Understanding Process Requirements for Additive Manufacturing on the example of a Beam-Based Process for Plastic Powders

GAFOE 2013

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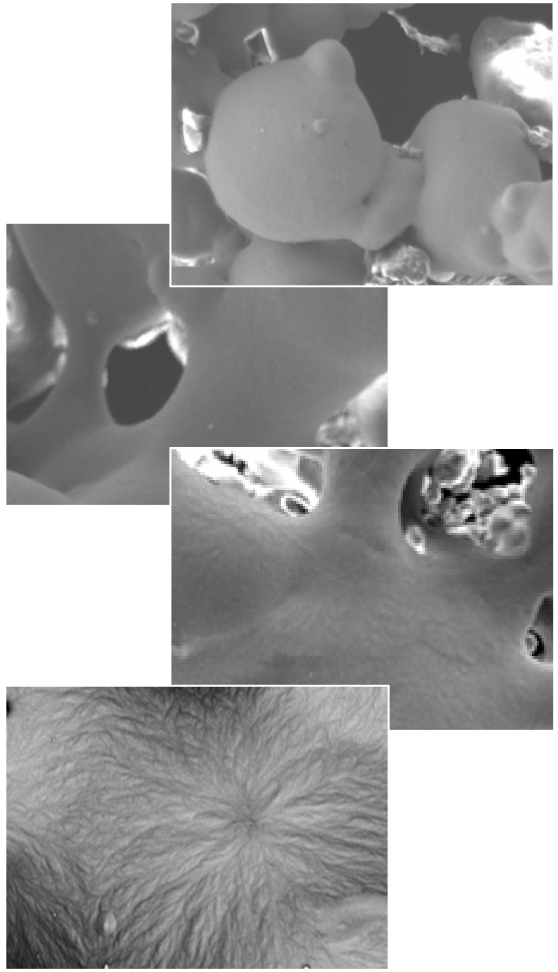
- FIT Group
- Introduction to the process
- Typical implementation of the process (SoA)
  - Preheating
  - Powder coating
- Economical and technical challenges for AM
- Solution statements for AM
  - Powder shuttle technology
  - Enhanced recyclability
- Conclusions and road map

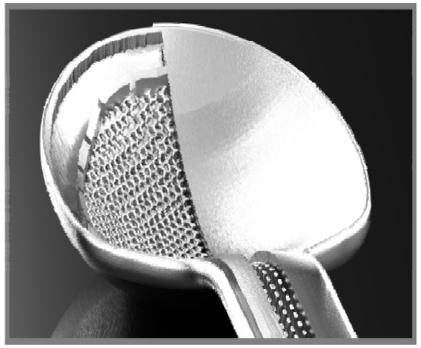


FIT Group

FIT prototyping
DO IT QUICK – GET IT RIGHT

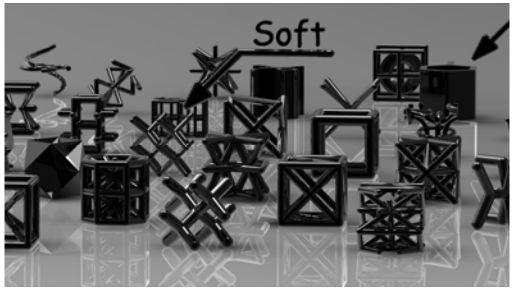
- Concept and design models
- Technical prototypes
- Prototype tooling and injection molding

FIT production
ABSOLUTELY ADDITIVE



- Additive Engineering
- Additive serial production (direct und indirect)
- Medical applications / individual implants
- Innovative tool cooling (Skin Freeze)

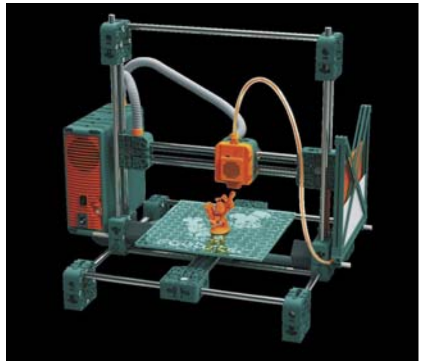
netFabb®
new age fabbing software



Software for Additive Manufacturing

- Data preparation and data repair
- Selective Space Structures
- Automated tool path planning and machinery control

sintermask



Fabbster Kit 11.1

sintermask

- SMS high productive additive manufacturing
- Stick Deposition Modeling (SDM), Fabbster Kit

Additive Processing

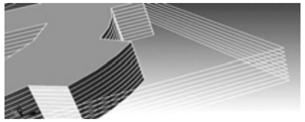
Pre processing | **Processing** | **Post processing**

e.g. Selective Laser Sintering or Selective Laser Melting

Set up apparatus

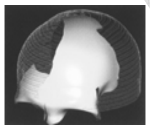
[e.g. EOSINT P380 EOS GmbH]

[Prechtl.]

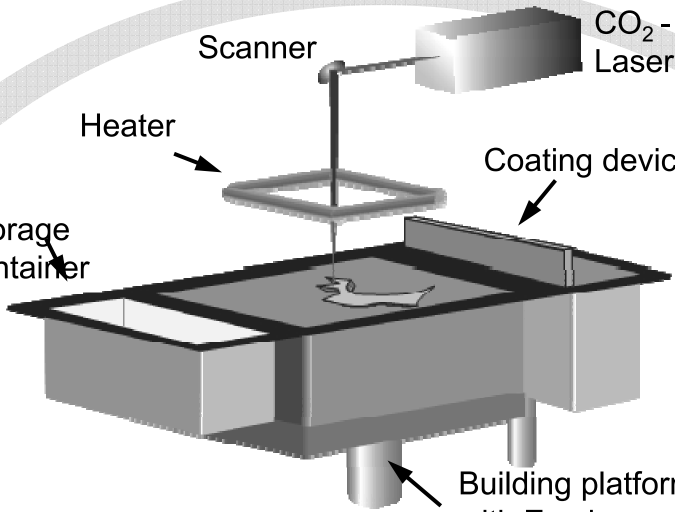


Generate layer and contur data

3D CAD Modell

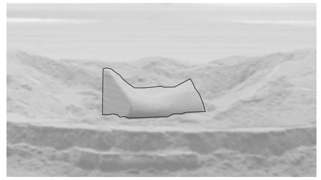


[FhG UMSICHT]



Thermoplastic parts, typical Polyamid 12 z. B. PA2200

Blood conseve container for centrifuge, Q: EOS



Unpacking, cleaning and identifying parts

Surface finish

[W.B.Wasserstrahl-Schneidtechnik GmbH]

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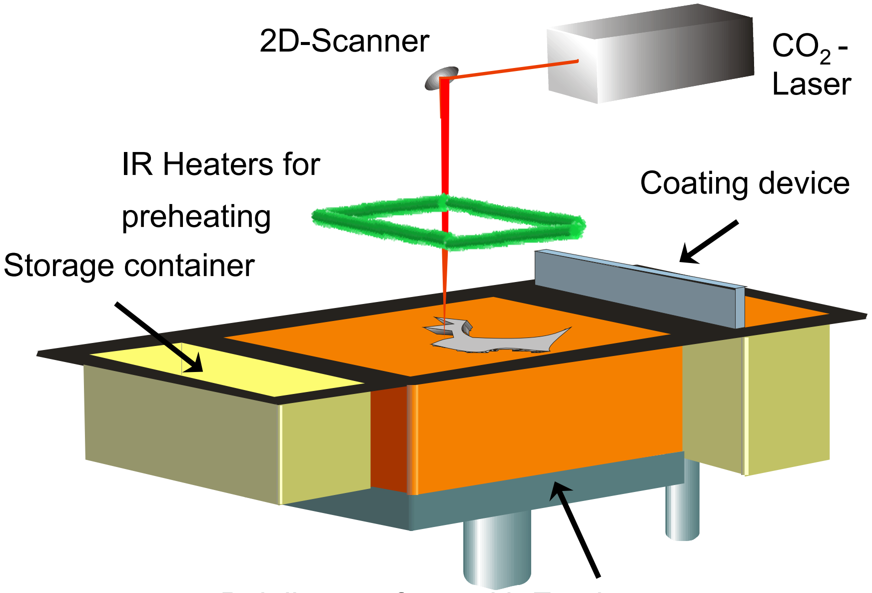
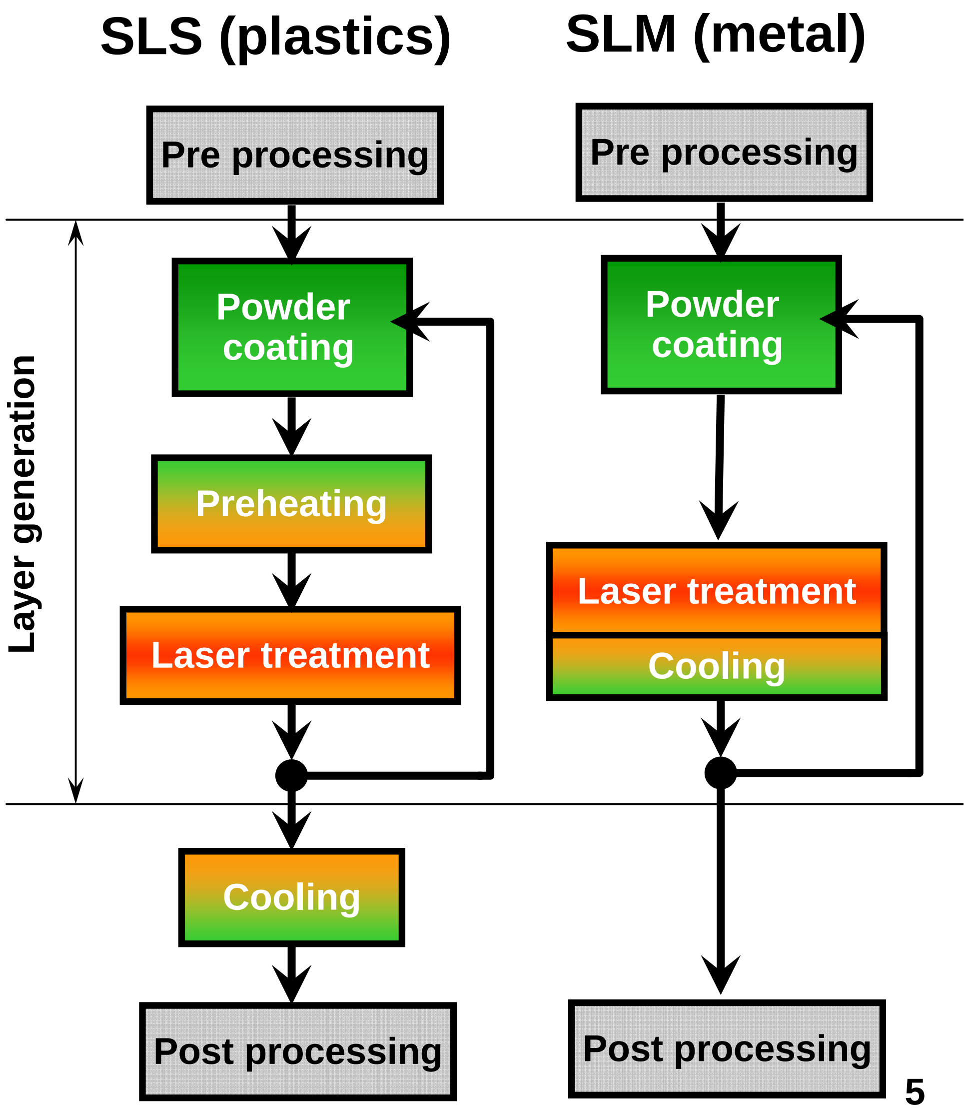
Selective Laser Sintering (SLS, thermoplastics)
Selective Laser Melting (SLM, metals)

System



Batch wise process (job by job)



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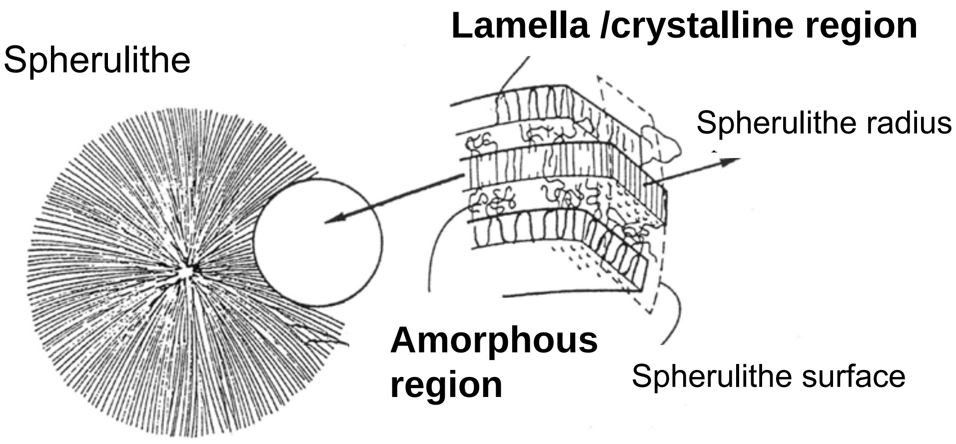
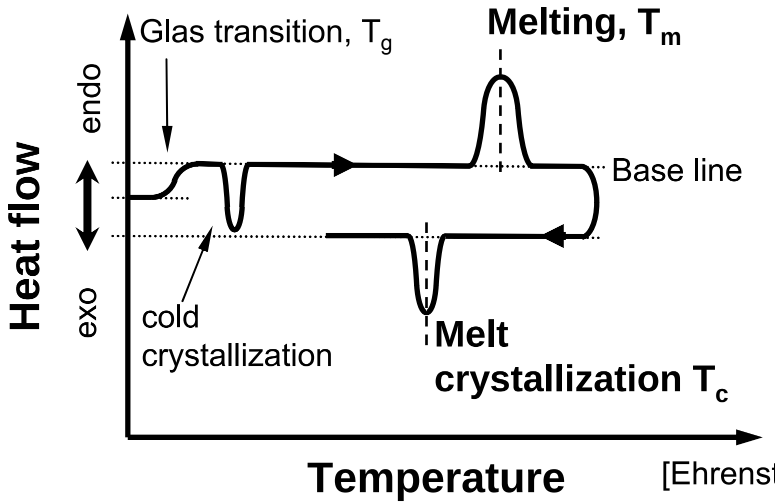
Laser sintering of semicrystalline thermoplastics



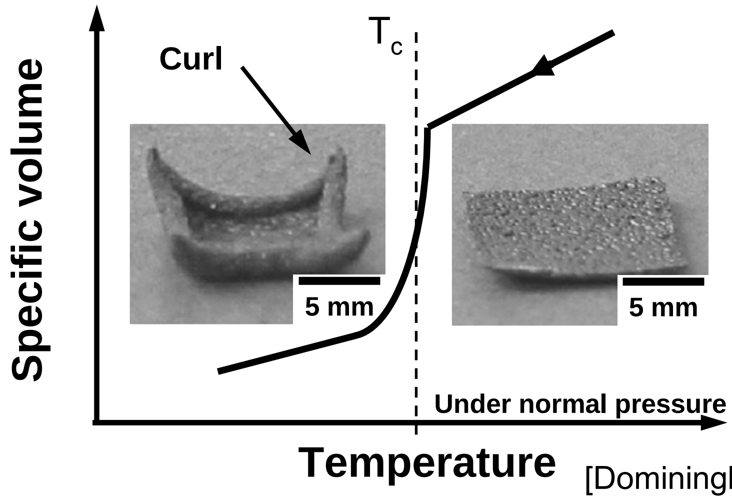
[McCrum et al.]



[Ehrenstein]

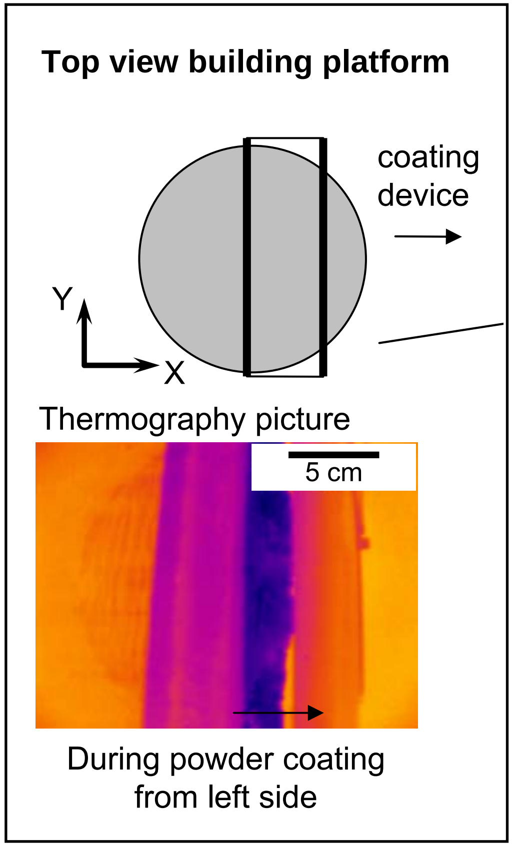
- Crystalline and amorphous regions
- Temperature interval between melting and crystallization, $T_m - T_c$ = 20…30 K
- Shrinkage (2-3 %) during crystallization at T_c
- Curl due to inhomogeneous cooling

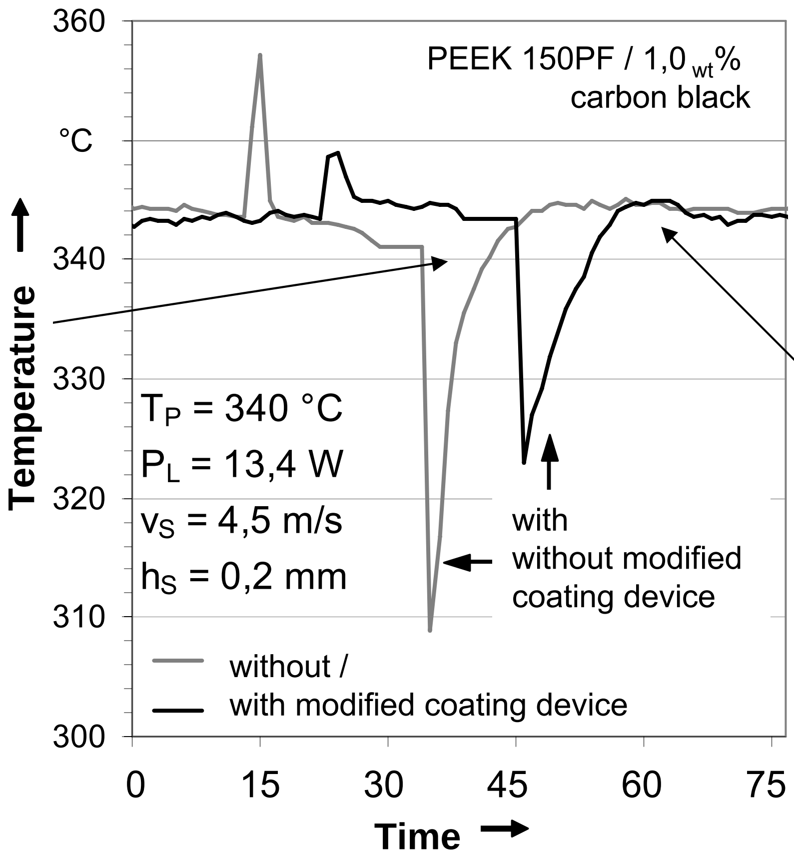
⇒ **Quasi-isothermal laser sintering**

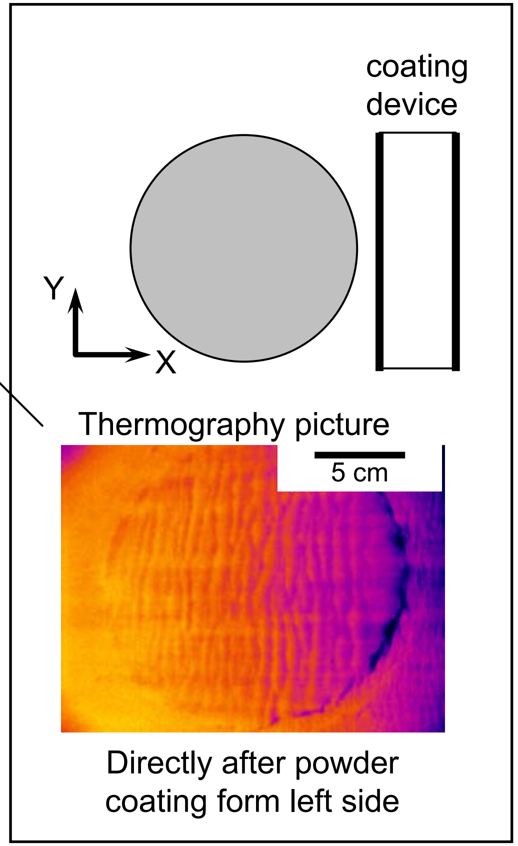


[Domininghaus]

SoA - Temperature vs. time during coating



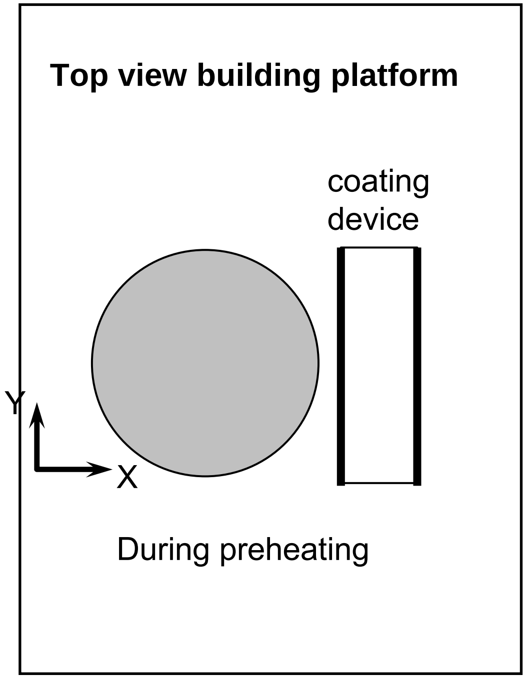


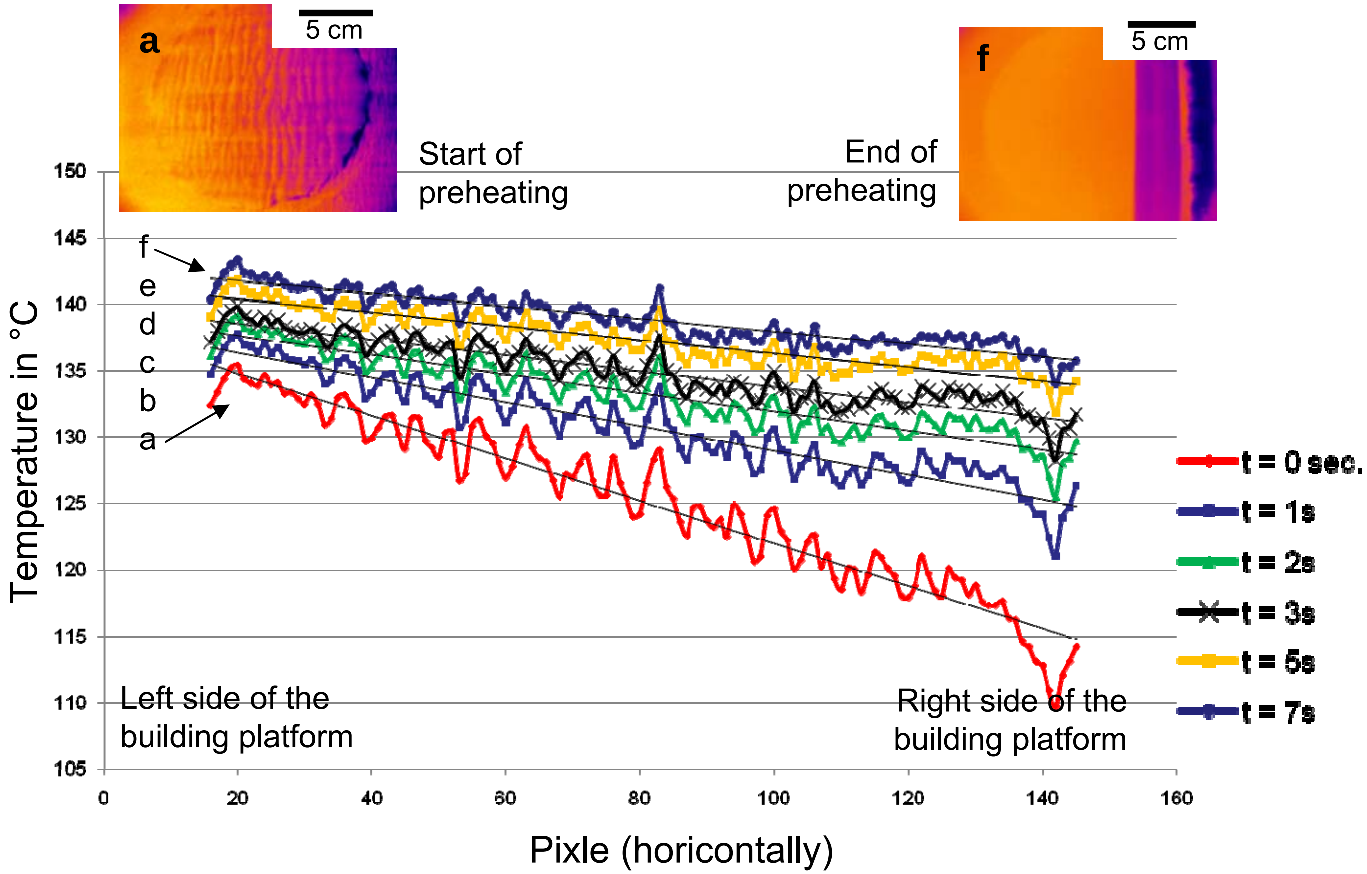


- Powder coating influence the critical thermal household
- Heating the coating device reduce temperature minima

SoA – Preheating of coated powder layers

After powder coating
from left to right

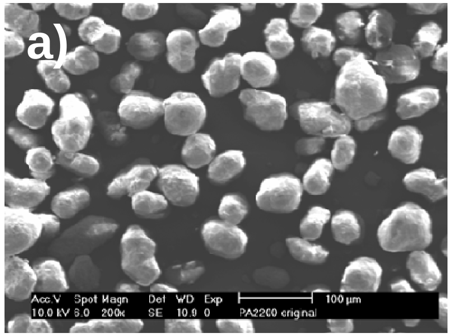


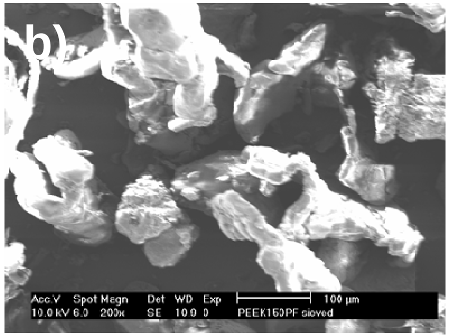


- The sensor for preheating control is measuring only average temperature
- Systematic deviations due to degraded IR heater and coating device: 20 -> 5 °C
- Arbitrary deviations due to powder properties: 8 -> 3 °C

=> Process control has to be improved

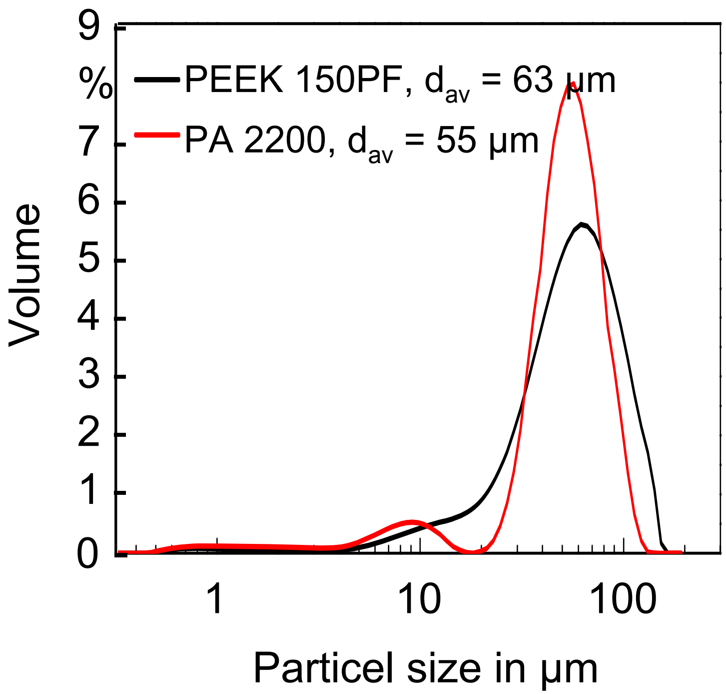
SoA - powder coating of thin layers

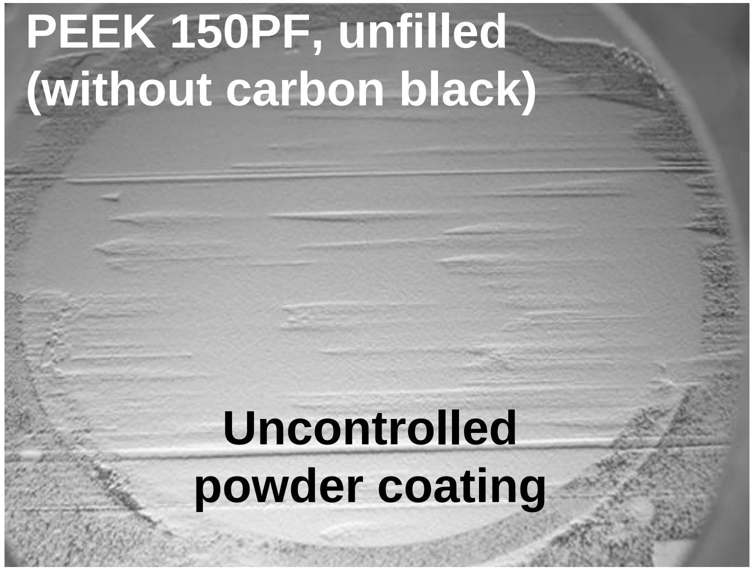


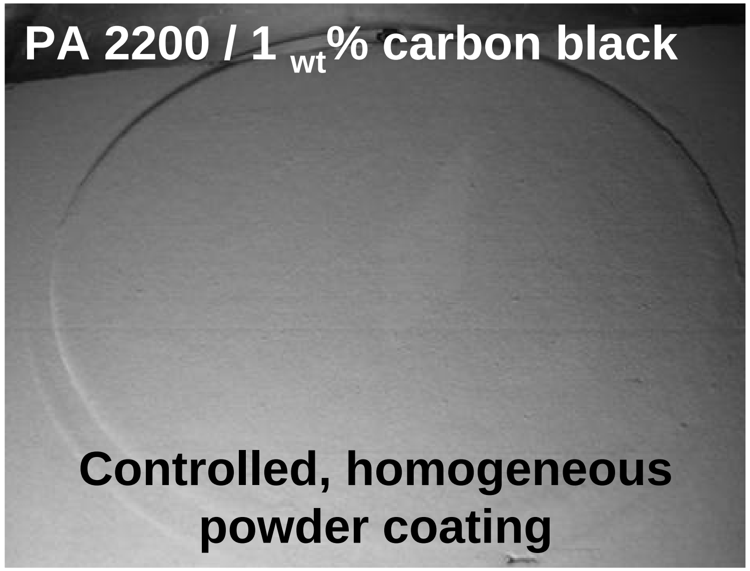


a) Polyamide PA 2200, regular shape

b) PEEK 150PF, irregular shape







SoA - Conclusion

	Time	SLS (plastics)	SLM (metal)
Investment / Material		350.000 € / 60 €/kg	250.000 € / 20 €/kg
Pre processing		Mostly automated	Partly automated
Powder feeding		Partly automated	Typical manually
Powder coating (roller, doctor blade)	5 s	high effort on material is necessary to fulfill requirements	Nearly all metal powder materials fulfill requirements
Preheating (Pyrometer)	5 s	Deviations critical for process stability	n. a.
Laser treatment (thermal short time activation)	5s	Suspected for material degradation	Excellent properties due to fine material structure
Quasi-isothermal laser sintering	5s	Reduce number of materials to several polymers	n. a.
Total process time and cooling		Thermal degradation of material, requires refreshing 40%	100% recyclability

➡ Rapid Prototyping

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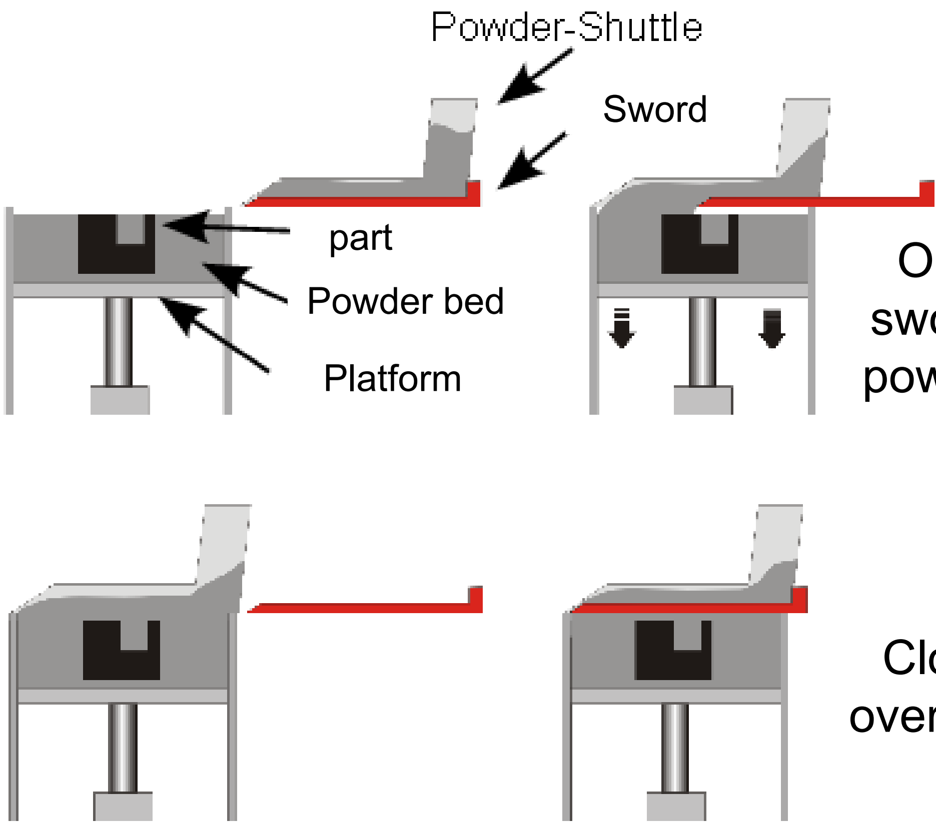
Economical and technical challenges

1. Reduce material costs per part
2. Reduce investment cost
3. Shorten time for layer generation
4. Reduce manual work
5. Improve process and quality control
6. Enlarge material diversity

Solution statements at sintermask

- New powder coating device for cost-efficient polymer powders (**Powder-Shuttle Technology)**
- Simultaneous light exposure techniques (mask technology)
- Process and quality control

Powder-Shuttle-Technology



Shuttle and sword besides powder bed

Opening sword over powder bed

open sword over powder bed

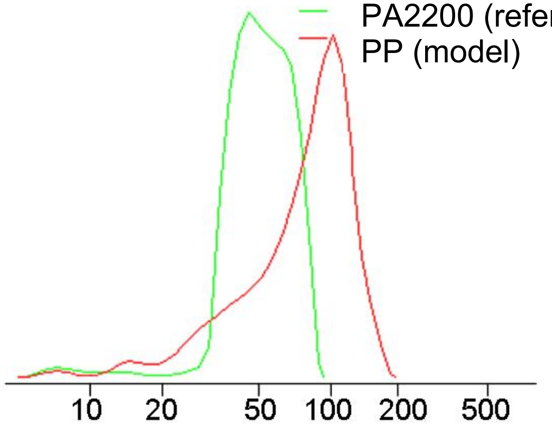
Closed sword over powder bed

- Fast and reproducible powder coating of powders with reduced free flow ability

Powder Shuttle Technology

Materials

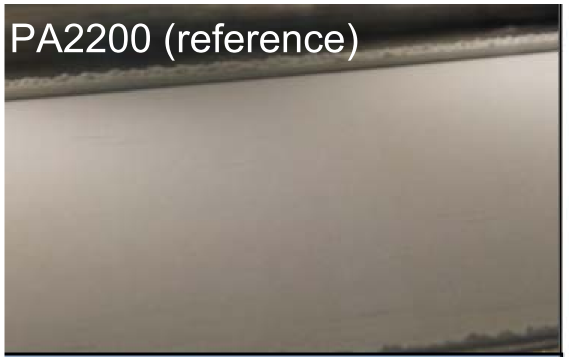
Materials	Unit Calculation	PA 2200 (reference)	PP (model)
Average particle size d_{50}	µm	60	117
Hausner-Factor (powder free flow ability)	ρ_{powder} / ρ_{tap}	1,15 ± 0,01 (high)	1,41 ± 0,03 (cohesive)
Range of preheating temperature (DSC meas.)	°C $T_{m,1} - T_{c,1}$	30	25

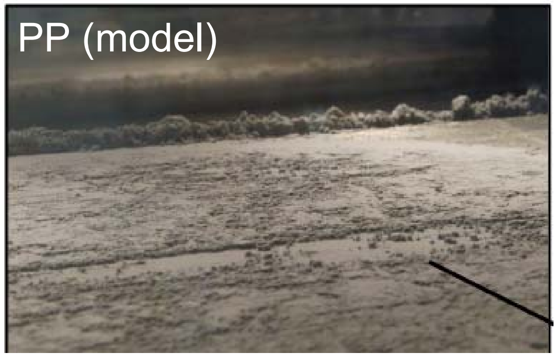


Particle size distribution

- PA2200 (reference): Narrow distribution without large amount of fine particles
- PP (model): Narrow distribution with fine particles, high mean particle size

Powder coating with roller:





Hausner-Faktor a number for powder free flow ability:

$H_R < 1,25$ – high powder free flow ability
$1,25 < H_R < 1,40$ – reduced powder free flow ability
$1,40 > H_R$ – cohesive poder

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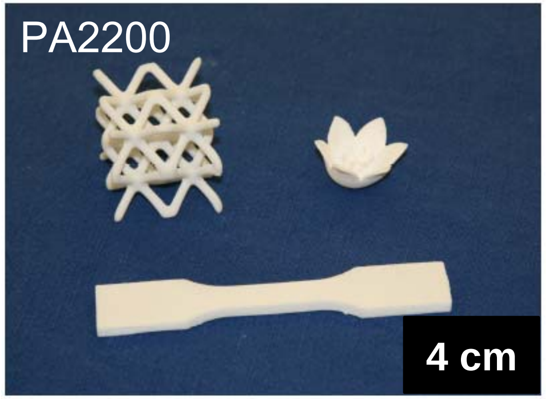
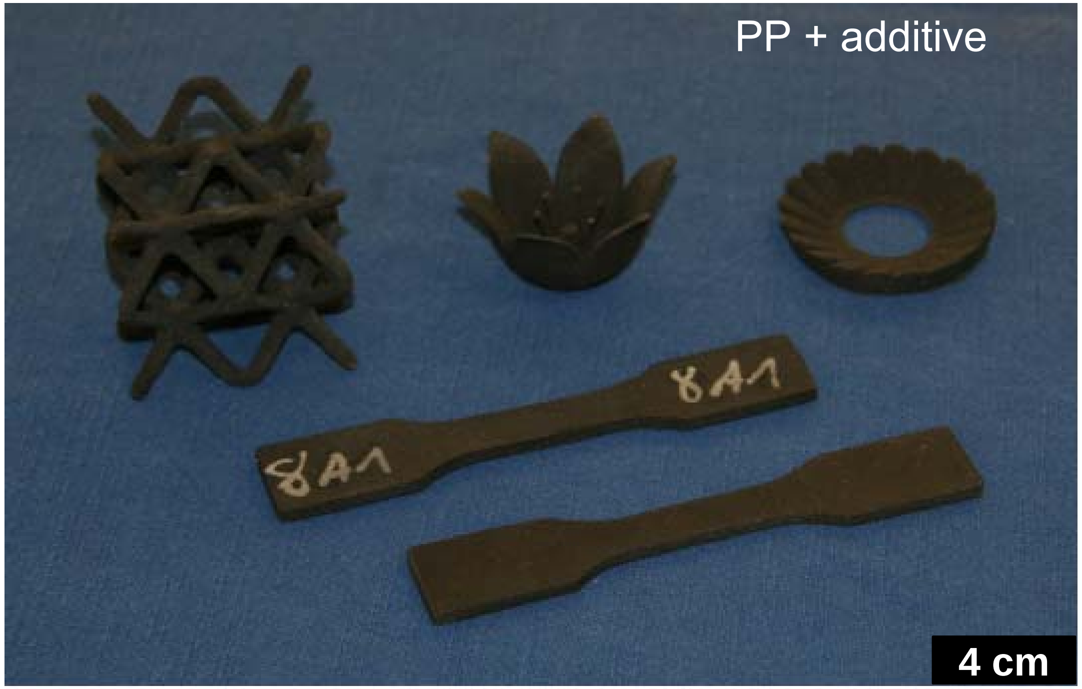
Results

Manufacturing of parts by powder shuttle and laser scanner



PA 2200 (reference)
Free flowing powder with
small particle size



PP (model)
Powder with reduced free flow ability
with bigger particle size

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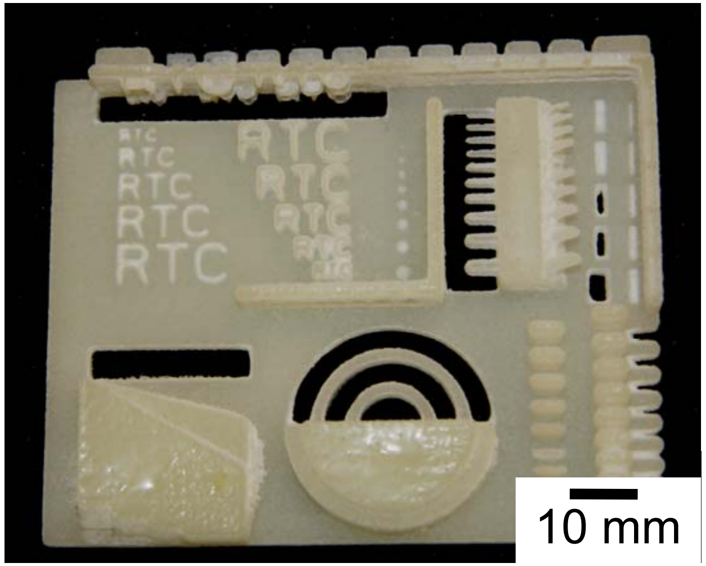
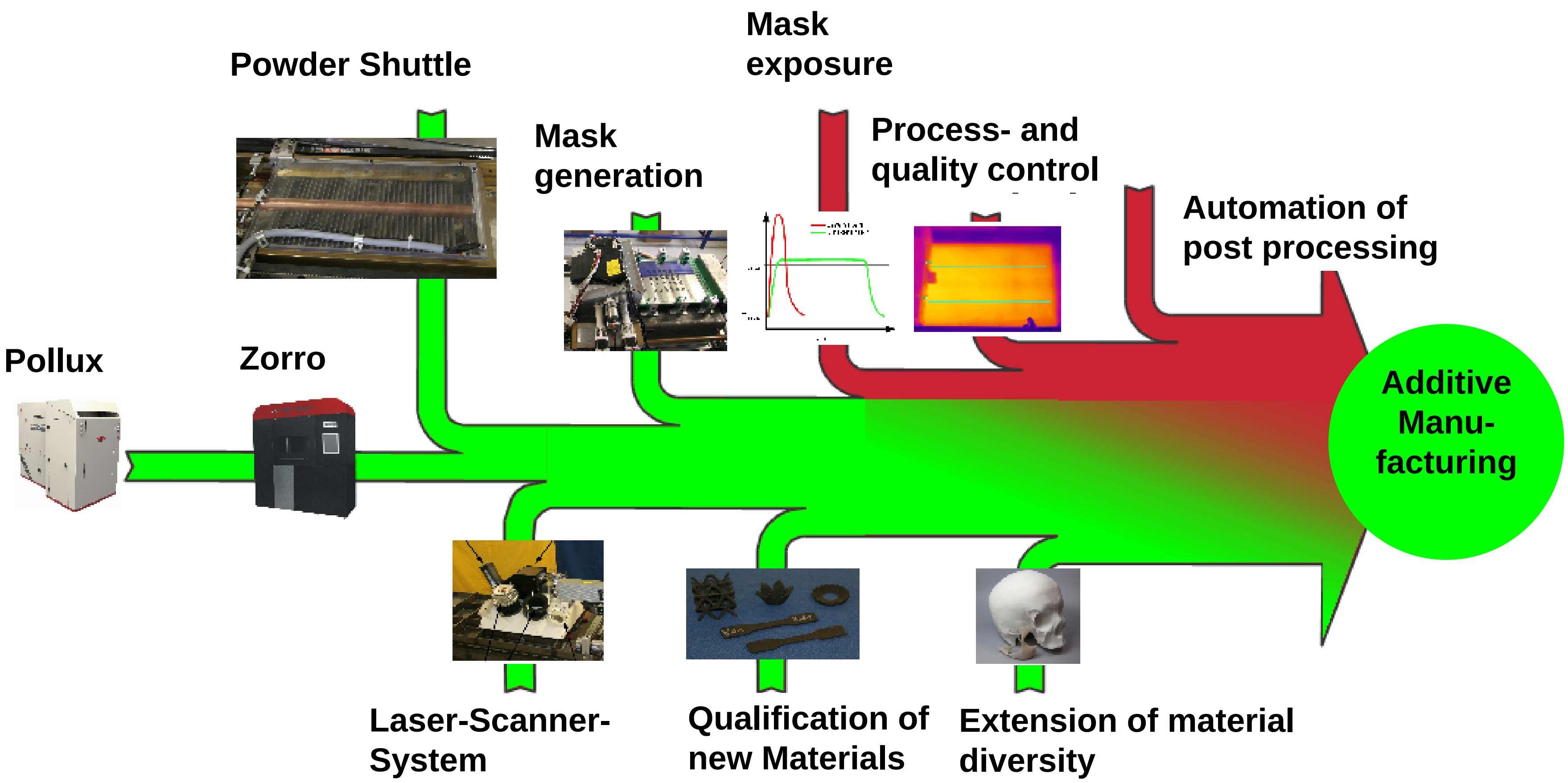
Material with 100% recyclability



DESMOSINT X92A

- SoA: Standard PA2200, needs 8kg new powder (about 500€) for 1kg part due to 5% average exposure per layer and refreshrate of 40%
- Desmosint is a new material which is based on TPU with a recyclabiltiy of 100%. It needs 1kg new powder (50 €) for 1 kg part
- Disadvantage: Less free flowability compared to PA2200, requires adaption of powder feeding mechanism and so far personnel controls
- Status: First parts for pilot customers show potential of the material

Conclusion and road map



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Thanks for attention

Sintermask GmbH
Eichenbühl 10
92331 Lupburg
Germany

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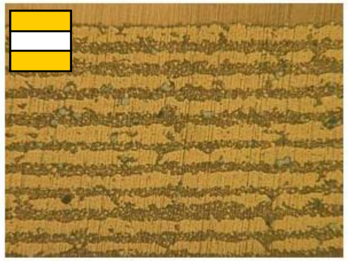
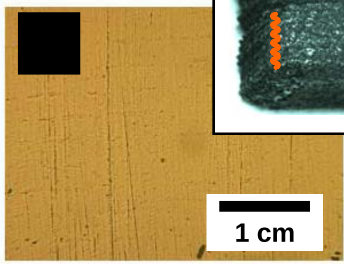
Process window for selective laser sintering

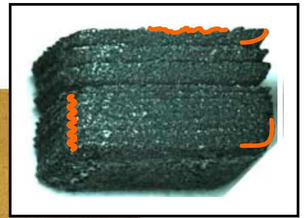


Incomplete sintered, layered structure

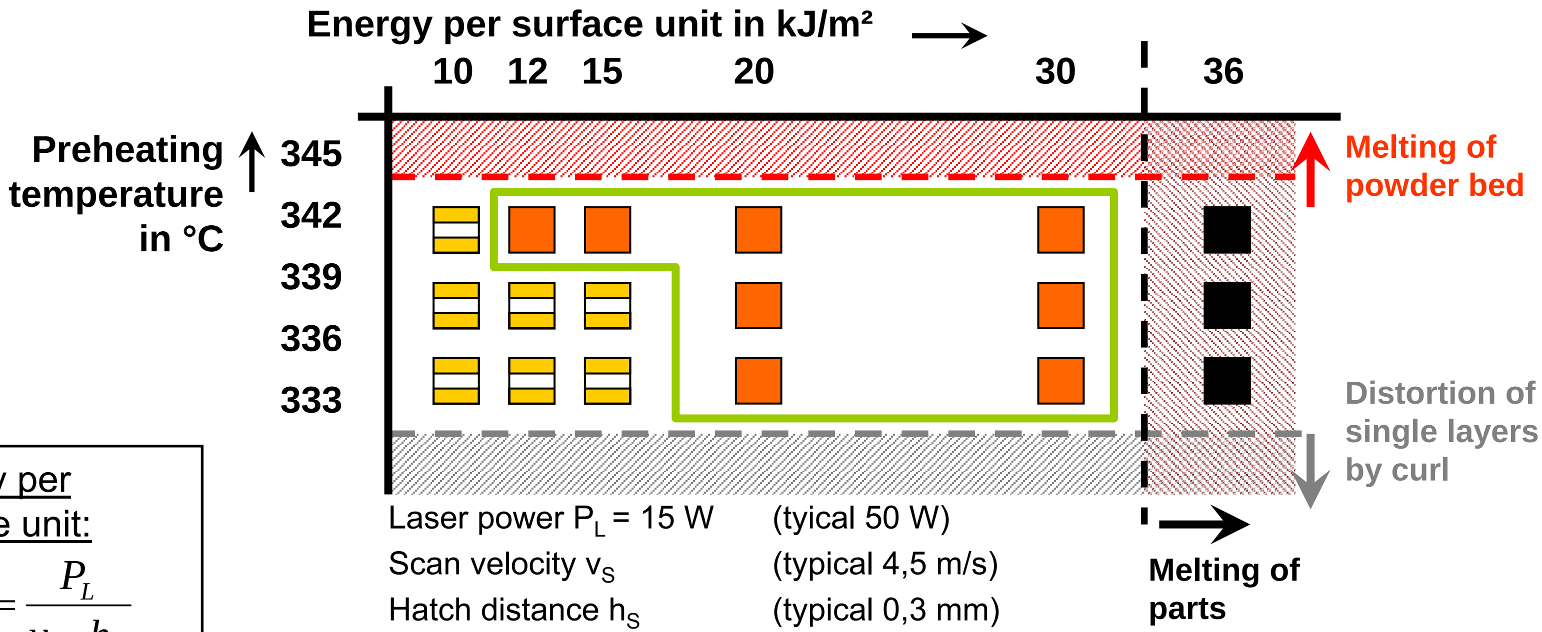
Totally sintered, dense structure



Dense structure, layers overmelted



PEEK 150PF/ 1 $_{wt}$% carbon black laser sintered, 6 x 6x 4 mm³

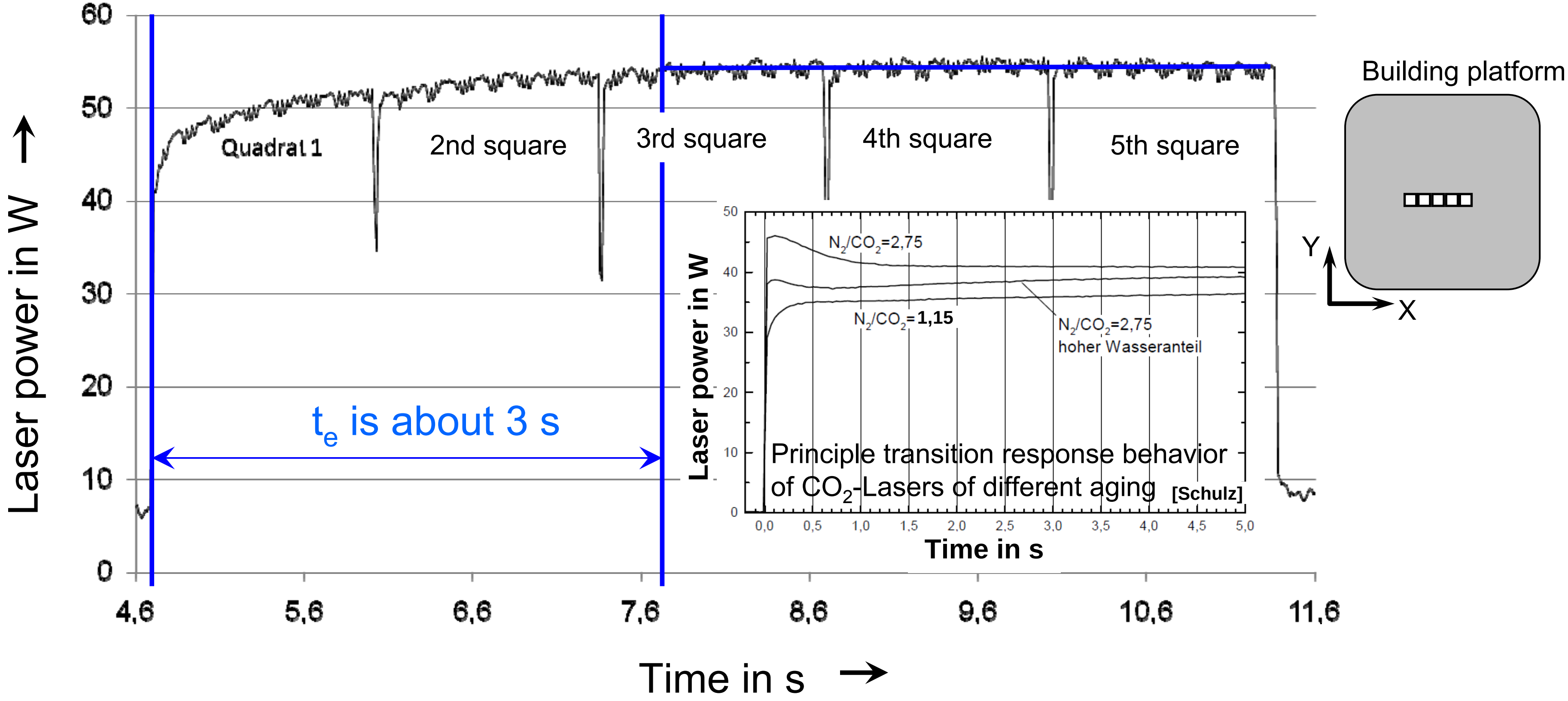


Energy per surface unit:

$$E_a = \frac{P_L}{v_S \cdot h_S}$$

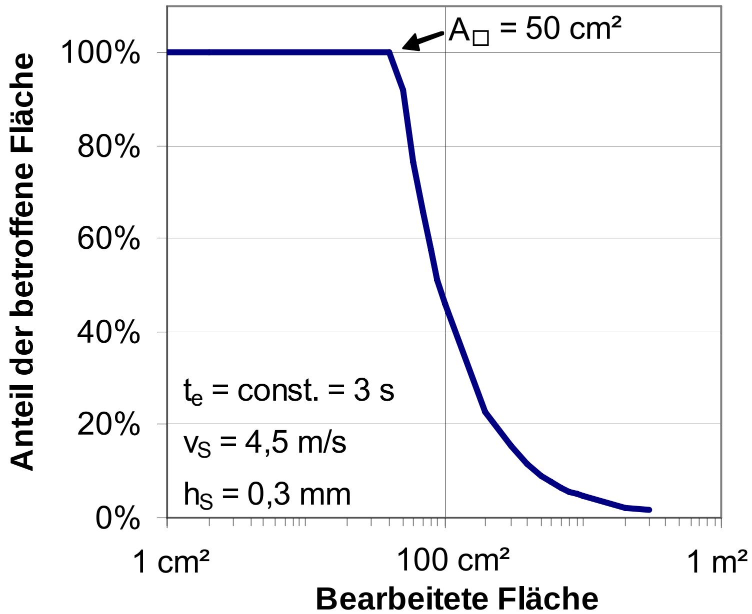
SoA - Laser treatment (laser power)

- Laser treatment of 5 squares, each with 2,5 cm edge length shows transition behavior after swich on the laser

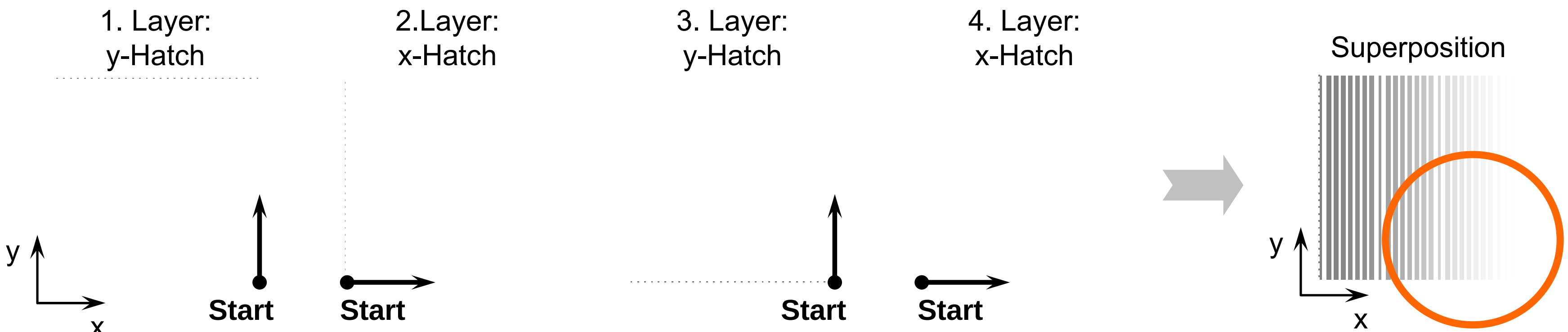


SoA - Effect of transition response on parts

- Duration of transition response t_e
- Portion of area which is affected by reduced laser power



- Location of area wich is affected by less laser power



Right front corner:
significantly less laser power

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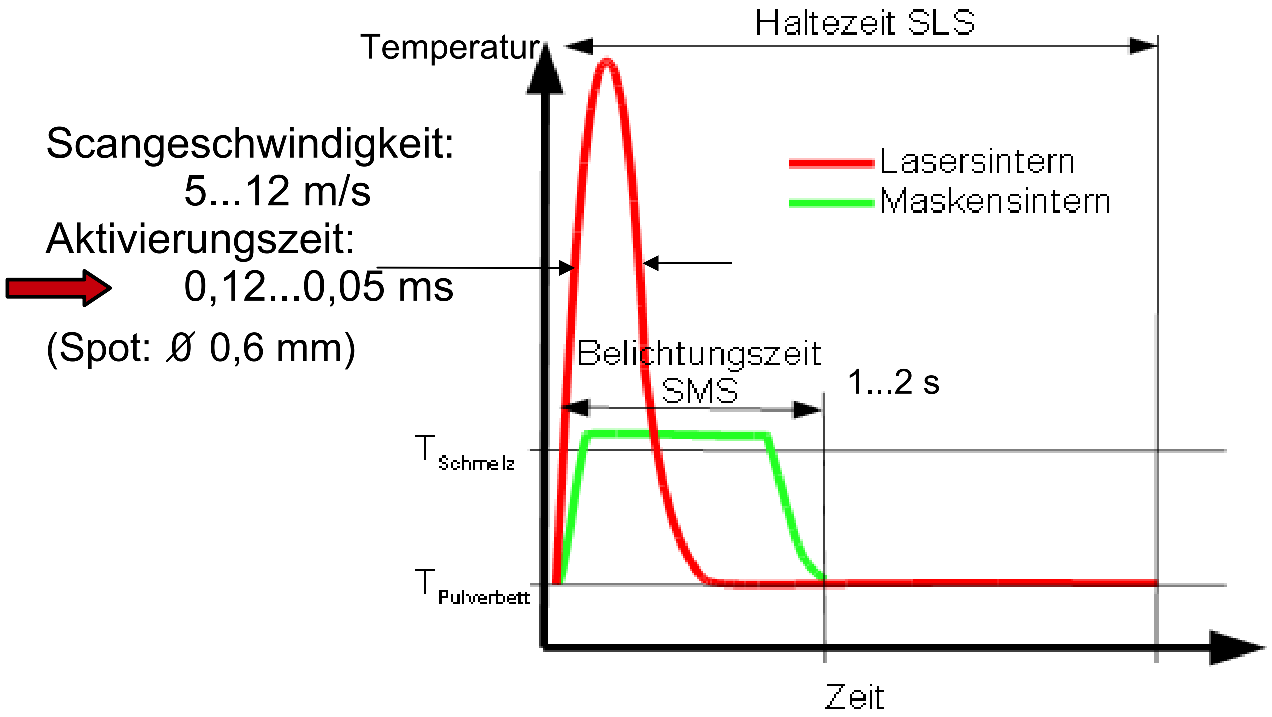
Bedeutung der simultanen Belichtung



- Verkürzung der Zeit für die Konsolidierung durch Optimierung des Temperatur- und Viskositätsverlaufs
- Belichtungszeit unabhängig vom Füllgrad
- Geringere Maximaltemperatur, geringere thermische Belastung des Werkstoffs

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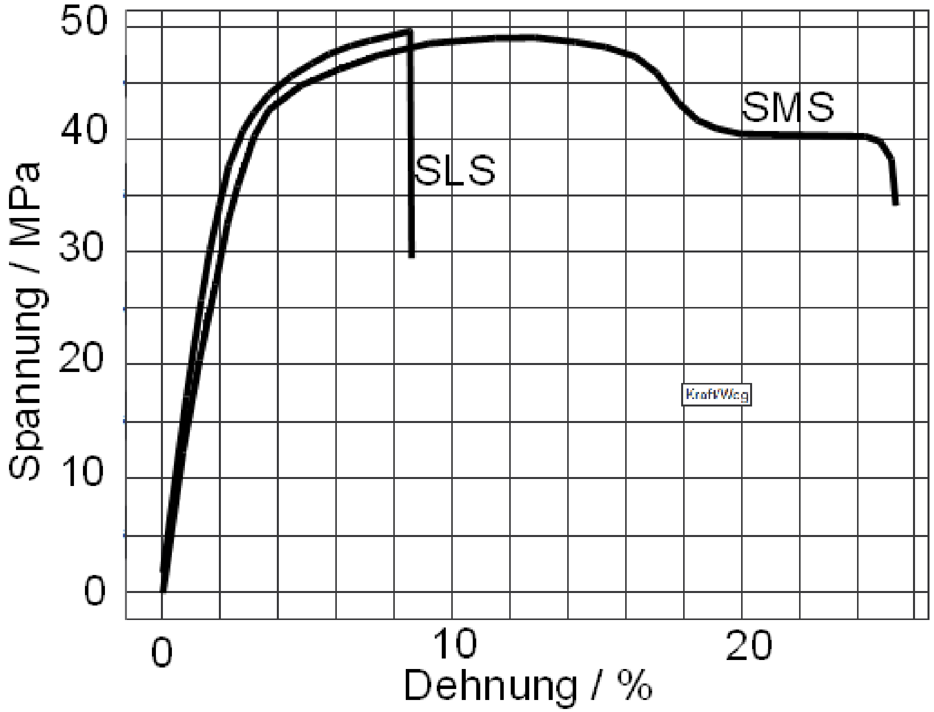
Ergebnisse: Vergleich SMS und SLS

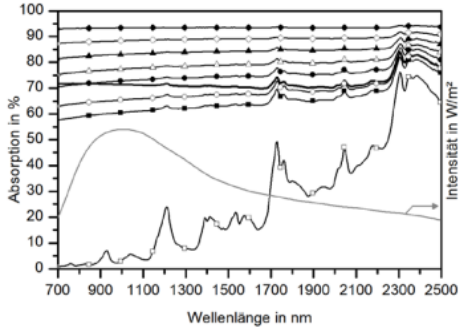


	SMS	SLS
Max. Spannung [MPa]	48,9	46,0
Bruchdehnung	25,2%	8,6%
E-Modul [MPa]	1906	1952

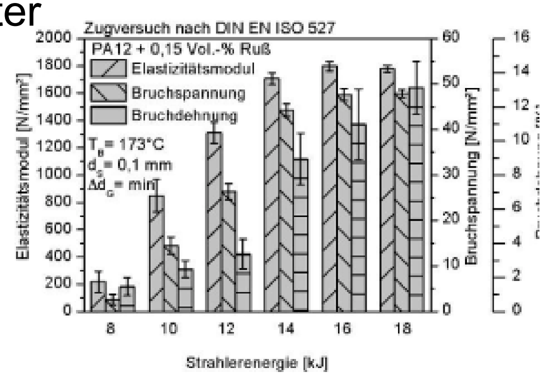
SMS-Teile haben spritzgussähnliche Eigenschaften

Selektives Maskensintern von Funktionsbauteilen

Werkstoffauswahl und Charakterisierung



Einfluss wesentlicher Prozessparameter auf die Bauteileigenschaften



Abhängigkeit der mechanischen Eigenschaften von der Orientierung des Bauteils im Bauraum

Verarbeitung modifizierter Materialien zur Herstellung funktionalisierter Bauteile

Ruß + 20 Vol.-% Al-Grieß

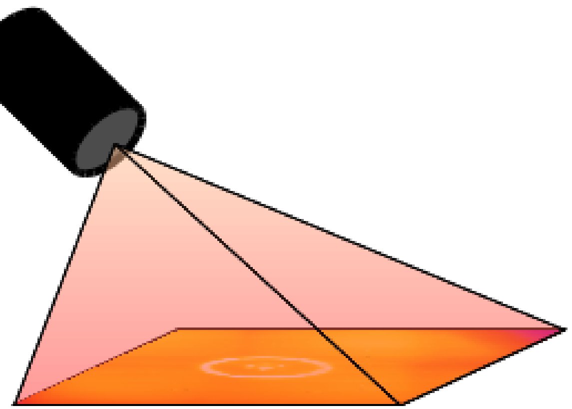
Ruß + 20 Vol.-% Cu-Kugeln

Prozess- & Qualitätskontrolle

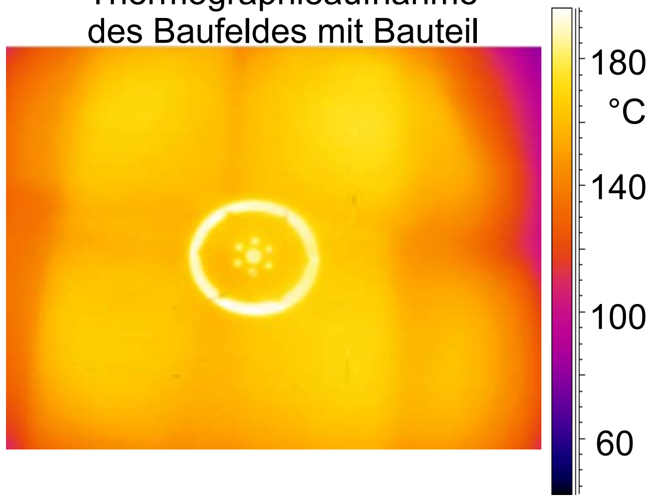
Defizite aktueller Lasersinteranlagen:

- Schwankende Materialeigenschaften
- Mangelnde Stabilität von Prozessparametern
- Unzureichende Prozessüberwachung

=> Nicht reproduzierbare Bauteileigenschaften
=> Häufige Prozessabbrüche



Thermographieaufnahme des Baufeldes mit Bauteil

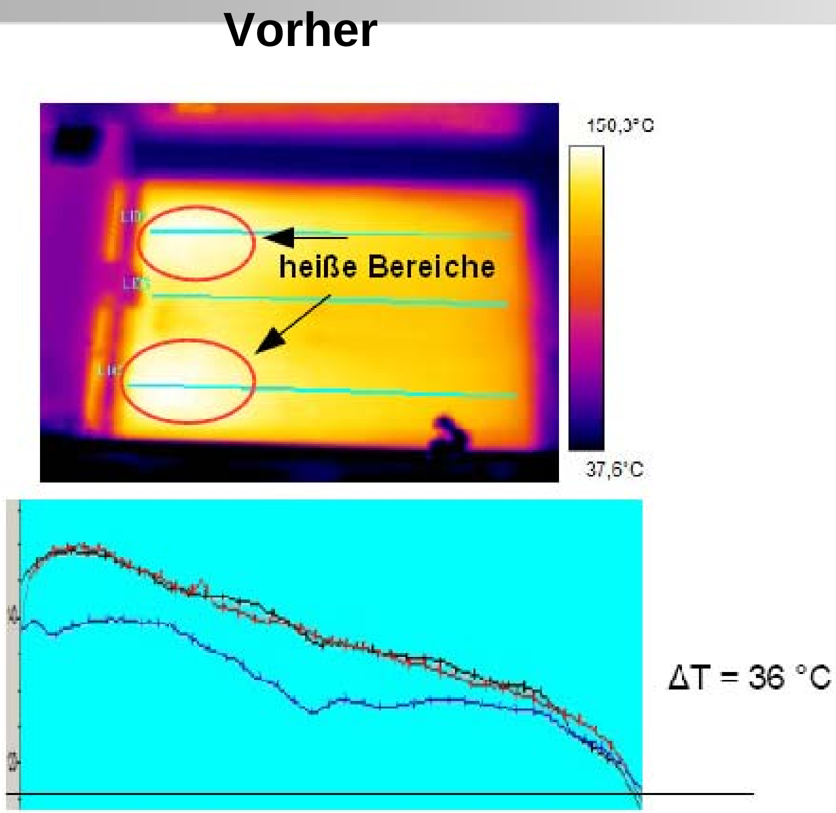


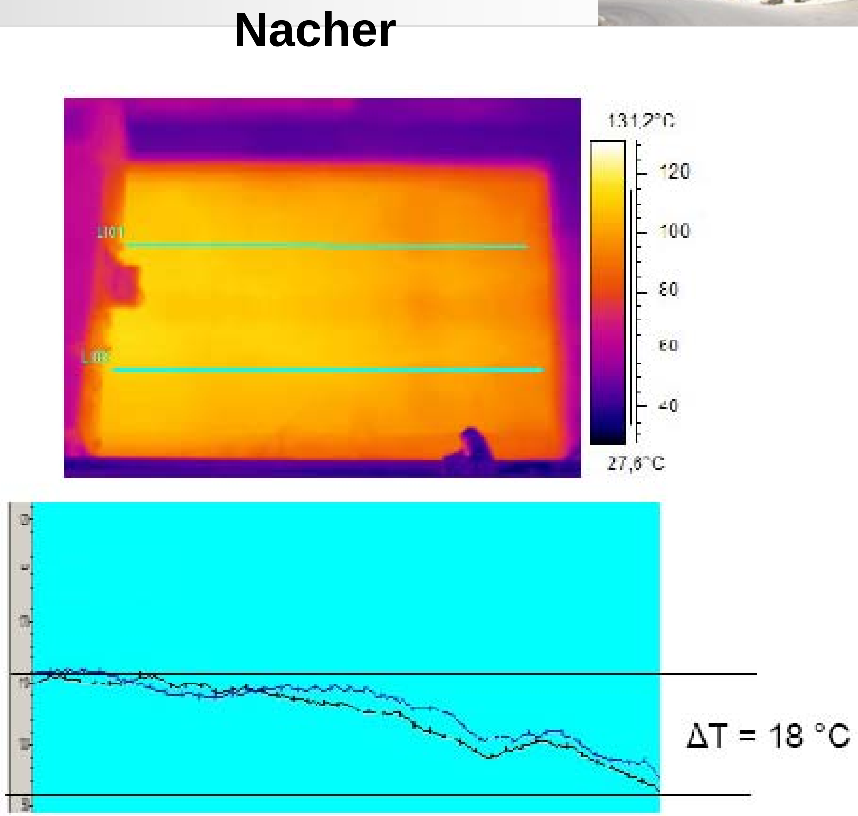
Thermographie: Überwachung von Schichtauftrag und Konsolidierung

- Identifikation schlechter Schichten
- Regelung des Energieeintrages

➡ **Verbesserte Reproduzierbarkeit der Bauteileigenschaften**

Optimierung Temperaturhaushalt PS





- Ursprünglicher Temperaturabfall ΔT = 36 K reduziert auf ΔT = 18 K
- Ziel ist ΔT = 10 K beim Materialauftrag
- Durch 2-Zonen Vorheizen mittels Lampen wird ΔT < 5 K

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