Trace elements influencing the microstructure of the $Al_{10}Co_{25}Cr_8Fe_{15}Ni_{36}Ti_6$ compositionally complex alloy

A. Manzoni[a], F. Dubois[a], C. von Schlippenbach[a], M. Mousa[b], U. Glatzel[c], N. Wanderka[a]

[a] Helmholtz-Zentrum Berlin für Materialien und Energie, Institut für Angewandte Materialien, Berlin, Germany

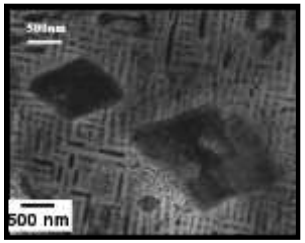
[b] Dept. of Physics, Mu'tah University, Al-Karak, Jordan.

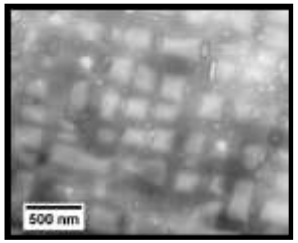
[c] University Bayreuth, Metals and Alloys, Bayreuth, Germany

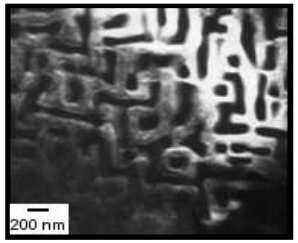
DFG Project

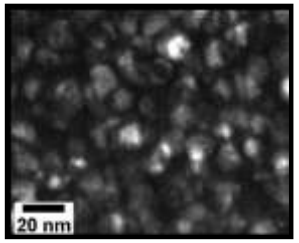
Quick view on optimisation steps

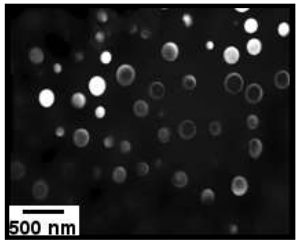
Manzoni et al., Entropy, 2016

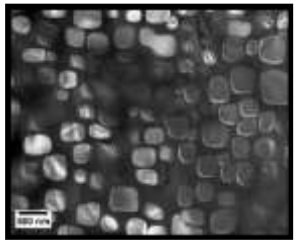












AlCoCr CuFeNi	**$Al_{23}Co_{15}Cr_{23}$ $Cu_8Fe_{15}Ni_{16}$**	**AlCoCr FeNi**	**$Al_8Co_{17}Cr_{17}$ $Cu_8Fe_{17}Ni_{33}$**	**$Al_8Co_{17}Cr_{14}$ $Cu_8Fe_{17}Ni_{33}$ $Mo_{0.1}Ti_1W_{0.1}$**	**$Al_{10}Co_{25}Cr_8$ $Fe_{15}Ni_{36}Ti_6$**
	↘Cu ↗Al&Cr	↘Cu	↘Al&Cu ↗Ni	↘ Al&Cu ↗Ni +Mo, Ti&W	↘ Al&Cu ↗Co&Ni +Ti
bcc	**bcc**	**bcc**	**fcc**	**fcc**	**fcc**
≥6 phases brittle	3 phases brittle	2 phases brittle	1 phase very ductile	2 phases very ductile	3 phases ductile

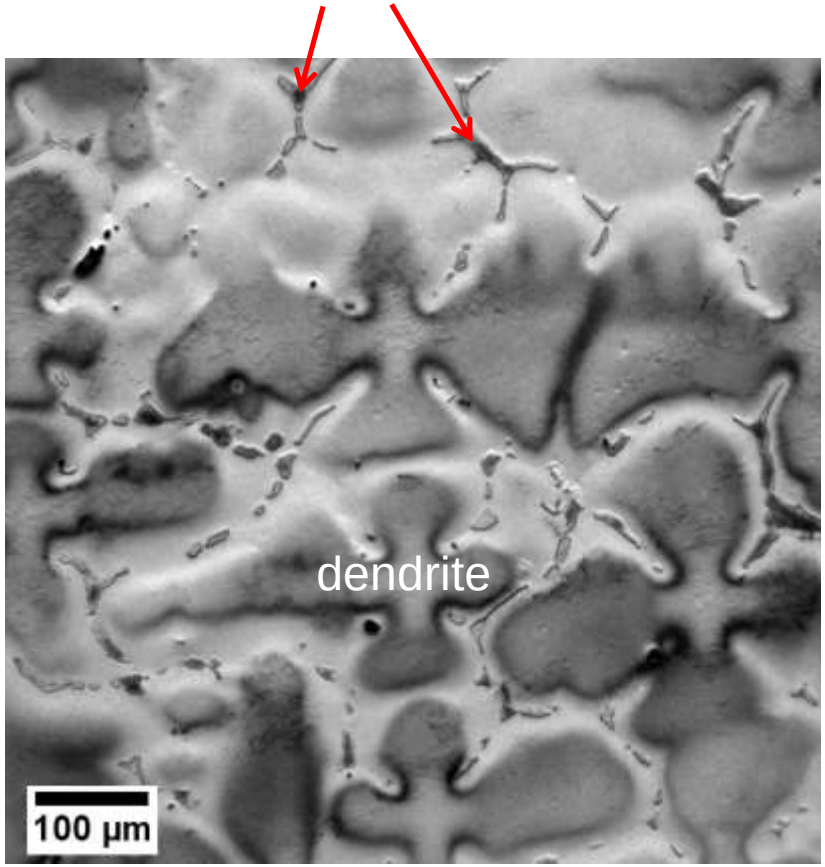
The new "base" alloy
$Al_{10}Co_{25}Cr_8Fe_{17}Ni_{36}Ti_6$
has an fcc solid solution with $L1_2$ precipitates (and a needle phase)

anna.manzoni@helmholtz-berlin.de

$Al_{10}Co_{25}Cr_8Fe_{17}Ni_{36}Ti_6$: microstructure

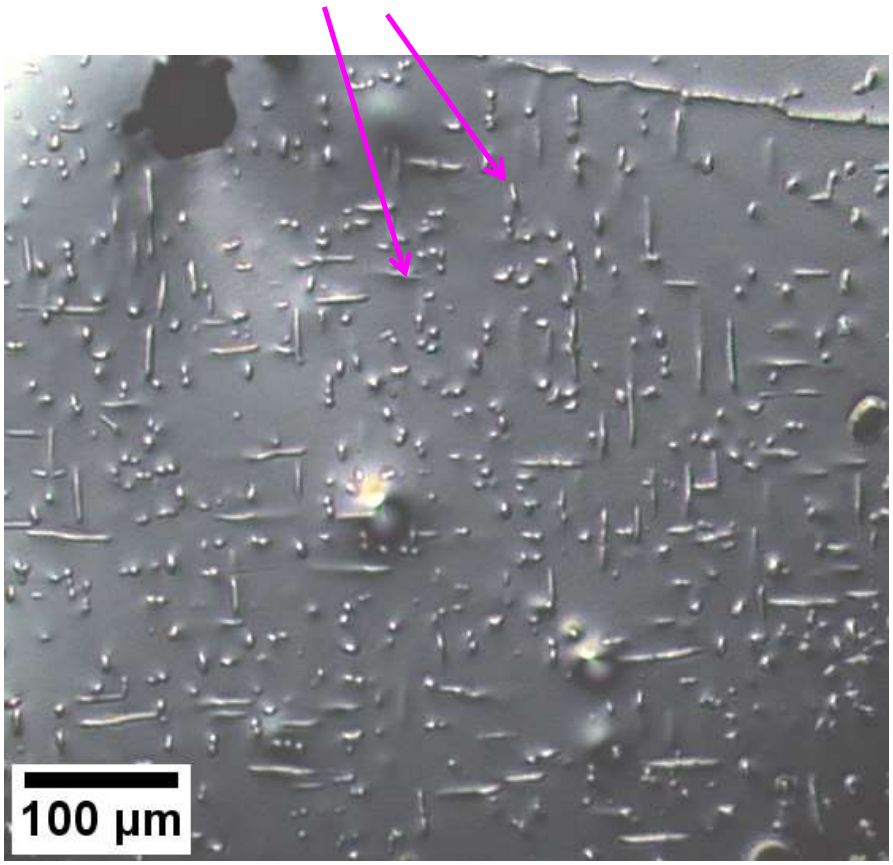
Manzoni et al., Entropy, 2016

Ti rich interdendritic regions



OM – as-cast sample

Al rich needle



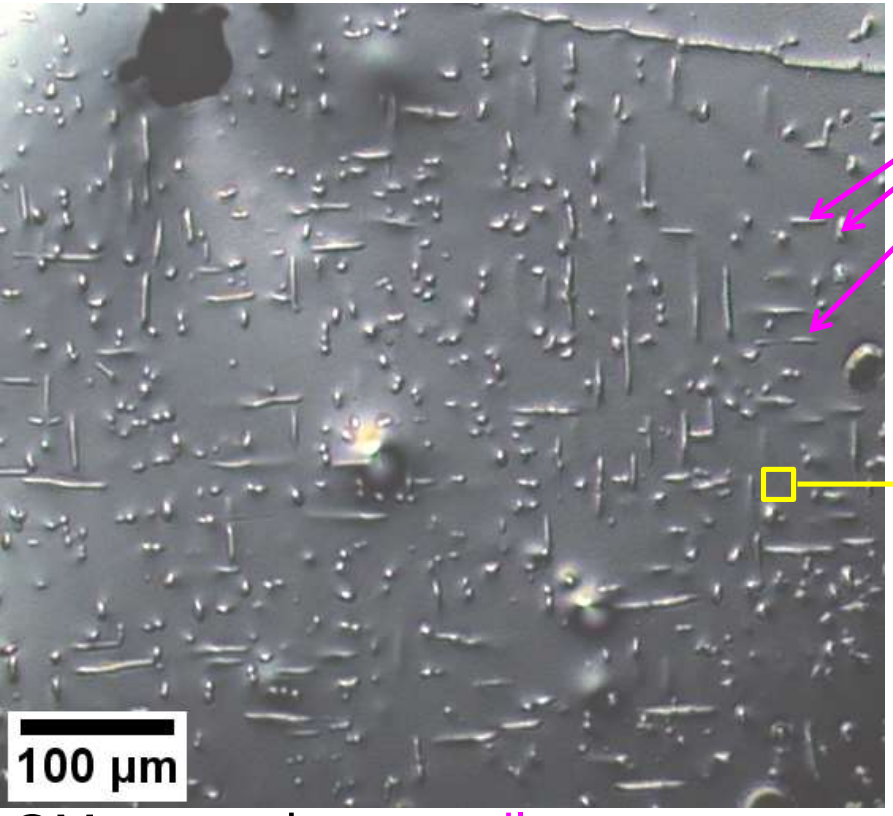
OM – heat treated sample

anna.manzoni@helmholtz-berlin.de

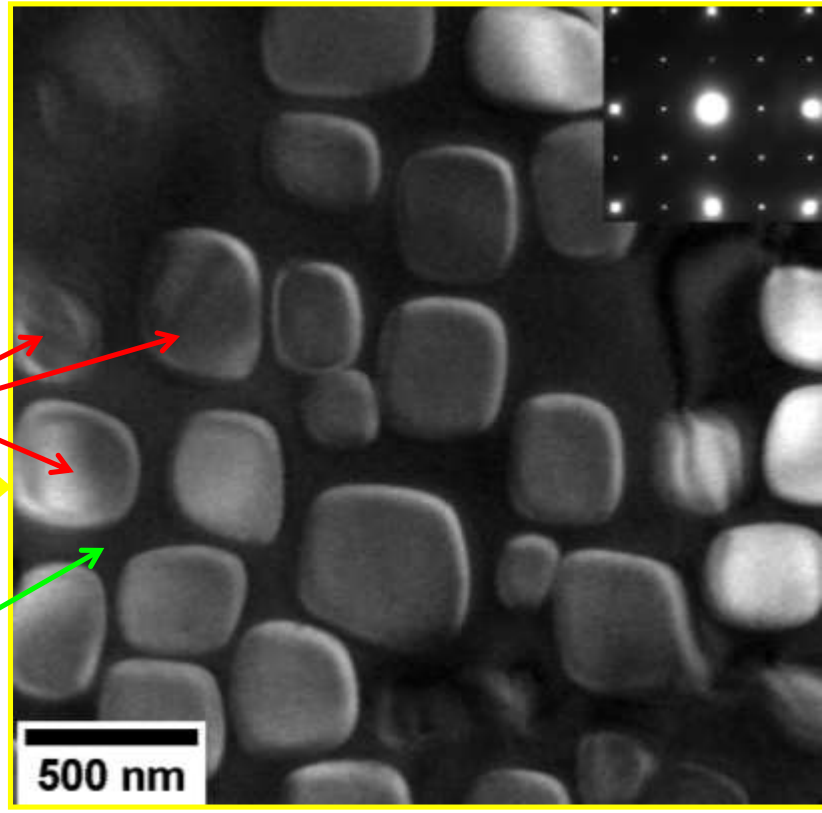
$Al_{10}Co_{25}Cr_8Fe_{17}Ni_{36}Ti_6$: microstructure

Manzoni et al., Entropy, 2016

1220°C 20 h homogenization - 900°C 50 h annealing



OM – overview: needles



DF TEM: γ' in γ matrix

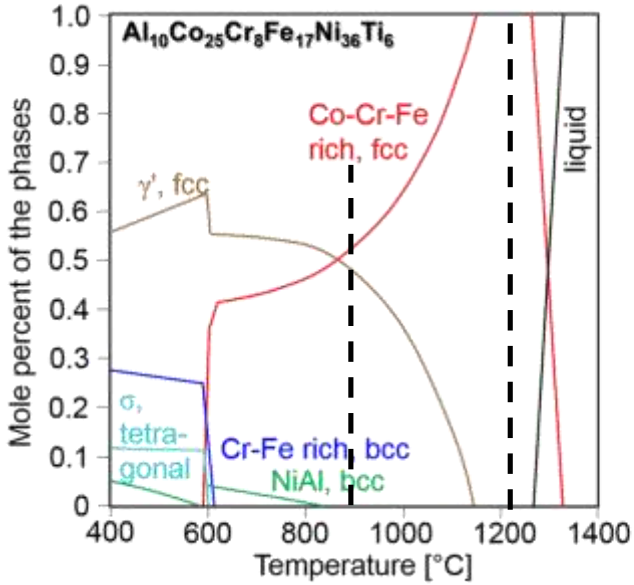
3 phases: γ, γ', needles

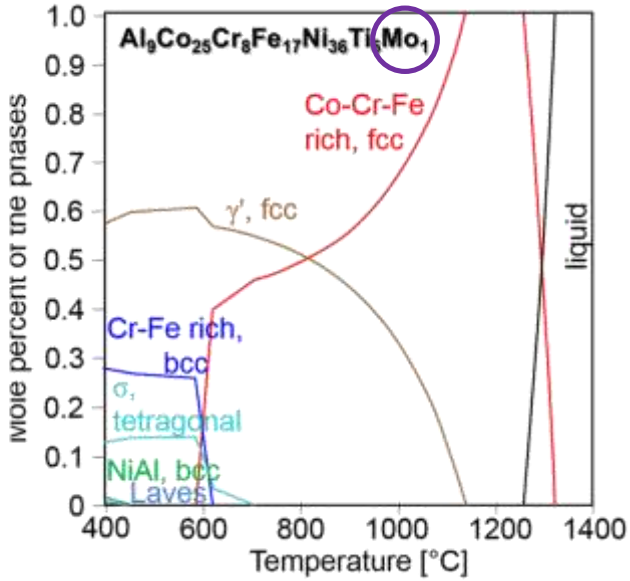
+ Mo, Zr, Hf, B

ThermoCalc Predictions (TTNi7 database)

Daoud et al., JOM, 2015

?!





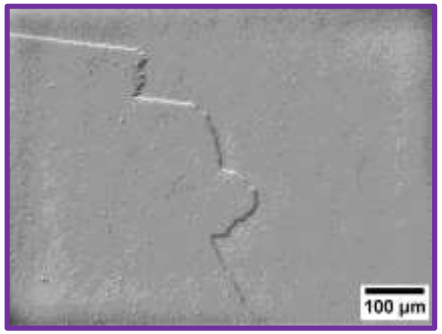
Two phase region:
1.Homogenization at 1220°C
2. Annealing at 900°C

Eutectic closer / reached!

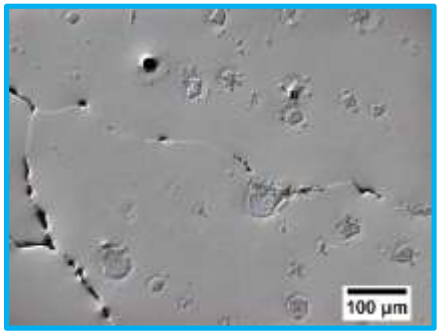
anna.manzoni@helmholtz-berlin.de

Homogenization challenges and eutectics

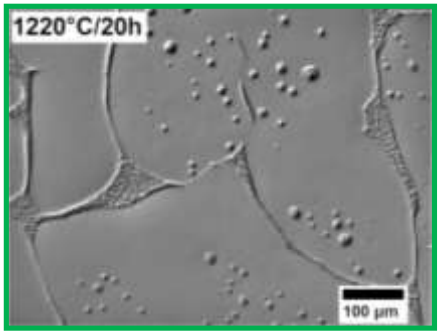
With 1 at.% **Mo**



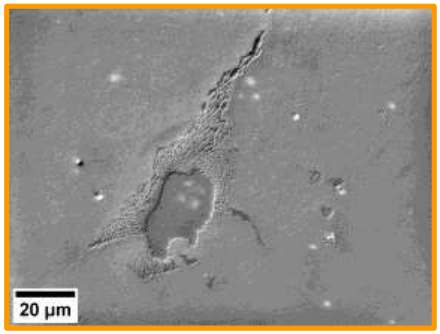
With 1 at.% **Zr**



With 0.5 at.% **Hf**



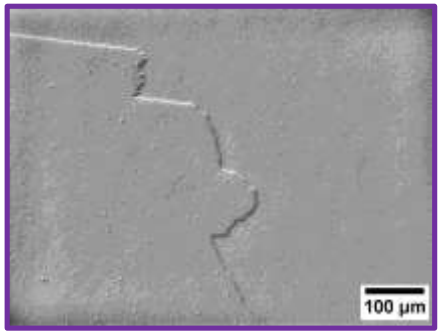
With 0.5 at.% **B**

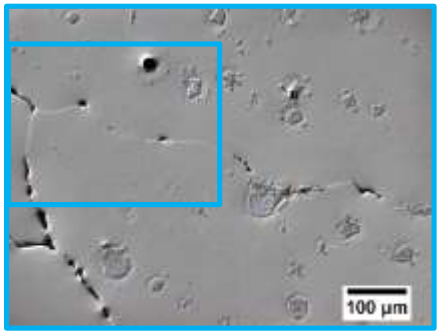


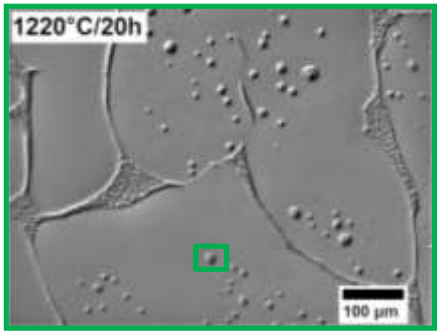
anna.manzoni@helmholtz-berlin.de

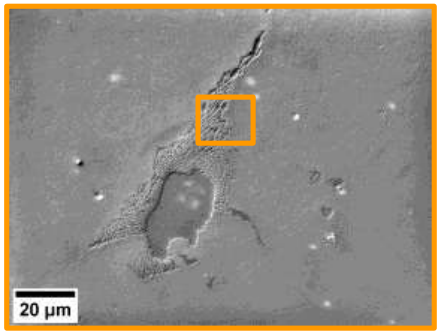
Homogenization challenges and eutectics

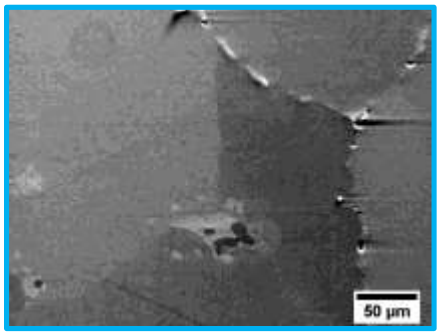
With 1 at.% **Mo** | With 1 at.% **Zr** | With 0.5 at.% **Hf** | With 0.5 at.% **B**

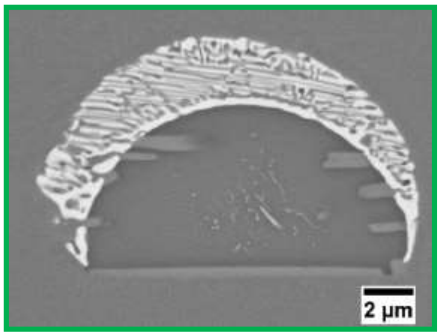


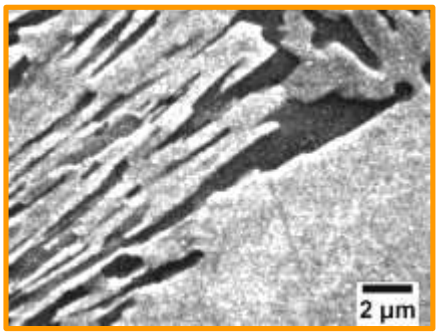








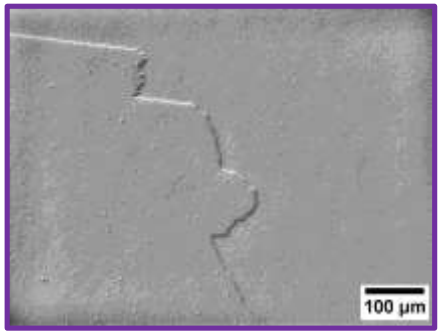


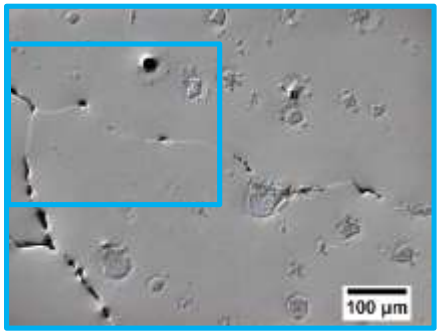


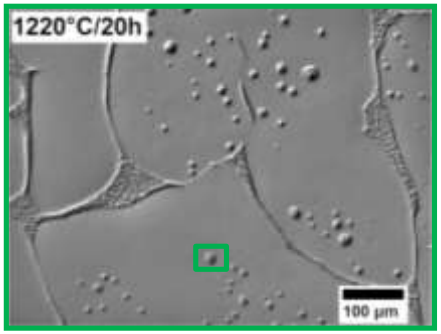
anna.manzoni@helmholtz-berlin.de

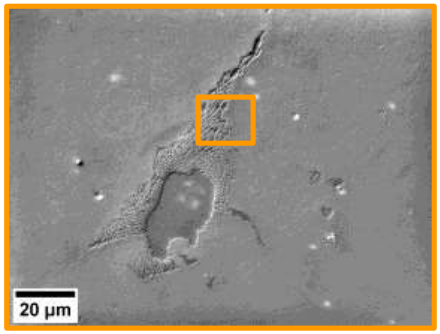
Homogenization challenges and eutectics

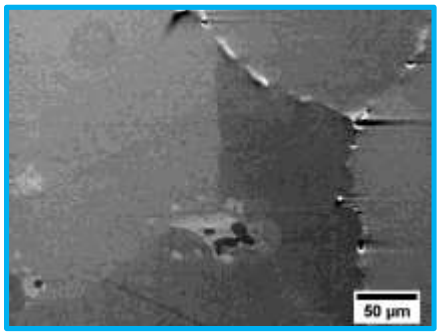
With 1 at.% **Mo** | With 1 at.% **Zr** | With 0.5 at.% **Hf** | With 0.5 at.% **B**

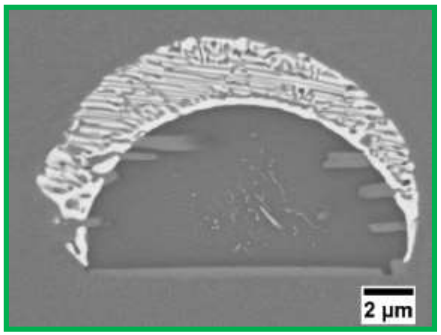


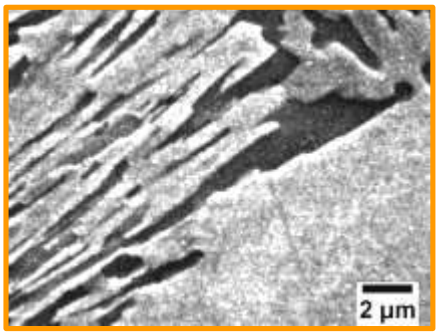












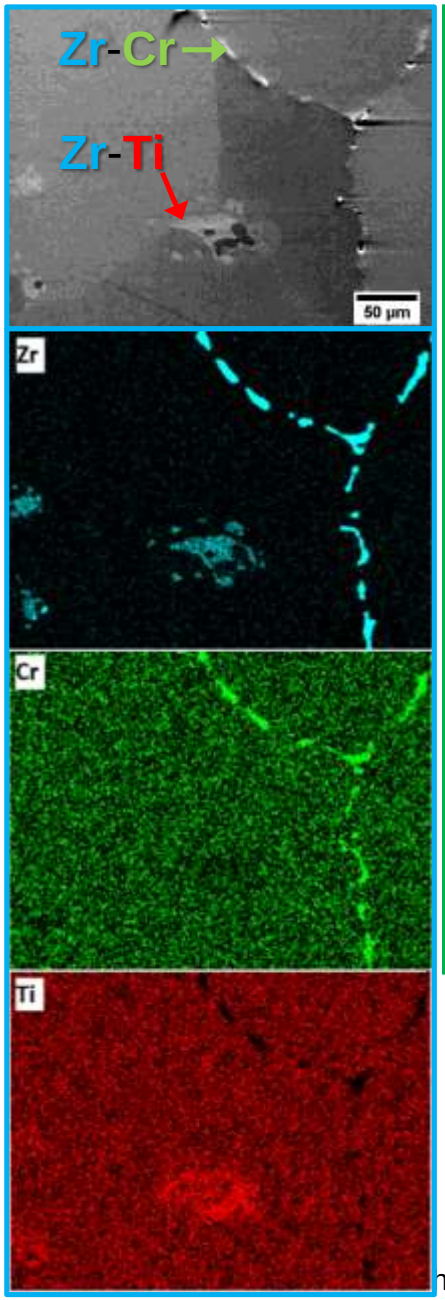
anna.manzoni@helmholtz-berlin.de

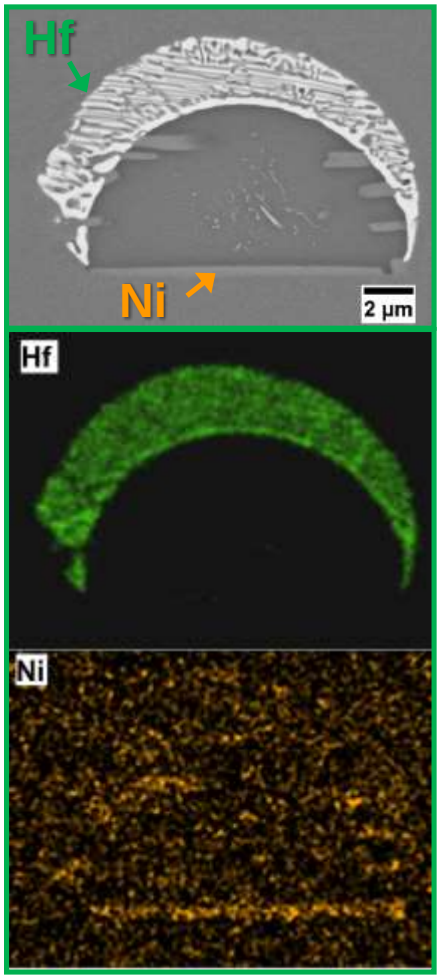
With 1 at.% Mo

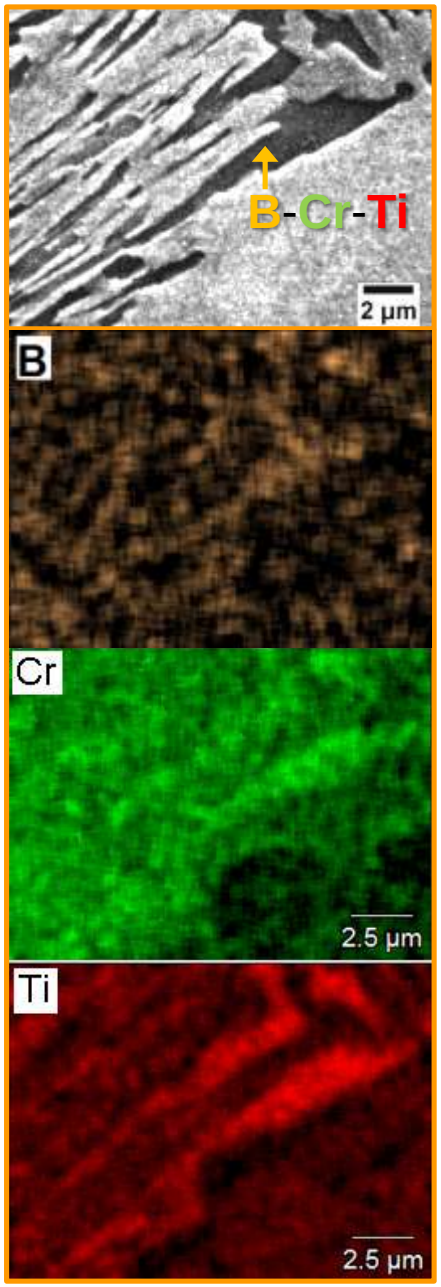
With 1 at.% Zr

With 0.5 at.% Hf

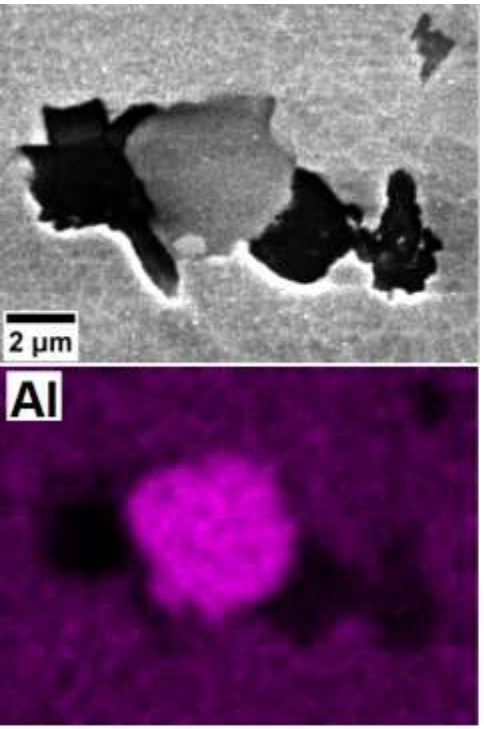
With 0.5 at.% B







That alloy with B…



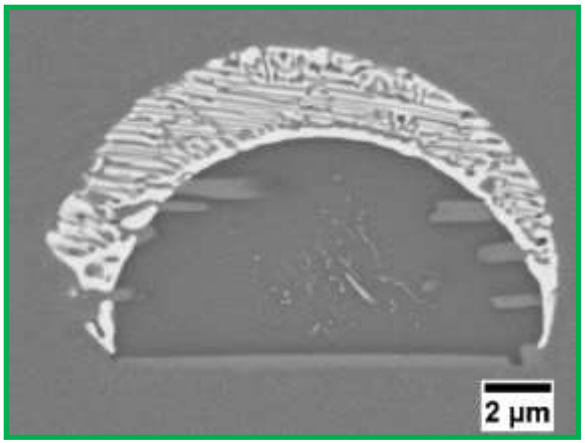
anna.manzoni@helmholtz-berlin.de

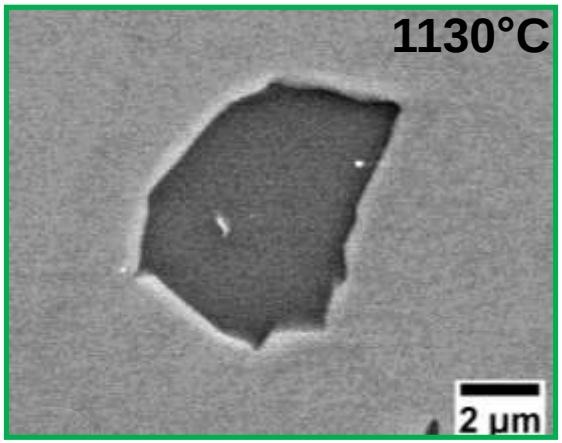
Finding the good homogenization

Too hot (1220°C)

Good temperature

With 0.5 at.% Hf

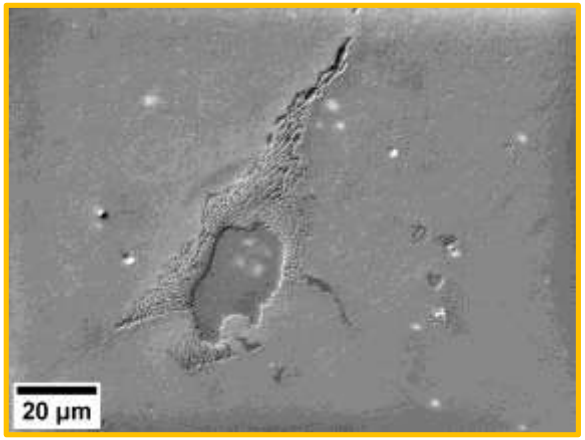


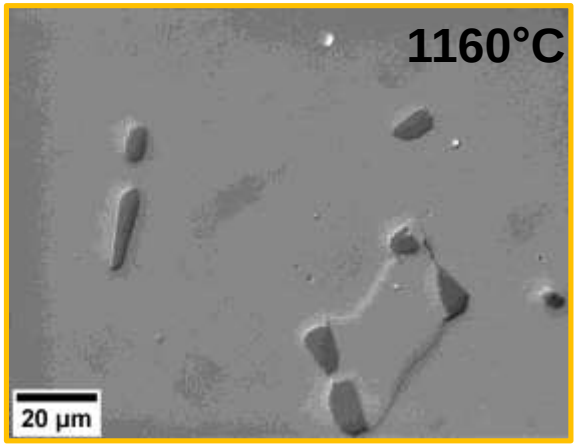


Eutectic phase, enriched in the trace element

No more eutectic phase!

With 0.5 at.% B

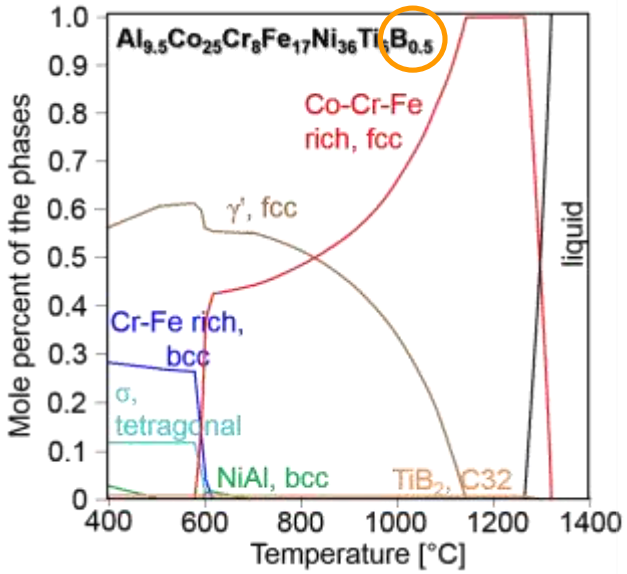


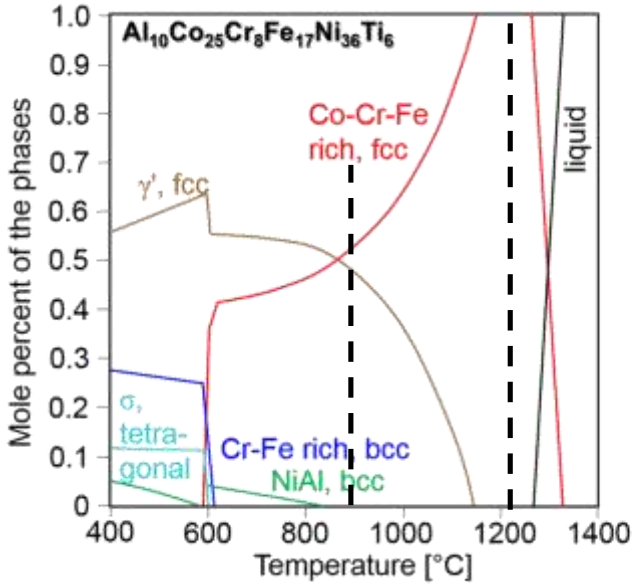


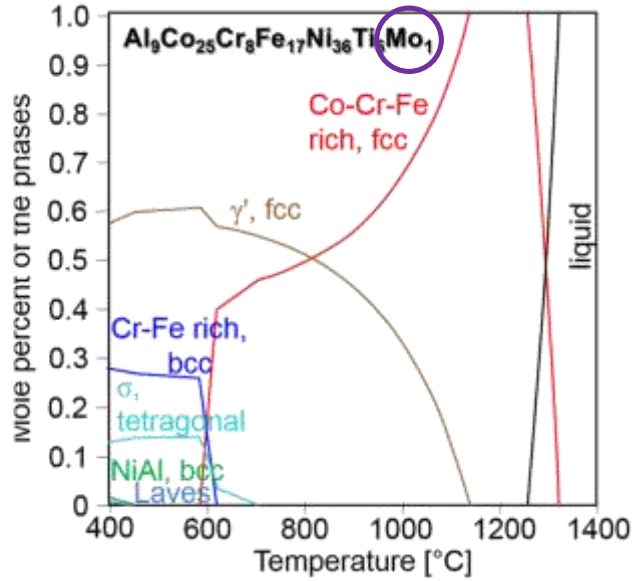
anna.manzoni@helmholtz-berlin.de

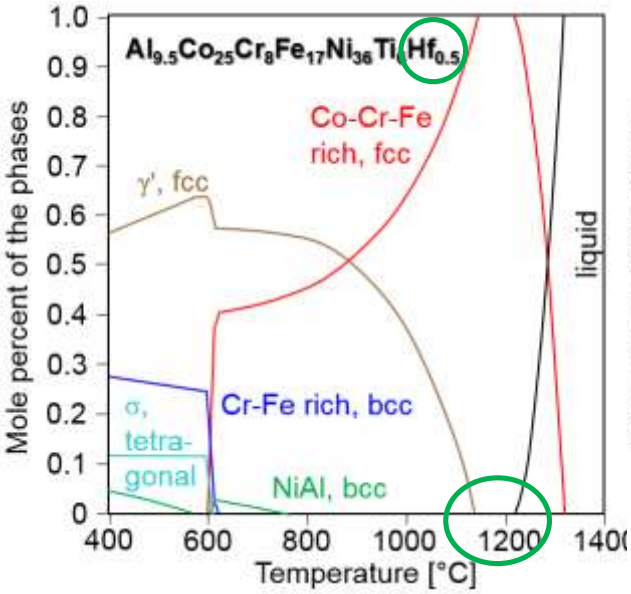
ThermoCalc Predictions (TTNi7 database)

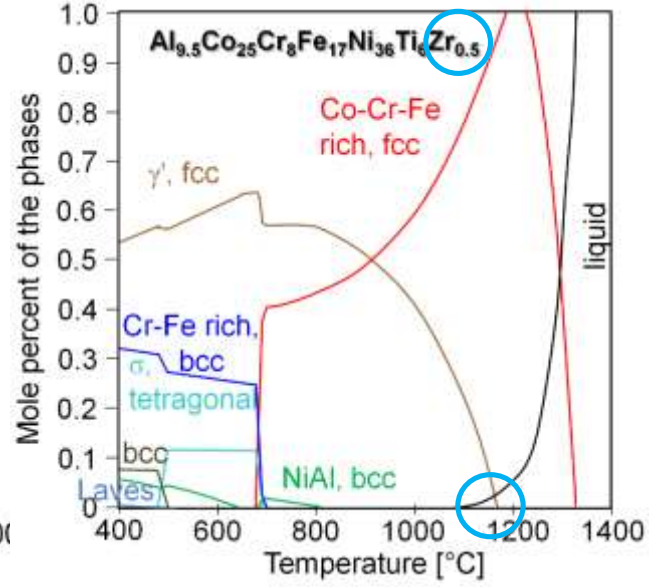
Daoud et al., JOM, 2015











anna.manzoni@helmholtz-berlin.de

Phases detected and predicted

Base alloy	With 1 at.% Mo	With 1 at.% Zr	With 0.5 at.% Hf	With 0.5 at.% B
(Too hot) homogenization at 1220°C				
γ γ' carbides nitrides	γ γ' carbides nitrides	γ γ' needles **Zr-Ti rich** **Zr-Cr rich** carbides nitrides	γ γ' needles **Hf rich** **Ni rich** carbides nitrides	γ γ' needles **B-Cr-Ti rich** carbides nitrides

Mixing enthalpies / atomic radii

Takeuchi et al., Materials Transactions 46(2005)

The values of heat of mixing are quoted as enthalpy of mixing $\Delta H^{mix}_{\{AB\}}$ of the binary liquid in an A–B system at an equiatomic composition.

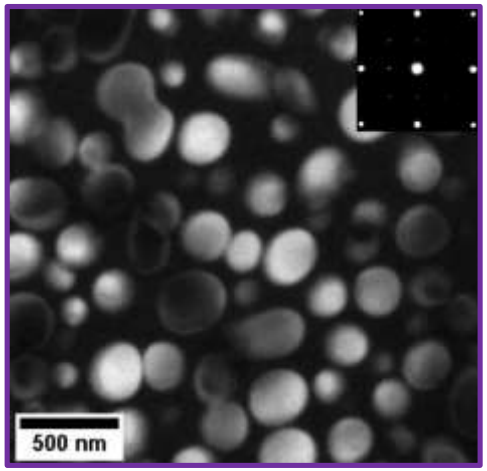
B\A	Al	Co	Cr	Fe	Ni	Ti
Mo	-5	-5	0	-2	-7	-4
Zr	***-44***	-41	-12	-25	***-49***	0
Hf	***-39***	-35	-9	-21	***-42***	0
B	0	-24	***-31***	-26	-24	***-58***

Atom radii [pm]

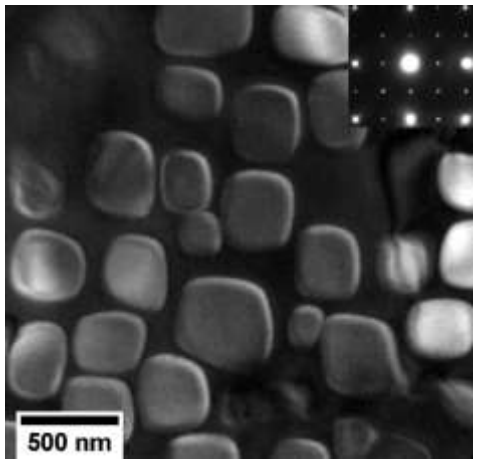
Al	Co	Cr	Fe	Ni	Ti	Mo	Zr	Hf	B
143	125	129	126	125	146	140	160	159	80

anna.manzoni@helmholtz-berlin.de

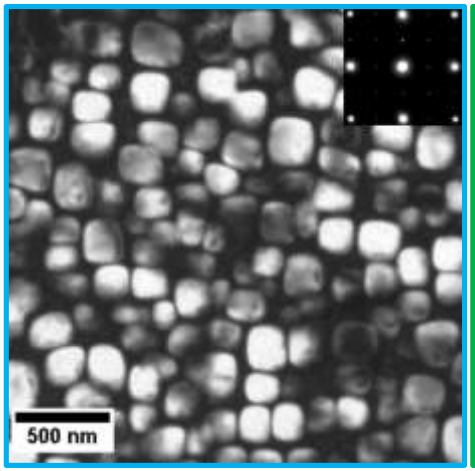
Comparison γ- γ' microstructure: TEM



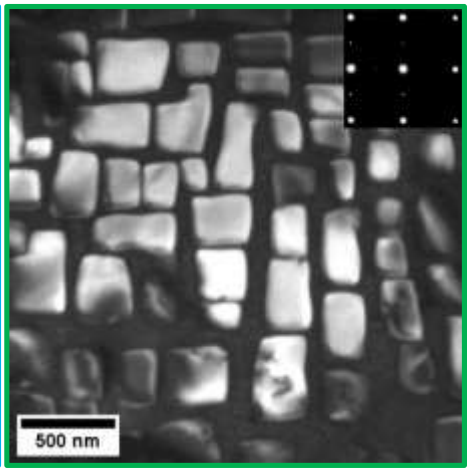
With 1 at.% **Mo**



Pure $Al_{10}Co_{25}Cr_8Fe_{15}Ni_{36}Ti_6$



With 1 at.% **Zr**



With 0.5 at.% **Hf**

"cubicity"
γ - γ' lattice misfit
γ' volume fraction

B still missing…
to be continued

anna.manzoni@helmholtz-berlin.de

Summary

- Many phases appear after bad homogenization of the alloys with trace elements