Deformation Behavior of CoCrFeMnNi+Al+C Alloys Manufactured by Laser Additive Manufacturing

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Project: “High-throughput experimental and Calphad screening of CCAs (Hi-Tecc) – towards new alloys with exceptional mechanical properties”

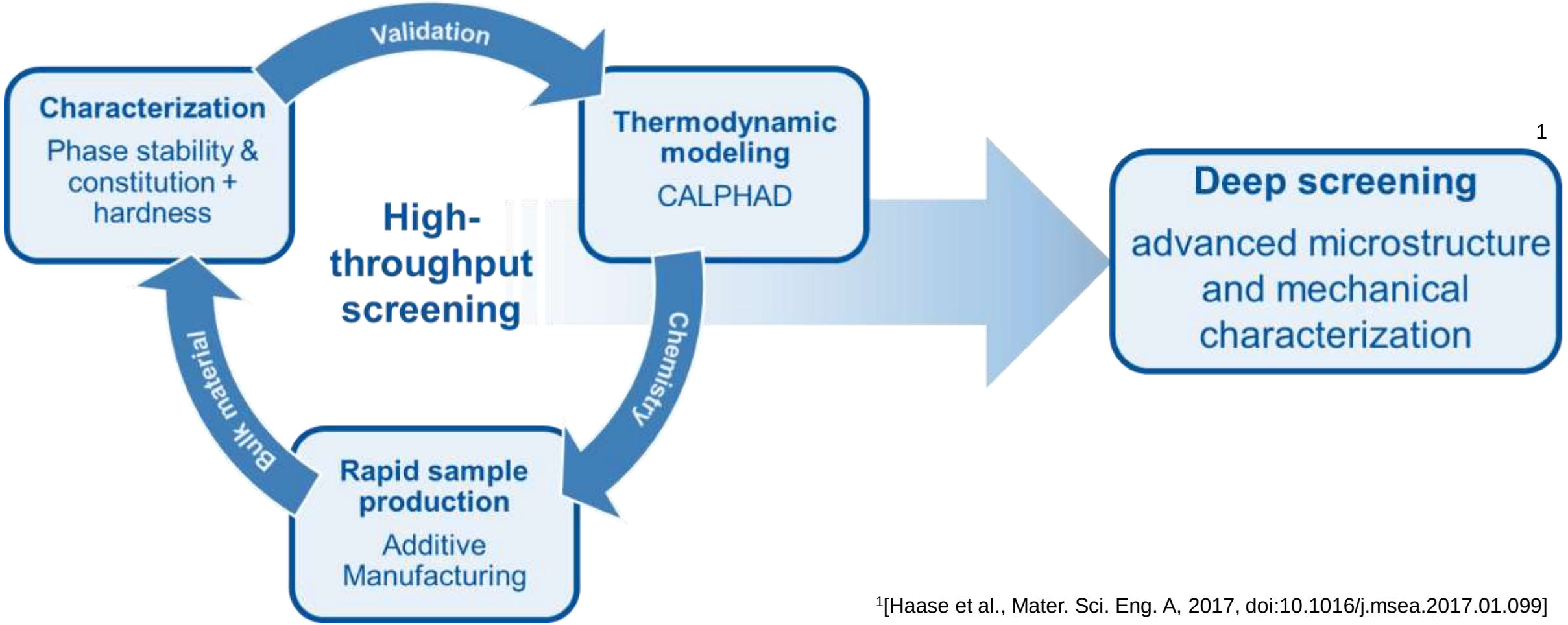
Priority Programme CCA – HEA
Subgroup Meeting “Mechanical Properties CCA”
Bayreuth, 18th September 2018

Content

1. Methodology
2. CoCrFeMnNi + Al
3. CoFeMnNi + Al + C
4. FeMnAlC + Ni + Co
5. Conclusions

Content

Methodology



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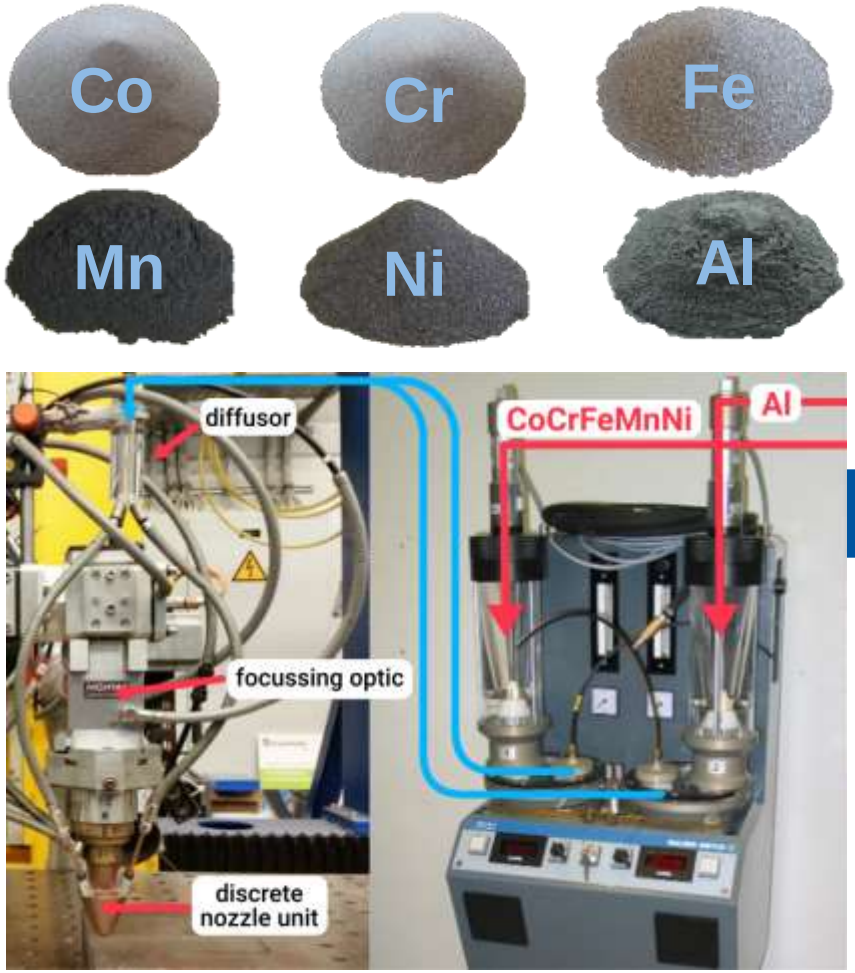
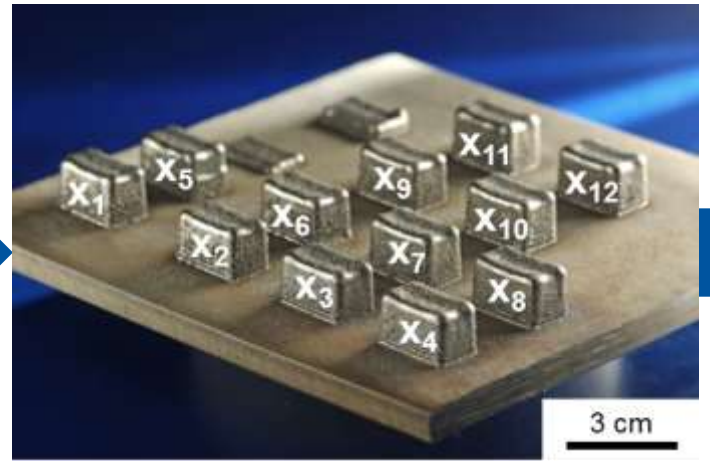
[1][Haase et al., Mater. Sci. Eng. A, 2017, doi:10.1016/j.msea.2017.01.099]

Laser Metal Deposition





High-Throughput Screening

- Microscopy
- XRD
- Hardness

Deep Screening

- SEM + EDS
- EBSD
- Tensile Test

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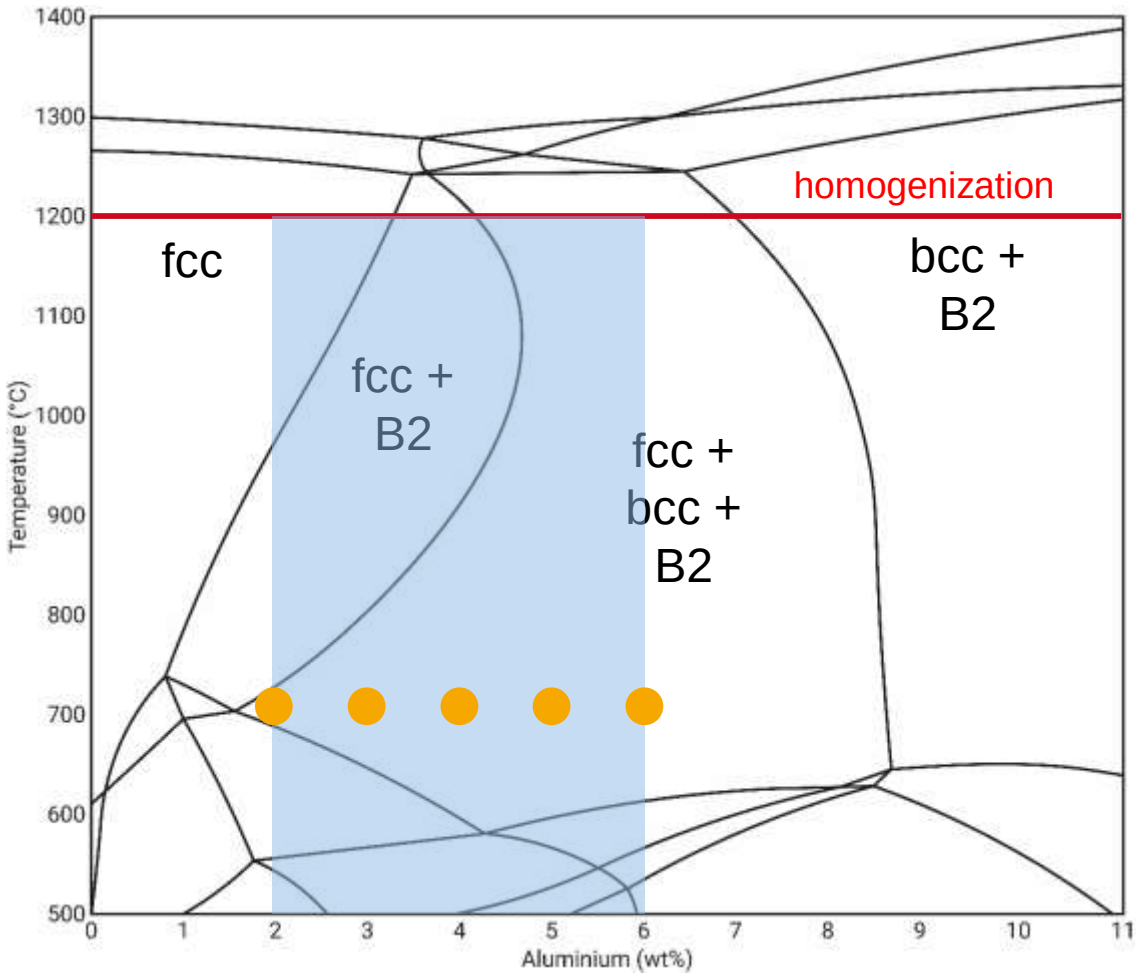
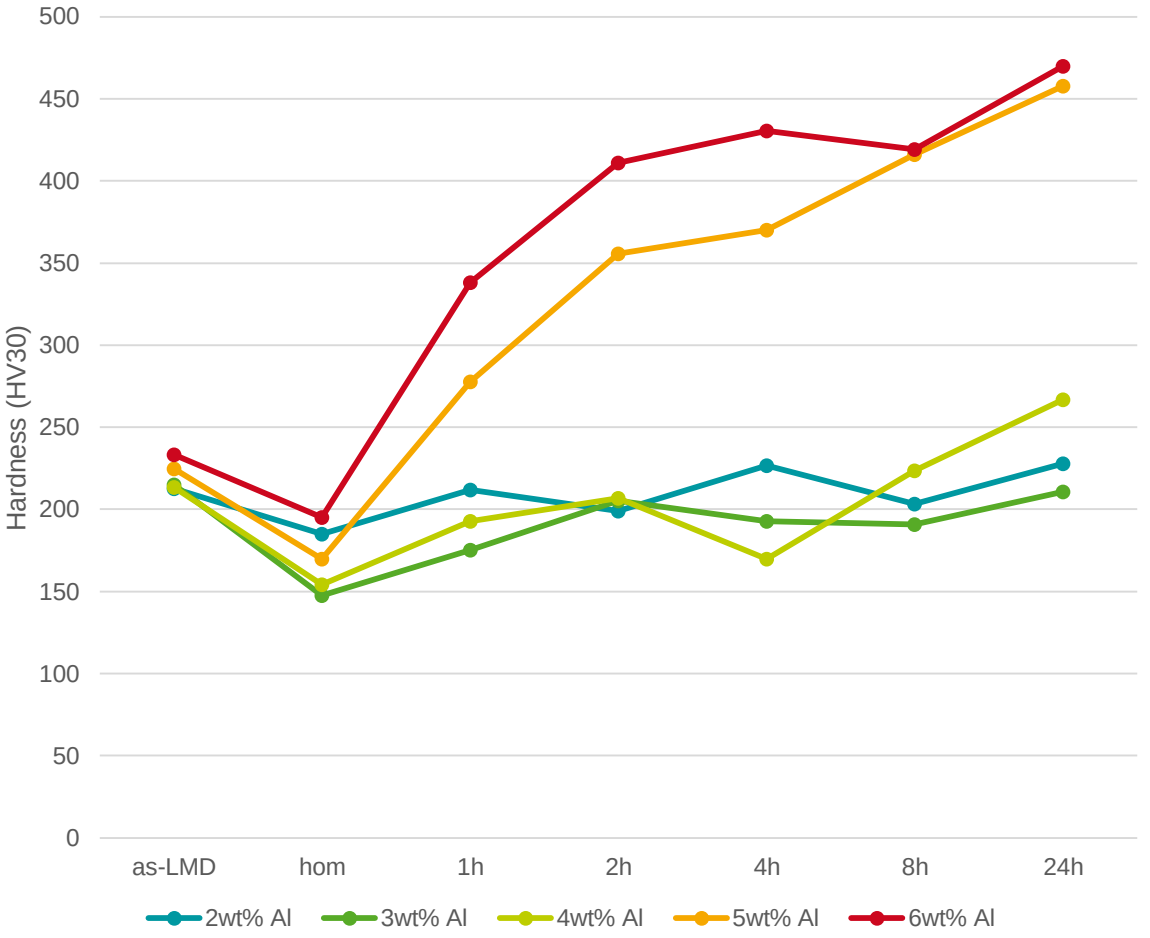
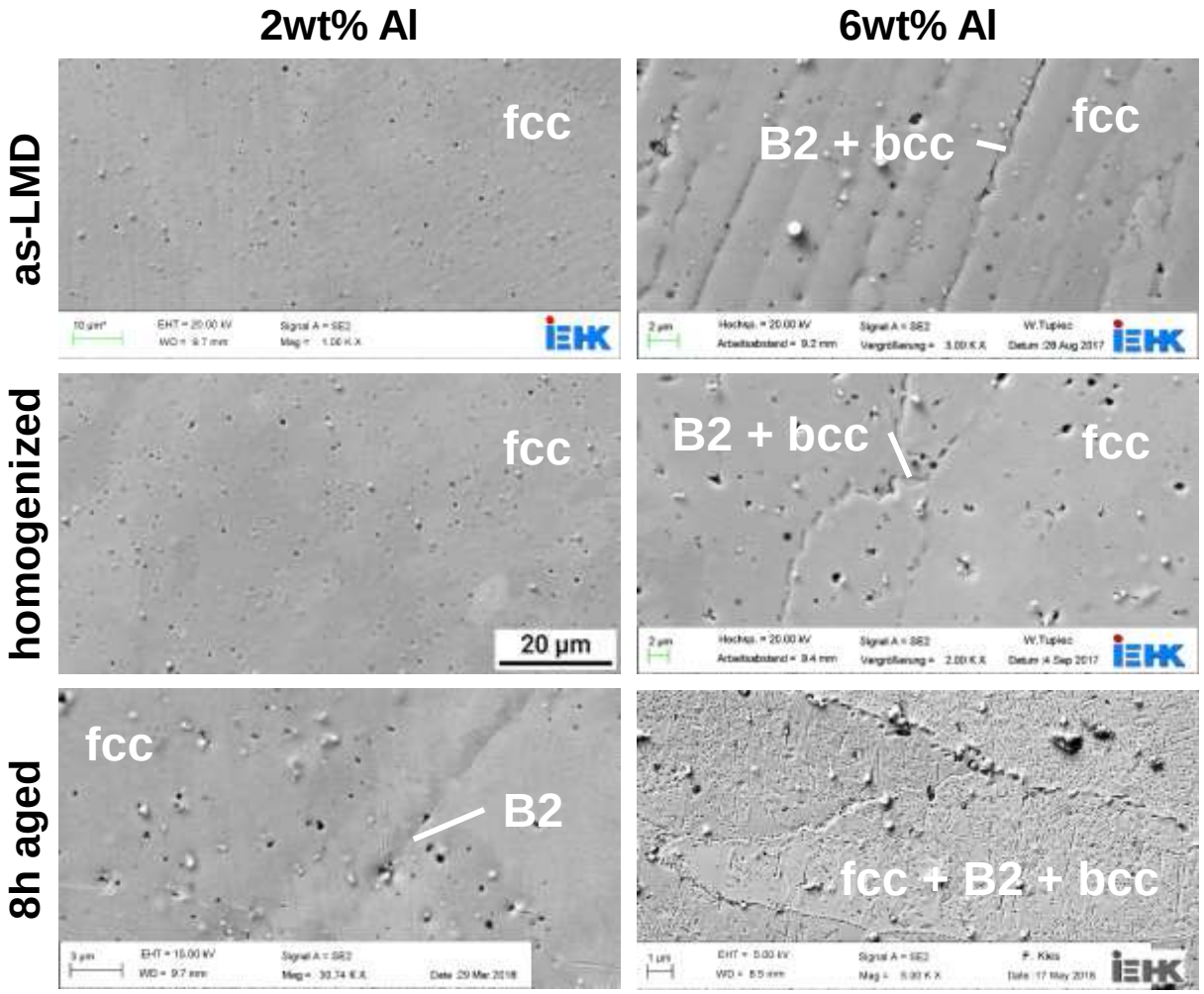
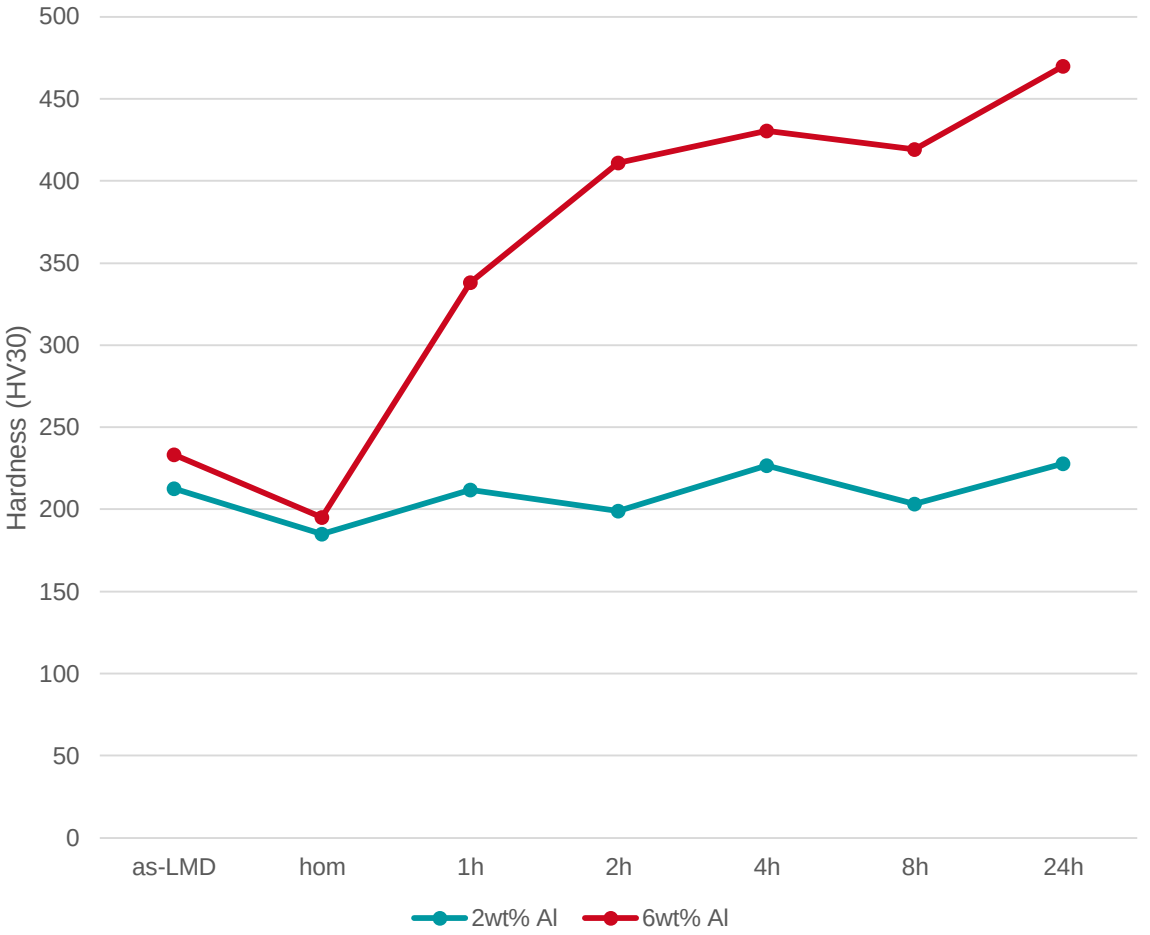
CoCrFeMnNi – High-Throughput Screening





CoCrFeMnNi – Microstructure Development

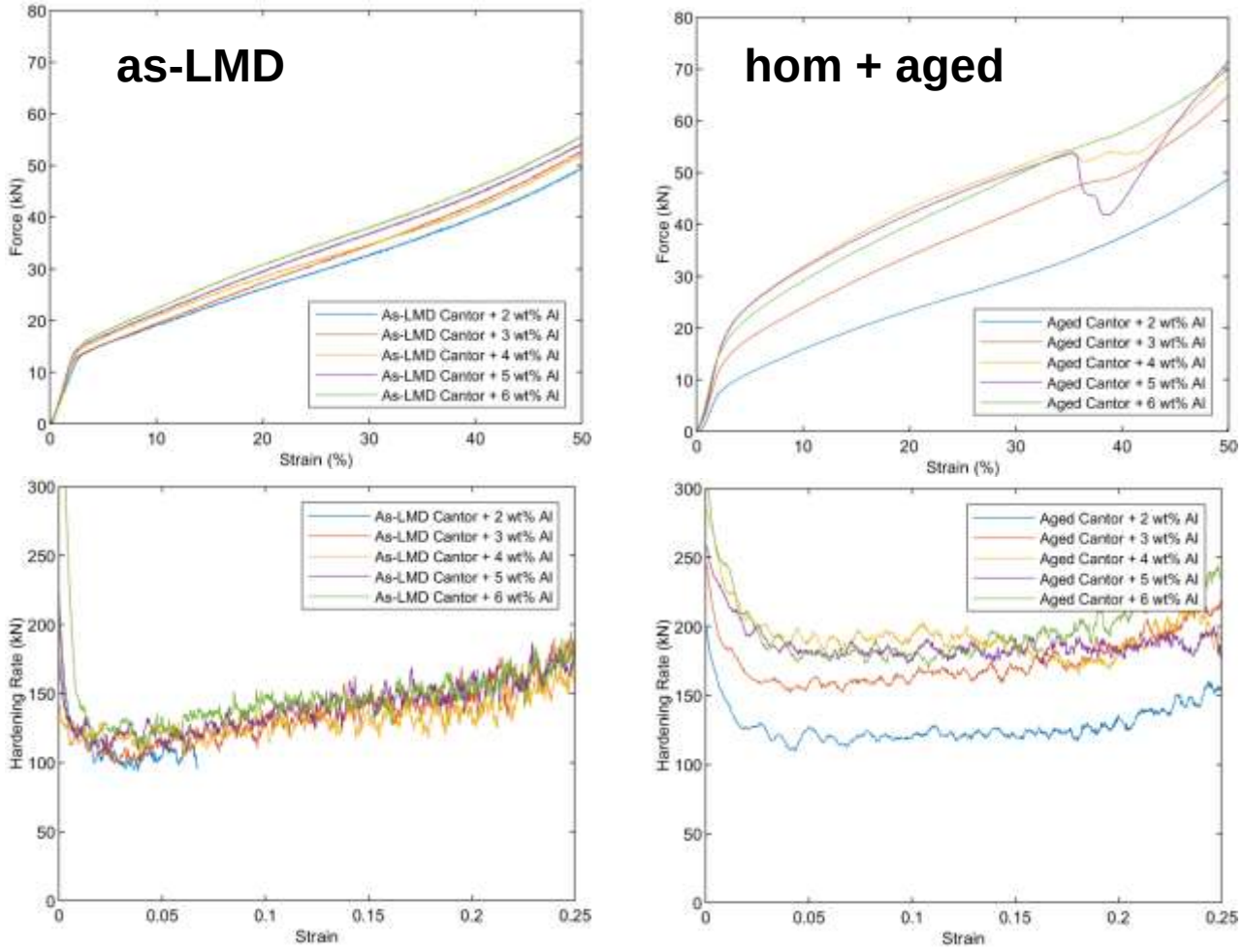




CoCrFeMnNi - Deformation Behavior

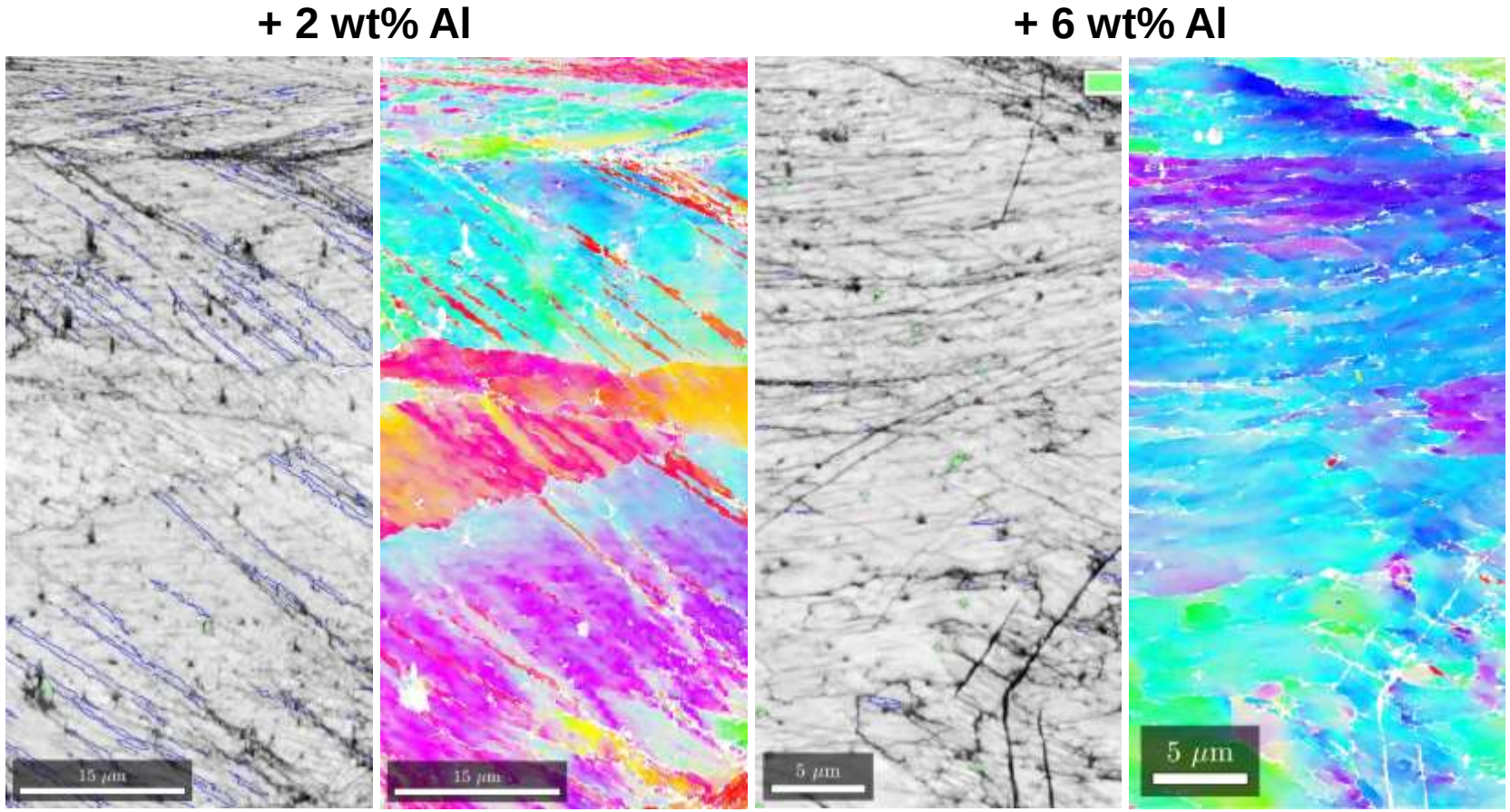
Compression Test

- Negligible effect of B2 and solid solution hardening in as-LMD material
- B2 / bcc precipitates effective hardening methods
  - YS and hardening increased
  - Ductility decreased



CoCrFeMnNi – Deformation Behavior

- Deformation twinning (TWIP) in low Al CoCrFeMnNi
  - Al increased stacking-fault energy (SFE)



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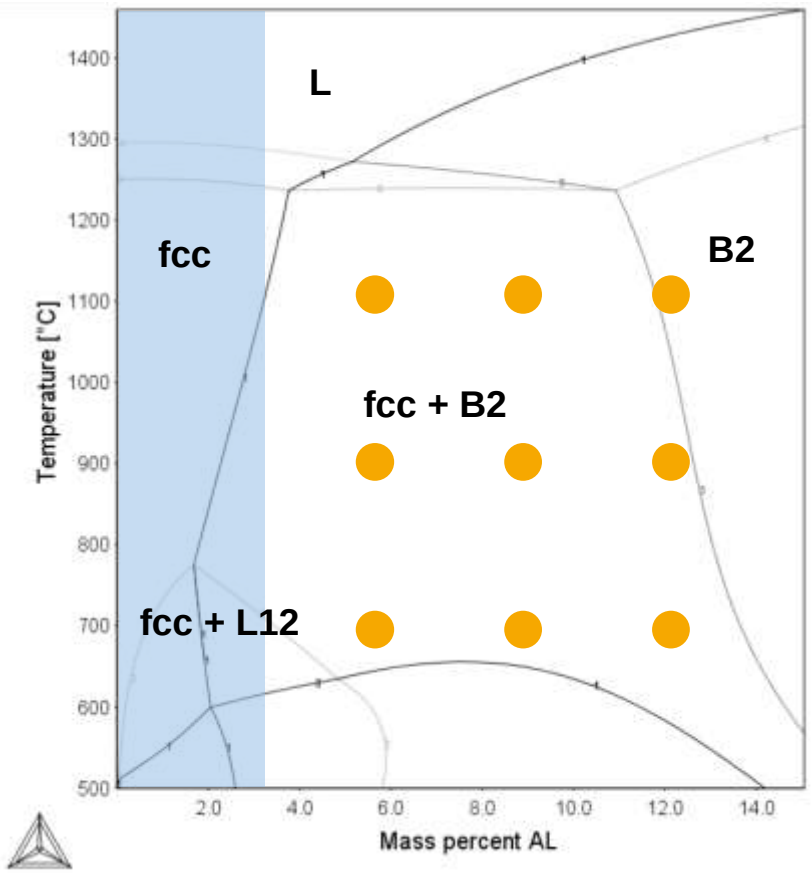
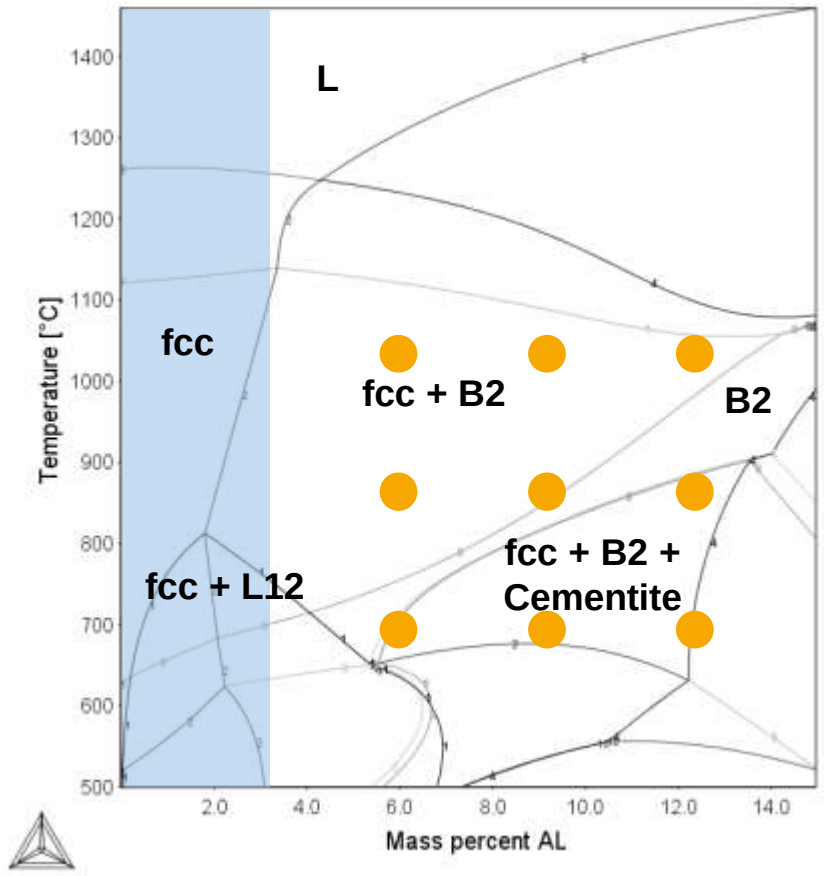
CoFeMnNi – High-Throughput Screening

CoFeMnNi + x wt% Al



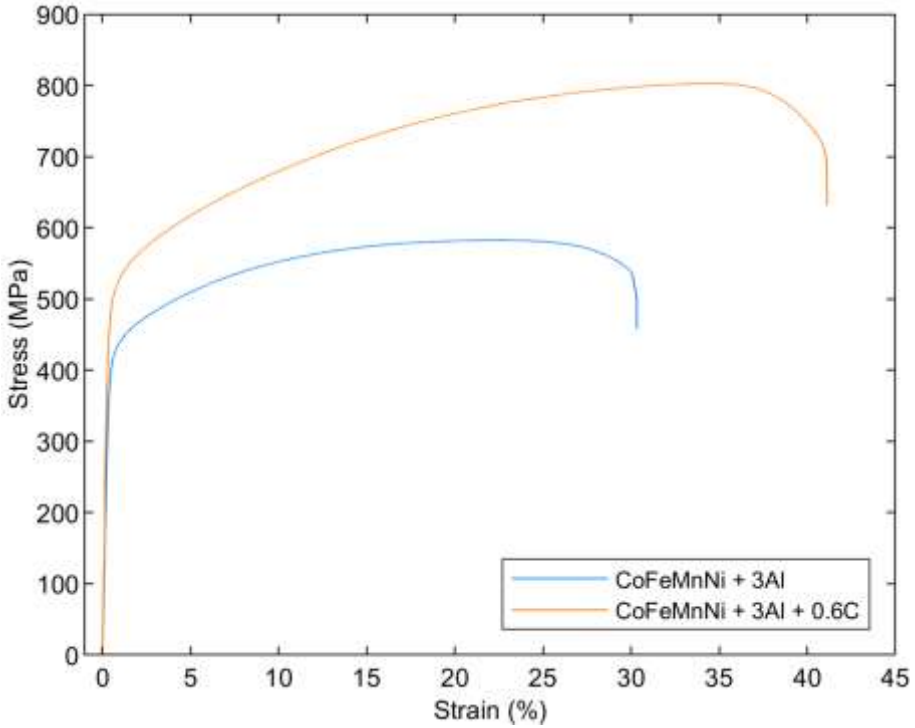
CoFeMnNi + 0.6 wt% C + x wt% Al

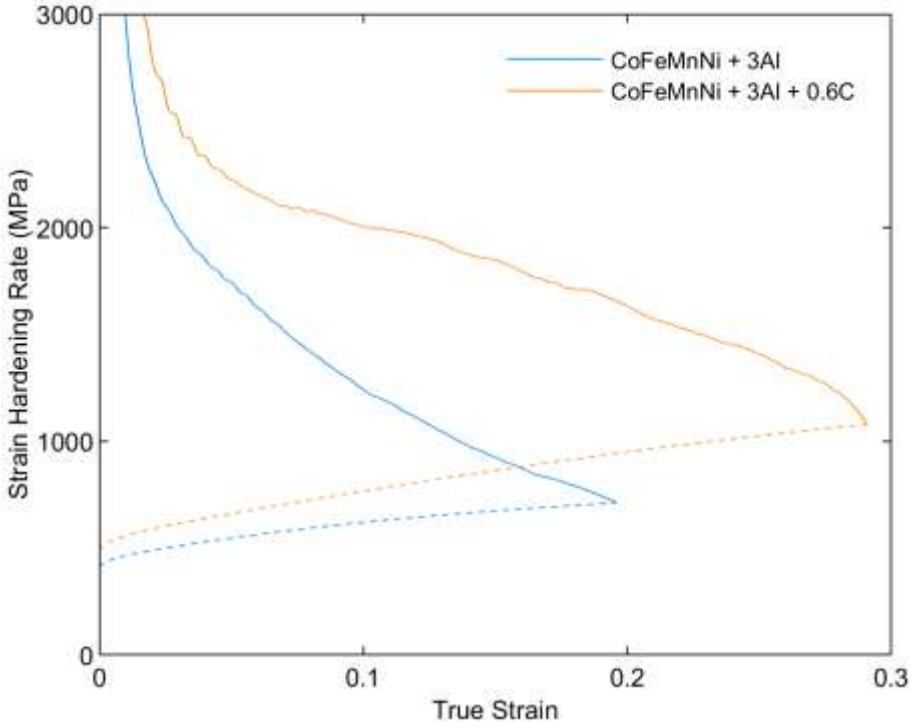


CoFeMnNi – Deformation Behavior

Tensile Test

- Interstitial hardening with C viable
  - YS + UTS increased
  - Ductility increased

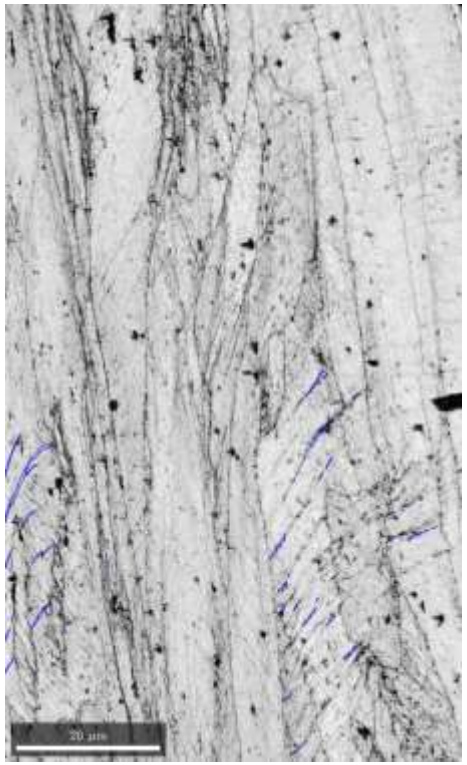




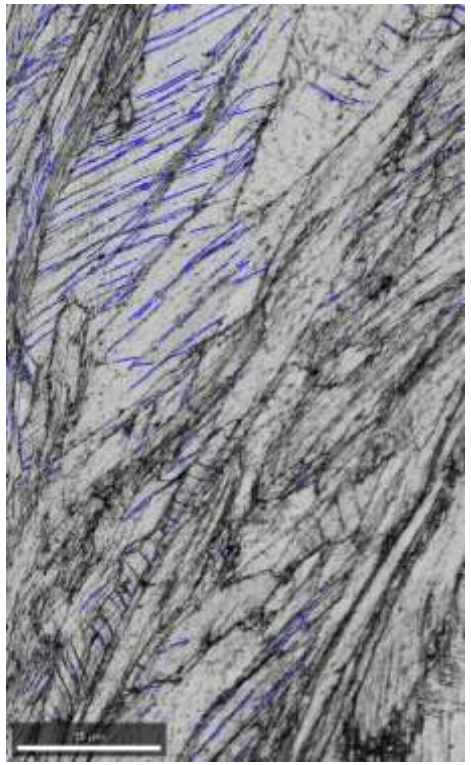
CoFeMnNi – Deformation Behavior

- TWIP activation with C addition
  - C reduced SFE in the AlCoFeMnNi System

CoFeMnNi + 3wt% Al



CoFeMnNi + 3wt% Al + 0.6wt% C



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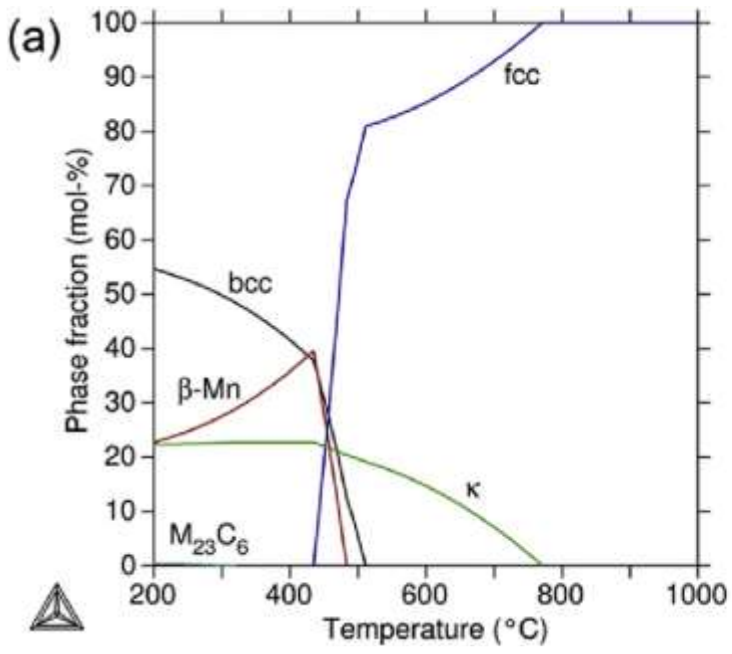
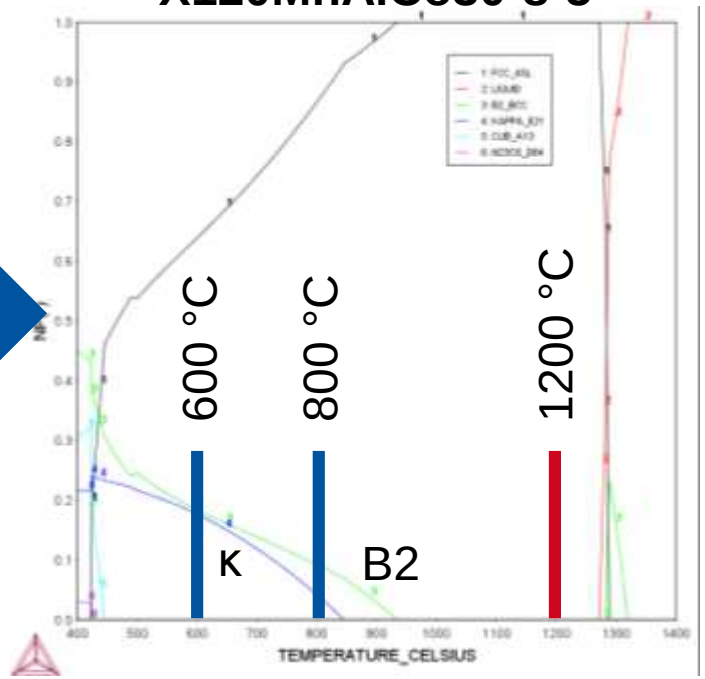
FeMnAlC – Approach

- Development of new CCAs by modifying promising high-Mn steel concepts
- Introduction of B2 into a SRIP steel

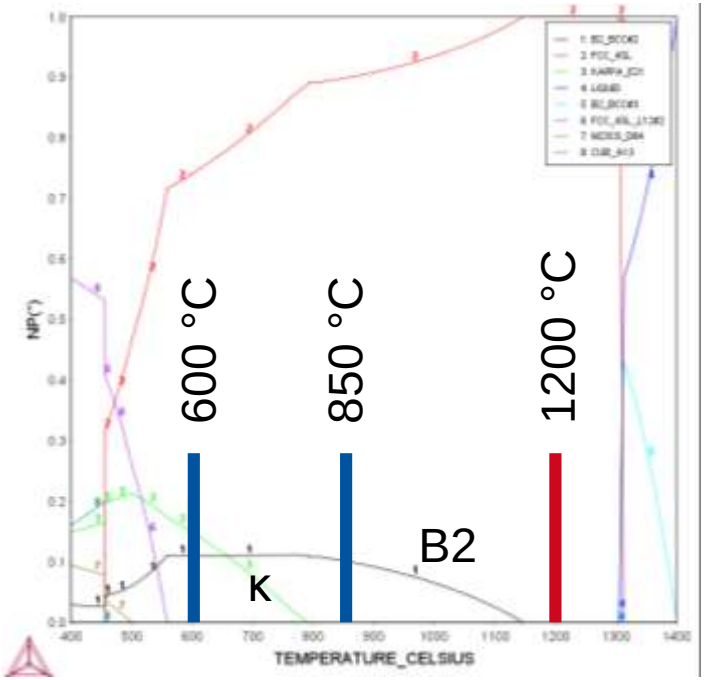
X120MnAl30-8



X120MnAlCo30-8-5



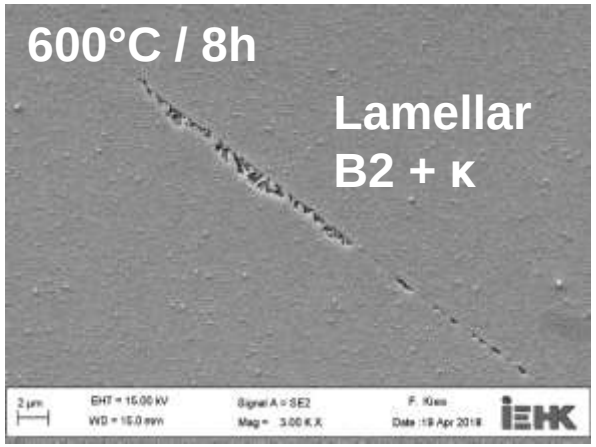
X120MnAlNi30-8-5

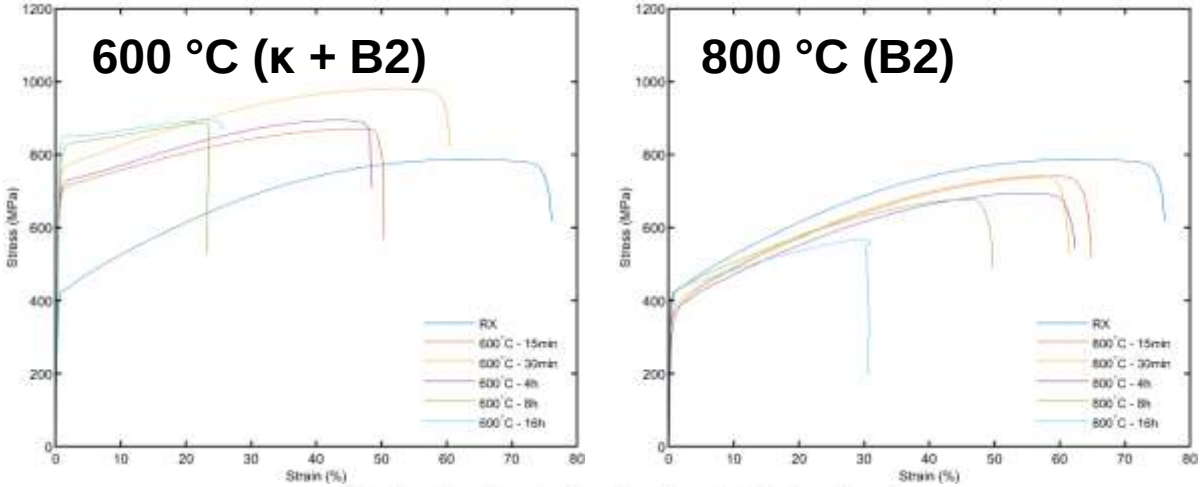


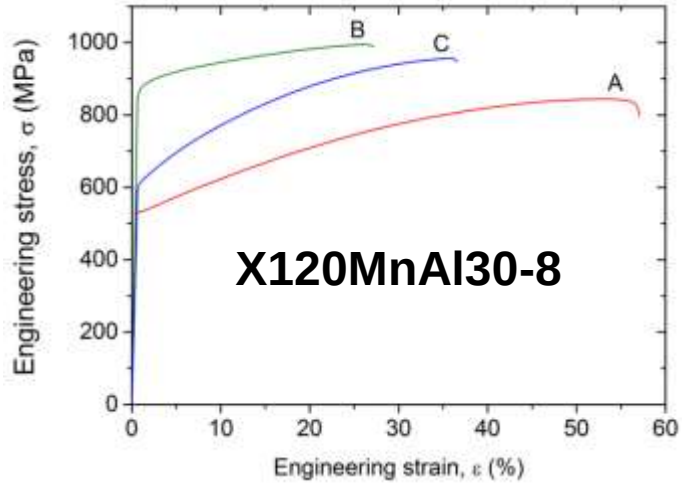
FeMnAlC – Mechanical Properties

X120MnAlCo30-8-5: Tensile Test

- Loss of ductility in pure B2 region
- Overaged state shows κ + B2
  - Formation in matrix likely at 600 °C aging
- No improvement over concept without Co



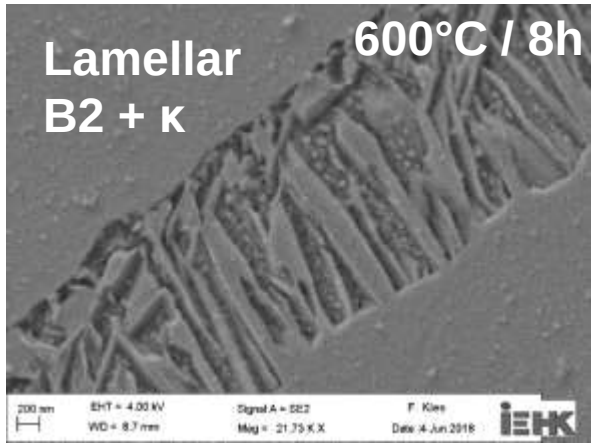


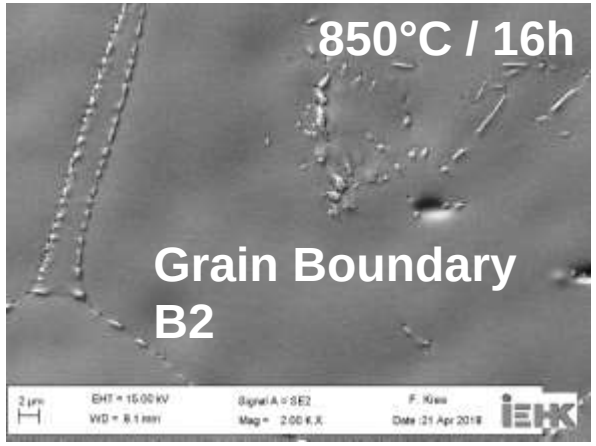


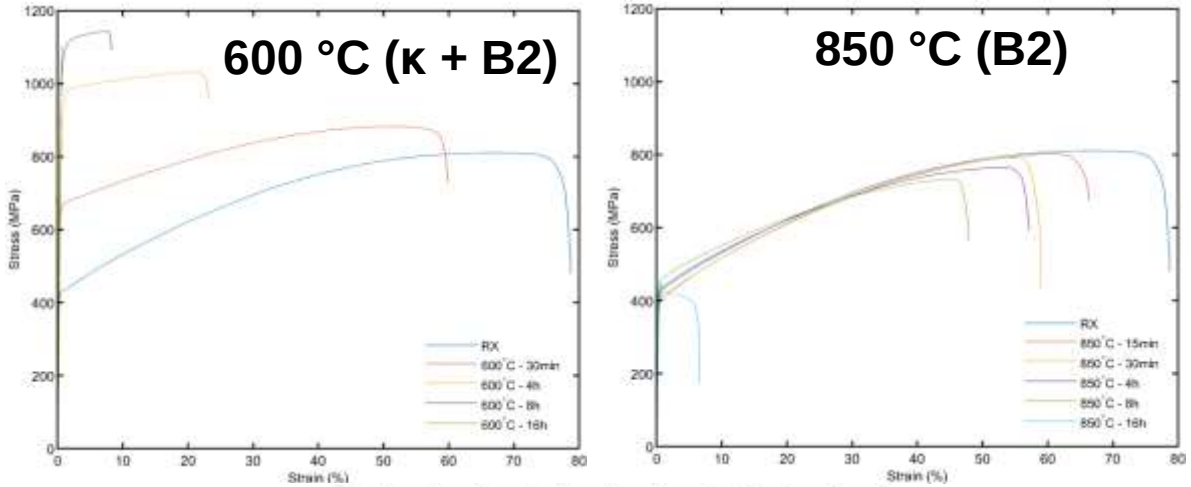
FeMnAlC – Mechanical Properties

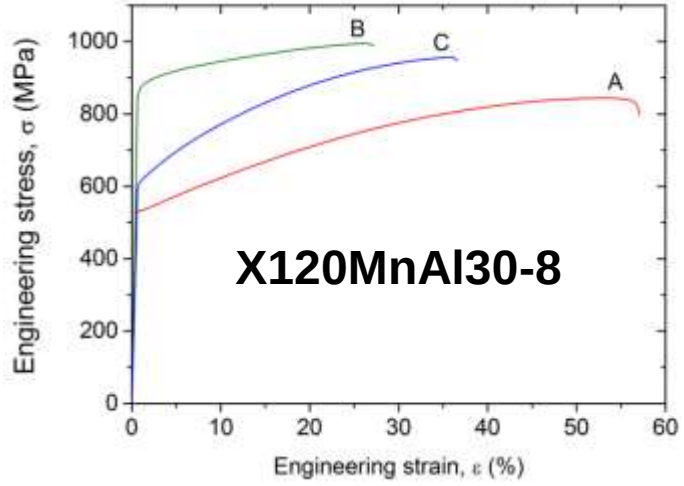
X120MnAlNi30-8-5: Tensile Test

- Loss of ductility in pure B2 region
- Overaged state shows κ + B2
  - Formation in matrix likely at 600 °C aging
- Improvement observed over concept without Ni



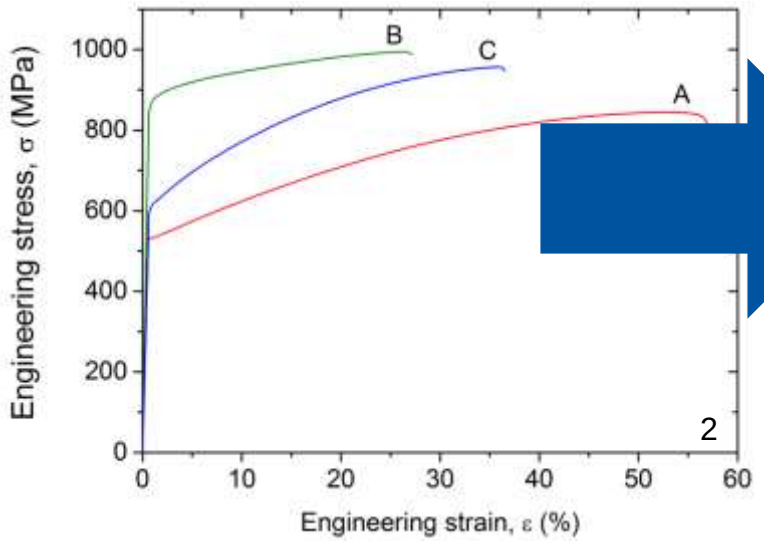




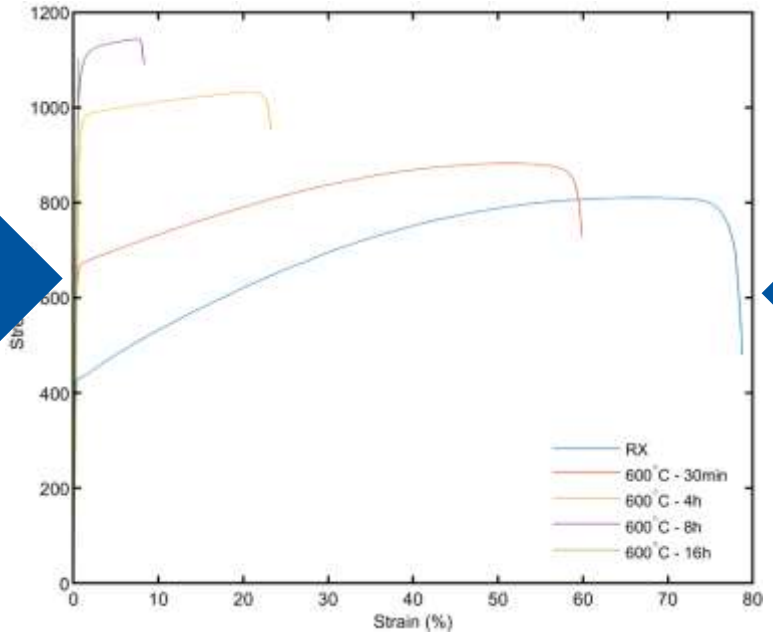


FeMnAlC – Mechanical Properties

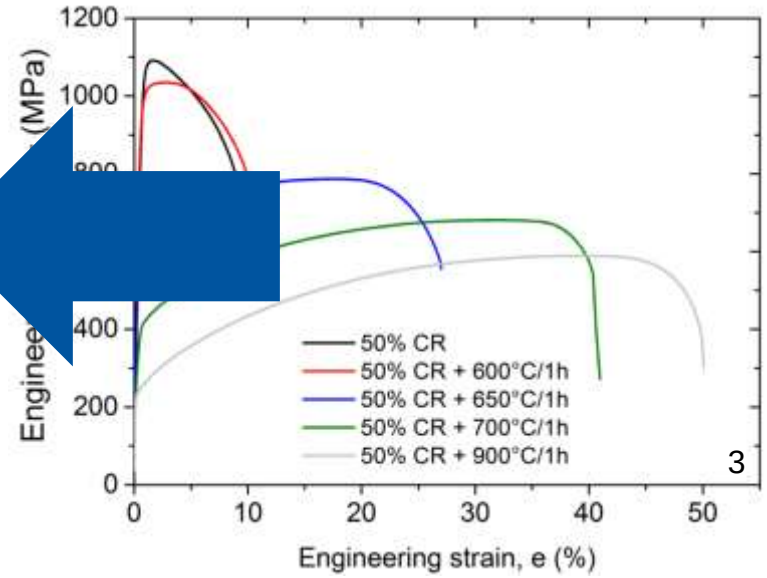
X120MnAl30-8



X120MnAlNi30-8-5



CoCrFeMnNi



[2][Haase et al., Acta Mater., 2017, doi:10.1016/j.actamat.2016.10.006]

[3][Haase et al., Acta Mater., 2018, doi:10.1016/j.actamat.2018.02.048]

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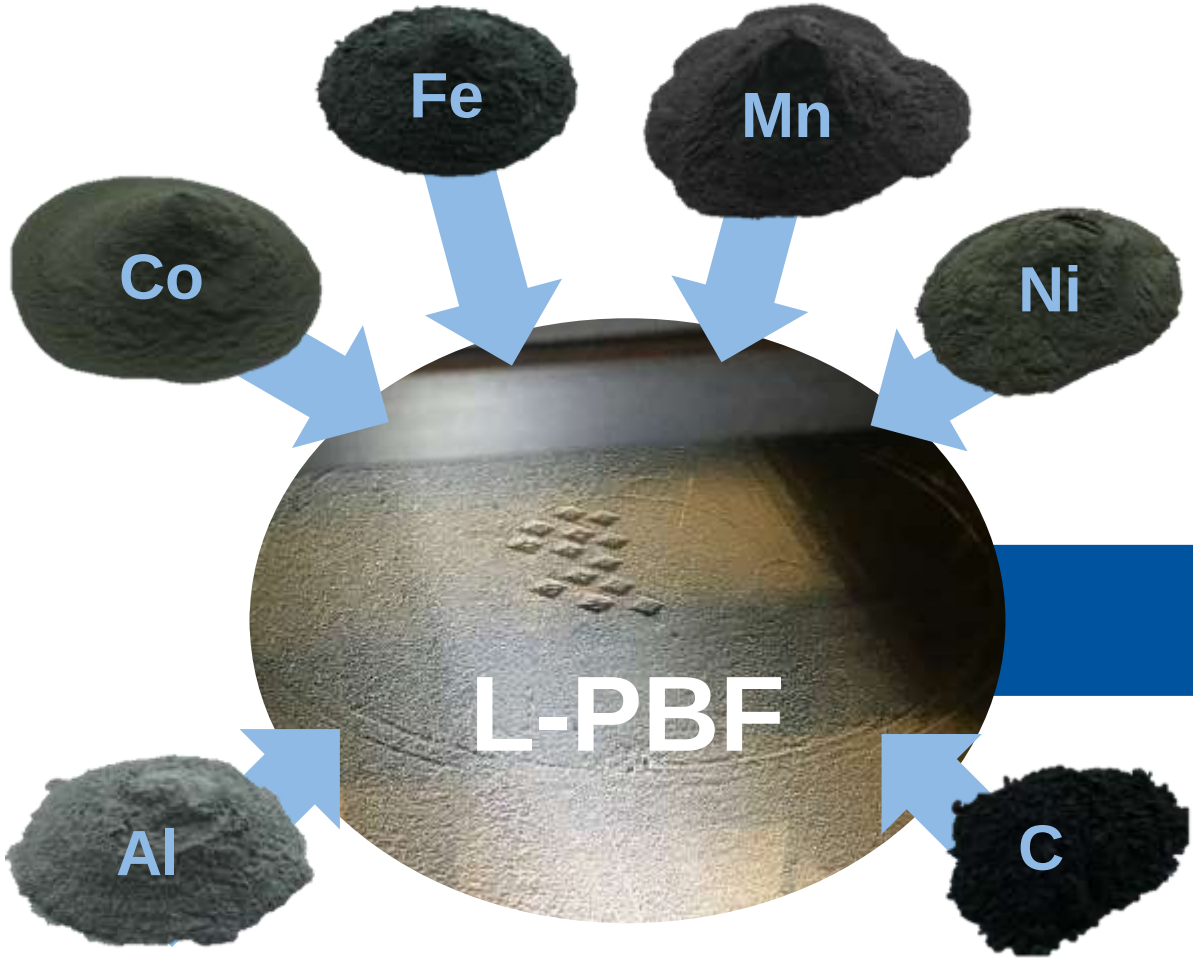
5. Conclusions

Conclusions

- CoCrFeMnNi + Al
  - B2 / bcc effective hardening mechanism
  - Further investigation into tensile behavior
- CoFeMnNi + Al + C
  - Interstitial C hardening viable in CCA
- FeMnAlC + Ni
  - Deformation mechanism retained
  - Promising methodology to design CCAs

Thank you
for your attention!

L-PBF – Approach



High-Throughput Screening

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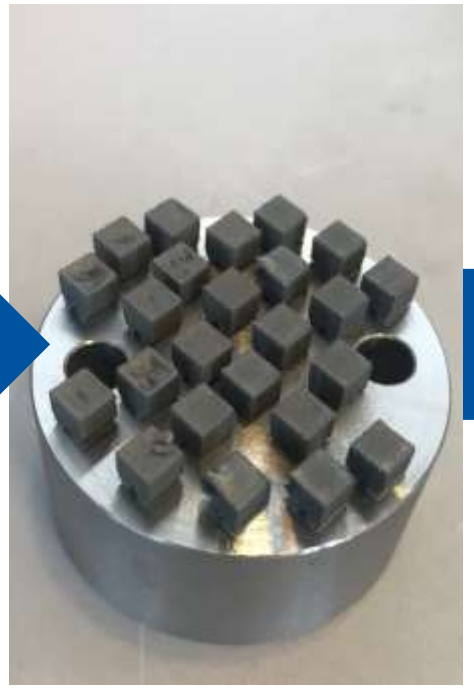
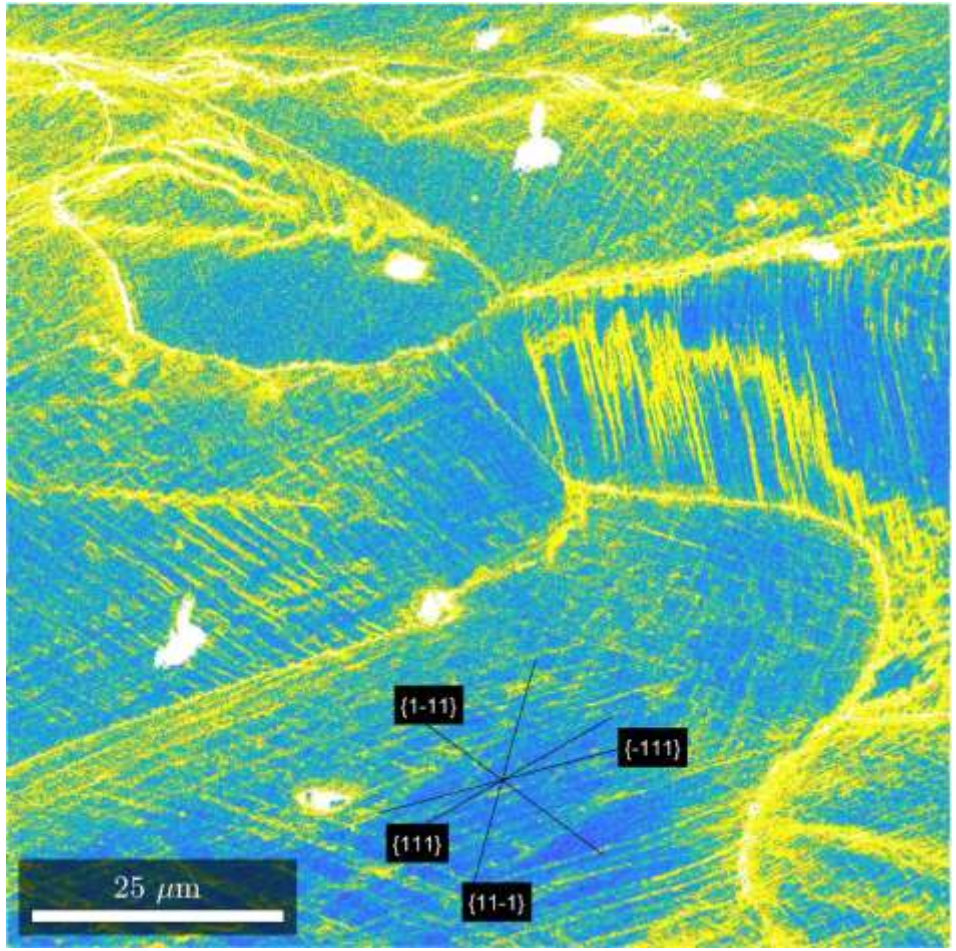
- XRD
- Hardness



Deep Screening

- SEM + EDS
- EBSD
- Tensile Test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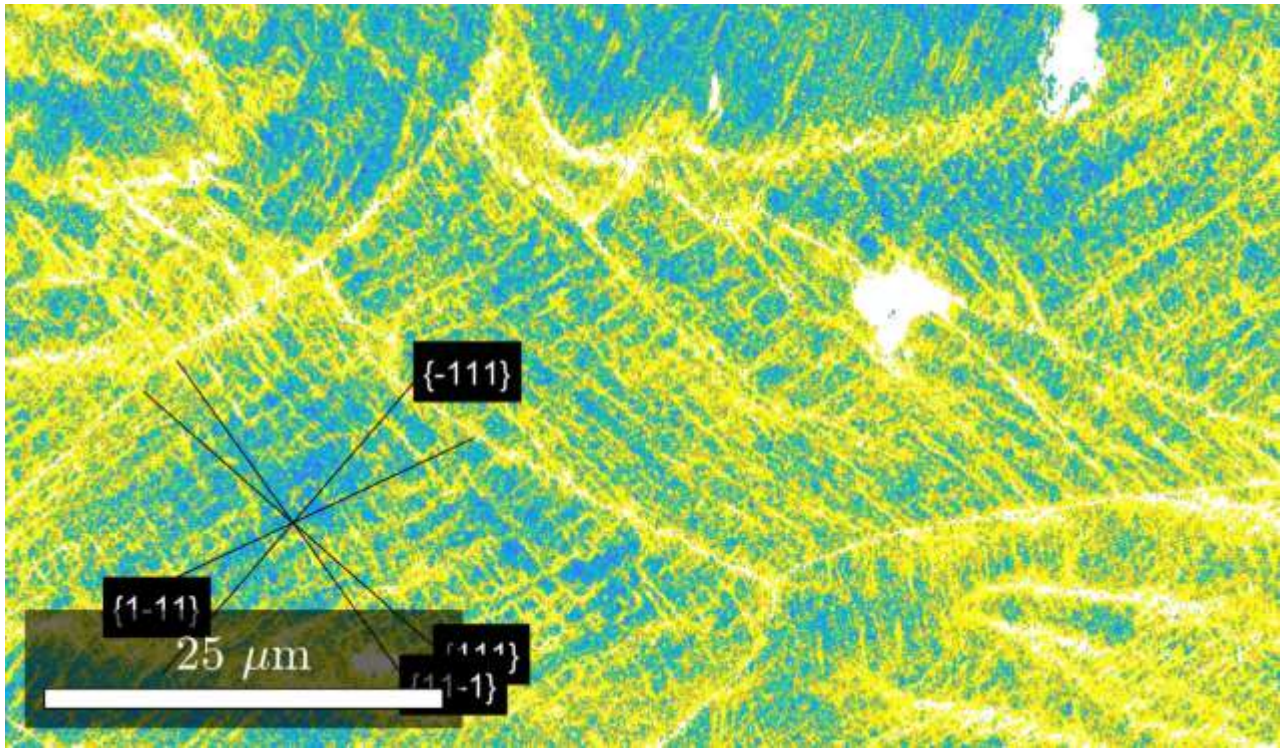
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25 μm