Karlsruhe Institute of Technology

Institute for Applied Materials

New Materials and Applications for Micro Powder Injection Molding

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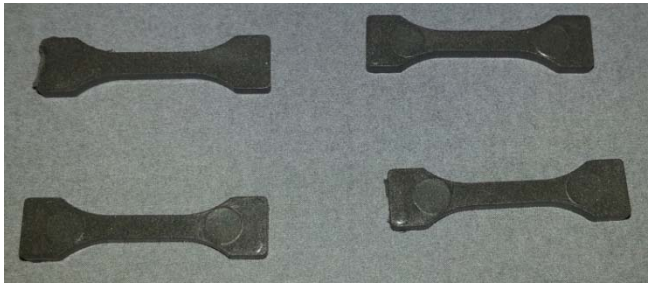
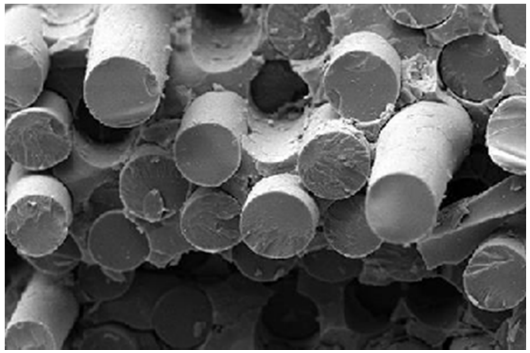
KIT - Institute for Applied Materials (IAM – WK)





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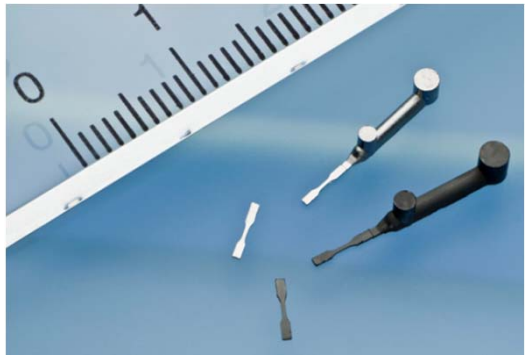

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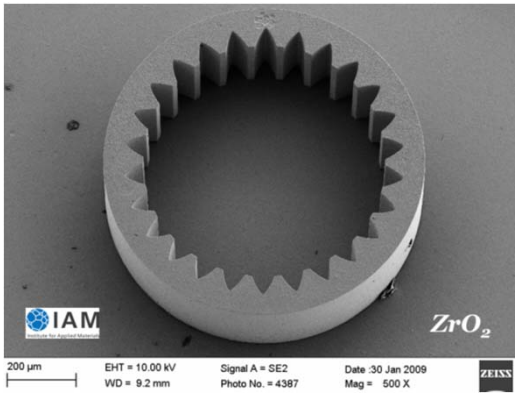
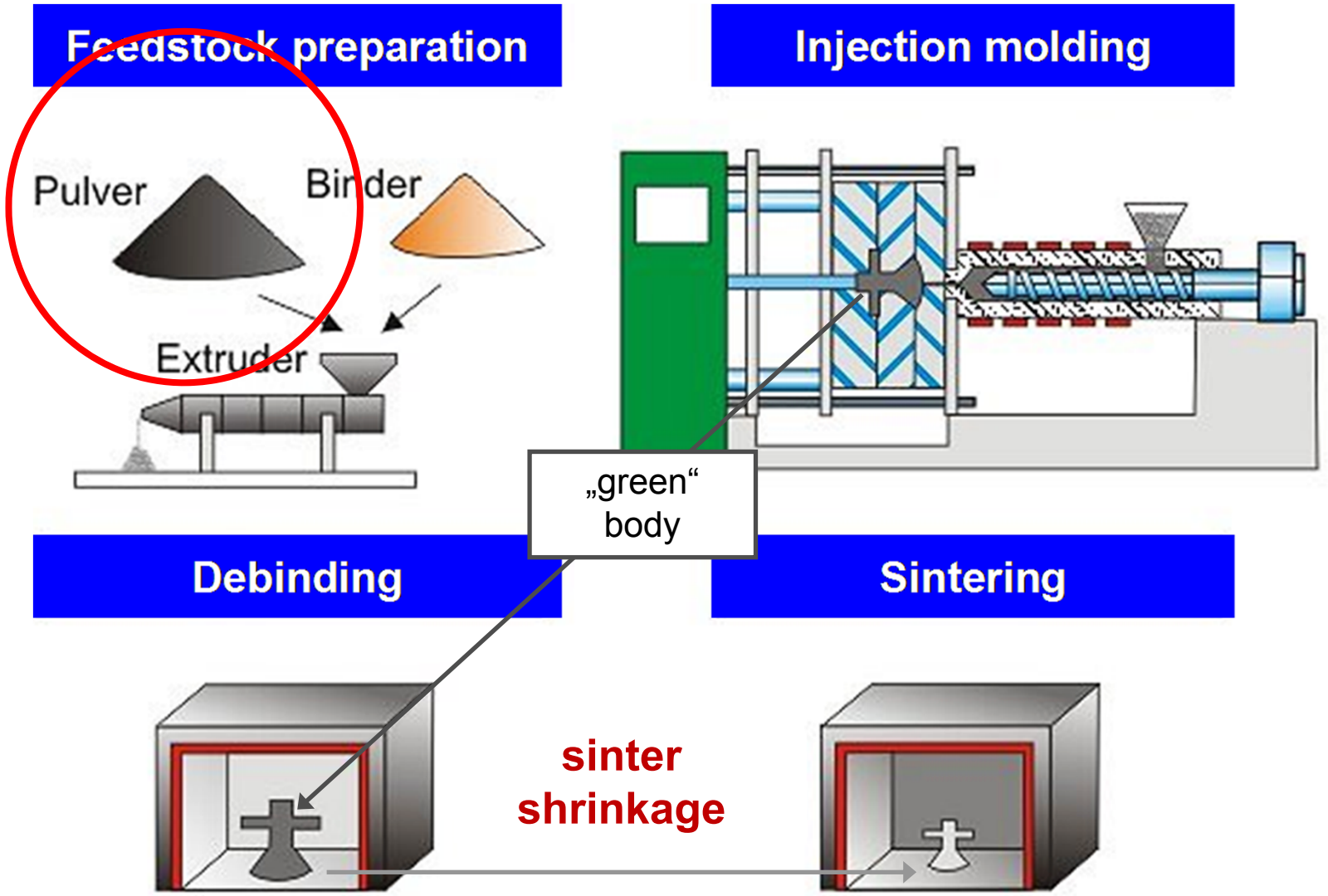


Powder Injection Molding (PIM)



New Materials for MicroPIM - HEA

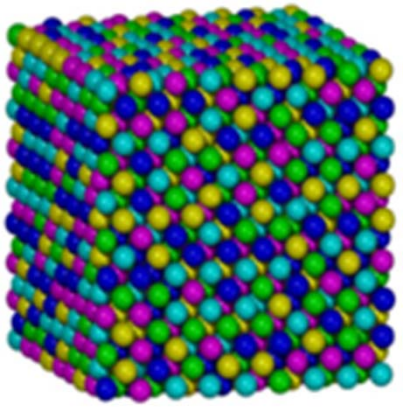
High Entropy Alloys

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

Possibility of exceptional properties

$Co_{20}Cr_{20}Fe_{20}Mn_{20}Ni_{20}$[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)*

Arc melting

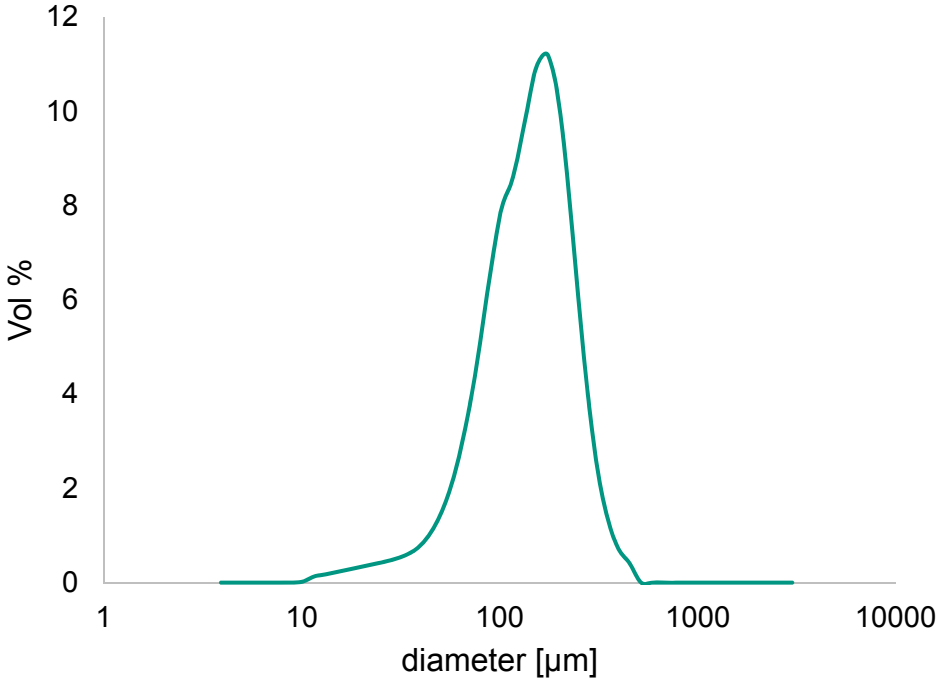
Gas atomization

MicroPIM

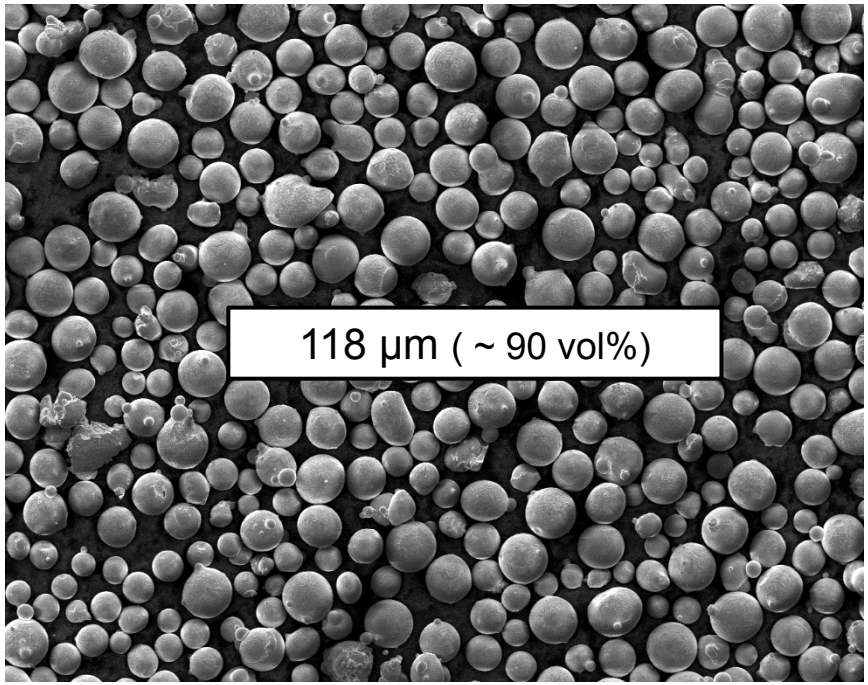
Investigations

Powder Characterization

Particle size distribution



CoCrFeMnNi powder

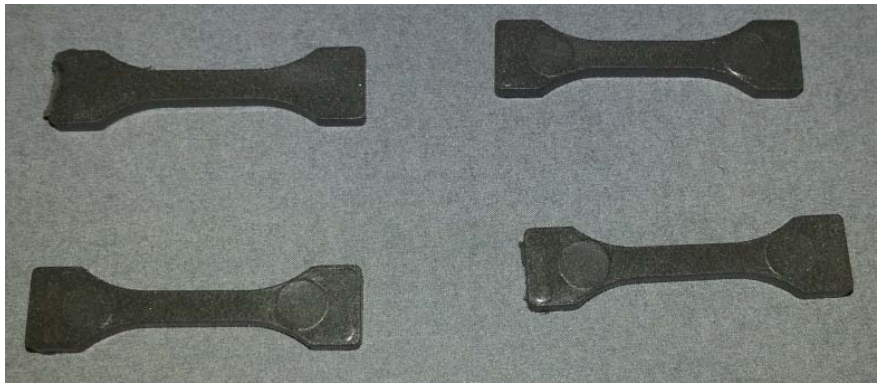


Rough powder → low sintering activity

Good homogenity

Powder Injection Molding of HEA

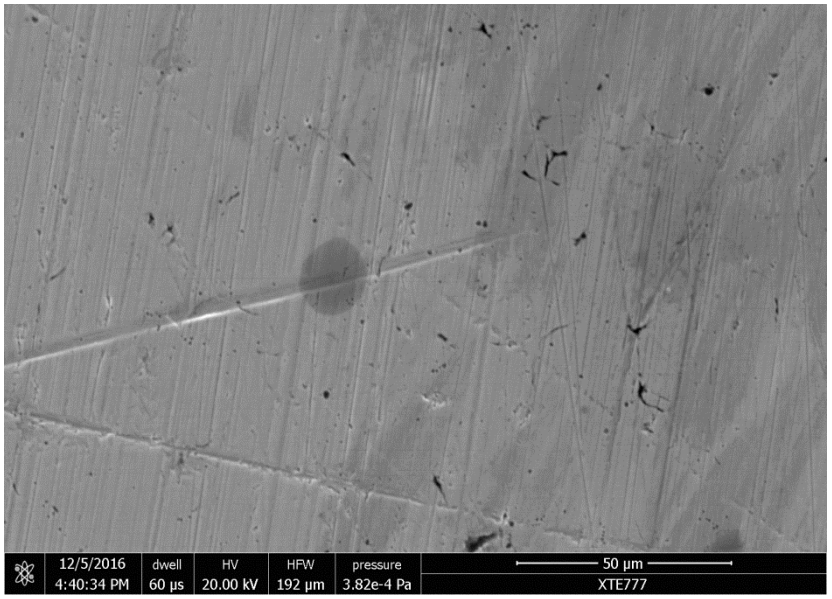
Feedstock:
50 vol% metal powder



1 cm

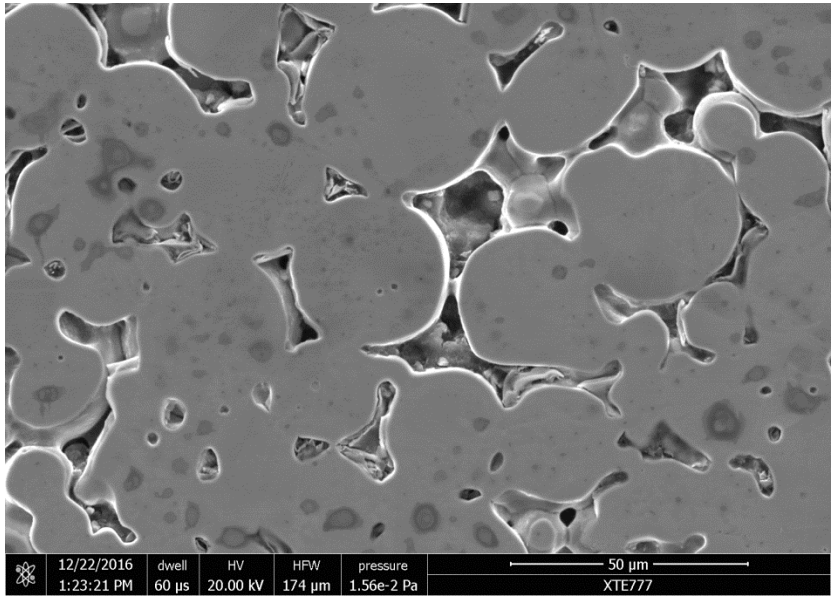
sintered body

Sintered HEA-samples



up to 96% of theor. density

porosity ≥ 35%



New Materials for MicroPIM - CMC

Ceramic Injection Molding (CIM) well established in industrial manufacturing

As further improvement oxide fibers might be embedded into the ceramic matrix

=> **increased mechanical properties** especially at **elevated temperatures**

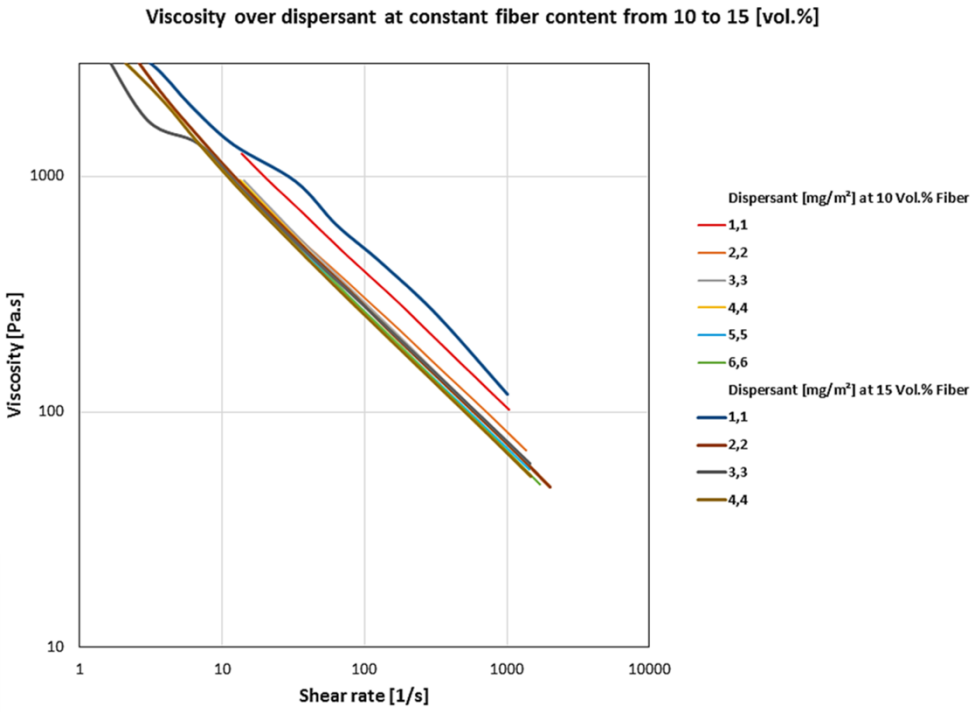
Objectives

- Development of feedstocks containing up to 50Vol% powders + fibers
- Specialities of injection molding process for CMC
- Investigation of samples in green + sintered state

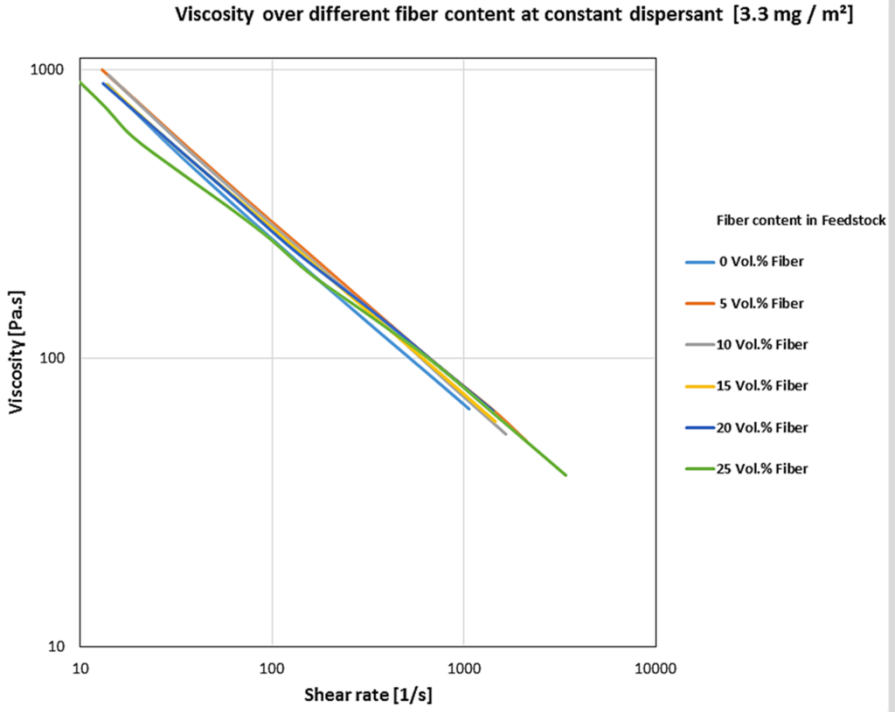
Materials

- Chopped Al_2O_3 fibers (Nextel 610)
- Al_2O_3 powder (TM-DAR), D50 ≤ 200nm
- Binder: Polyethylen, paraffin wax, stearic acid, dispersants

Investigation of Feedstocks



Viscosity vs dispersant concentration. Best flowability could be reached with dispersant concentrations > 2.2 mg/m²

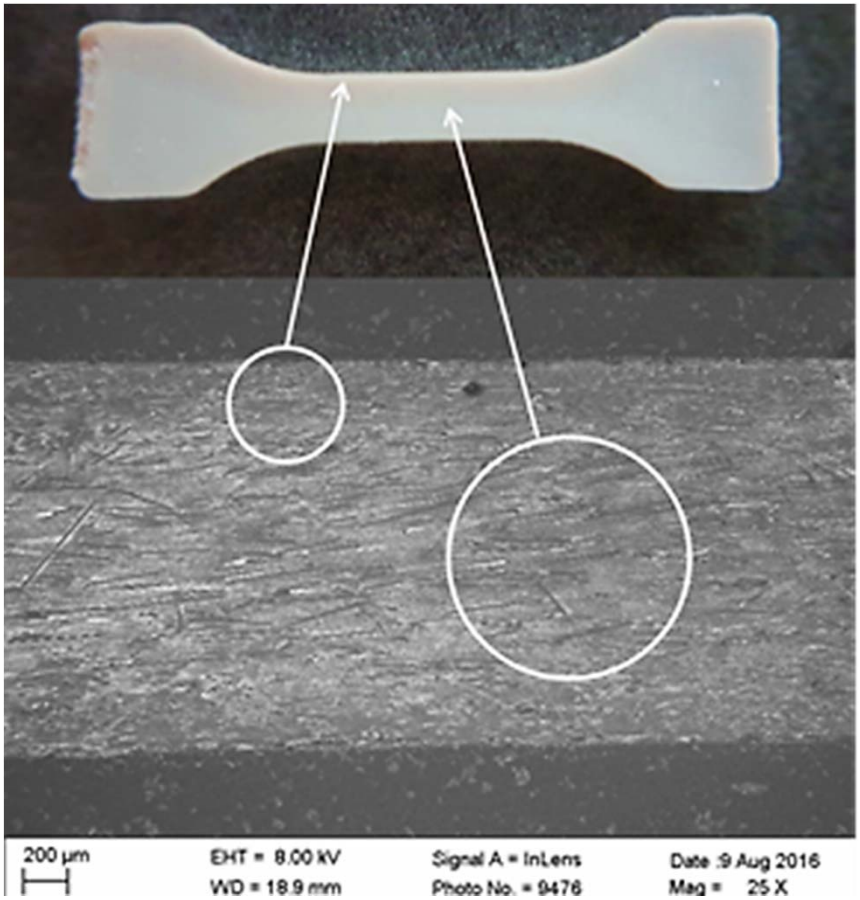


Viscosity vs fiber content. Flowability depends less strongly on fiber content as expected

Investigation of CMC-samples

Tensile specimen made of CMC feedstock (green body)

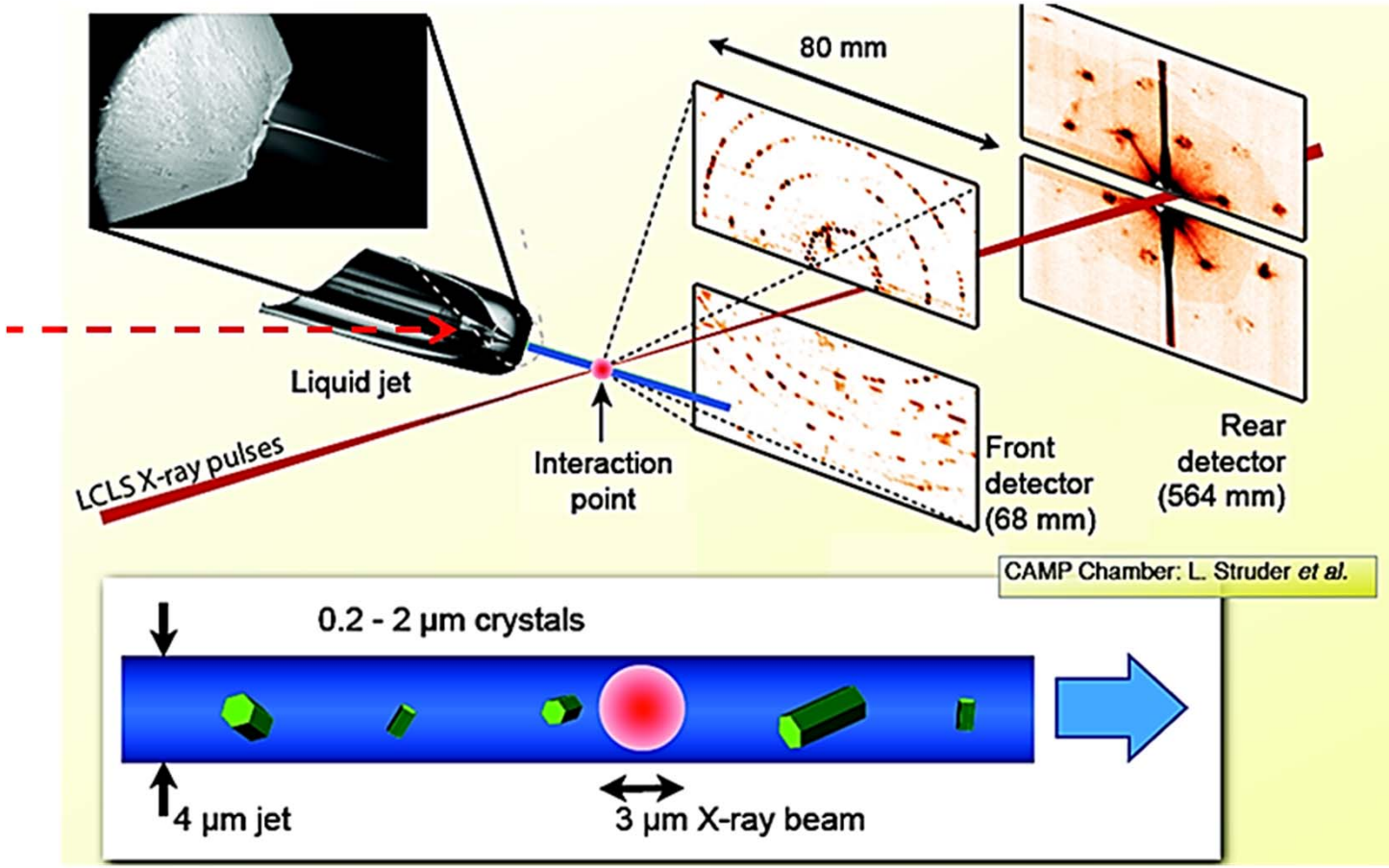
SEM picture of the same sample showing the high degree of fibre orientation near to the surface (high shear area) and a less degree of orientation in the bulk, i.e. in the low shear area



Precision Ceramic Capillaries

Liquid Jet Nozzles for European X-ray Free Electron Laser

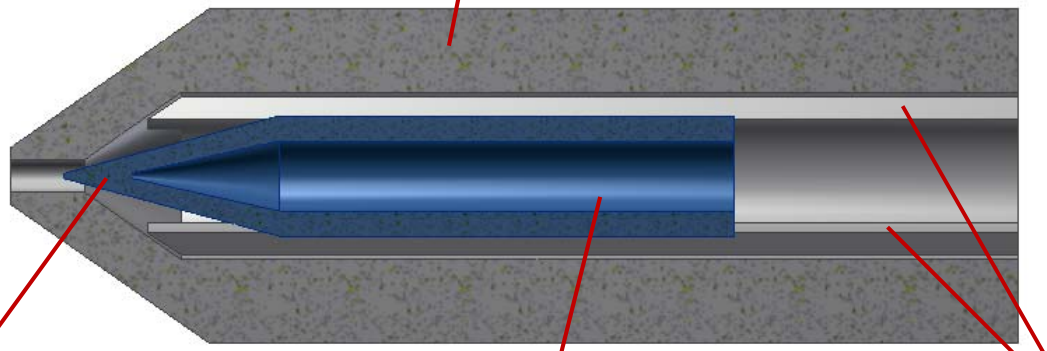
Collaborative project between DESY-CFEL and KIT-IAM

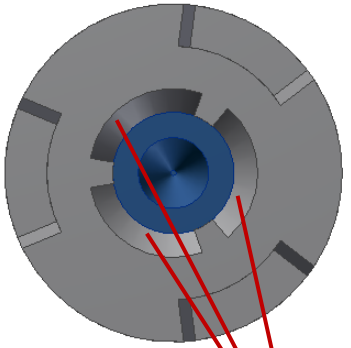


Current Design

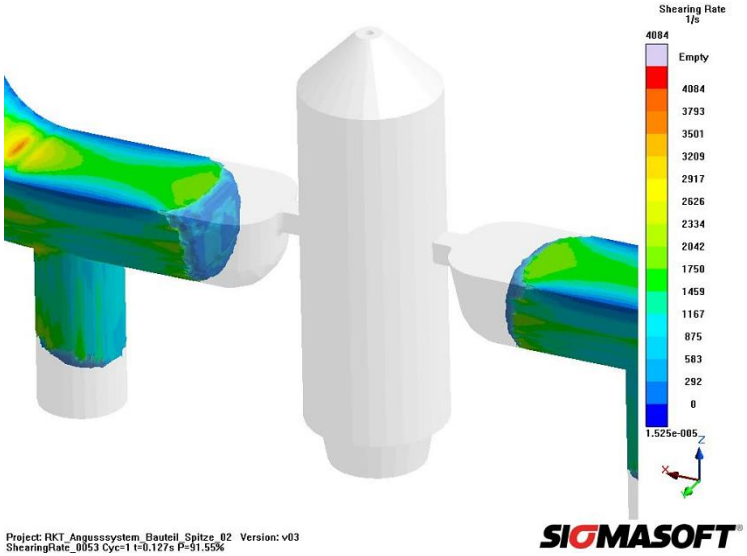
outer-Ø = 1,56 mm
inner-Ø = 0,8 mm

isometric view





Simulation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1/s
4084
Empty
4084
3793
3501
3209
2917
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2334
2042
1750
1459
1167
875
583
292
0
1.525e-005
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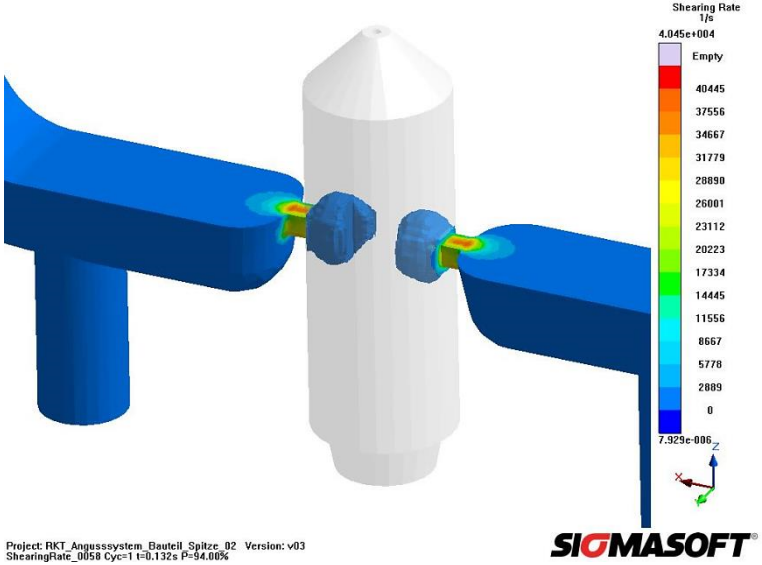
SIGMASOFT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Empty
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11556
8667
5778
2889
0
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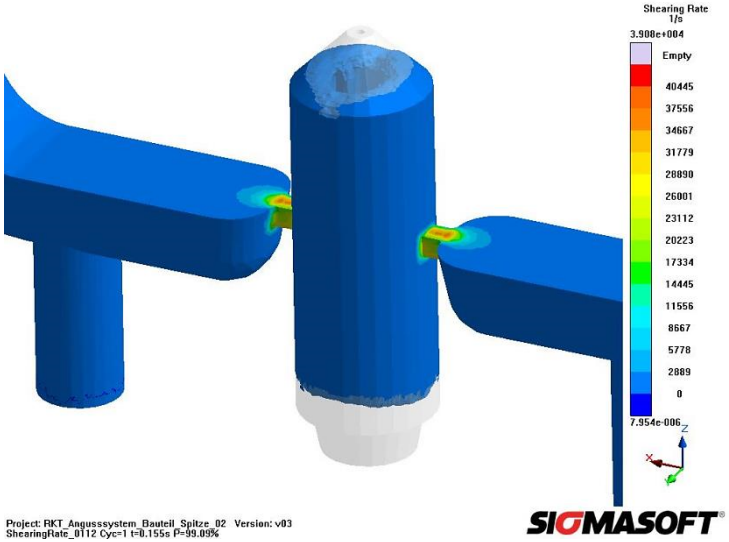
SIGMASOFT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1/s
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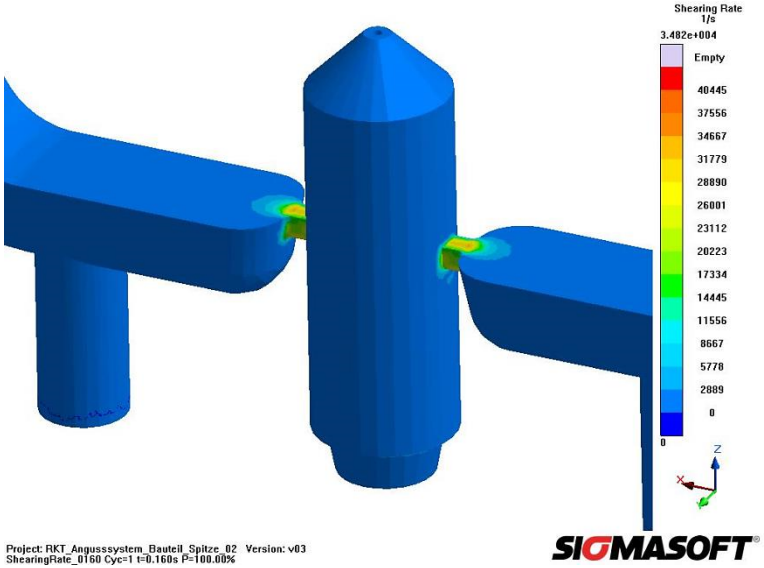
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Empty
40445
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34667
31779
28890
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11556
8667
5778
2889
0
0
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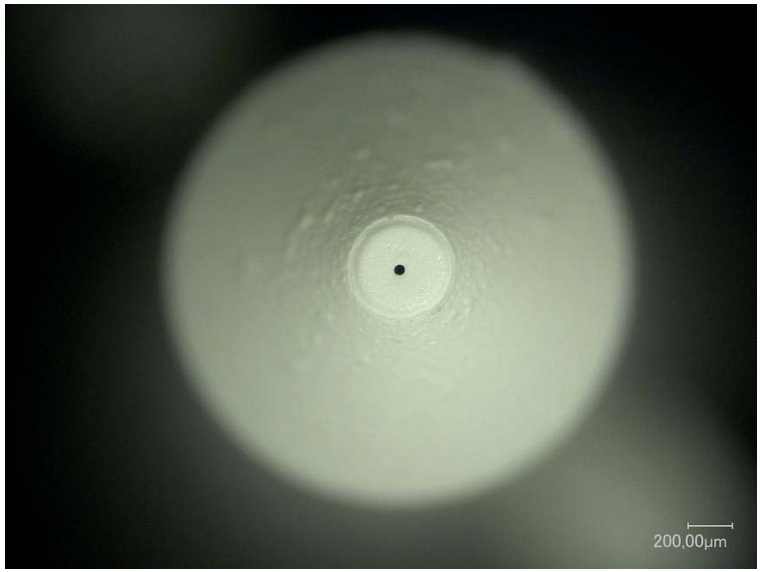
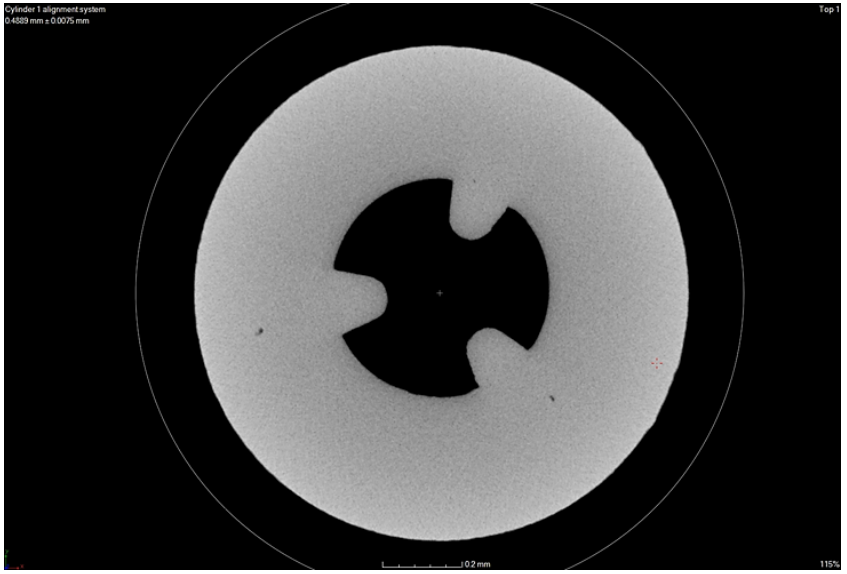
SIGMASOFT

First Results



Front view of ceramic capillary
Ø = 40 µm



CT cross section image
with internal guide bars

Current precision of CIM parts: ± 0.3%

Might be much better for particular dimensions

Outlook

HEA-PIM

- improve gas atomization for finer powders
- investigate microstructure and mechanical properties

CMC-PIM

- improve densification process
- measure mechanical properties

Ceramic Nozzles

- functionality tests

Acknowledgment

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- Fraunhofer Institutes IKTS and IFAM
- Boysen Foundation
- All colleagues at KIT

Thank you !