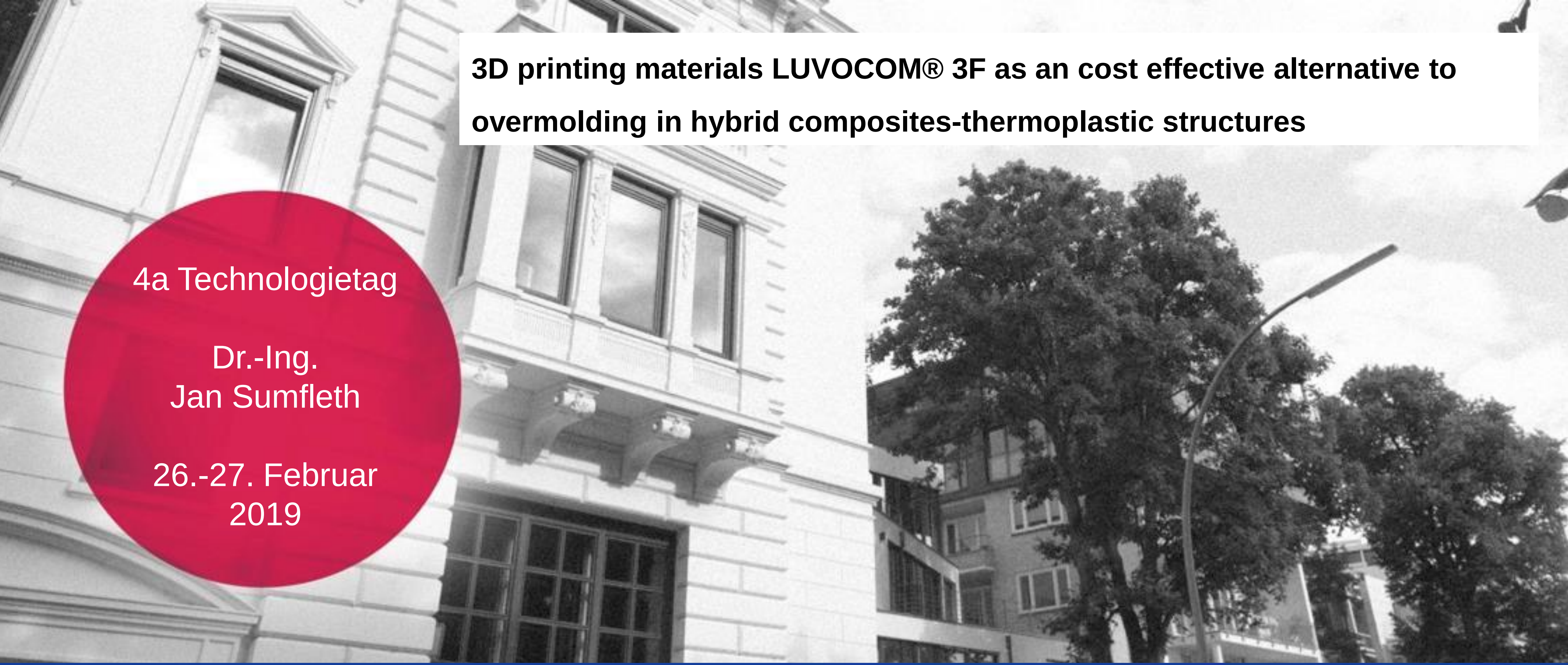
3D printing materials LUVOCOM® 3F as an cost effective alternative to overmolding in hybrid composites-thermoplastic structures



4a Technologietag

Dr.-Ing.
Jan Sumfleth

26.-27. Februar 2019

iwk INSTITUT FÜR WERKSTOFFTECHNIK UND KUNSTSTOFFVERARBEITUNG

Karin Brändli Hedlund, Prof. Dr.-Ing. Frank Ehrig

LEHVOSS Group

www.lehvoss.com

Agenda

- Introduction to Lehvoss Group
- Thermoplastic compound expertise
  - LehVoss 3F strategy
- Why LUVOCOM 3F for „overmolding"?
  - Fundamentals aspects of LUVOCOM 3F
  - Viscosity and solidification
  - Effect of fillers, e.g. carbon fiber
  - Printing of LUVOCOM 3F on organosheets
- Excursion: Showcase of hybrid structures with LUVOCOM 3F and thermoset composites

The LEHVOSS Group

- Lehmann&Voss&Co. established 1894
- Family-owned business in 4th generation
- 595 employees*
- 21 subsidiaries world-wide
- 365 €MM revenue*
- 6 business units:
  - Trading of specialty chemicals
  - Production of specialty polymers

*LEHVOSS Group, without joint ventures

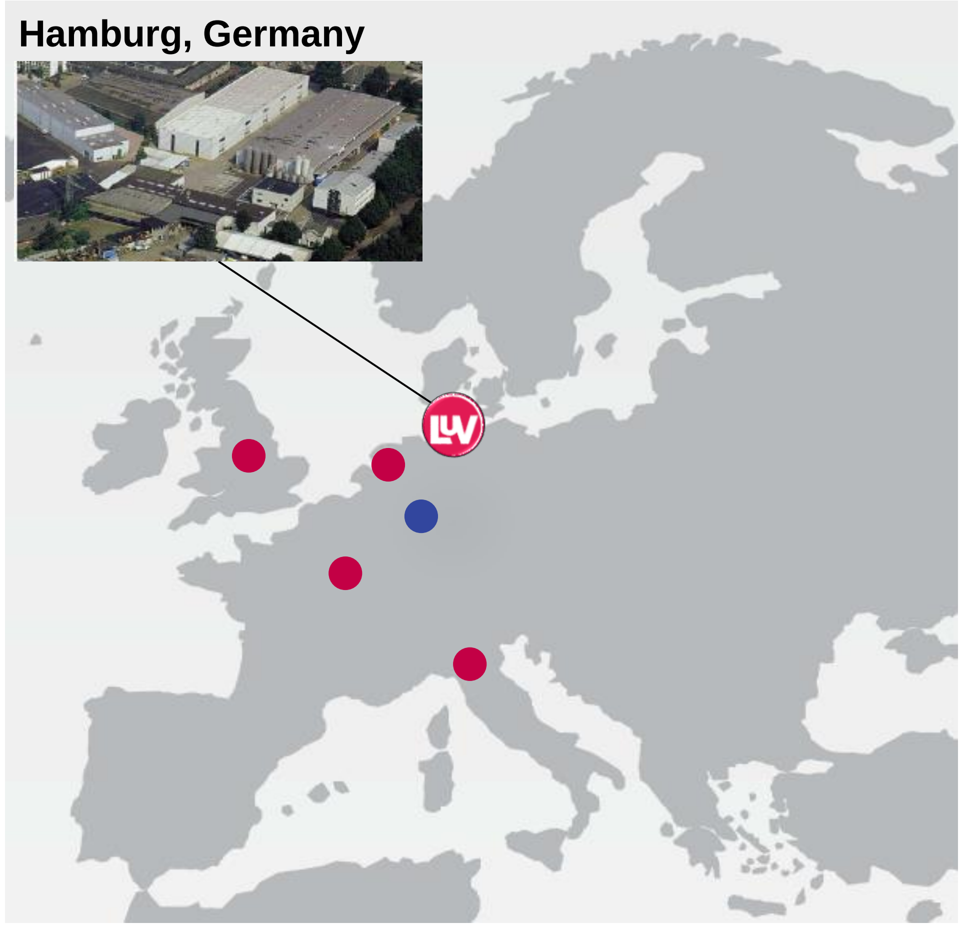
The LEHVOSS Group – Your Partner in the Polymer Industry

LEHVOSS
Group

BU Customized Polymer Materials (CPM)			BU Additives & Concentrates
High Performance Compounds	3D Printing Materials	Technical Compounds WMK Plastics	Functional Masterbatches

- 4 business teams with sales, marketing & development
- 45+ years of experience in compounding
- >200 employees
- 4 production sites: 2x Germany, USA and China
- 20 extrusion lines with a capacity of 25,000 MT

Business Unit CPM
Region Europe



Relevant subsidiaries:

Lehmann&Voss&Co.
WMK PLASTICS LEHVOSS Group
LEHVOSS France
LEHVOSS Italia
LEHVOSS United Kingdom
LEHVOSS Nederland

Highlights

- Company headquarter in Hamburg, Germany
- ISO 9001 certified production site in Hamburg
- Central product development, engineering, pilot plant and analytical testing facility
- Business development organization with sales offices in key countries

- WMK, an independent business team:
  - ISO 9001 certified production site in Solingen, Germany
  - Sales organization in Germany & Austria

Business Unit CPM
Region North America

Highlights

- Regional headquarter in Connecticut (LEHVOSS North America)
- ISO 9001 certified production site since 2012 with comparable capabilities as in Europe
- Established contract manufacturing (Performance Compounding Inc.) with analytical testing facility
- Experienced business development organisation

Relevant subsidiaries:

LEHVOSS North America

PERFORMANCE Compounding

Business Unit CPM
Region Asia

Relevant subsidiaries

LEHVOSS Shanghai

LEHVOSS Kunshan

LEHVOSS Korea

Highlights

- Regional headquarter in Shanghai (LEHVOSS Shanghai), sales office in Guangzhou and subsidiary in South Korea (LEHVOSS Korea)
- Business development organization in China and South Korea
- Production, engineering and testing facility in China (LEHVOSS Kunshan)

Solutions - Individually Engineered

CUSTOMIZED
POLYMER MATERIALS

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LEHVOSS Group - Customized Polymer Materials

Our Brands

LUVOCOM®
High-performance compounds

Customized High-Performance Compounds

LUVOCOM® 3F
Additive manufacturing solutions

LUVOSINT®
Additive manufacturing solutions

3D Printing Materials

LUVOCOM® P
Powder-coating solutions

Powders for Electrostatic Coating

LUVOBATCH®
Customized masterbatches

Additives and Masterbatches

Our Competences

STRUCTURAL
RESISTANT
TRIBOLOGICAL
SURFACE
CONDUCTIVE
WEIGHT
PROTECTION

CUSTOMIZED POLYMER MATERIALS

PROCESSES
DESIGN
REGULATORY
SPECIFICATION

Customized Polymer Materials

Customer Needs → Process and Material Development → Compounding

Polymers *(examples)*

	Amorphous	Semi-crystalline
High Performance Polymers	**PES, PEI, PSU, PPSU**	**PAEK, PEEK, PA46, PPA, PA9T PPS, LCP**
	TPI Fluropolymers	
Engineering Polymers	**PC, PPE-PS, PPE-PA**	**PA 6, PA 66, PA 12, PA 6.10, PET, PBT, POM, PK**
	TPU, TPE	
Standard Polymers	**ABS**	**PP, PE-LD, PE-HD**

Reinforcement

Carbon fibers
X carbon fibers
Glass fibers
Glass flakes
Glass spheres
Aramid fibers
Mineral fibers
Minerals

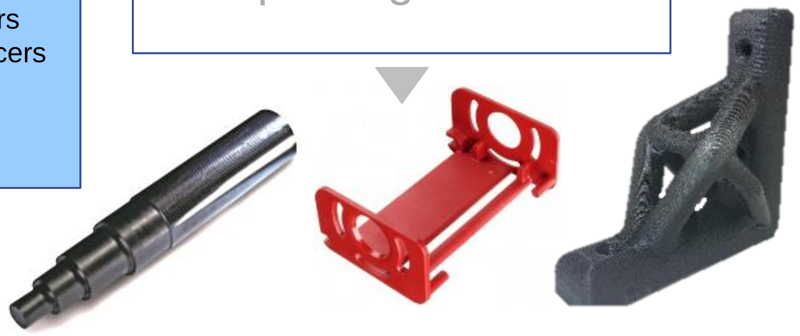
Others

Additives

PTFE
Graphite
Silicone oil
Nano-additives
CNT
Metals
Pigments
Flame retardents
Ceramics
UV stabilizers
Flow enhancers

Others

- Injection molding
- Extrusion
- Compression molding
- Powder coating
- 3D printing



CUSTOMIZED POLYMER MATERIALS

Product Highlights in a Nutshell

STRUCTURAL

- Stiffness 52 GPa
- Strength 530 MPa

CONDUCTIVE

- Thermal conductivity 40 W/mK
- Electrical resistance $10^{-0.5}$ Ω

RESISTANT

- Withstand > 500 sterilization cycles
- Continuous use temperature 320°C

WEIGHT

- Heavy 5 g/cm^3
- Light 0.9 g/cm^3

TRIBOLOGICAL

- Wear < 10^{-8} mm^3/Nm (28 m/s / 30 MPa)
- Coefficient of friction 0.04

PROTECTION

- Detection of 1 mm particle size
- Shielding effectiveness 76 dB @ 500 MHz

SURFACE

- Broadest color range for PEEK compounds
- Glossy surfaces for high strength materials

PROCESSES

- 50 % shorter annealing time for parts
- 3D printing of high-temperature polymers at room temperature
- Separation stable EMI materials

Customized Solutions for Industrial 3D-Printing – Materials, Technology and Processing

LEHVOSS
Group

CUSTOMIZED POLYMER MATERIALS

3D Printing Materials

Customized Solutions for Industrial Production

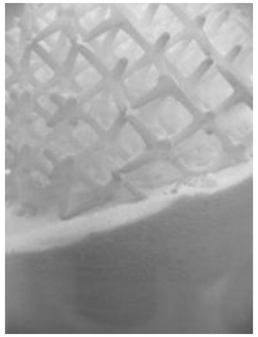
3D PRINTING MATERIALS
Experience the 3Difference

LUVOCOM® 3F Materials

- Made for extrusion based processes
- Product: pellet / filament
- Simple geometries multi-material
- Composite materials

LUVOSINT® Materials

- Made for powder fusion processes
- Product: powder
- 100 % design freedom
- Nano-filled materials



Product Overview

Material	Polymer	Modification	Color	Further information
LUVOCOM® 3F PEEK 9581 NT	PEEK	Modified neat	Natural beige	
LUVOCOM® 3F PEEK CF 9676 BK	PEEK	15% CF	Black	
LUVOCOM® 3F PEEK GF 9761 BK	PEEK	15% GF	Black	
LUVOCOM® 3F PEEK GR 9710 BK	PEEK	Thermally conductive	Black	Not for filament production
LUVOCOM® 3F PA^{HT} 9825 NT	PA^{HT}	Modified neat	Natural white	
LUVOCOM® 3F PA^{HT} 9875 NT	PA^{HT}	Modified neat	Natural white	Minimized water uptake
LUVOCOM® 3F PA^{HT} 9936 BK	PA^{HT}	Modified neat	Black	Optimized surface appearance
LUVOCOM® 3F PA^{HT} CF 9742 BK	PA^{HT}	15% CF	Black	
LUVOCOM® 3F PA^{HT} CF 9891 BK	PA^{HT}	15% CF	Black	Minimized water uptake
LUVOCOM® 3F PA^{HT} CF 9743 BK	PA^{HT}	25% CF	Black	Not for filament production
LUVOCOM® 3F PA^{HT} GK 9874 NT	PA^{HT}	10 % glass spheres	Natural white	
LUVOCOM® 3F PA^{HT} 9826 BK	PA^{HT}	Tribological	Black	
LUVOCOM® 3F PET CF 9780 BK	PET	15% CF	Black	

Further products are under development. → PPS, TPU, PP, PP/CF

Materials for Fused Filament Fabrication

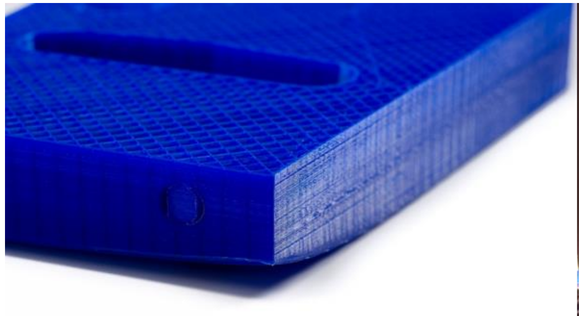
LUVOCOM® 3F

Additive manufacturing solutions

Fundamentals and Basics

Current FFF Printing Challenges

- Standard materials being used (injection/extrusion moulding grades)
- Poor processability (low repeatability, warpage, high scrap ratio)
- High anisotropy
- No engineering/HT polymers available
- Poor surface finishing



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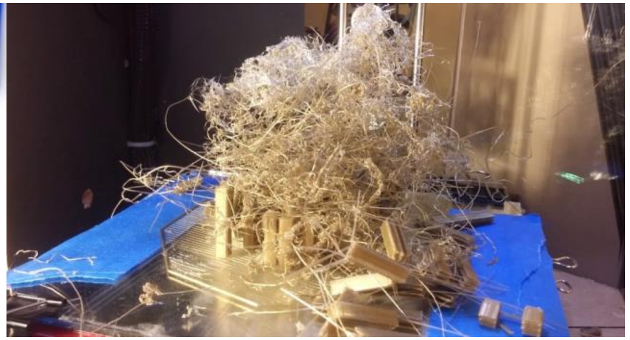


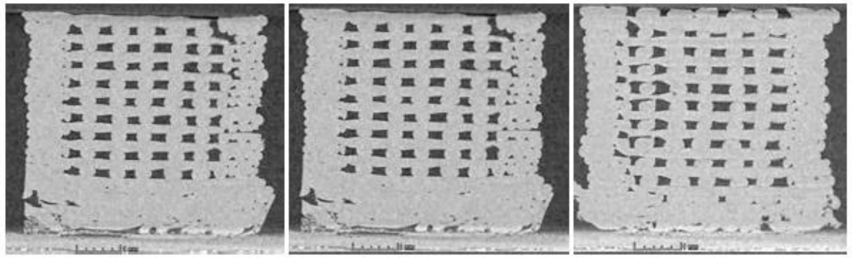
Our LUVOCOM 3F strategy

- Tailored polymers for 3D Printing (reduced anisotropy, enhanced printability)
- Broader material choice (high-performance, composites, functional)
- Focus on industrial applications
- 35 years LUVOCOM experience is in LUVOCOM 3F

LUVOCOM 3F PA^{HT} – Micro CT Analysis*

STRUCTURAL

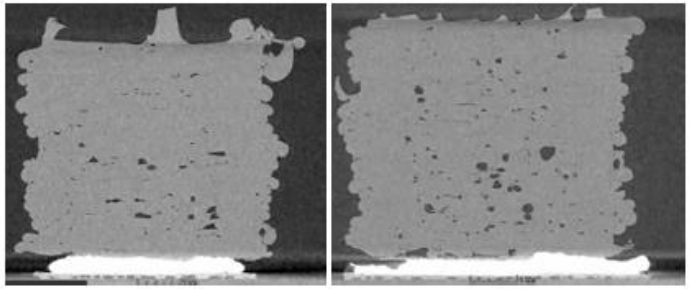
Standard PA6



245 °C 255 °C 265 °C

Printing Temperature	Porosity Measurement 1	Porosity Measurement 2
245°C	28.90%	27.73%
255°C	22.28%	22.08%
265°C	26.64%	26.45%

LUVOCOM 3F PA^{HT}



255 °C 265 °C

Printing Temperature	Porosity Measurement 1	Porosity Measurement 2
255°C	2.08%	2.02%
265°C	3.42%	4.6%

* All specimens were printed in the same machine using the same printing parameters (speed, extrusion width, extrusion multiplier, etc…)

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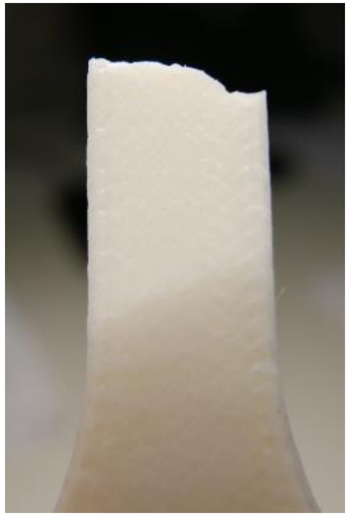
LUVOCOM 3F PA^{HT} 9875 NT – Competitive Advantage

STRUCTURAL

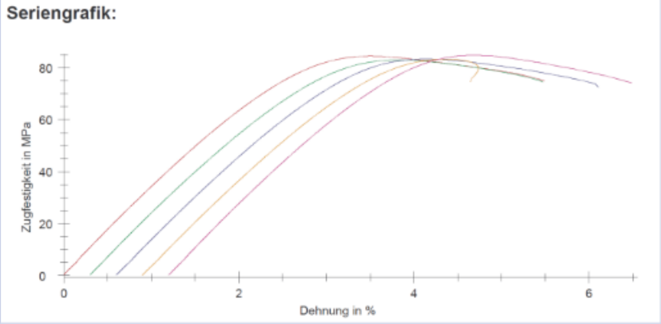
Close-up on the fracture of a 3D printed LUVOCOM 3F PA^{HT}



No Printing Pattern in break area, why is that?

1) Interdiffusion
2) Right viscosity
3) Reasonable solidification time
4) Right crystallisation after solidification

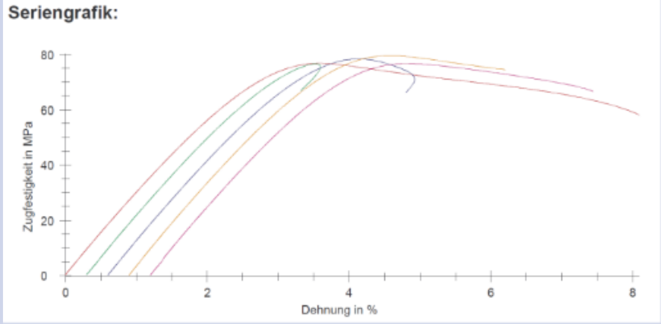
Injection Molded



Statistik:

Serie n = 5	Zugfestigkeit MPa	Dehnung bei Fmax %	Zugmodul E_t GPa	Bruchspannung MPa	Bruchdehnung %
$\bar{x}$	83,77	3,50	3,47	74,11	5,04
s	0,80	0,03	0,10	0,95	0,74
ν [%]	0,96	0,93	2,75	1,29	14,62

3D Printed (260 °C nozzle, 70 °C bed, 100% infill, ±45 ° infill orientation)

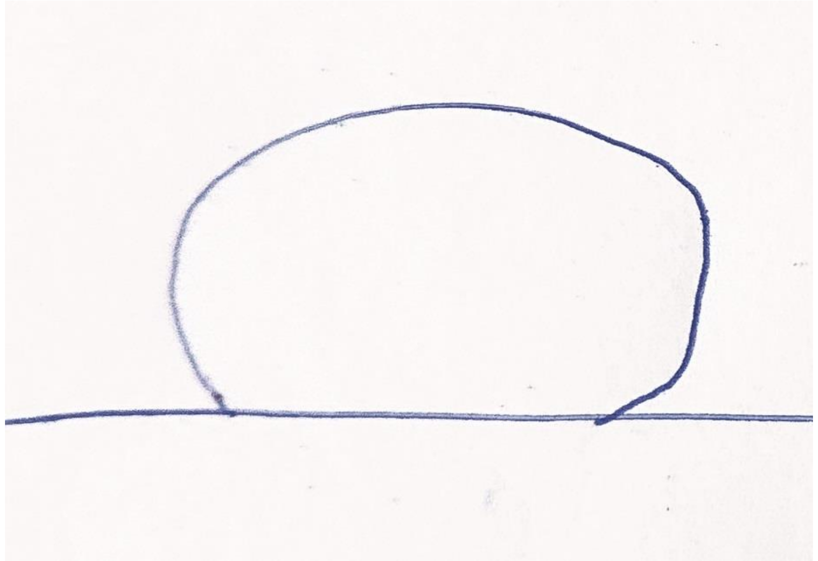


Statistik:

Serie n = 5	Zugfestigkeit MPa	Dehnung bei Fmax %	Zugmodul E_t GPa	Bruchspannung MPa	Bruchdehnung %
$\bar{x}$	77,62	3,53	3,20	66,48	5,37
s	1,31	0,18	0,09	5,80	1,94
ν [%]	1,69	5,05	2,88	8,73	36,10

1) Adhesion vs Interdiffusion

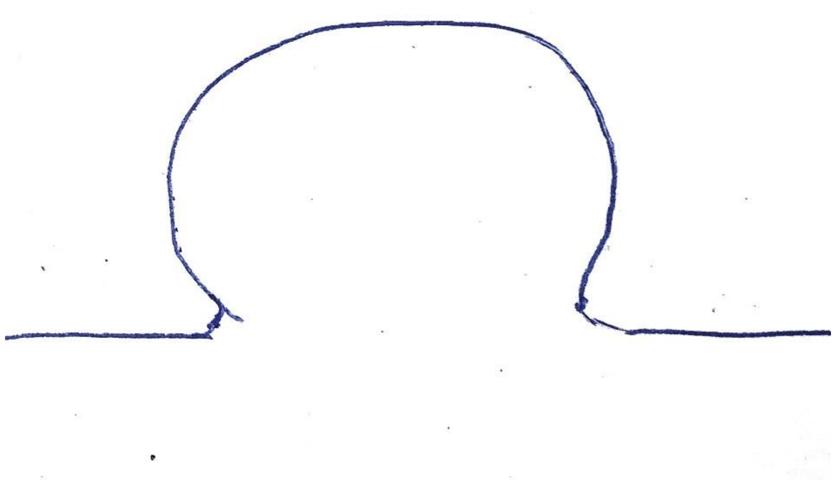
STRUCTURAL



<u>Adhesion</u>

Particle is bound by adhesion force

- Easy to achieve
- High precision
- Poor mechanics
- No thermal endurance

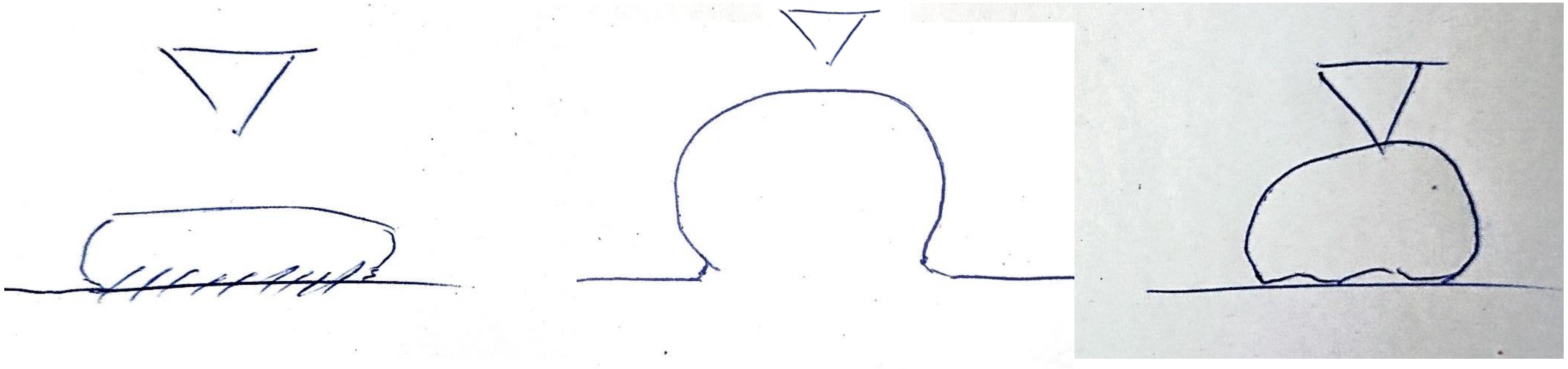


<u>Interdiffusion</u>

Particle has fused by interdiffusion

- Good mechanical Performance
- High thermal endurance
- Propper wetting essential
- Extended energy needed

2) Viscosity and print quality



Low viscosity

High MFI at Tm +20° C

- Good wetting
- Low Warp
- Good interdiffusion
- Poor precision
- Support is essential

right viscosity

Intermediate MFI at Tm +20° C

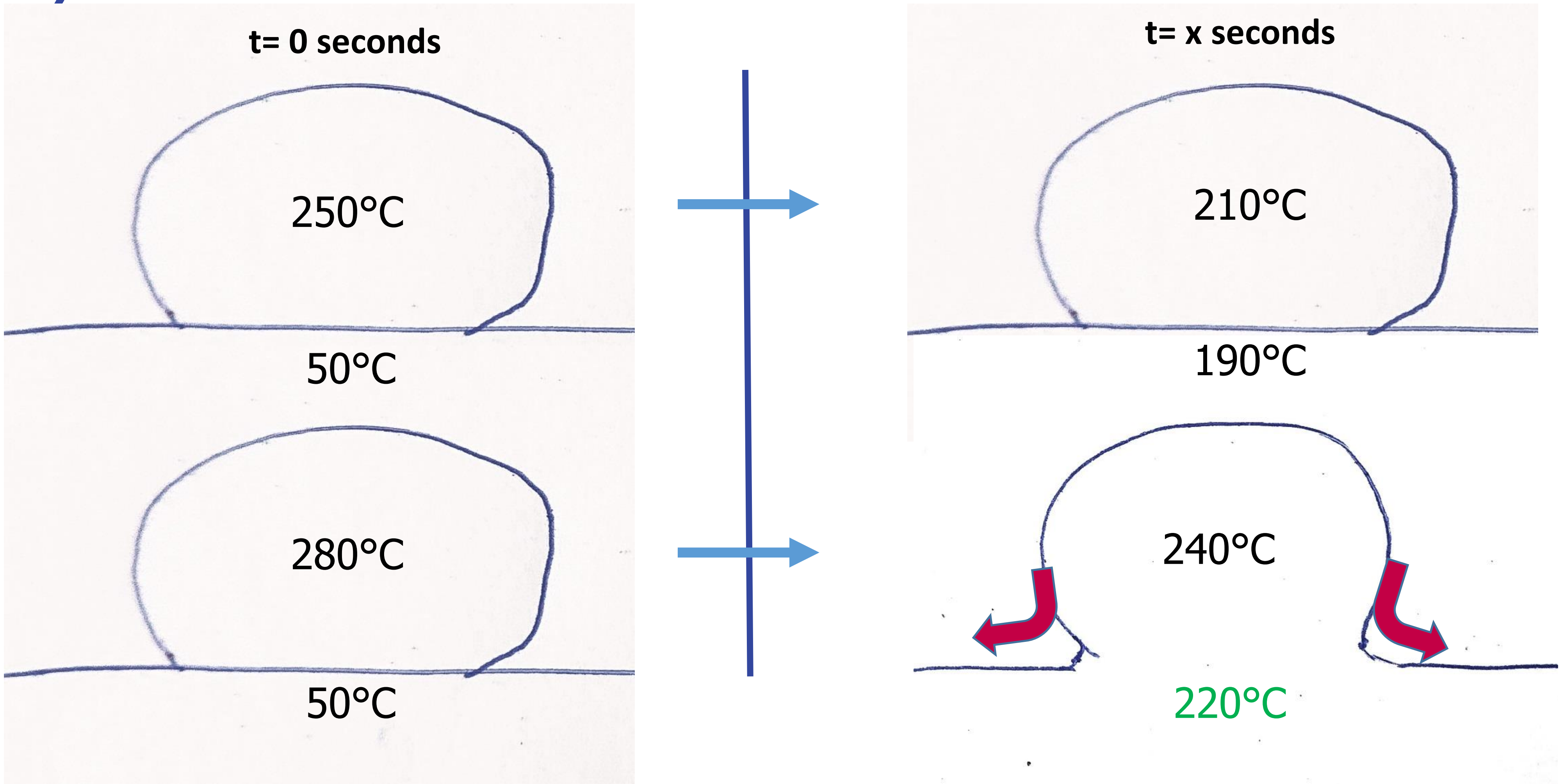
- Good wetting
- Support not essential
- Good Precision
- Interdiffusion slow but still sufficient

High viscosity

low MFI at Tm +20° C

- High Precision
- High design freedom
- Poor wetting
- Interdiffusion too slow
- Poor mechanical properties

3) Solidification time

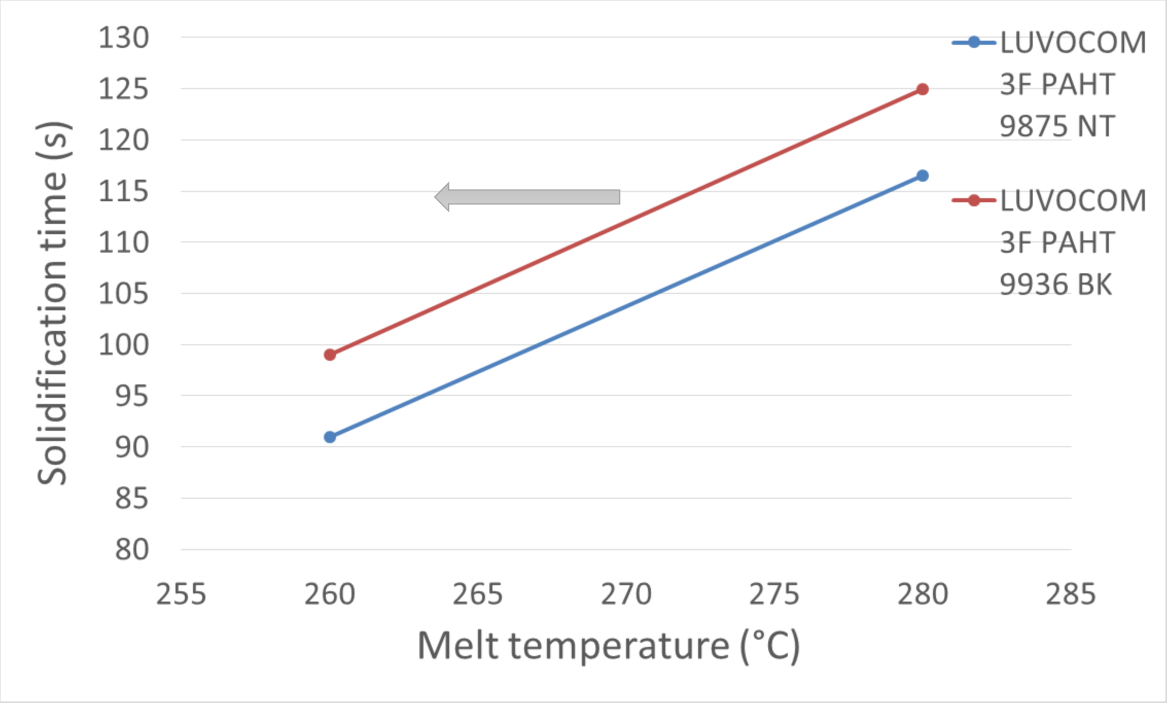


Example
PA6 with
Tm 220°C

Sufficient energy enables proper welding by interdiffusion – but what about the melt stability? → LUVOCOM PA^{HT} 3F

LUVOCOM 3F formulation technology: increase in solidification time

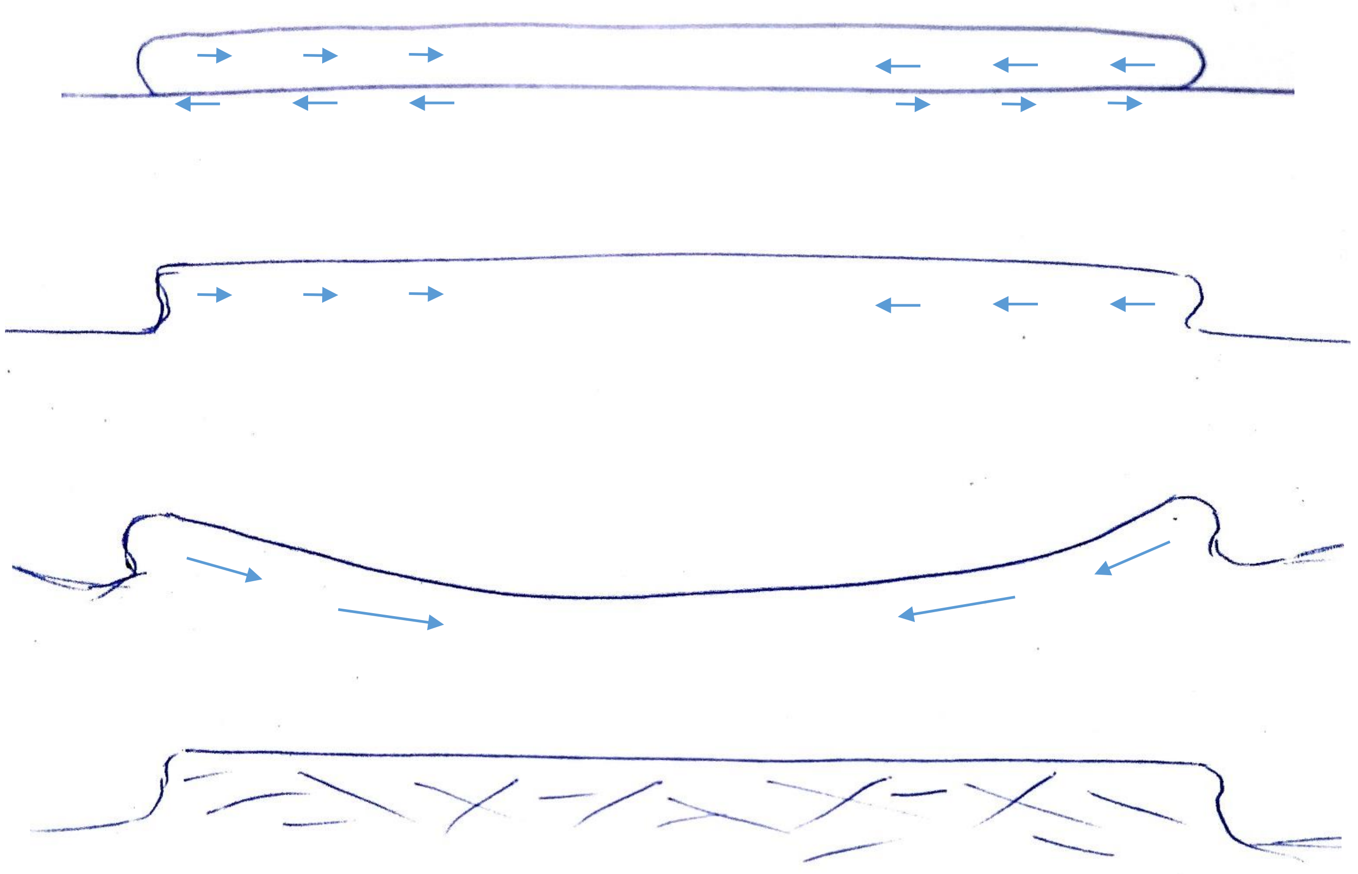
STRUCTURAL



Benefits

- Better welding and lower warping at lower temp
  → Reduction of 10°C possible
- Enabling bigger process window
- Enabling high flow materials such as PPS to interdiffuse

4) Crystallisation after solidification



<u>Adhesion</u>

Shearing /stress cracks

<u>Newly fused material</u>

slow crystallization:

stress can be compensated by relaxation if applied slowly

fast crystallization:

stress cannot be compensated leading to warpage

special additives might be used as “shear stress relief”

In any case filler help reduce warpage by reducing CTE and suppressing shrinkage stress

LUVOCOM 3F PA^{HT} with Carbon Fibers

STRUCTURAL

Carbon fibre reinforced high temperature PA (T_m= 250°C)

- PA6 similar mechanical properties but…
- …without moisture issues
- …without warpage issues

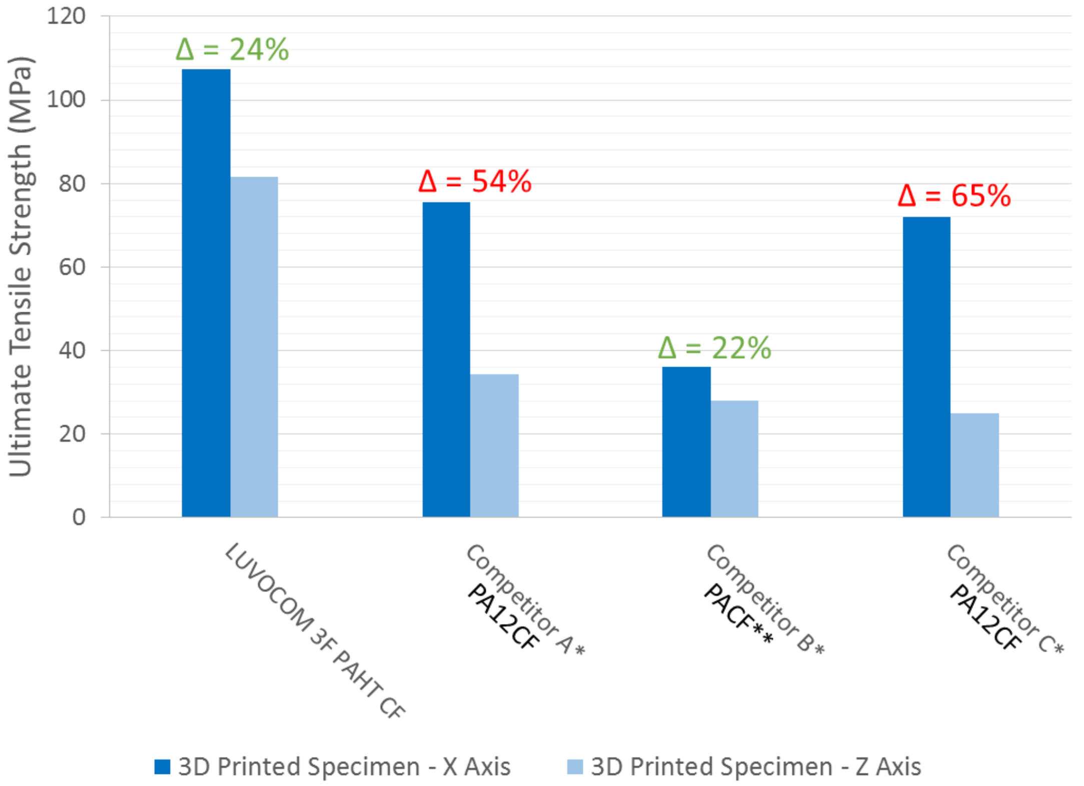
Carbon fibre are actually reinforcing

- 170 MPa strength
- 15.5 GPa Young’s modulus

LUVOCOM 3F PA^{HT} CF - Benchmark vs Market

High performance level

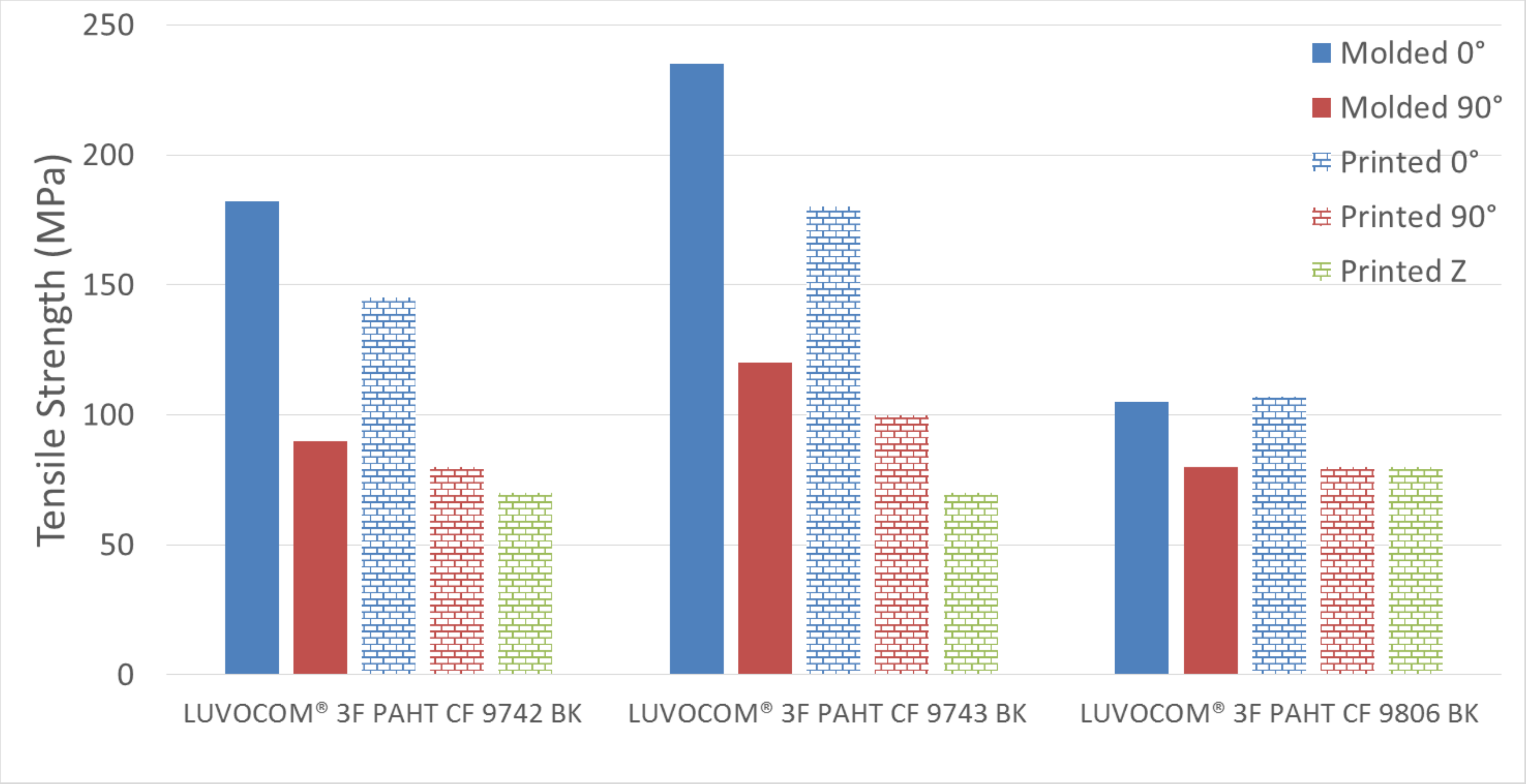
- LUVOCOM 3F better in Z as competitors in X direction



* All mechanical data was taken from technical datasheets available at the manufacturer's website.
** The type of PA is not specified by the manufacturer

LUVOCOM 3F PA^{HT} CF - Mechanical Properties

Injection molding vs. 3D Printing



Various grades

- 9742 (CF15): ca. 20% Offset
- 9743 (CF25): ca. 20% Offset
- 9806 (CF10): no Offset

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LUVOCOM® 3F

Additive manufacturing solutions

Materials for Hybrid Overmoding replacement

Overmolding of organosheets

3D Printing !!!

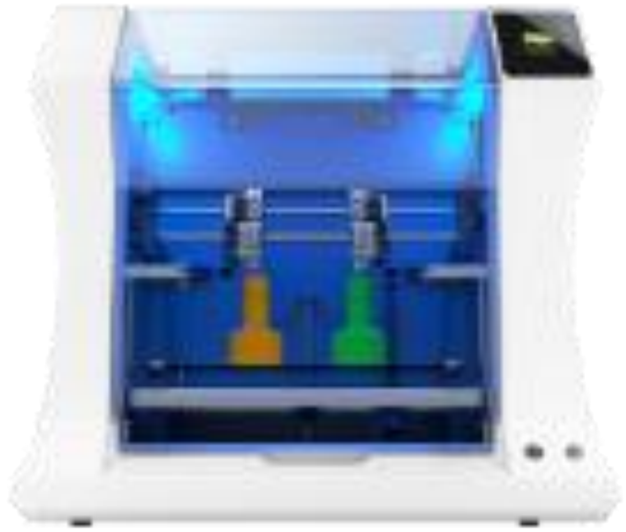
- High invests (molding, robot, IR-heating, auxalliry systems)
- High volume needed to have counterbalance invest
- Current applications: Brake pedal, Seat shell, Floor panels, Stringers etc.

Plastics Technology /LANXESS

Fraunhofer ICT

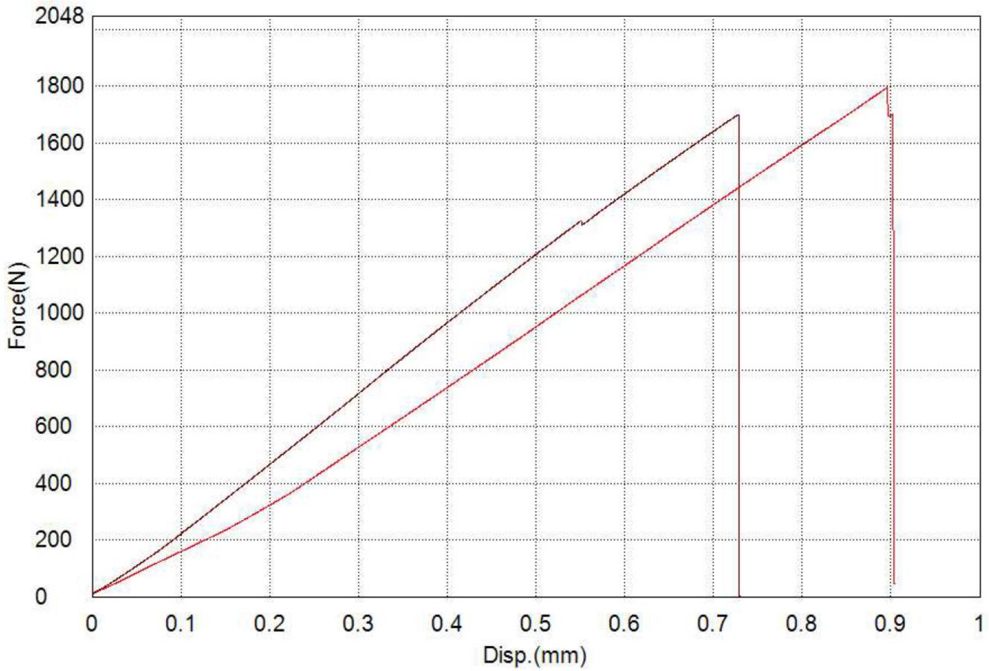
TRI-Mack/Victrex

3D printing on organosheets



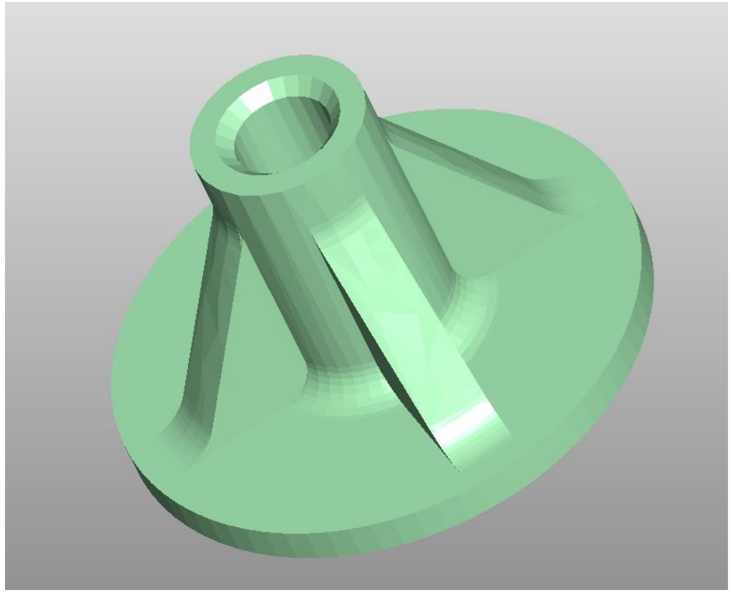
- Low invests
  - → 3D Printer
  - → No high volume needed
- LUVOCOM 3F provides similar performance as compounds for injection molding
- As in overmolding main issue is bonding between organosheet and 3F compound
  - Adaption of process technology
  - Adaption of adhesive strength and viscosity by LUVOCOM 3F formulation technology

Evaluation of bonding strength



- Heated chamber + hot air for the first 4 layers
- 3 of 5 specimen showed i.O. fracture
- Fracture strength around 20-25 MPa

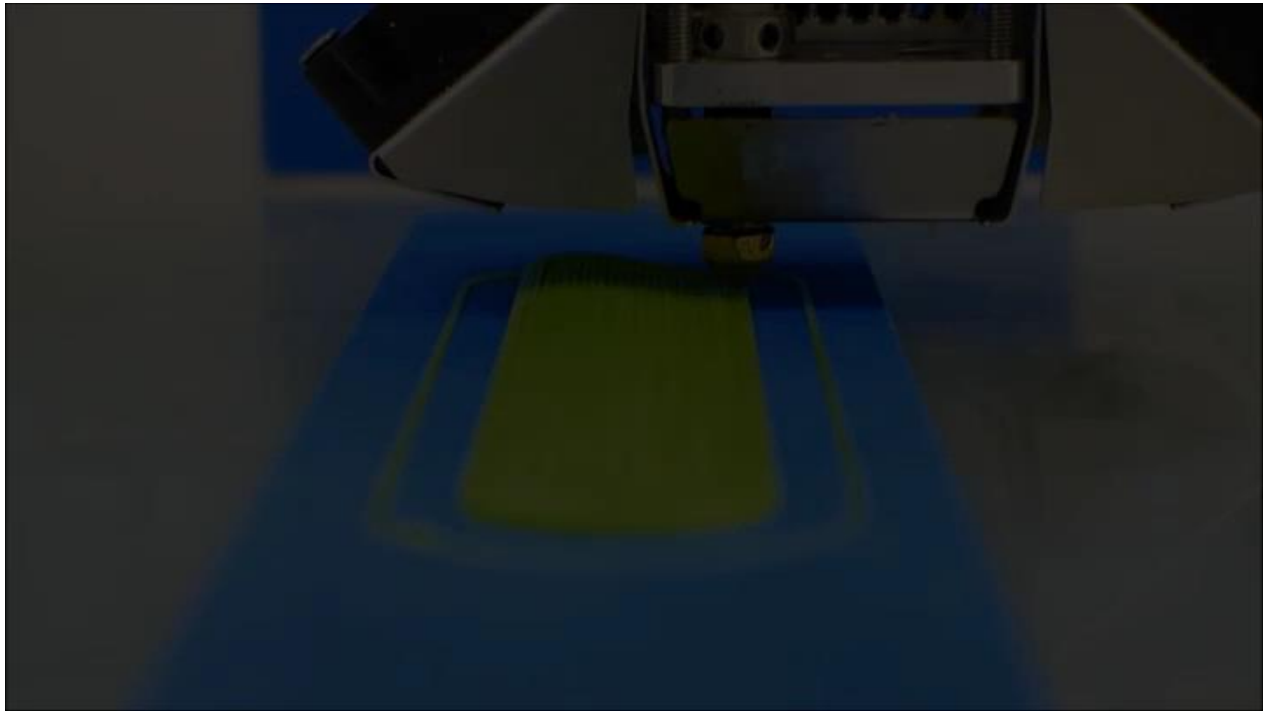
→ Z-strength around 70MPa



Future of CF reinforced 3D printing for hybrid structures

What is needed to potentially surpass injection molding?

- “Real” 3D printing by z-axis and feed rate control
    - “Controlled” anisotropy
    - Software modification needed
- Adaption of nozzle
- Placement of endless CF
- Adjustments of the 3F compounds



CUSTOMIZED POLYMER MATERIALS

LUVOCOM® 3F

Additive manufacturing solutions

Materials for thermosetting FRP technology
In yacht construction and building

Mold build up – conventional yacht building

Mold build up – conventional yacht building








Thermosetting FRPs in yacht design consists of…

- Fiber intermediates (fabrics, Pre-preg)
- Resin (Epoxy, Polyester)
- Core materials (foams, Balsa)

	PET	PVC	Balsa	LUVOCOM PAHT CF
Density (g/cm3)	0,16	0,13	0,275	1,22
Shear modulus (GPa)	0,03	0,03	0,17	7,5
Shear strength (MPa)	0,86	1,15	3,03	100-150

- **Thermoplastic bulk material as replacement for core materials?**

3D Thermoplastic bulk material as replacement for core materials!

- Flexible material deposition

  → complex and light 3D structures acting as lightweight core

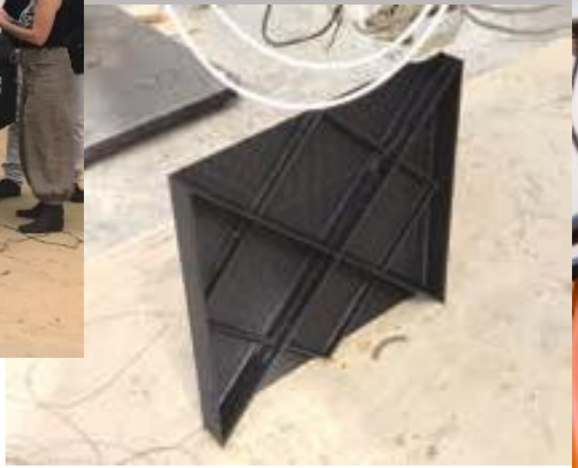
- Due to high strength, (partially) replacement of skin layers

  → weight savings

- 3D printed core can be used as a mold

© adidas

3D printing of lightweight core



- High deposition system, direct from pellets, up to 1.5 kg/h of deposition
- Due to LUVOCOM 3F technology no heating chamber is needed
- Load oriented material deposition, so called anisogrid lattice
- Material placement by 6 axis KUKA robot system
- Reduction of cycle time: 70%

LIVREA Mini Transat 650

La Rochelle
Las Palmas de Gran Canaria
Le Marin

la mini transat
la Boulangère

www.ocore.it www.livreayacht.com

LUVOCOM 3F as FRP replacement

STRUCTURAL

CUSTOMIZED POLYMER MATERIALS

Our Competences

STRUCTURAL

RESISTANT

TRIBOLOGICAL

CONDUCTIVE

WEIGHT

PROTECTION

SURFACE

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