UNIVERSITÄT BAYREUTH

Werkstoffe Metallische

Refractory metals improving the mechanical properties of $Al_{10}Co_{25}Cr_8Fe_{15}Ni_{36}Ti_6$

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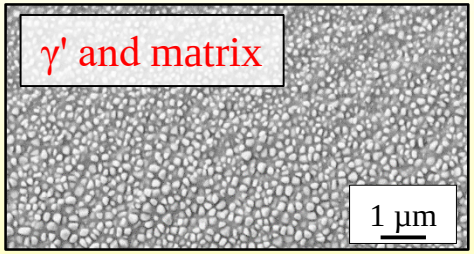
Base alloy

$Al_{10}Co_{25}Cr_8Fe_{15}Ni_{36}Ti_6$ (in at.%)

Dendritical solidification after melting by induction casting or arc melting

4 co-existing phases:

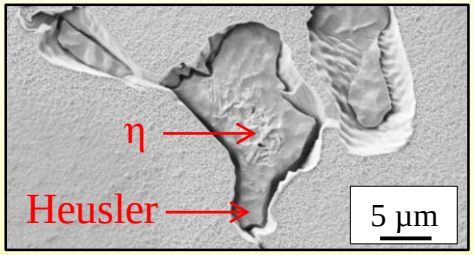
Dendrites:



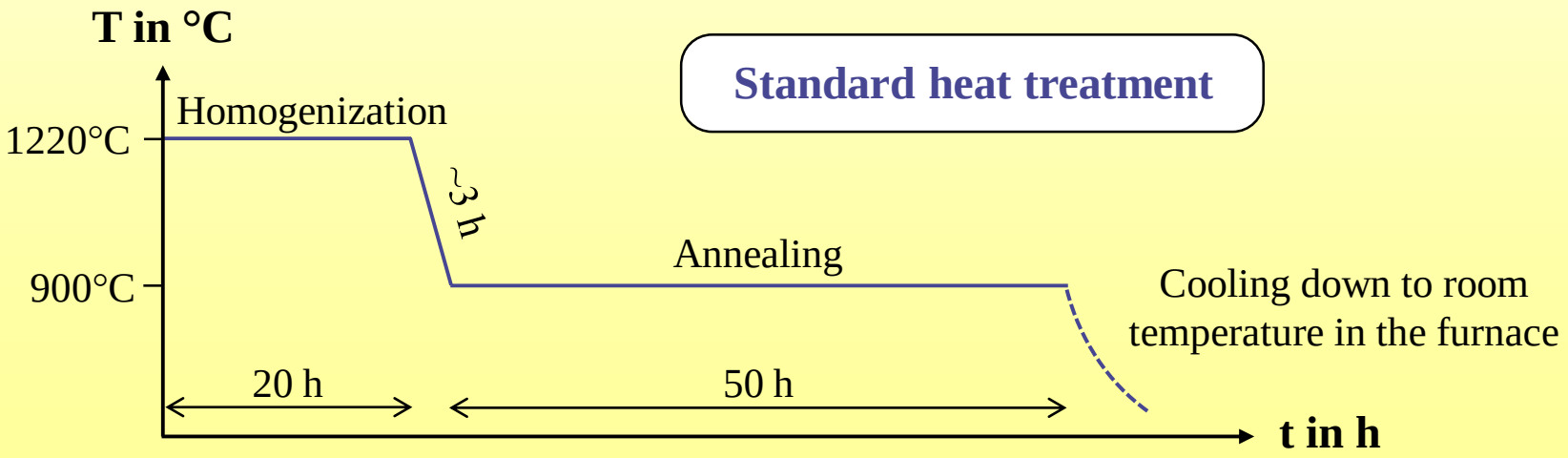
Finely distributed γ'-particles in a fcc-matrix

Interdendrites:

η-phase Ni_3Ti embedded in coarse Heusler-phase

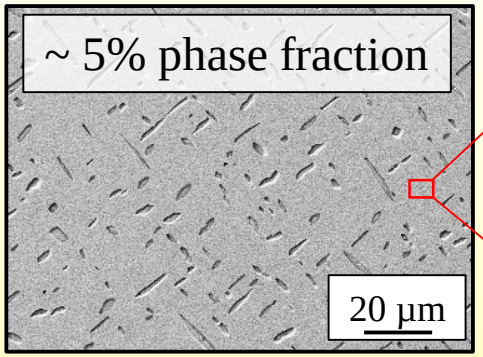


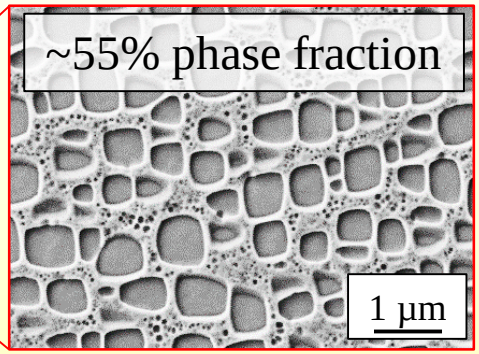
Standard heat treatment

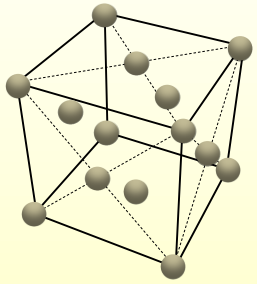


Characterization of the annealed base alloy

Microstructure after annealing at 900°C for 50 h and furnace cooling:





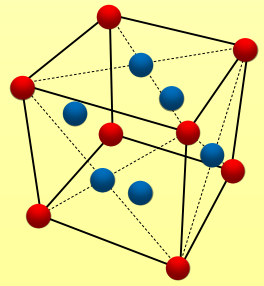


Disordered fcc-matrix

$L2_1$-ordered Heusler-Phase

in at.%	Al	Co	Cr	Fe	Ni	Ti
matrix	6,4	29,4	13,4	25,9	22,5	2,4
γ'	13,1	18,8	2,0	5,8	48,9	11,4
Heusler	27,3	19,8	2,7	9,8	33,5	6,9

$L1_2$-ordered γ'-phase $Ni_3(Al,Ti)$



Ni_2AlTi with big amounts of Co and Fe

Influence of high melting elements

Goal:

Development of a high-temperature material in the range of 600-800°C

- Addition of small amounts of specific elements; always at the cost of Al

	W	Mo	Hf	Zr	Y	B
Melting point in °C [1]	3414	2622	2233	1854	1522	2075
Content in at.%	1,0		0,5			

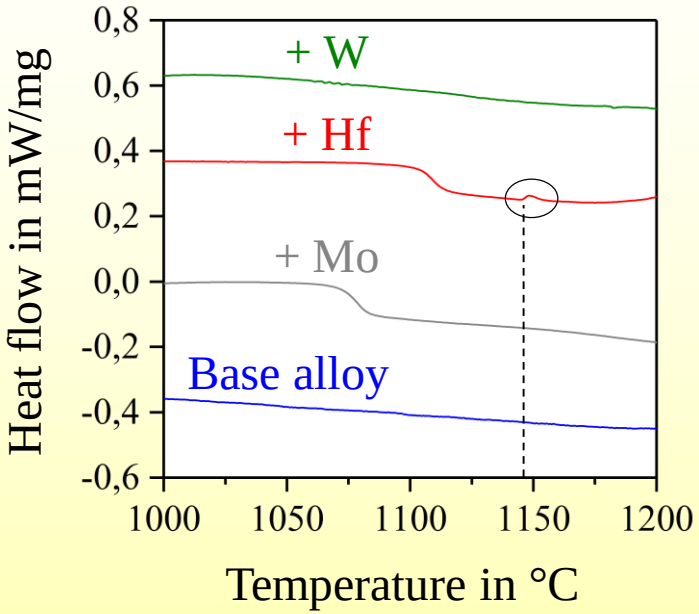
Changes in the microstructure: → High temperature resistance:

- Morphology of Heusler-phase
- Morphology of γ'-phase

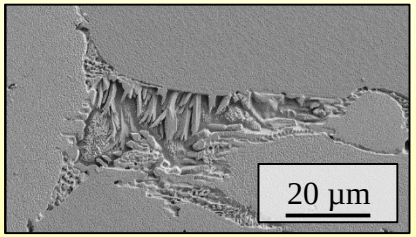
- Creep resistance
- Tensile strength

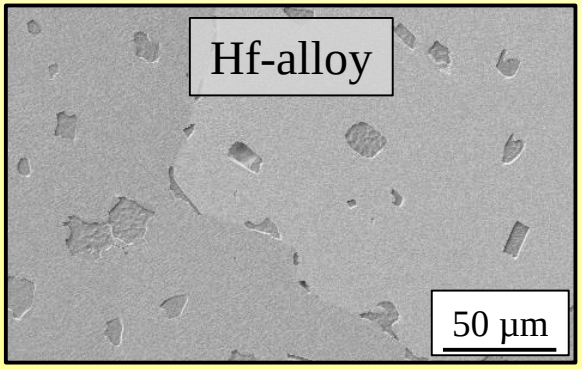
[1] Lide D. R.; *CRC Handbook of Chemistry and Physics*; CRC Press, Boca Raton, 2004, 85. Auflage

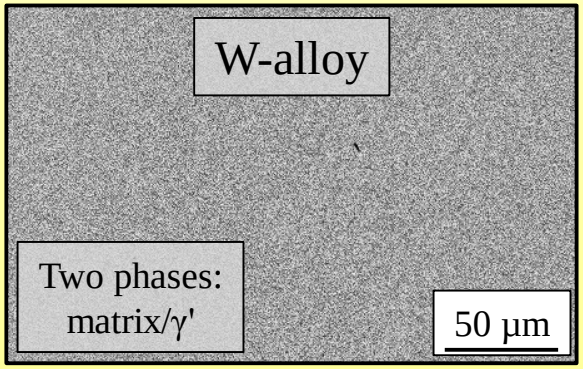
Morphology of the Heusler-phase

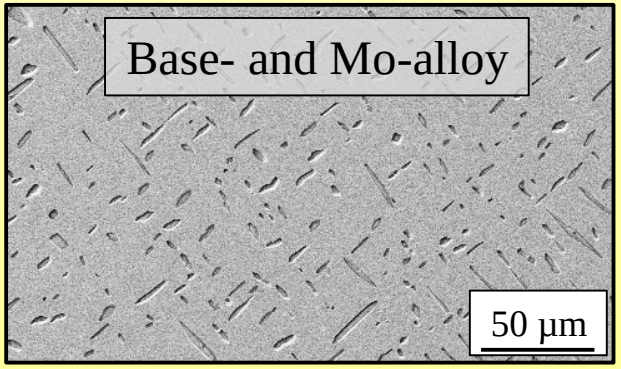


- The base-, W- and Mo-alloy can be homogenized as standard at 1220°C for 20 hours.
- The element Hf leads to eutectic reactions at the grain boundaries.
  - **T_{hom}(Hf) = 1140°C**







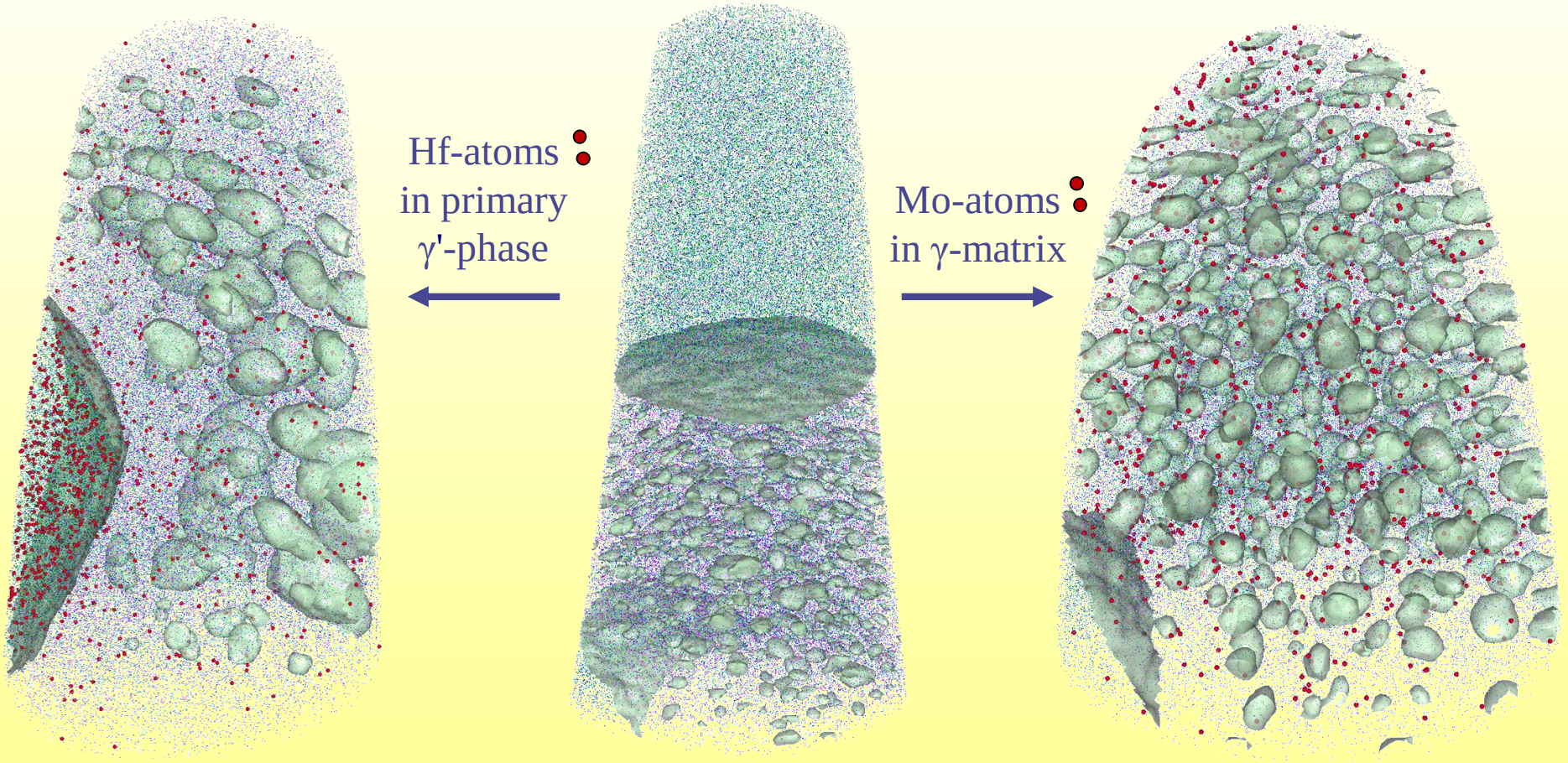


Atom probe tomography:
MPIE Düsseldorf

Hf-alloy

Base alloy

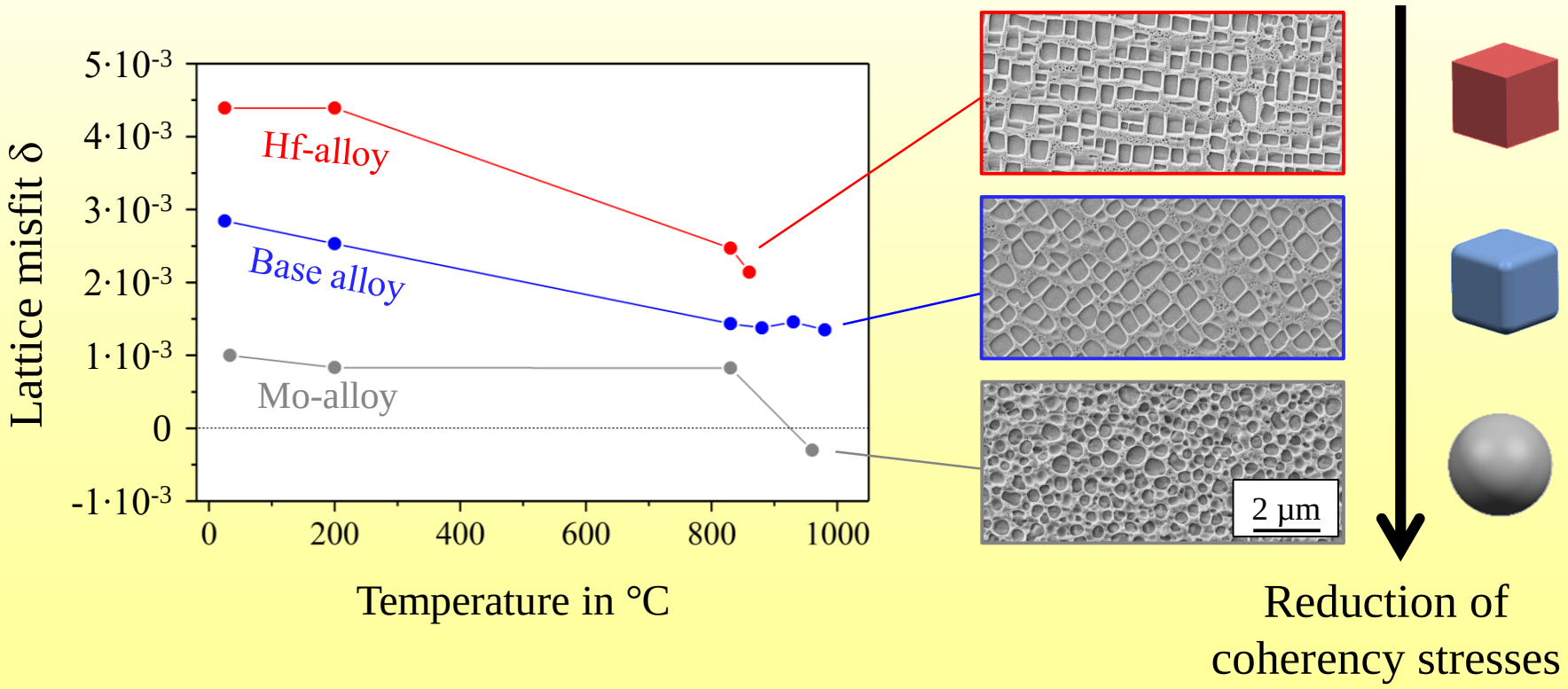
Mo-alloy



Lattice misfit:
Synchrotron radiation BESSY II

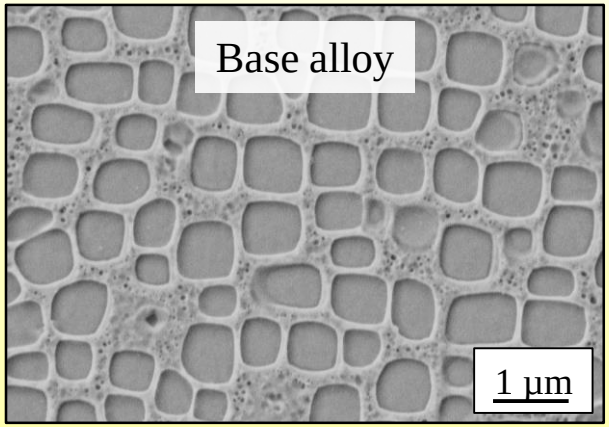
Determination of temperature dependent lattice parameters of the matrix and γ'-phase using x-ray diffraction

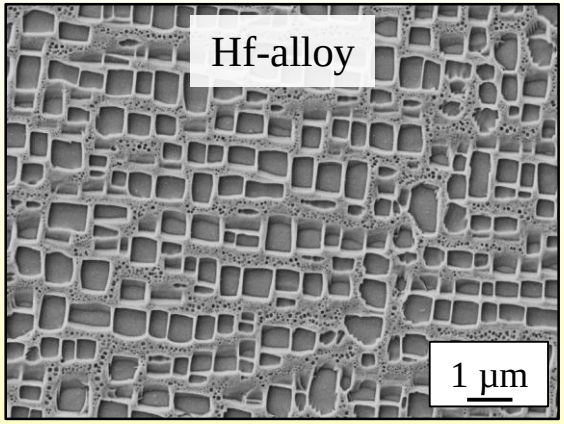
$$\delta = 2 \cdot \frac{a_{\gamma'} - a_{matrix}}{a_{\gamma'} + a_{matrix}}$$

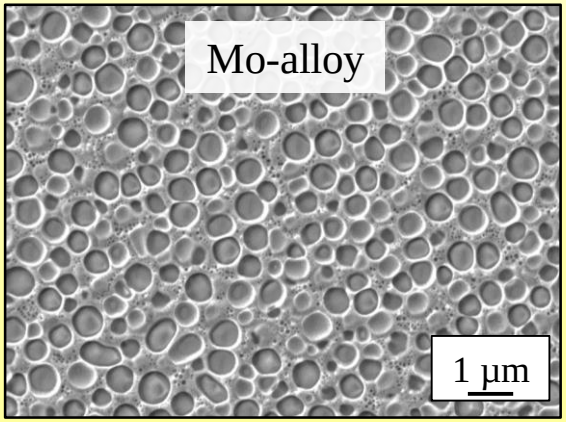


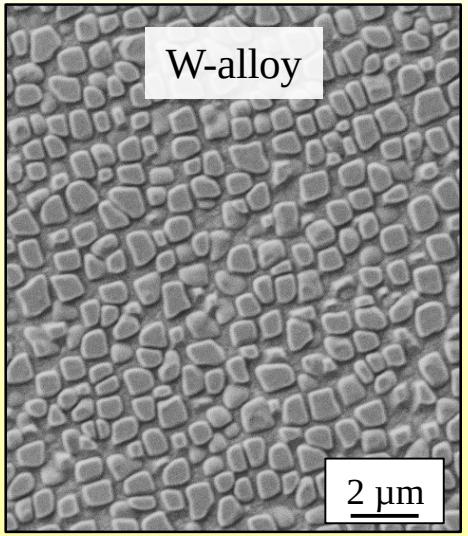
Morphology of the γ'-phase

High coherency stresses: Cubic γ'-particles



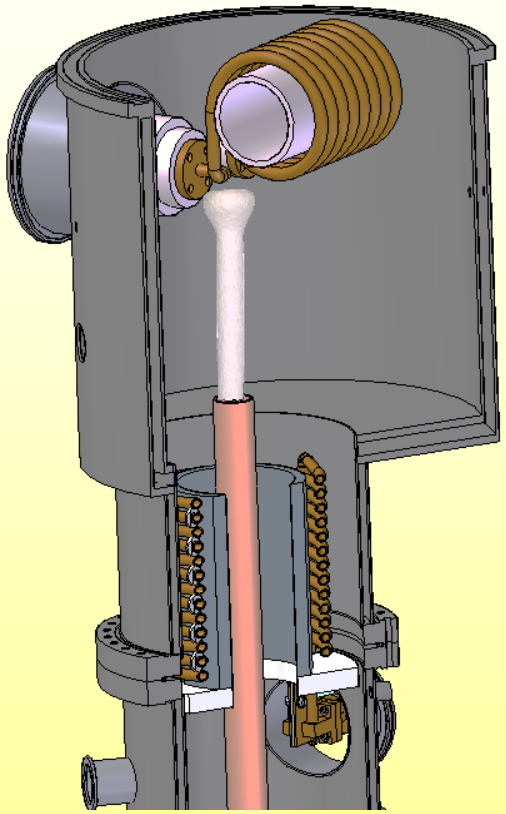






Low coherency stresses: Round γ'-particles

Characterization of directionally solidified material



Bridgman Process:

In [001]-orientation directionally solidified material to reduce the influence of grain structure

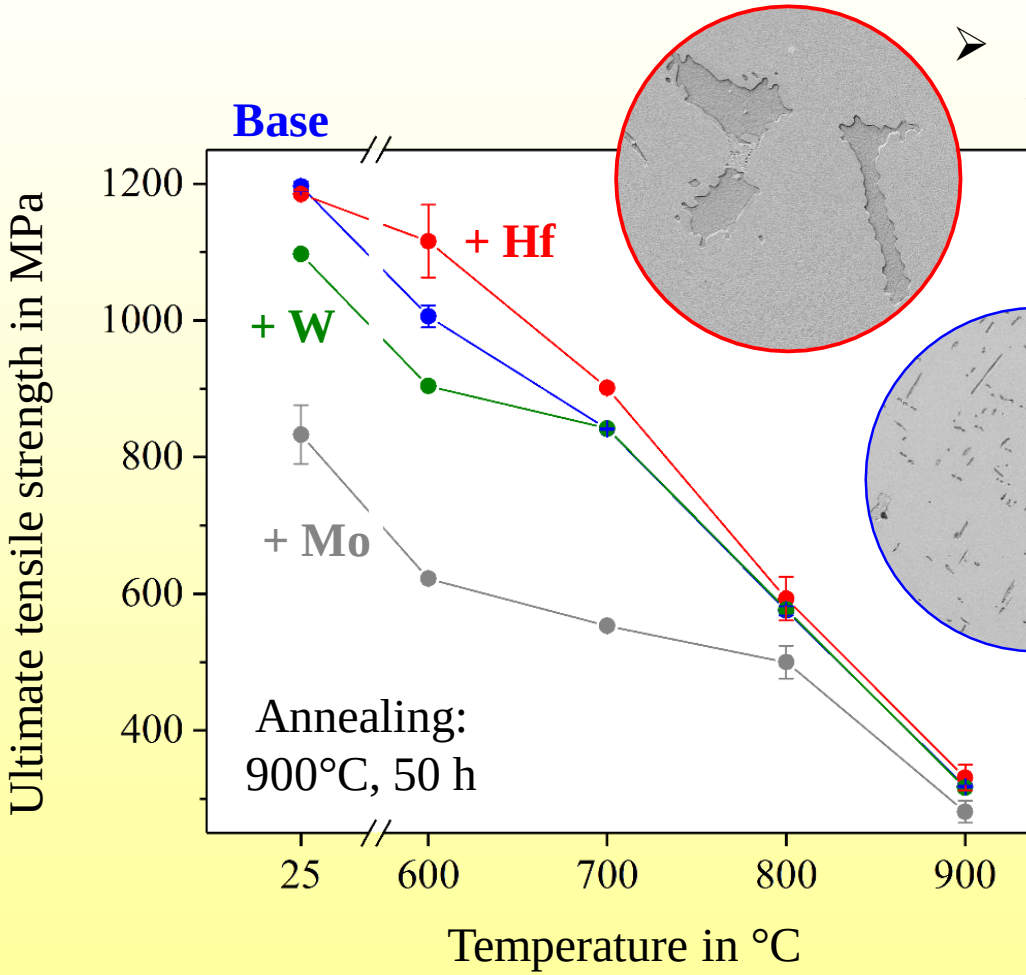
Heat treatment:

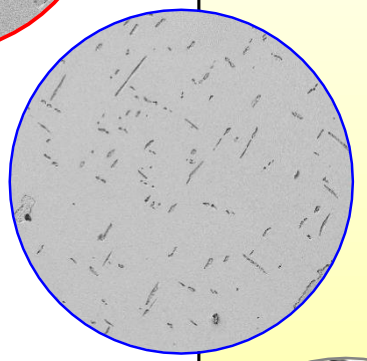
- 1100 – 1220°C / 20 h
- Cooling down to: 900°C
- 900°C / 50 h
- Slow furnace cooling

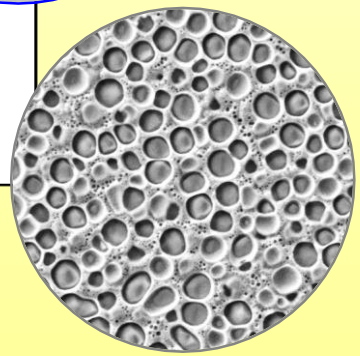
Wire EDM:

- Samples for tension- and creep-experiments

Tensile test behaviour

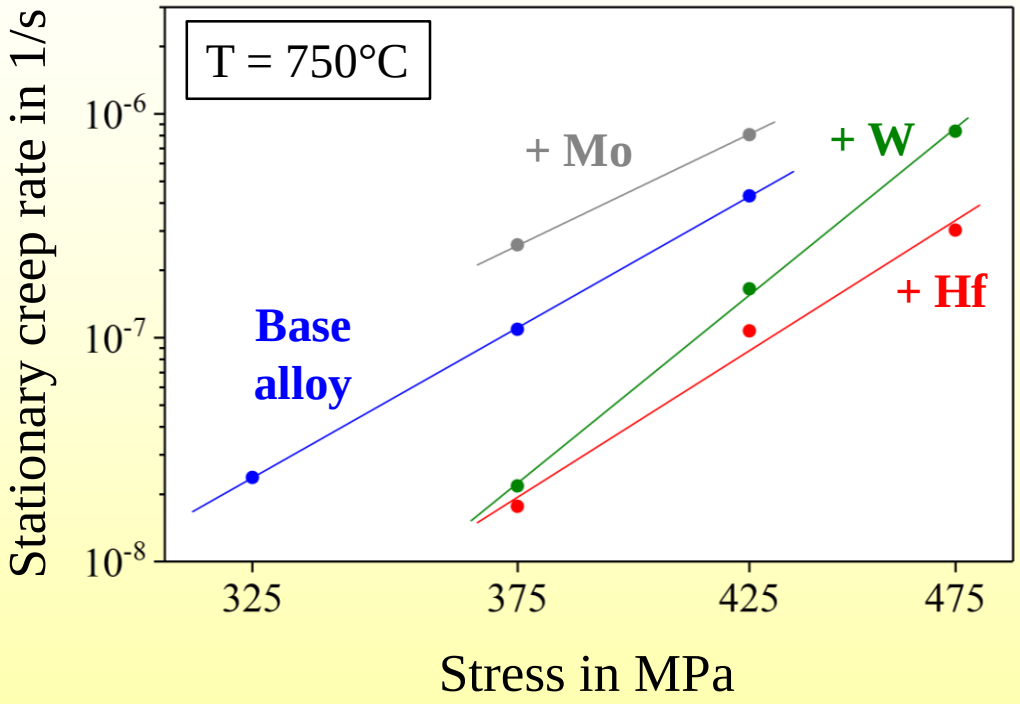






- Coarse and stable Heusler-phase from the as-cast state
- High coherency stresses and sharp edged γ'-particles
- Needle-shaped Heusler-phase with a content of 5% is not detrimental
- Low coherency stresses and round γ'-particles

Creep resistance of the modified alloys



Stress exponents:

+ Mo	Base	+ W	+ Hf
9,1	10,8	15,4	12,1

- Mo-alloy:
  - Low coherency stresses
- Base alloy:
  - Detrimental needle-shaped Heusler-phase (~5%) at time-dependent creep deformation
- W-alloy:
  - Pure two-phase microstructure
- **Hf-alloy:**
  - High coherency stresses
  - Desirable coarse Heusler-phase remaining from the as-cast state

Conclusion

- Development of a high temperature material on the base of the alloy $Al_{10}Co_{25}Cr_8Fe_{15}Ni_{36}Ti_6$ using small amounts of high melting elements

Goal

- Heat treatment: Form, size and fraction of the Heusler-phase
- γ'-morphology as a result of varying positive lattice misfit

Microstructure

- Needle-shaped Heusler-phase (~5%) not detrimental at time independent, but detrimental at time dependent deformation
- Coarse Heusler-phase from as-cast state desirable
- Accumulation of Hf-atoms in the γ'-phase leads to an increase of the positive lattice misfit, the coherency stresses and an improvement of the mechanical properties

Mechanical properties

Thank you very much for your attention!