Tailoring the melting behaviour of LBM powders

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Motivation

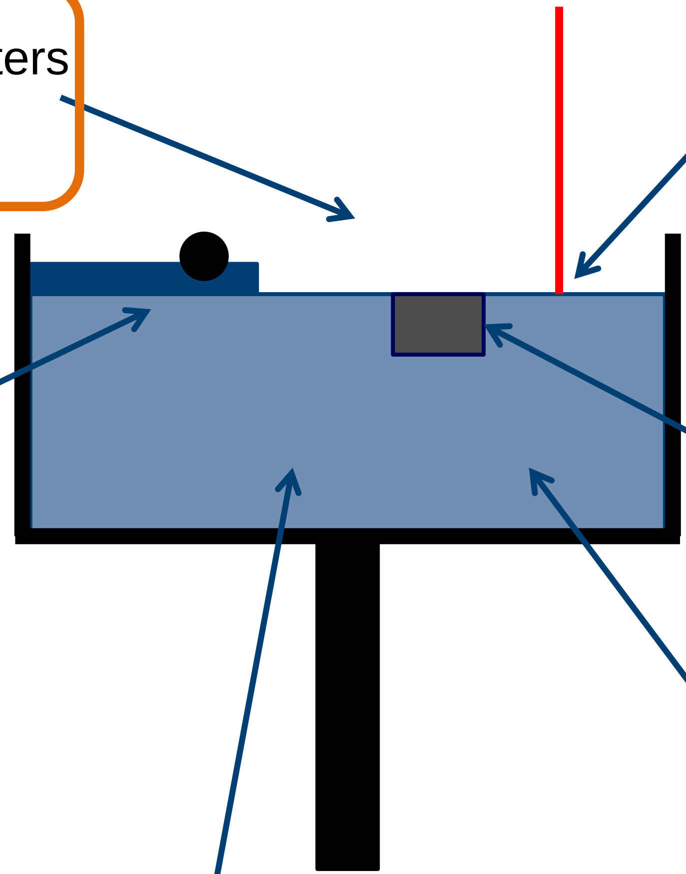
Processing parameters

$T_{\text{Building chamber}}$

Energy density

Interaction

Beam ↔ Particle



Powder flowability

Part Properties

Surface roughness

Mechanical stability

Electrical conductivity

Colour

Packing density / Surface porosity / Part density

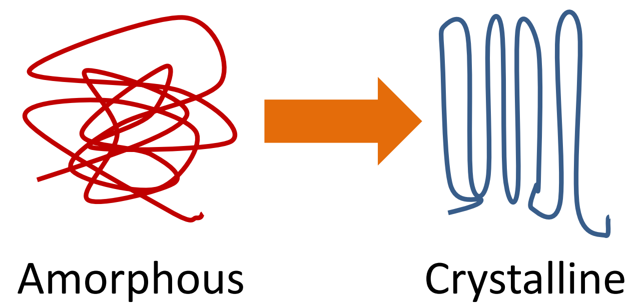
Aging behaviour

Chemical degradation ↔ Polymers

Structure ↔ Metals

- Overcome material limitations in LBM processes
  - Processing of multi-materials
    - Not possible due to different preheating temperatures of the building chamber
    - Adjustment of this preheating temperature possible by changing crystalline state of polymeric material

      → Increase of crystalline structure

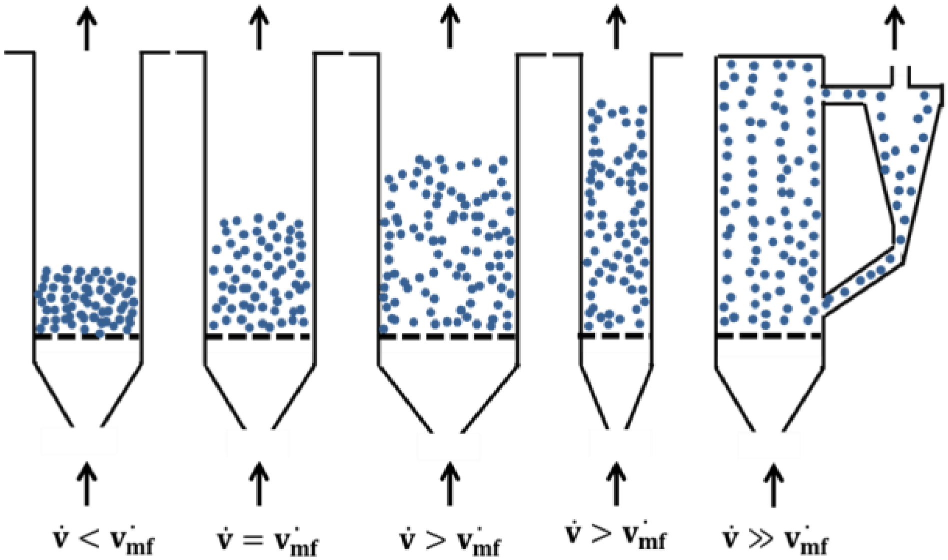


- Process route
  - Manipulation of crystalline structure of polymeric material
    - Possible by heat treatment
      - Temperature just below melting temperature

Concept for Reactor Design
Fluidized Bed Reactor

- Prerequisite
  - Temperature adjustable within few °C
  - No temperature gradients
  - Scale-Up to industrial range

→Fluidized Bed Reactor



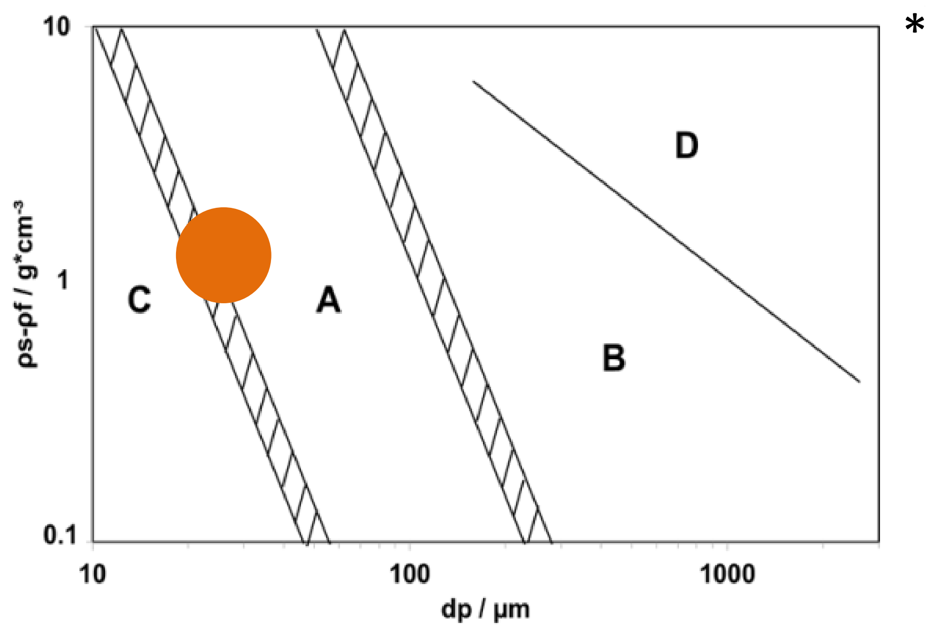
- Powder bulk flown through by gas
- Gas velocity exceeds gravity force
  - Particles show liquid behaviour
  - Excellent heat and mass transfer
  - No “hot spots” due to temperature gradients

- A (aeratable)
  - Small particle size & small density
    → Good fluidization behavior

- B (bubbling)
  - Increased particle size
    → Formation of gas bubbles

- C (cohesive)
  - Small particle size & low density
    → Bad flowability and fluidization

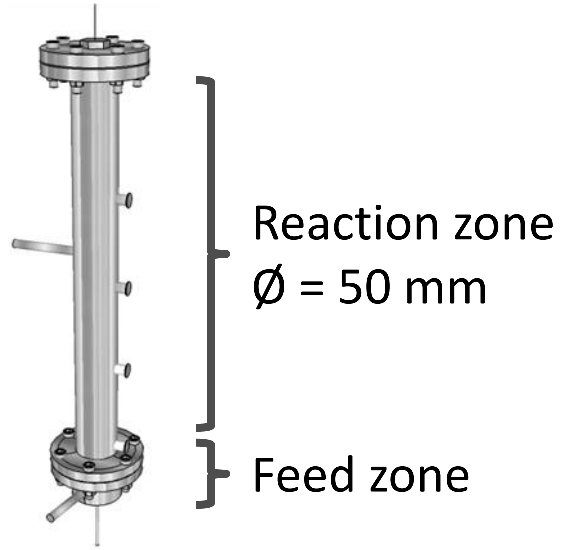
- D (dense)
  - High density and rather big particles
    → Poor fluidization behavior



* D. Geldart: ''Types of gas fluidisation"; Powder Technology, Volume 78, Issue 5, 1973

Experimental Set-Up

- Reactor
  - Fluidized Bed Reactor
    - Diameter 50 mm
      → Lab scale for proof-of-concept
    - Material: Stainless steel
    - Fluidization gas N_2
      → No oxidative degradation



- Material
  - Polyethylene-HD
    - Coathylene NB5374, DuPont CH
  - Polypropylene
    - Coathylene PD 0580, DuPont CH

  - Powder material coated with nanoscale fumed silica
    → Improved flowability

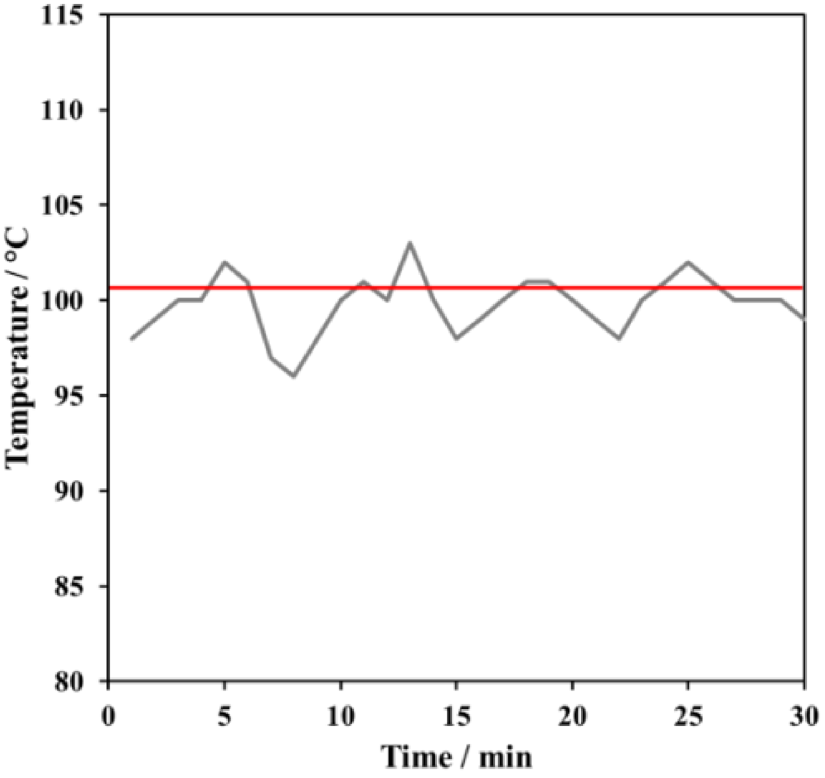
Experimental Procedure

- Temperature necessary close to $T_{Melting}$

- Inaccuracy / Fluctuation of $T_{Reactor}$ to be avoided

  → Otherwise: Melting of polymer powders

  → Reactor concept gives opportunity to set the reactor temperature within few °C

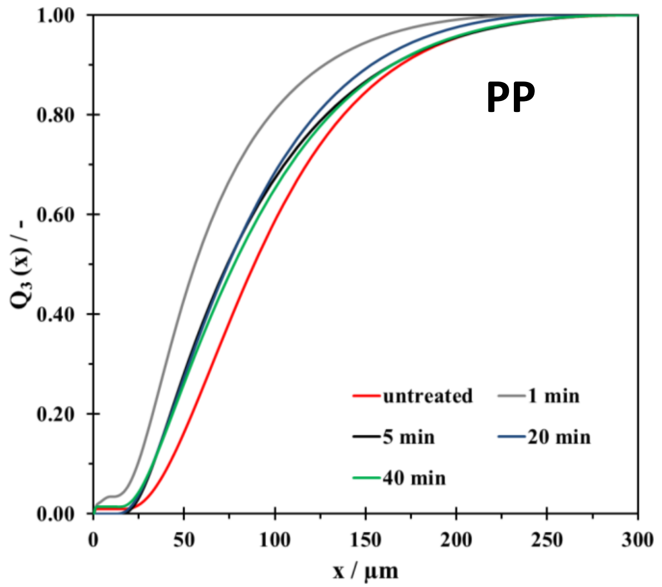


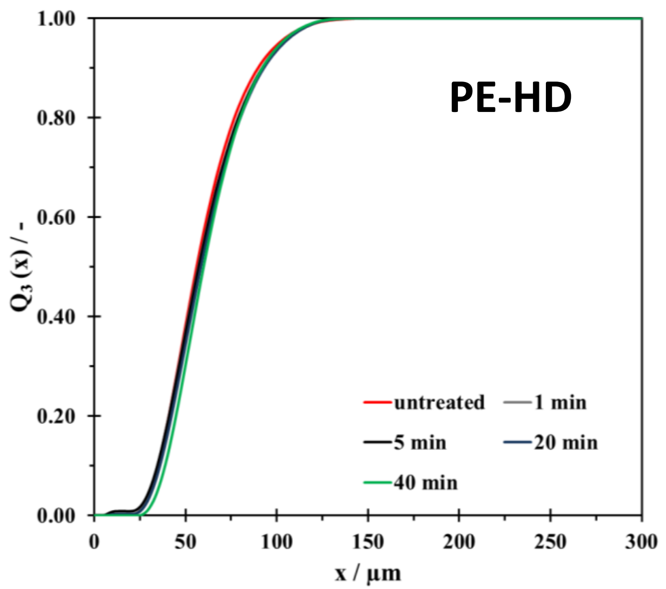
- Heating time to treatment temperature
  - Set-to 15 Min

Particle Size Distribution

- Particle size distribution measured by Malvern Mastersizer
- No major shifts observable
  - Melting of polymer material is avoided within treatment procedure
- Coating of fumed silica not affected by treatment
  - Observed using SEM

→ No effect of heat treatment on flowability and thus behaviour of material in deposition process





Results
Melting Temperature

- Maximum increase of peak temperature after 1 min treatment time

- Effect of increasing treatment time
  - Polypropylene
    - No degradation effects observable
      - Crystallisation further increases
  - Polyethylene
    - Degradation effects due to longer treatment times
- Effects in 2nd heating procedure
  - Polypropylene
    - No degradation observable
  - Polyethylene
    - Again decrease measured
      - Degradation of polymeric structure

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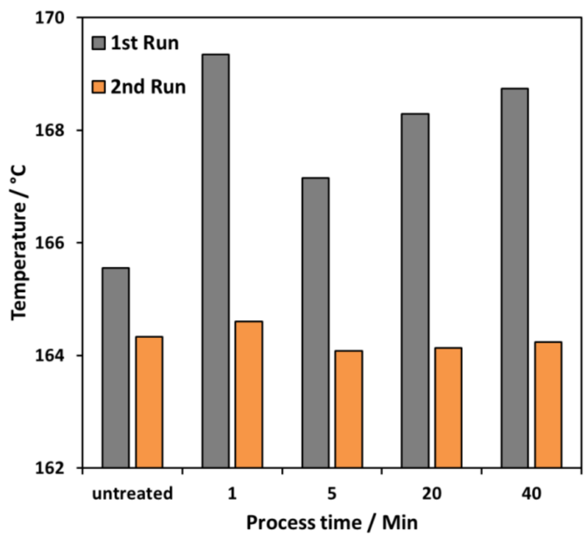
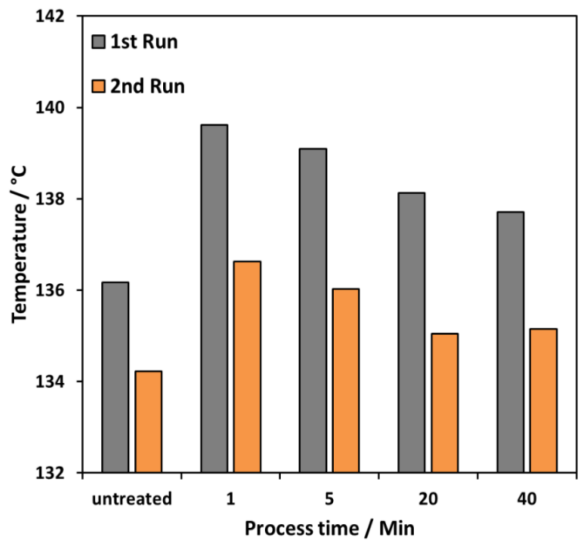


PE-HD



- Increase of melting enthalpies after 1 min treatment time in FBR
  - Fast kinetics of structural change
- Polypropylene
  - No effect with increasing treatment time
  - Crystalline state does not further increase
- Polyethylene
  - Further change of necessary melting heat
    - Degradation of polymeric structure
- Effect in 2nd heating procedure follow same principles

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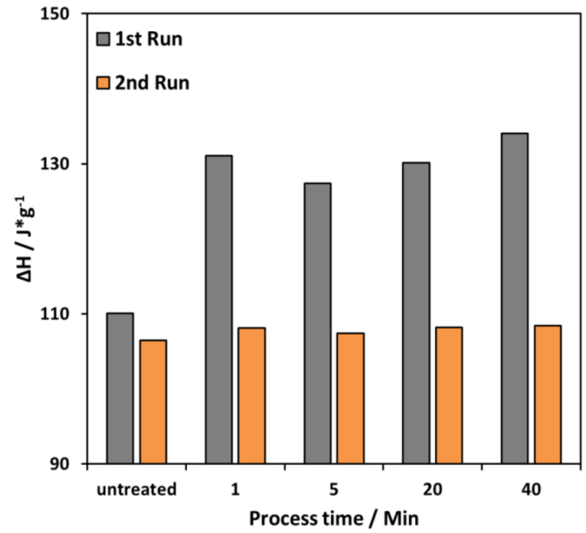
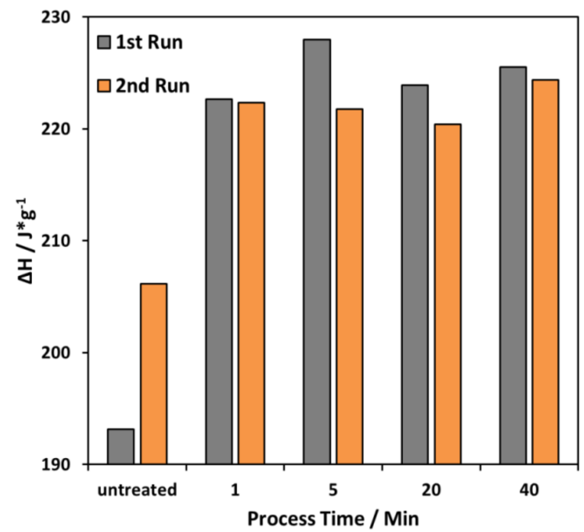


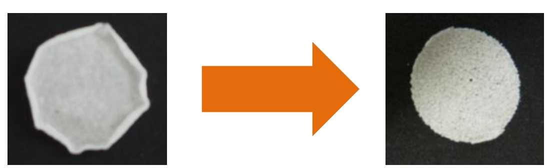
PE-HD



- Treatment of sensitive polymer material near of melting temperature in fluidized bed reactor established
  - Control of process temperature within fe °C possible

- Effect of heat treatment on thermal behaviour of material determined using Differential Scanning Calorimetry
  - Measured peak temperature and onset temperature controllable
  - Necessary melting enthalpies adjustable

- Manufacturing of single layers in LBM process (Cooperation with blz)
  - Dramatic reduction of curling effects due to thermal tensions
  - Increased stability of the material towards temperature fluctuations



Acknowledgements

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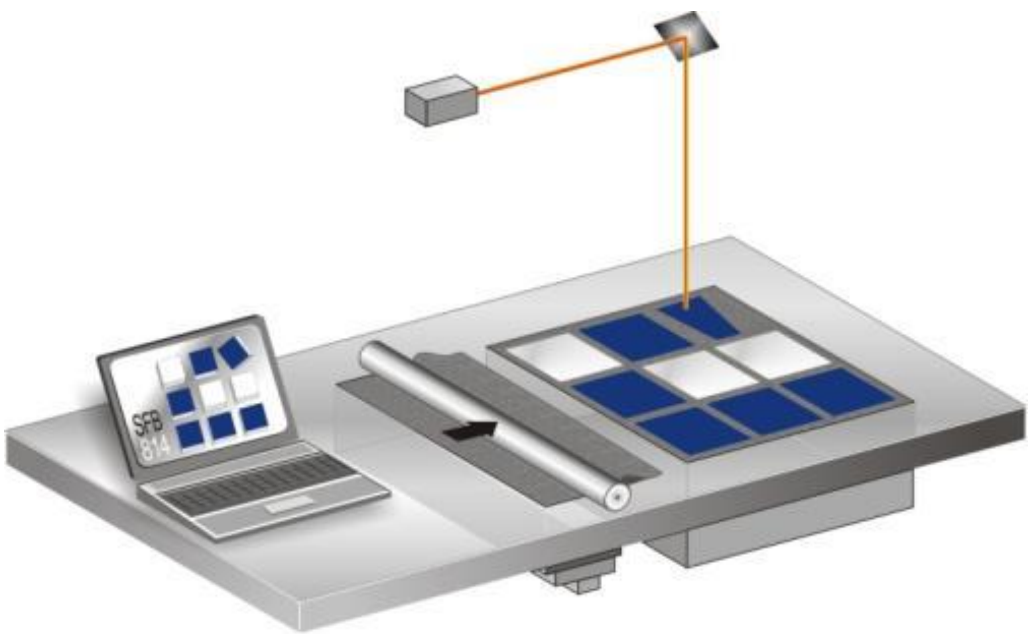

Thank you for your attention!