

# Particle-strengthened Compositionally Complex Alloys

Interlinking powder synthesis, additive manufacturing, microstructure evolution and deformation mechanisms (PaCCman)

V. Uhlenwinkel



E. A. Jägle



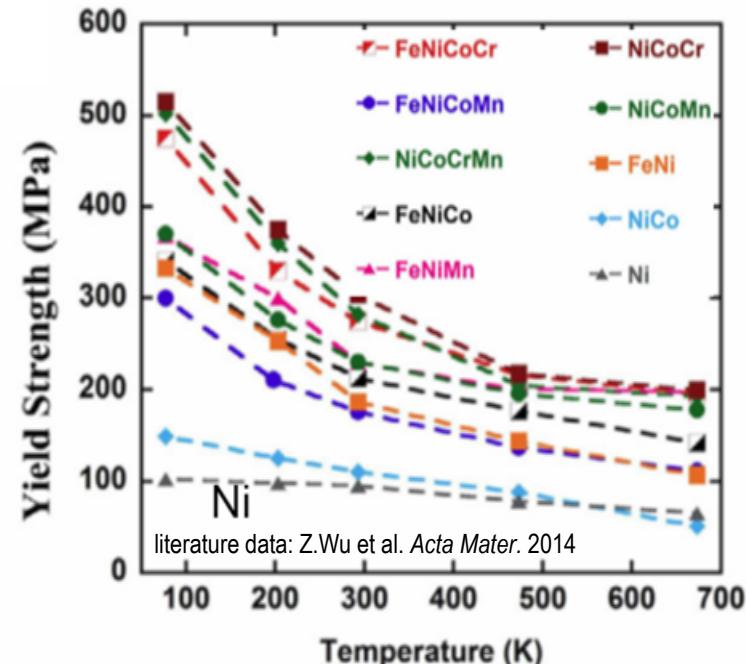
G. Dehm



# Dislocation Deformation Mechanisms



Deformation Mechanism



Additive Manufacturing

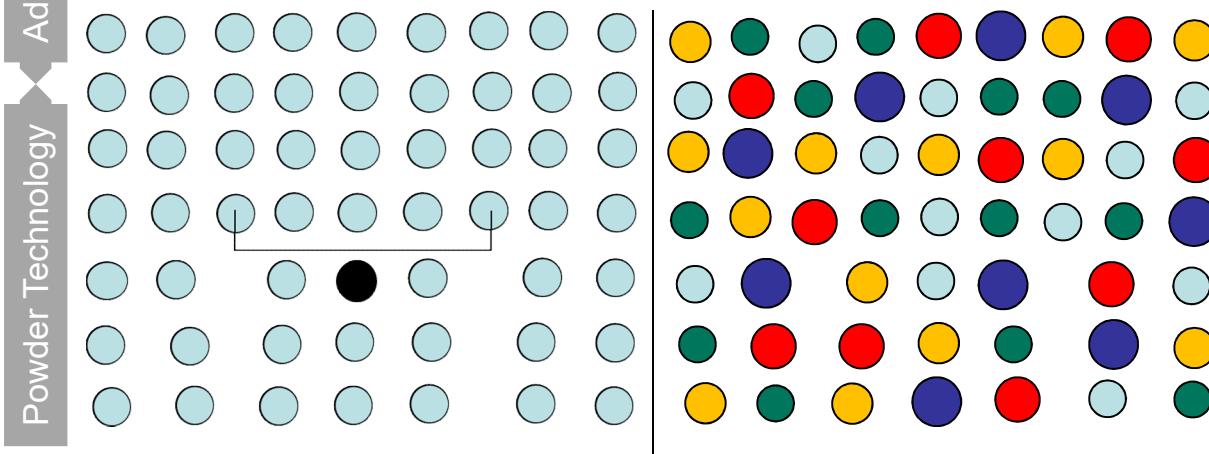
Powder Technology

## Literature:

Mechanical data linked to  
TEM dislocation studies

e.g. Otto et al. *Acta Mater.* 2013, Tasan et al. *JOM* 2014, Okamoto et al. *Sci. Rep.* 2016,  
Laplanche *Acta Mater.* 2017, Hong et al. *Mater. Sci. Eng. A* 2017, ...

Modelling & simulation strength of concentrated  
solid-solutions: e.g. Varvanne et al. *Acta Mater.* 2016



# Dislocation Deformation Mechanisms



Deformation Mechanism

Large scatter of values in the literature

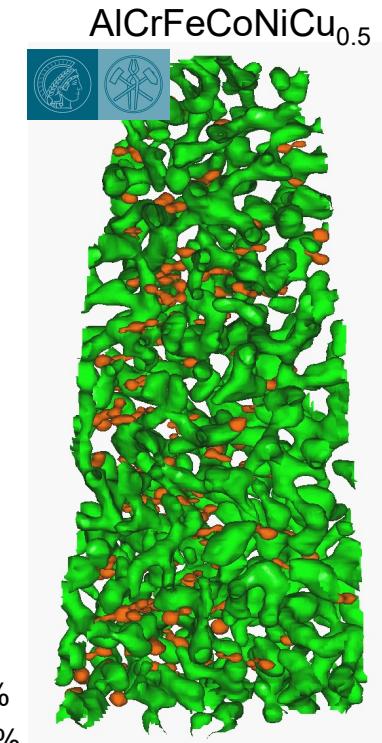
One reason: nm-sized **precipitates** are often overlooked  
and CCA are interpreted as HEA

**Particle-strengthening** is a promising mechanism for  
application of **high-strength CCA at elevated temperatures**

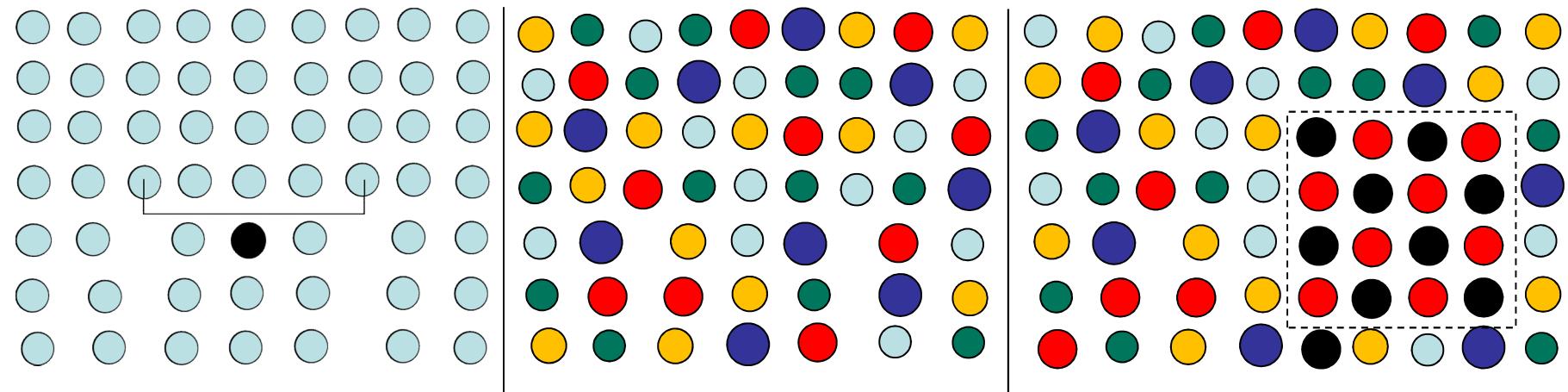
⇒ **Fundamental understanding** of

- dislocation-based deformation mechanisms
- dislocation-particle interaction
- at elevated temperatures

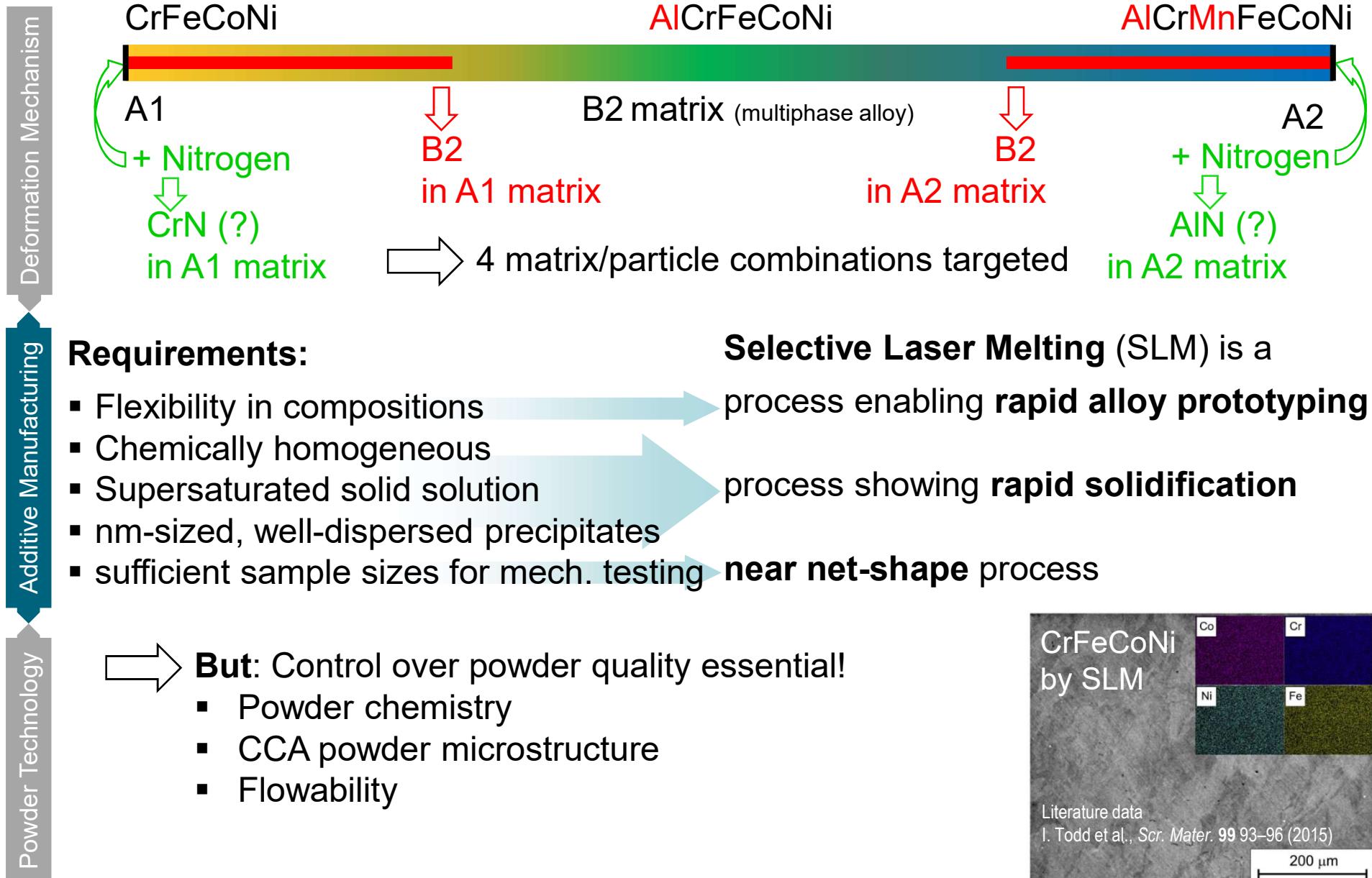
in concentrated solutions is still in its infancy.



Powder Technology



# Investigated CCA systems and AM



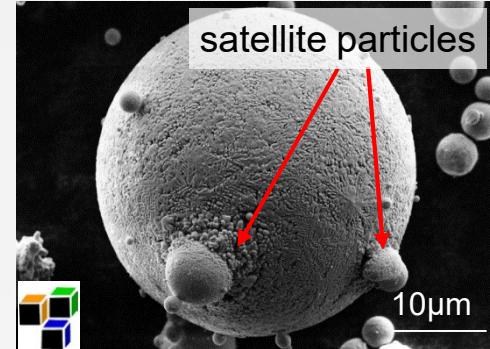
# Powder Processing for atomized CCA particles



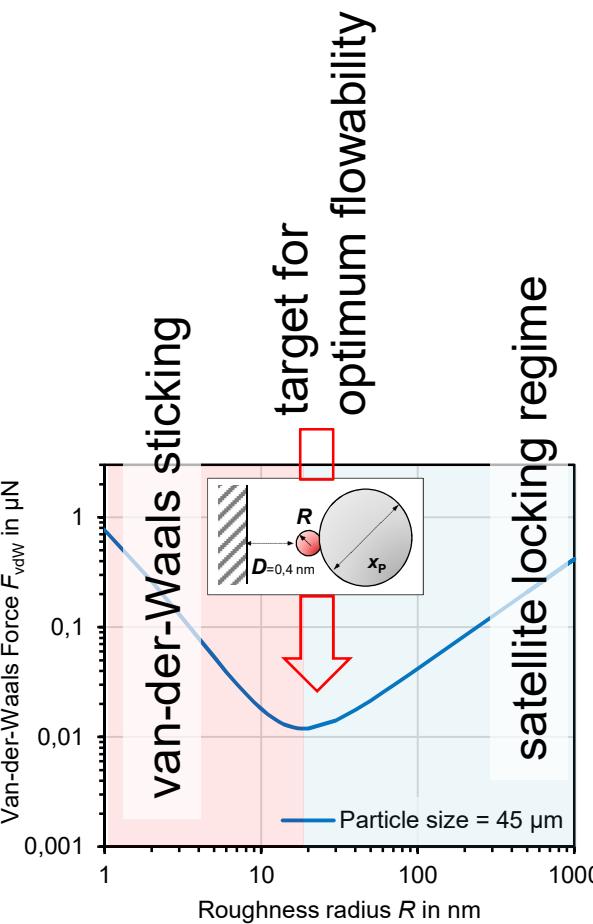
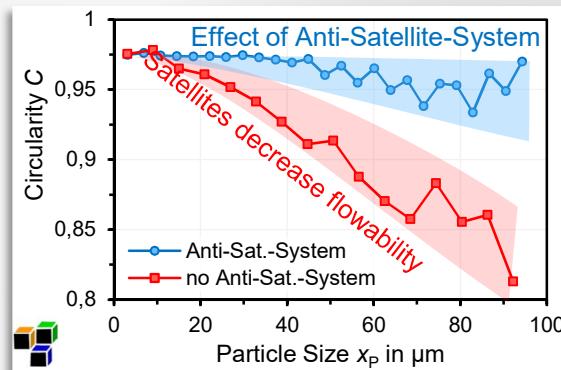
Powder Technology      Additive Manufacturing      Deformation Mechanism

## Synthesis

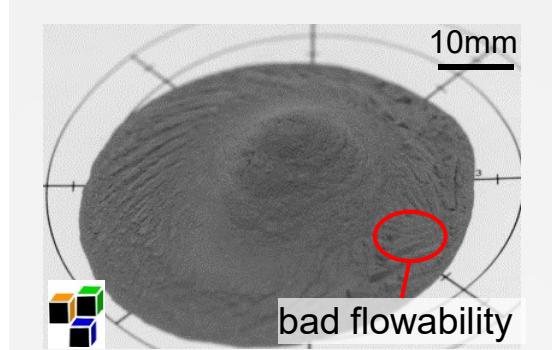
close-coupled-atomization of CCA



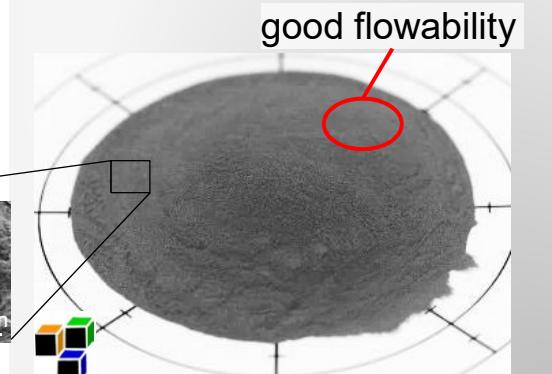
Desired optimal flowability via Anti-Satellite atomization



## Anti-Adhesion Additives



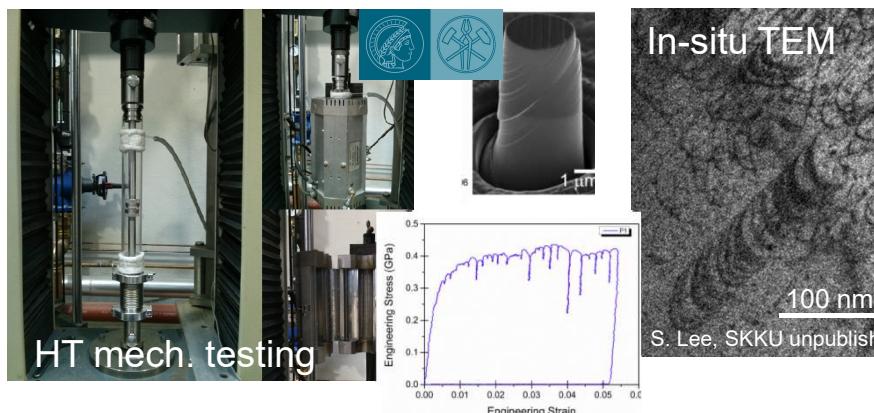
Enhanced powder processing via additive  $\text{SiO}_2$  nanopowder



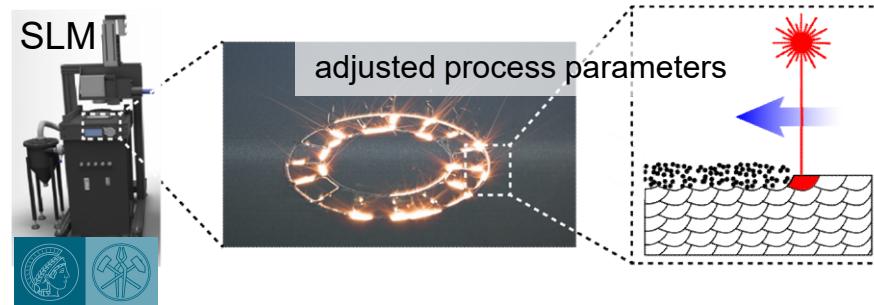
# Toolbox and preliminary work



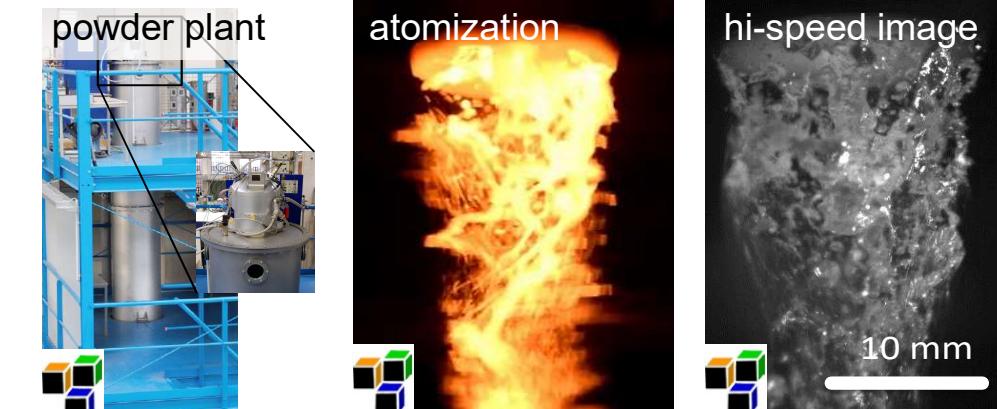
## Deformation Mechanism



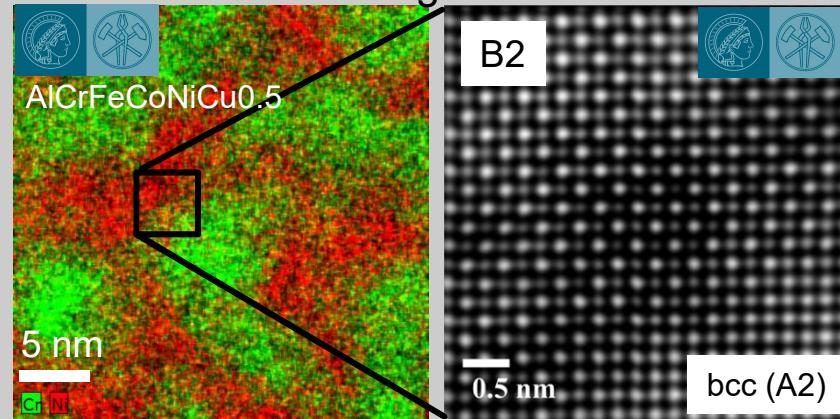
Additive Manufacturing



Powder Technology

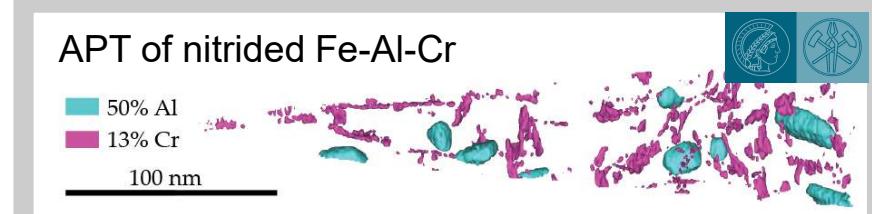


EDS – Scanning TEM – Z-contrast



N. Peters, MPIE unpublished

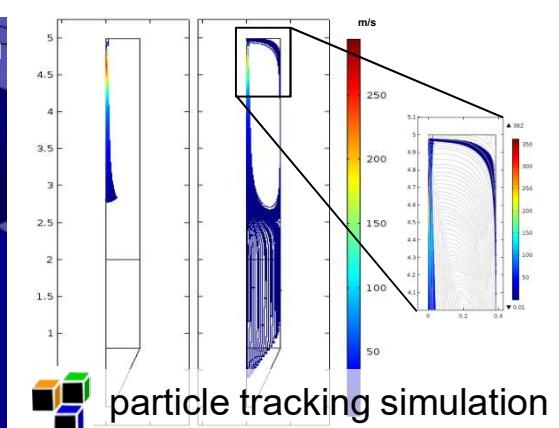
## Characterization



APT of nitrided Fe-Al-Cr



100 nm



## particle tracking simulation

# Summary and collaborations



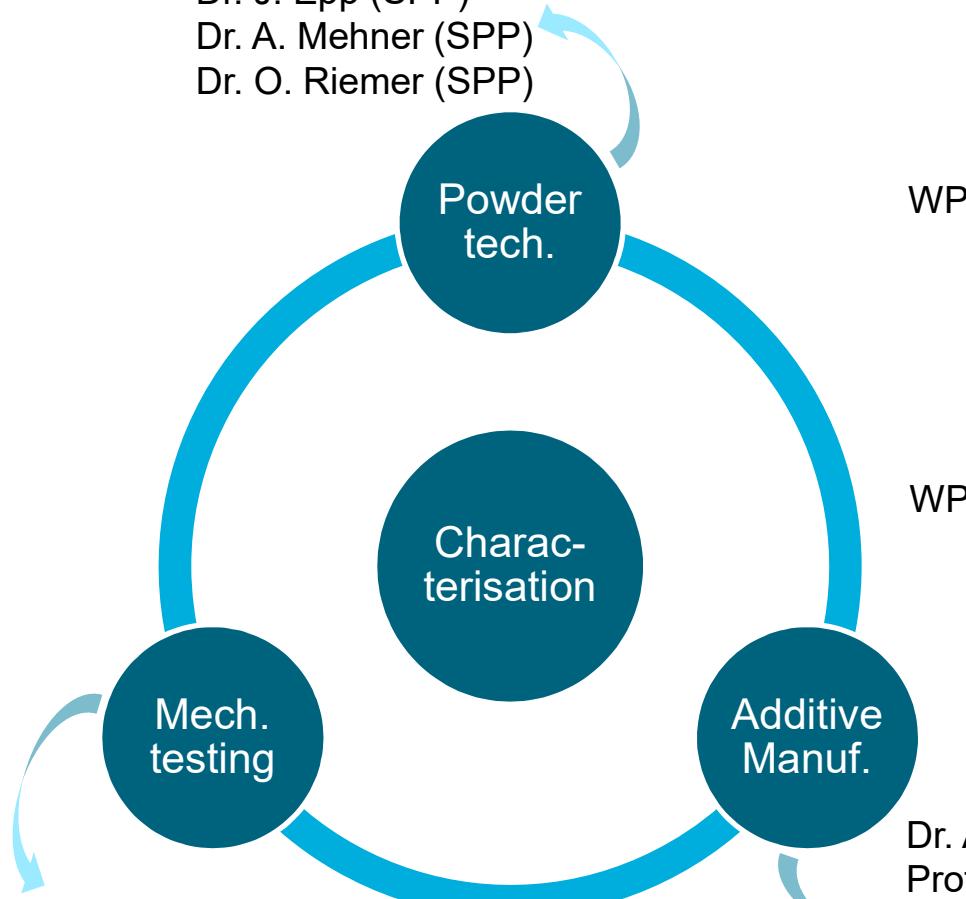
Dr. V. Srivastava

Prof. S.-P. Hannula

Dr. J. Epp (SPP)

Dr. A. Mehner (SPP)

Dr. O. Riemer (SPP)



Dr. M. Feuerbacher (SPP)

Dr. M. Heidemann (SPP)

Prof. Dr. M. Bamberger

- WP1 • Develop powder synthesis of particle-strengthened CCA

⇒ **Ensure composition-independent powder flowability and hence processability**

- WP2 • Establish Selective Laser Melting as component production process for particle-strengthened CCA

⇒ **Flexible and fast production of homogeneous cm-sized parts**

- WP3 • Fundamental understanding of dislocation-based plasticity in CCA matrix and particle-strengthened CCA

⇒ **Tailor mechanical properties at variable temperatures**

Dr. A. Weisheit (SPP)  
Prof. Schleifenbaum (SPP)



*Thank you for your attention!*