Karlsruhe Institute of Technology

IAM
Institute for Applied Materials

Adaption of metal injection molding to quinary high entropy alloys

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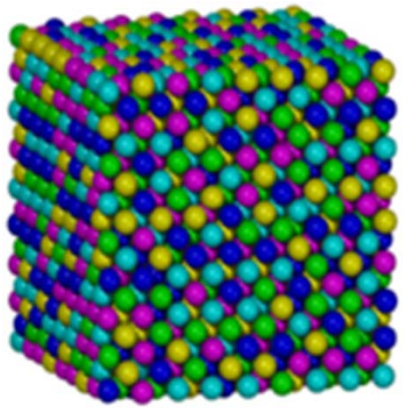
KIT- Institute for Applied Materials

1 cm



Motivation

Is it possible to produce High Entropy Alloy parts with Powder Injection Molding?

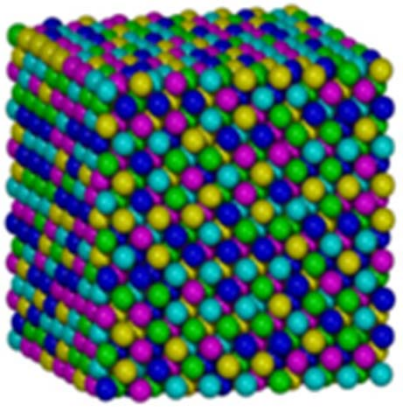
- Casting of HEA leads to heterogeneities (e.g. microstructure)
- Obtain parts with **high homogeneity & density** thus good mechanical properties
- Compare with:
  - Casting methods
  - Other PM processes

High-entropy alloys (HEA)

- High configurational entropy
- Lattice distorsion
- Sluggish diffusion
- Cocktail effect

possibility of new exceptional properties

- **CoCrFeMnNi[1]**
  - Single phase with fcc crystal structure
  - High strength & ductility
  - Application as structural material



CoCrFeMnNi[2]

[1]*Cantor et al., Mater. Sci. Eng., A 375 (2004)*
[2]*Wang et al., MDPI, Entropy 15 (2013)*

Powder injection molding (PIM)

- Big volume of parts & short time

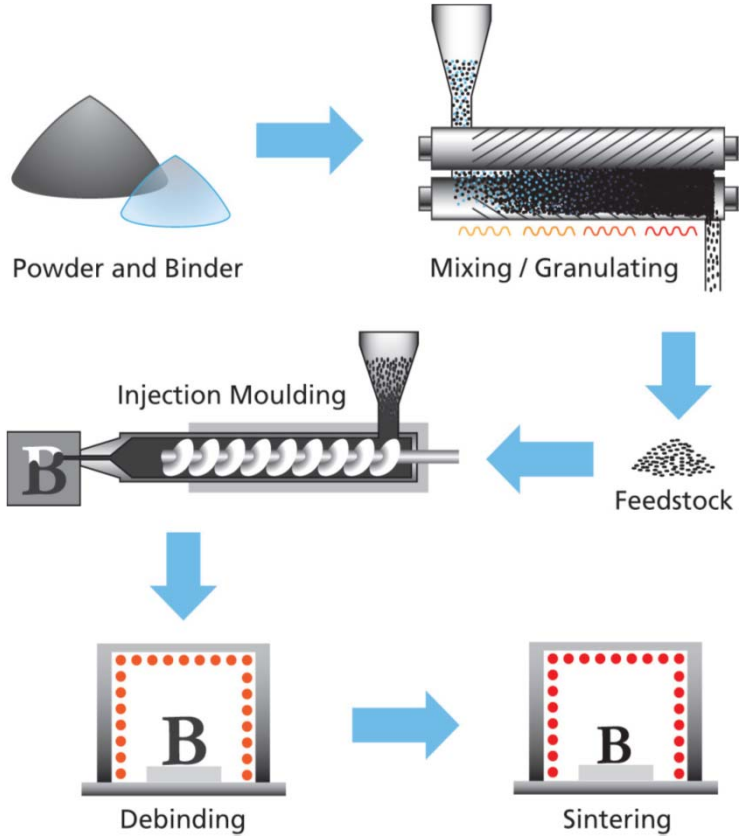
  = cost-efficient

- Complex geometry & near-net shape

  = reliable

- Less waste & energy consumption

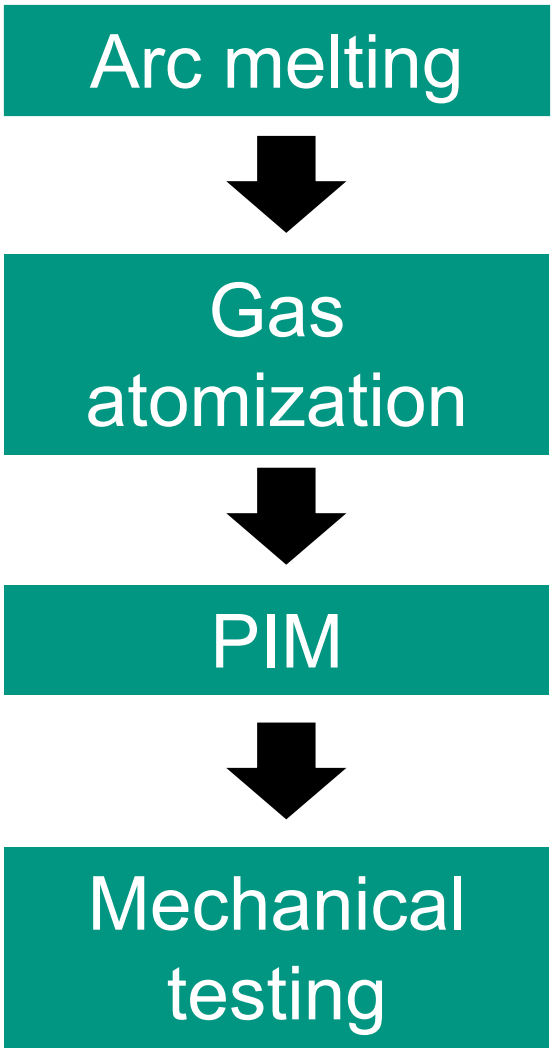
  = environmentally friendly



PIM process[1]

[1] *European Powder Metallurgy Association (2013)*

Content



Arc melting

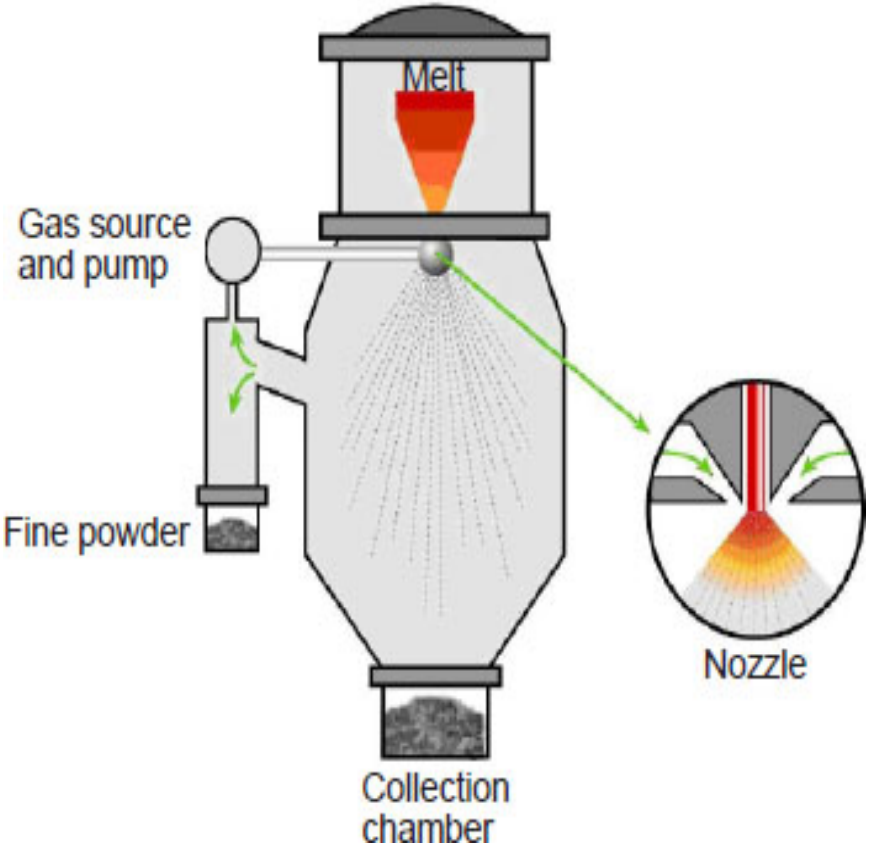
- 8 buttons produced
- Each button remelted and flipped 5 times for homogeneity and drop cast as a rod
- Need to compensate for Mn evaporation to get the nominal composition (20 at% of each element)

Arc melter AM/0.5[1]

At%	Co	Cr	Fe	Mn	Ni
ICP-OES[2]	20.4	19.7	20.3	19.2	20.4

[1] *Edmund Bühler GmbH*
[2] *Courtesy of Dr. T. Bergfeldt, KIT*

Gas atomization



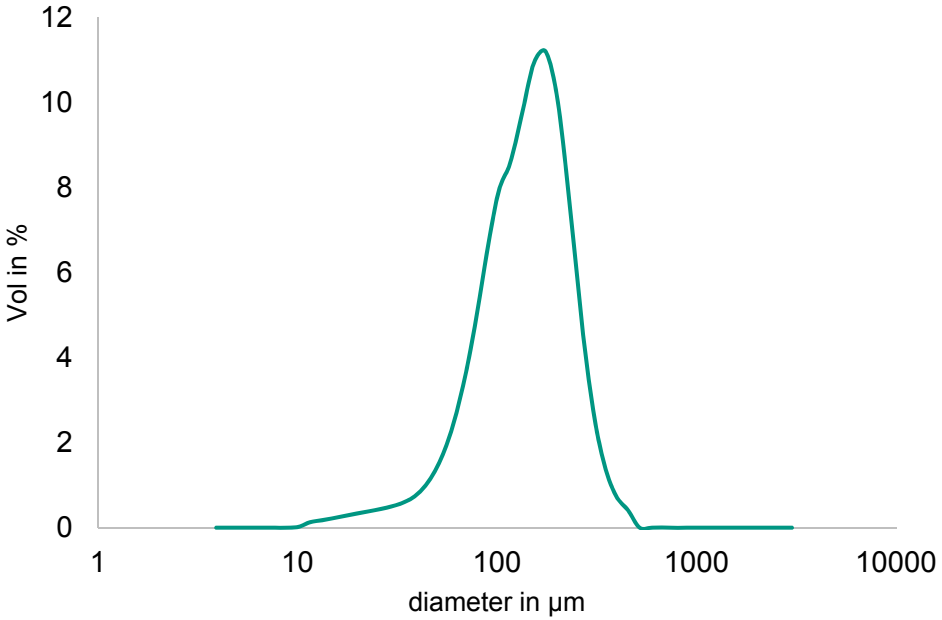
Gas atomization principle[1]

CoCrFeMnNi rods in a crucible of a vacuum induction furnace

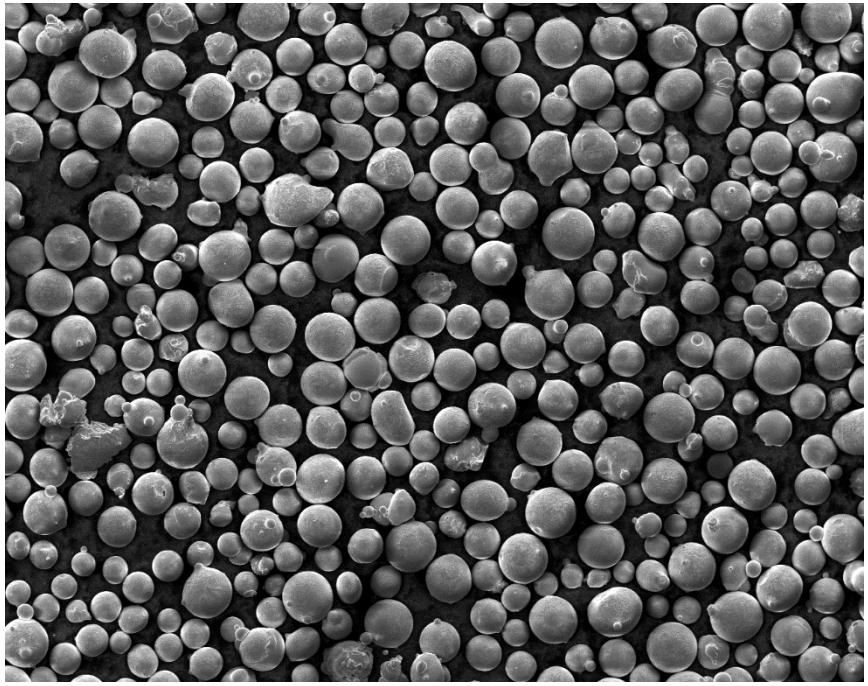
[1]*Courtesy of PW Technology*

Gas atomization

Particle size distribution of the big receiver



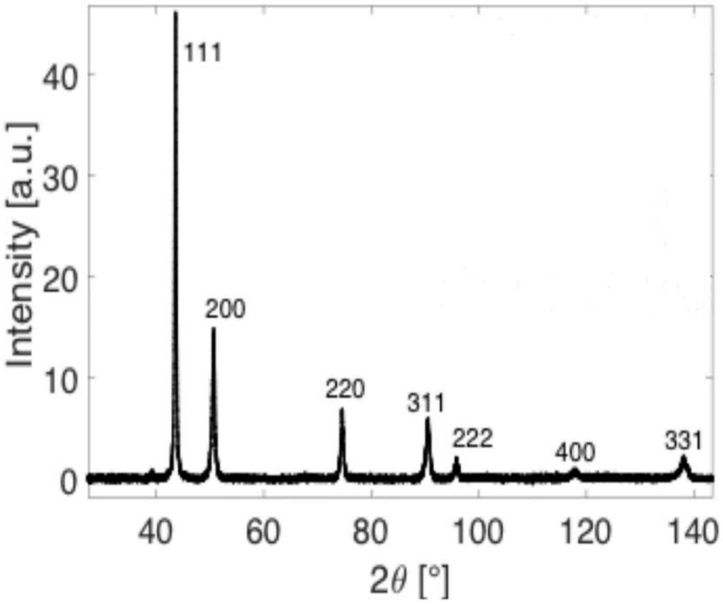
CoCrFeMnNi powder



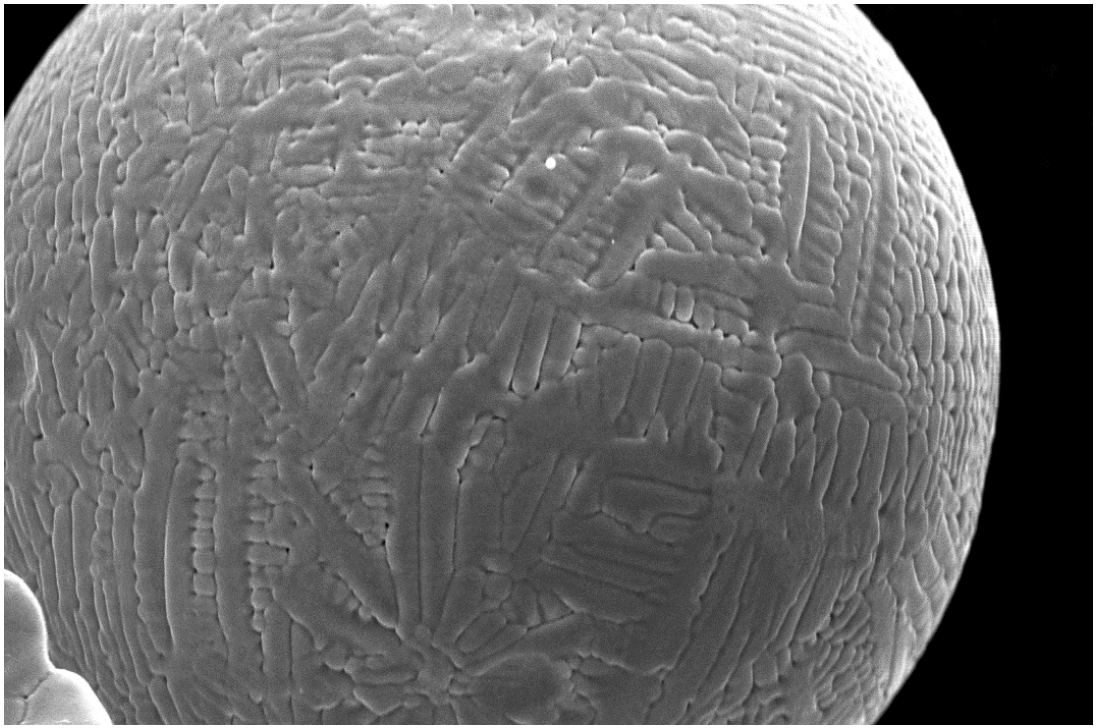
118 µm (~ **90 vol%**)

Sieving < 80, <50, <32 µm

Gas atomization



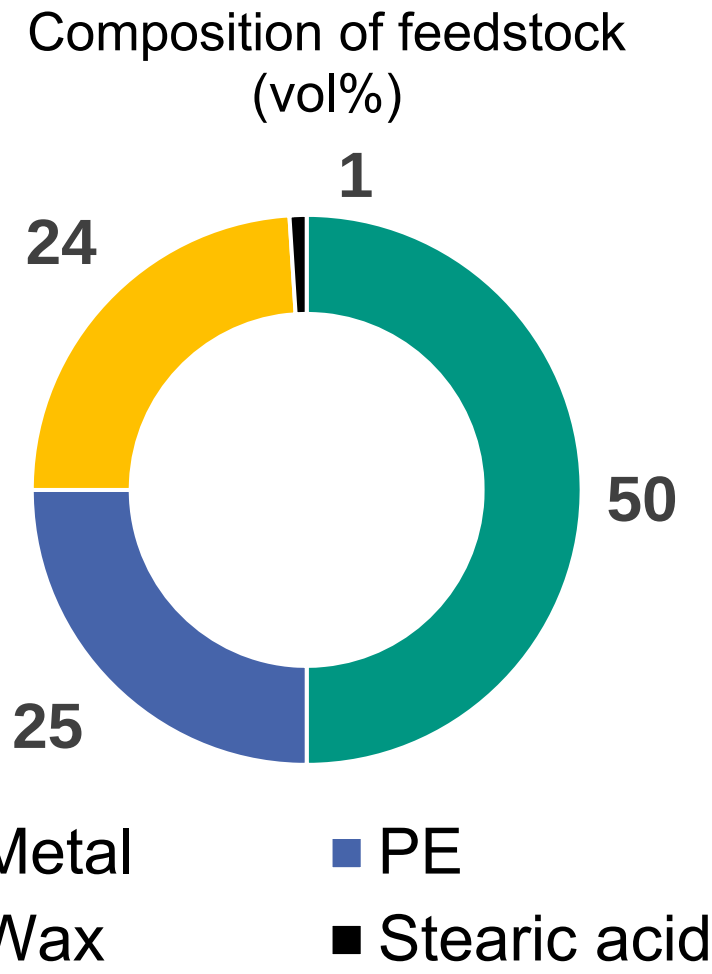
CoCrFeMnNi powder



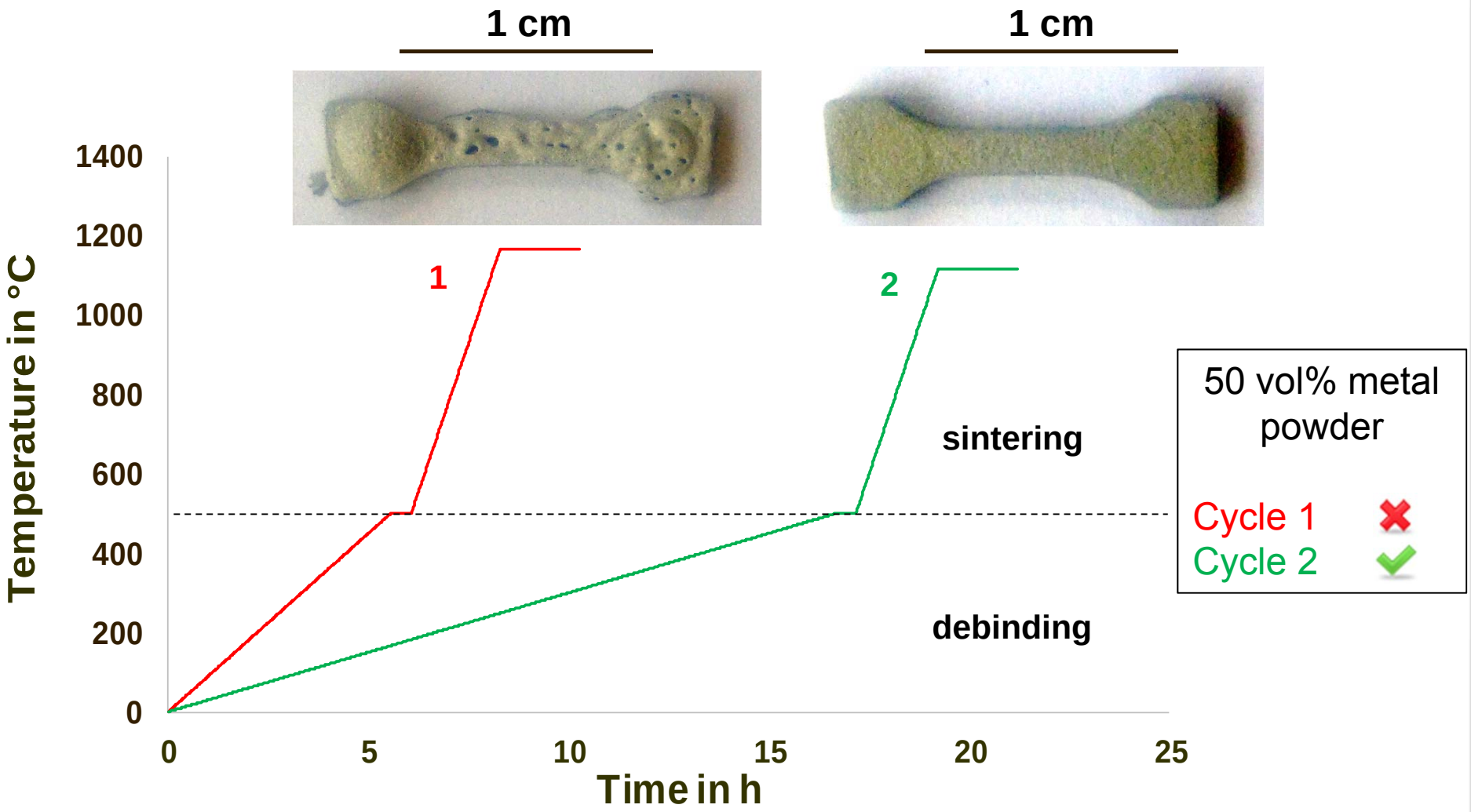
- Single fcc phase
- Spherical particles
- Dendritic microstructure

Feedstock development

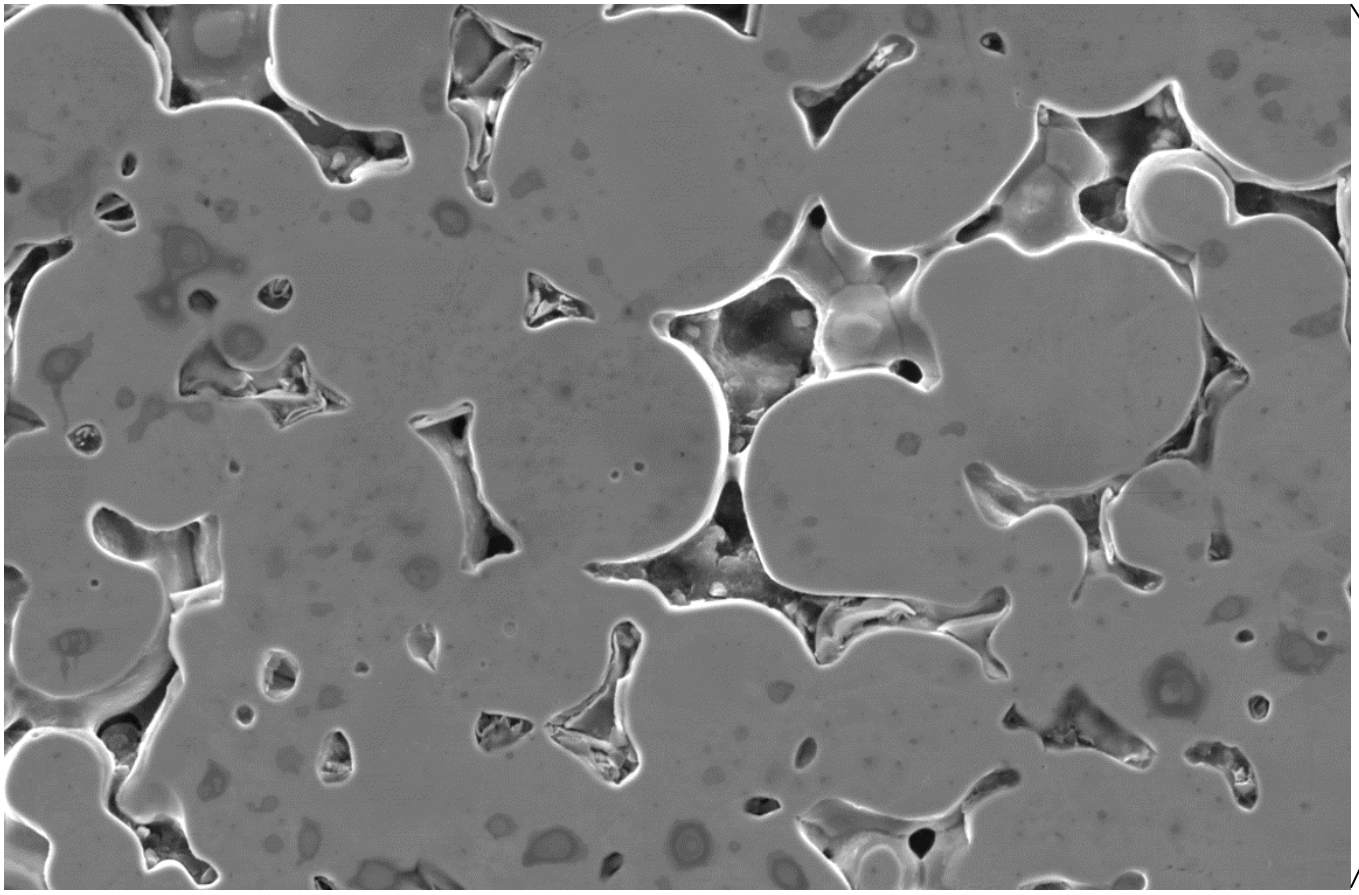
- CoCrFeMnNi metal powder: 50 < x < 80 µm
- Trials with different amounts of metal powder
  - 63 vol%
  - **50 vol%**

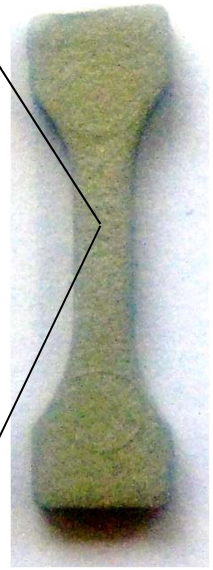


Debinding and sintering



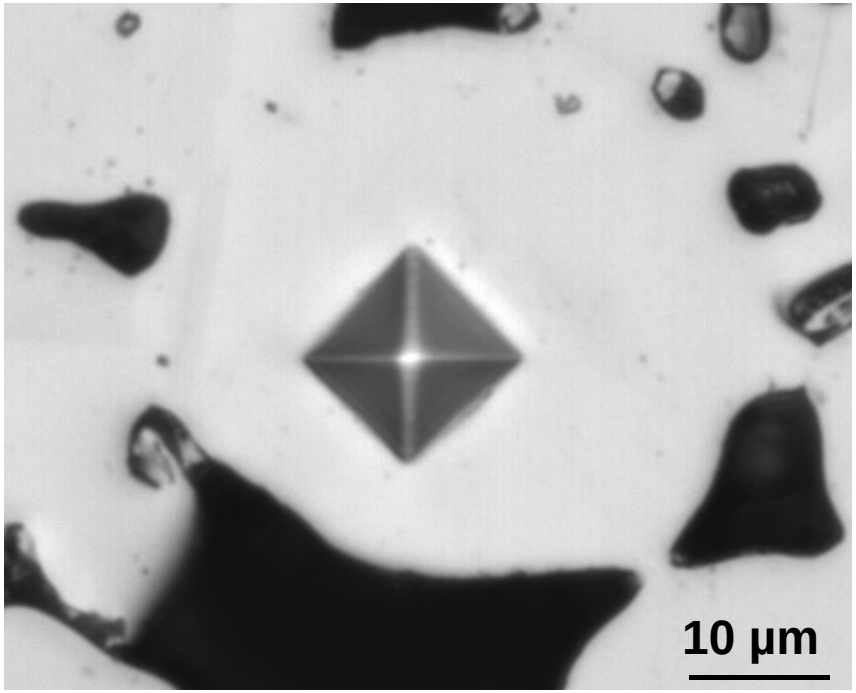
Microstructure of PIM sample





Close porosity ≈ 5%
Open porosity > 30%

Mechanical tests



	PIM	MA[1]	Cast[2]
Hardness (HV)	**140**	**145**	**160**
Standard deviation (HV)	20	3	15
Load (g)	10	50	10

- No cracks observed
- Ductile deformation

[1] *Irving et al., JOM vol 35, No 12 (2013)*
[2] *Schuh et al., Acta Mater. 96 (2015)*

Conclusion

- It is possible to produce parts made out of HEA with PIM
- Powder particles have good homogeneity
- Residual porosity by PIM
- Low hardness & ductile behavior

Outlooks

- **Gas atomization**

  Increase the yield of small particles by adjusting the parameters (e.g. atmosphere)

- **Feedstock production**

  Find the right ratio metal/binder

  Find an appropriate debinding procedure

- **Mechanical tests**

  Tensile and compression tests (room and high T)

Thank you for your attention

pim-international.com