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

CUSTOMIZED
POLYMER MATERIALS

Materials for Fused Filament Fabrication

LUVOCOM® 3F

Additive manufacturing solutions

Fundamentals and Basics

CUSTOMIZED
POLYMER MATERIALS

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

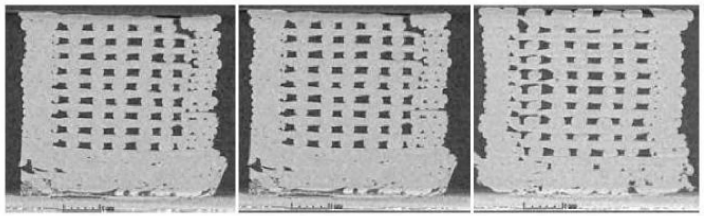
© ultimaker

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*

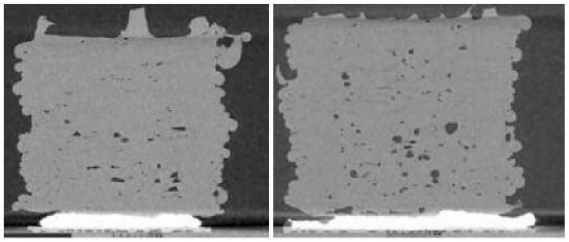
Standard PA6



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...)

CUSTOMIZED POLYMER MATERIALS

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	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 %
$\bar{x}$	83,77	3,50	3,47	74,11	5,04
s	0,80	0,03	0,10	0,95	0,74
v [%]	0,96	0,93	2,75	1,29	14,62

Statistik:

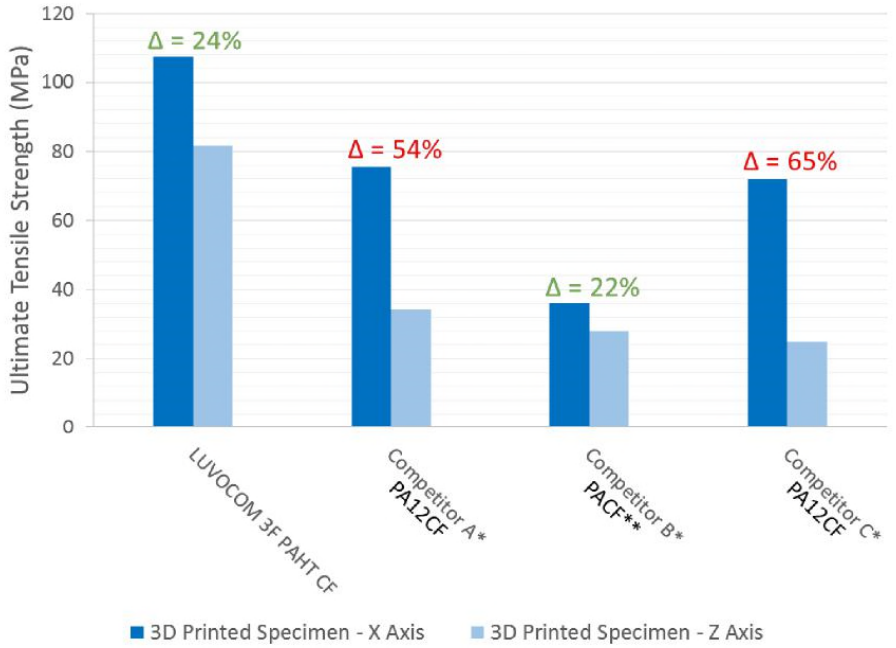
Serie n = 5	Zugfestigkeit MPa	Dehnung bei Fmax %	Zugmodul E$_t$ GPa	Bruchspannung MPa	Bruchdehnung %
$\bar{x}$	77,62	3,53	3,20	66,48	5,37
s	1,31	0,18	0,09	5,80	1,94
v [%]	1,69	5,05	2,88	8,73	36,10

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

High performance level

- LUVOCOM 3F better in Z

as competitors in X direction

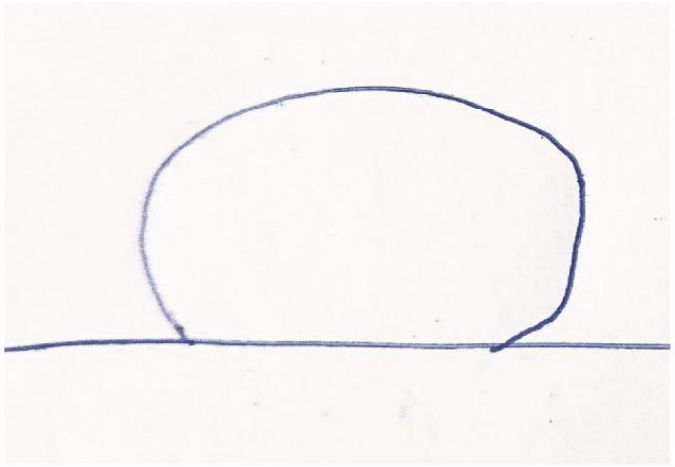


* All mechanical data was taken from technical datasheets available at the manufacturer's website.
** The type of PA is not specified by the manufacturer

CUSTOMIZED POLYMER MATERIALS

STRUCTURAL

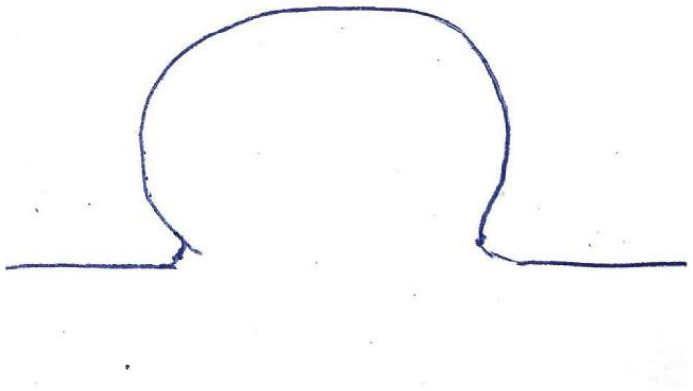
1) Adhesion vs Interdiffusion



Adhesion

Particle is bound by adhesion force

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

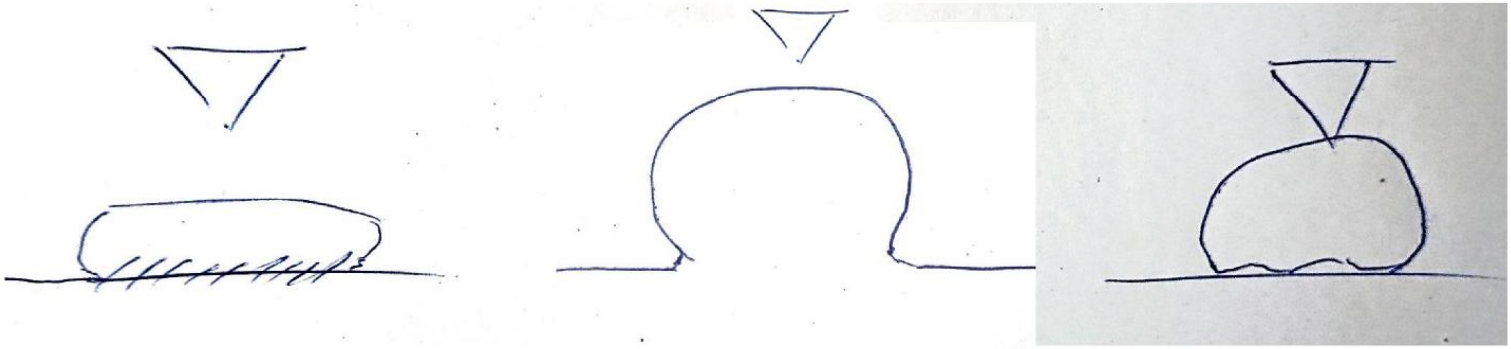


Interdiffusion

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

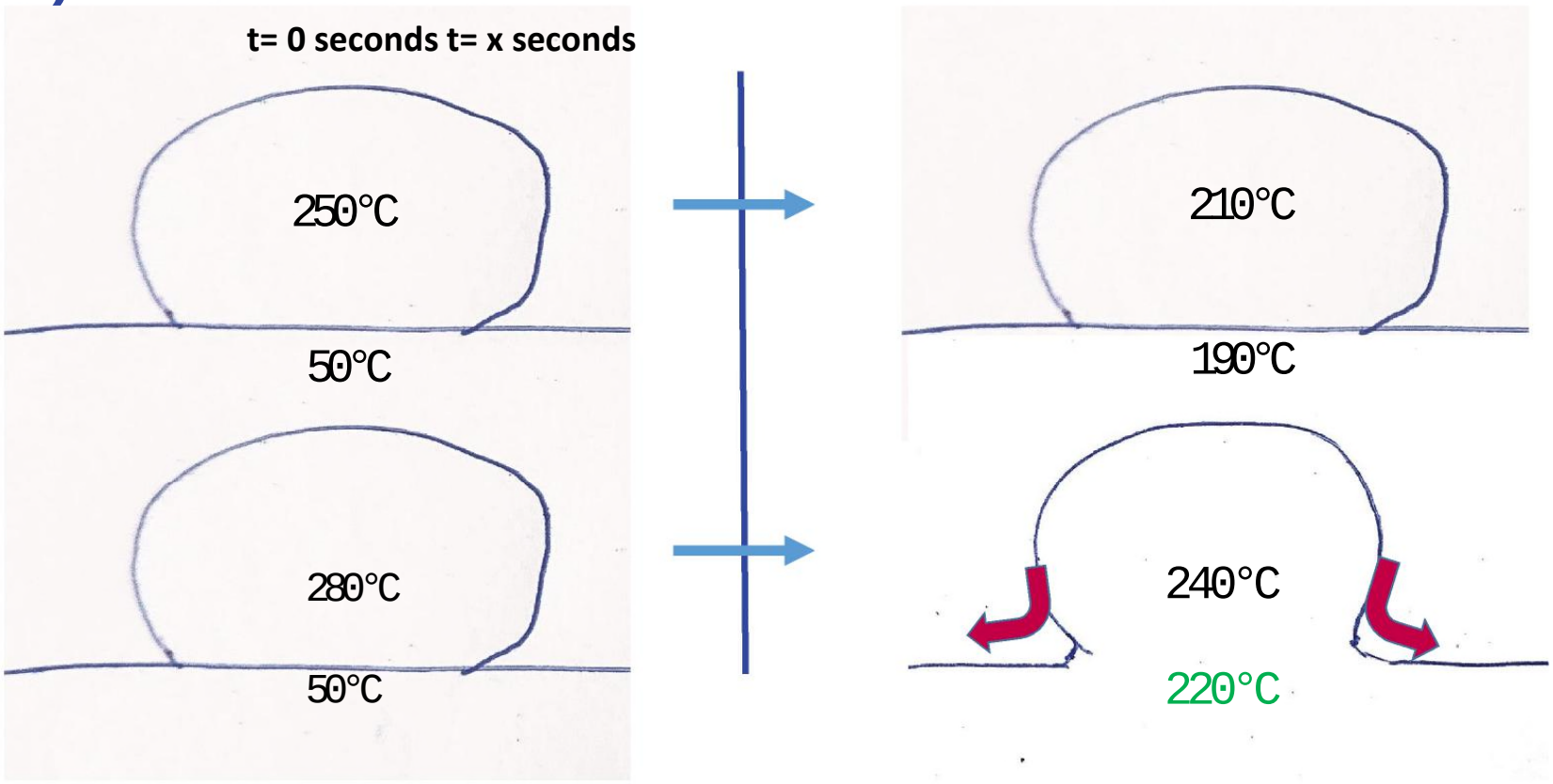
- **Good wetting**
- **Support not essential**
- **Good Precision**
- Interdiffusion slow but still sufficient

High viscosity

low MFI at Tm +20˚ C

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

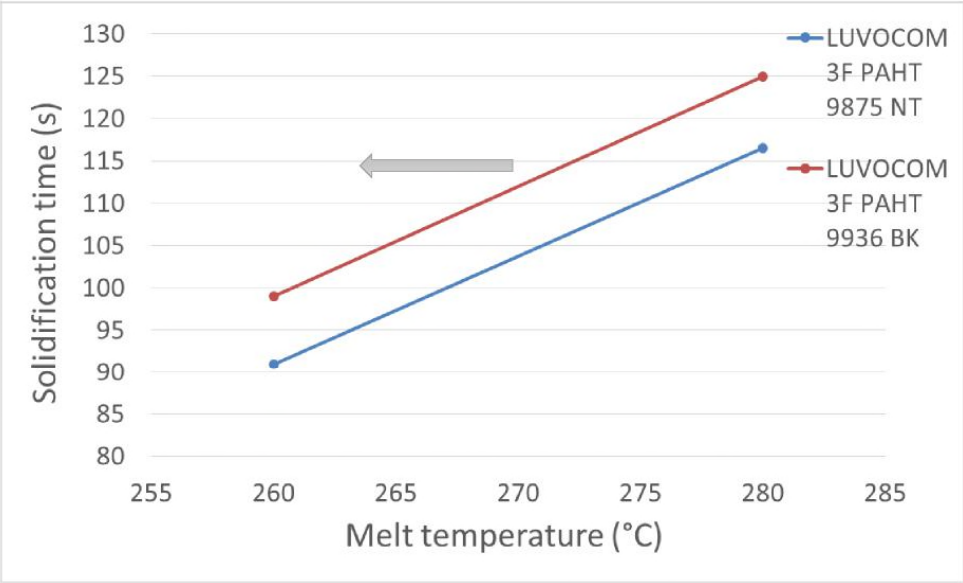
3) Solidification time



Example
PA6 with
Tm 220°C

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

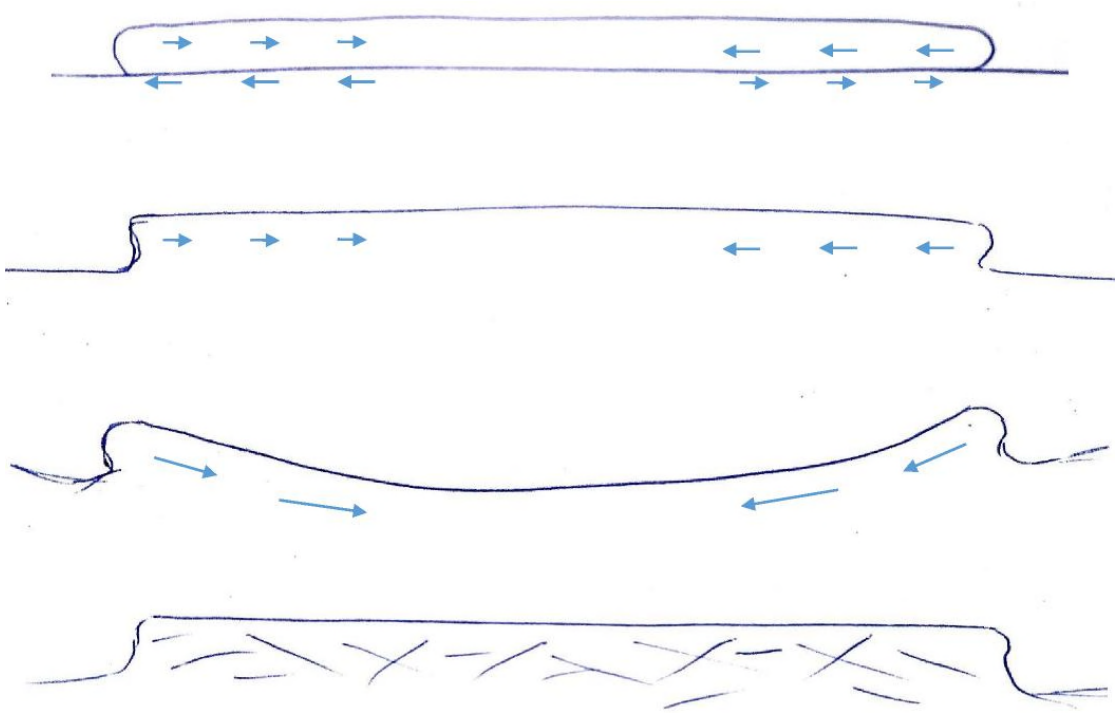
LUVOCOM 3F formulation technology: increase in solidification time



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



Adhesion

Shearing /stress cracks

Newly fused material

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

CUSTOMIZED
POLYMER MATERIALS

Product Overview

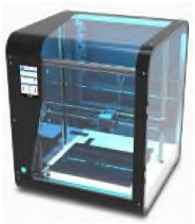
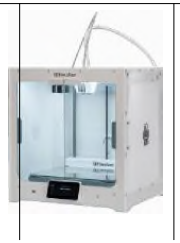
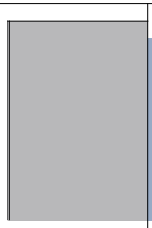
Material	Polymer	Modification	Color	Further information
LUVOCOM® 3F PEEK 9581 NT	PEEK	Modified neat	Natural beige	
LUVOCOM® 3F PEEK CF 9676 BK	PEEK	15% CF	Black	
LUVOCOM® 3F PEEK GF 9761 BK	PEEK	15% GF	Black	
LUVOCOM® 3F PEEK GR 9710 BK	PEEK	Thermally conductive	Black	Not for filament production
LUVOCOM® 3F PPS 9937 BK	PPS	Modified neat	Black	
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	
LUVOCOM® 3F PP CF 9928 BK	PP	15% CF	Black	

Further materials are under development PPS, TPU, PP, PP/CF

CUSTOMIZED
POLYMER MATERIALS

3DP Development Lab

- FFF Printers – 6 machines

						
Model	CEL Robox PRO	CEL Robox Dual	Ultimaker S5	Flux Delta	Leapfrog Bolt	Roboze One+400
Build Volume	210 x 300 x 400 mm 210	x 150 x 100 mm	330 x 240 x 300 mm	Ø170 x 210 mm	330 x 330 x 205 mm	200 x 200 x 200 mm
Extruder Type	Dual material bowden	Bowden	Bowden (2.85 mm)	Bowden	Independent Direct Drive	High Temperature Direct Drive

- Filament extruder for small batches and samples;

CUSTOMIZED POLYMER MATERIALS

LUVOCOM 3F PET

STRUCTURAL

Carbon fiber reinforced

- Easy to print
- Much higher heat resistance than competitive materials (PETG)
- No moisture issues, good dimension stability
- Good barrier properties
- Improved mechanical properties by annealing

CUSTOMIZED
POLYMER MATERIALS

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

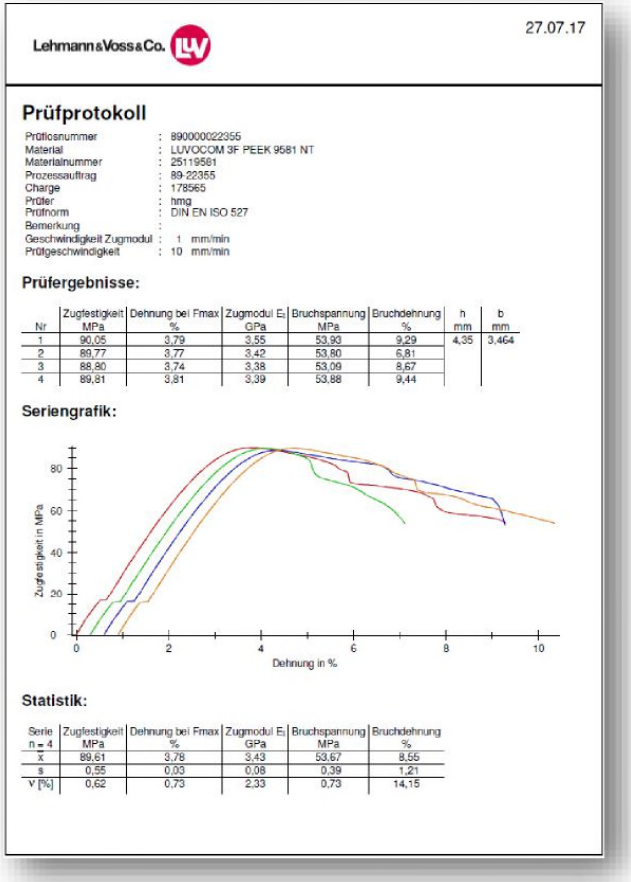
CUSTOMIZED
POLYMER MATERIALS

LUVOCOM 3F PEEK

STRUCTURAL

Unreinforced, CF and GF reinforced PEEK

- Outstanding chemical and thermal resistance
- No heated build chamber needed
- No raft needed due to no warpage



Lehmann&Voss&Co.

27.07.17

Prüfprotokoll

Prüflosnummer	:	890000022355
Material	:	LUVOCOM 3F PEEK 9581 NT
Materialnummer	:	25119581
Prozessauftrag	:	89-22355
Charge	:	178565
Prüfer	:	hmg
Prüfnorm	:	DIN EN ISO 527
Bemerkung	:	
Geschwindigkeit Zugmodul	:	1 mm/min
Prüfgeschwindigkeit	:	10 mm/min

Prüfergebnisse:

Nr	Zugfestigkeit MPa	Dehnung bei Fmax %	Zugmodul E_t GPa	Bruchspannung MPa	Bruchdehnung %	h mm	b mm
1	90,05	3,79	3,55	53,93	9,29	4,35	3,464
2	89,77	3,77	3,42	53,80	6,81		
3	88,80	3,74	3,38	53,09	8,67		
4	89,81	3,81	3,39	53,88	9,44		

Seriengrafik:

Statistik:

Serie n = 4	Zugfestigkeit MPa	Dehnung bei Fmax %	Zugmodul E_t GPa	Bruchspannung MPa	Bruchdehnung %
x	89,61	3,78	3,43	53,67	8,55
s	0,55	0,03	0,08	0,39	1,21
v [%]	0,62	0,73	2,33	0,73	14,15

CUSTOMIZED POLYMER MATERIALS

Materials for High Deposition Systems

STRUCTURAL

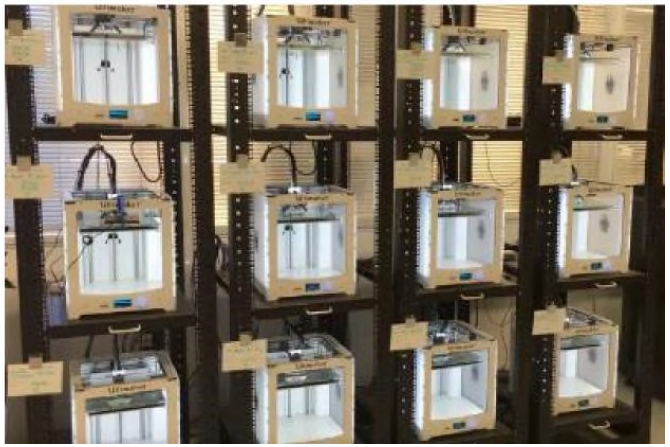
- Direct from pellets, up to 1.5 kg/h of deposition

LUVOCOM 3F PA^{HT}CF25
No heated chamber needed!

LUVOCOM 3F – Industrial View

Industrial size vs Desktop Size

=



Machine cost ≈ 400k EUR Machine cost = 3.5k EUR (114 units)

Build volume = 500 litres/build Total build time ≈ 5 days

Build volume = 9.5 litres (1083 litres) Total build time ≈ 3 days

CUSTOMIZED
POLYMER MATERIALS

Materials for Powder Fusion Processes

LUVOSINT®

Additive manufacturing solutions

CUSTOMIZED
POLYMER MATERIALS

LUVOSINT Material Strategy

Our business focus

- Development of customized laser sinter powders
- Focus is on industrial production
- Requirements: Injection molding quality of printed parts, 100% consistent

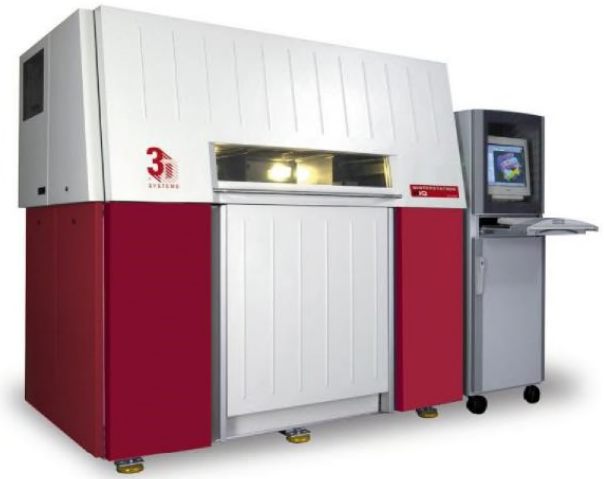
Our advantage

- 35+ years LUVOCOM experience is in LUVOSINT
- No raw materials but compounded materials
- Pellets milled/sprayed/mixed to powder product
- Result: guaranteed quality and consistency

CUSTOMIZED
POLYMER MATERIALS

LUVOSINT Development Lab

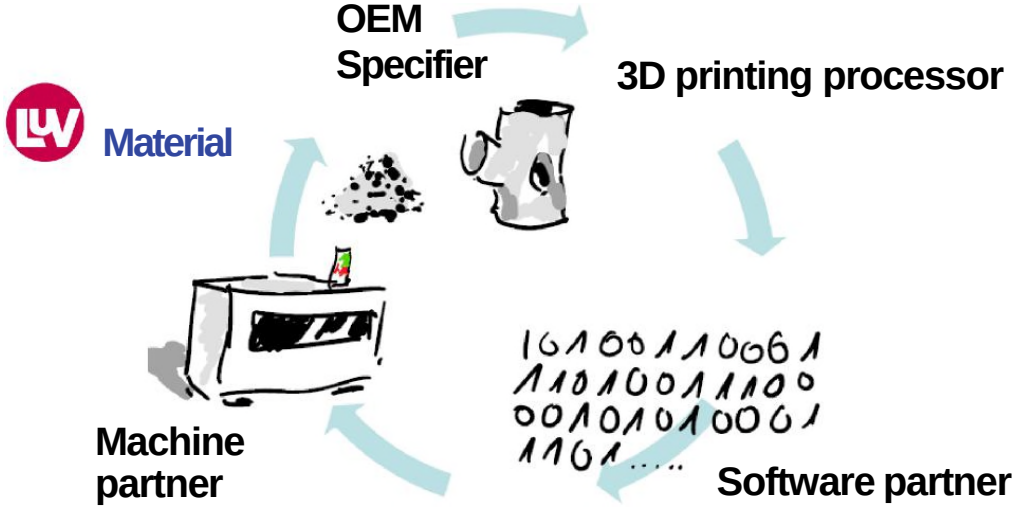
Sinterit Desktop



3D Systems - Sinterstation

Farsoon

LUVOSINT Market Approach

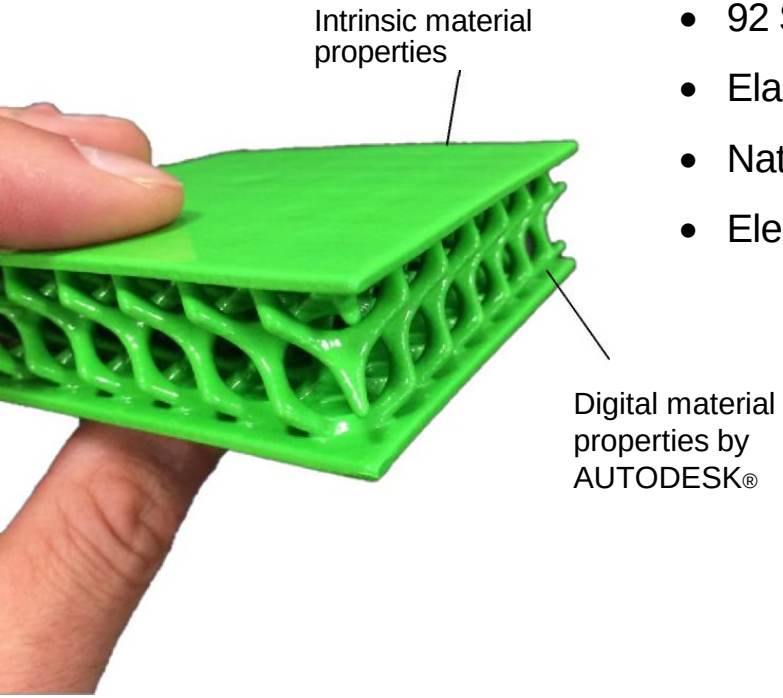


CUSTOMIZED POLYMER MATERIALS

LUVOSINT TPU X92A

Flexible parts with high strength 3D printed

STRUCTURAL



- Ester based TPU
- 92 Shore A hardness
- Elastic and extremely durable
- Natural, white, black and customized colors
- Electrically conductive grade available ($1 \cdot 10^5$ Ω)

LUVOSINT in Fashion Industry

LUVOSINT TPU is established in 3D printed wearables and footwear

© adidas

© Under Armour © PEAK Sport

CUSTOMIZED
POLYMER MATERIALS

LUVOSINT in Orthopedics

LUVOSINT TPU at the end of a fully digital process chain

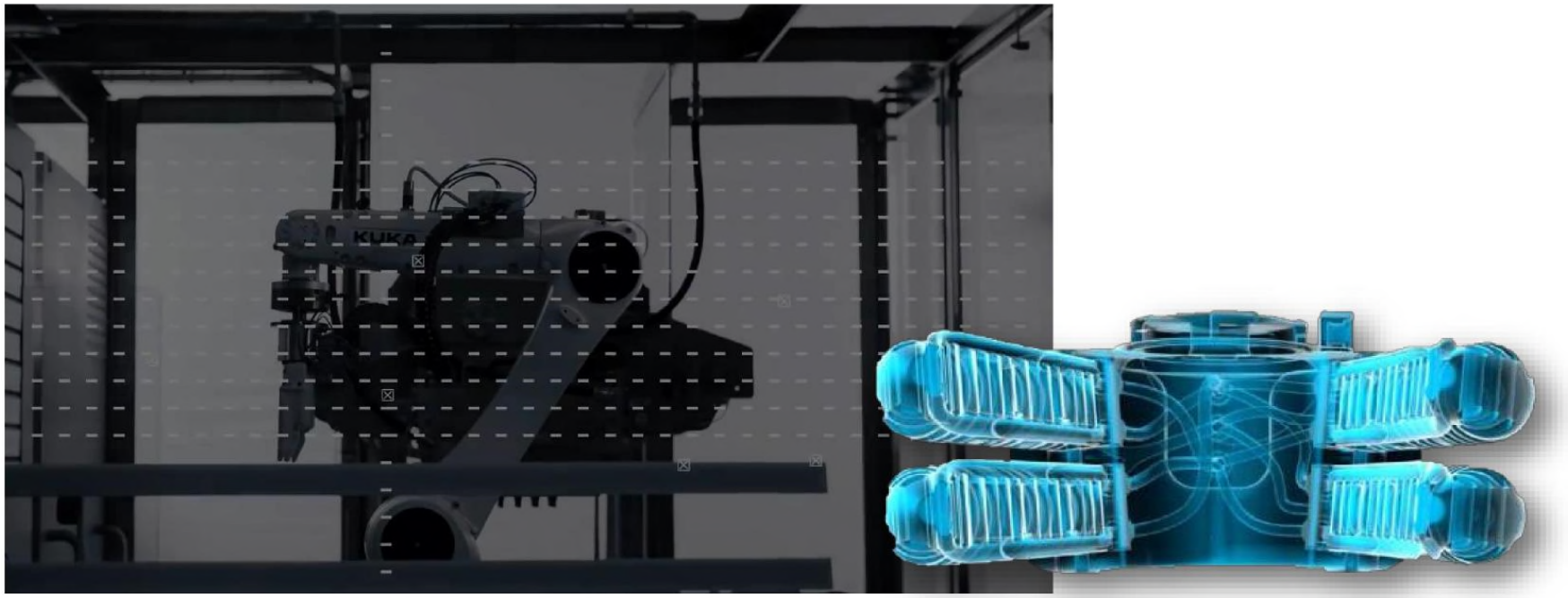


CUSTOMIZED
POLYMER MATERIALS

LUVOSINT in Industrial Applications

STRUCTURAL

Pneumatic robot grippers 3D printed with LUVOSINT TPU and LUVOSINT PP



CUSTOMIZED
POLYMER MATERIALS

LUVOSINT in Industrial Applications

STRUCTURAL

LUVOSINT TPU is used in 3D printed AIRSKIN® safety technology

CUSTOMIZED
POLYMER MATERIALS

LUVOSINT PP 9703 WT

parts offering very high chemical resistance

- Easy-to-print PP due to antistatic formulation
- Based on random-copo PP-R
- Tough and light-weight
- High chemical resistance
- Weldable
- ESD properties $1 \cdot 10^{11}$ Ω
- Toughness modified grades on request

Printing Farm Concept

Powder Bed Fusion

Industrial size vs. Desktop size

Machine cost ≈ 750k EUR

Build volume = 150 litres/build **Total build time ≈ 90 hours**

Machine cost = 10k EUR (75 units)

Build volume = 8.7 litres (653 litres) **Total build time ≈ 32 hours**

CUSTOMIZED
POLYMER MATERIALS

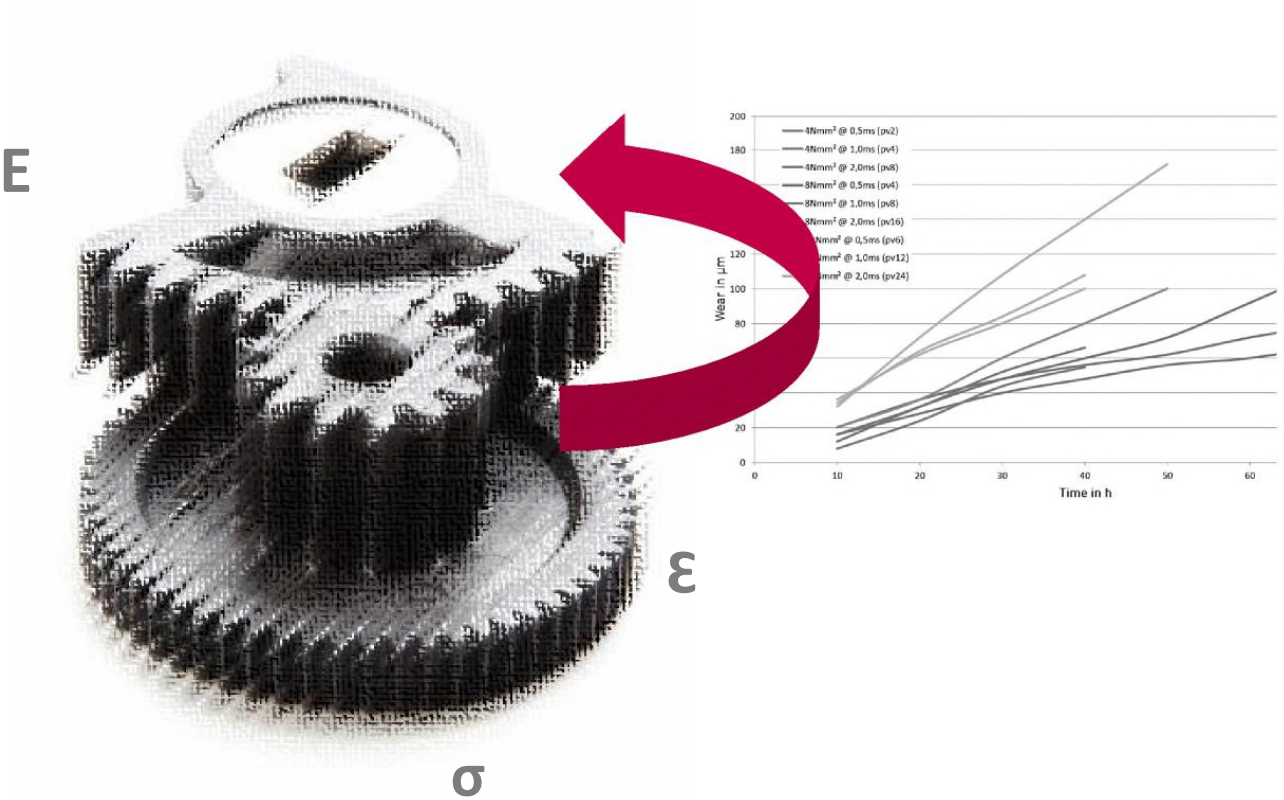
Summary LEHVOSS 3D Printing Materials

- Tailored polymers to 3D Printing for different processes
  - Improved layer bonding
  - Enhanced printability (warping control, increased speed)
- Broader material choice (high-performance, composites)
- Functional Materials (ESD, thermally conductive, electrical conductive; tribological applications)
- Injection molding quality of printed parts, 100 % consistent

Case Studies

E

pv



ε

σ

CUSTOMIZED
POLYMER MATERIALS

Exhaust System for Racing Motorbikes

STRUCTURAL

CUSTOMIZED
POLYMER MATERIALS

Exhaust System for Racing Motorbikes

Requirements:

- High strength
- Low weight
- High temperature resistance up to 250°C

CUSTOMIZED
POLYMER MATERIALS

Exhaust System for Racing Motorbikes

Material choice:

LUVOCOM 3F PEEK with carbon fibers

Density 1.40 g/cm3
Tensile strength 176 MPa
E-modulus 14.5 GPa

3D printed on Roboze in non-heated chamber

5 times
weight reduction to steel

130%
cost reduction to CFRP

CUSTOMIZED
POLYMER MATERIALS

Footrest for Racing Motorbikes

STRUCTURAL

CUSTOMIZED
POLYMER MATERIALS

Footrest for Racing Motorbikes

Requirements:

- High strength
- Low weight
- High temperature resistance up to 200°C

CUSTOMIZED
POLYMER MATERIALS

Footrest for Racing Motorbikes

Material choice:

LUVOCOM 3F PEEK

Density 1.31 g/cm3
Tensile strength 97 MPa
E-modulus 3.8 GPa

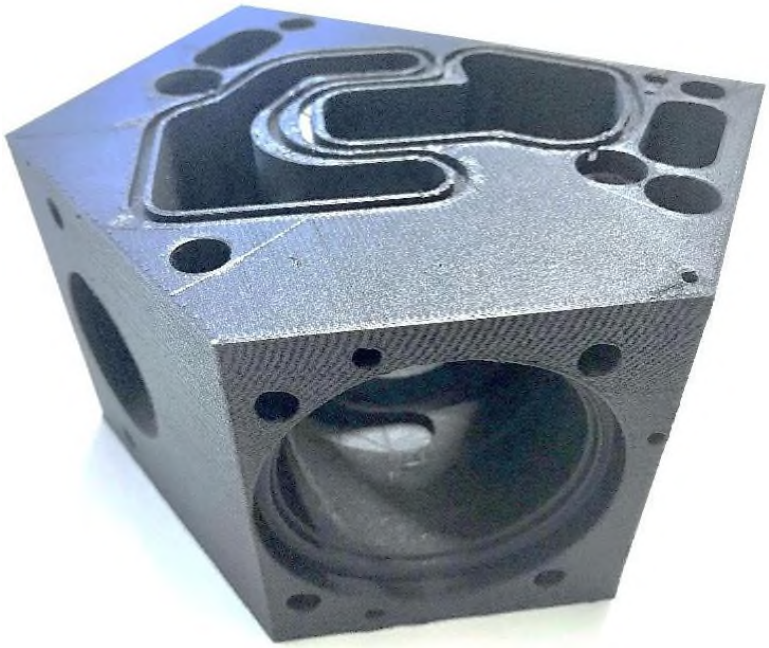
3D printed on Roboze in non-heated chamber

52%
weight saving
to aluminium

CUSTOMIZED
POLYMER MATERIALS

STRUCTURAL

Machine Part

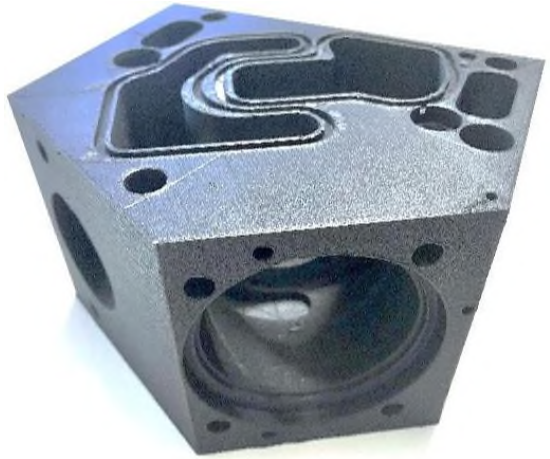


CUSTOMIZED
POLYMER MATERIALS

Machine Part

Requirements:

- High strength
- Oil resistant
- Temperature resistance up to 120°C
- Dimension stability
- Good surface quality
- Cost effective



CUSTOMIZED
POLYMER MATERIALS

Machine Part

Material choice:

LUVOCOM 3F PA^{HT} CF

Density 1.25 g/cm3
Tensile strength 170 MPa
E-modulus 15 GPa

3D printed on CEL Robox in non-heated chamber

40%
cost saving
to stock shape
solution

CUSTOMIZED
POLYMER MATERIALS

Lever for Coffee Processing Machine

STRUCTURAL

CUSTOMIZED
POLYMER MATERIALS

Lever for Coffee Processing Machine

Requirements:

- High strength
- Temperature resistance up to 100°C
- Dimension stability
- Good surface quality
- Cost effective

CUSTOMIZED
POLYMER MATERIALS

Lever for Coffee Processing Machine

Material choice:

LUVOCOM 3F PA^{HT} CF

Density 1.25 g/cm3
Tensile strength 170 MPa
E-modulus 15 GPa

3D printed on 3NTR in non-heated chamber

80%
cost saving
to injection molded
version

CUSTOMIZED
POLYMER MATERIALS

Mount for Monitor of Medical Diagnostic Machines

STRUCTURAL

Mount for Monitor of Medical Diagnostic Machines

Requirements:

- High strength
- Chemical resistance
- Dimension stability
- Good surface quality
- Cost effective
- 4 different parts. 5000 mounts / year

CUSTOMIZED
POLYMER MATERIALS

Our Competences

STRUCTURAL · RESISTANT · TRIBOLOGICAL · CONDUCTIVE · WEIGHT · PROTECTION · SURFACE → CUSTOMIZED POLYMER MATERIALS

Europe & Head Office
Lehmann&Voss&Co. KG
Alsterufer 19
20354 Hamburg
Germany
Tel +49 40 44 197-250
Fax +49 40 44 197-487
Email: luvocom@lehvoss.de

North-America
LEHVOSS North America, LLC
185 South Broad Street
Pawcatuck, CT 06379
USA
Tel +1-855-681-3226
Fax +1 860 495 2047
Email info@lehvoss.com

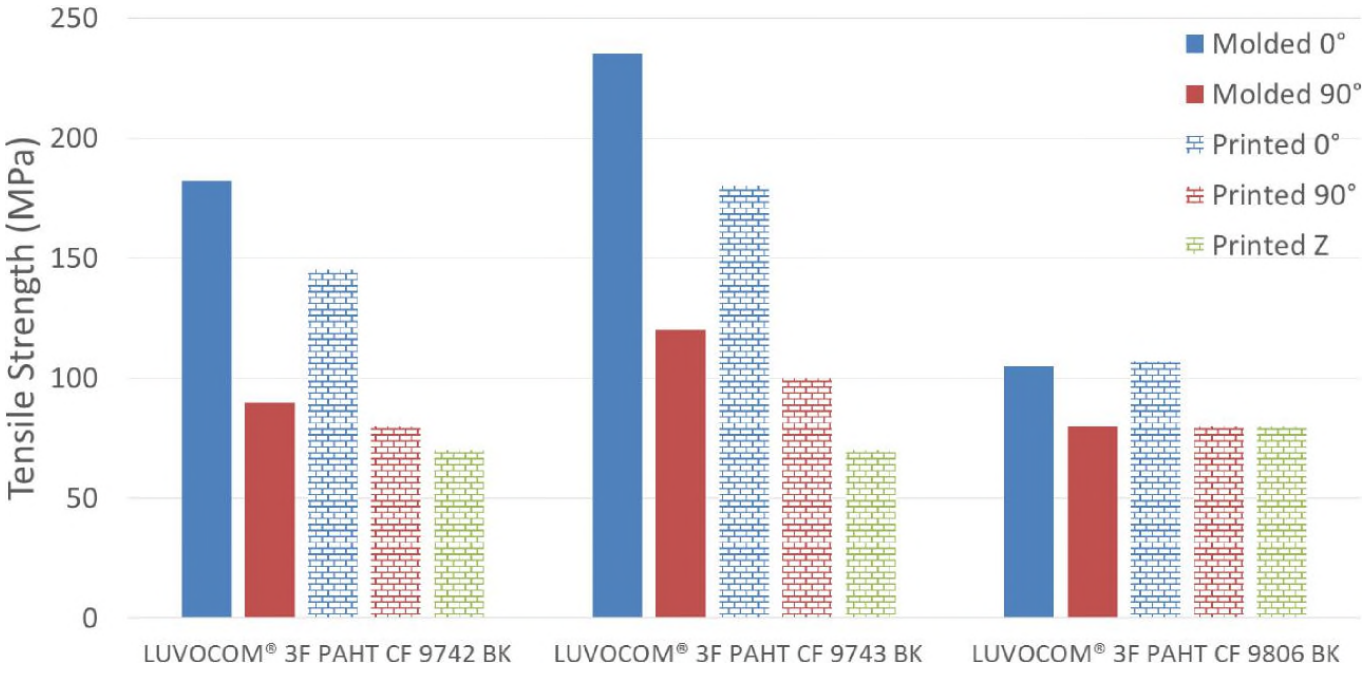
Asia
LEHVOSS (Shanghai) Chemical Trading Co., Ltd.
Unit 4805 Maxdo Centre
8 Xingyi Road, Changning District
Shanghai 200336
China
Tel +86 21 6278 5181
Email info@lehvoss.cn

We are members of:

PlasticsEurope · SKZ Das Kunststoff-Zentrum · FVA Forschungsvereinigung Antriebstechnik e.V. · FASERINSTITUT FIBRE BREMEN · Elastopôle · tmp · Mobility Additive

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

Injection molding vs. 3D Printing



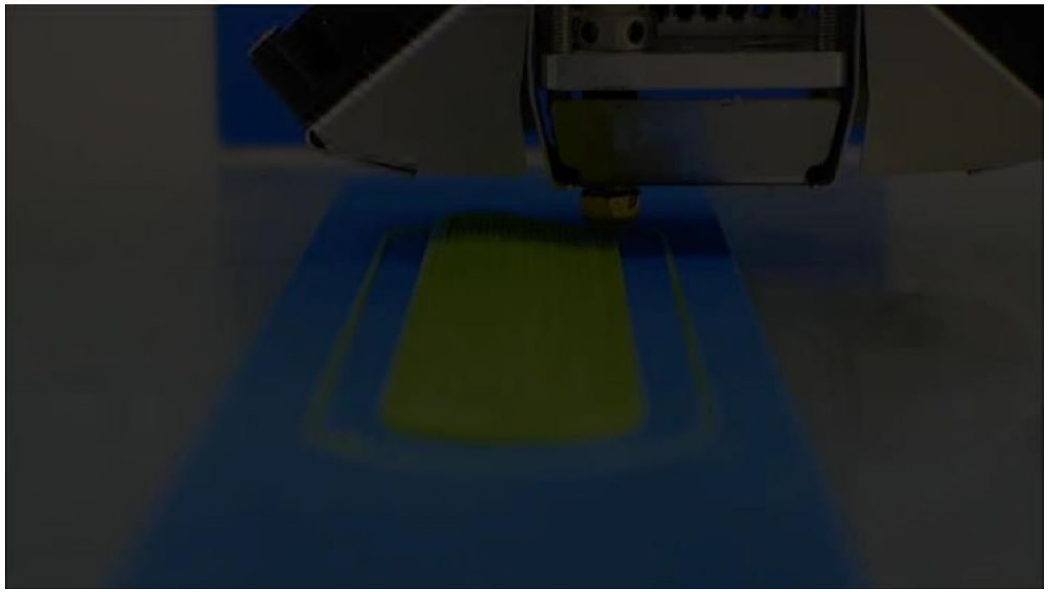
Various grades

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

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

CUSTOMIZED
POLYMER MATERIALS

Mold build up – conventional yacht building

CUSTOMIZED
POLYMER MATERIALS

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

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

3DThermoplastic 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

CUSTOMIZED
POLYMER MATERIALS

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%

CUSTOMIZED POLYMER MATERIALS

STRUCTURAL

LIVREA Mini Transat 650

La Rochelle
Las Palmas de
Gran Canaria
Le Marin
la mini transat
la Boulangère

www.ocore.itwww.livreayacht.com

CUSTOMIZED POLYMER MATERIALS

STRUCTURAL

LUVOCOM 3F as FRP replacement

CUSTOMIZED
POLYMER MATERIALS

Our Competences

STRUCTURAL · RESISTANT · TRIBOLOGICAL · CONDUCTIVE · WEIGHT · PROTECTION · SURFACE → CUSTOMIZED POLYMER MATERIALS

Europe & Head Office
Lehmann&Voss&Co. KG
Alsterufer 19
20354 Hamburg
Germany
Tel +49 40 44 197-250
Fax +49 40 44 197-487
Email: luvocom@lehvoss.de

North-America
LEHVOSS North America, LLC
185 South Broad Street
Pawcatuck, CT 06379
USA
Tel +1-855-681-3226
Fax +1 860 495 2047
Email info@lehvoss.com

Asia
LEHVOSS (Shanghai) Chemical Trading Co., Ltd.
Unit 4805 Maxdo Centre
8 Xingyi Road, Changning District
Shanghai 200336
China
Tel +86 21 6278 5181
Email info@lehvoss.cn

We are members of:

PlasticsEurope · SKZ Das Kunststoff-Zentrum · FVA Forschungsvereinigung Antriebstechnik e.V. · FASERINSTITUT FIBRE BREMEN · Elastopôle · tmp · Mobility Additive