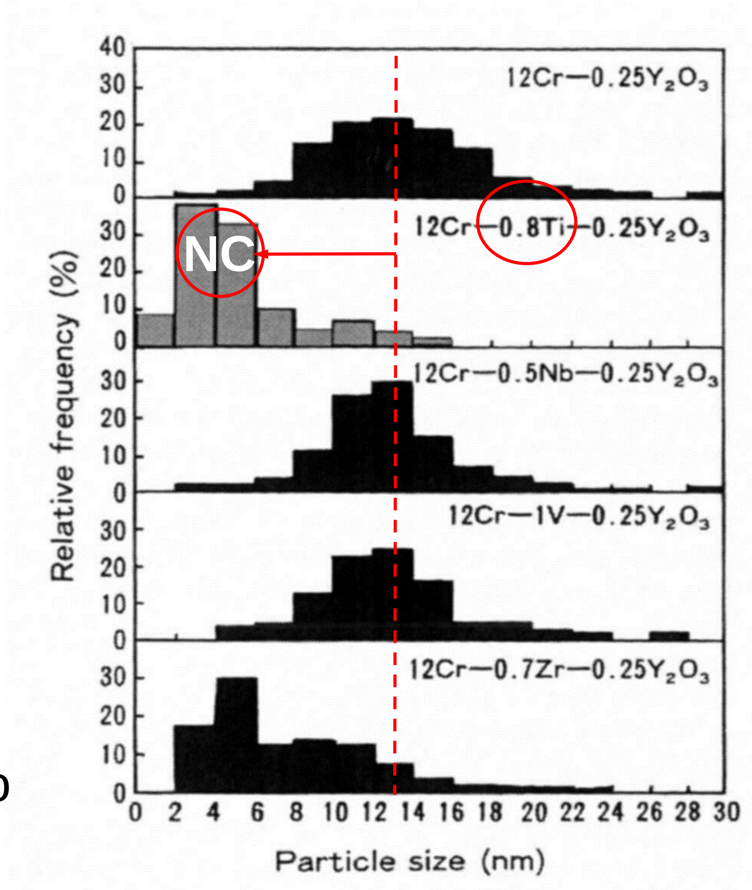
- Low density, low cost, well characterized but use limited up to 700 °C

Benefits of oxides additions

- Formation of nanoclusters
  > limit mean free path of dislocations
- Pinning of grain boundaries hinder grain growth
- Micro alloying elements influence cluster formation

Characteristics of oxide dispersion strengthened (ODS) steels

- Extraordinary good creep resistance
- Stable long-term microstructure up to 1000 °C



Ukai and Fujiwara, J. Nucl. Mater. (2002)

- **Analysis of the thermal stability of the microstructure of ferritic ODS steels**
- **Finding relationships between microstructure and strength**
- **Development of an austenitic ODS steel with nanoclusters (different processing)**

Different ferritic and austenitic ODS steels were produced by

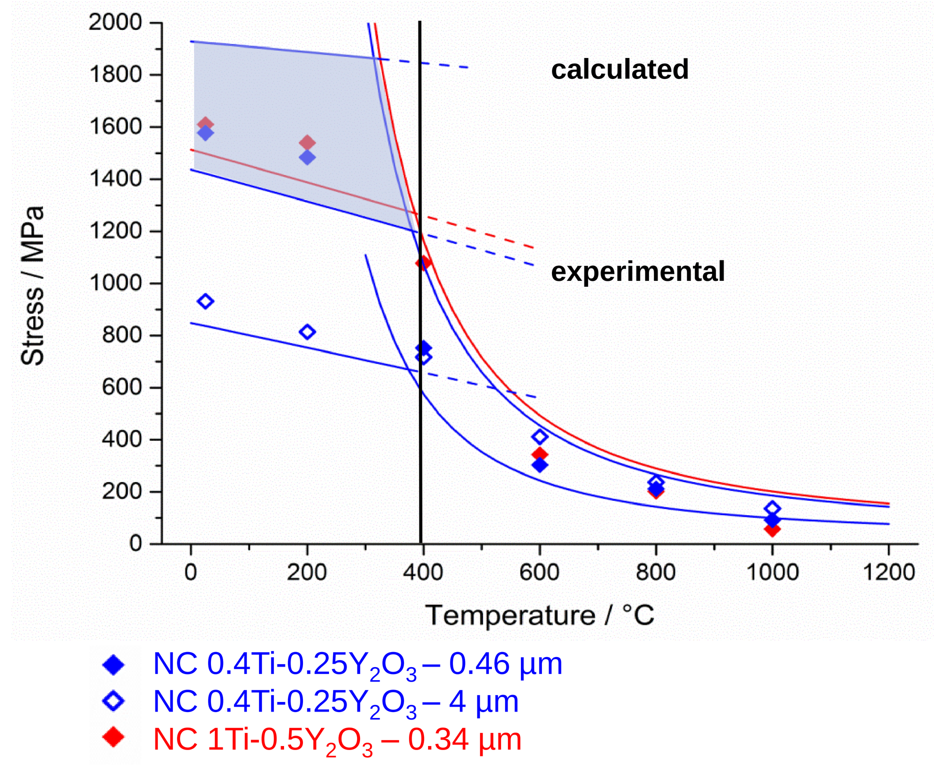
- Mechanical alloying (MA) with an attrition mill or planetary ball mill
- Field Assisted Sintering Technique (FAST)

Nominal comp. / wt.%	Fe	Cr	Ni	Ti	Y_2O_3
NC 0.4Ti-0.25Y_2O_3	balance	14	-	0.4	0.25
NC 1Ti-0.5Y_2O_3	balance	14	-	1	0.5
ANC 0.4Ti-0.25Y_2O_3	balance	25	20	0.4	0.25

Mechanical properties of ferritic ODS steels

Compression tests between room temperature and 1000 °C

- Modelling the temperature dependent strength
- Blum & Zeng model at temperatures > 400 °C
- Superposition of Orowan and Hall-Petch hardening below 400 °C
  > from calculation and experiment

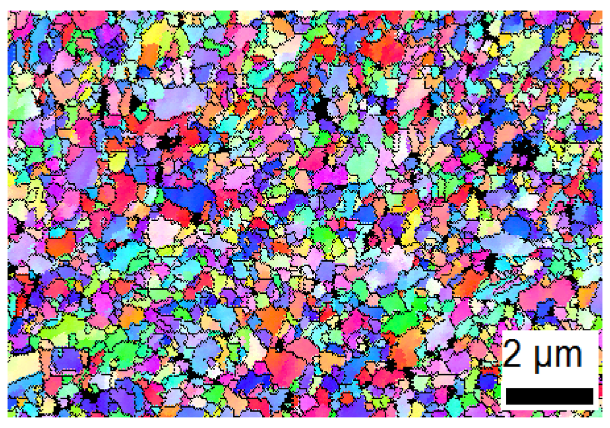


- **For a detailed description knowledge about grain sizes (EBSD) and particle sizes as well as particle distribution is necessary (APT).**

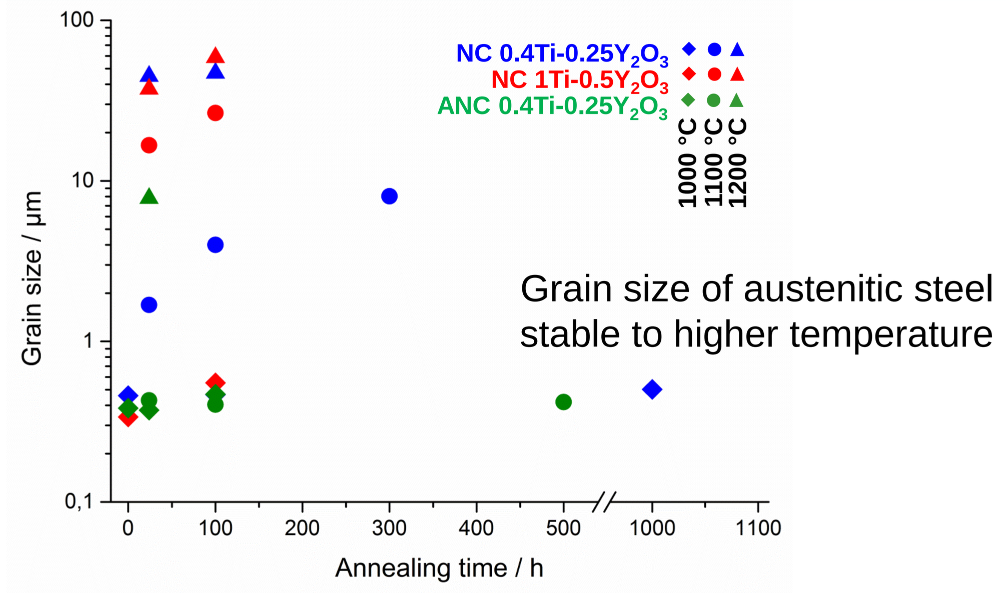
Grain sizes by EBSD

Initial grain size of ferritic and austenitic alloys almost the same

NC 0.4Ti-0.25Y_2O_3	0.46 ± 0.21 µm
NC 1Ti-0.5Y_2O_3	0.34 ± 0.13 µm
ANC 0.4Ti-0.25Y_2O_3	0.38 ± 0.13 µm



Initial state of NC 0.4Ti-0.25Y_2O_3 (EBSD orientation mapping)

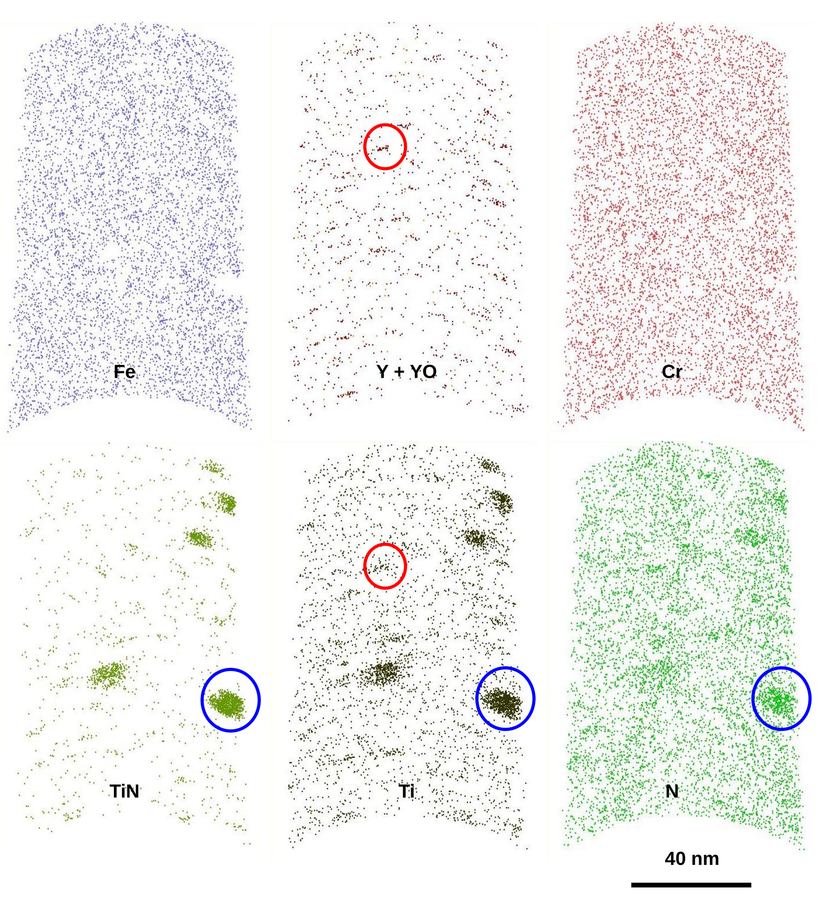


Particle analysis by APT

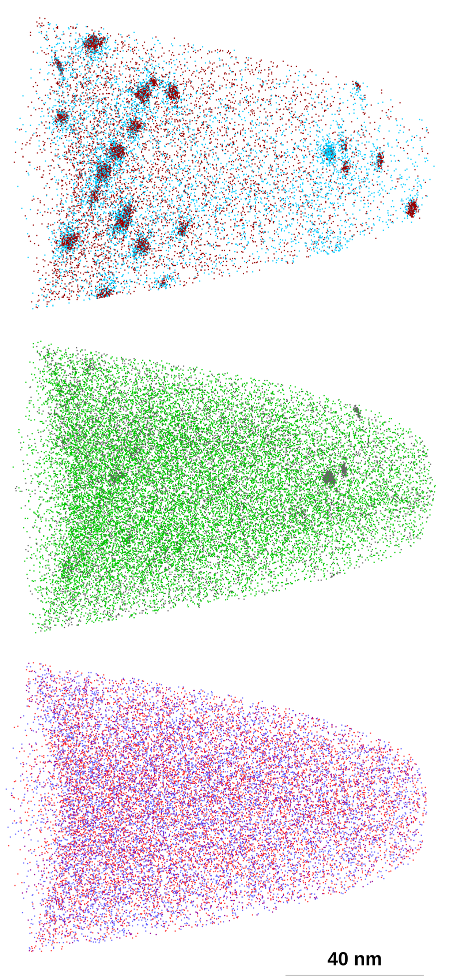
- **Which parameters are suitable?**

Voltage mode (ferritic ODS)		Laser mode (austenitic ODS)	
Detection rate:	0.5 %	Detection rate:	0.3 %
Pulse rate:	200 kHz	Pulse rate:	250 kHz
Pulse fraction:	19 to 20 %	Pulse energy:	25 pJ
T_{set}:	60 K	T_{set}:	30 K

- **How do the particles look like?**



Reconstruction of a NC 0.4Ti-0.25Y_2O_3 tip in the initial state



Y^{3+} (brown)
O^{2+} (blue)

C^{+} (grey)
N^{+} (green)

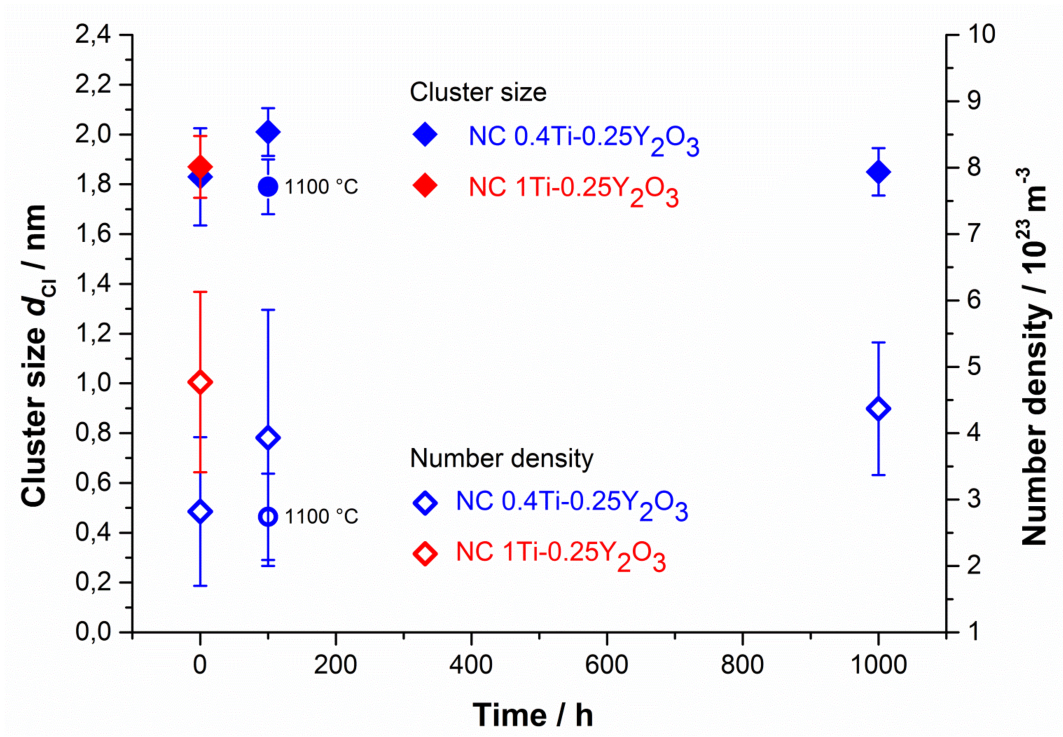
Fe^{2+} (red)
Cr^{2+} (blue)
Ni^{2+} (purple)

Reconstruction of a ANC 0.4Ti-0.25Y_2O_3 tip in the initial state

- **How to quantify the particles using IVAS?**

1. Cluster count distribution to find d_{max}
2. Cluster size distribution to find N_{min}
3. Cluster analysis
4. Cluster size from radius of gyration (z-direction)
5. Cluster density (particles per volume)

- **Temperature stability of particles?**



- Cluster size in both ferritic alloys around 2 nm
- No cluster growth although grains coarsen
- Same number density of clusters in both alloys

- **Clusters in austenitic ODS steel?**
- Clusters exist in spite of different processing
- First assumption: larger clusters (3.4 nm) and lower one order of magnitude lower number density (10^{23} m^{-3})
- **Coming soon:** What will be the consequences of this cluster configuration on the mechanical properties?

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