TECHNICAL UNIVERSITY OF LIBEREC

New Opportunities for the Development of Education at the Technical University of Liberec

Specific objective A2: Development in the field of distance learning, online learning and blended learning

NPO_TUL_MSMT-16598/2022

KNT_TNA_Centrifugal spinning

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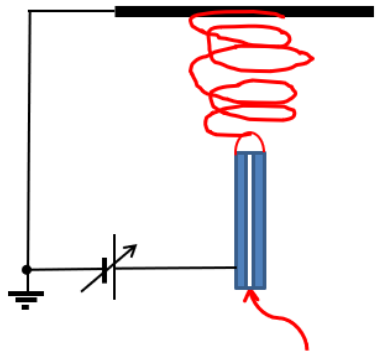
NextGenerationEU

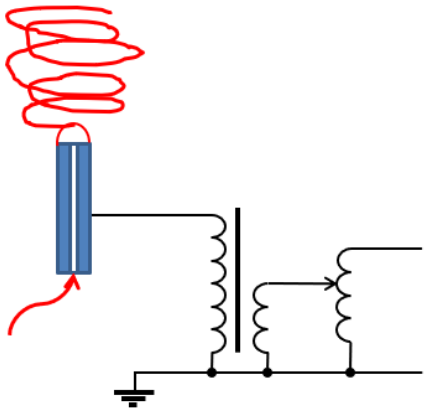
CZECH RECOVERY PLAN

MINISTRY OF EDUCATION, YOUTH AND SPORTS

Repetition

- Production of nanofibrous materials:
  - DC spinning
    - An electrically active collector is required for spinning
  - AC spinning
    - An electrically active collector is not required for spinning





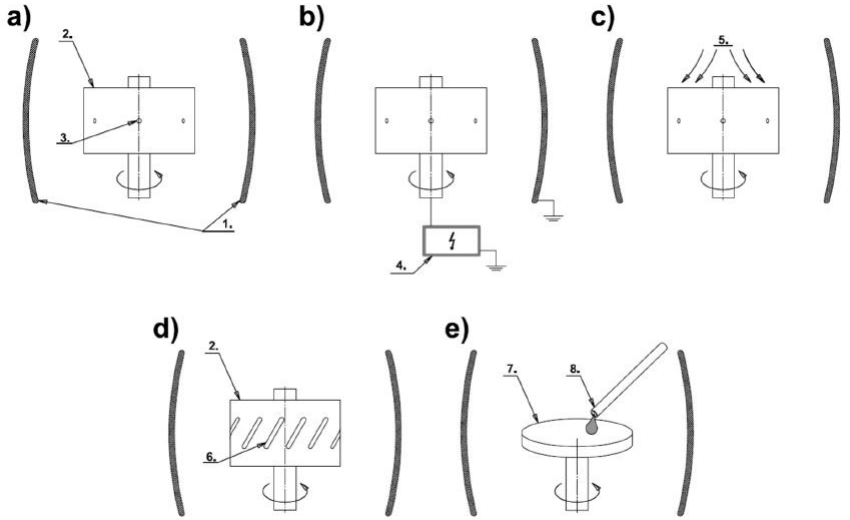
Centrifugal spinning

- The production of fibers uses centrifugal forces caused by the high speed of rotation of the spinneret
- Spinning from both solutions and melts
- Advantage: no conductive solution is required

Cotton candy production - centrifugal spinning

Types of centrifugal spinning

- Centrifugal spinning
  - Needle
  - Needle-less
- Electro-centrifugal spinning
  - Needle
  - Needle-less



Needle centrifugal spinning

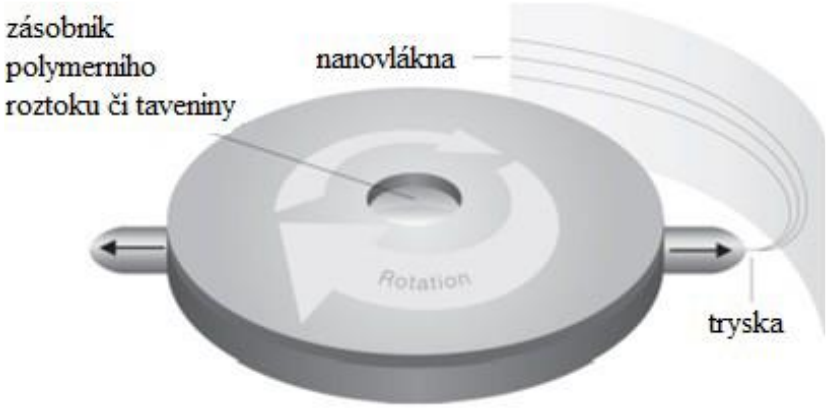
- To start the spinning process, it is necessary to balance the centrifugal and capillary forces

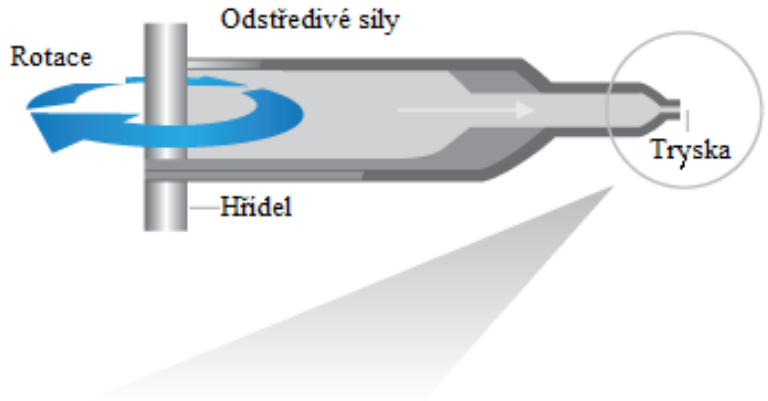
  - Centrifugal force $F_\Omega = \rho \Omega^2 s_0 a$
  - Capillary force $F_c = \sigma a$
  - Critical value of angular velocity $\Omega_{crit} = \sqrt{\frac{\sigma}{a^2 s_0 \rho}}$

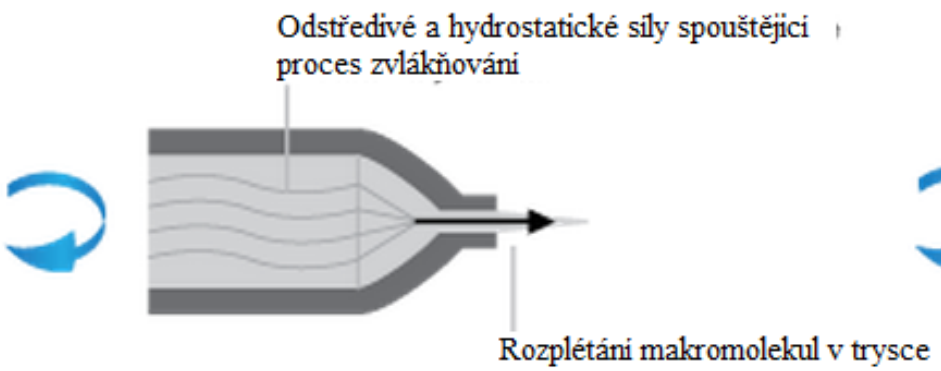
ρ – density
Ω – angular velocity
s_0 – radius of the tank
a – spinning hole radius
σ – surface tension

Spinning starts when the angular velocity exceeds the critical value of the angular velocity

Principle


zásobník
polymerního
roztoku či taveniny
nanovlákna
Rotation
tryska

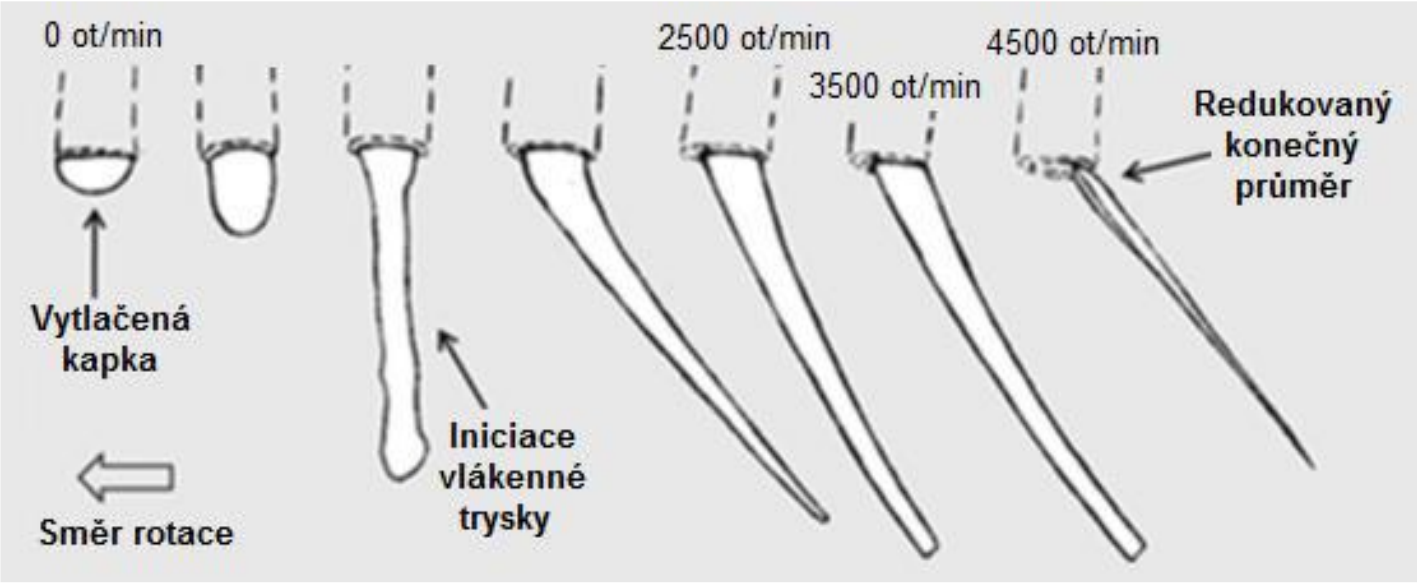

Odstředivé síly
Rotace
Tryska
Hřídel


Odstředivé a hydrostatické síly spouštějící
proces zvlákňování
Rozplétání makromolekul v trysce


Přetváření polymerního proudu do
nanorozměrů
urovnání makromolekul
Proud vzduchu
vyvolávající
smykové tření

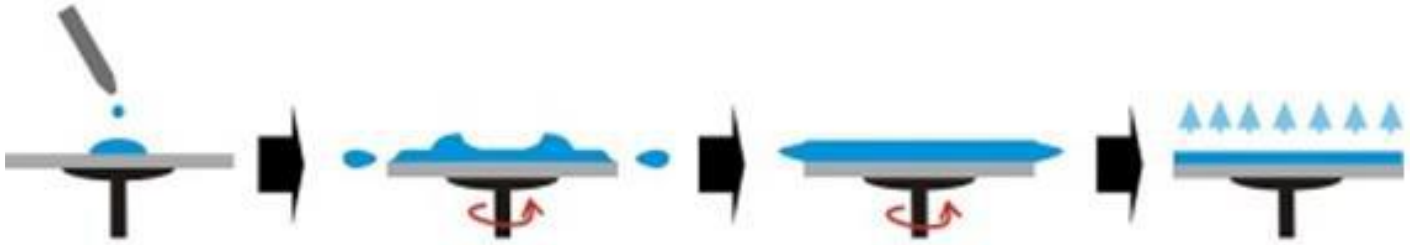
Principle

- The process of fiber formation consists of:
  - The formation of a nozzle
  - By extending the nozzle
  - By evaporating the solvent

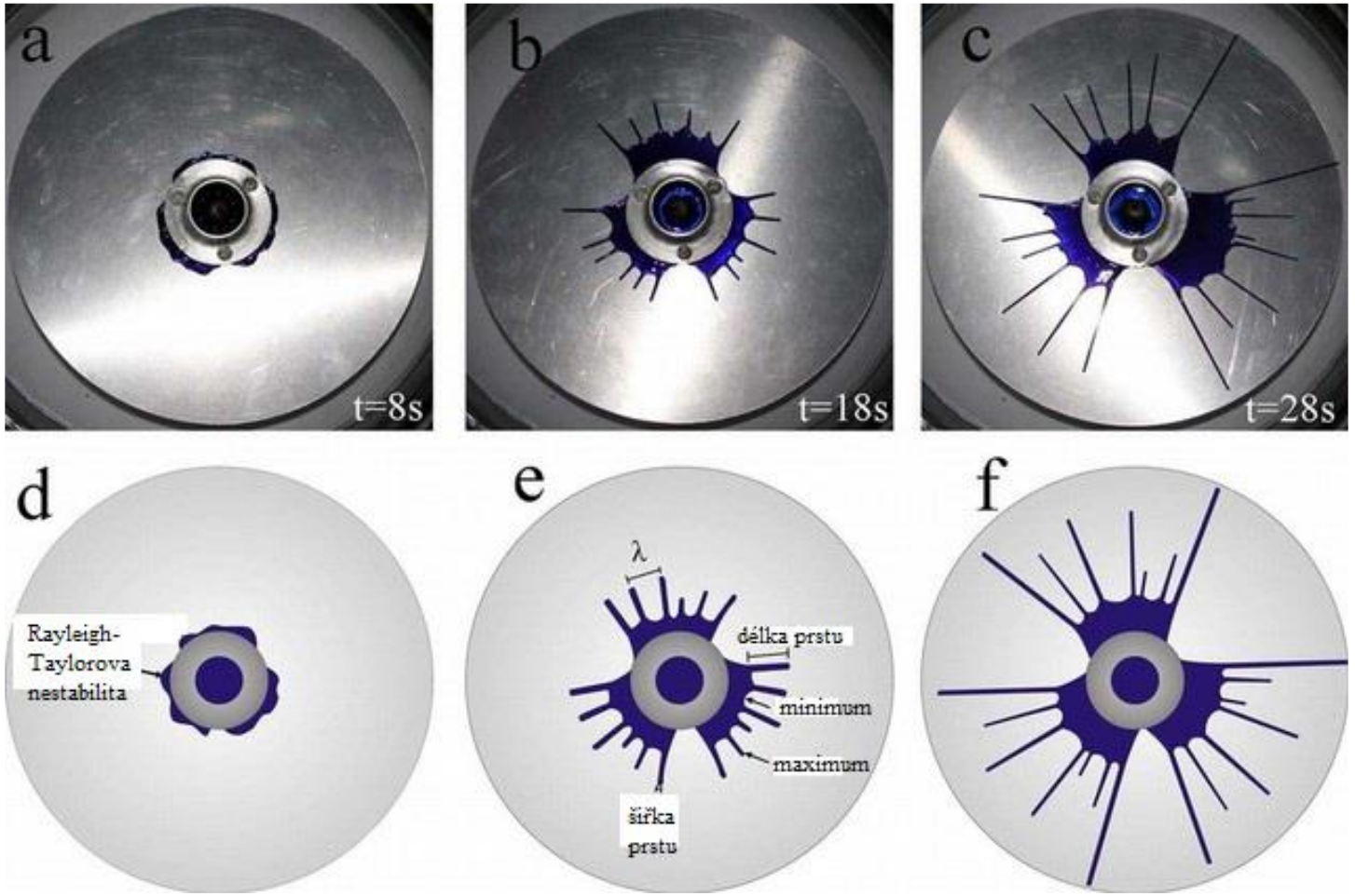


Needle-less centrifugal spinning

- Fiber formation due to polymer film instability
- Instability arises due to centrifugal and Laplace forces
- Rayleigh-Taylor instability causes thin currents to form

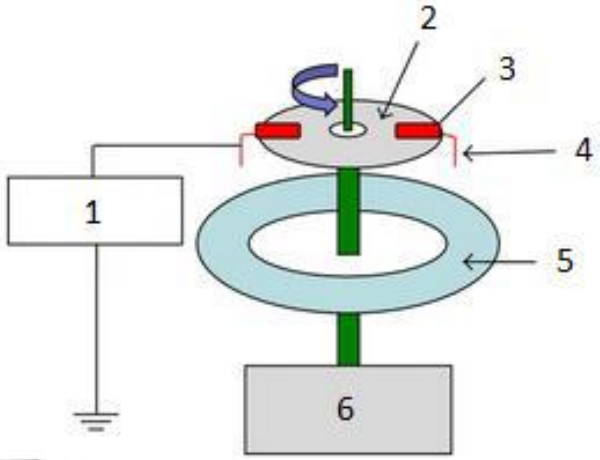


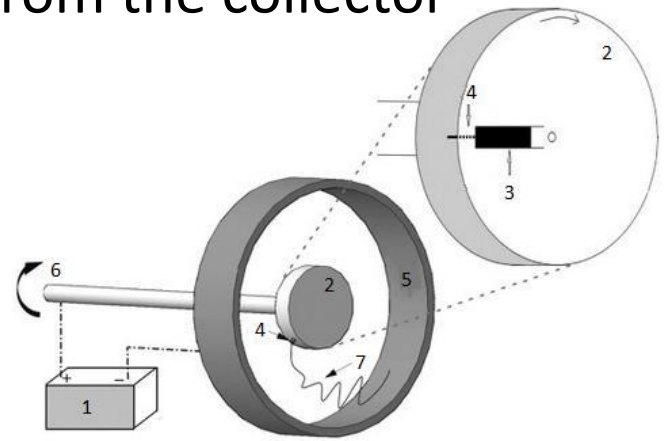
Needle-less centrifugal spinning



Electro-centrifugal spinning

- Combination of centrifugal spinning and high voltage source
- Needle and needle-less spinning
- Advantages:
  - Lower spinneret rotation speed
  - Lower electrical voltage
  - Smaller distance from the collector





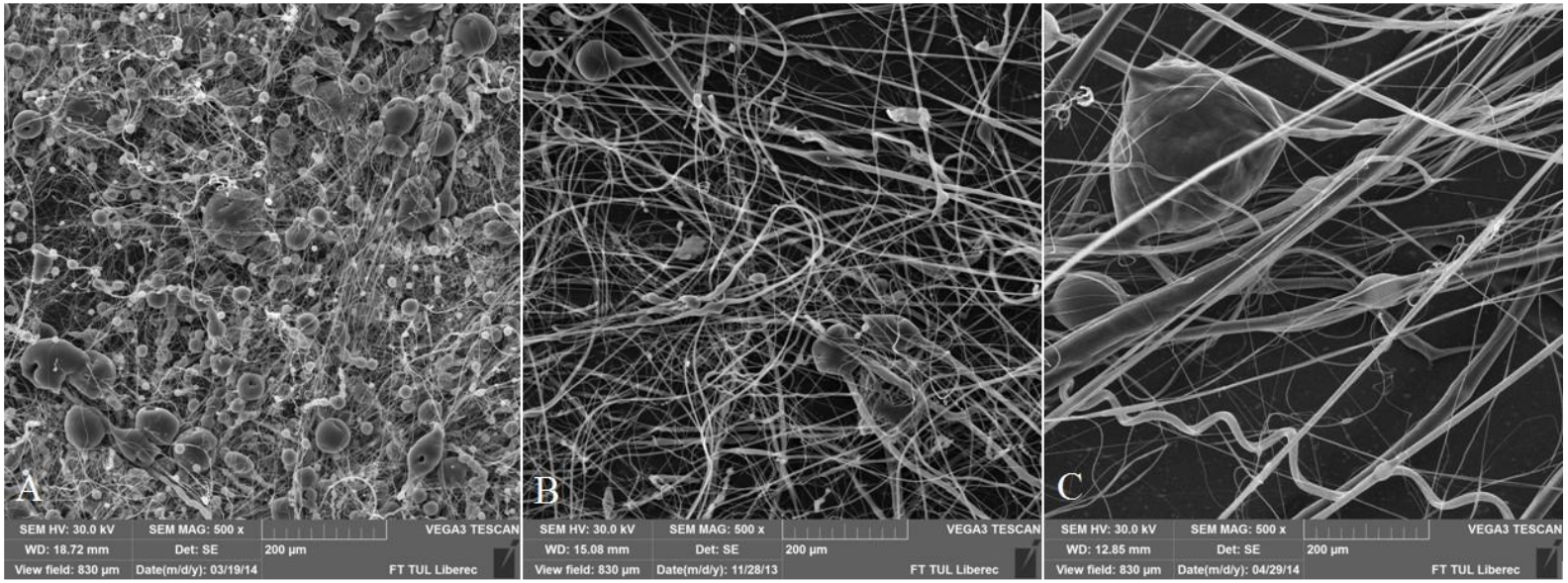
Material conditions

Material conditions the same as for electrostatic spinning, except for electrical conductivity

- Melt / solution
- Type of polymer
- Molecular weight
- Solvent system
- Concentration
- Viscosity
- Surface tension
- Temperature

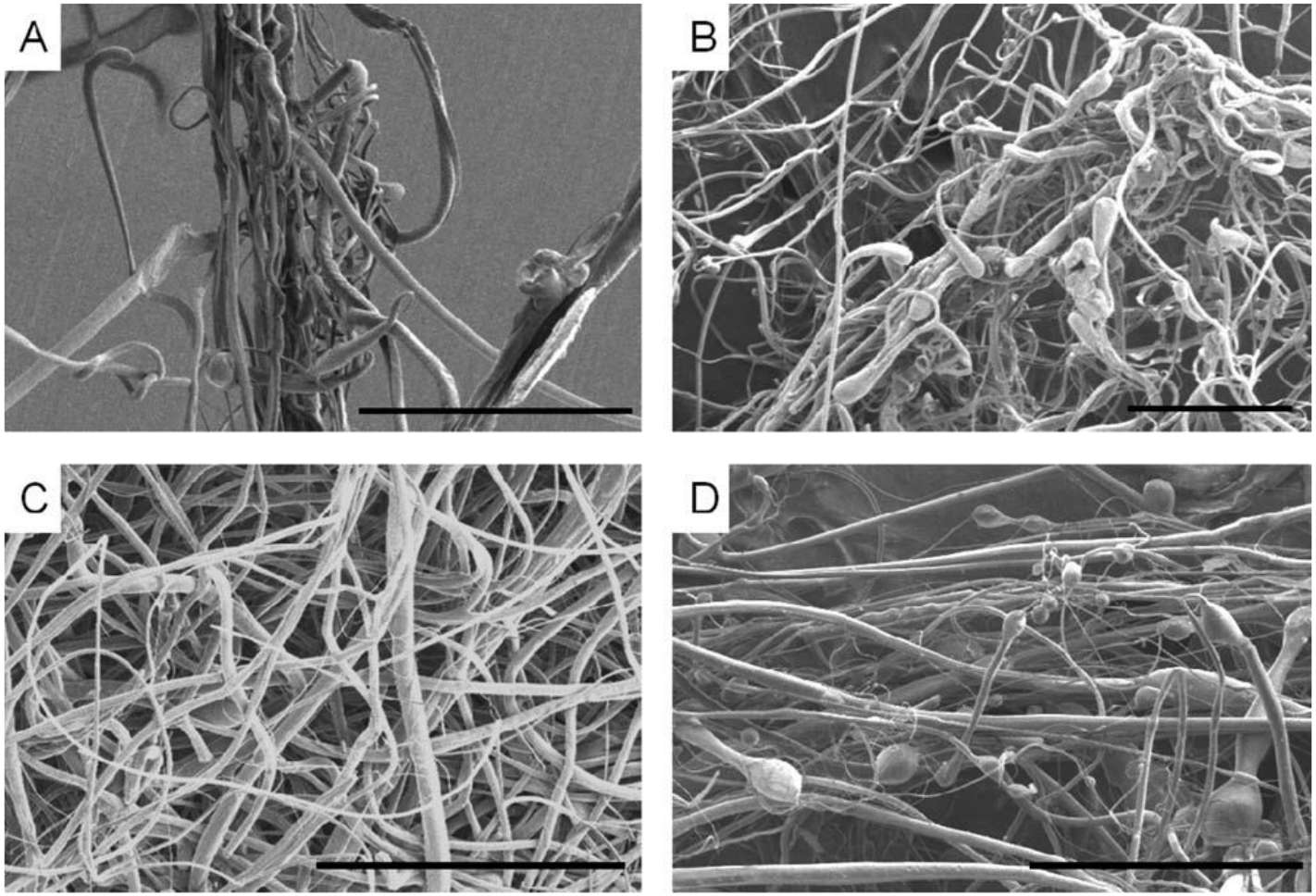
Influence of molecular weight

- Molecular weight affects the centrifugal spinning process as well as electrospinning process
- It is necessary to find a suitable concentration for a given molecular weight



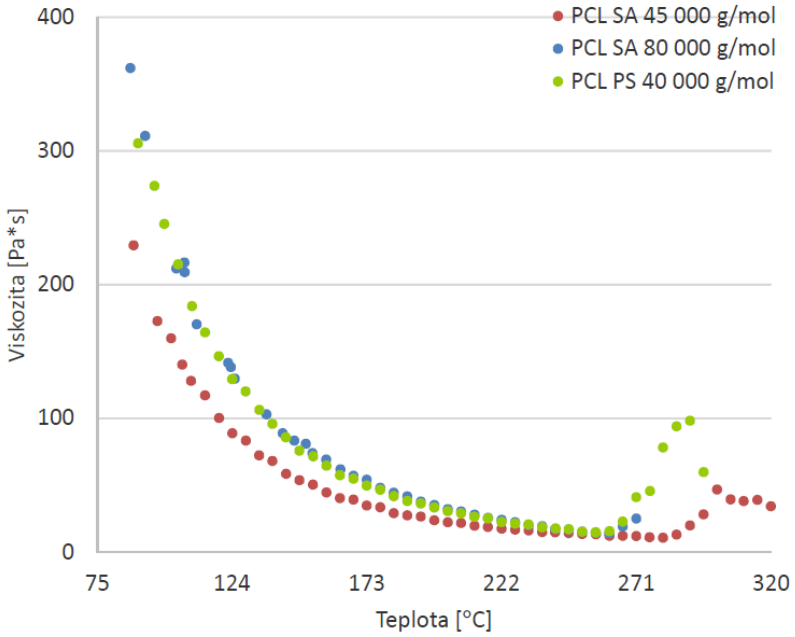
Influence of molecular weight on the resulting structure. All samples were spun at a concentration of 20 wt% and a speed of 22 m / s. A) Mn 10,000, B) Mn 45,000, C) Mn 80,000

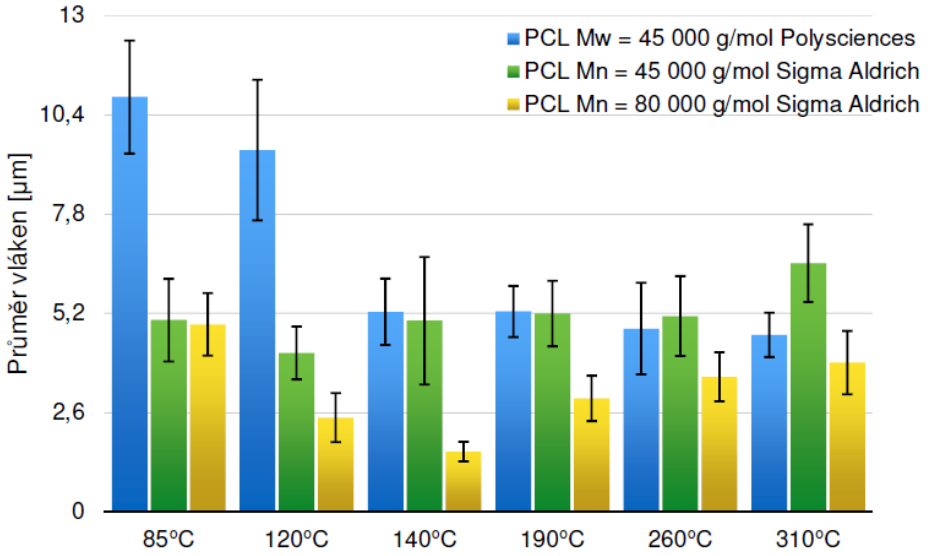
Melt temperature

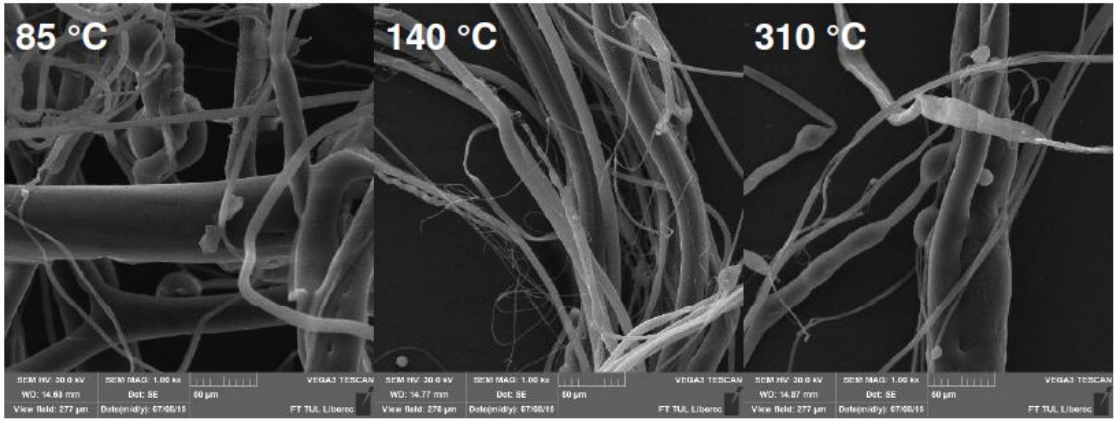


Scanning electron micrographs of melt-spun polycaprolactone fibers spun at different temperatures. (A) 120°C, (B) 140°C, (C) 200°C, (D) 250°C. Scale bar denotes 300 µm. Rotation speed and collector distance were fixed at 14,000 rpm and 14 cm, respectively.

Melt temperature

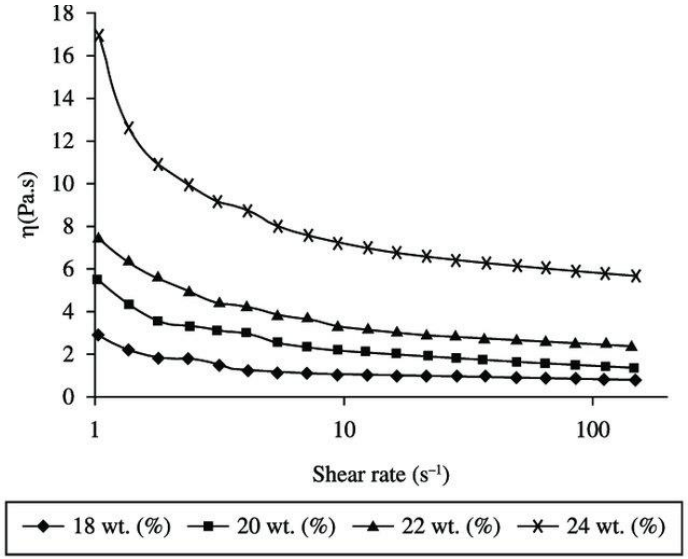




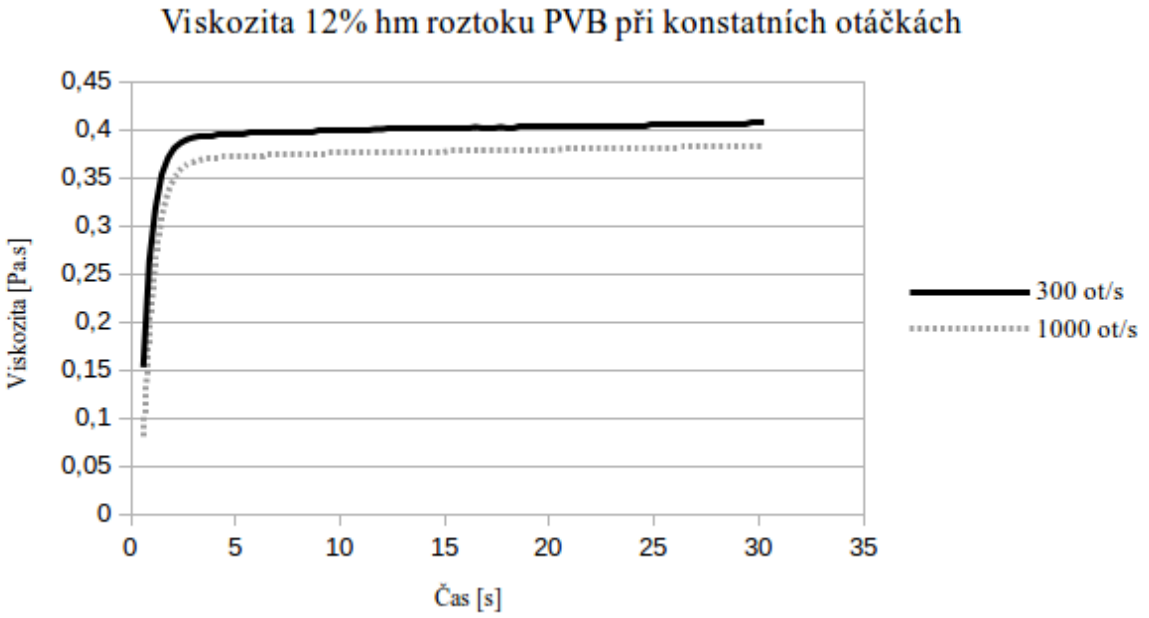


Viscosity

- Polymer solutions and melts – Non-Newtonian fluids
- Pseudoplastic fluids – viscosity decreases with strain rate



Shear viscosity and shear rate relationship for the SF solutions.

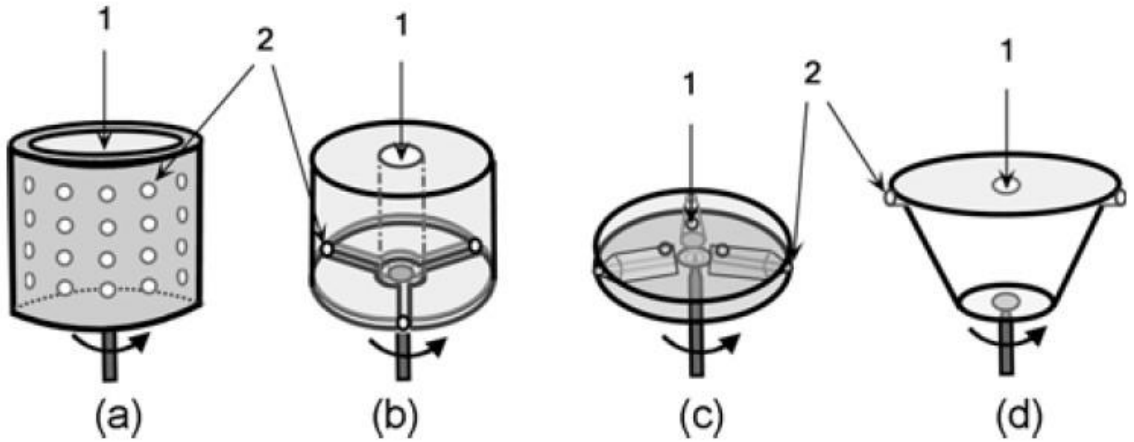


Process conditions

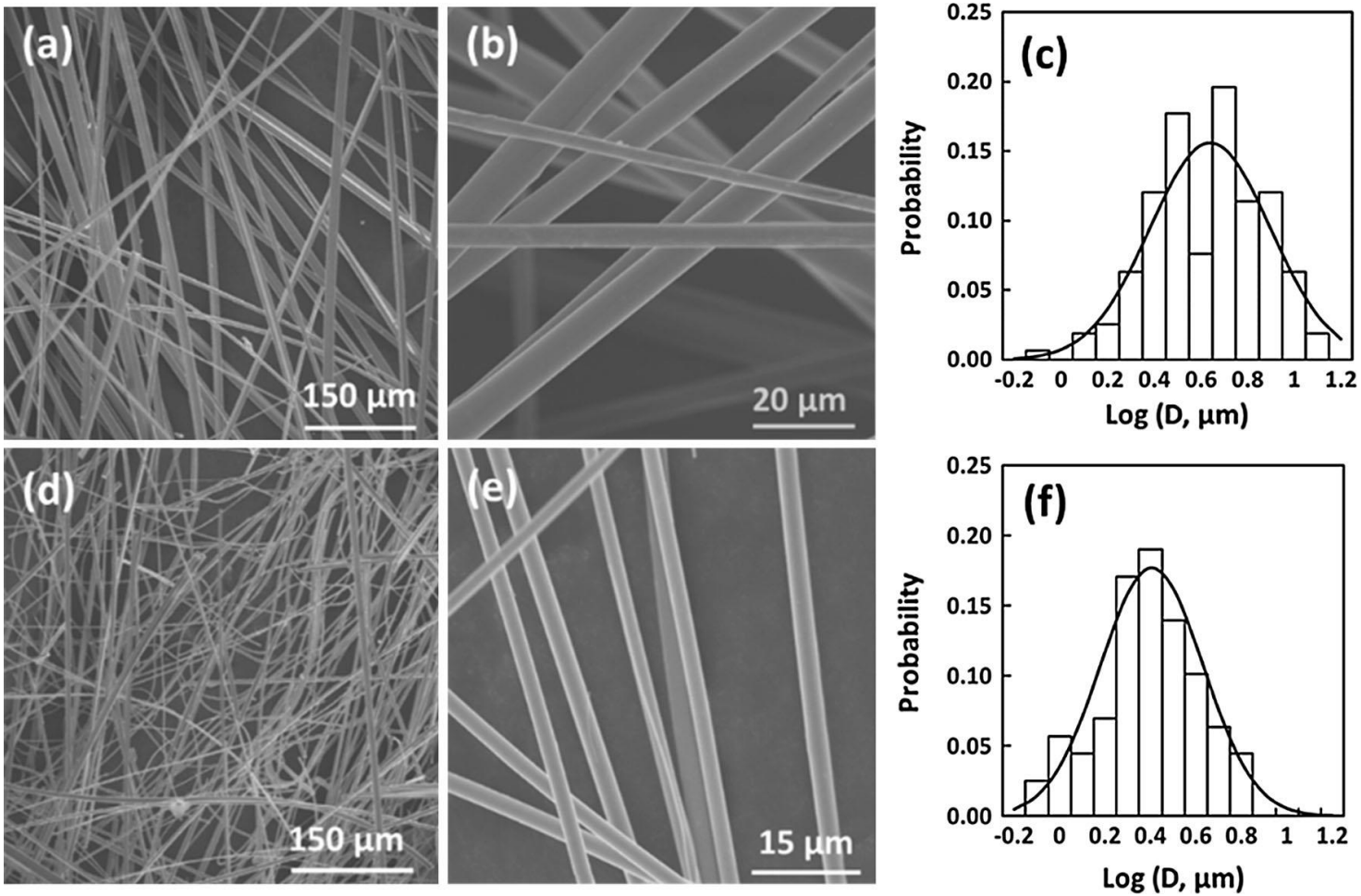
- Type of spinneret
- Spinneret rotation speed
- Collector distance
- Temperature and humidity

Type of spinneret

- Important parameters influencing the spinning process:
  - Spinneret shape
  - Spinneret size
  - Needle diameter
  - Number of needles
  - Needle shape



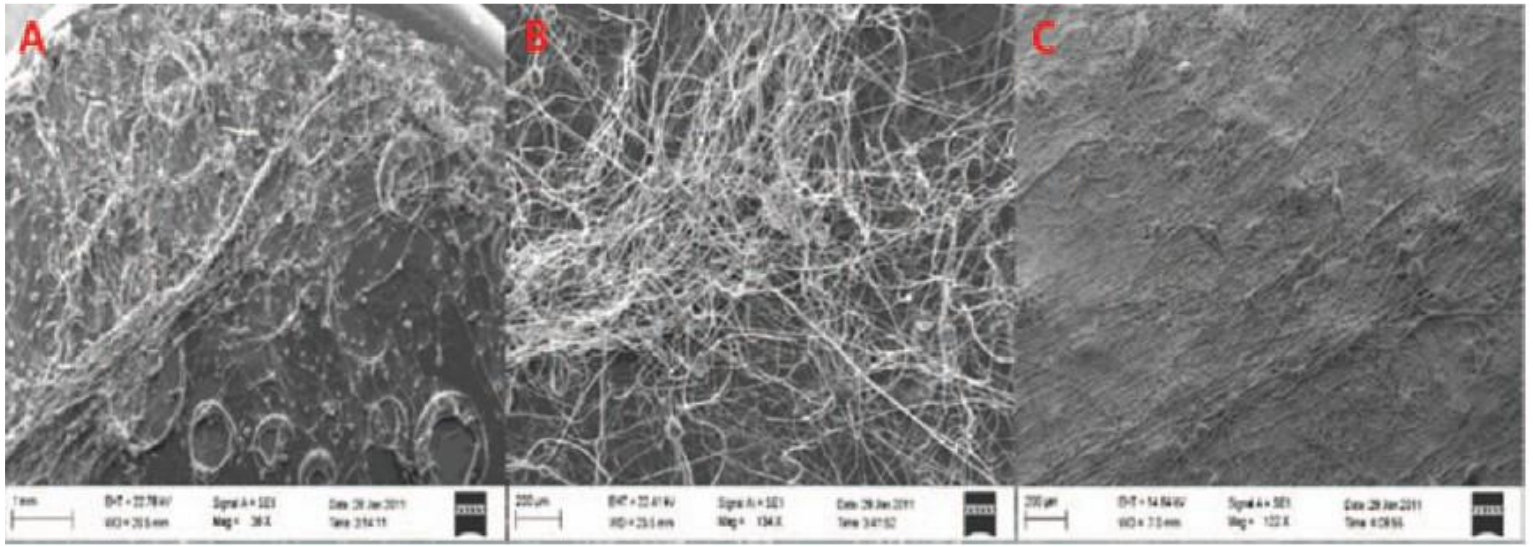
Type of spinneret - size



Representative SEM images and fiber diameter distributions of TFP fibers made at 270°C, 10,000 rpm, with a 20 gauge spinneret (a)–(c) and 30 gauge spinneret (d)–(f), respectively. The fiber diameter distributions were fit to logarithmic normal distributions (solid lines)

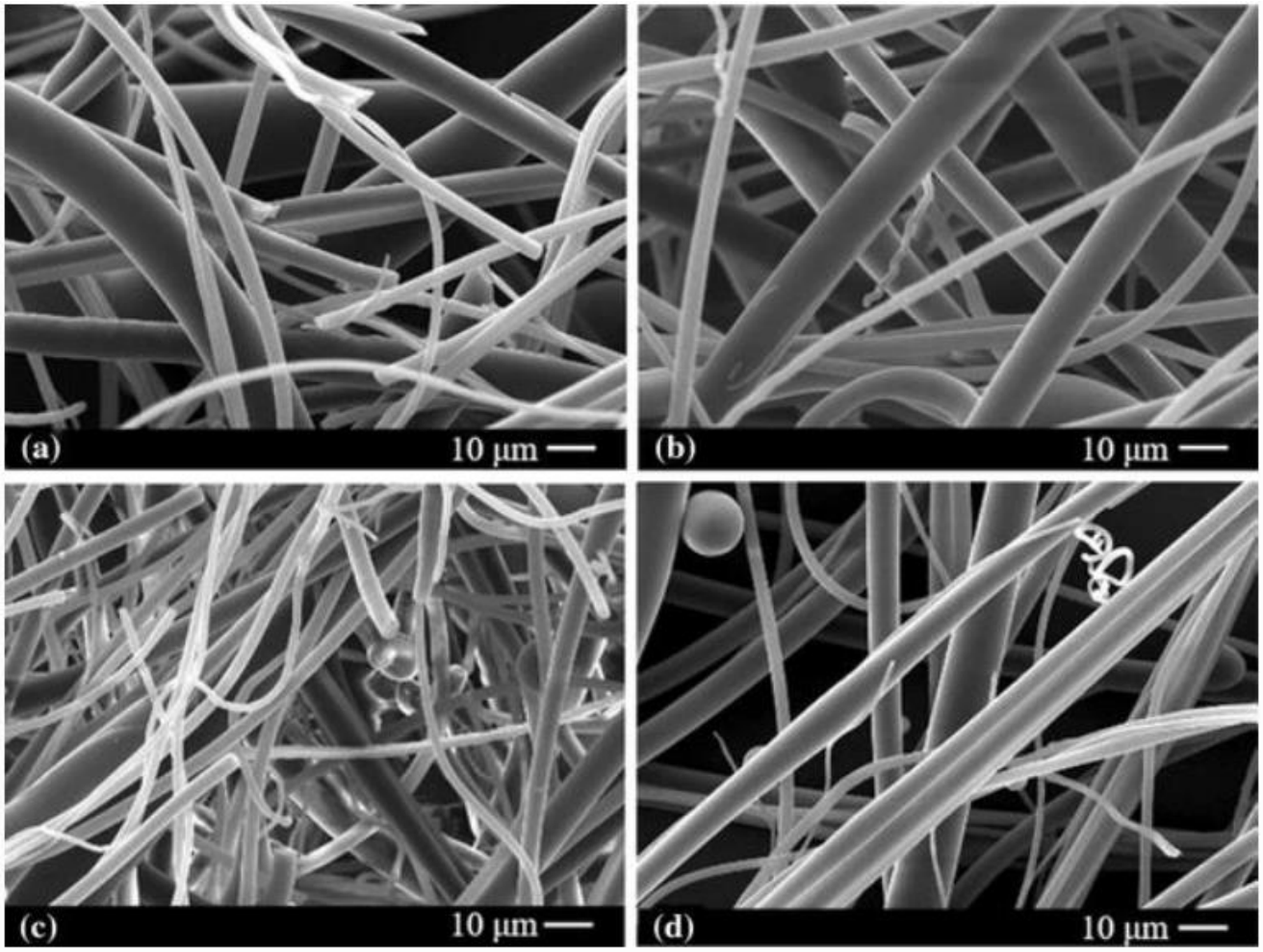
Spinneret rotation speed

- The speed of the spinneret affects the centrifugal force and the frictional force of the surrounding air
- The centrifugal force and the frictional force cause the resulting nozzles to elongate



Beads effect on PCL fibers spun centrifugally using Fiberlab L - 1000 with a change in rotation speed A) 3000 rpm, B) 6000 rpm, C) 9000 rpm.

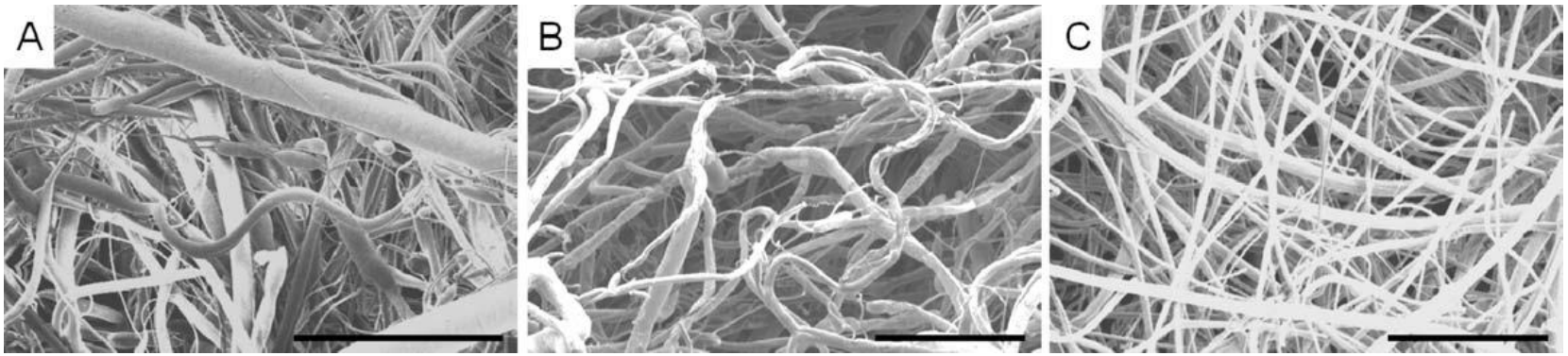
Spinneret rotation speed



SEM micrographs of PVP/TA fibres produced using the coarse spinneret at **a** 8000, **b** 10,000, **c** 12,000 and **d** 14,000 r min^{-1}, respectively

Collector distance

- The distance of the spinneret from the collector affects the morphology of the layer
- Too small distance leads to insufficient elongation of the fibers, in the case of melts also to insufficient cooling of the fibers



Scanning electron micrographs of melt-spun polycaprolactone fibers spun with different collector distances. (A) 10 cm, (B) 12 cm, (C) 14 cm. Scale bar denotes 200 lm. Rotation speed and temperature were fixed at 14,000 rpm and 200C, respectively.

Industrial line

Thank you for your attention!

TEST

- What are the types of centrifugal spinning?
- What are the process conditions for centrifugal spinning?
- How does the melt temperature affect the spinning process?
- How does the speed of the spinneret affect the spinning process?