Karlsruhe Institute of Technology

Process development for the powder injection molding of short fiber reinforced ceramic-matrix-composites

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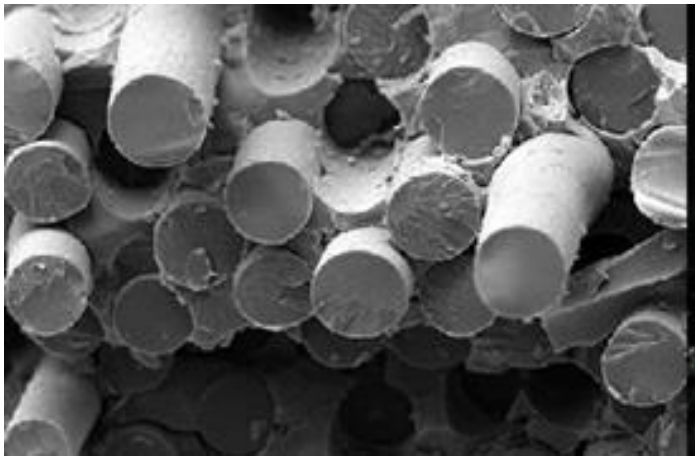
Group Processing



Content

- Motivation
- Objective
- Processing
- Results
- Discussion

Motivation

Conventional oxide Ceramics
(monolithic)

- Excellent high temperature and corrosion resistance
- High stiffness (mechanical stability)
- Low creep rate

- **Low fracture toughness (brittle)**

+

Ceramic Fibers
(chopped Nextel 610 Alumina Fibers)

- **High strength & stiffness**
- **Sensitive to creep & grain growth**

- **Fibers proved capable of increasing the resistance to cracks and ductility, breakage strength**

Ceramic Injection Molding

- Near-Net-Shaping
- Automation

Ceramic Matrix Composites (CMCs)

- All positive properties of conventional ceramics remain the same
- Precise parts can be produced fast & automated in large amounts
- **Ceramic composite parts with increased fracture toughness**

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Objective

Development of a process chain (including feedstock development) for the injection molding of short fiber reinforced ceramic oxide-oxide composites with increased fracture toughness and acceptable strength compared to non-reinforced ceramic feedstocks.

Following points will be considered in this project:

- Feedstock homogeneity
- Flow behavior
- Fiber orientation
- Error-free debinding process
- Microstructure of the fibers at sintering

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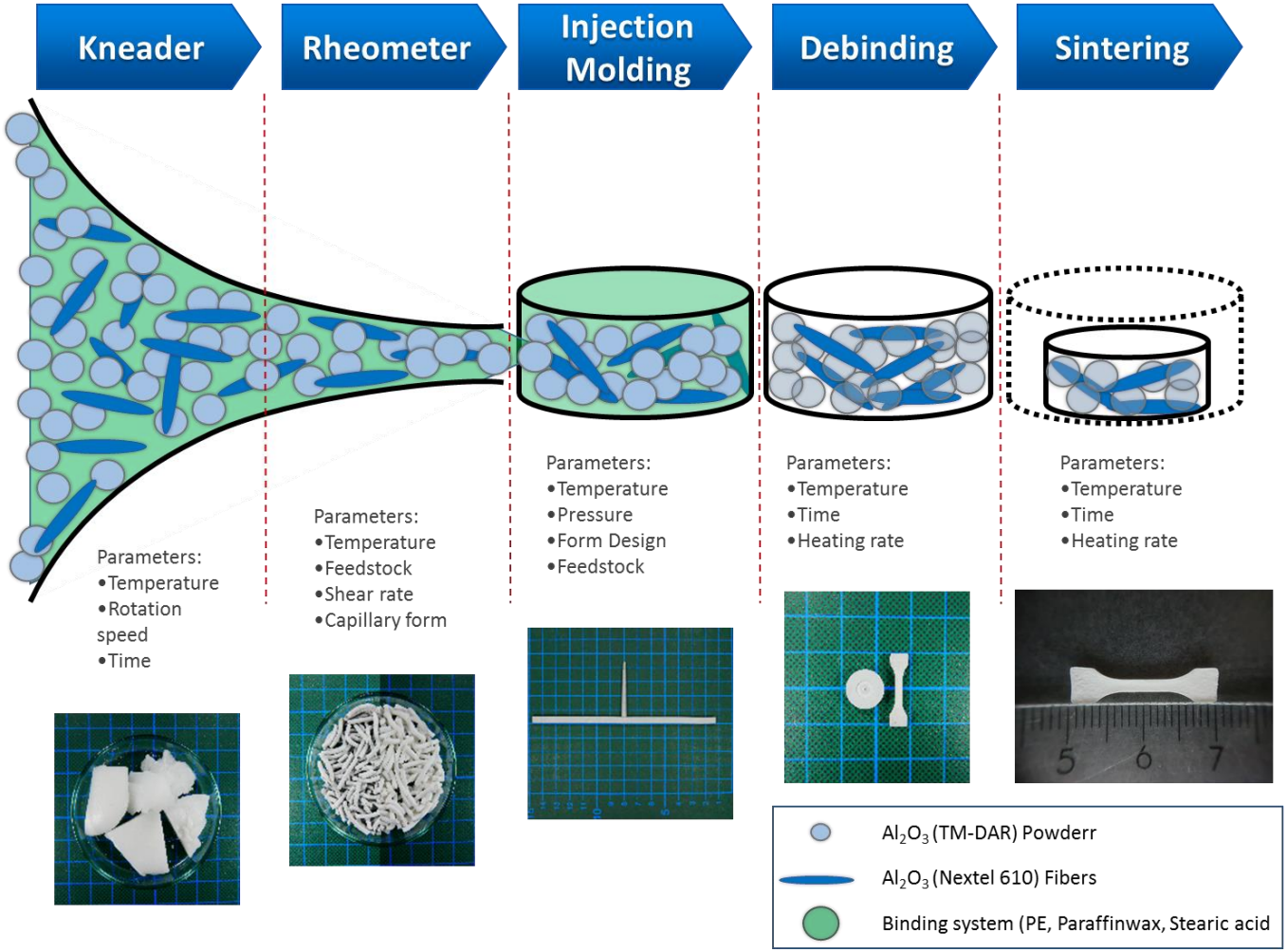
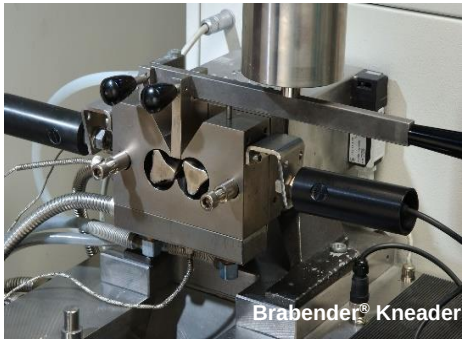
Prozessablauf




Brabender® Kneader


Göttfert® Rheograph25


Battenfeld® Microsystem

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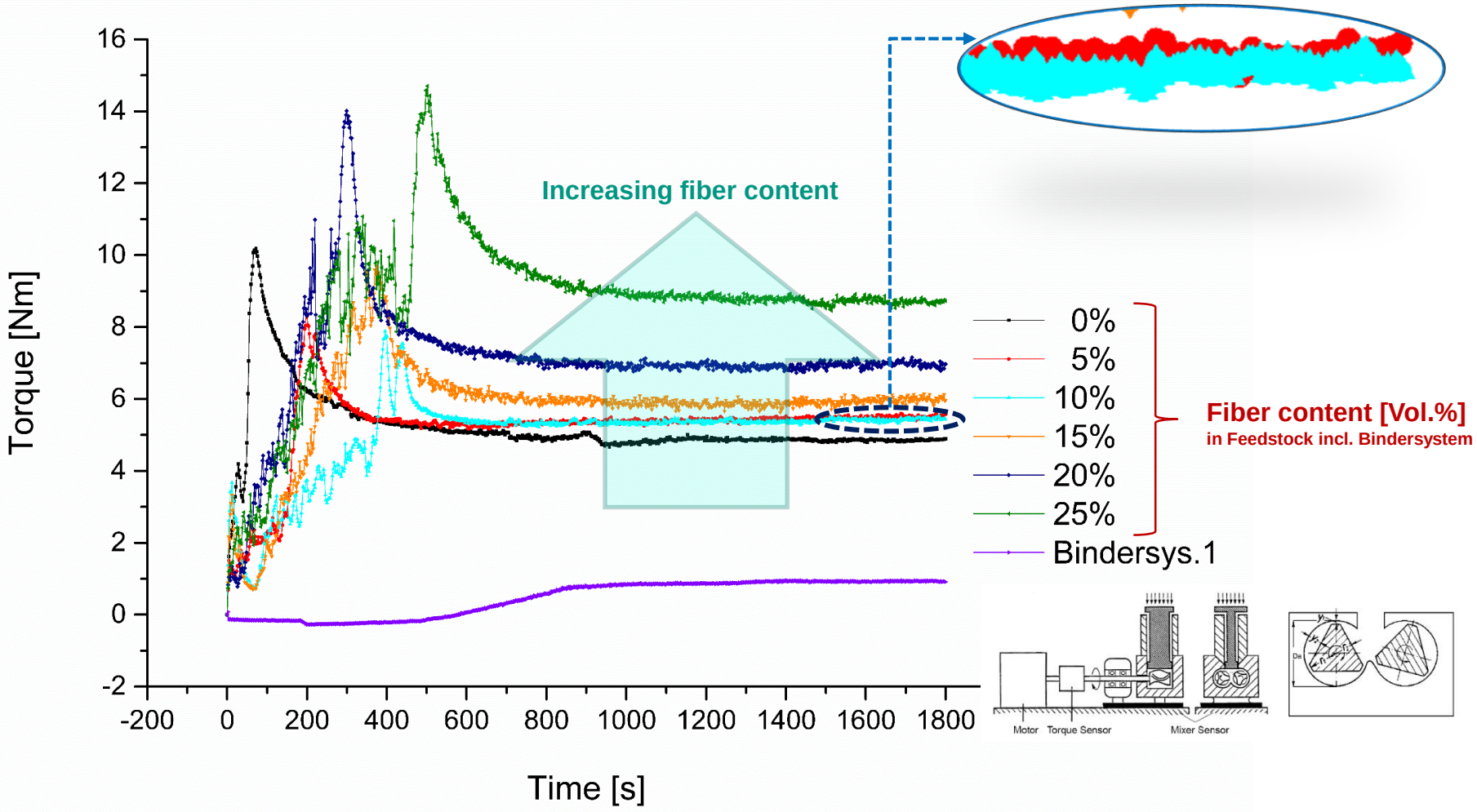
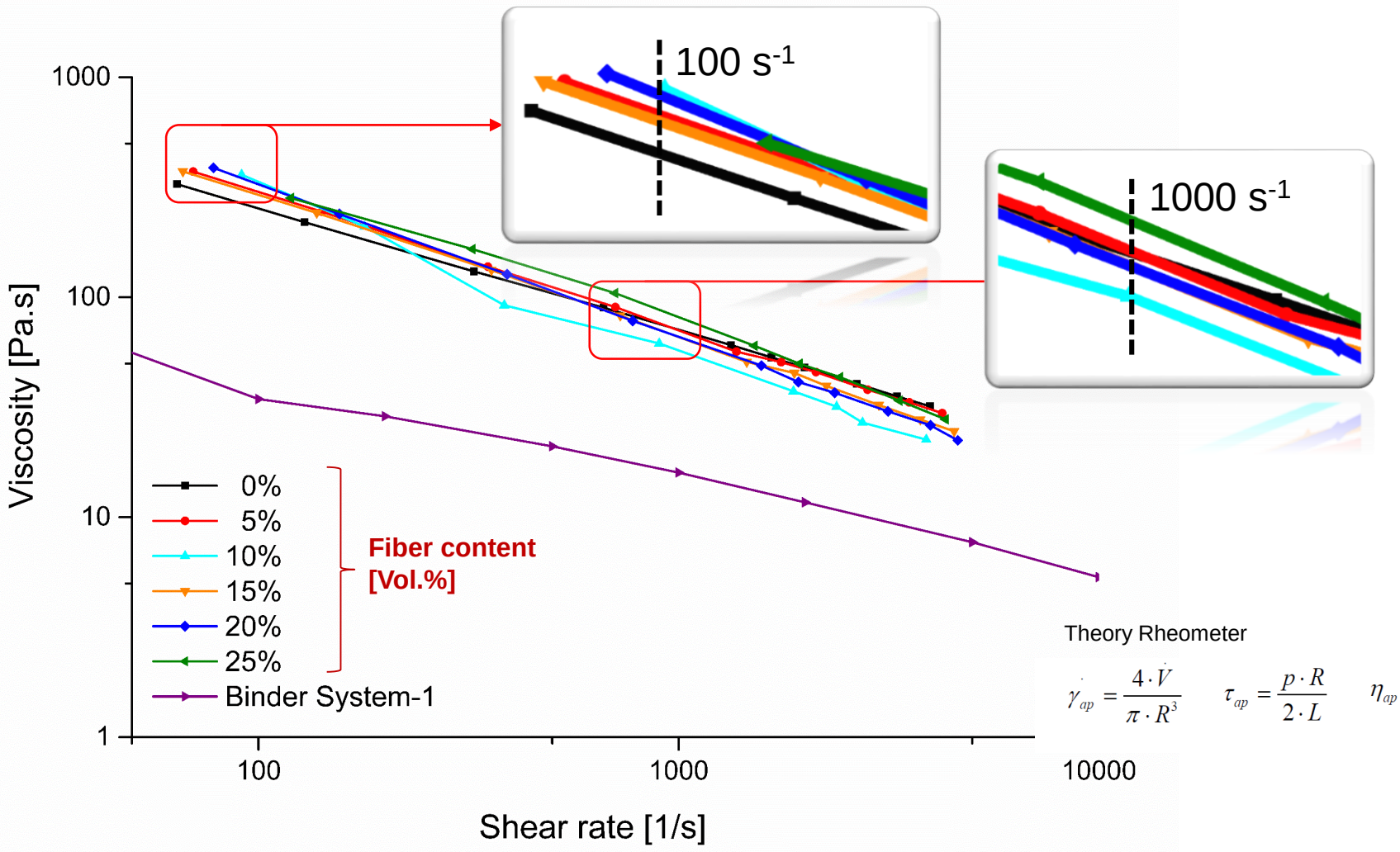
Results: Kneader



Results: Rheometer

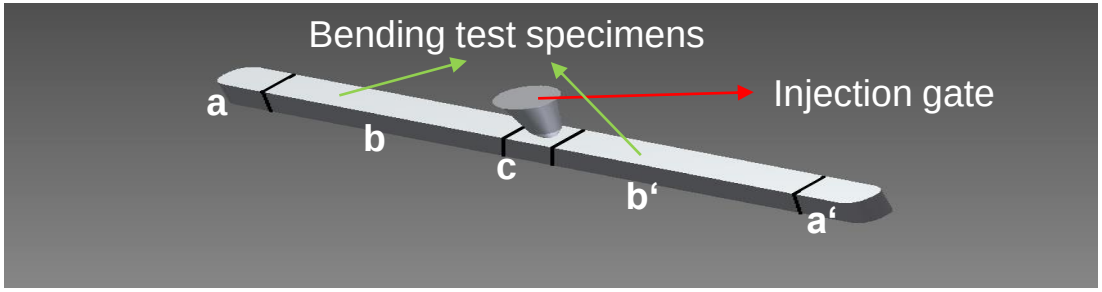


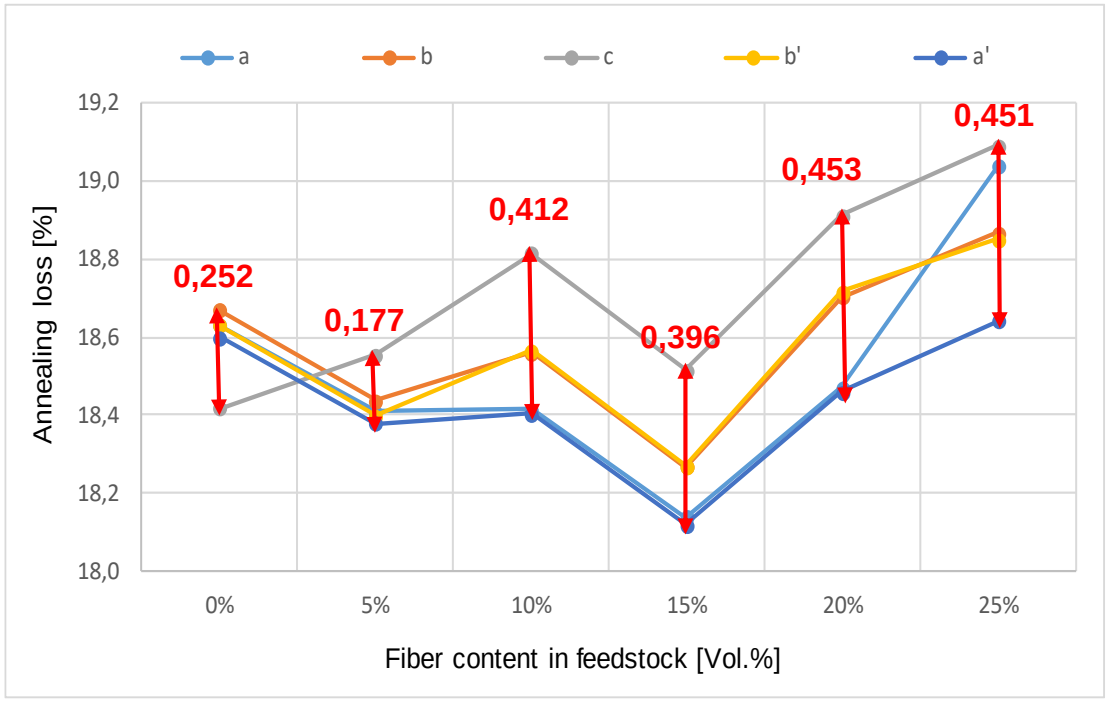
Theory Rheometer

$$\dot{\gamma}_{ap} = \frac{4 \cdot \dot{V}}{\pi \cdot R^3} \qquad \tau_{ap} = \frac{p \cdot R}{2 \cdot L} \qquad \eta_{ap} = \frac{\tau_{ap}}{\dot{\gamma}_{ap}}$$

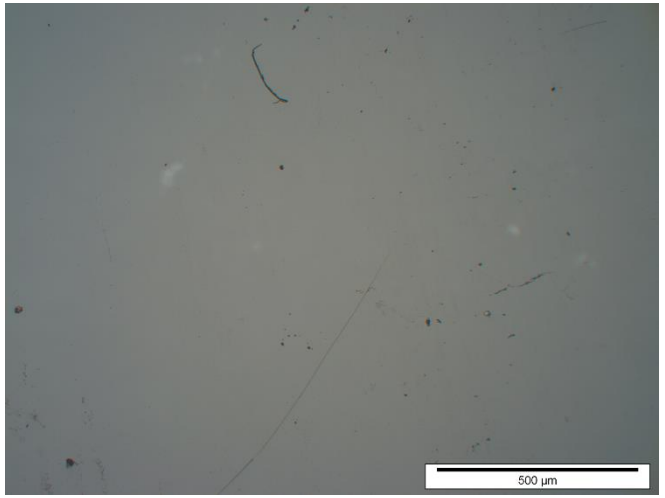
Results: Homogeneity

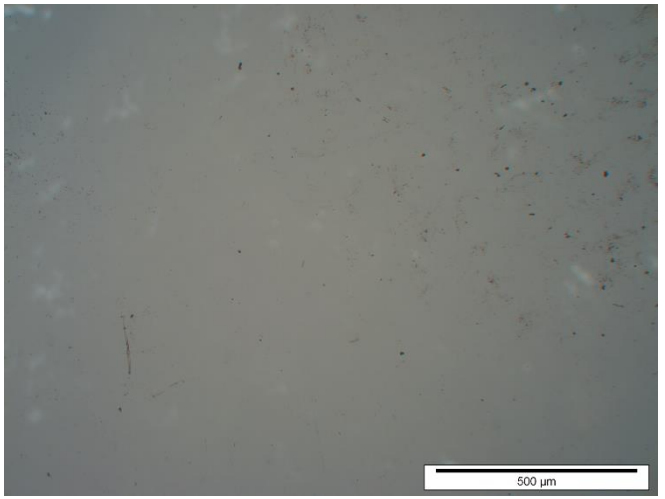
Annealing Loss Test:



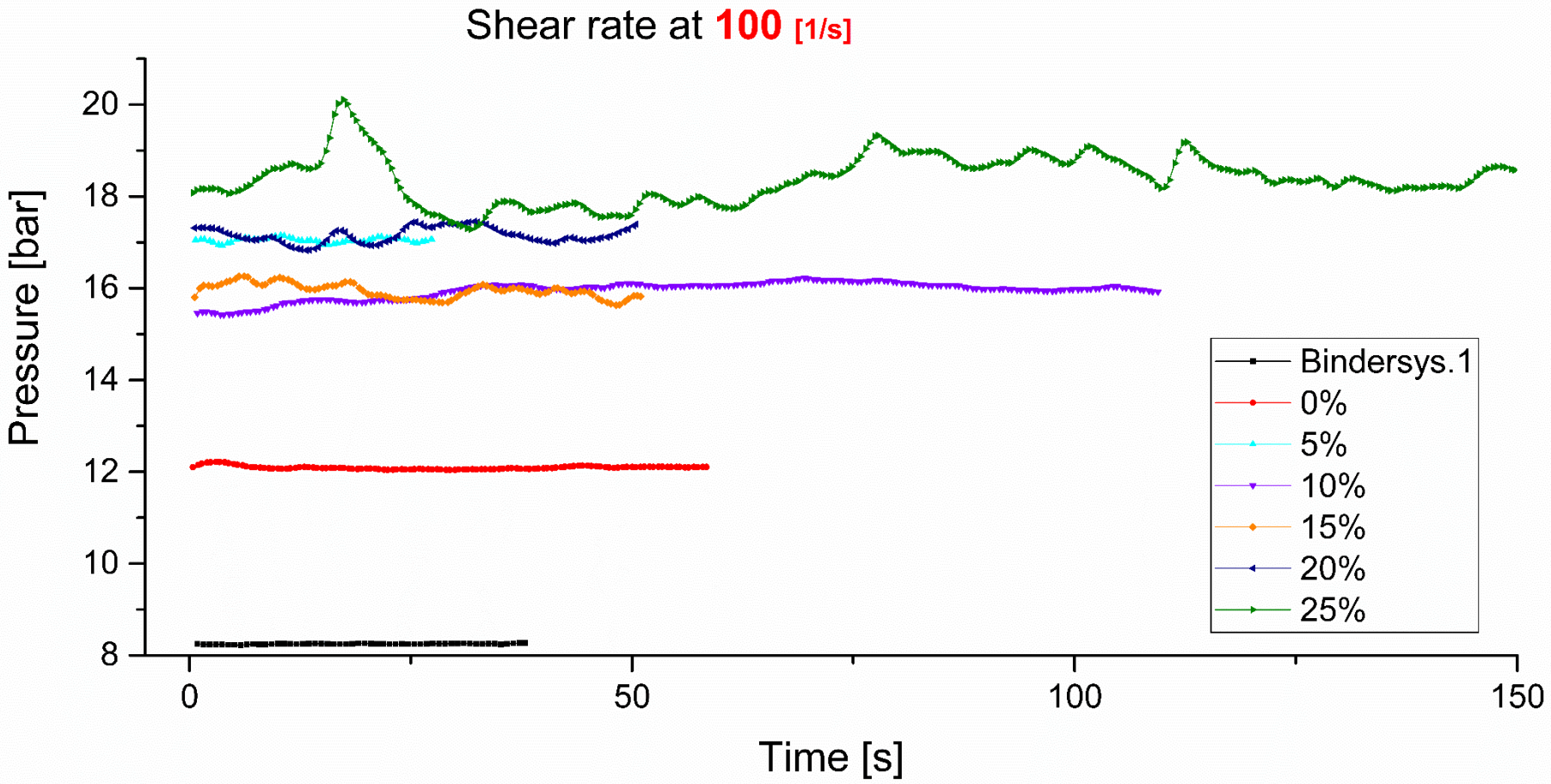


Lichtmikroskopie:

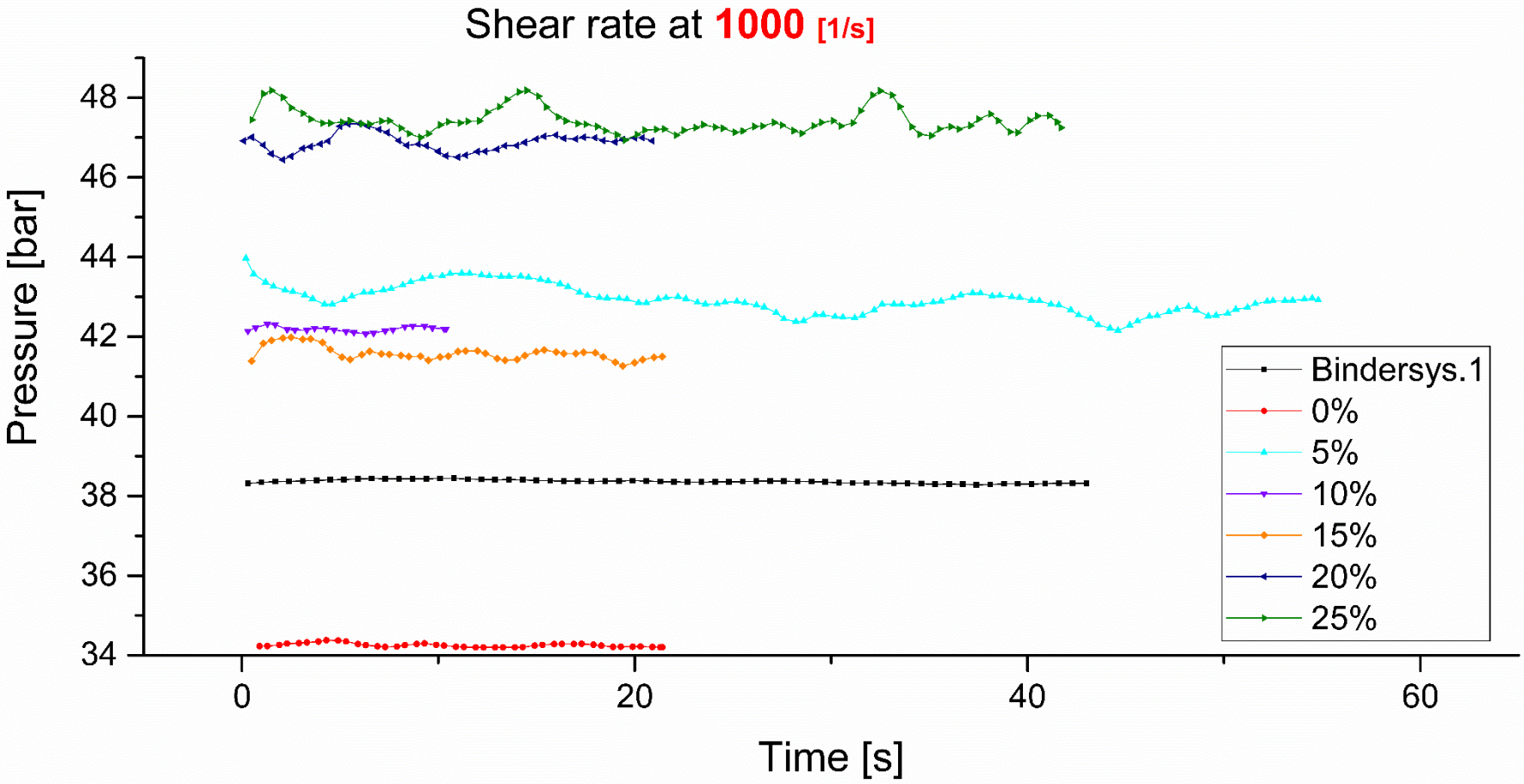




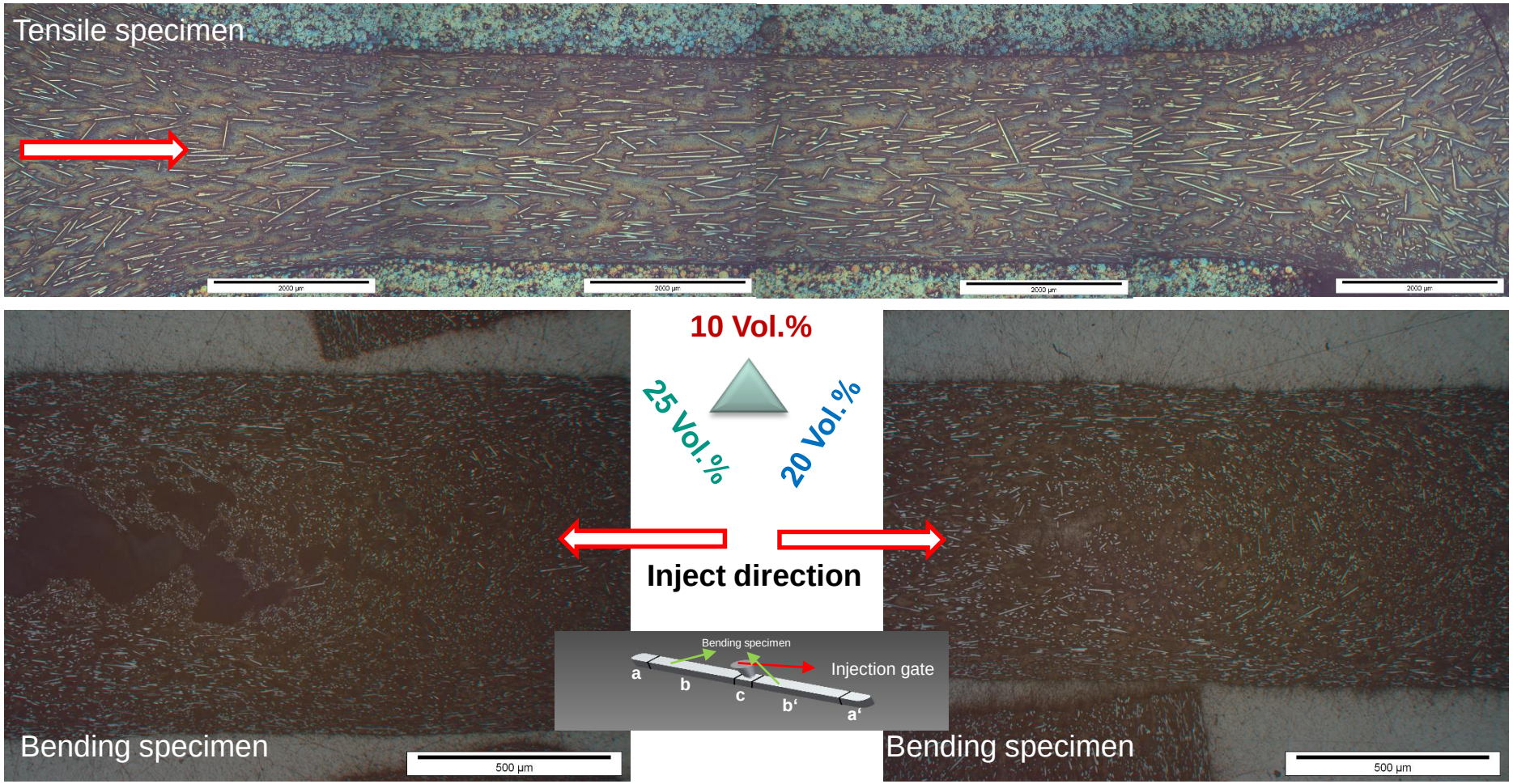
Results: Homogeneity



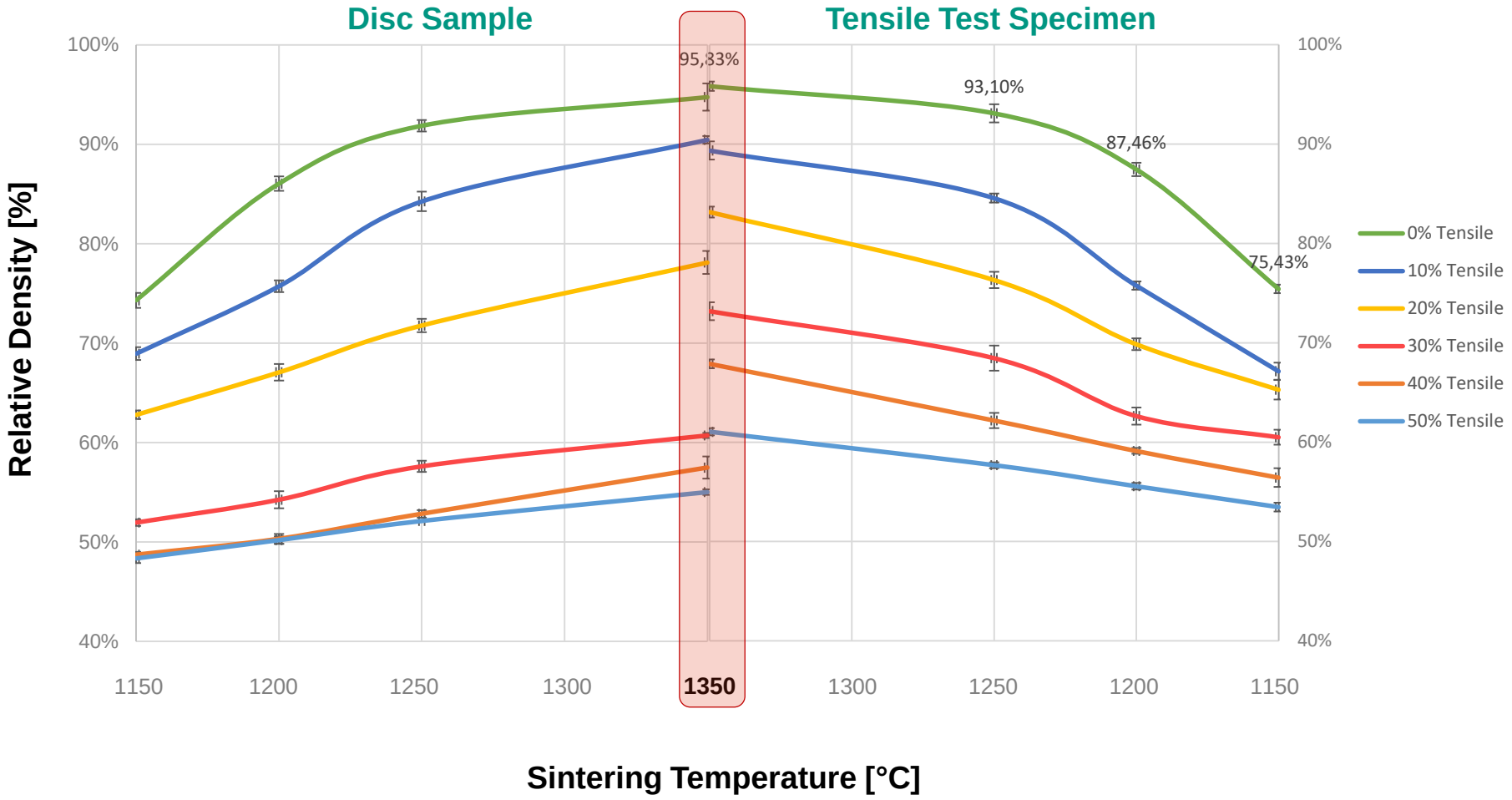
Results: Homogeneity



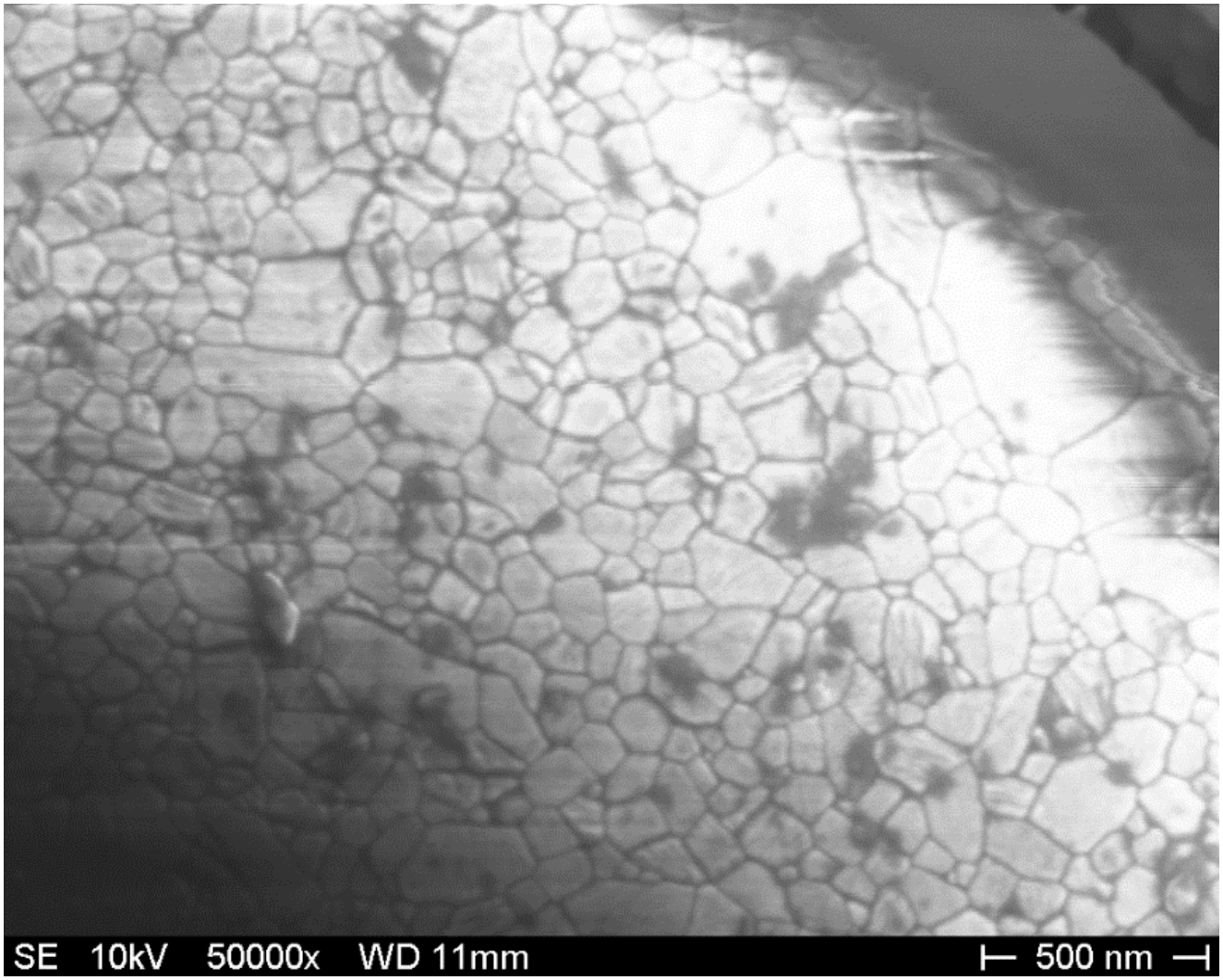
Results: Fiber orientation



Results: Sintered density



Results: Microstructure of a fiber sintered at 1250 °C



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Discussion: Quality

- Increase in roughness with increasing fiber content in feedstock
- Decrease in fiber orientation and increase in fiber content lead to deformation in the injected parts
- It´s hard to control the fiber length distribution
- Increasing fiber content caused production problems and an inhomegeneities

Discussion

Feedstocks up to with 25 Vol.% fiber content are suitable for powder injection molding even thought increase in fiber content leads to decreased part quality.

Fiber orientation can be partly controlled through mold and feedstock design, that can increase the part quality. (except the forms like disc, in which there is no fiber orientations – random distribution)

Next steps:

- Mechanical characterization will be done depend on fiber content, orientation and sintering conditions
- Flow behavior of different feedstocks will be simulated

All associates from
IAM-WK and IAM-KWT

DFG Deutsche Forschungsgemeinschaft