

Faculty Mechanical Engineering | Innovation

3D PRINTING OF BIOPOLYMERS FOR COMPONENTS

Workshop: 3D Printing of Biobased Materials for Applications in Manufacturing and Biomedical Devices

iwk INSTITUT FÜR WERKSTOFFTECHNIK UND KUNSTSTOFFVERARBEITUNG

Prof. Dr. Frank Ehrig, Director of Institute

Rapperswil, July 25th , 2018

HSR HOCHSCHULE FÜR TECHNIK RAPPERSWIL

FHO Fachhochschule Ostschweiz

Introduction IWK: Fields of innovation in six research groups

Mechanics/
Kinematics
(2005)





Composites/
Light weight
construction
(2015)



Light weight
construction

Integration of
functions and
processes

Simulation

Hybrid technology

Fields of Innovation

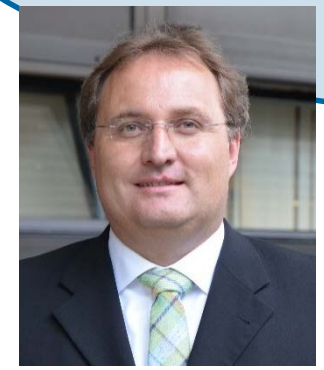
3D Printing/AM

Polymerengineering

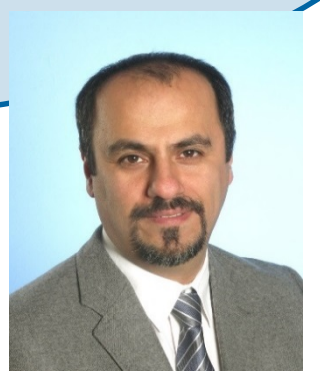
Interfaces and surfaces



Injection Moulding/
Polyurethane
(2005)



Biopolymers/
Recycling



Bonding
technologies
(2015)

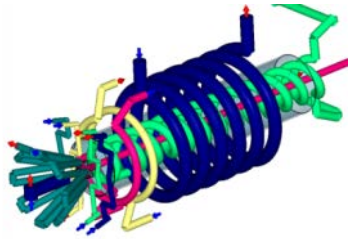
Compounding/
Extrusion (2010)

Metal Processing
(2016)

Introduction IWK: Support along the whole value-added chain



Compoundierung



Filling simulation

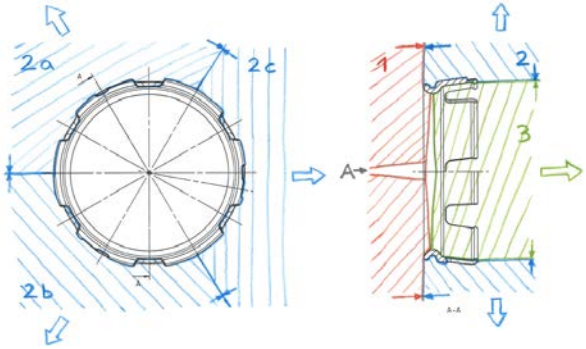


Integration of illumination

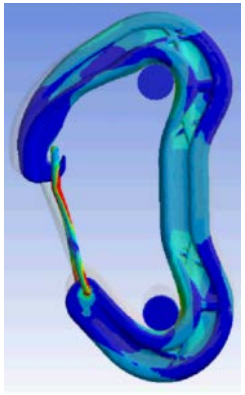


Electro leight weight car

Material Development → Part Design → Part Development → Mould Technology → Process Technology → Prototyping Pilot runs → Part Testing



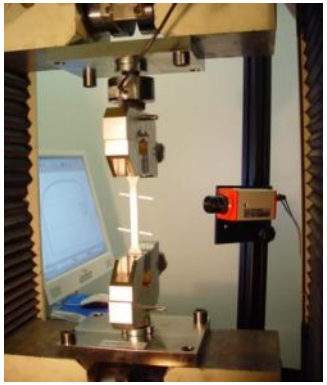
Development of concepts



Structural analysis



Special Processes



Material parameters

Exchange with industry: yearly Rapperswiler Plastics Conference



Components made out of biopolymers/biocomposites

Lignin-based bioplastics



[photo: tecnaro]



[photo: purac]

Swiss army knife: cover CEP



[photo: victorinox]

PHA products



[photo: bioplastics magazine]

Packaging cosmetics



[photo: FKuR]

Overview 3D Printing Technologies

General Challenge:

Choosing the right material and process combination

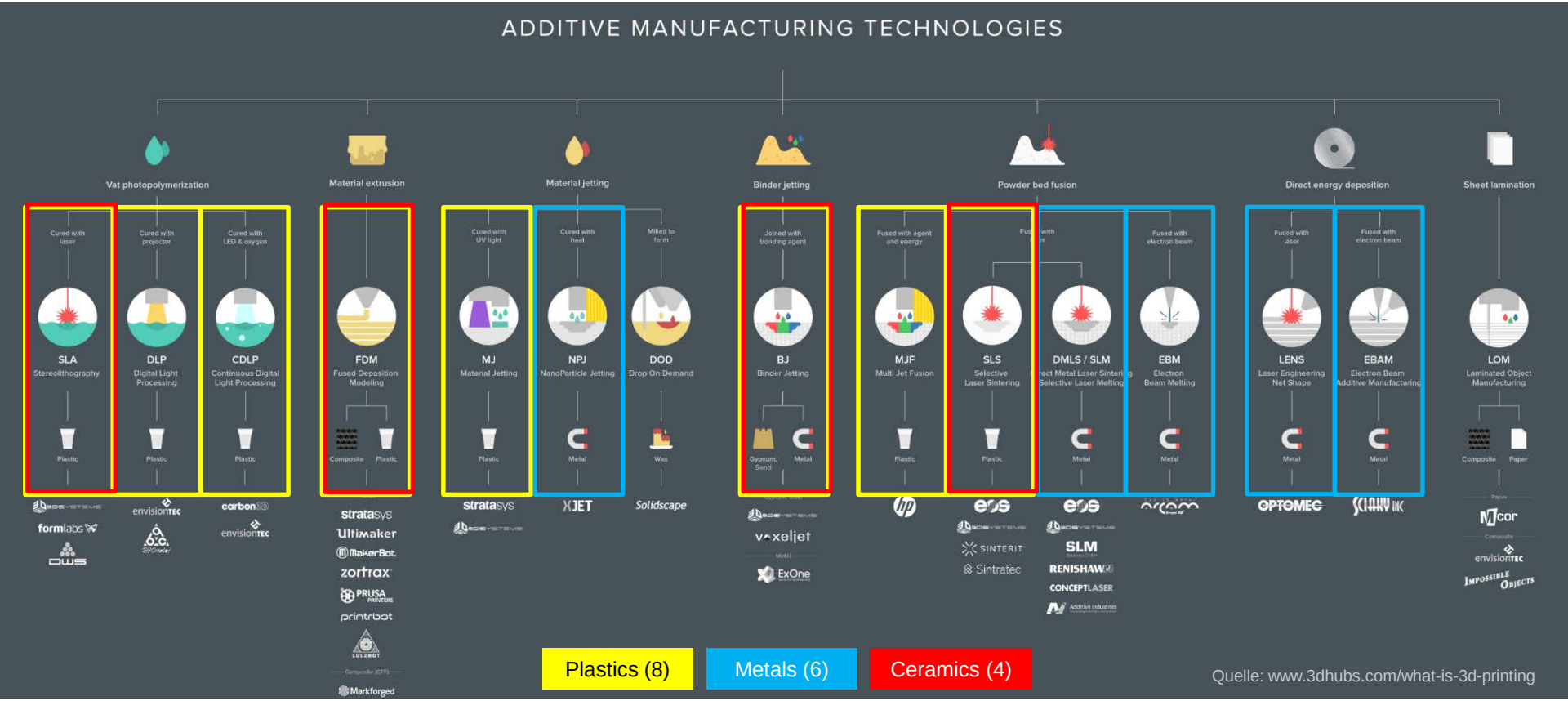
in a mature price driven commodity market

Specific Challenge:

Which 3D Printing Technology is ready for biopolymers/biocomposites?

Which biopolymers/biocomposites can be used?

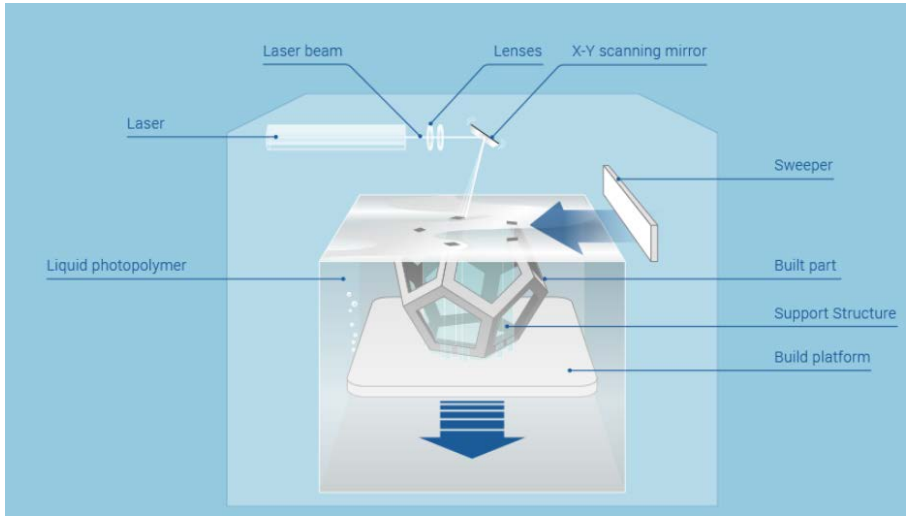
Overview 3D Printing Technologies



Quelle: www.3dhubs.com/what-is-3d-printing

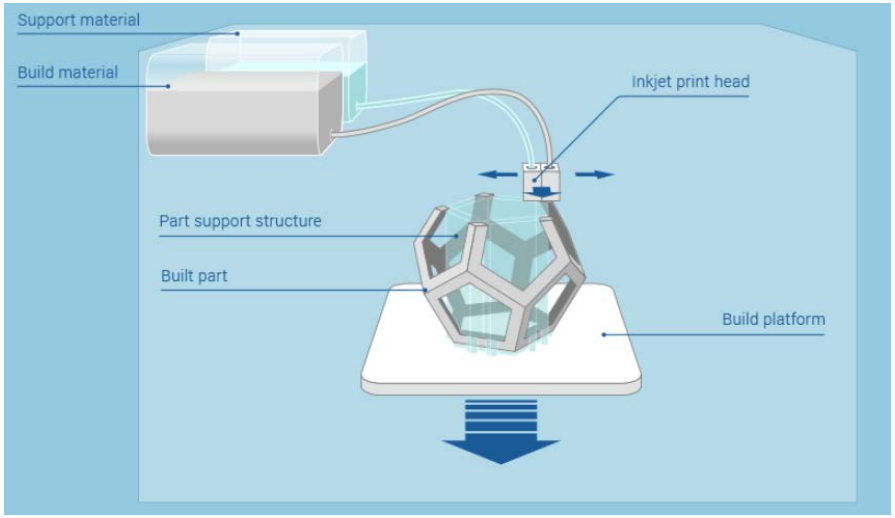
3D Printing Technologies for plastics

Stereolithography



A UV laser is curing a liquid photopolymer in a vat. The part is built by lowering the build platform into the vat.

Material Jetting

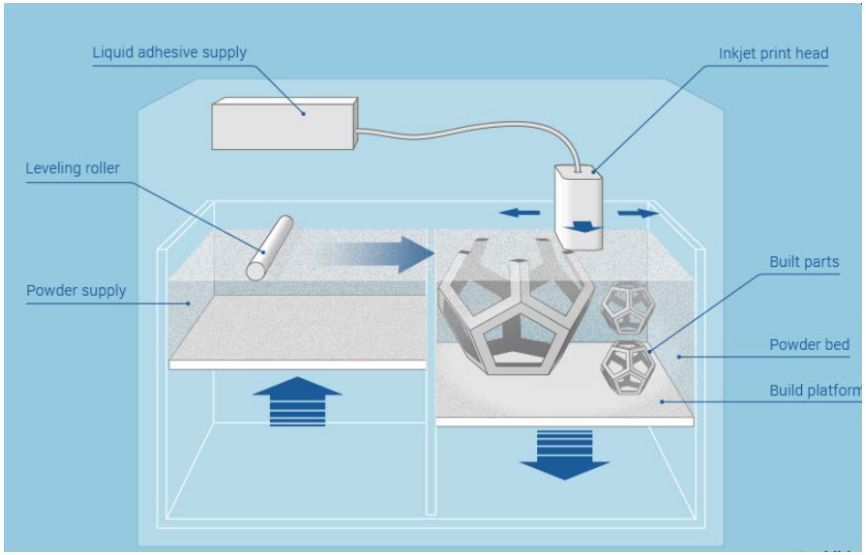


Material jetting can achieve very good accuracy and surface finishes. However the technology only works with wax-like materials.

All information from www.additively.com

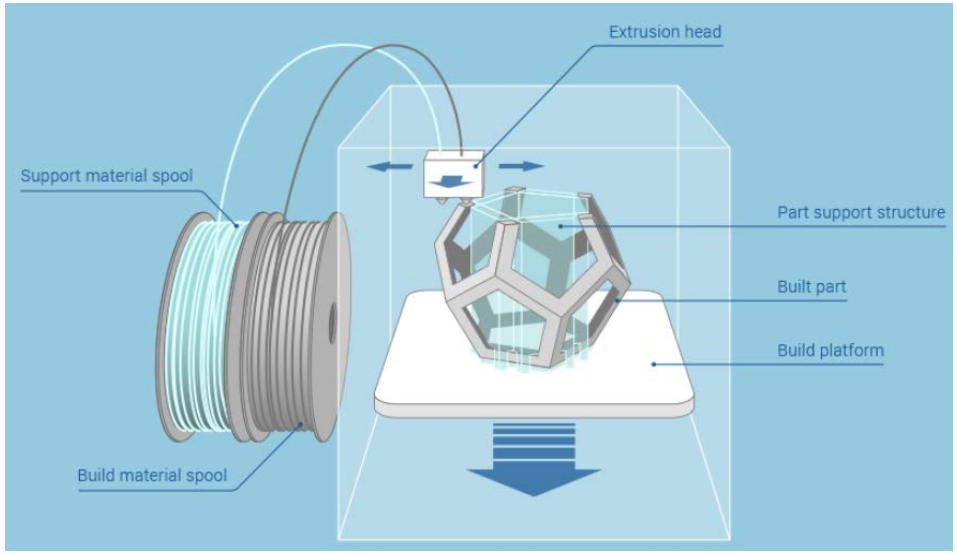
3D Printing Technologies for plastics

Binder Jetting



Inkjet print heads apply a liquid bonding agent onto thin layers of powder. By gluing the particles together, the part is built up layer by layer.

Fused Filament Fabrication

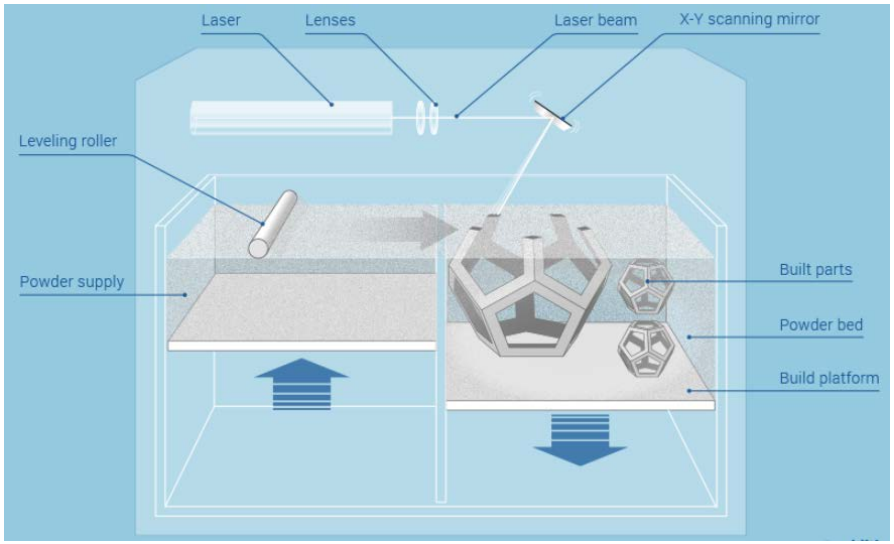


A plastic filament is melted and extruded through a nozzle. Parts are built by laying down layer-by-layer

All information from www.additively.com

3D Printing Technologies for plastics

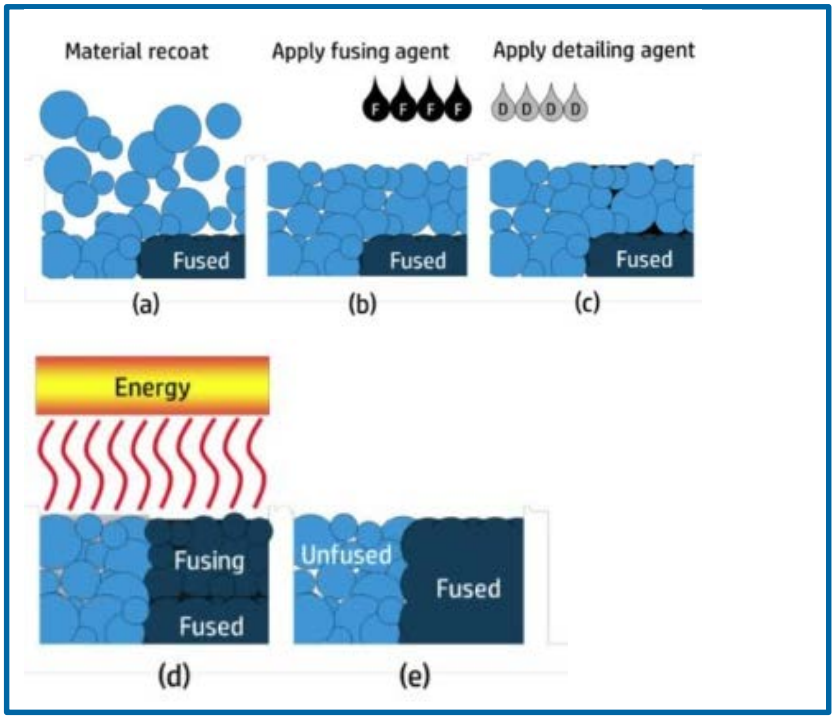
Selective Laser Sintering



A thin layer of plastic powder is selectively melted by a laser. The parts are built up layer by layer in the powder bed.

www.additively.com

HP Multi Jet Fusion

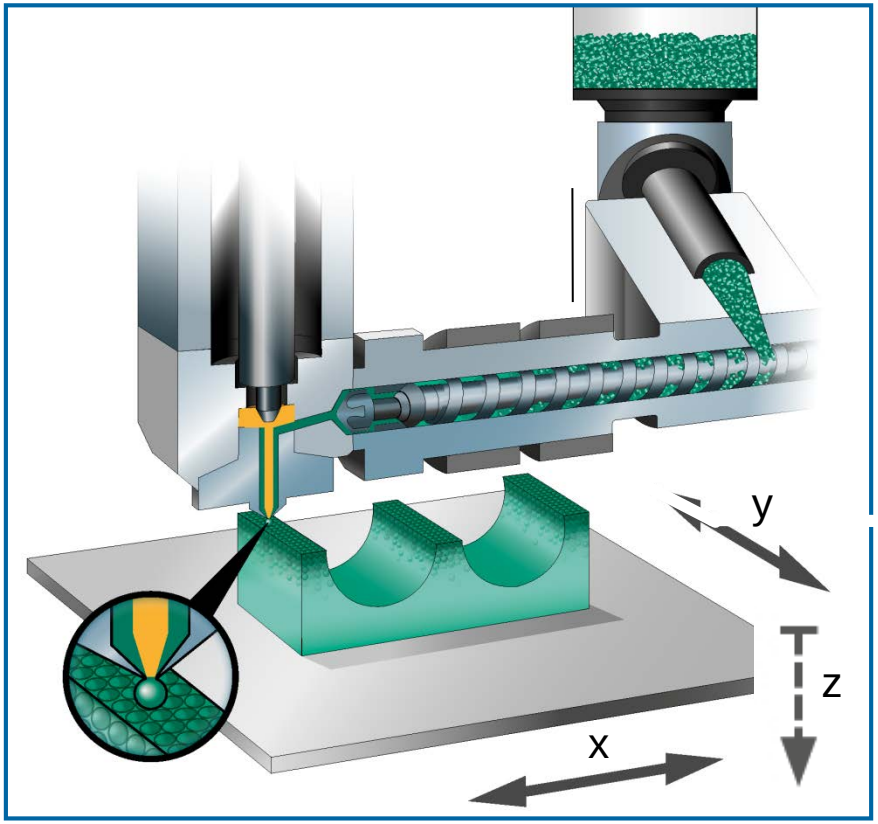


A thin layer of plastic powder is selectively melted by light and agents. The parts are built up layer by layer in the powder bed.

www.3dprint.com

3D Printing Technologies for plastics

Arburg Plastics Freeformer



[Picture: Arburg]

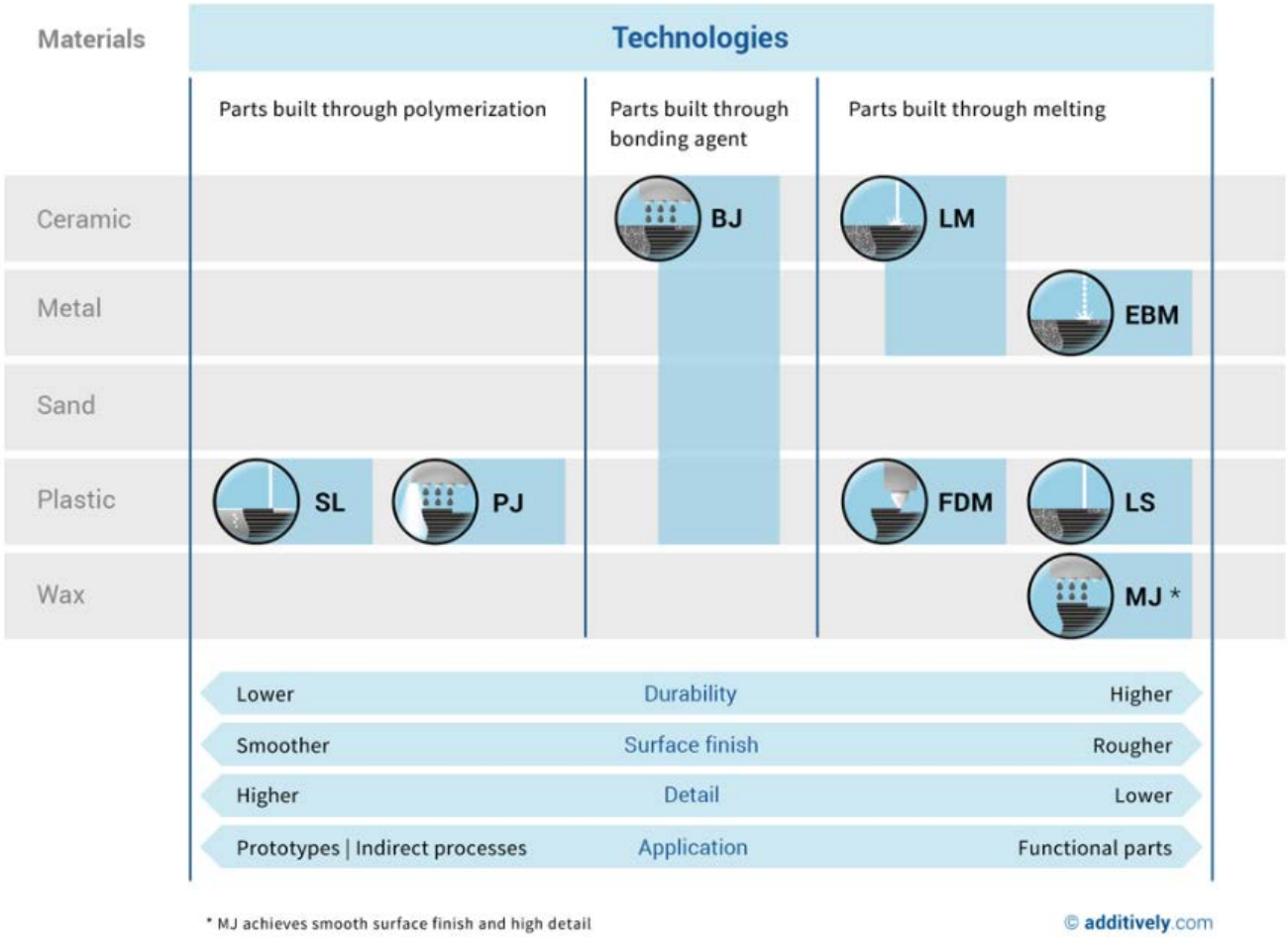
Basis: Qualified standard granulates

Material preparation via screw as with injection moulding

Actuator performs pulsed nozzle closure

Discharge of individual droplets from the nozzle tip

Conclusion 3D Printing Technologies



www.additively.com

Conclusion 3D Printing Technologies

- The market is in strong motion
  - Development of new or improved technologies
  - Development of new or improved materials

- The use of biopolymers as we know it from series production like injection moulding, blow moulding, extrusion etc. at the moment only could be realized with
  - Fused Filament Fabrication
  - Arburg Platics Freeformer

3D-Printing activities at IWK



Twin screw compounder
Dosing & mixing equipment
Pelletizer
Material modification
Water-soluble support material



MATERIAL DEVELOPMENT

Technologies: APF (Freeformer) & FDM/FFF
Material qualification
Process optimization
Post-processing
Application development



3D PRINTING & QUALIFICATION



ADDITIVE MANUFACTURING @IWK



FILAMENT EXTRUSION



GOLD AWARD Material

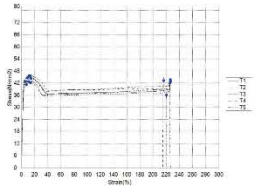
CREAMELT 3D PRINTING MATERIALS



Single screw extruder
Double line cooling section
Double line filament winder
Laser measuring system
Packaging station



TESTING & CHARACT-ERIZATION

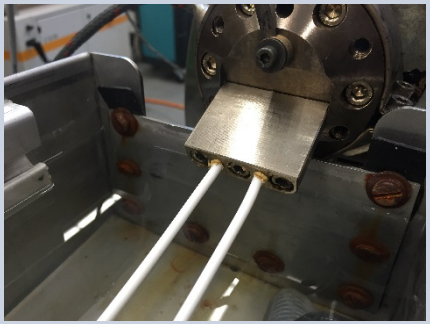


Mechanical properties (tensile, impact, etc.)
Optical microscopy
Thermal characterization
Capillary rheometry
Application testing



3D-Printing activities at IWK

Customized filaments for FFF

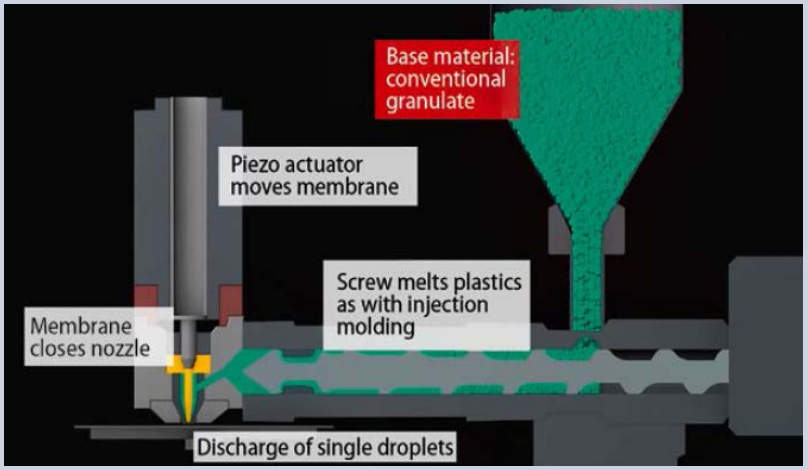


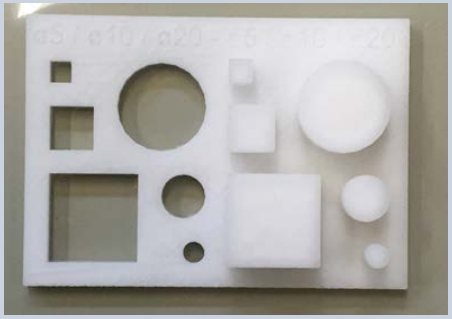




CREAMELT
3D PRINTING MATERIALS

Use of Freeformer technology







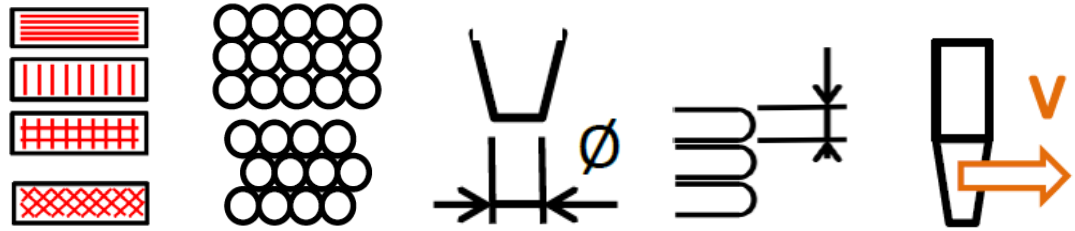
[Figures Arburg, IWK]

FFF processing parameters

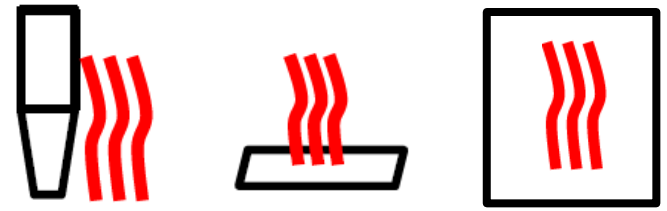
- Filament production: In general efforts necessary to keep the roundness in the tolerances (e.g. 2.8 mm +/- 0.2 mm)



- Variation of process parameters to find the best setting



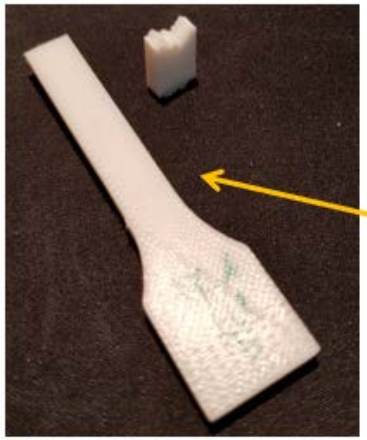
Direction of paths | Layer build-up | Nozzle diameter | Layer height | Printing speed

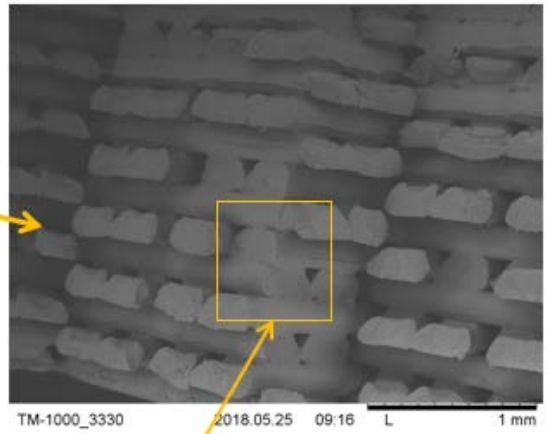


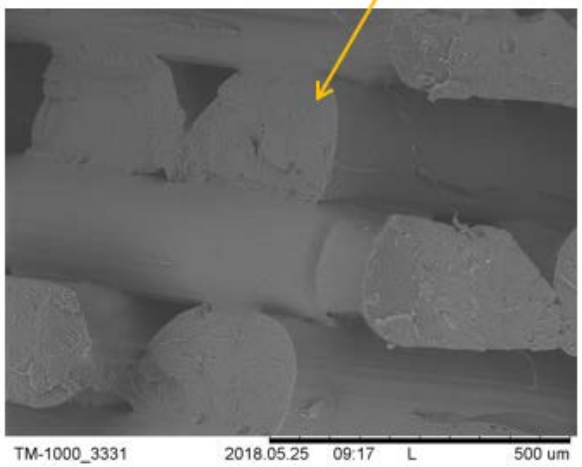
Nozzle temperature | Heated bed temp. | space temp.

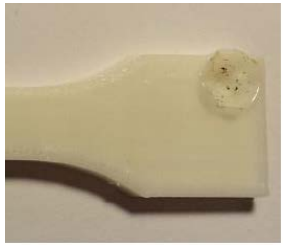
Insufficient properties due to processing or slicing

Voids due to processing

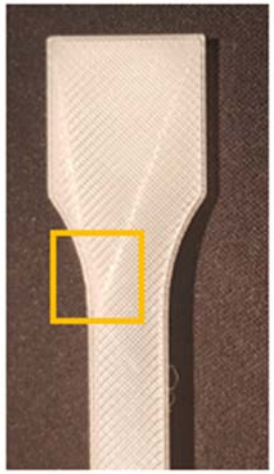




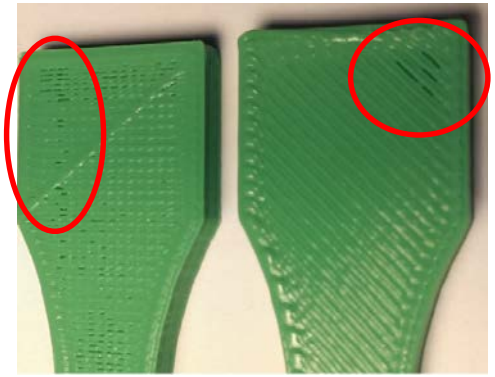




Defect at the edge



Notch effect due to bad slicing



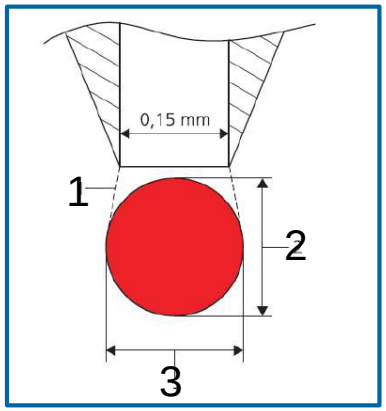
Crazes between the paths



Dirt or burned material

Process parameters APF

- **Many process parameters similar to FFF**
- **Shape of drops**



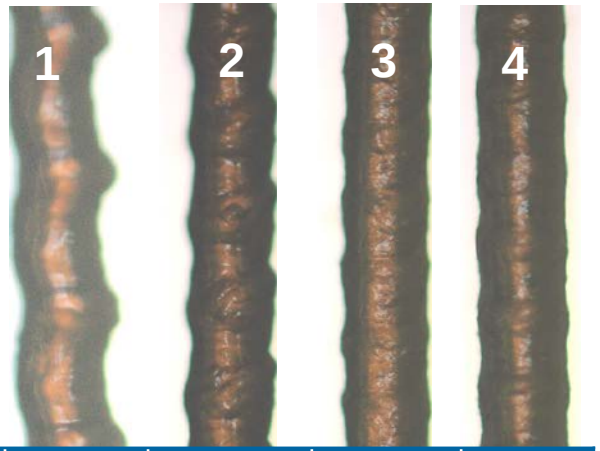
1 Expansion
2 Height
3 Width

Shape factor = Width/Height

- **Material qualification PLA-HI**

Parameter variations:

Analysis of drop chain shape



	1	2	3	4
Frequency [Hz]	143	143	143	143
Melt temp. [°C]	200	200	200	200
Output [mm/s]	20	20	20	20
Output [%]	100	50	40	45
Pressure [bar]	290	240	237	245
Height [mm]	0.41	0.25	0.19	0.22
Width [mm]	0.22	0.22	0.21	0.22
Shape factor	0.54	0.88	1.11	1.00

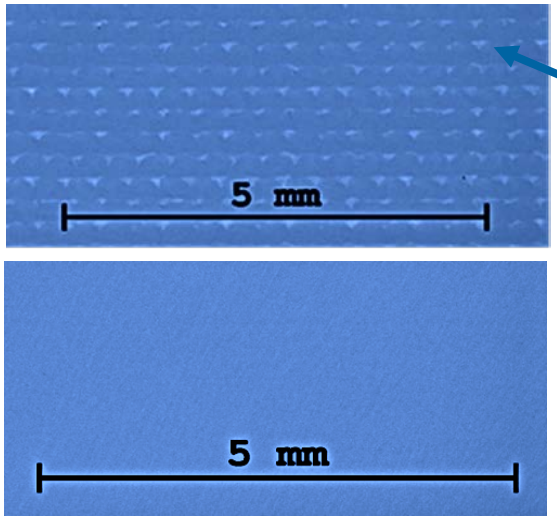
Process parameters APF

- **Complex interaction of parameters**

Layer thickness	Shape factor W/H	Part density
0.27 mm	0.99	90%
0.21 mm	1.14	93%
0.15 mm	1.42	95%

[Picture: Arburg]

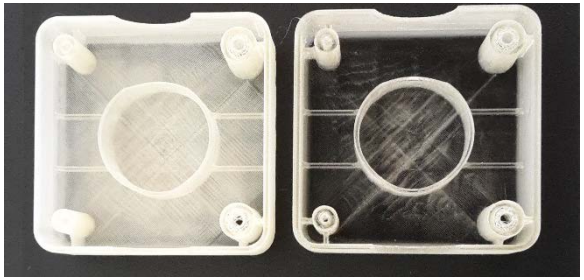
- **Comparison of recordings with diffenent shape factors**



voids

[Picture: Arburg]

Material PC: left with voids, right with less or without

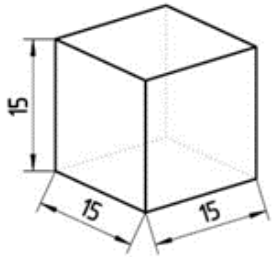


[Picture: IWK]

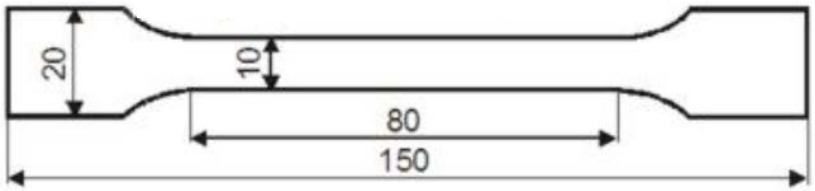
Evaluation of performance of FFF and APF

Test specimen for property comparison

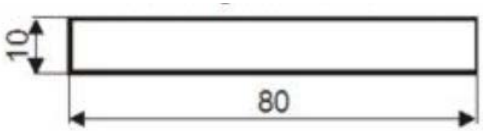
- Test block for material qualification and density determination

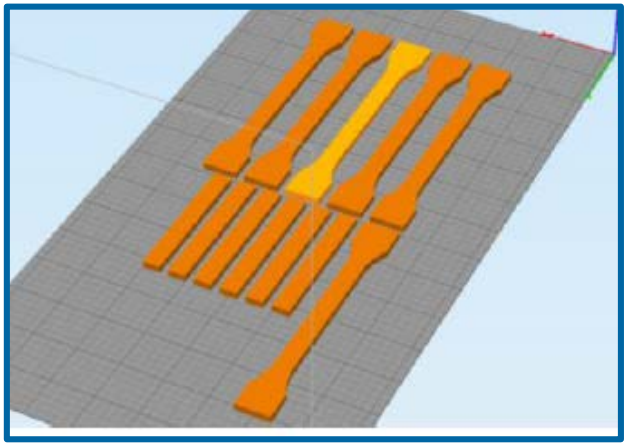


- Tensile test bar (DIN EN ISO 527)



- Impact resistance bar (DIN EN ISO 179/180)





Position in the build-up space for FFF

Experimental set-up

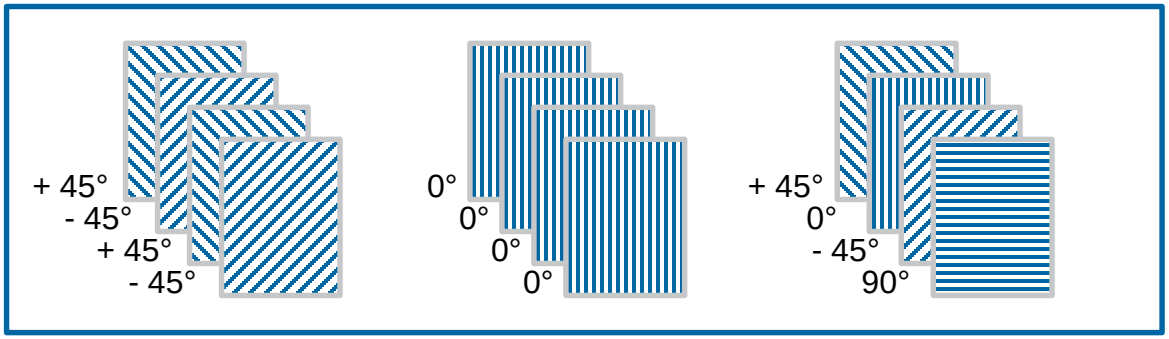
Materials used:

- PLA: CREAMELT® PLA-HI
- PBS: FZ91 PM

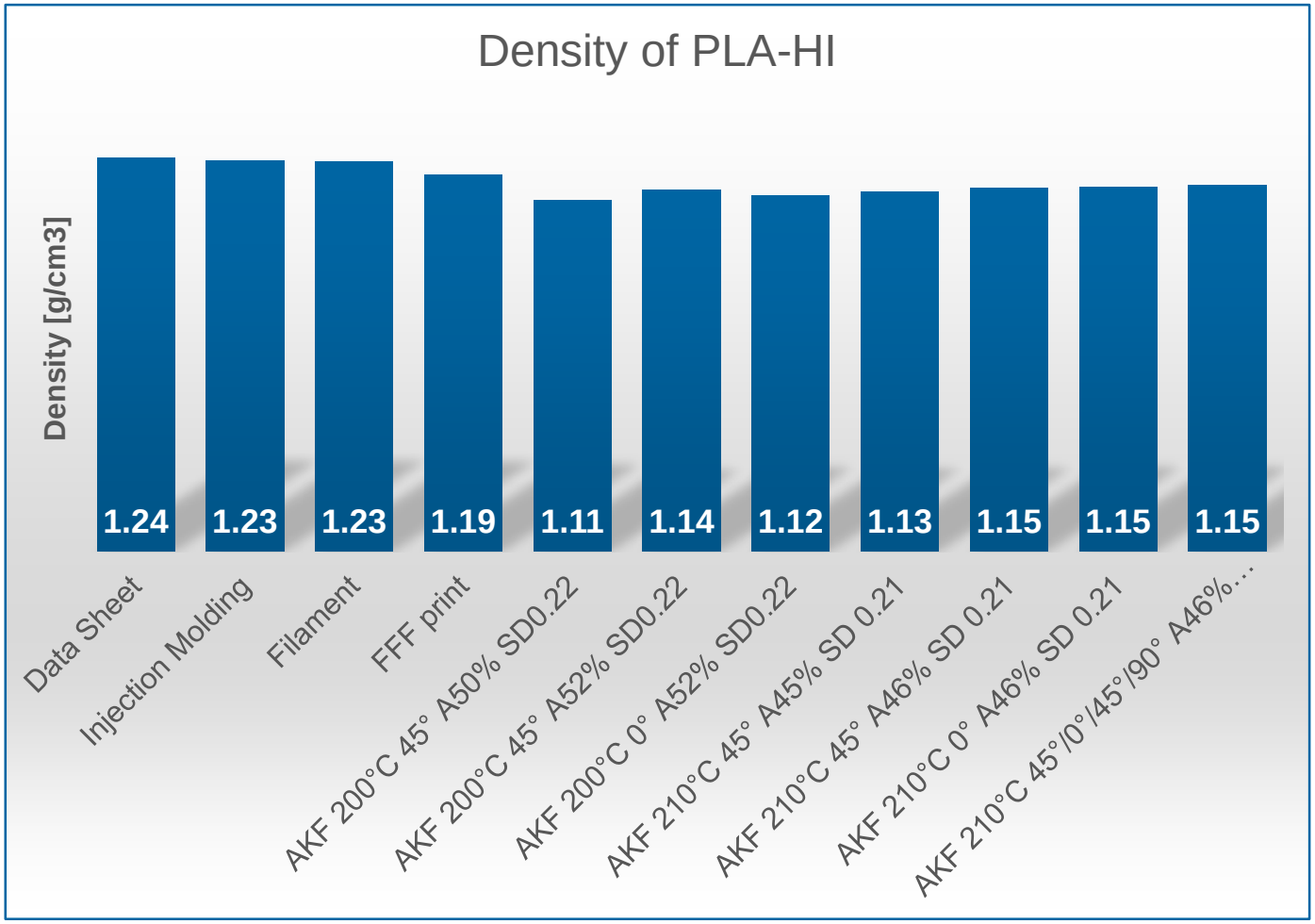
Machines used:

- APF: Freeformer
- FFF: BCN3D Sigma
- IM (Injection Moulding): Battenfeld Smart Power 60

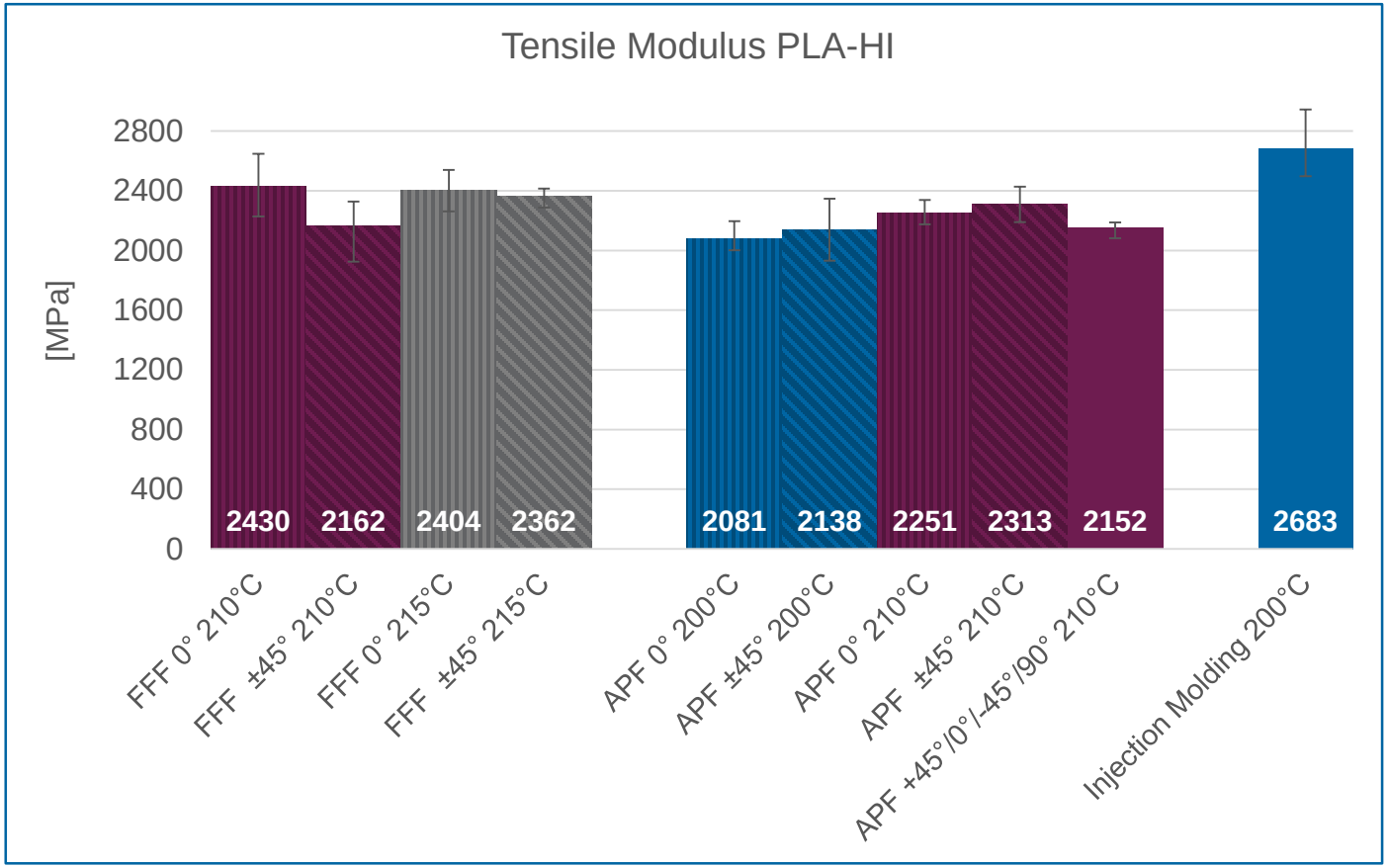
Explanation of layer structures:



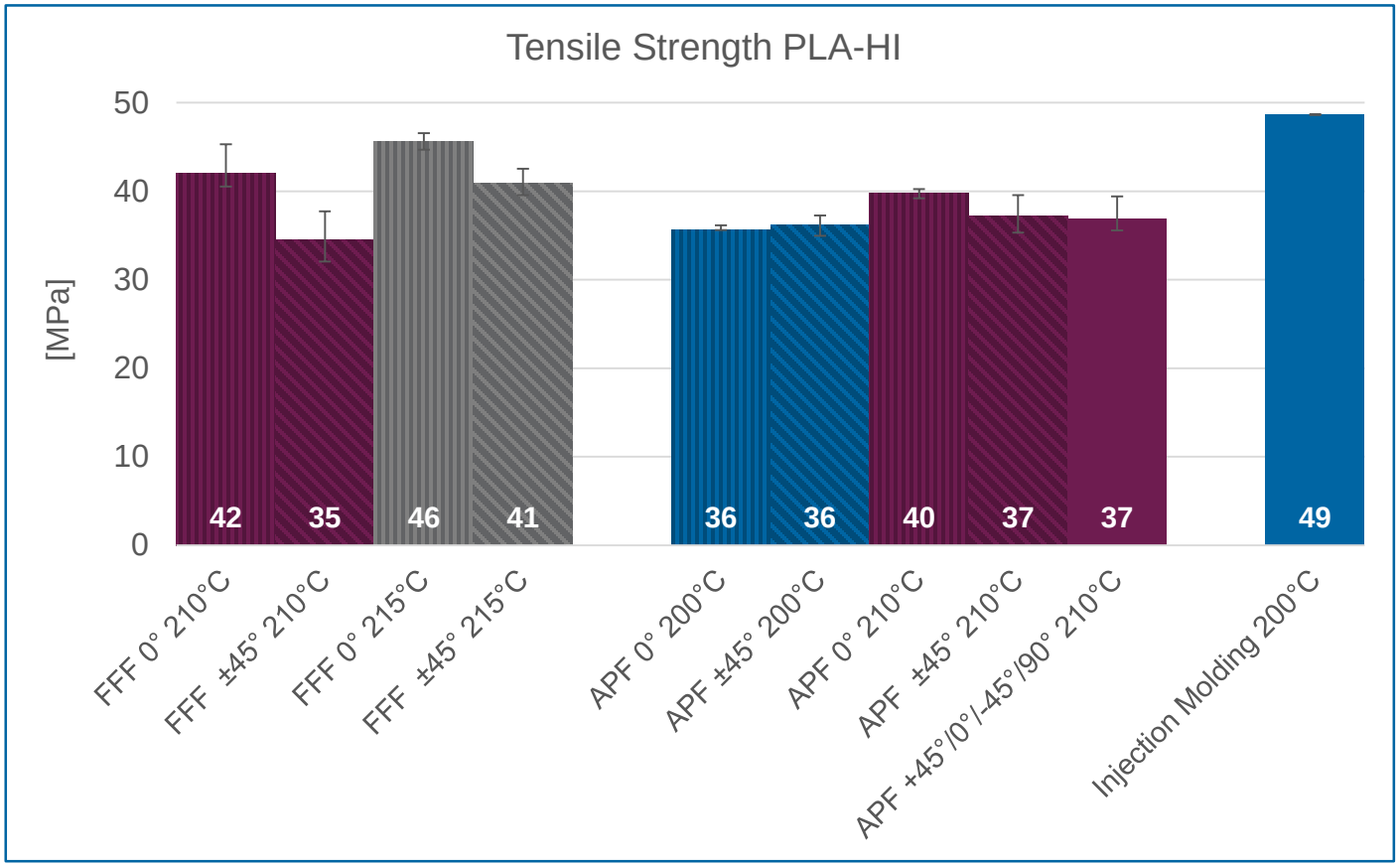
Density Comparison PLA-HI: IM – FFF - AKF



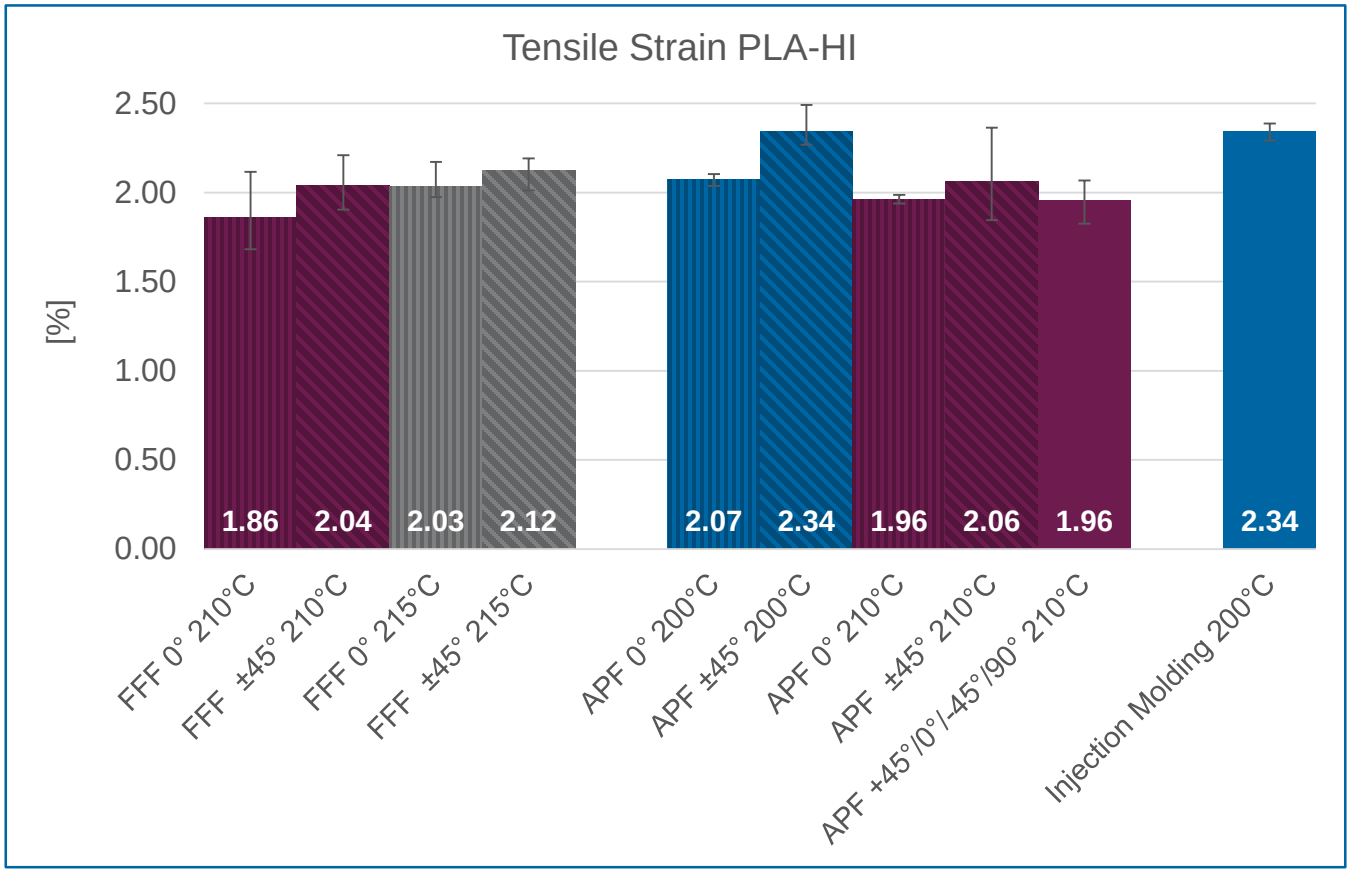
Mechanical properties PLA-HI



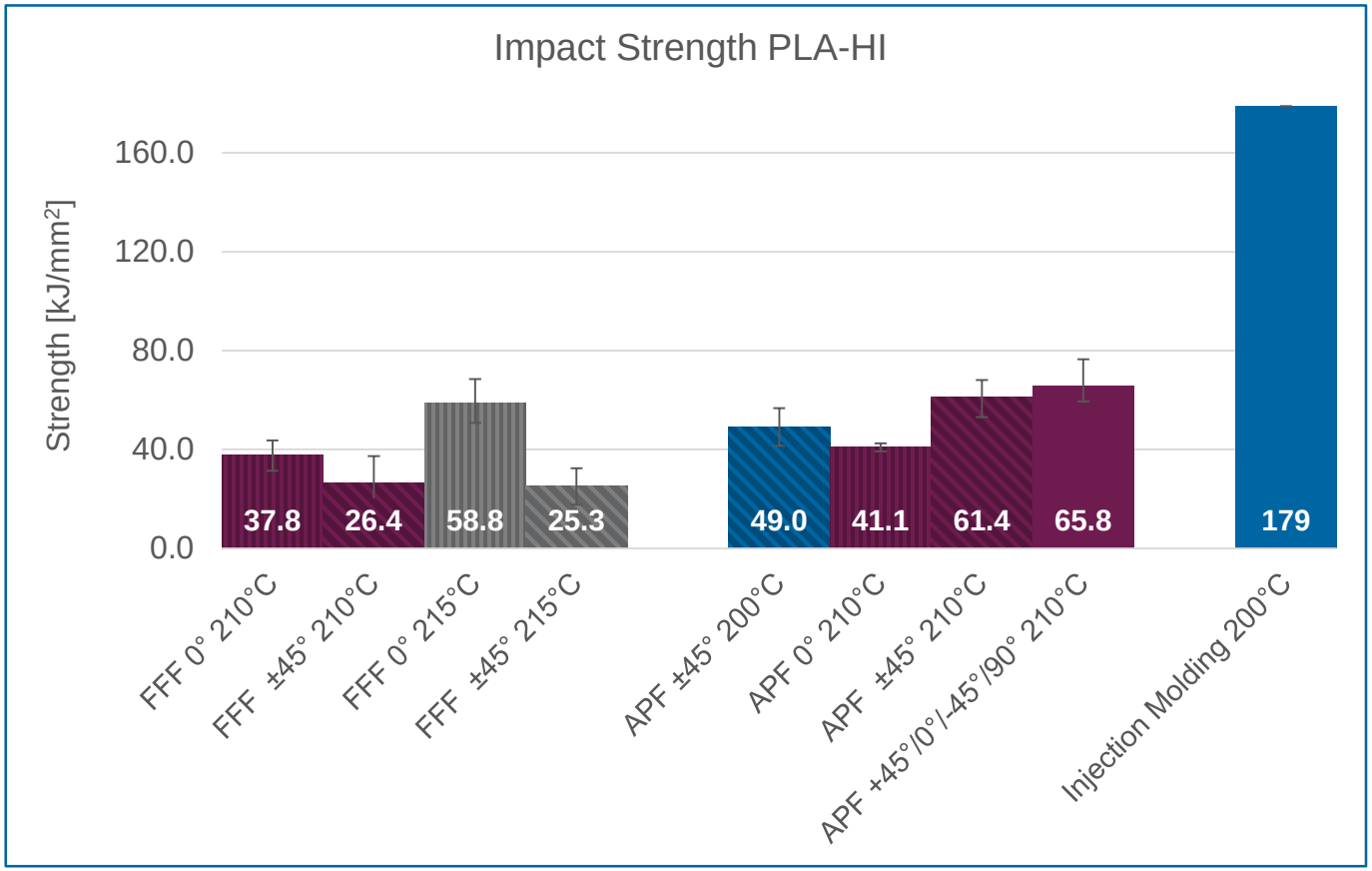
Mechanical properties PLA-HI



Mechanical properties PLA-HI

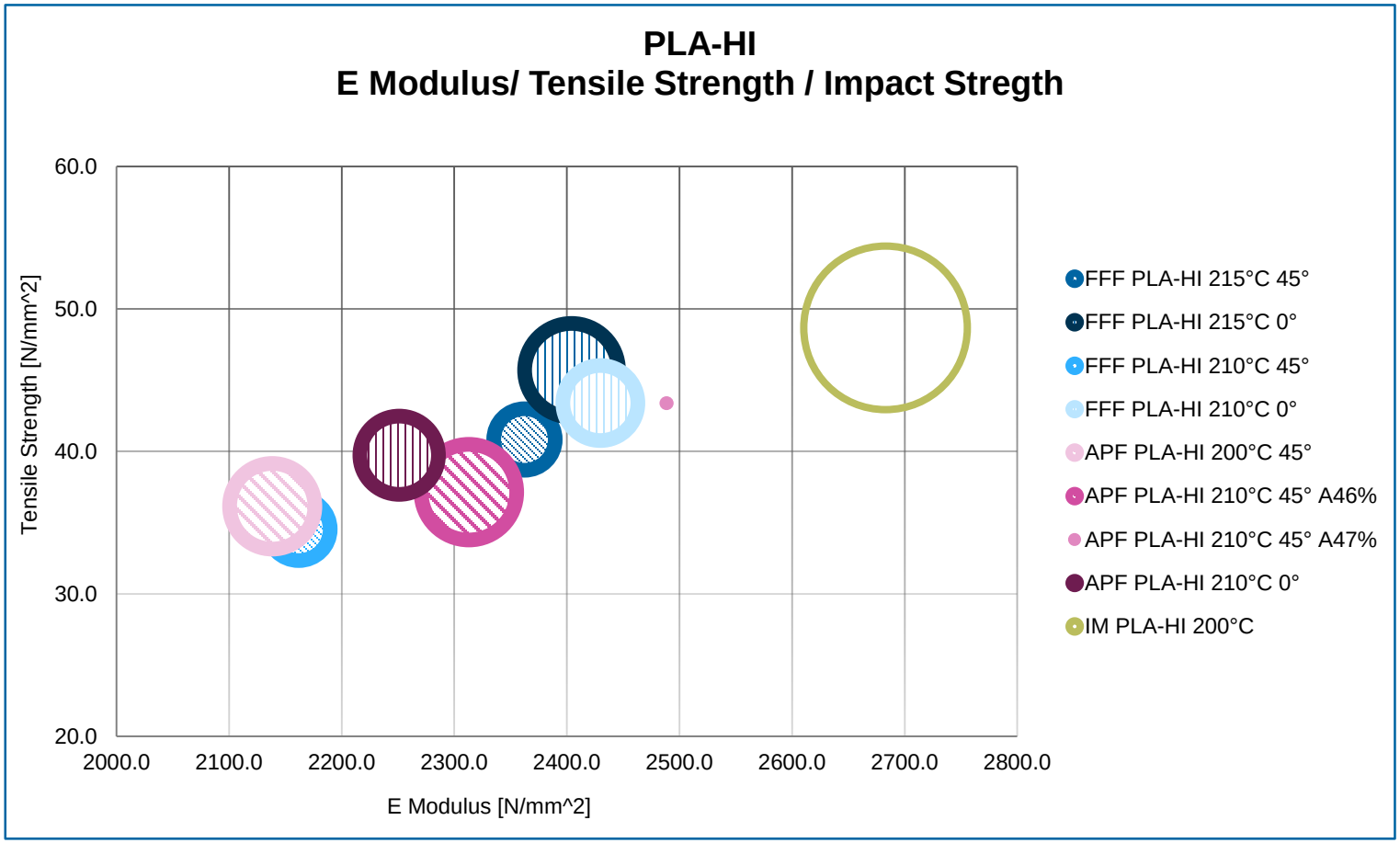


Mechanical properties PLA-HI



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Mechanical properties PLA-HI



Process parameters APF

- **Material: Poly (L-lactide)**
  - Certified standard material for medical applications
  - Low material requirement
  - Application: Individual implants cranial bone / orbital bone
  - Build time: 25 minutes each
  - Layer height: 0.27 mm
  - Part weight: 4 g / 3.5 g



[Picture: Arburg]

Results for PBS

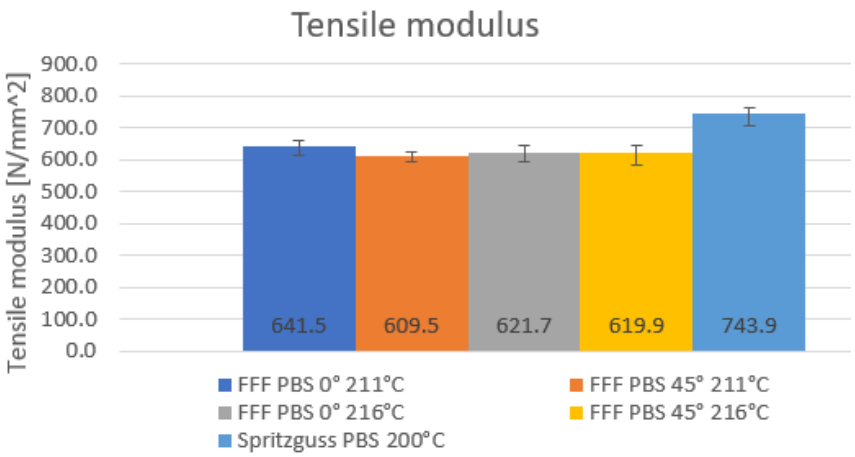
- **FFF process**
  - Production of filament no problem
  - Problems of filament feed due to elastomeric behaviour
  - Warpage due to high shrinkage of 2.5%

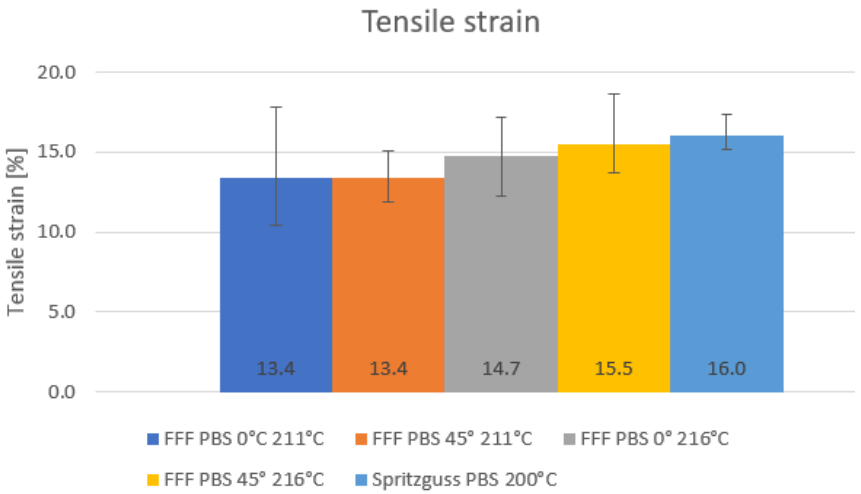


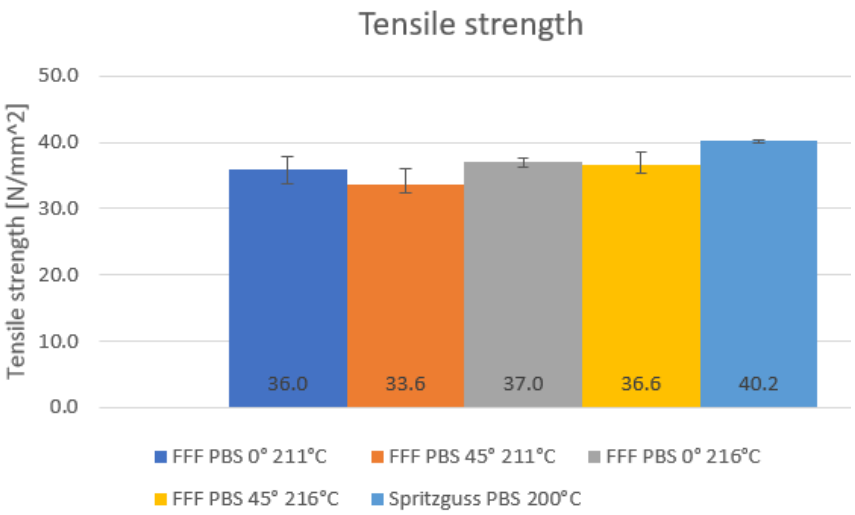
  - Tests to avoid over- and underfilling

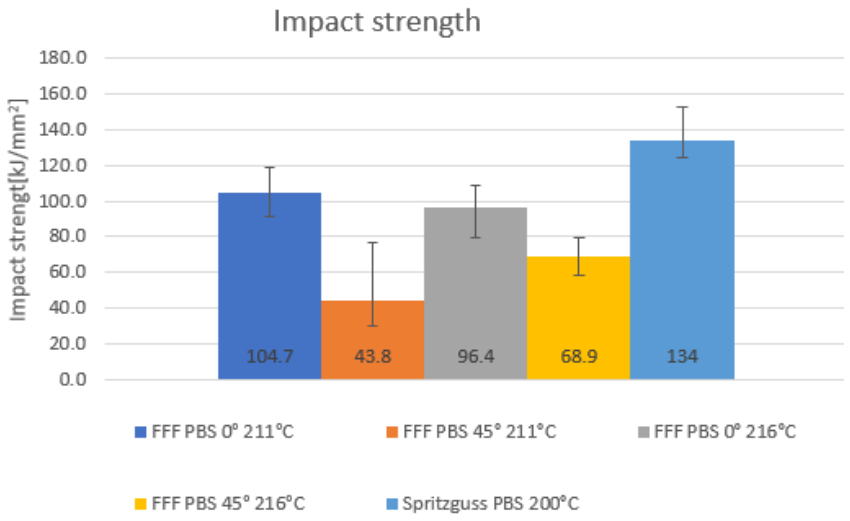
- **APF process**
  - Warpage also big issue
  - No results due to time reasons

Mechanical properties PBS









Conclusion 3D Printing of Biopolymers

- There are potential technologies on the market (FFF, APF)
- The results are sufficient/good/very good depending on the material and part's geometry
- It's not plug and play – pre-tests have to be carried out

Market of biopolymers is growing

and

Technologies for 3D printing will be improved

Opportunities for biopolymers will increase

Thank you for your attention…

