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NOVEL BIOBASED MATERIALS TO IMPROVE CIRCULARITY

Improving the circularity of complex plastic multi-material composites using novel biobased materials in B2B semi-finished products

Processing of Biopolymer Yarns: Melt Spinning, Drawing and Weaving

Open training session - Silkeborg

25th March 2026

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Bio-based Industries Consortium

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GA. No: 101111996

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Outline

- Polymers
  - Bio-based
  - Properties (Tg, Tm, Tc)
- Melt spinning
  - Processing steps
  - Drawing
  - Multifilaments
  - Monofilaments
  - Properties
- Composites
  - Formation from filaments
  - Weaving

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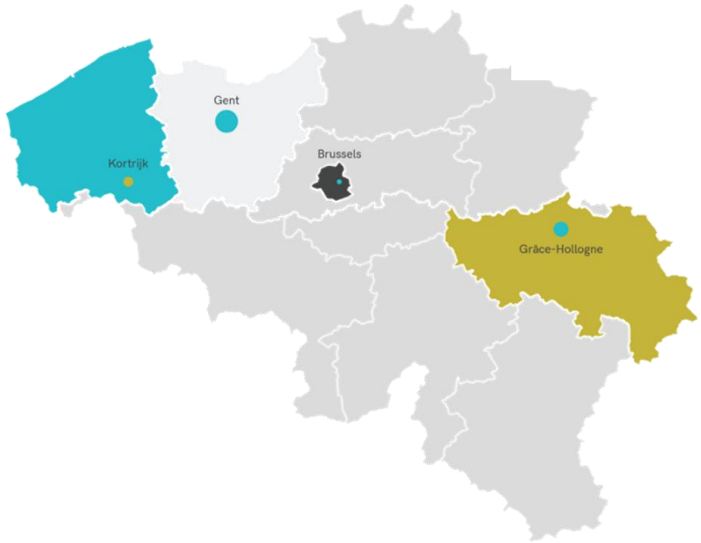
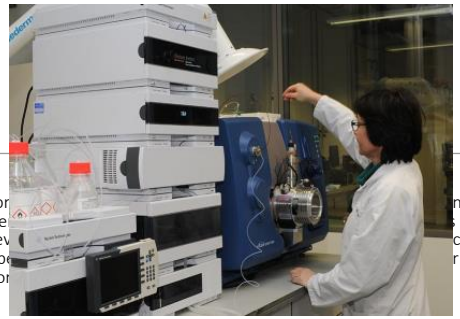
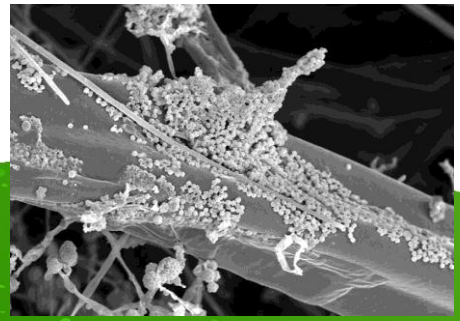
Centexbel

- Collective research and technical center
- Focus on ‘Textiles’ and ‘Plastics’
- 180 collaborators - 3 sites in Belgium
- Well-equipped testing laboratories:
  physical – chemical – fire – microbiological
- Pilot platforms:
  extrusion – textile – coating & finishing







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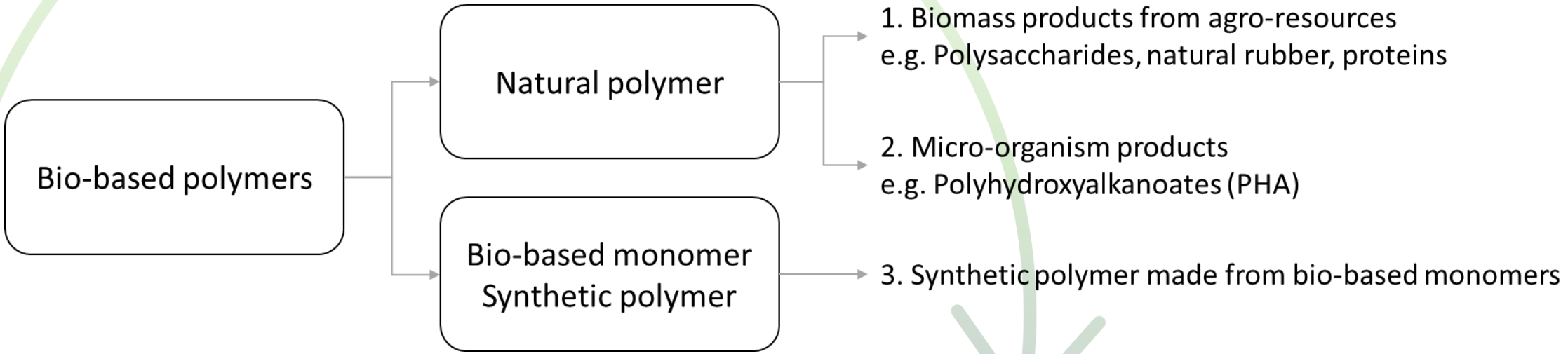
Pathways to biobased plastics

*Depending on their **structure**, biobased plastics can be classified into 3 categories*



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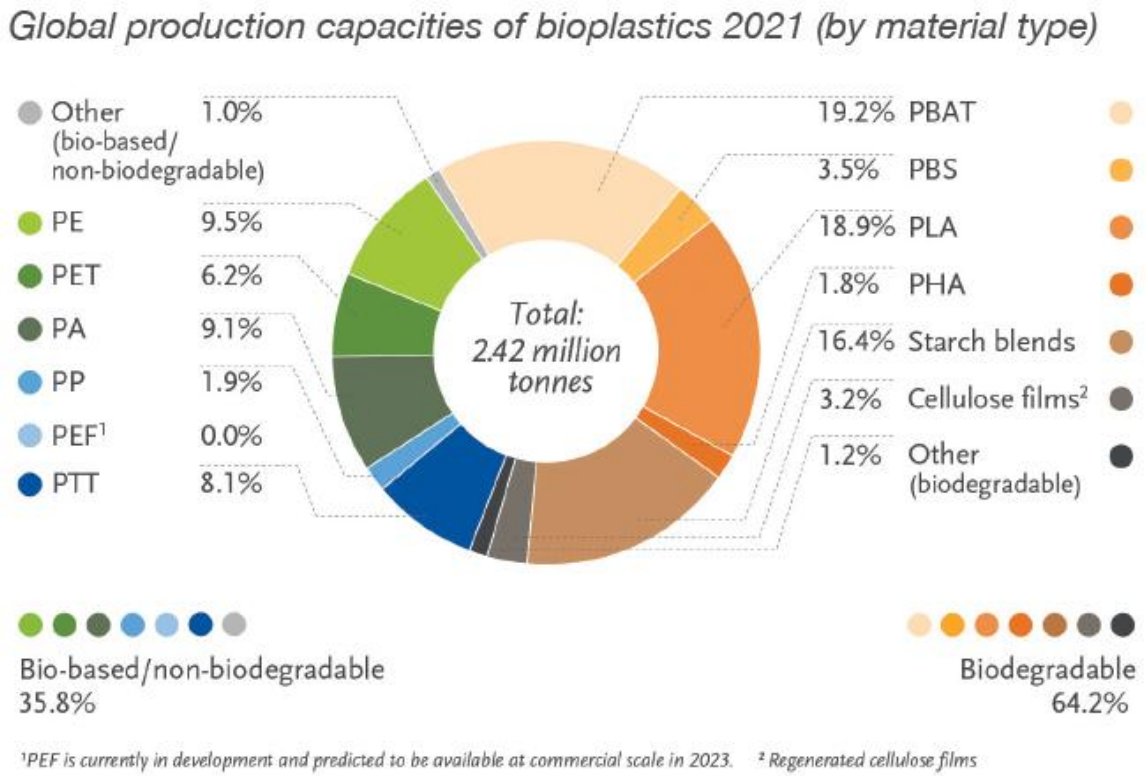
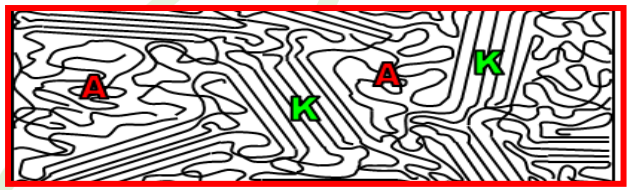
Biobased plastics production - thermoplastics

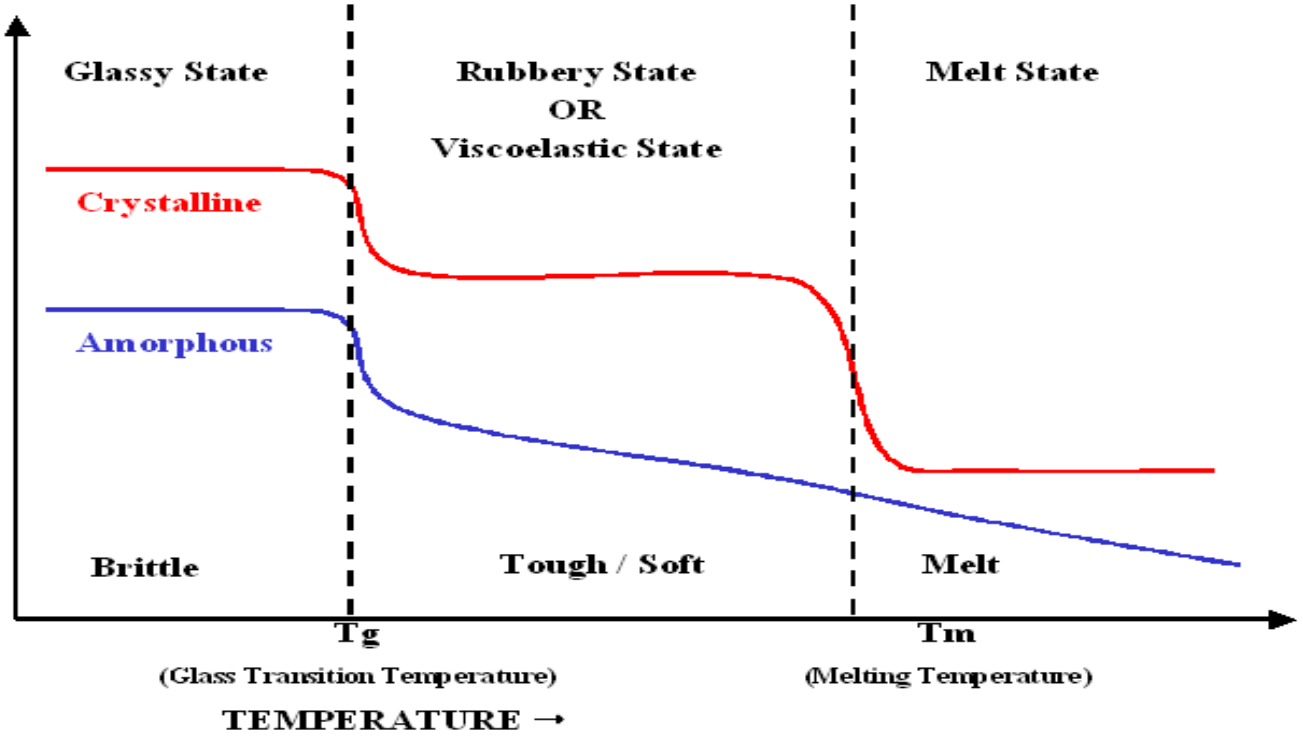


Biobased plastics production is still relatively limited

Processing temperatures



Property →



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PROCESSING

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Drying

- PLA 100ppm
- PA 1000ppm
- Drying conditions on TDS
  - High melting
  - Low melting

Compared to conventional plastics, biobased plastics generally require drying more often

	material	drying time	drying temperature [°C]	max. moisture [%]	
	CA	2-4 h	60	< 0.15	*Foaming*
polyesters	PHBV	2 h	100	< 0.025	*Hydrolysis*
polyesters	PLA	6 h	80	< 0.025	*Hydrolysis*
polyesters	PLLA	6 h	80	< 0.025	*Hydrolysis*
	TPS	-	-	-	*Present water acts as a plasticizer*

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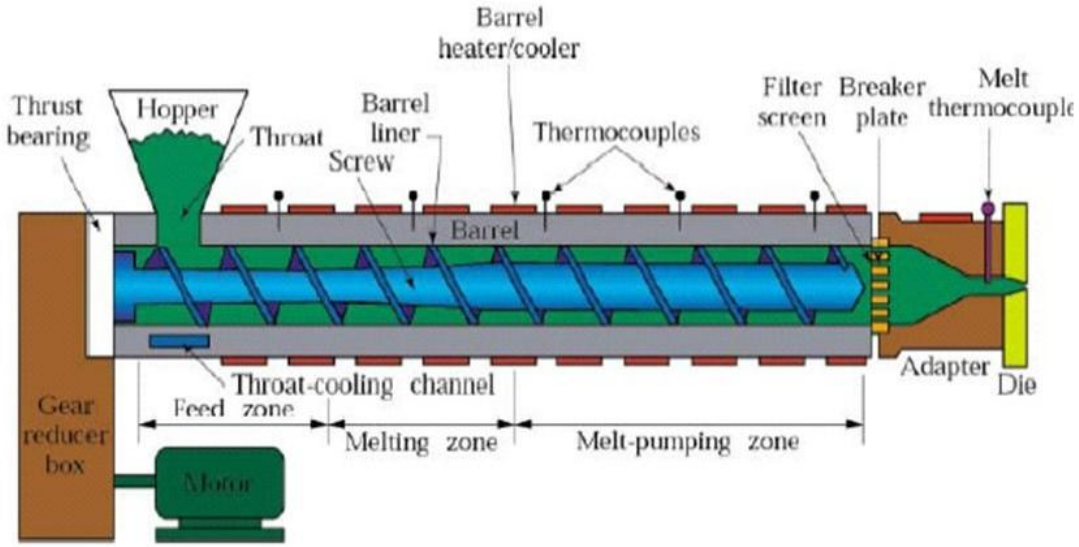
Extruder

- Viscosity of material; generally for filament extrusion = high (MFI 20)
- Tprofile (pilot extrusion ≠ industrial)
- 30-40 °C above Tm
- Pressure



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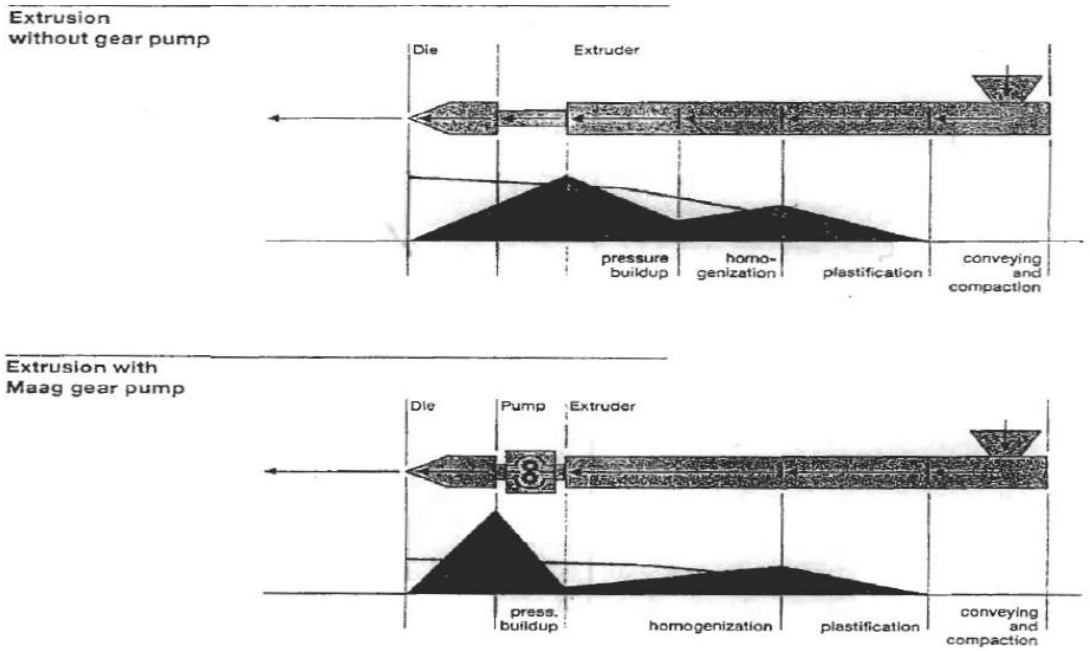
Gear pump

– Pressure and temperature distribution when used melt gear pump



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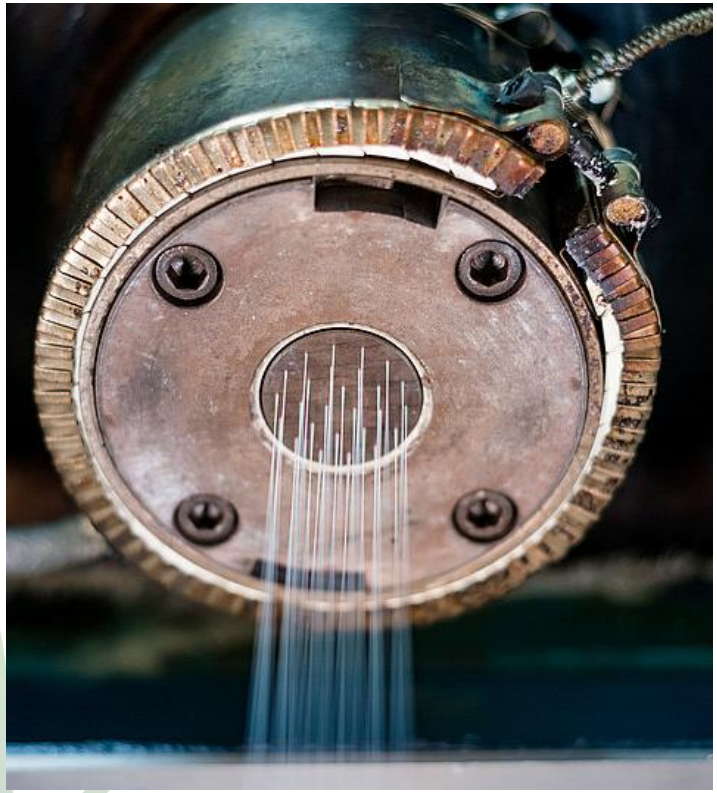
Die

- Pressure necessary for homogeneous filament
- Monofilament vs multifilament
- Amount of filaments
- Dpf
- L/D
- Introduction bicomponent



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Die: L/D

- See Bio4Self

Table 1. Effect of L/D ratio and cold draw ratio on modulus of PLA yarn.

L/D ratio spinneret (-)	Cold draw ratio (x)	Modulus (GPa)
2	6.1	7.7
2.6	6.1	7.3
4	6.1	8.7
4	3.2	7.8
4	1.8	7.2

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Drawing

- Melt drawing
- Cold/hot drawing
- Explanation per step (extrusion → water bath → rolls (or ovens)
- Difference rolls/ovens
- Shrinkage!

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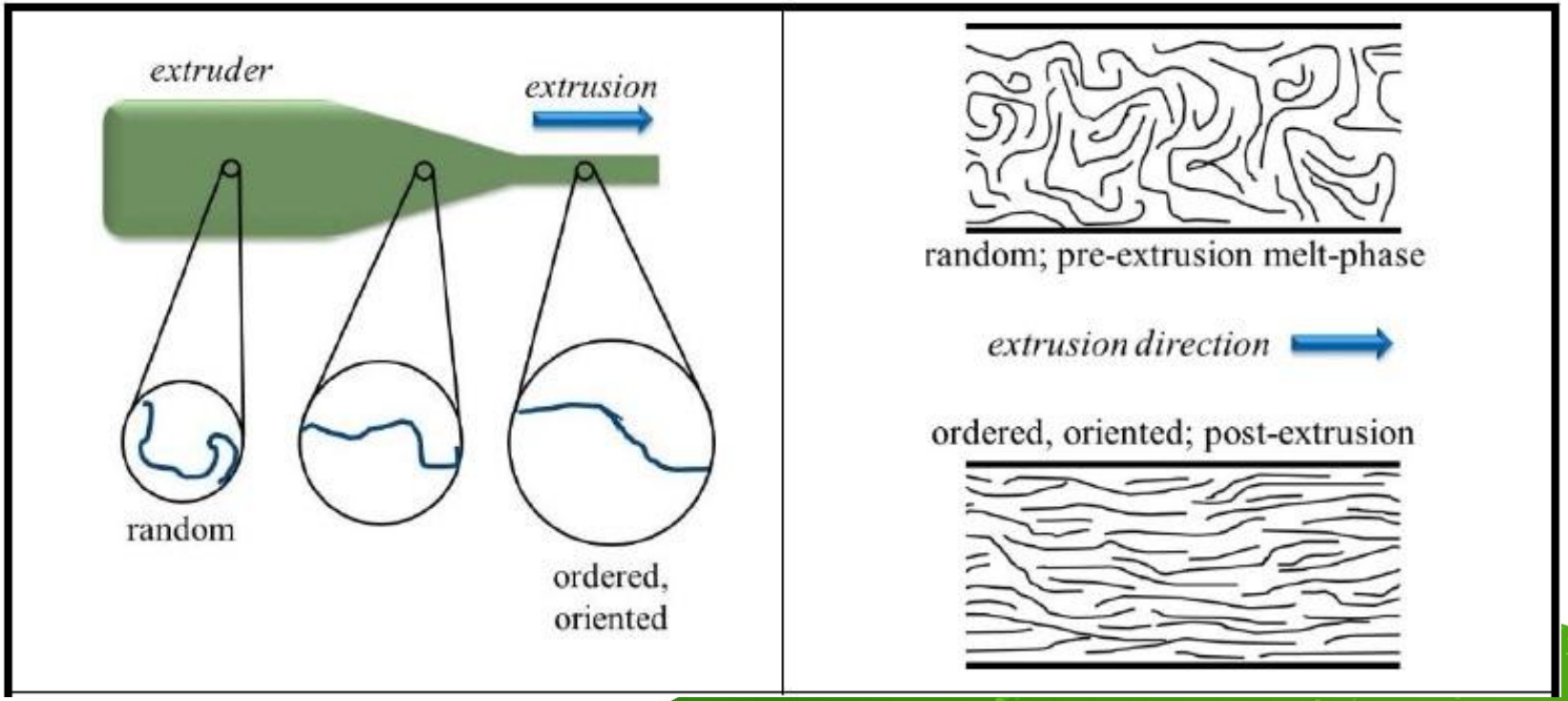
Drawing

- What is drawing of polymers?
- Why?



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Drawing

- Different types of drawing
  - T>Tm: “melt drawing”
  - Tc*<T<Tm: ”hot” solid state drawing
  - Tg<T<Tc*: “cold” solid state drawing
  - T<Tg: no drawing (or very limited)

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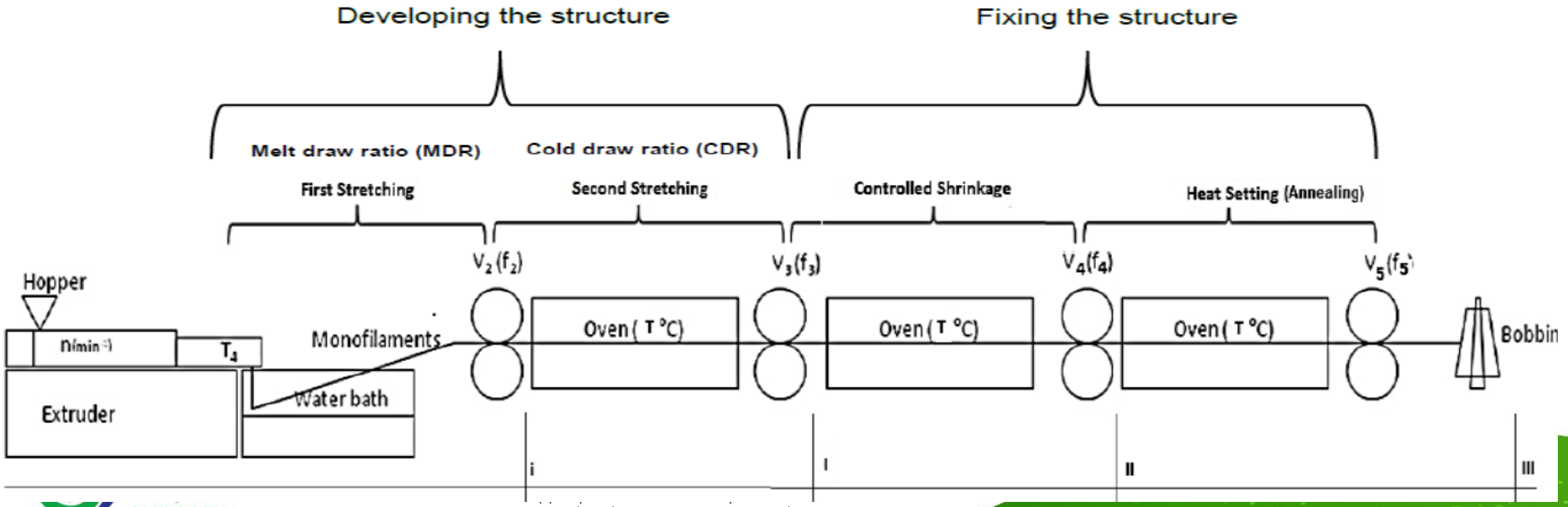
Drawing in process (monofilament)



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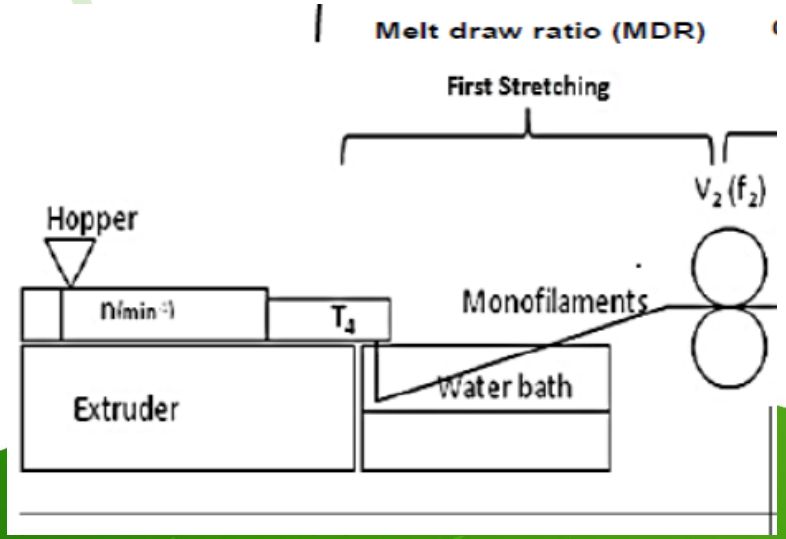
Melt drawing

- From extruder (and water bath) to first rolls
- Temperature is high (above Tm)
- Polymer is in the melt state
  - No crystalline structure yet



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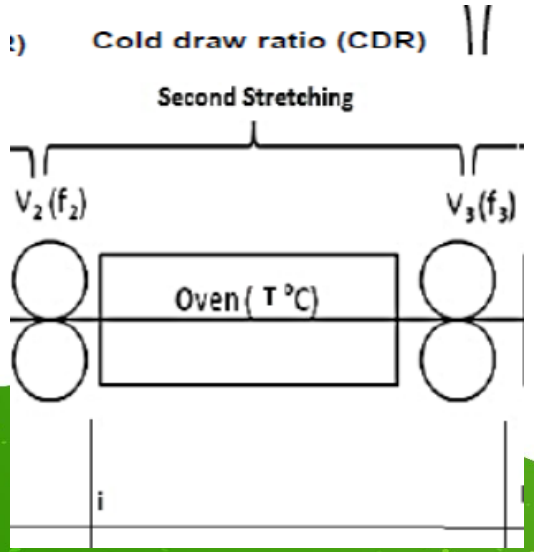
Drawing in process (monofilament)

- From first rolls to second rolls
- Solid state drawing
  - Alignment of polymer chains
  - Continuous recrystallization
  - Increased crystallinity



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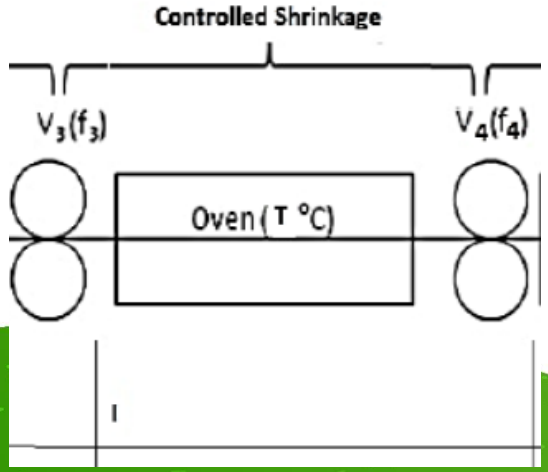
Drawing in process (monofilament)

- Reheating of drawn yarns will lead to shrinkage → complications later
- Prevented by allowing for controlled shrinkage at this stage
  - Rolls at higher T (heating up the yarn)



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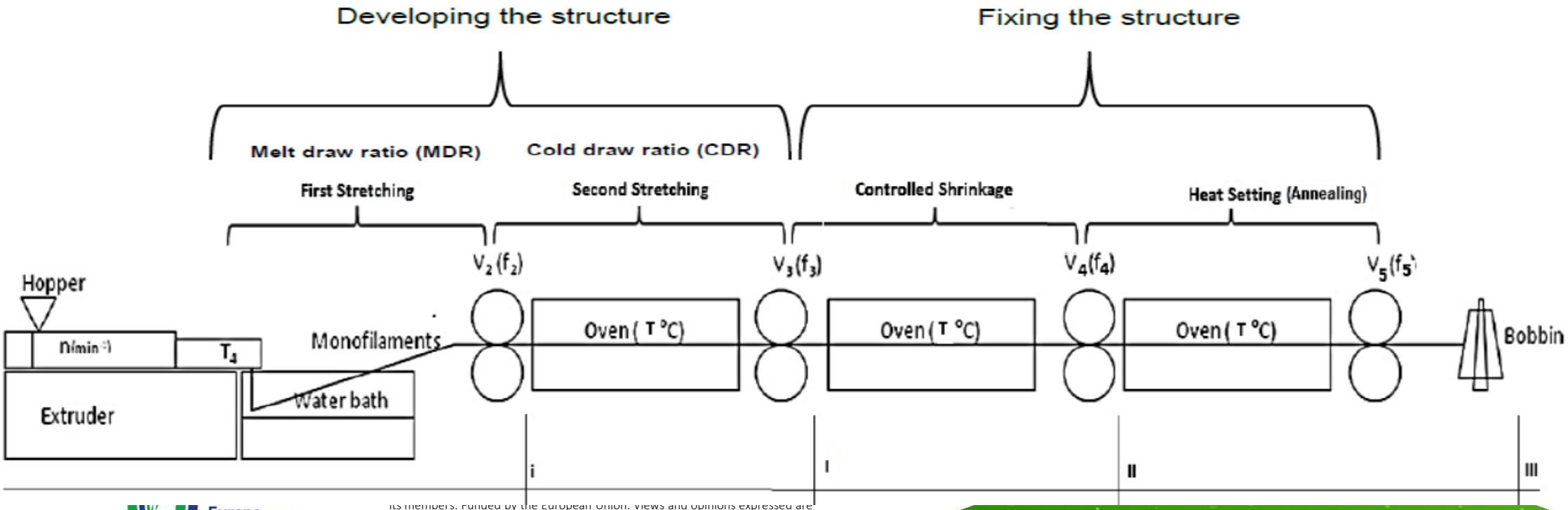
Monofilament



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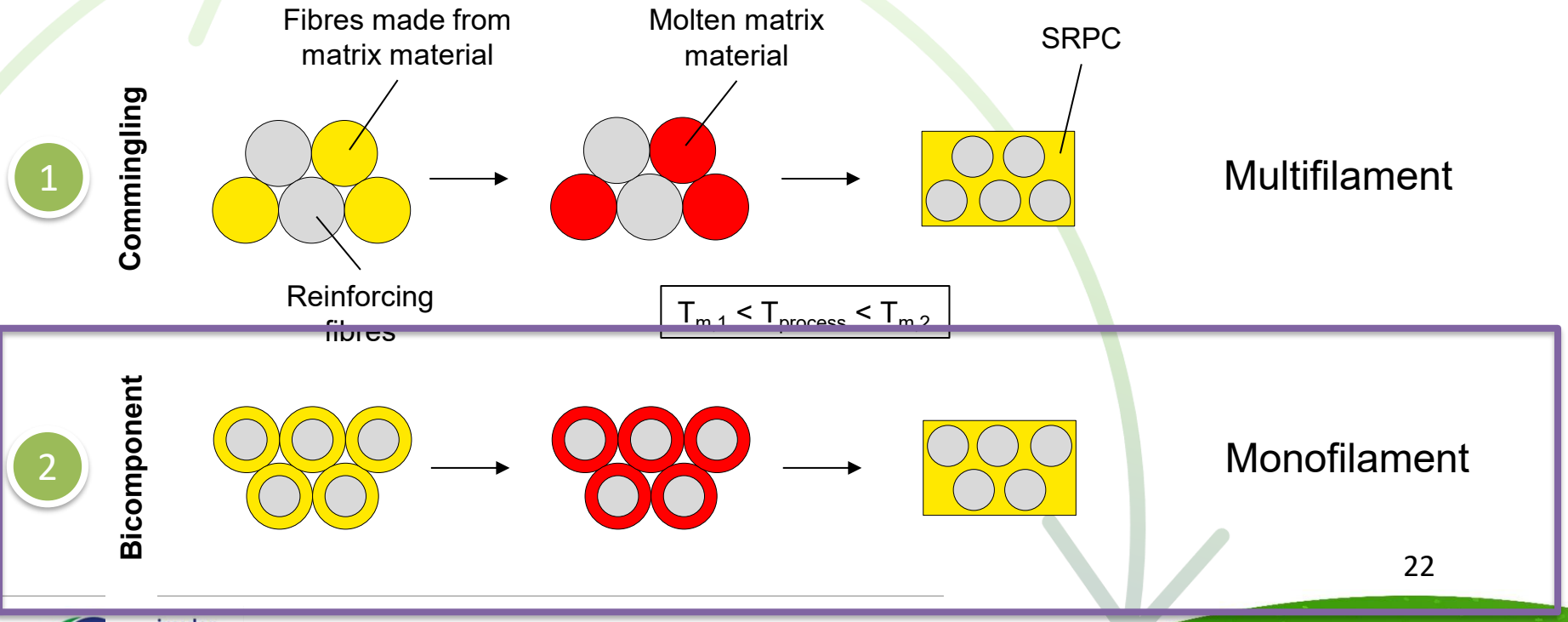
Composite formation



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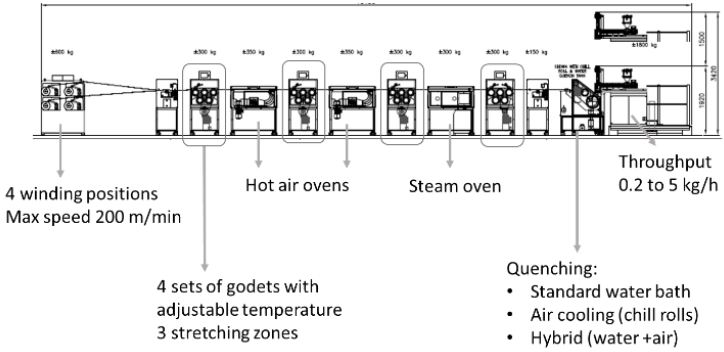
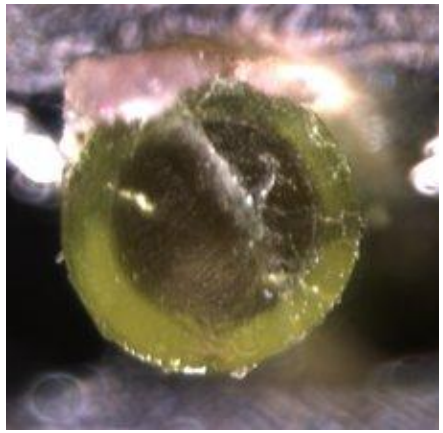
Extrusion bico monofilament



- Benefits
  - Each reinforcement yarn is fully covered in matrix
  - No other processes needed
- Attention points
  - More challenging to decrease shrinkage
  - Difficult to assess the mechanical properties



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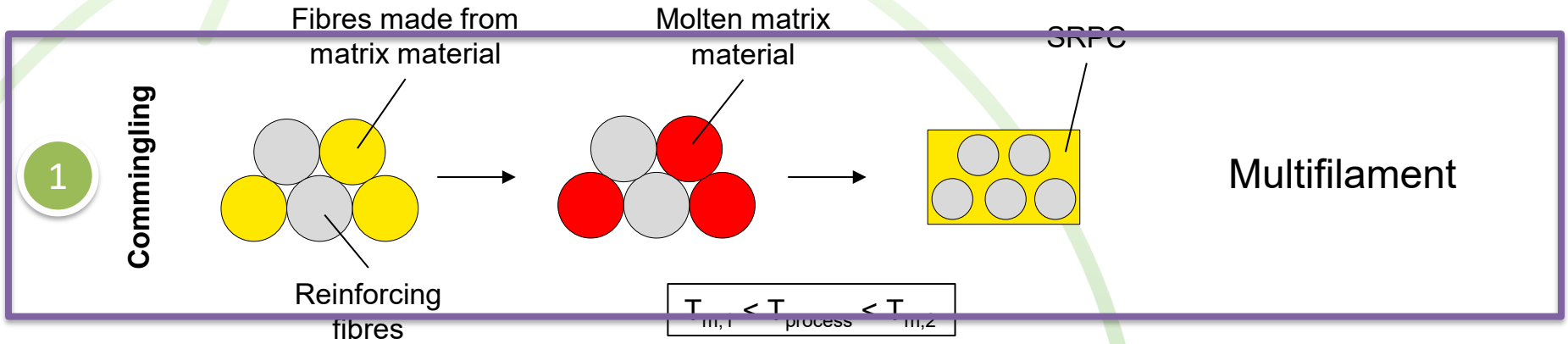
Composite formation



One-step drawing proces – FDY

Two-step drawing proces

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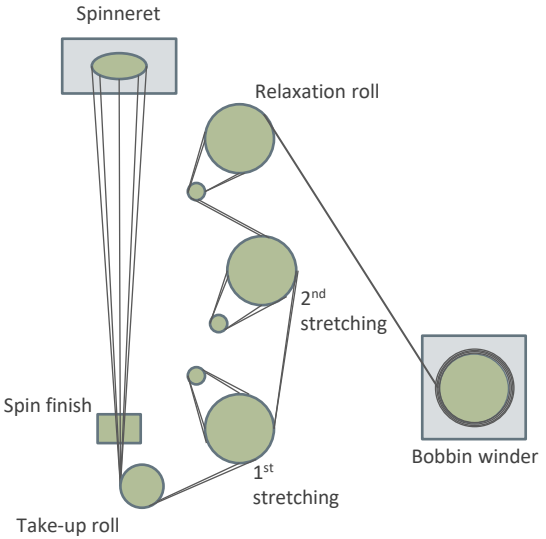
Extrusion multifilament

- One-step drawing process
  - Melt draw ratio ($T > T_m$)
  - Cold draw ratio ($T_m > T > T_g$)
- Matrix yarn
  - 40-50tex
  - Strength does not matter
- Reinforcement yarn
  - 20-30tex
  - 2,8 N/tex
  - Shrinkage 15% – 22% @150°C

Lab-scale melt extrusion line for multifilaments



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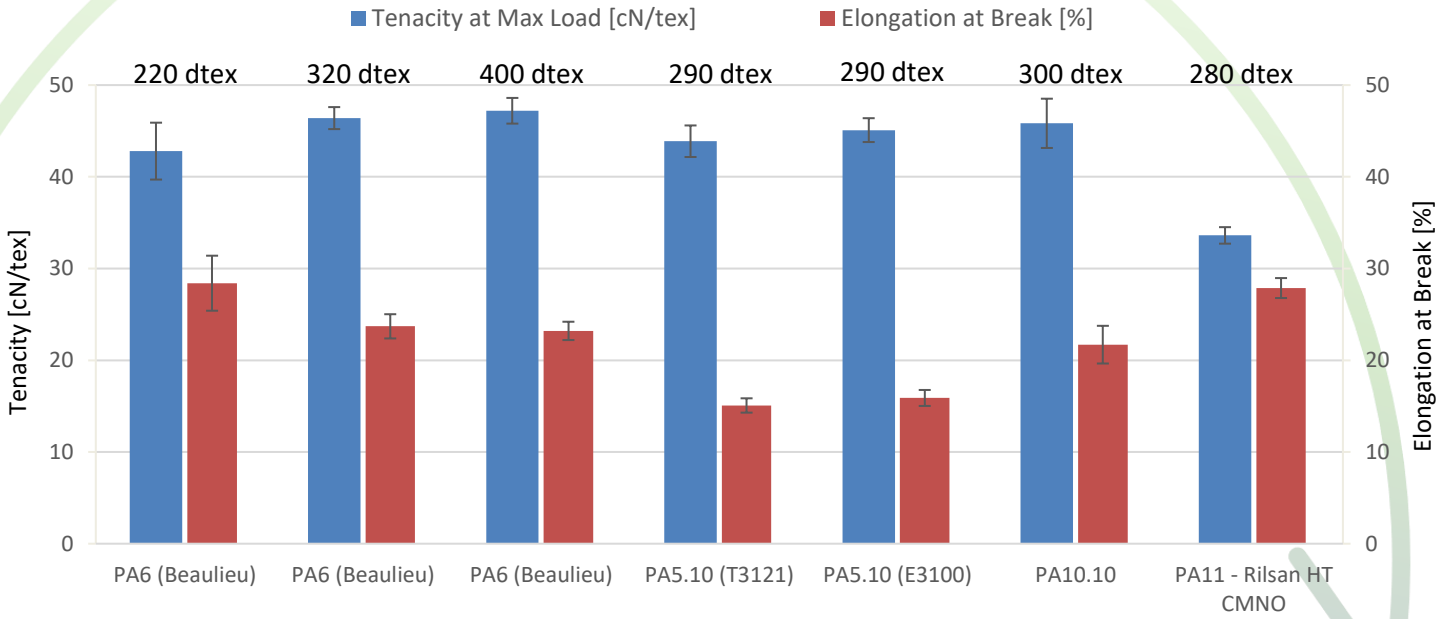
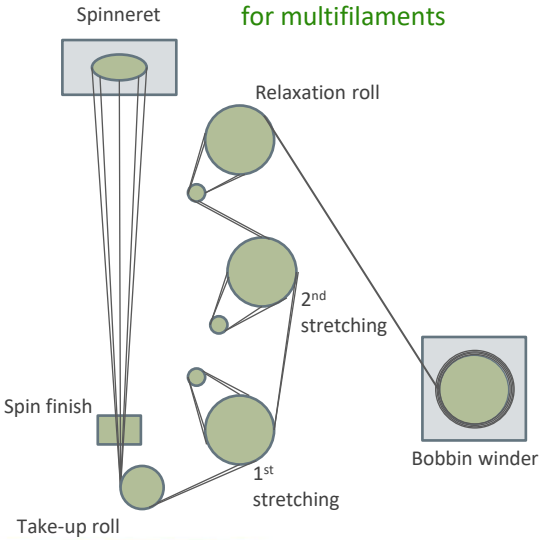
Multifilament Extrusion (Lab-scale)

- ✓ PA6, PA5.10, PA10.10 and PA11
- ✓ Good processability
- ✓ Strength: around 45 cN/tex except PA11



Lab-scale melt extrusion line for multifilaments



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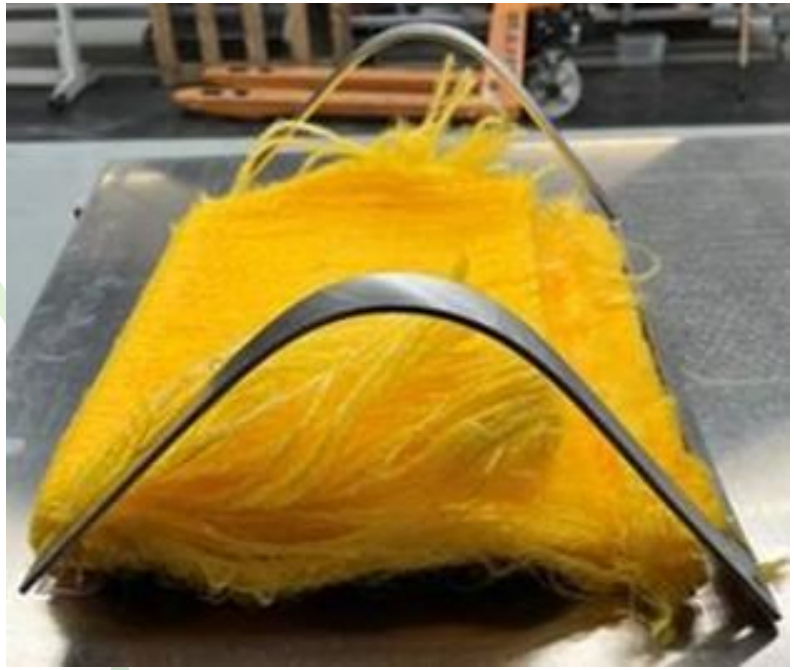
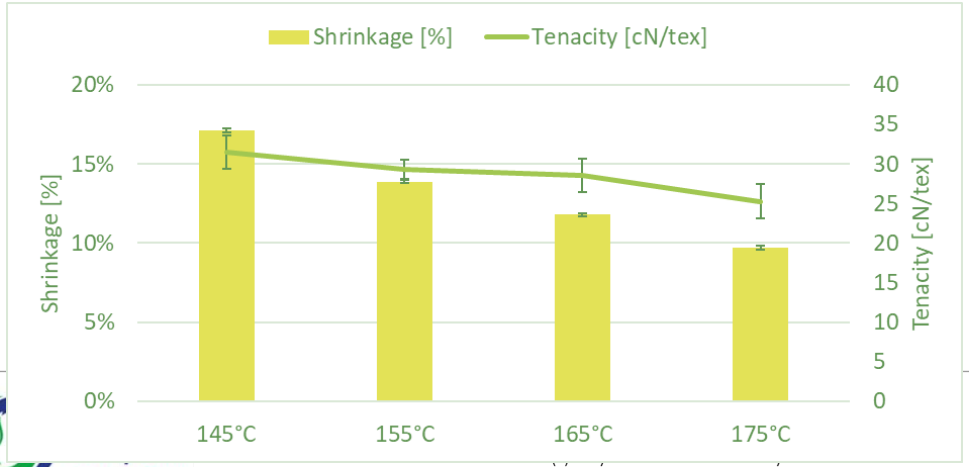
Extrusion multifilament

- Importance of shrinkage
- One-step drawing process
  - Limited control of shrinkage
  - Shrinkage ↘ causes strength ↘





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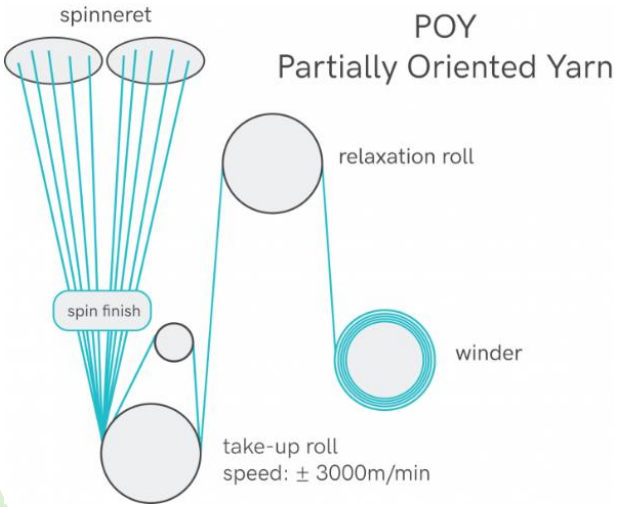
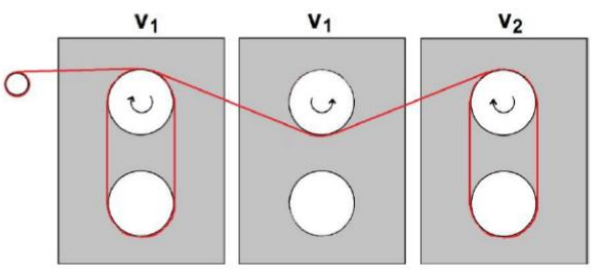
Extrusion multifilament

- Two-step drawing process
  - POY (only melt drawing)
  - 2nd separate stretching process
  - Better control of shrinkage
- Only for reinforcement yarn
  - Strength up to 5N/tex
  - Shrinkage 7% @150°C





Post-stretching process

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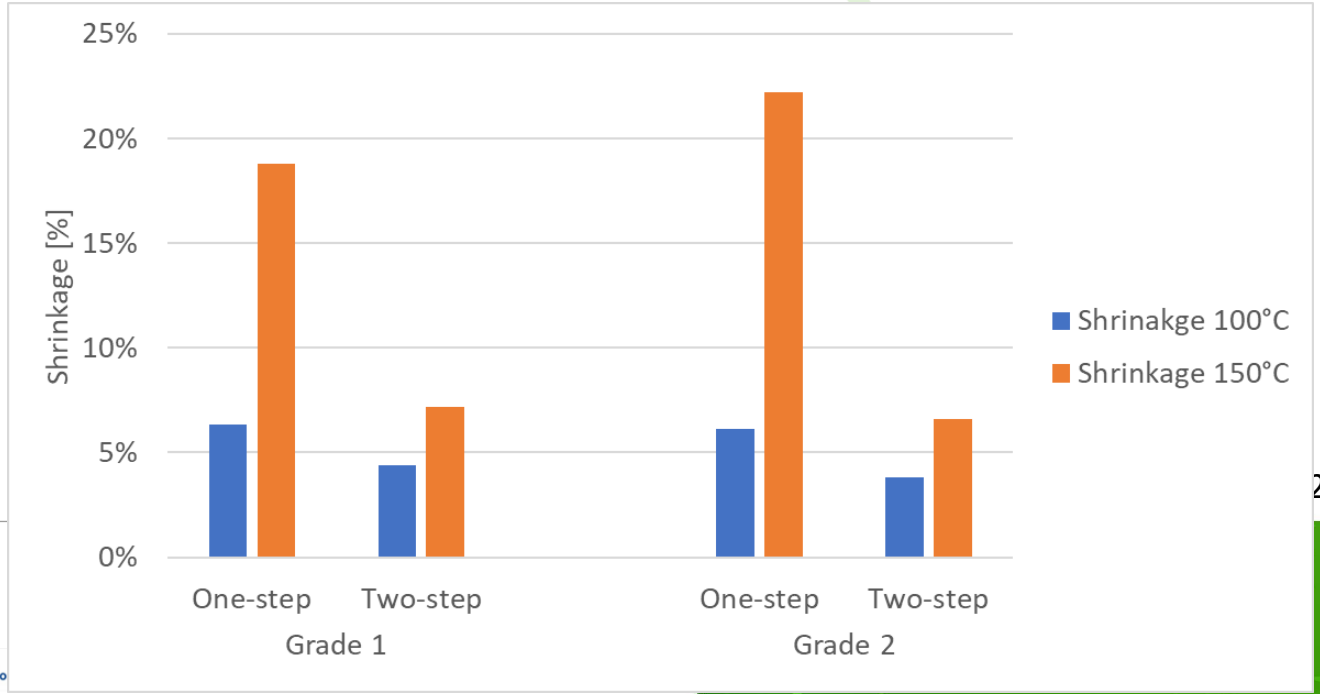
Extrusion – overview properties

- Shrinkage lowers to 7% @150°C
- Heated ovens ≠ heated rolls



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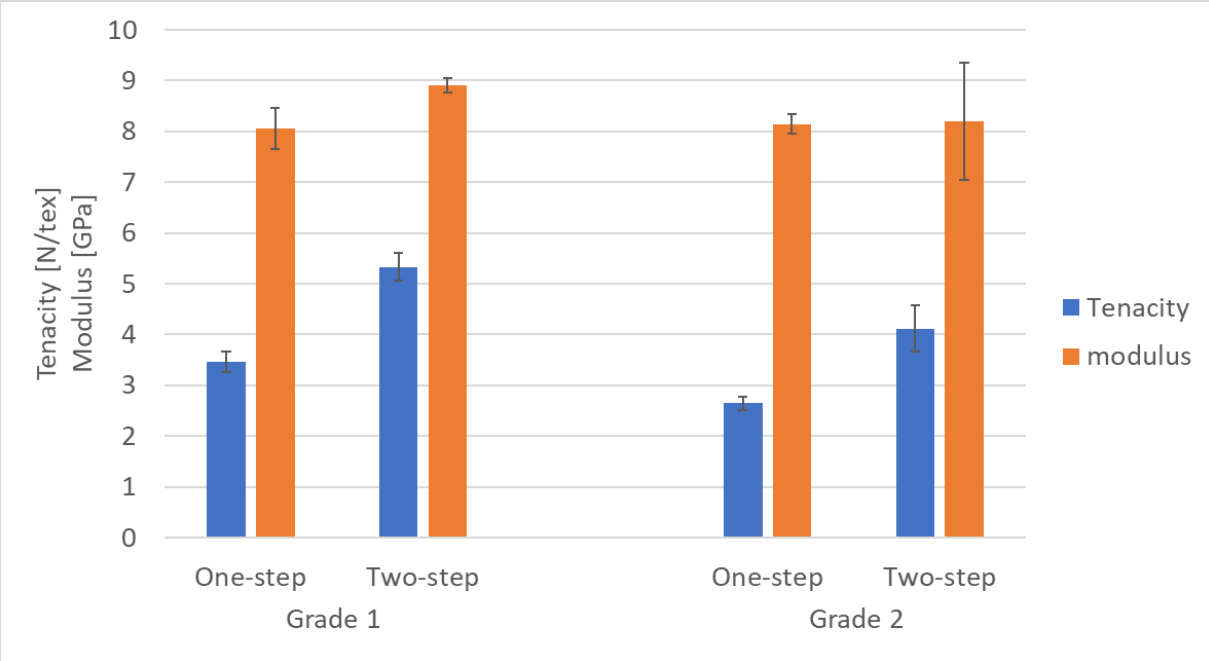
Extrusion – overview properties

- Strength increases to 5N/tex
- Modulus increases to 9 GPa



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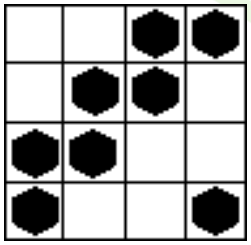
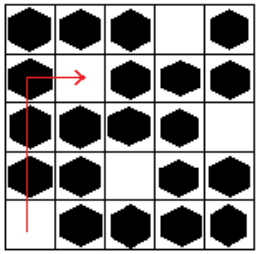
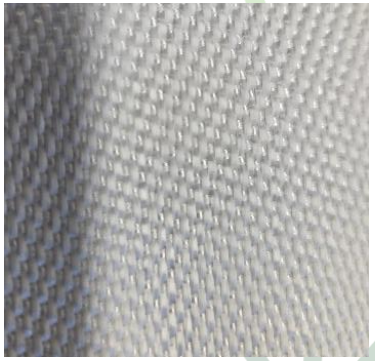
Weaving

- Dobby weaving machine
  - Width 50cm
  - 11 yarns/cm warp
  - 10 yarns/cm weft
  - Two patterns
    - Twill 2x2
    - Satin 5 (warp effect, shift 3)







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Bio-based Industries Consortium
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