

# Microstructure and high temperature oxidation behavior of novel refractory compositionally complex alloys

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a) Nb-Mo-Cr-Ti-Al

b) Ta-Mo-Cr-Ti-Al

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a) Nb-Mo-Cr-Ti-Al

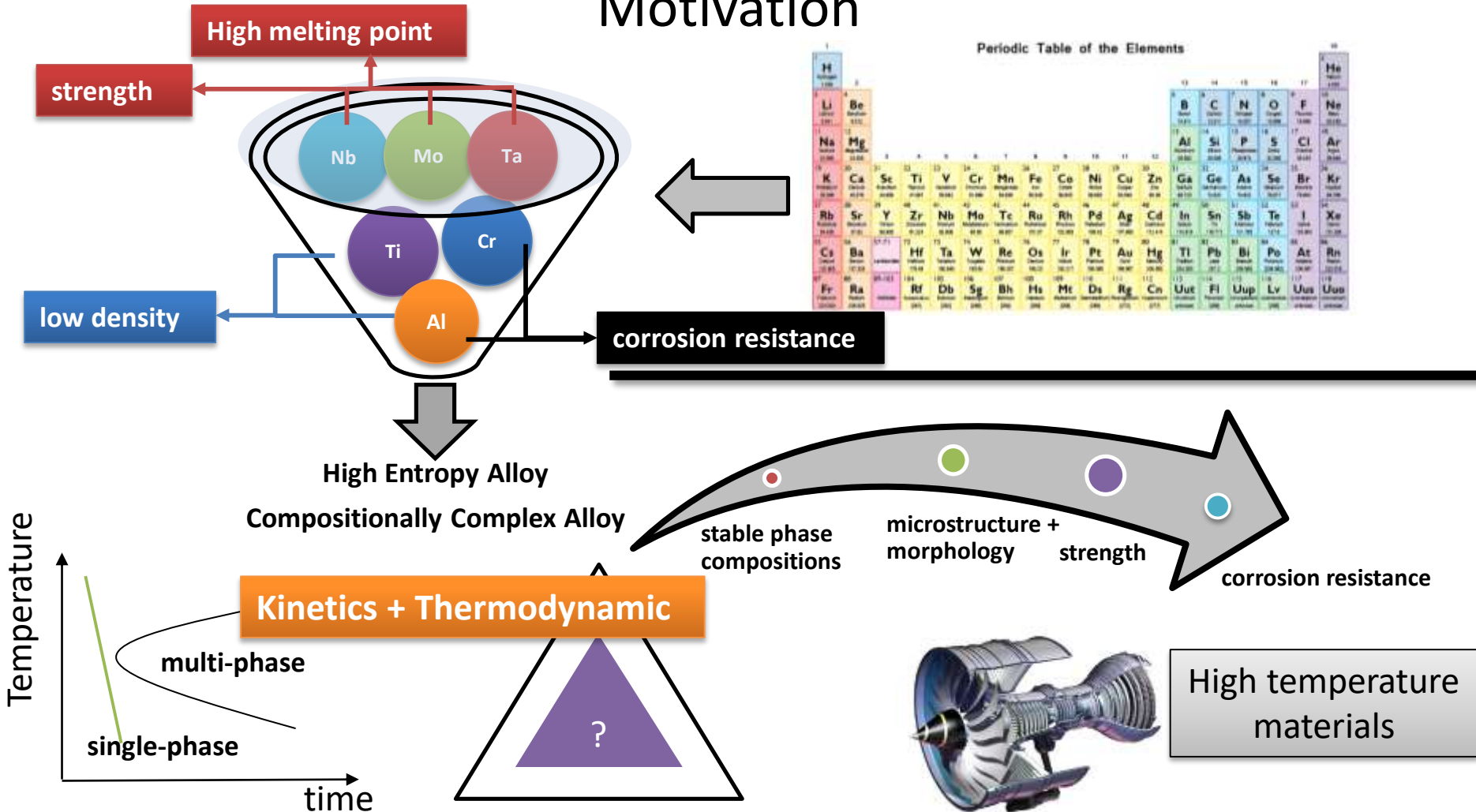
b) Ta-Mo-Cr-Ti-Al

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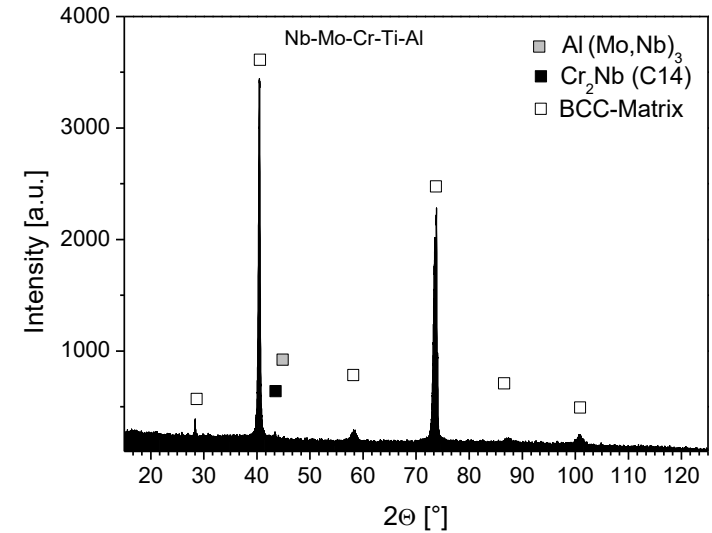
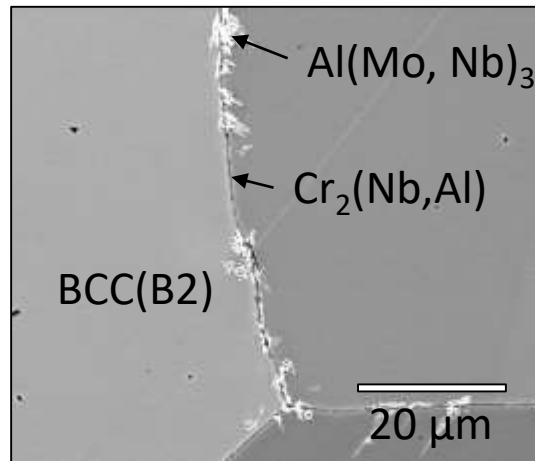
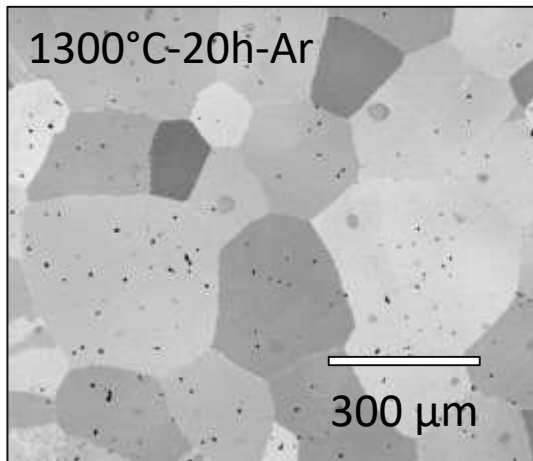
# Motivation



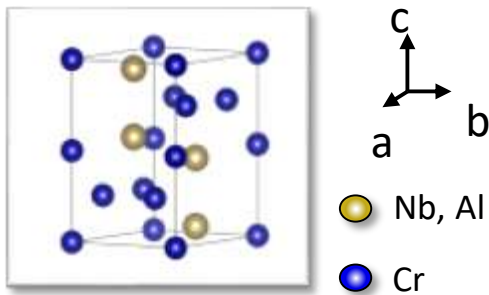


## II. Microstructure

# Nb-Mo-Cr-Ti-Al

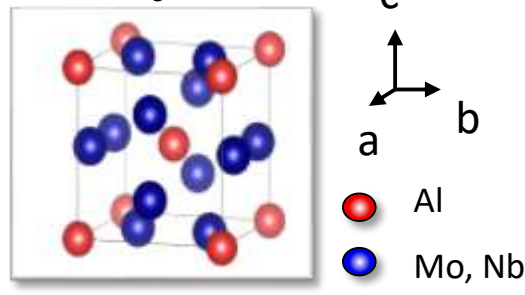


Cr<sub>2</sub> (Nb, Al) (C14)

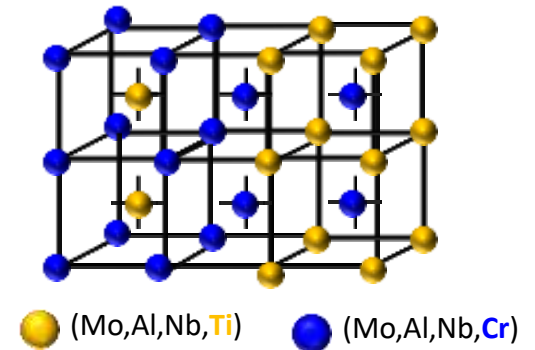


Minor amounts of (Al,Cr)<sub>3</sub>Ti (AuCu<sub>3</sub>)

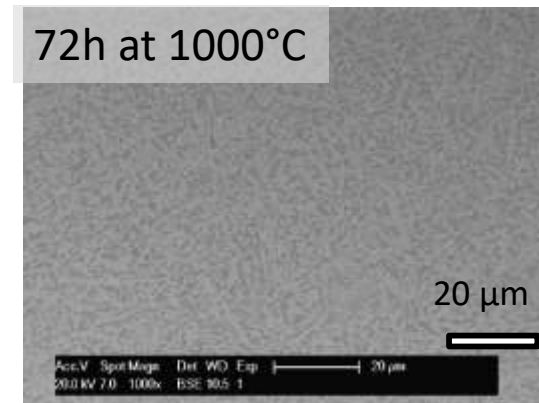
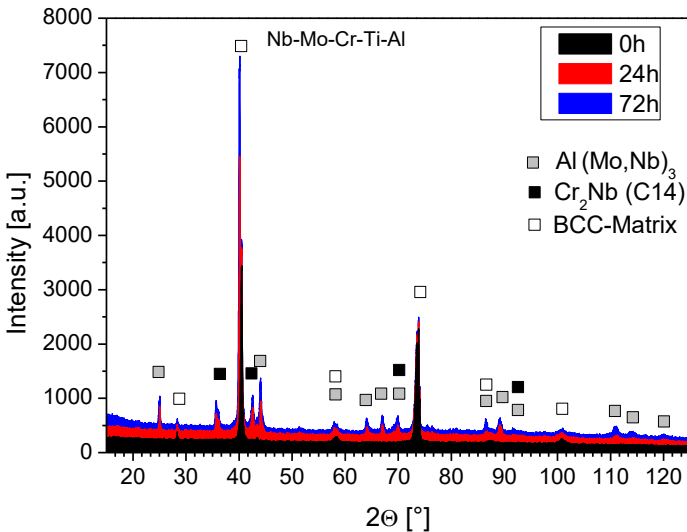
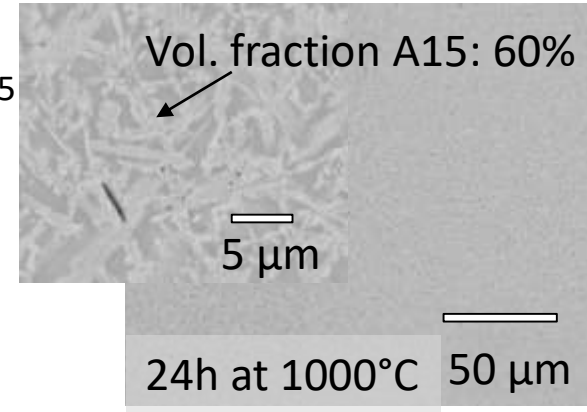
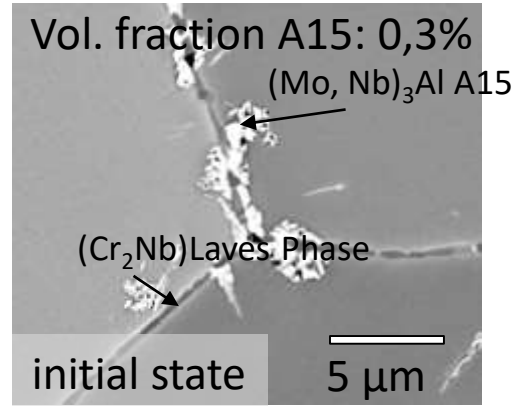
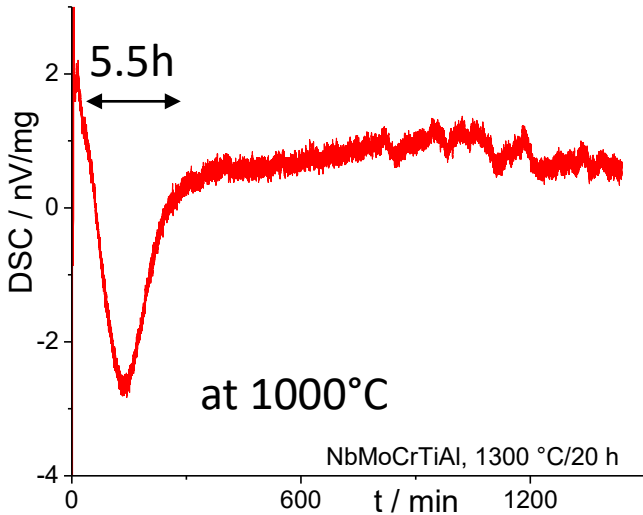
(Mo, Nb)<sub>3</sub>Al (A15)



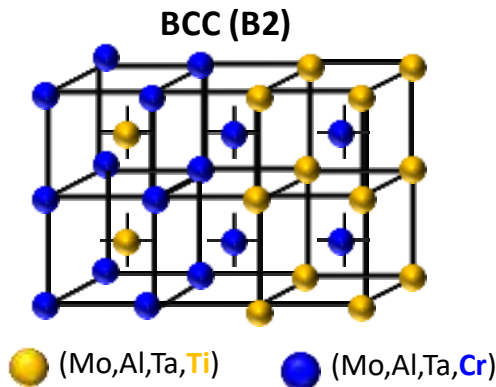
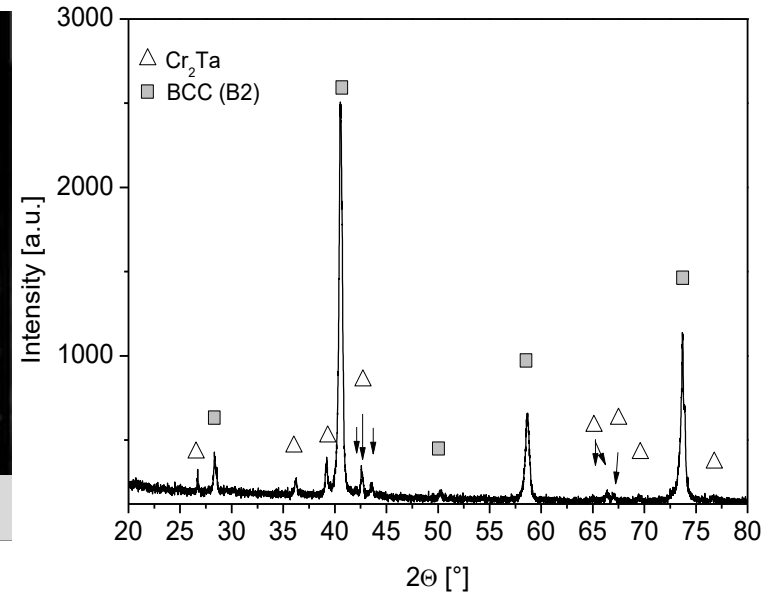
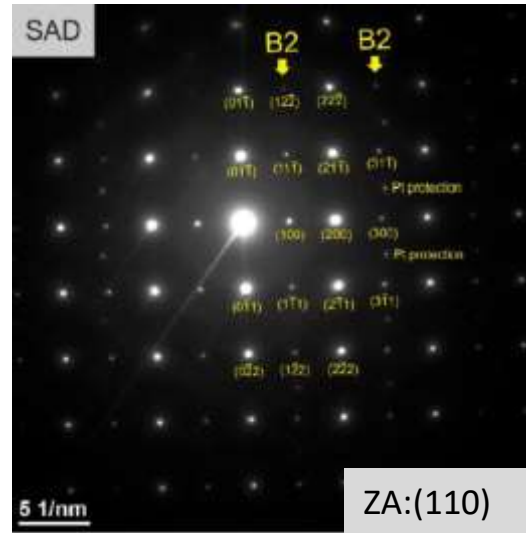
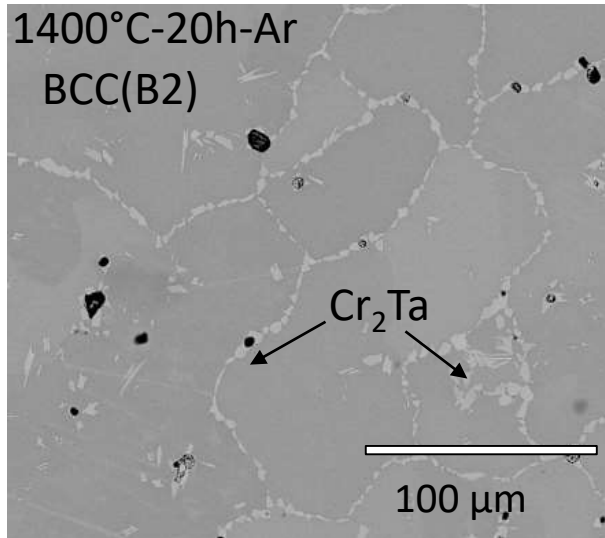
BCC (B2)



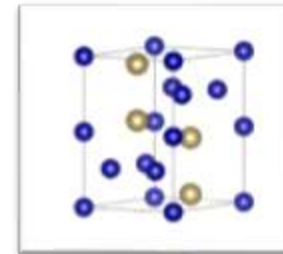
# Nb-Mo-Cr-Ti-Al



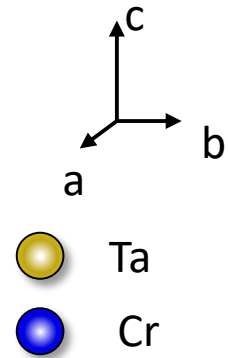
# Ta-Mo-Cr-Ti-Al



Laves Phases (Cr<sub>2</sub>(Ta, Al))

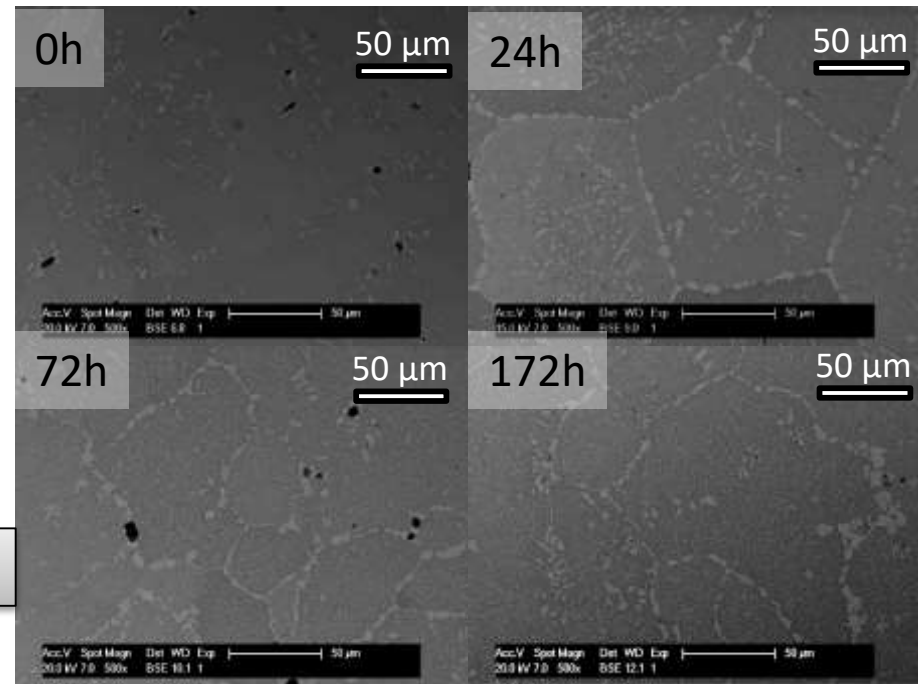
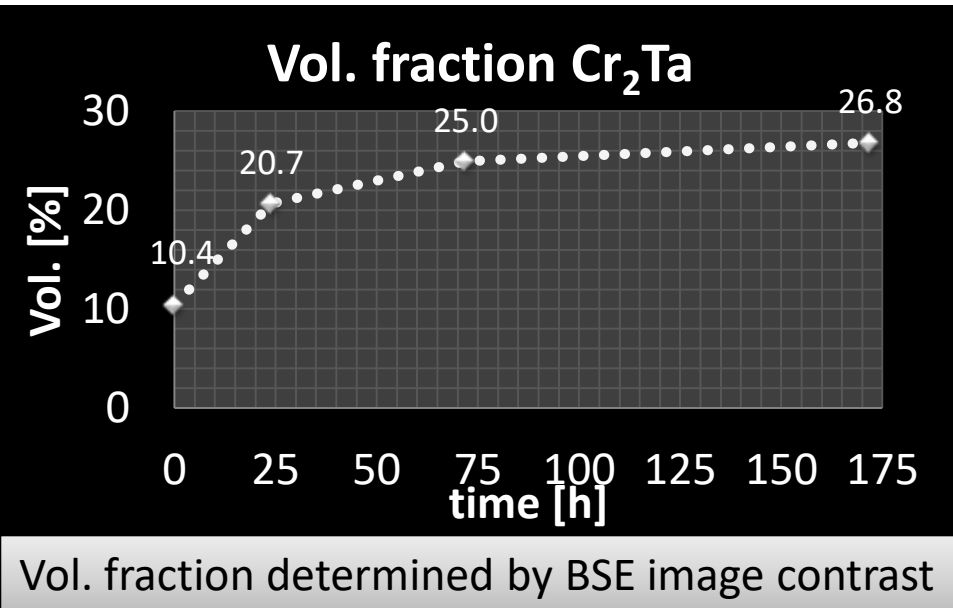


(C14)





## Ta-Mo-Cr-Ti-Al



### Ageing at 1000°C

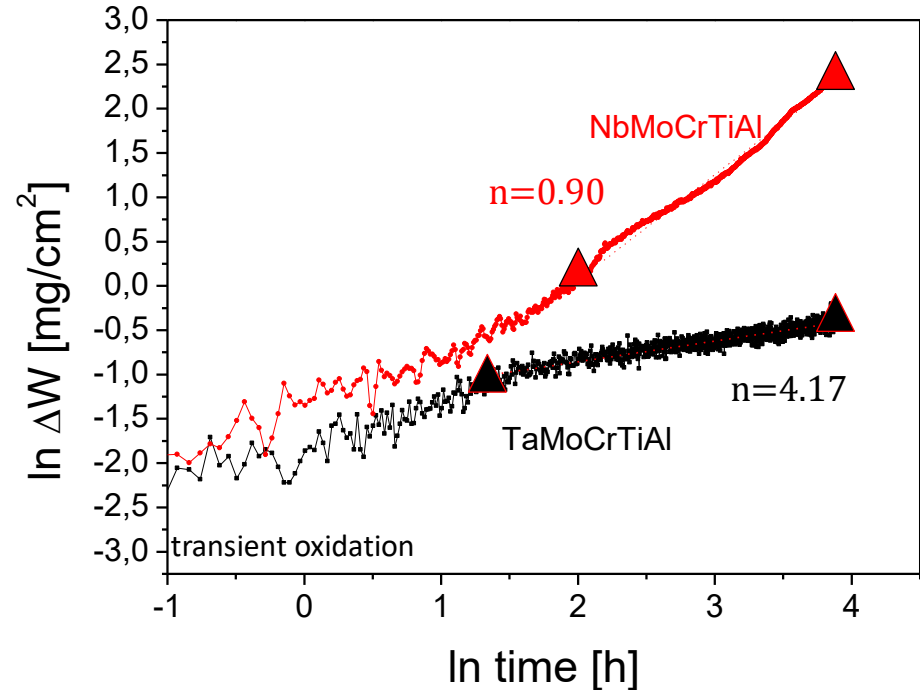
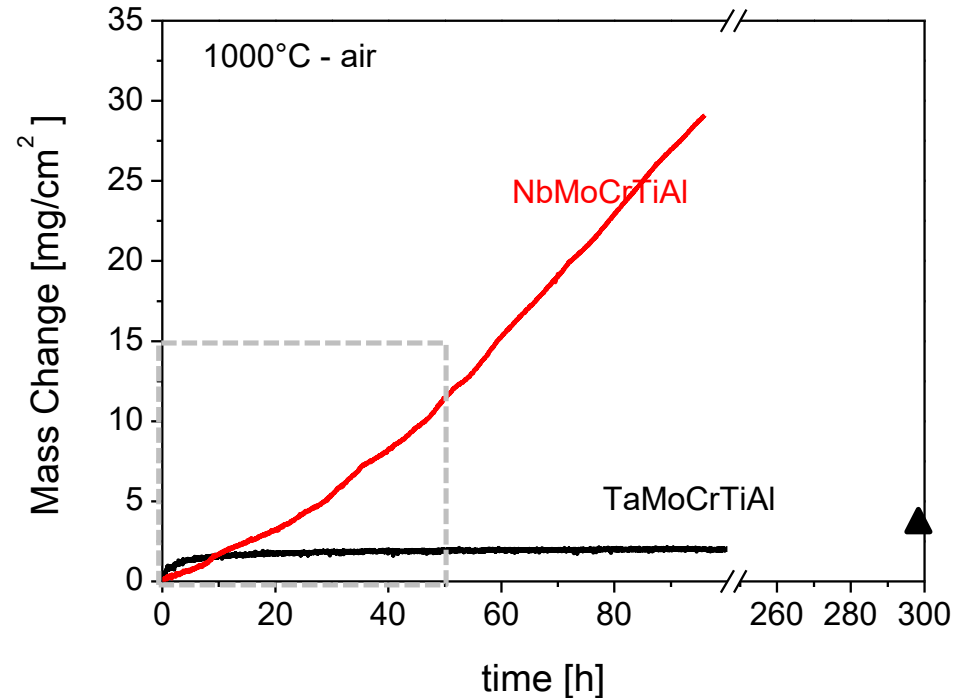
1. No further intermetallic phases observed
2. Vol. fraction of  $\text{Cr}_2\text{Ta}$  Laves Phase increases





# III. High temperature oxidation behavior

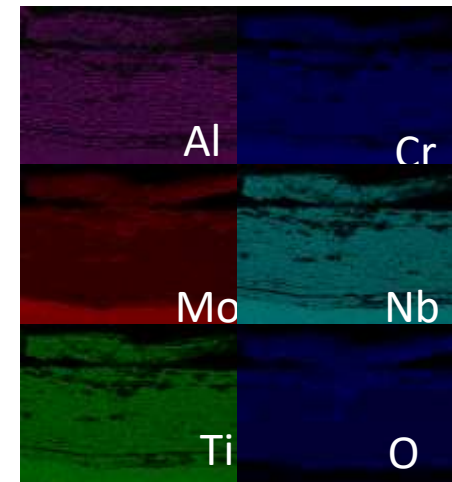
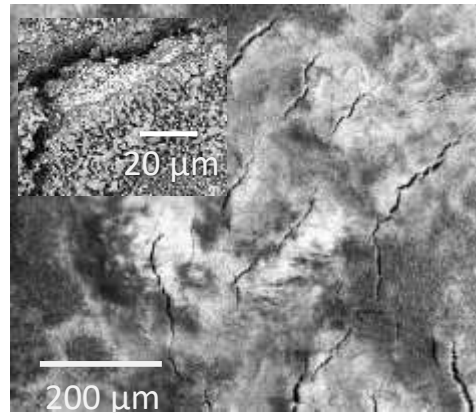
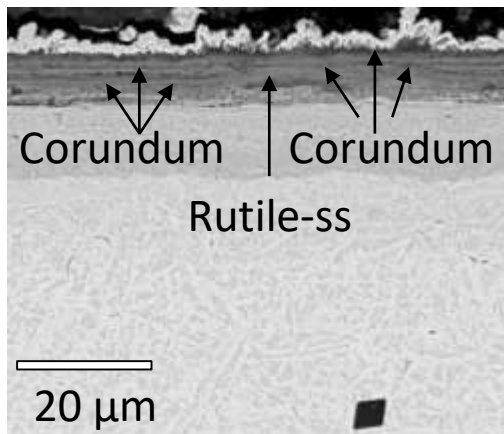
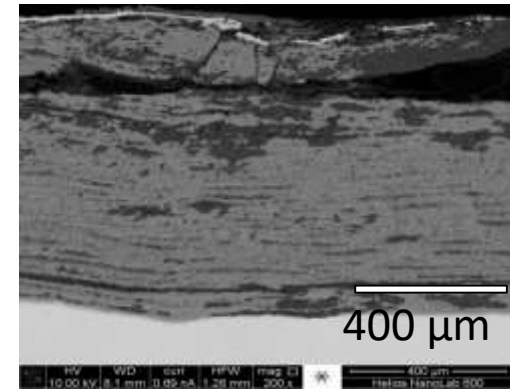
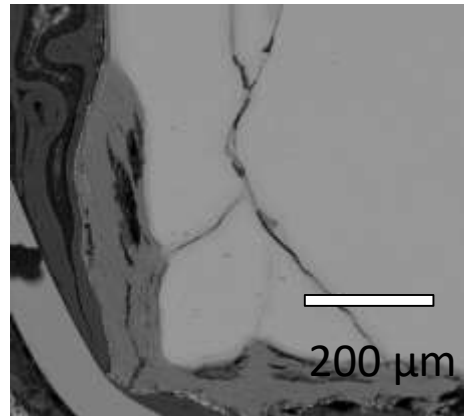
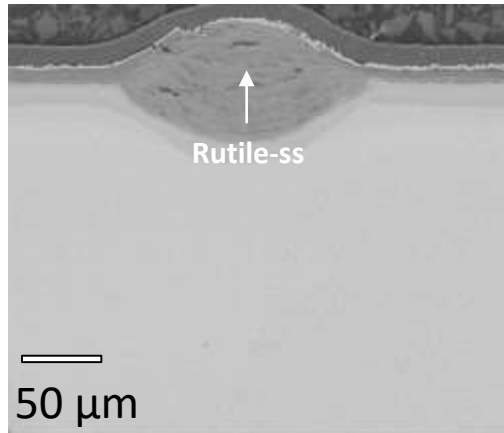
## Nb/Ta-Mo-Cr-Ti-Al 1000°C-air



$$(\Delta W)^n = kt$$

$$(\Delta W) = 1/n \ln K + 1/n \ln t$$

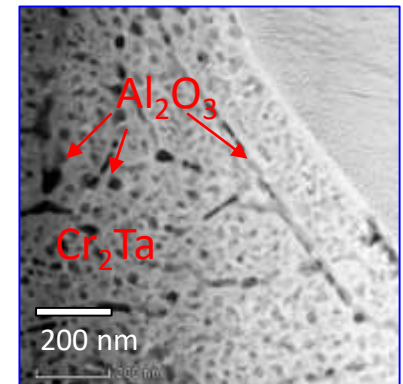
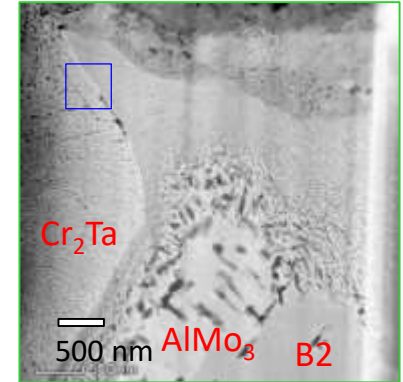
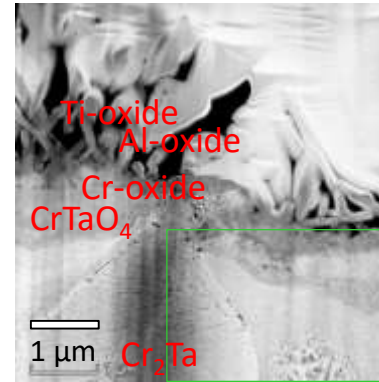
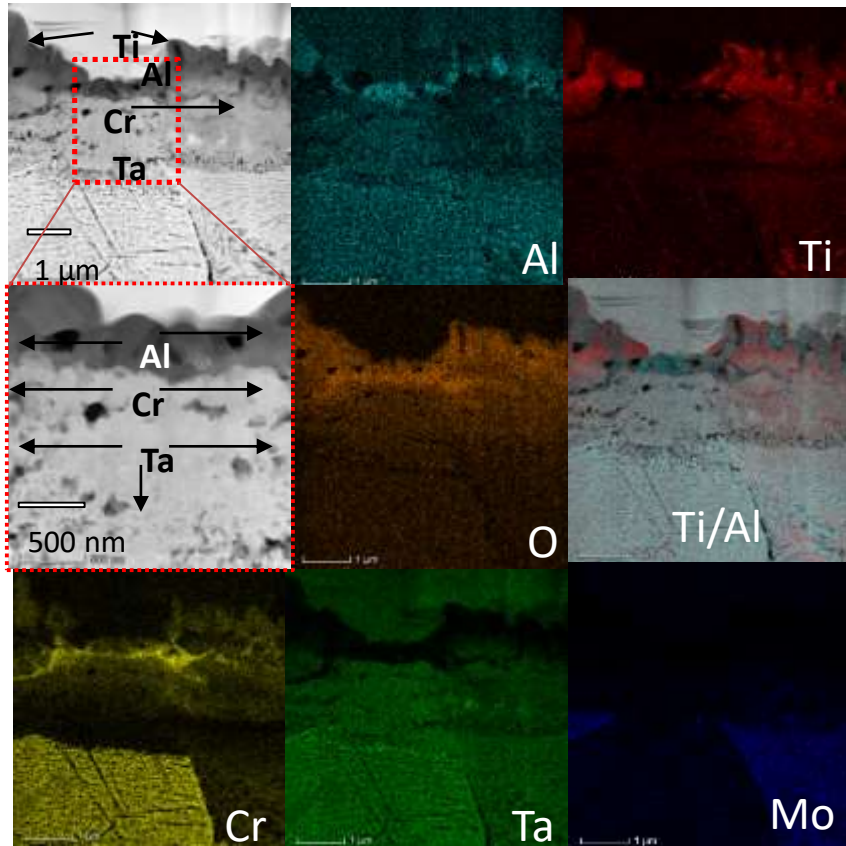
## Nb-Mo-Cr-Ti-Al 1000°C- air



24 h

100 h

# Ta-Mo-Cr-Ti-Al 1000°C-air



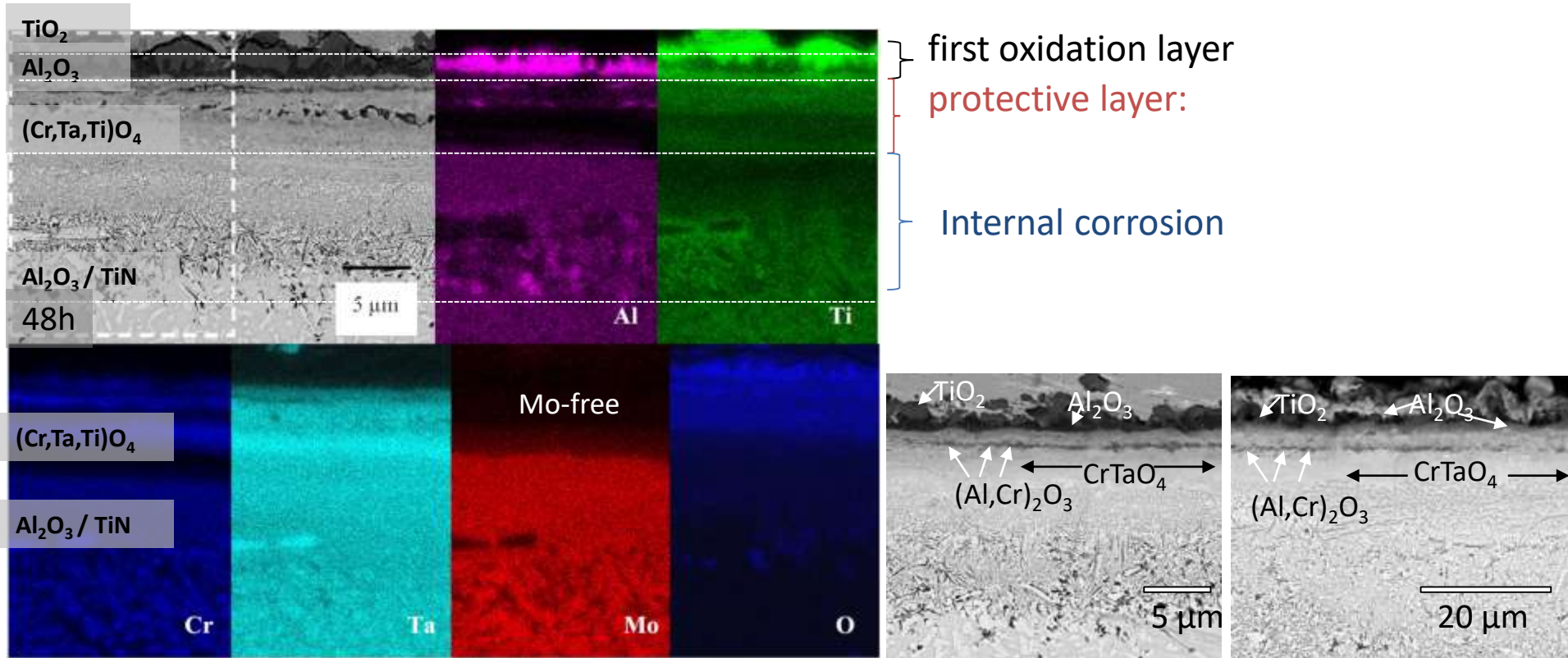
10 min

3 h

time →



## Ta-Mo-Cr-Ti-Al 1000°C-air



48 h

100 h

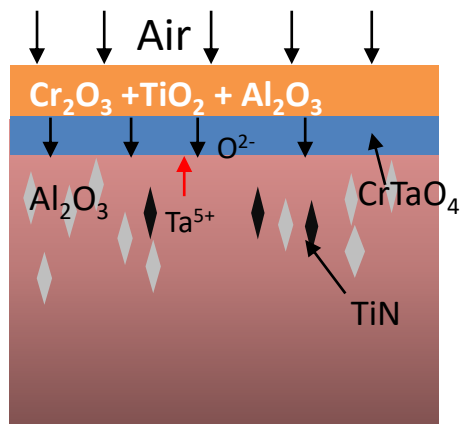
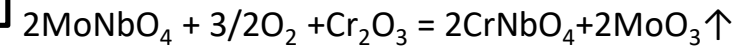
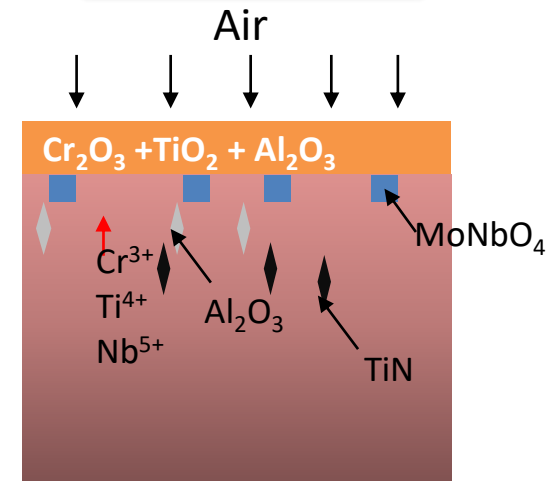
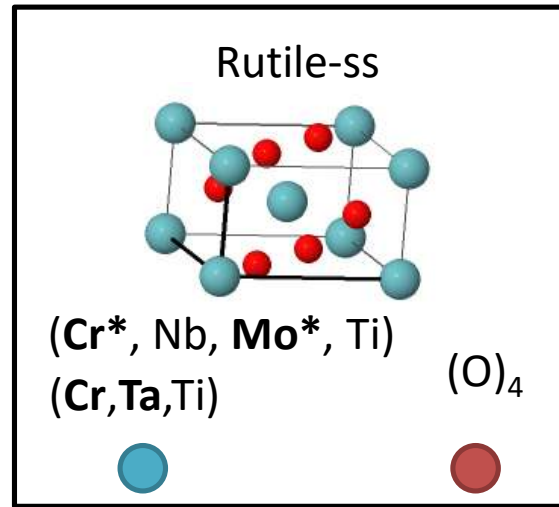
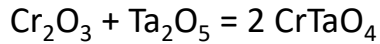
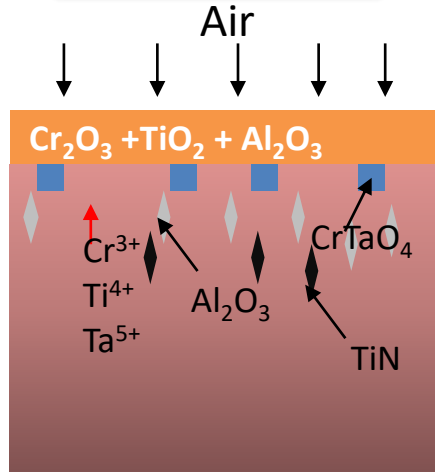
300 h

time

Ta-Mo-Cr-Ti-Al

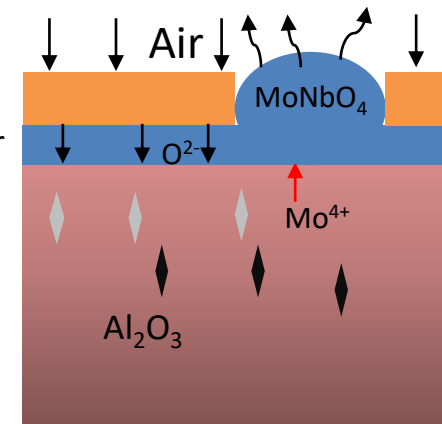
Oxidation behavior

Nb-Mo-Cr-Ti-Al



initial oxide layer  
 protective layer  
 internal corrosion

initial oxide layer  
 nonprotective layer  
 internal corrosion



Temperature

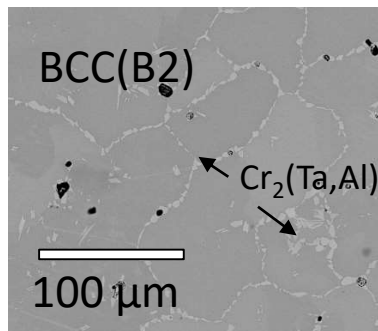
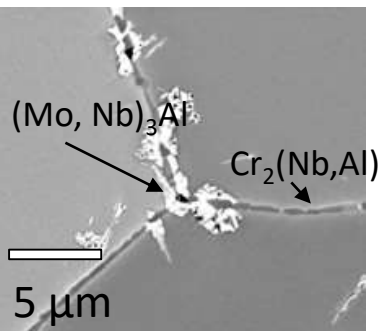
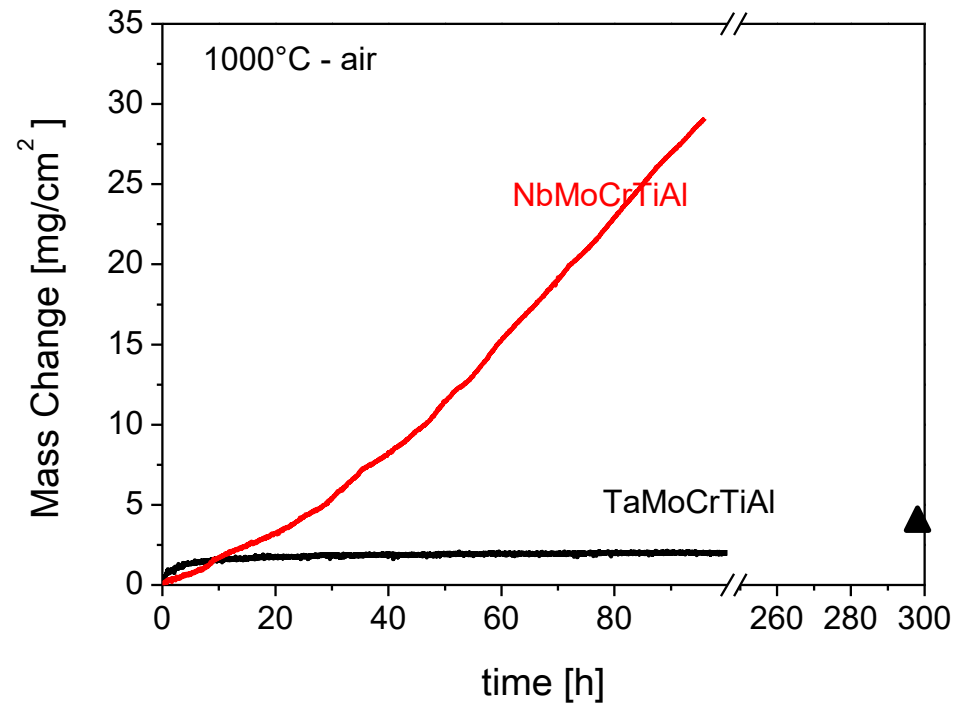
↑  
BCC(A2)  
1300°C  
BCC(A2)+  
Cr<sub>2</sub>Nb+A15  
1030°C  
BCC(B2)+  
Cr<sub>2</sub>Nb+A15  
RT

Nb-Mo-Cr-Ti-Al

BCC(A2)  
1500°C  
BCC(A2)+Cr<sub>2</sub>Ta  
1110°C  
BCC(B2)+Cr<sub>2</sub>Ta  
RT

Ta-Mo-Cr-Ti-Al

## Summary

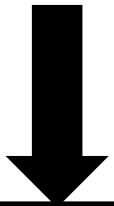




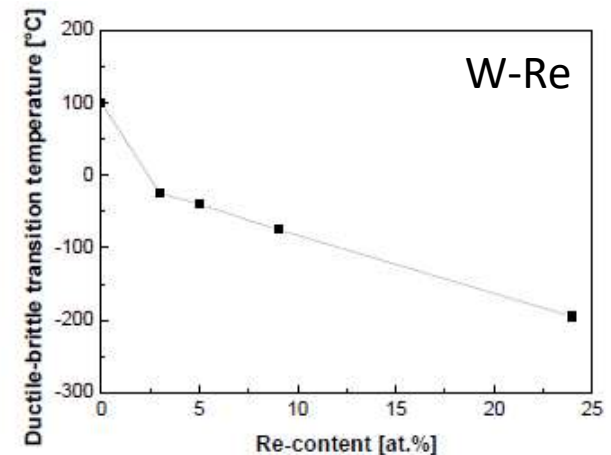
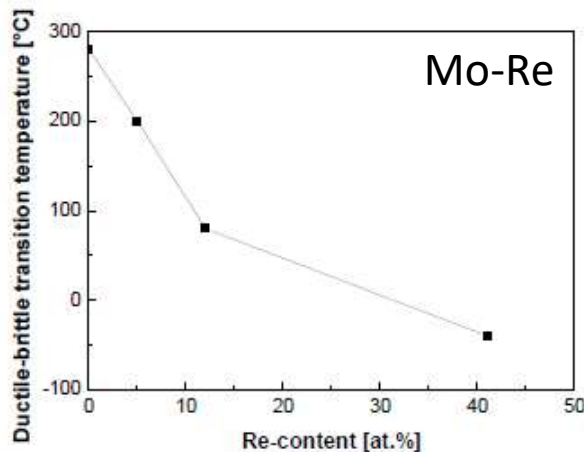
## Outlook

- Suppression of the inherently brittle Laves phases ( $\text{Cr}_2\text{Ta}$ ) by lowering the Cr, Ta content in Ta-Mo-Cr-Ti-Al but keeping up the good oxidation resistance
- Establishment of a two-phase microstructure (BCC(A2/B2)) with a substantial amount of the second strengthening B2 phase by varying the concentration of the ordering elements
- Ductilizing the alloy matrix at ambient temperature by additions of Re

Re addition



decrease D-btt





# Thank you for your kind attention

 **DFG** Deutsche  
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