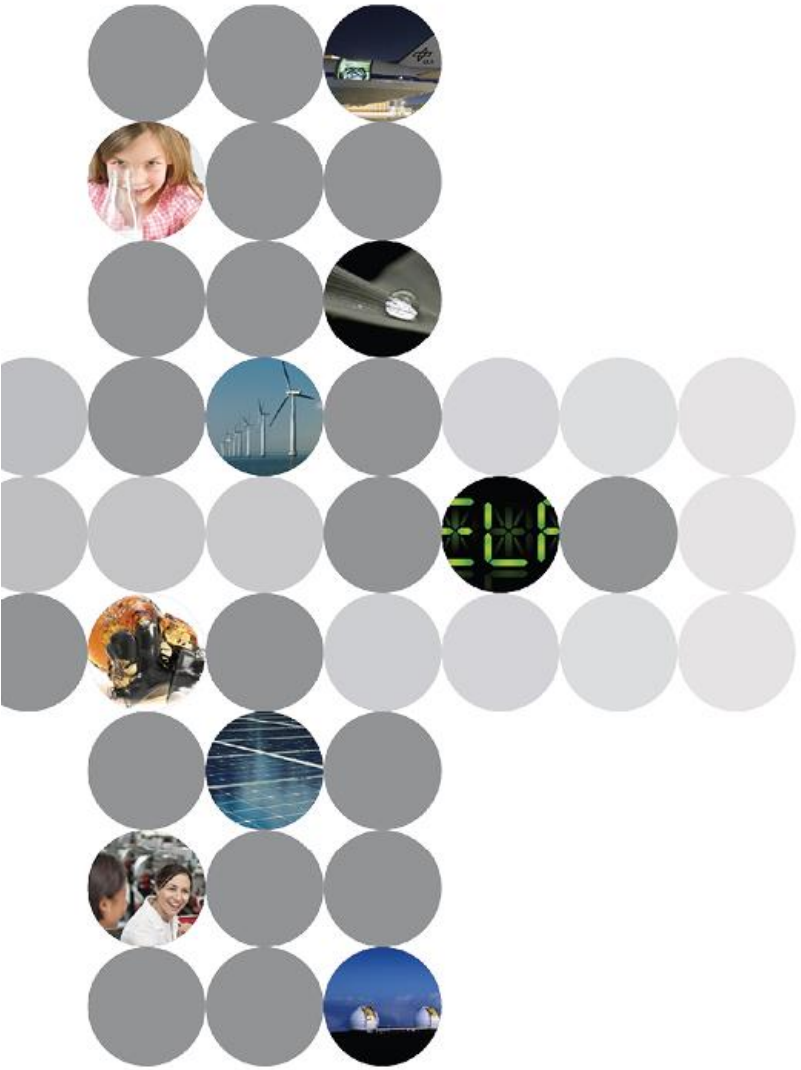


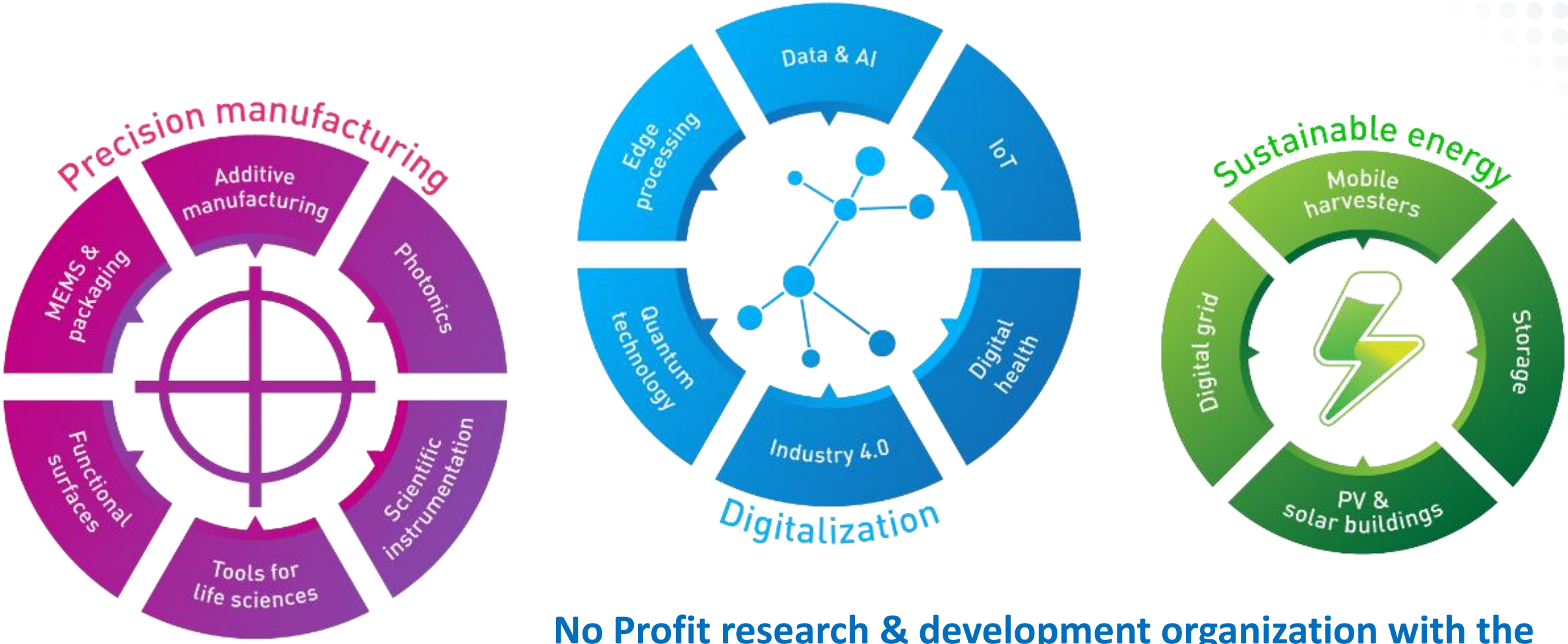
AIDAINNOVA

METAL ADDITIVE MANUFACTURING

WP10 20.03.2024

SAMUEL UNTERHOFER

CSEM FOCUS AREAS



No Profit research & development organization with the mission of technology transfer to the industrial sector in Switzerland and in Europe.

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METAL ADDITIVE MANUFACTURING AT CSEM

L-PBF

Spot size: 40 µm

Building volume: 250 x 250 x 300 mm^3

Layer thickness: 10-200 µm

L-PBF

Spot size: 30 µm

Building volume: Ø 100 x 90 mm^3

Layer thickness: 10-50 µm

LMM

Pixel size: 35 µm

Building volume: 56 x 90 x 120 mm^3

Layer thickness: 10-100 µm

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CSEM AIM FOR AIDAINNOVA WP10

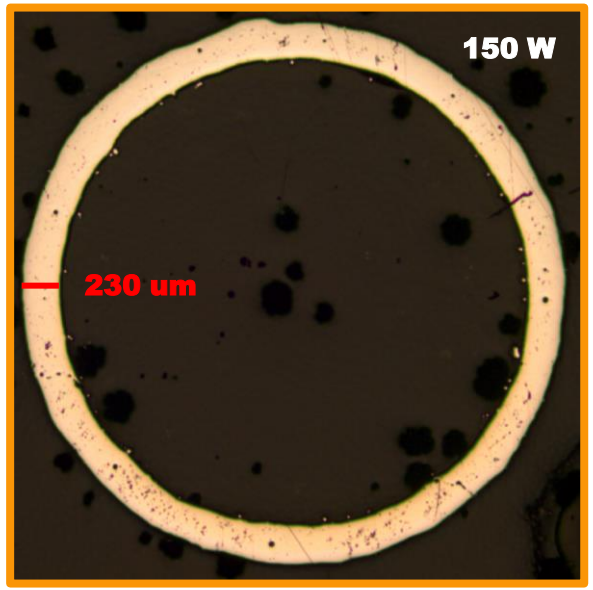
Define the optimal geometrical features attainable for 3D printed **ultra-thin cold plates** in **metal** alloys

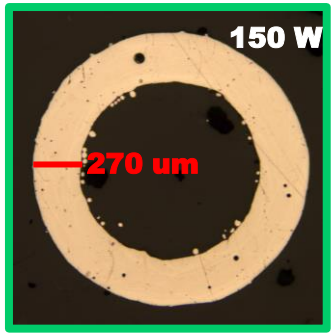
CSEM OBJECTIVES FOR AIDAINNOVA WP10

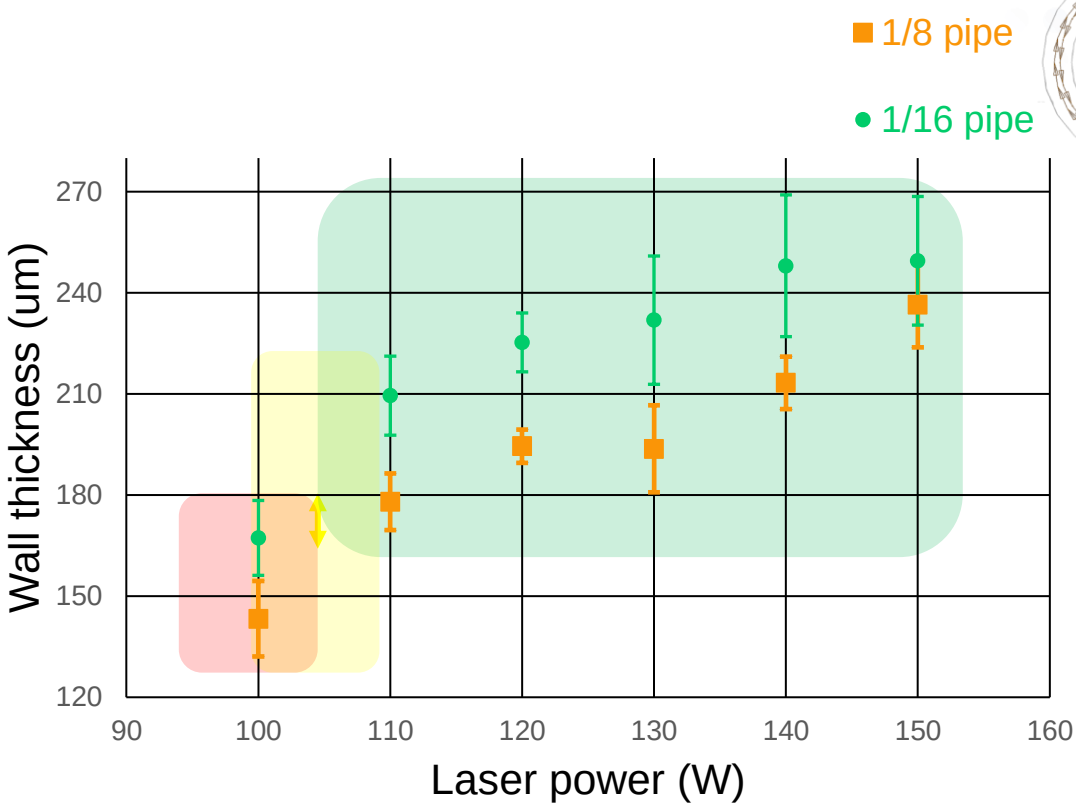
Aluminium: Al-12-Si

- **Test samples**
  - ✓ Thermal conductivity
  - ✓ Long test cavity
  - ➢ Pipe roughness
  - ❑ Flatness (multi-microchannel)
- **Minimal wall thickness**
  - ➢ Minimum leak-tight wall thickness
- **Powder management**
  - ✓ Minimum ratio (D/L) for single straight pipes
  - ➢ Design feature for 180° bent pipes
  - ❑ Minimum ratio (D/L) for multi-microchannel
- **Smart pipe device**
  - ➢ Printing parameters

MINIMUM LEAK-TIGHT WALL THICKNESS







- Results:
  - **≥ 110 W → Leak-tight (180-210 um)**
  - **≤ 100 W → Not leak-tight (140-170 um)**

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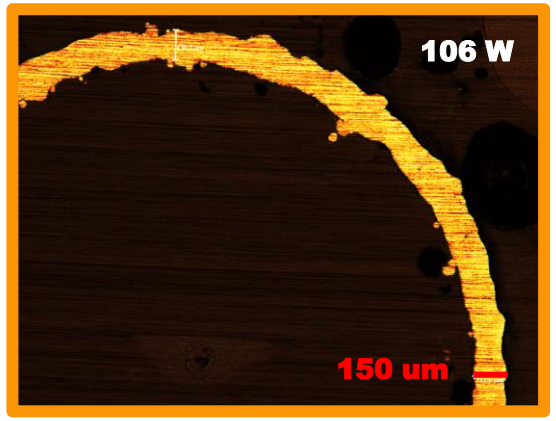
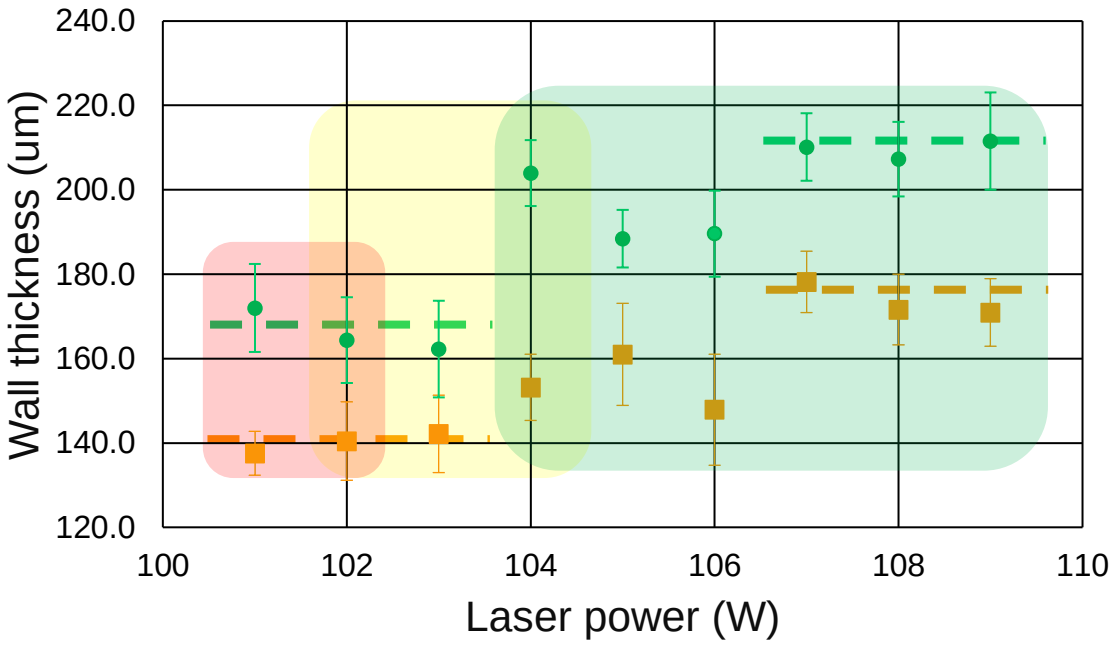
MINIMUM LEAK-TIGHT WALL THICKNESS





- Fine tuning between 100W and 110W:
  - **≥ 105 W → Leak-tight (160-190 um)**
  - **≤ 101 W → Not leak-tight**

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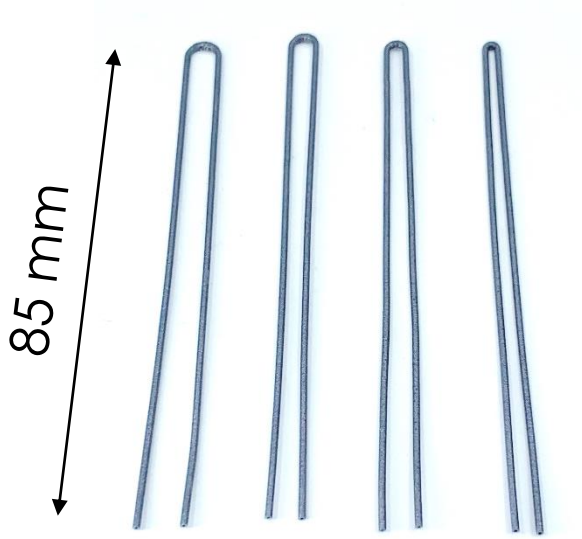
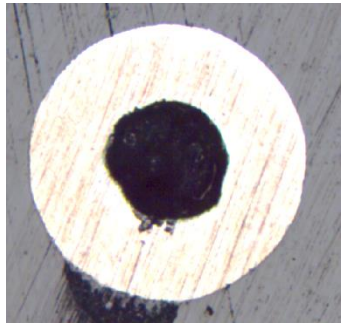
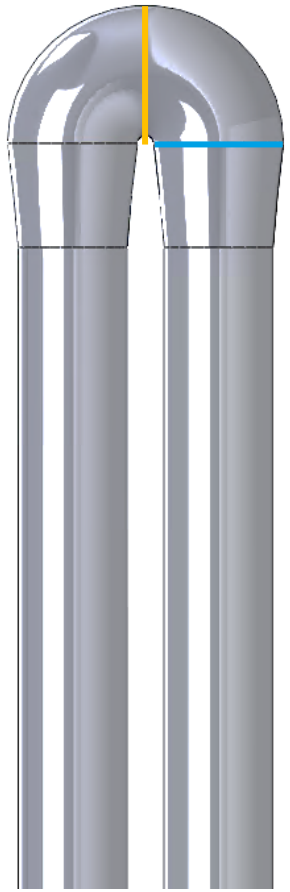
POWDER REMOVAL FOR 180° BENT PIPE





0.44 mm hole

Curvature radius



Pipe diameter on curvature

Pipe diameter on curvature (mm)

Curvature radius (mm)	0.65	0.70	0.75	0.80	0.85
0.55					
0.60					
0.65					
0.70					
0.75					
0.80					

Clogged pipe

Empty pipe

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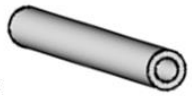
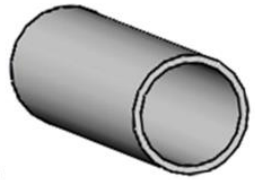
PIPE ROUGHNESS

Minimum wall thickness investigation

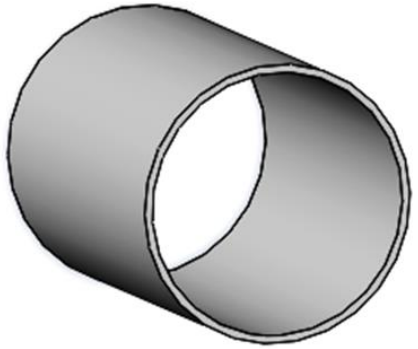


Ø 1.6 mm



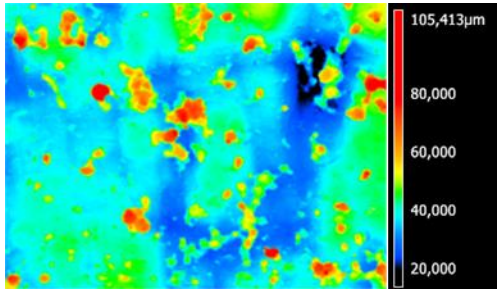
Ø 3.2 mm

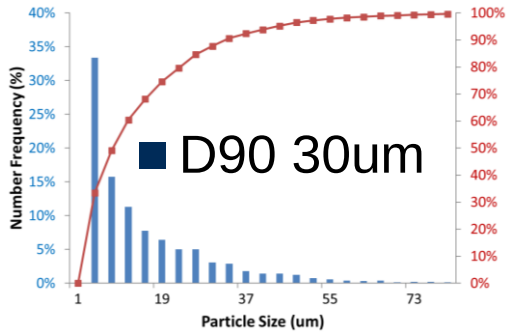
Smart pipe investigation

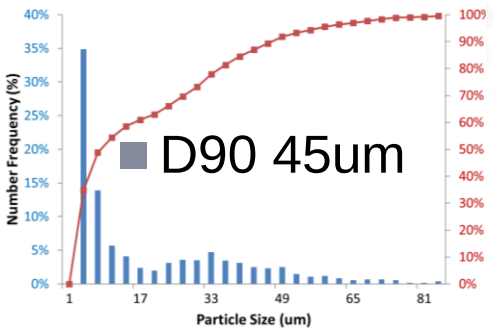


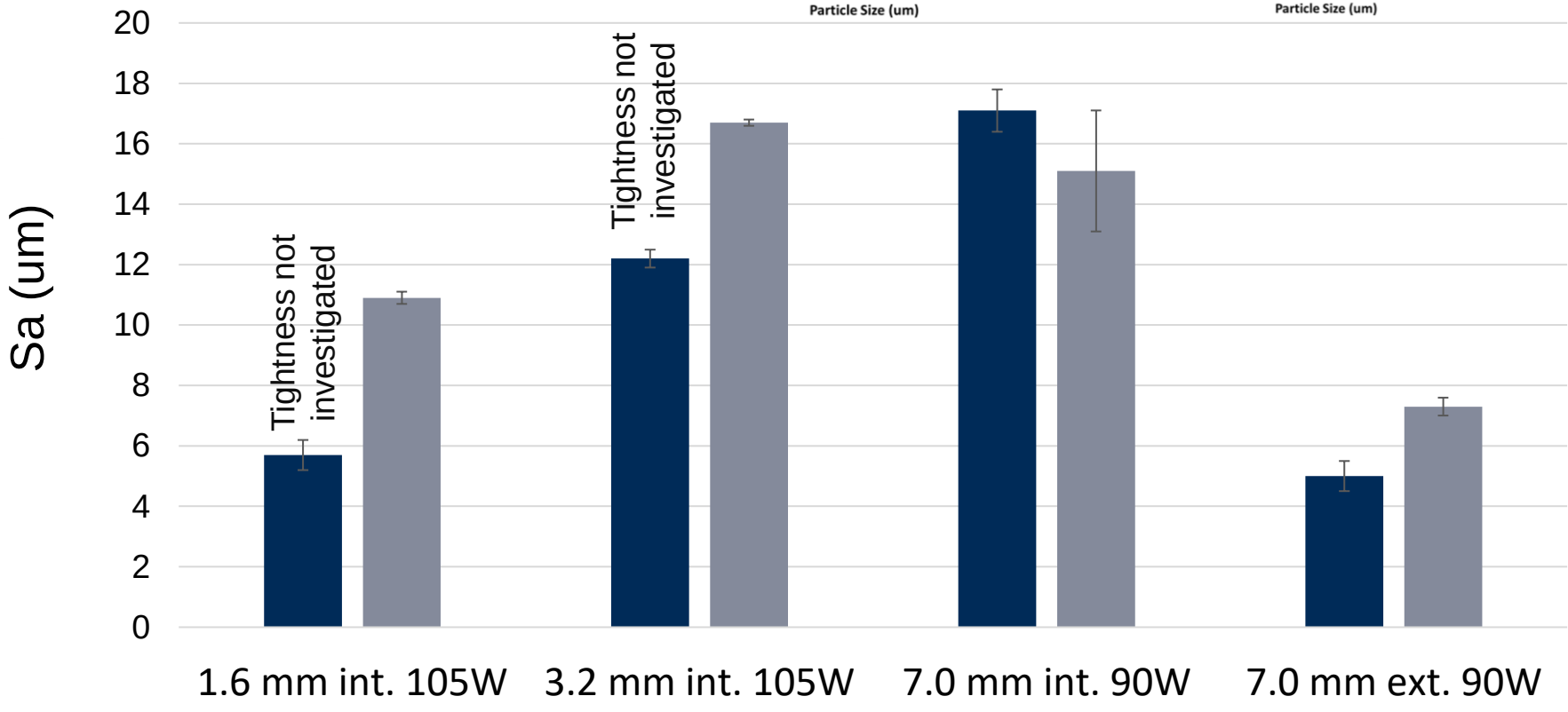
Ø 7.0 mm

Laser confocal









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PARTIAL CONCLUSION

Aluminium: Al-12-Si

- **Test samples**
  - ✓ Thermal conductivity
  - ✓ Long test cavity
  - ✓ Pipe roughness
  - ❑ Flatness (multi-microchannel)
- **Minimal wall thickness**
  - ✓ Minimum leak-tight wall thickness
- **Powder management**
  - ✓ Minimum ratio (D/L) for single straight pipes
  - ✓ Design feature for 180° bent pipes
  - ❑ Minimum ratio (D/L) for multi-microchannel
- **Smart pipe device**
  - ✓ Printing parameters

CSEM OBJECTIVES FOR AIDAINNOVA WP10

KOVAR: Fe-29-Ni-17-Co

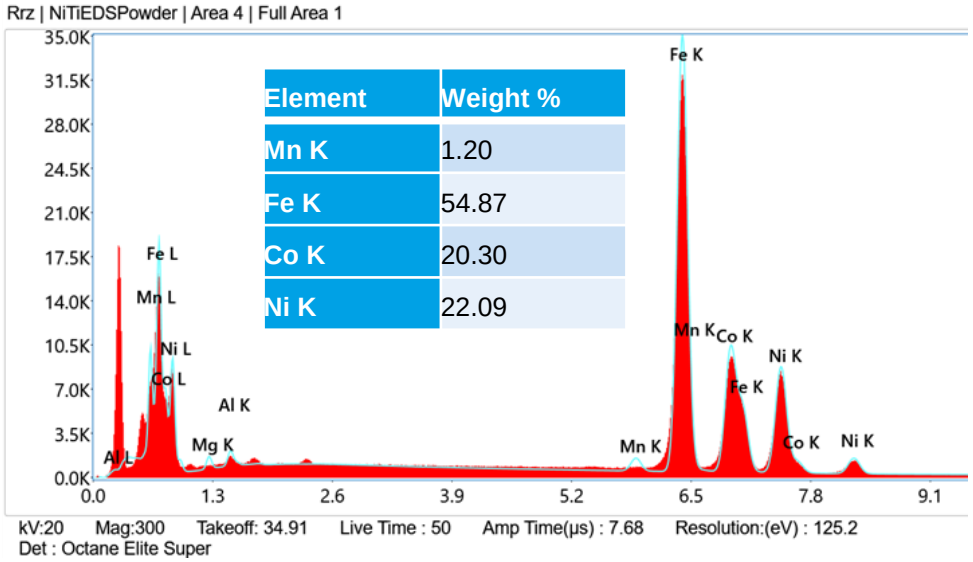
✓ **Phase 1**

- Benchmarking for AM grade powder
- Development of process parameters

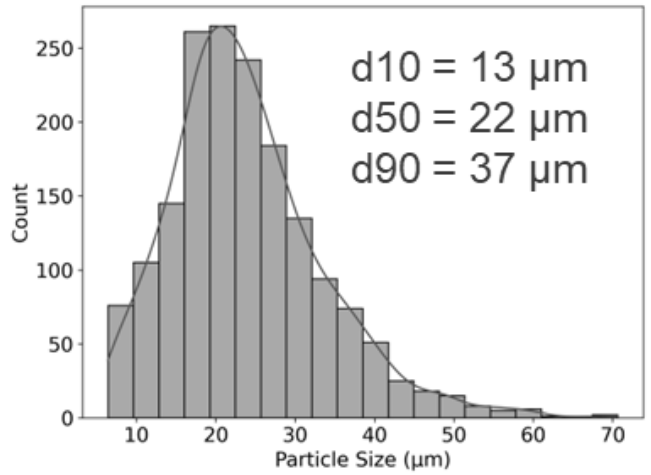
❑ **Phase 2**

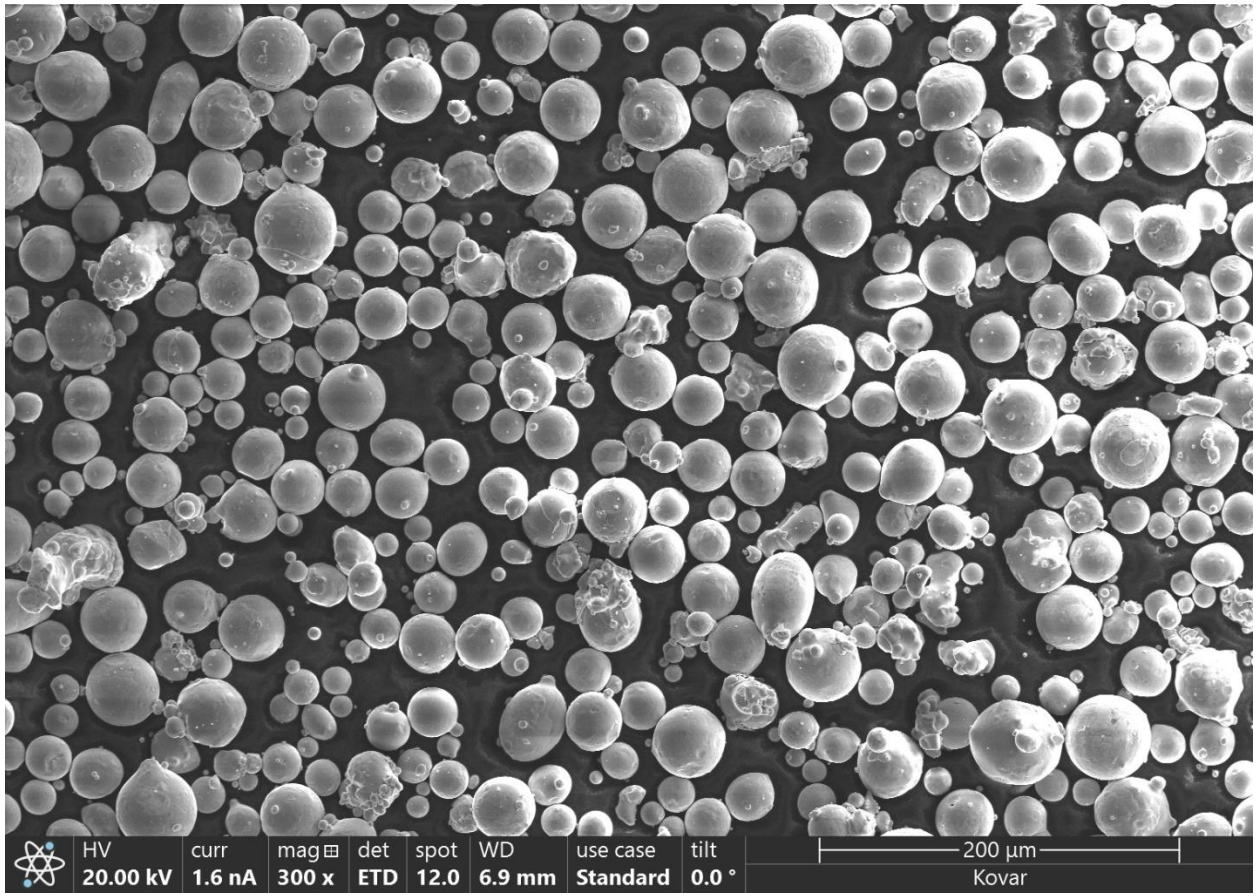
- ❑ Same investigation as Al-12-Si but on a limited number of samples

BENCHMARKING FOR AM GRADE POWDER



Element	Weight %
Mn K	1.20
Fe K	54.87
Co K	20.30
Ni K	22.09





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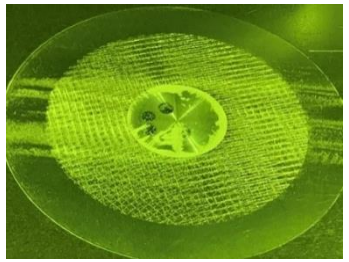
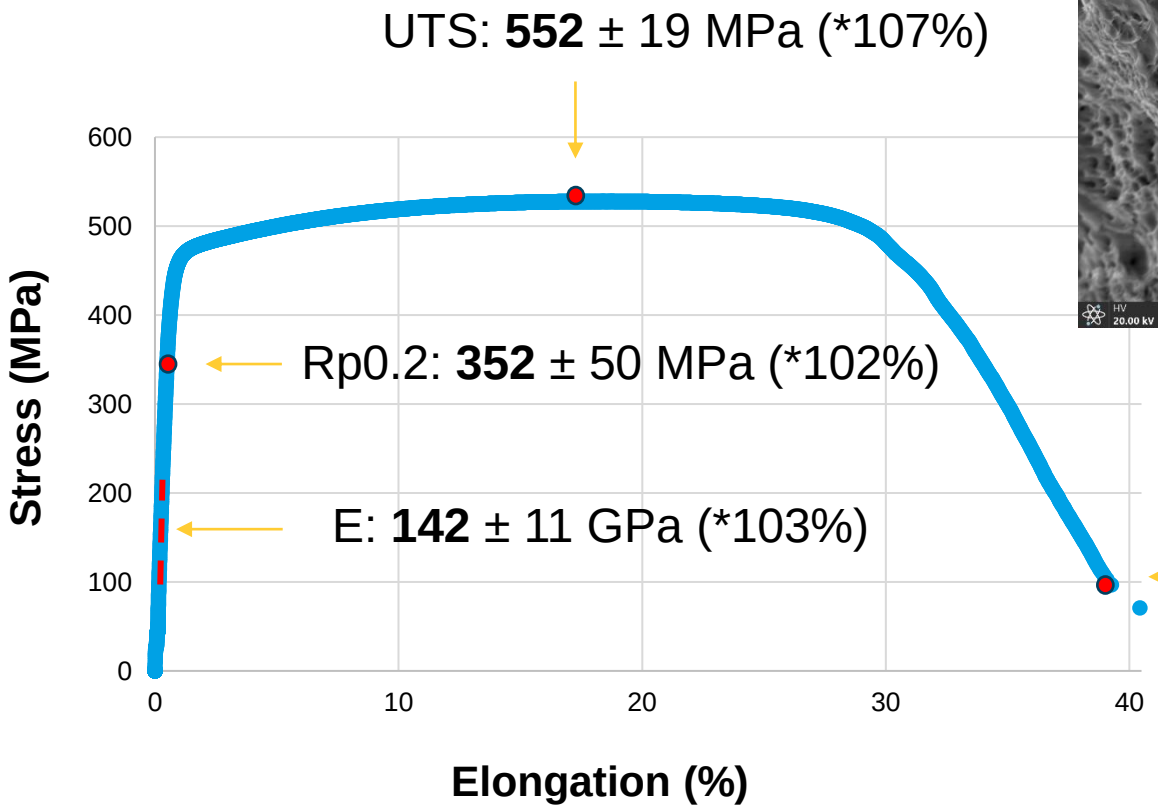
DEVELOPMENT OF PROCESS PARAMETERS



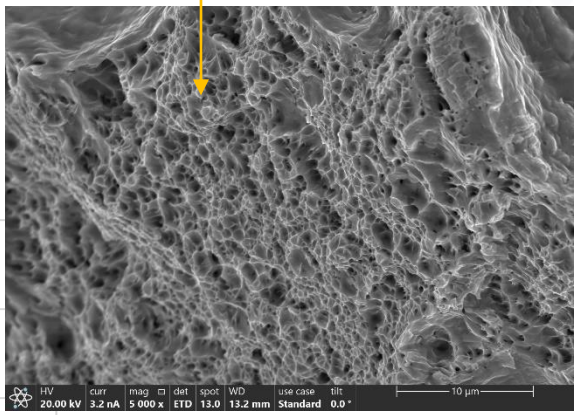
KOVAR

AlSi12

8130 kg/m3 (99.5% density)



Dimples → ductile



*Compared to Kovar strip tested parallel to the direction of rolling. Material annealed 999°C for 30 minutes, then furnace cooled.

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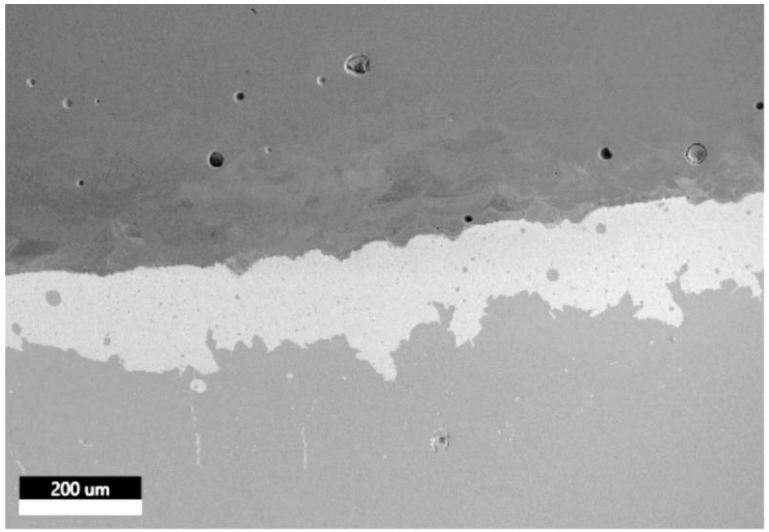
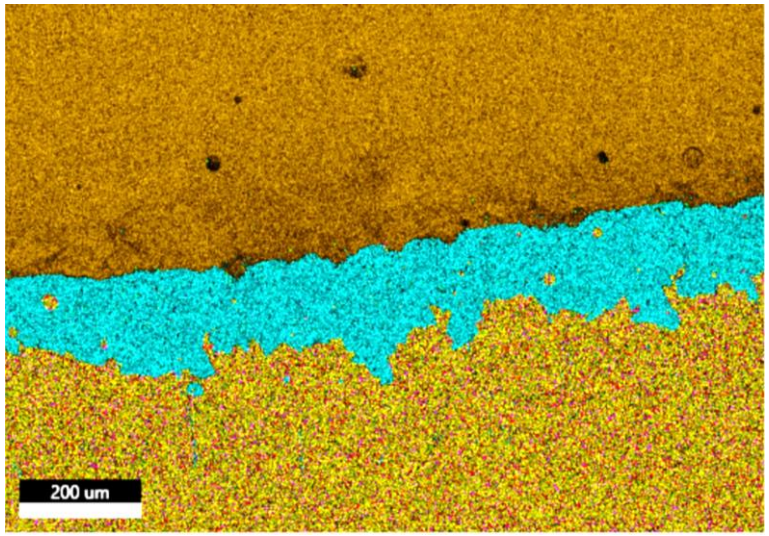
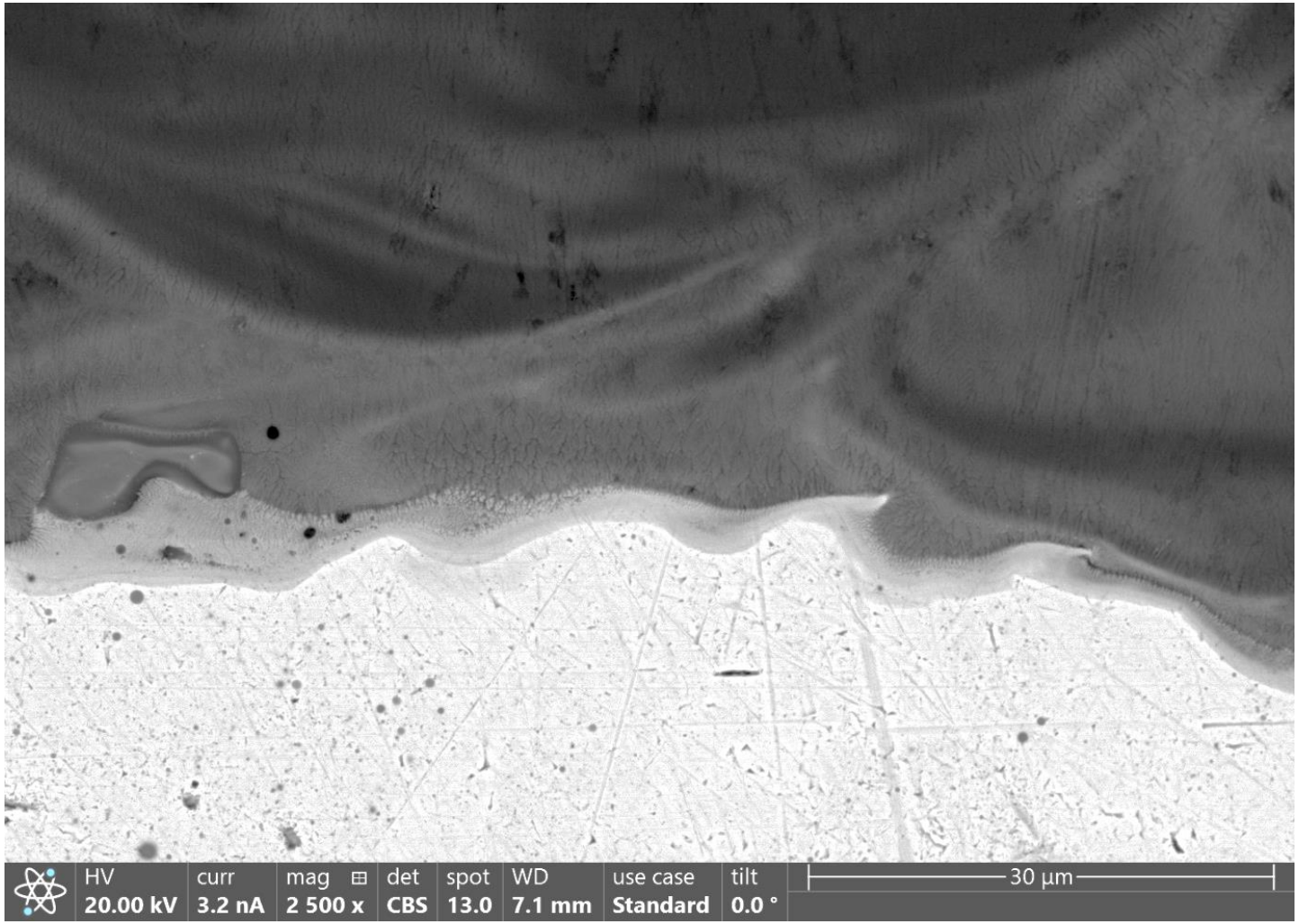
MULTIMATERIAL PRINTING: KOVAR - AG - AL

Printing direction





AlK
SiK
AgL
FeK
CoK
NiK



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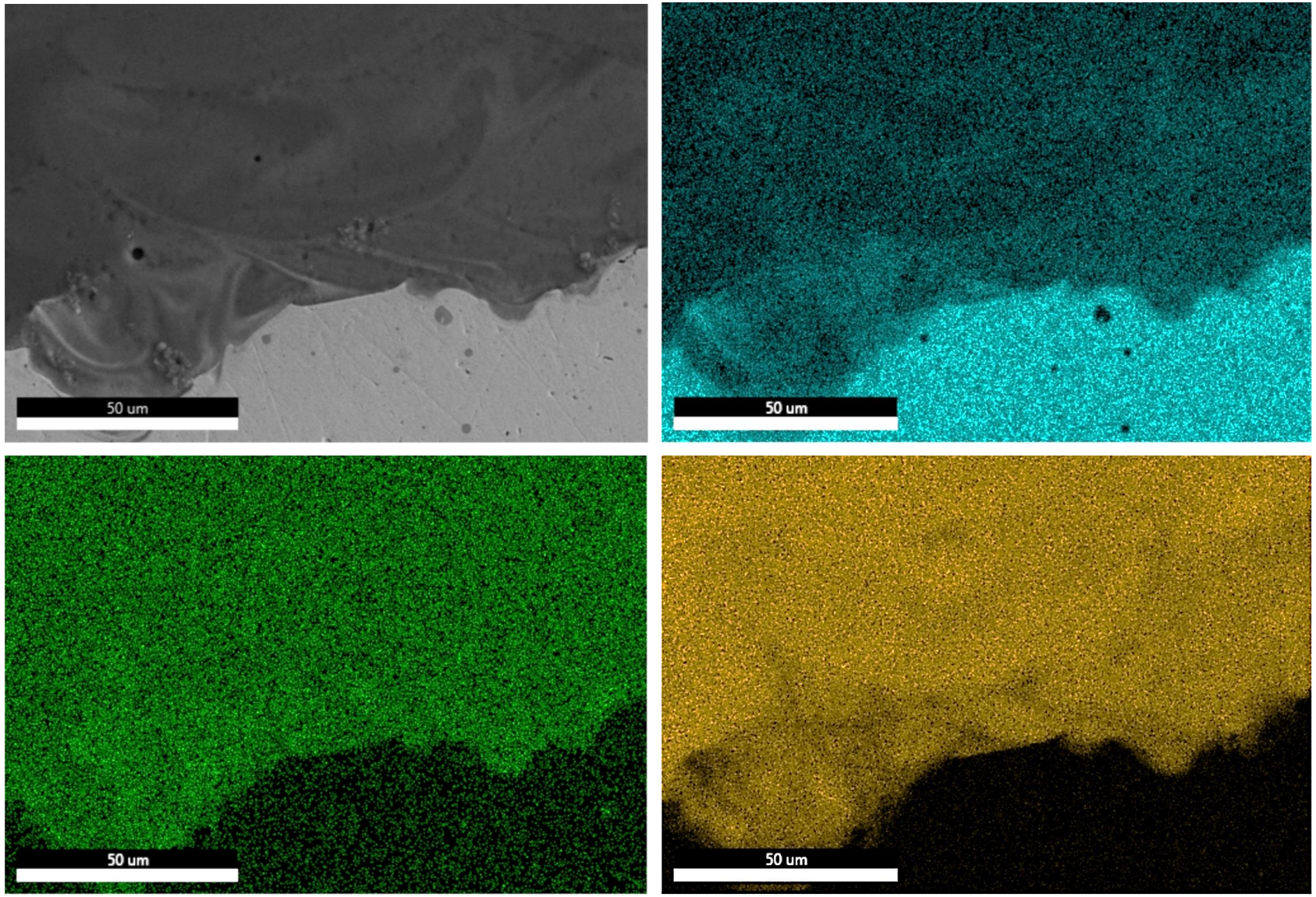
MULTIMATERIAL PRINTING: KOVAR - AG - AL

Printing direction



csem

PARTIAL CONCLUSION

KOVAR: Fe-29-Ni-17-Co

- ✓ **Phase 1**
  - ✓ Benchmarking for AM grade powder
  - ✓ Development of process parameters

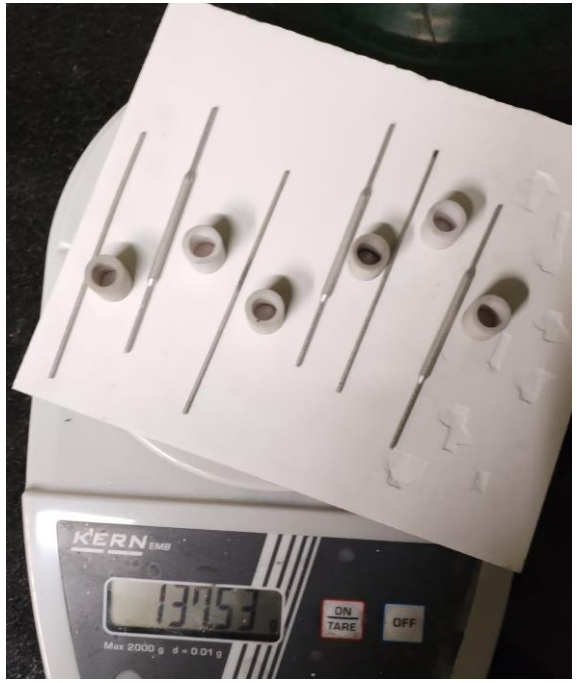
- ❑ **Phase 2**
  - ❑ Same investigation as Al-12-Si but on a limited number of samples
    - ✓ Joint feasibility between aluminium and kovar
    - ❑ Thermal cycling and adhesion tests

EXTRA: SINTERING

MetShape

Before

After



- Increase in length after sintering with the decrease in outer diameter
- Outer diameter was measured from the middle of the part

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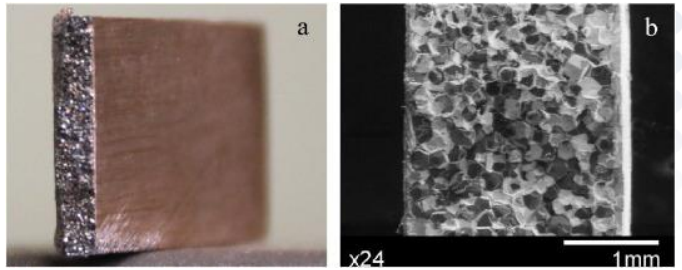
EXTRA: DYMALLOY PRINTING



Dymalloy characterisitcs

- High thermal conductivity (400-700 W/mK)
- Tunable CTE (close to silicon)
- High radiation lenght of diamond (combined with a metal of choice radiation lenght)

Incus main advantages:

- Solid state resin - high thermal conductivity of particles
  - Highly reduced supports structures
  - No particles precipitation

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