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_Process conditions

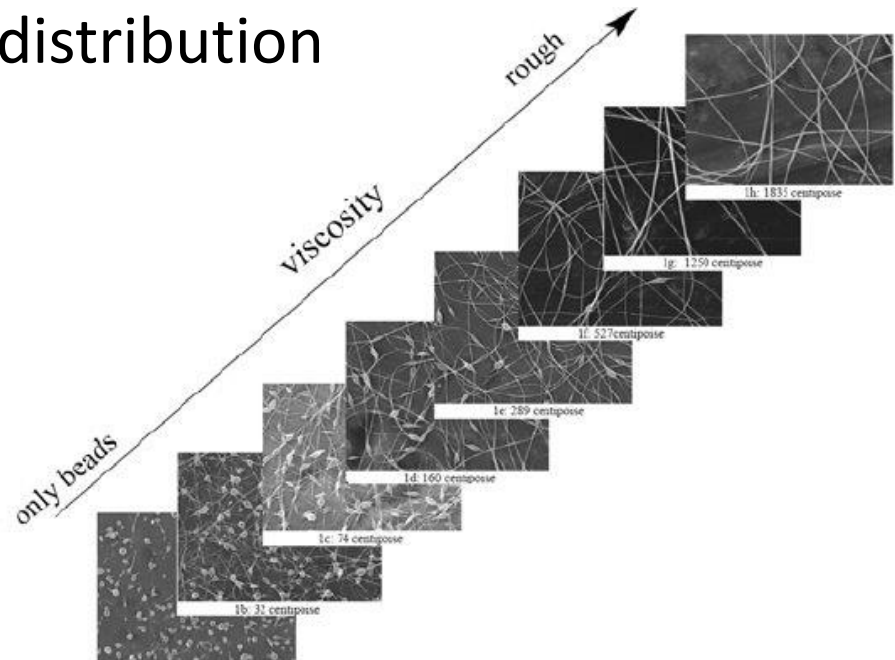Ing. Radek Jirkovec, Ph.D.

Repetition

Material conditions:

- Polymer type
- Molecular weight and its distribution
- Concentration
- Solvent system
- Electric conductivity
- Viscosity
- Surface tension
- Additives

Conditions affecting electrospinning

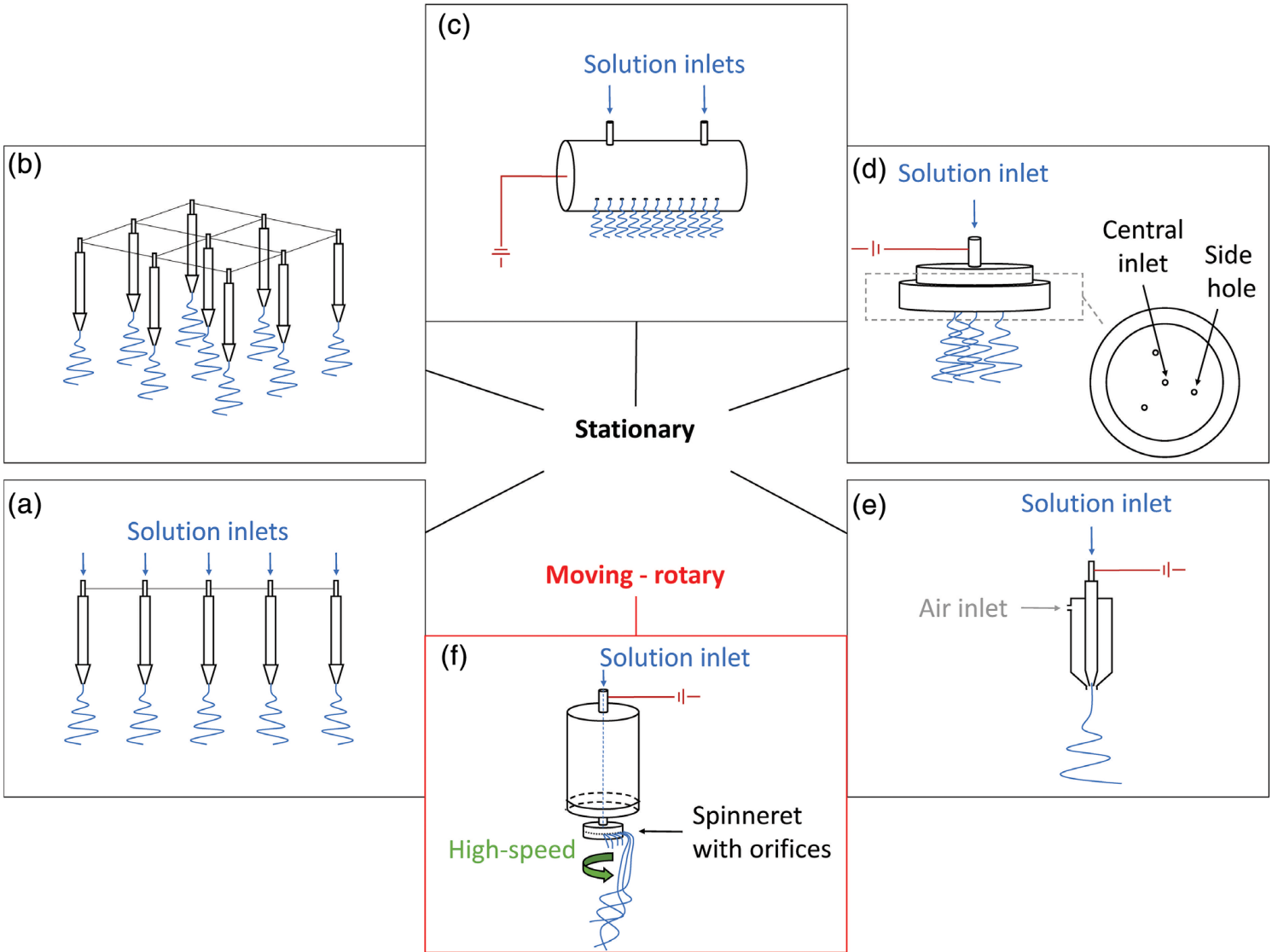Process conditions x material conditions

Process conditions

- Spinner configuration

- Voltage

- Distance of the collector from the electrode

- Dosage of the solution

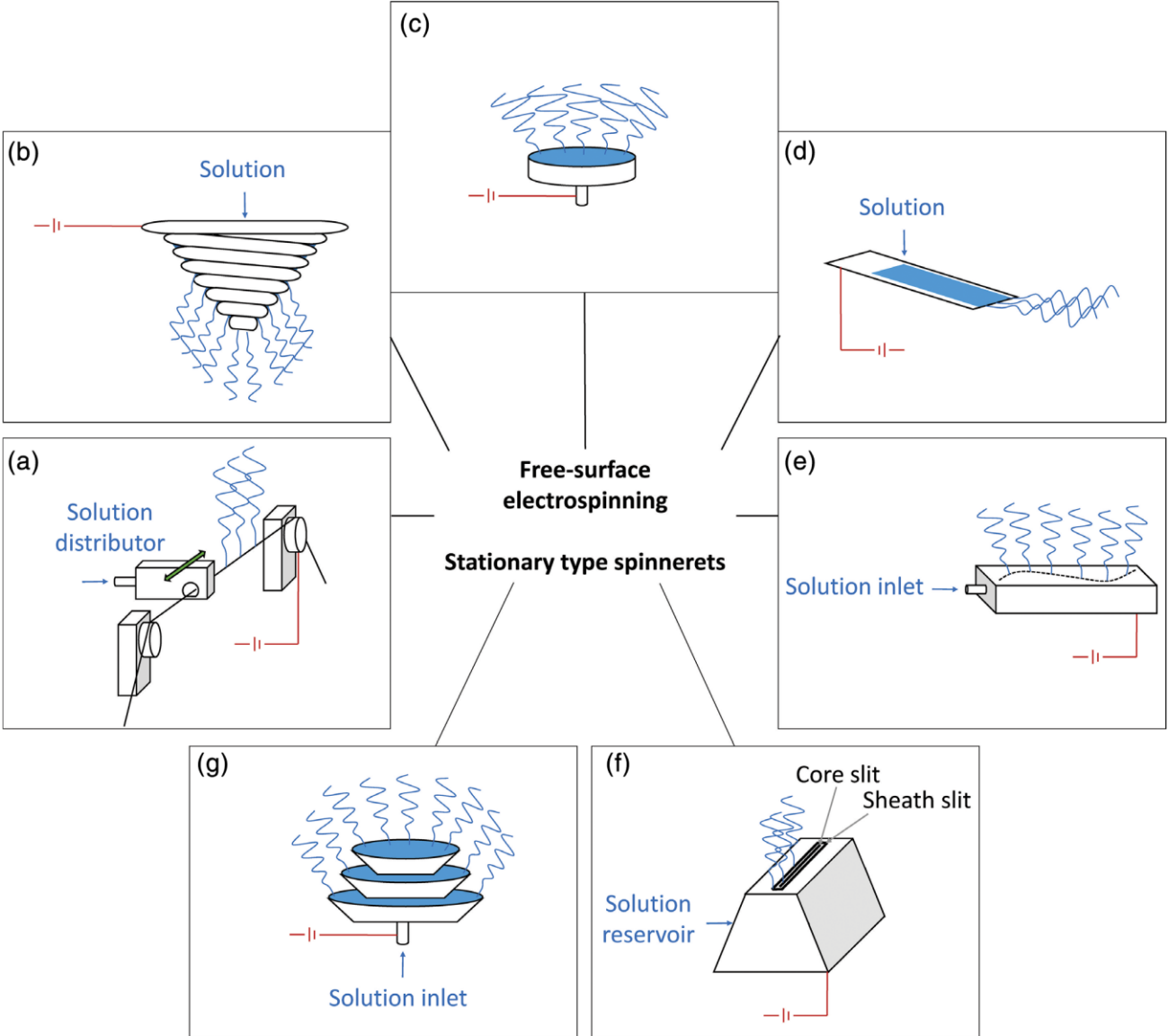- Background material

- Temperature

- Humidity

Spinner configuration

- The configuration affects the electric voltage and electric field during the spinning process, further the configuration affects the fiber diameters and the productivity of the whole process

- Electrode type:
  - Needle spinning x Needle-less spinning

- Device configuration:
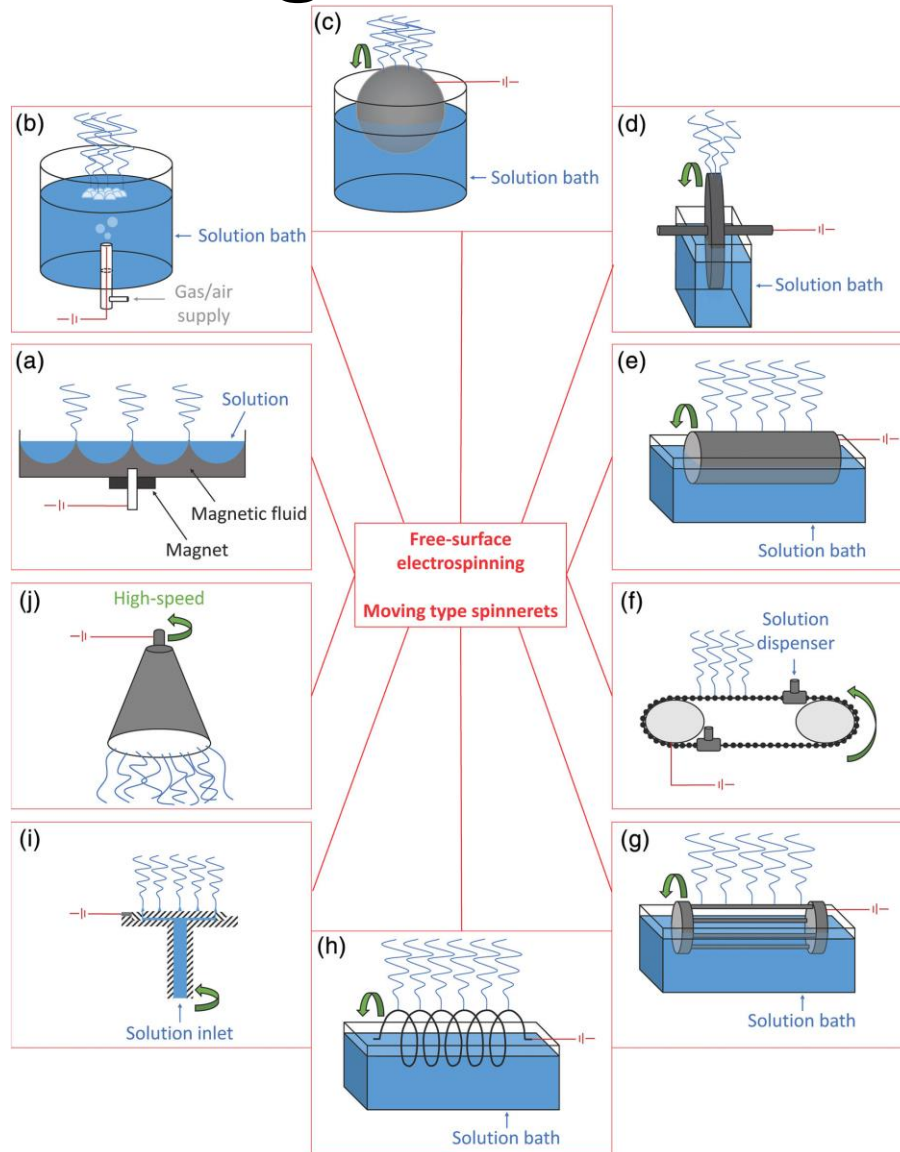 - Electrode: charged / grounded
  - Collector: charged / grounded

Spinner configuration

(c) Solution inlets

(b)

(d) Solution inlet
Central inlet
Side hole

Stationary

(a) Solution inlets

Moving - rotary

(e) Solution inlet
Air inlet

(f) Solution inlet
High-speed
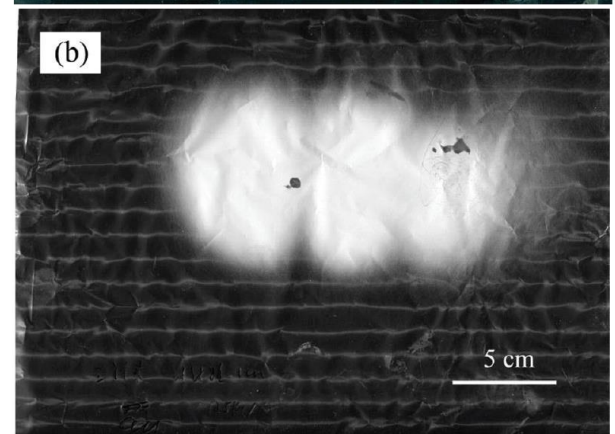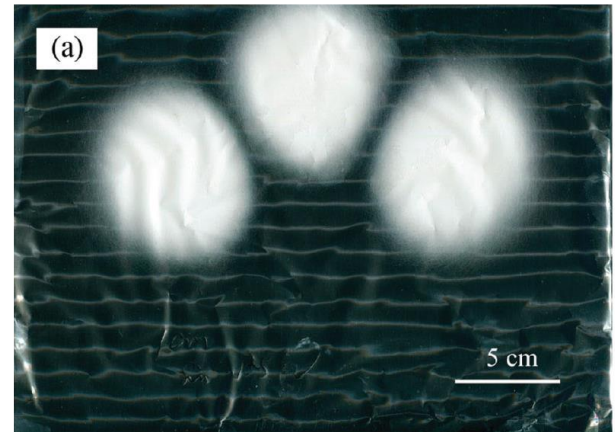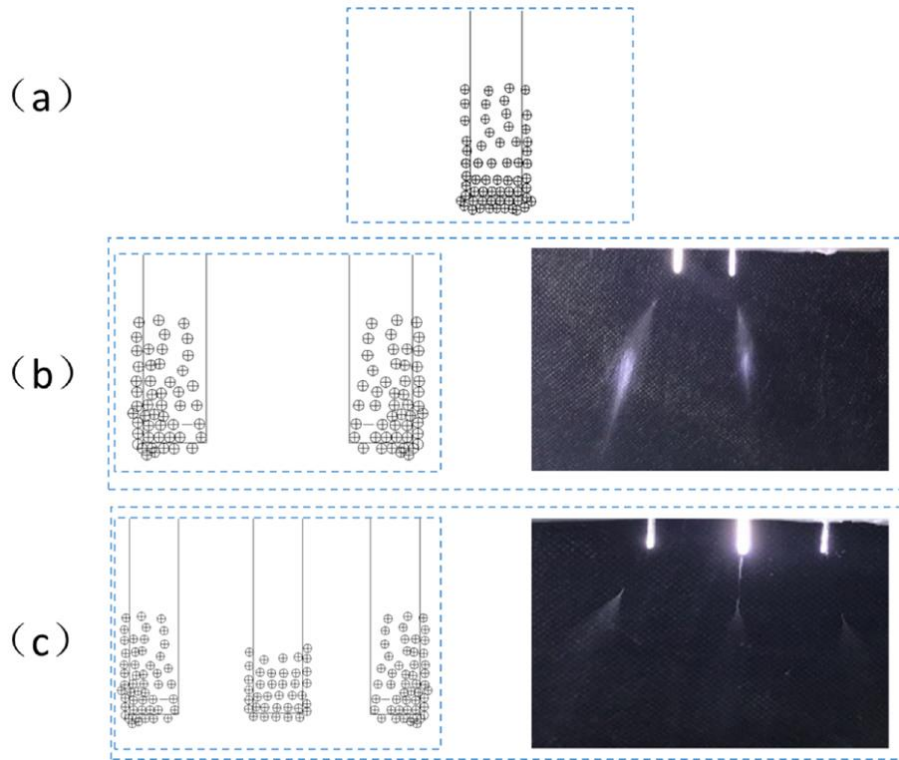Spinneret with orifices
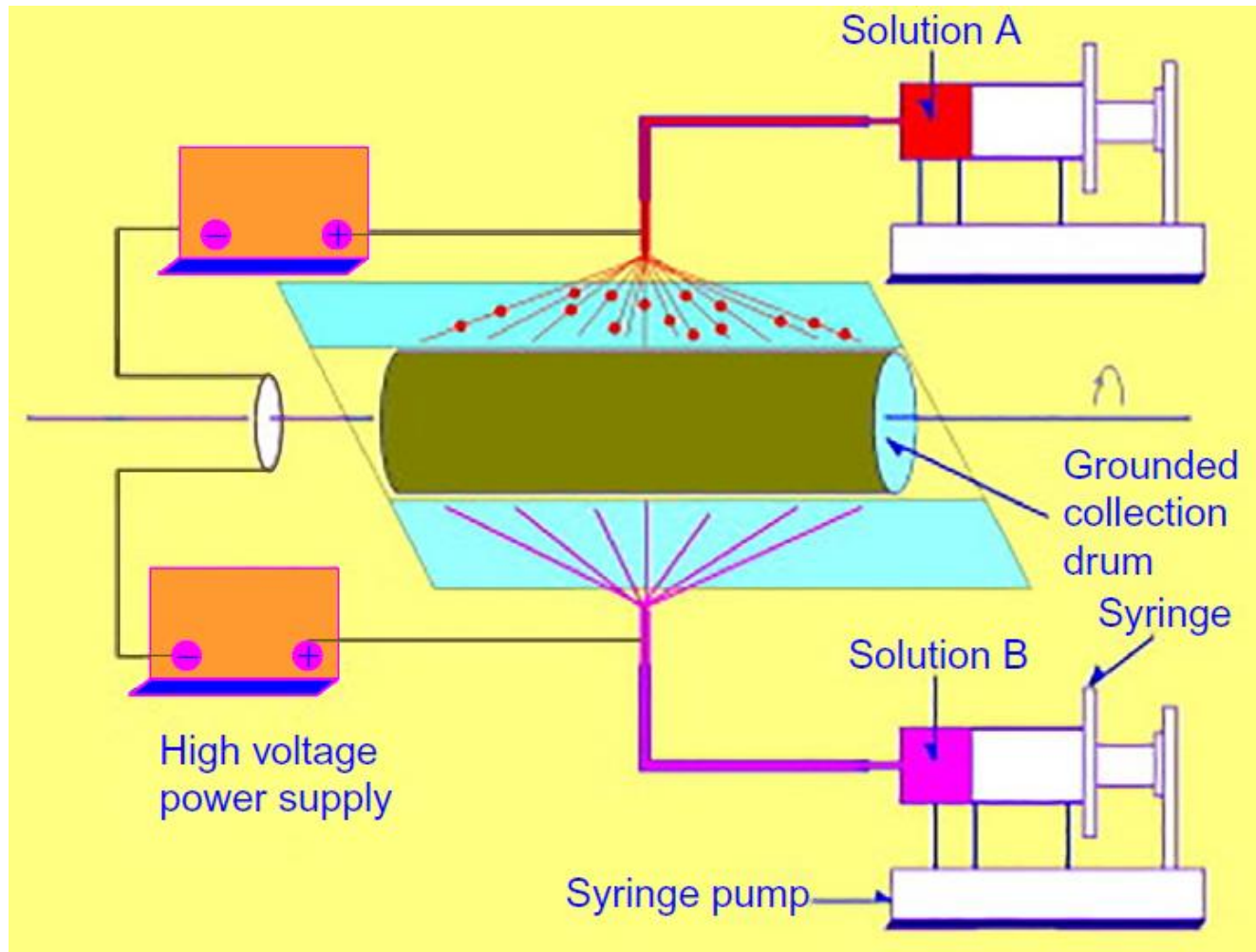
Spinner configuration

Spinner configuration

Spinner configuration

- The number of electrodes affects the distribution of the electric field and thus the deposition of the resulting fibers
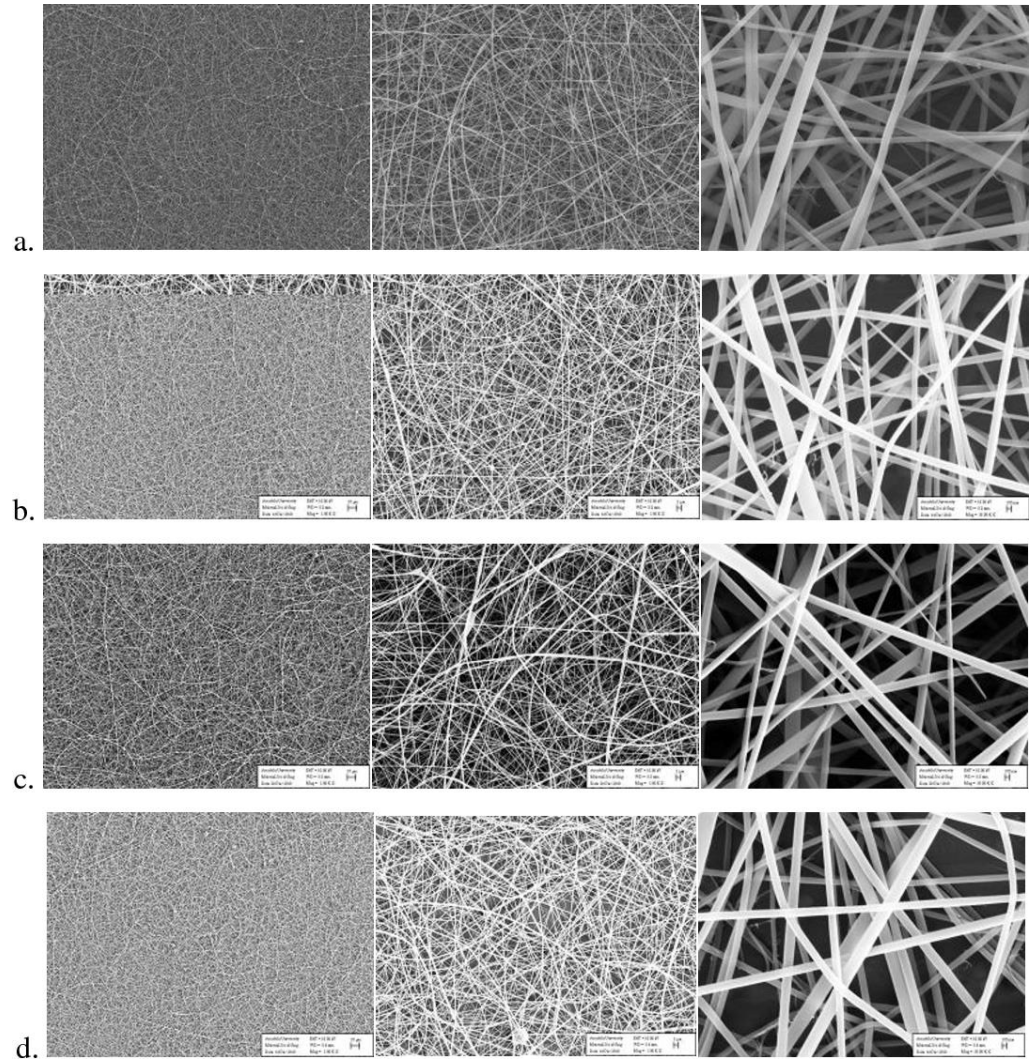
Spinner configuration

Needle diameter

Sample No.	Needle Gauge (Needle Diameter)	N	Mean
S1	22G (0.70mm)	100	149.778
S2	20G (0.90mm)	100	155.336
S3	19G (1.06mm)	100	162.438
S4	18G (1.25mm)	100	171.464

Descriptives for nanowebs produced from 18wt% SF solution

SEM images of samples a.S1; b.S2; c.S3; d.S4

Electrical voltage

- The difference in electrical potentials between two points

$$U \ [V]$$

- We distinguish: DC voltage x AC voltage

- The most important factor of electrostatic spinning
  - It affects the formation of the Taylor cone and the morphology of the layers

- By increasing the electrical voltage, homogeneous fibers are formed, ie the beads are removed
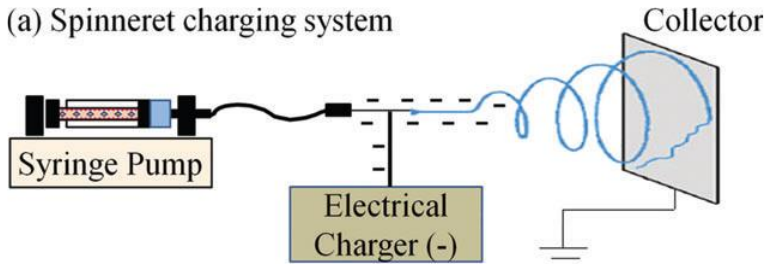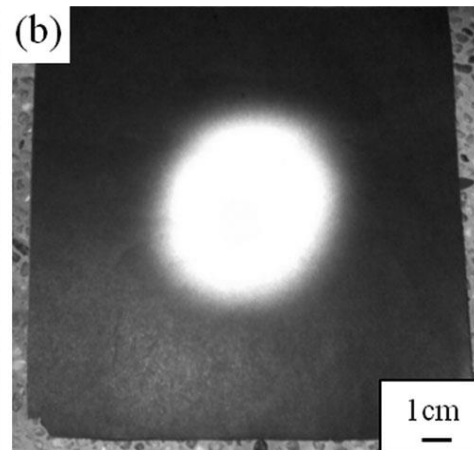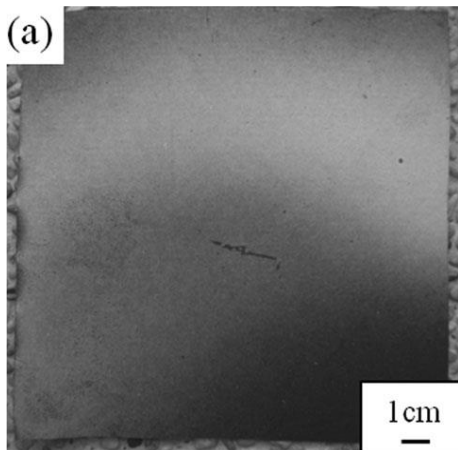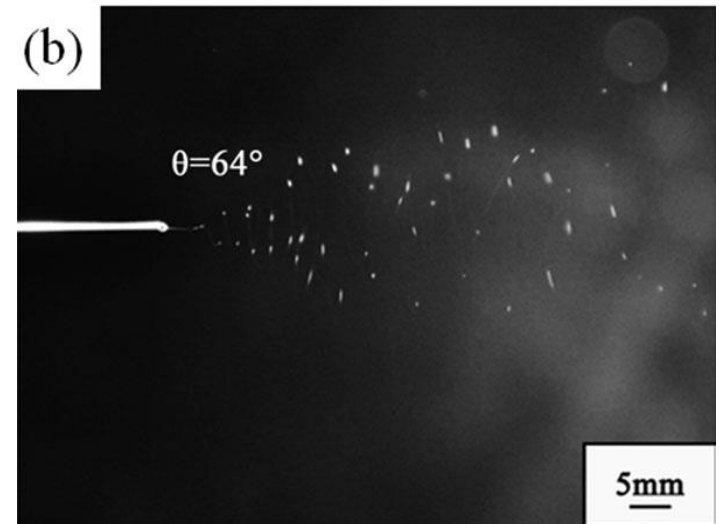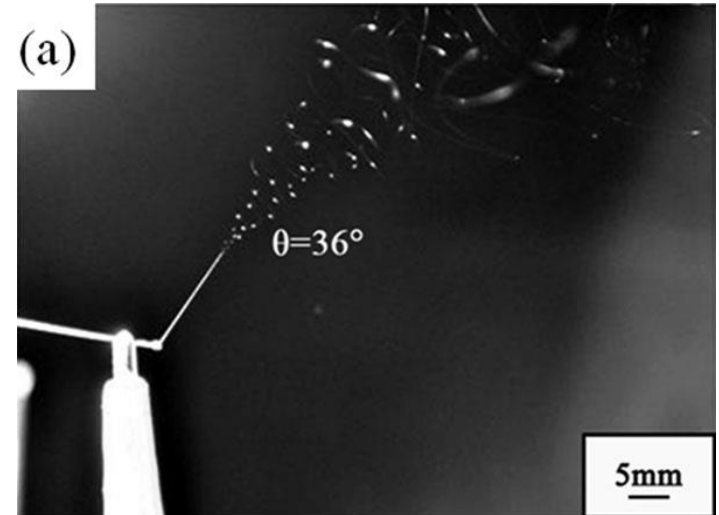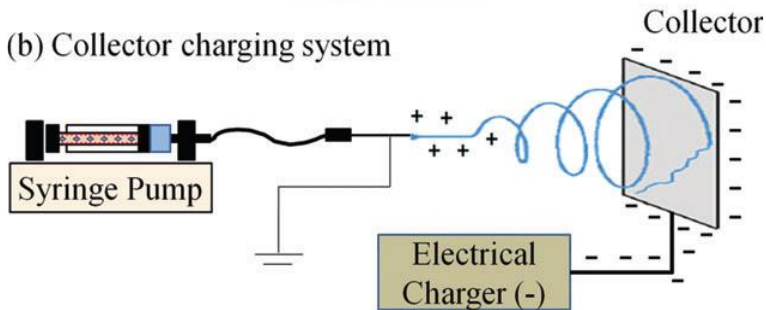
Electrical voltage
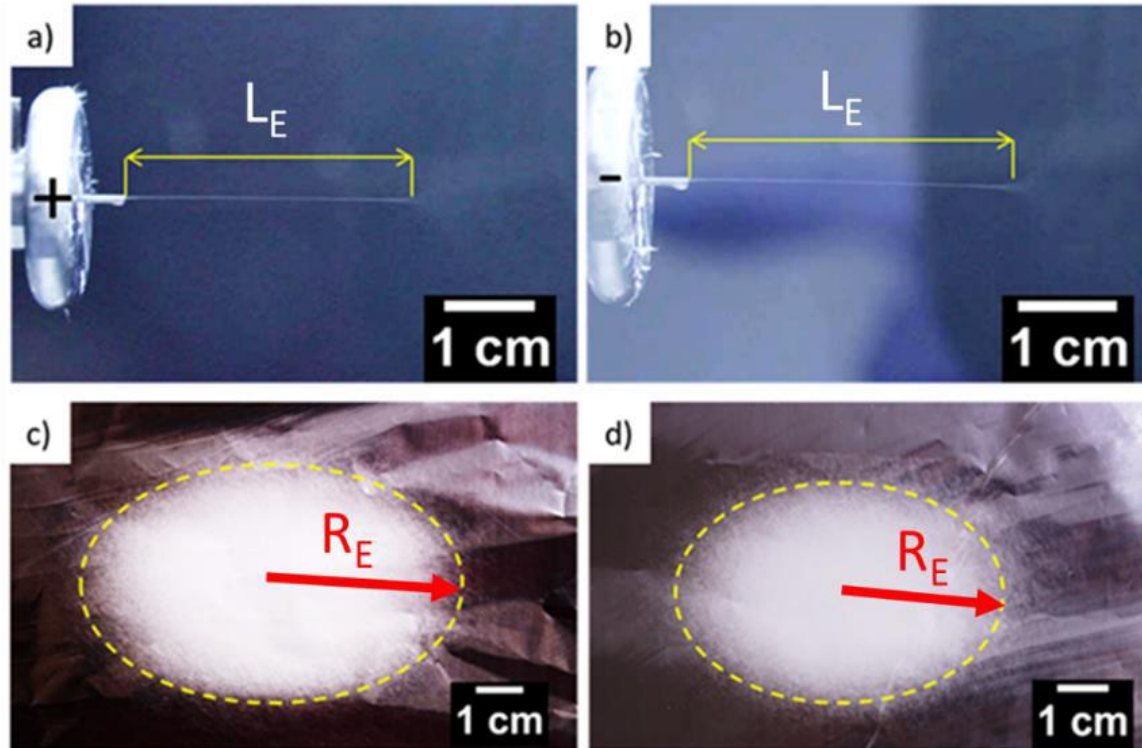
Images of the electrospinning polymer jet length before the bending instability begins and the area of deposited random fibers on Al foil for poly(methyl methacrylate) (PMMA)+ (a,c) and PMMA- (b,d), respectively.

Electrical voltage

(a) Spinneret charging system

Collector

Syringe Pump

Electrical Charger (-)

(b) Collector charging system

Collector

Syringe Pump

Electrical Charger (-)

(a)

θ=36°

5mm

(b)

θ=64°

5mm

(a)

1cm

(b)

1cm

Images of jet movement for (a) spinneret charging system, (b) collector charging system, at electrospinning conditions: applied voltage: 20 kV, working distance: 18 cm, flow rate: 0.008 mL/min, RH%: 40%

Electrical voltage

- By changing the voltage, we mainly affect the productivity of the process
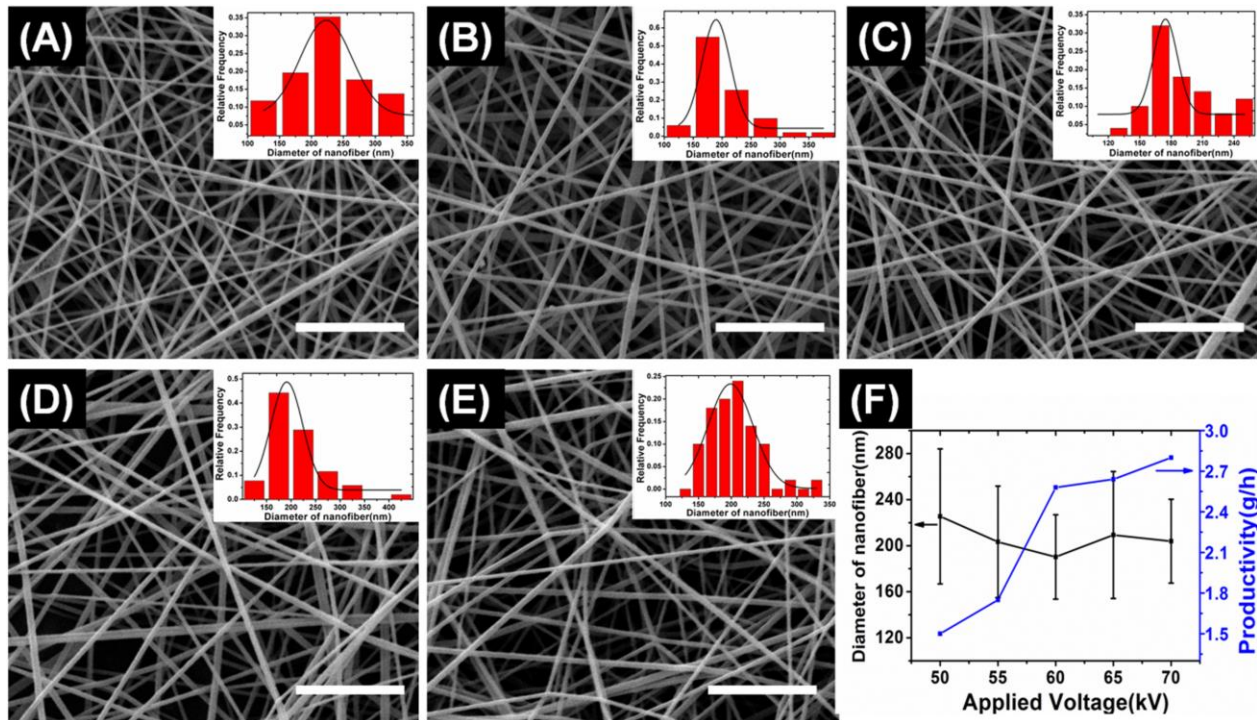
SEM images of electrospun PAN nanofibers from different applied voltages: (A) 50 kV, (B) 55 kV, (C) 60 kV, (D) 65 kV, (E) 70 kV. Insert images: the distribution of nanofiber. (F) The productivity and diameters of nanofibers with different applied voltages.
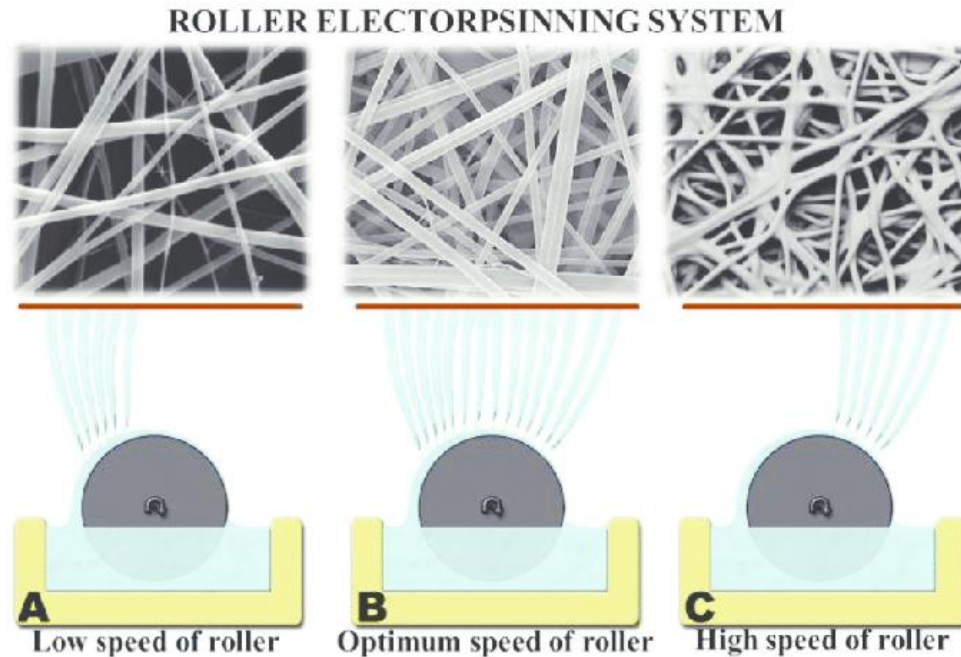
Distance from the collector

- The distance of the electrode from the collector affects the morphology of the layer

- Too small a distance of the electrode from the collector leads to insufficient evaporation of the solvent and the formation of connected fibers
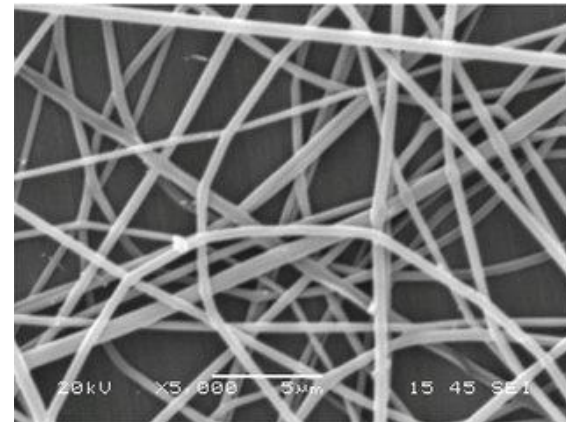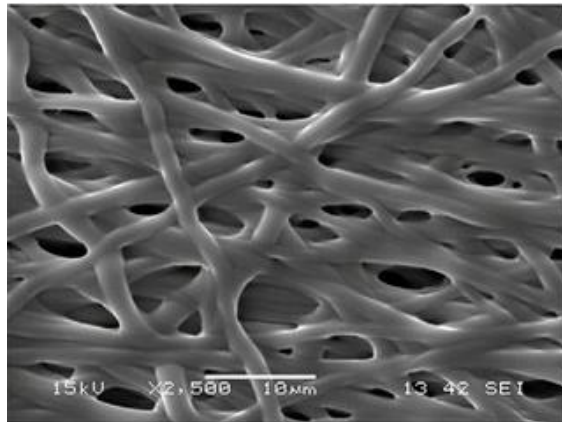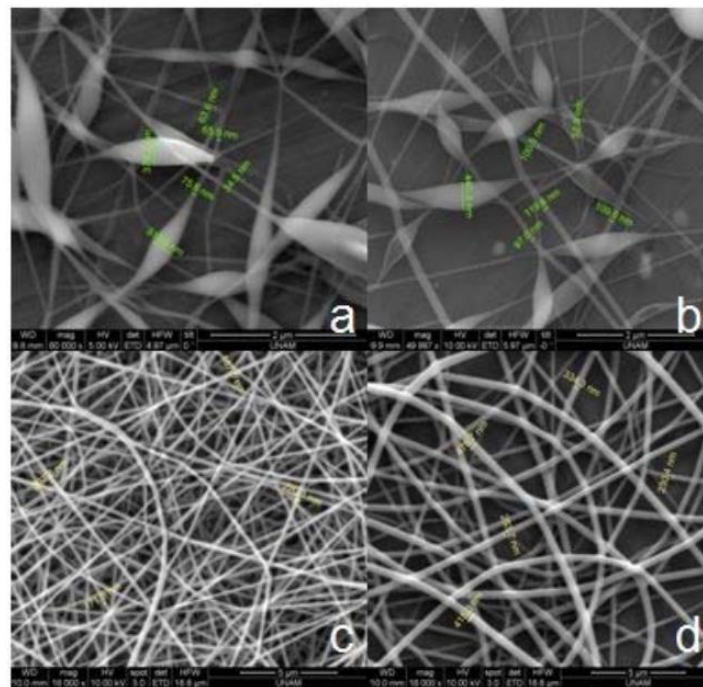
Dosage

- The dosage change applies to both needle and needleless spinners

- Dosage affects fiber diameters and the structure of the resulting layer

ROLLER ELECTORPSINNING SYSTEM

A — Low speed of roller   B — Optimum speed of roller   C — High speed of roller

Dosage

- The dosage change applies to the needle spinning
- Too much dosing leads to the formation of defects

SEM images of electrospun nanofibers a) flow rate of 10 ml/h, 30-60 nm fiber diameter, 300 nm bead diameter, b) flow rate of 6ml/h, 50-100 nm fiber diameter, 440 nm bead diameter, c) flow rate of 1.6 ml/h, 170-220 nm fiber diameter, non-beaded structure d) flow rate of 1.1 ml/h, 230-476 nm fiber diameter, non-beaded structure.

Dosage
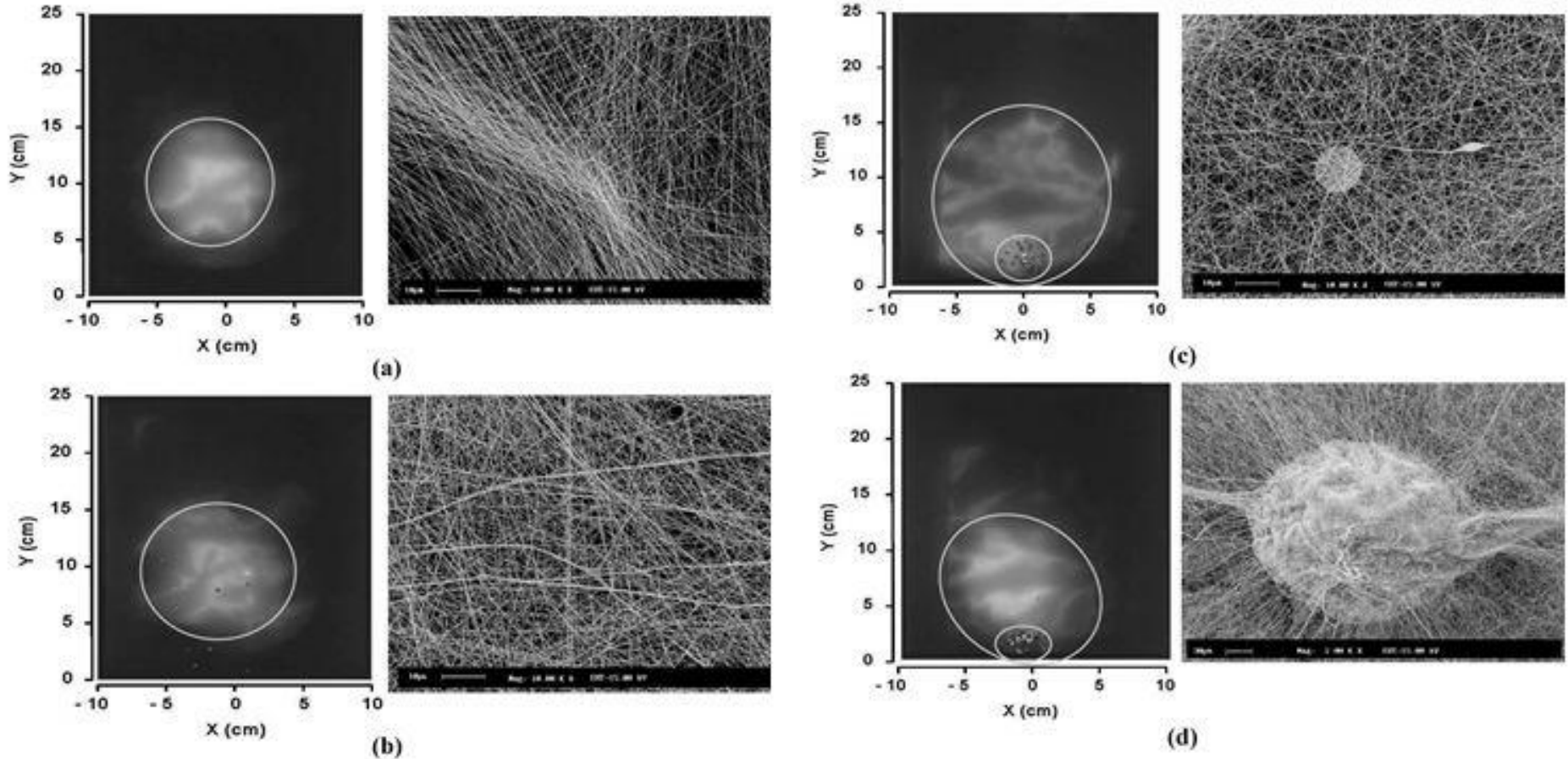
The effect of flow rate on deposition area based on SEM and scanning images of deposited nanofibers at various flow rates; (a) 0.1 mL/hr, (b) 0.5mL/hr, (c) 1.0 mL/hr, (d) 1.5mL/hr.

Humidity

- The humidity of the environment greatly affects the electrospinning process

- Ambient humidity affects fiber diameters, defects, but also the size of pores in the fibers

- The optimum ambient humidity must be determined for each spun polymer

Humidity

- In the case of PEG spinning, higher humidity leads to the formation of a defective structure
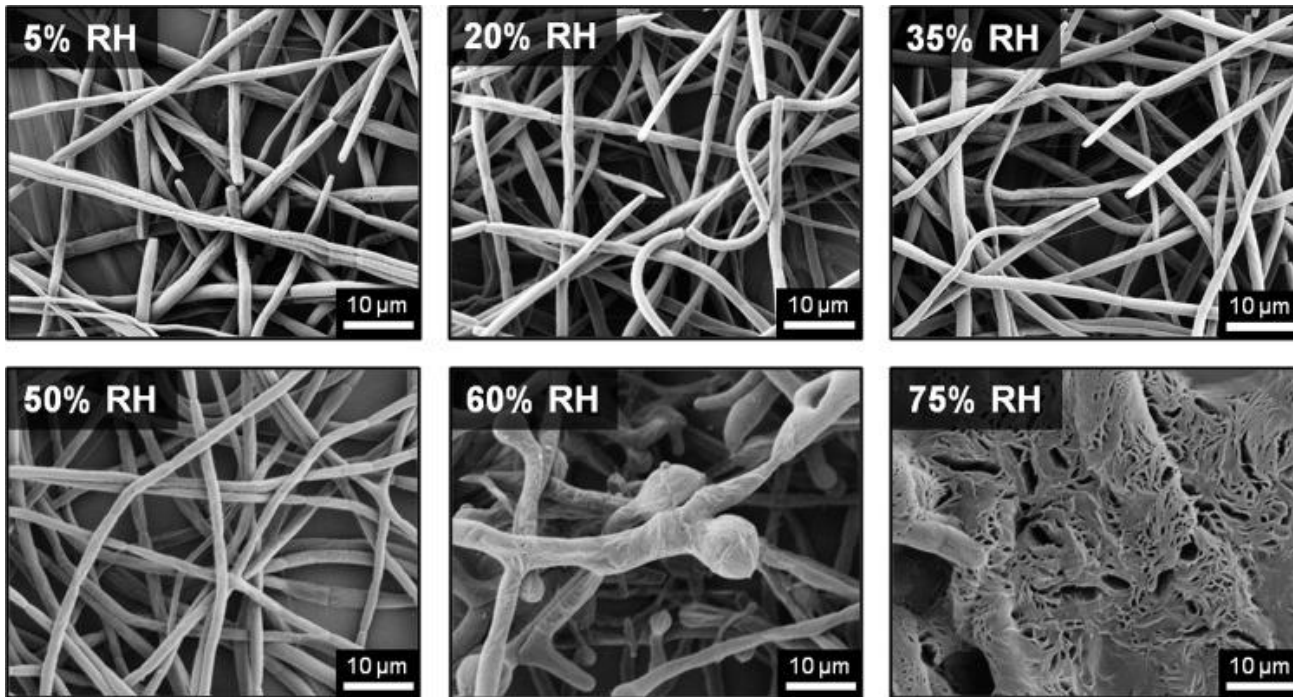
Scanning electron micrographs of poly(ethylene glycol) (PEG) electrospun at relative humidity (RH) ranging from 5% to 75%.

Humidity

- In the case of P(L)LA spinning, higher humidity leads to the removal of beads
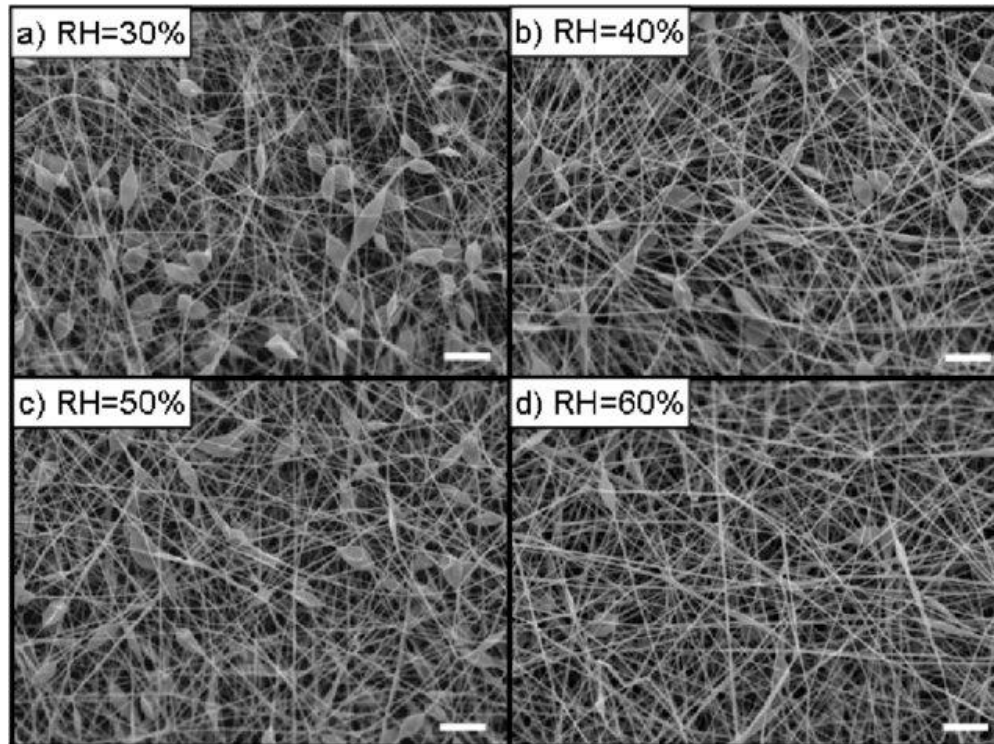
Effect of relative humidity on P(L)LA beaded fibre SEM micrographs of PLLA fibres electrospun at a) RH = 30%, b) RH = 40%, c) RH = 50% and d) RH = 60%. Scale bar = 10 μm.

Humidity

- By increasing the humidity, it is possible to form porous fibers

- Higher ambient humidity leads to larger pores in the fibers
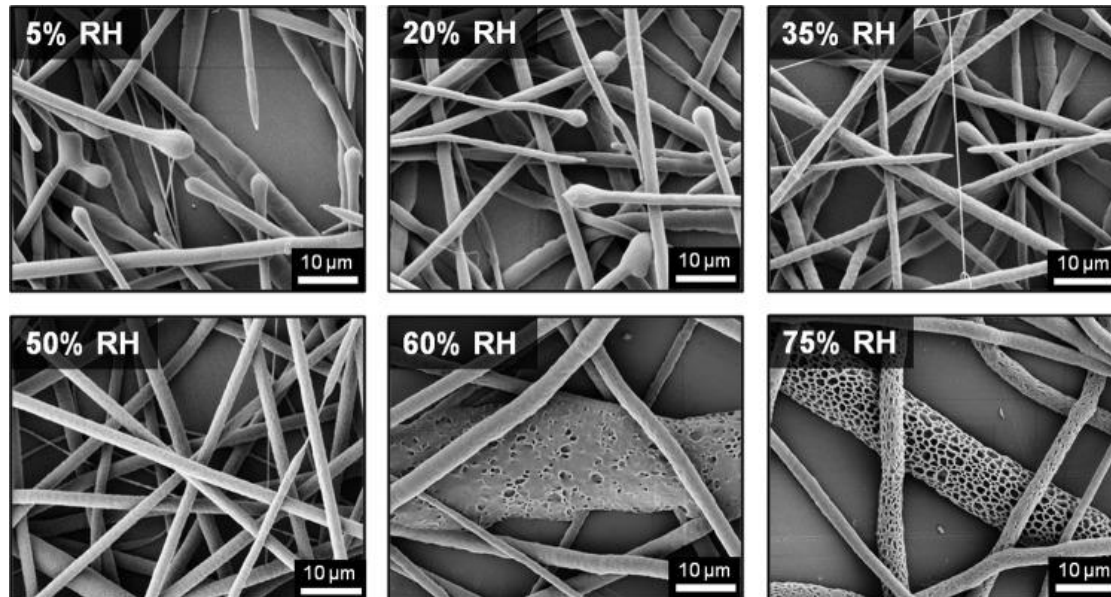
Scanning electron micrographs of polycaprolactone (PCL) electrospun at relative humidity ranging from 5% to 75%.

Collector

- The produced nanofibers must be captured in some way for further processing

- Catchment device - the collector is designed according to the requirements for the final product

- The shape and structure of the collector has a significant effect on the structure of the resulting nanofibrous product

Collector

- Using special collectors, we can create oriented fibrous structures, or fibrous structures with collector relief
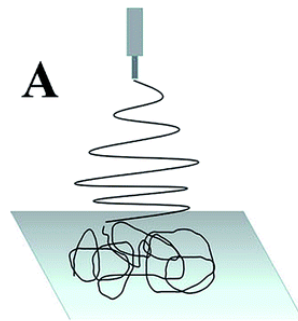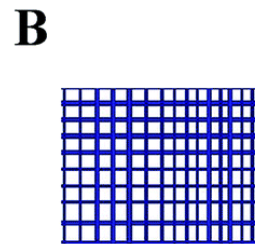
A • solid collector
B • guide wires collector
C • rotating mandrel
D • rotating wire drum
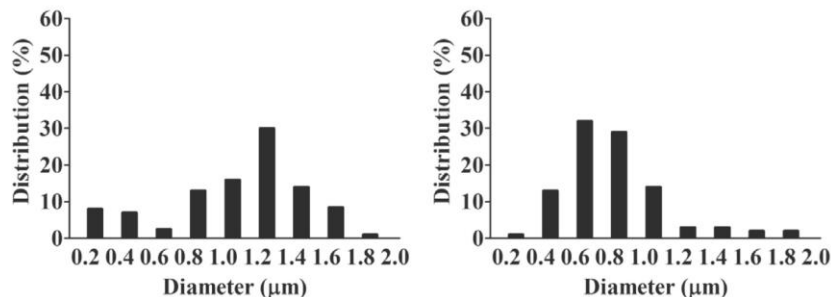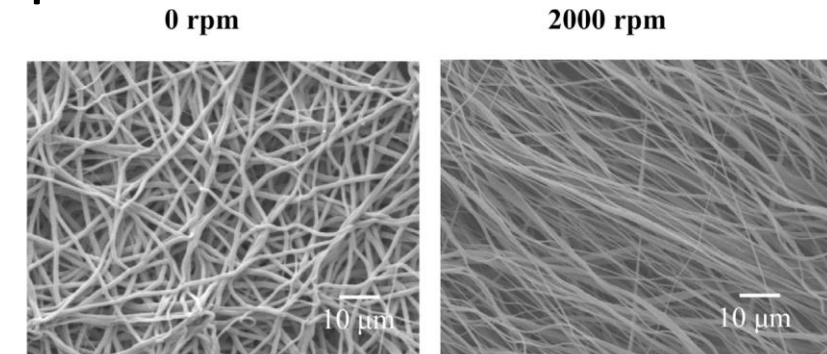E • rotating disk
F • liquid bath collector
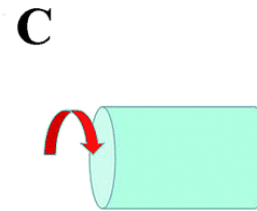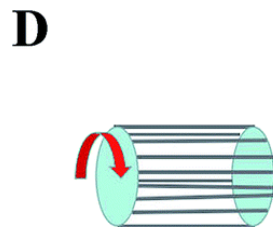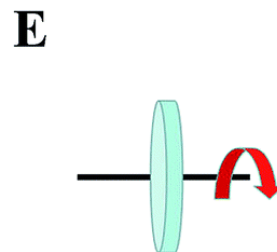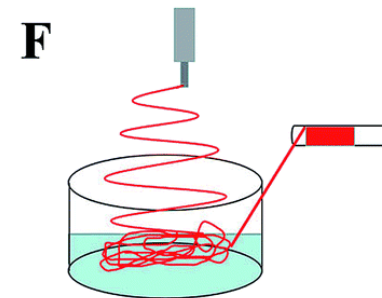
Collector

- By using a structured collector, a nanofiber layer with the same structure can be obtained
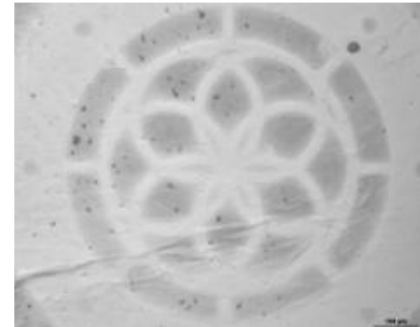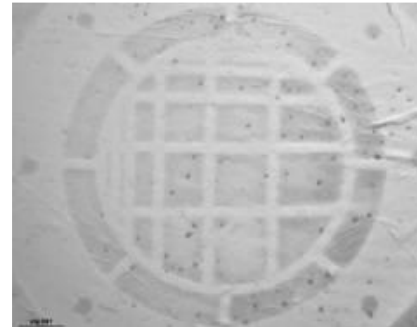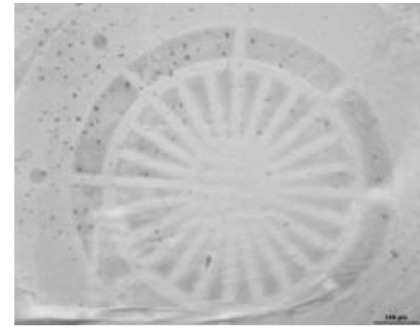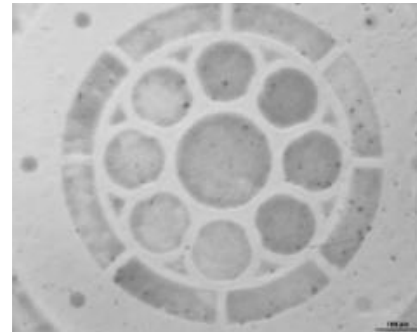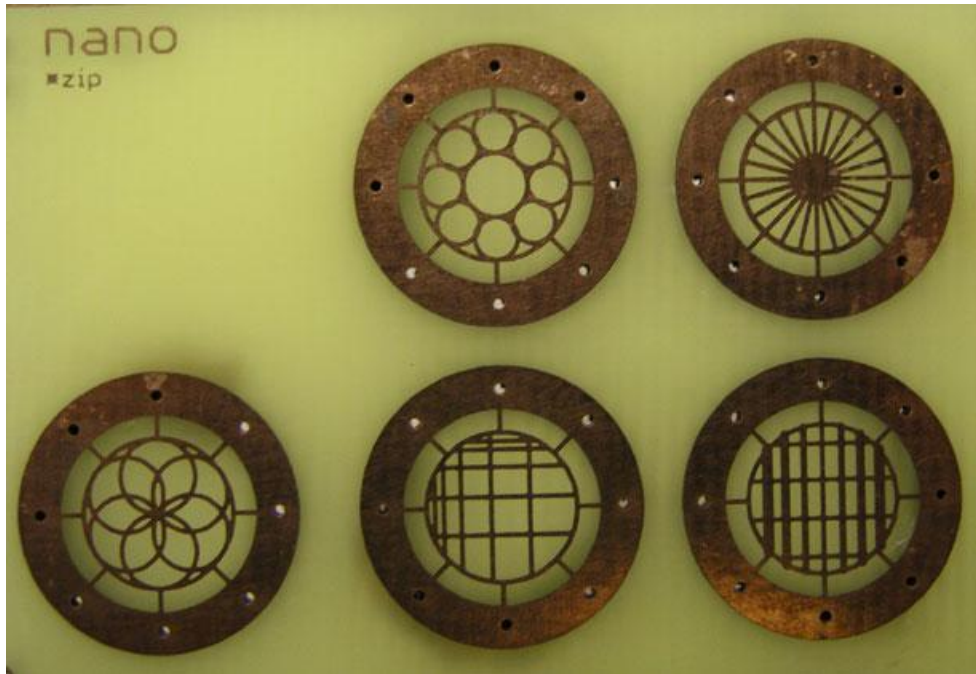
Collector

- The orientation of the fibers can be done by means of a rotating drum or, for example, by means of printed circuits

SEM images and their respective fiber diameter distribution, showing the effect of rotational speed on the characteristics of fibers collected on the rotating drum.
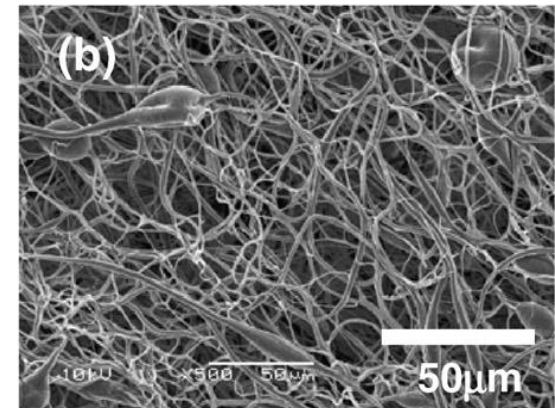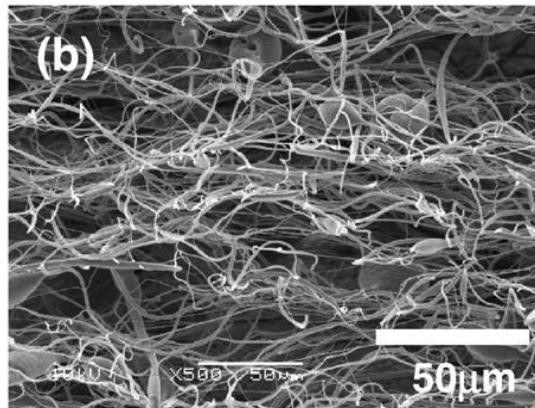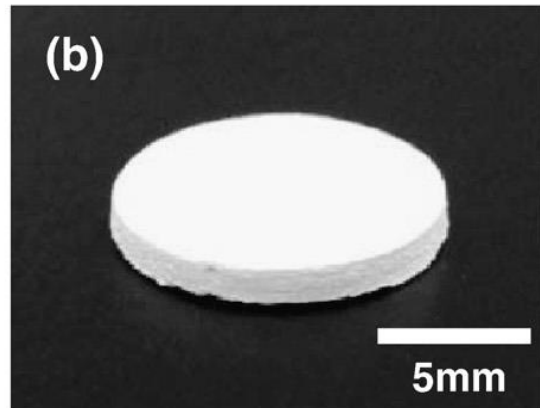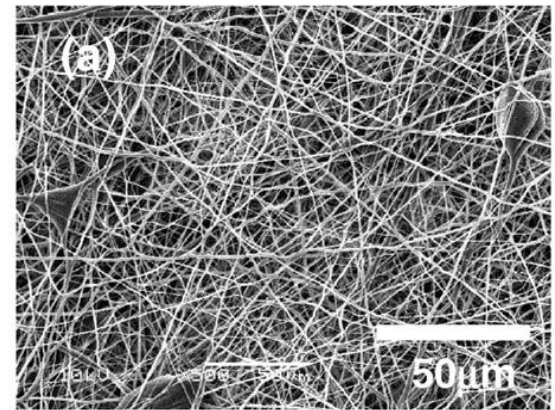

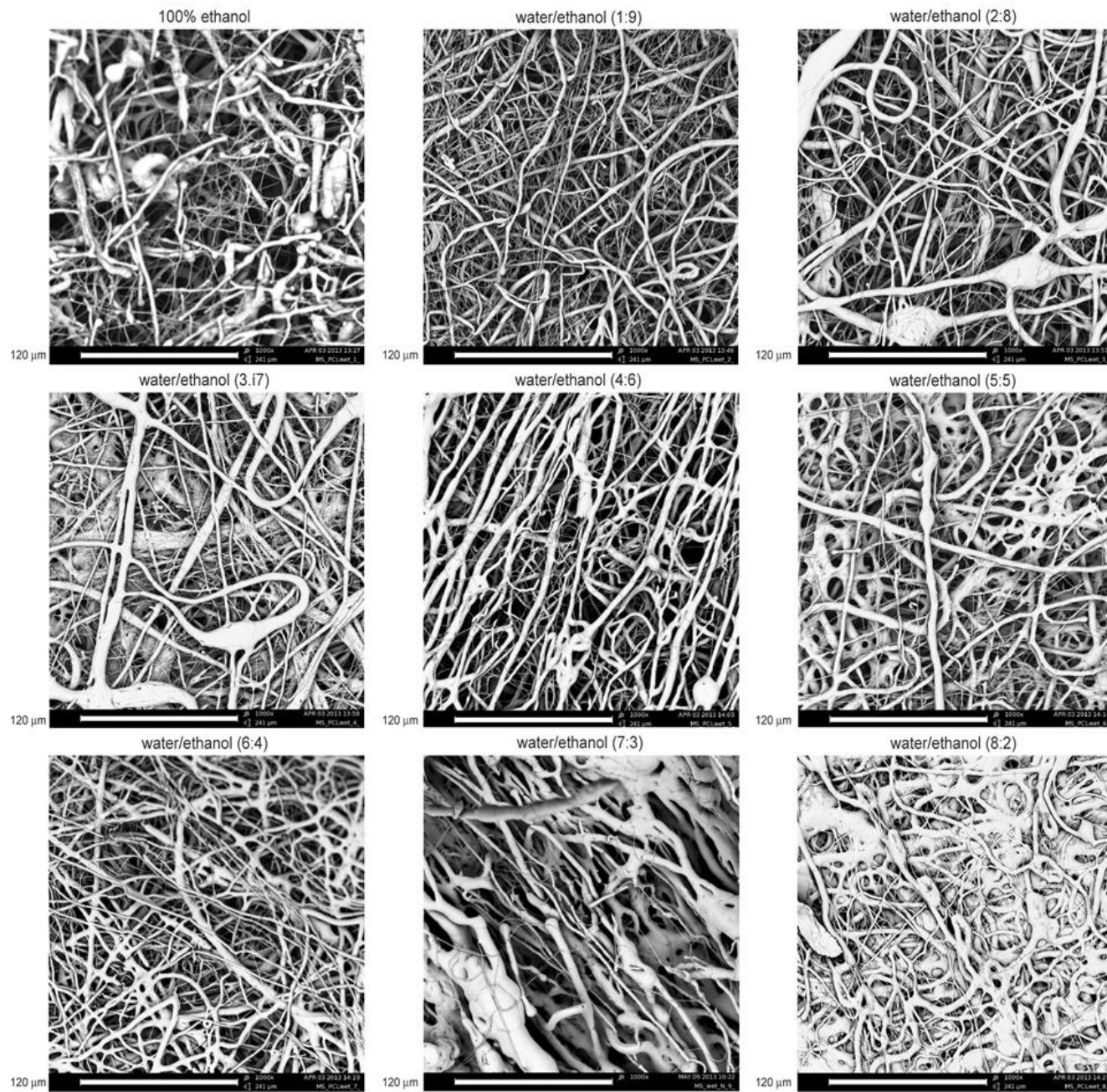Detail of a rotating disk collector with four points.
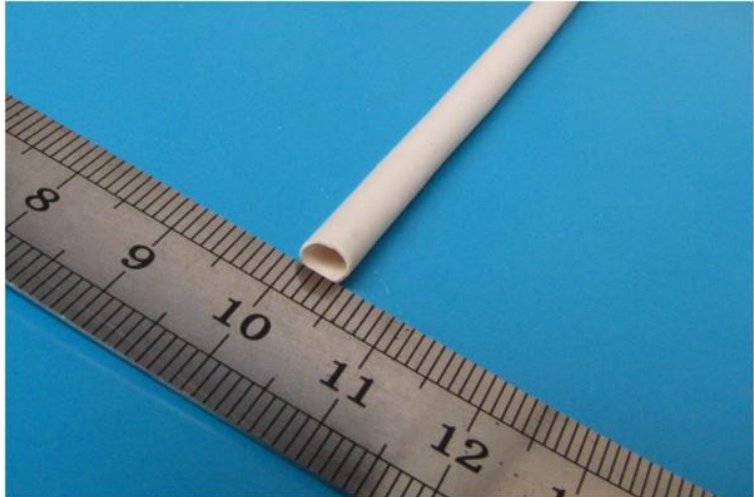
Collector
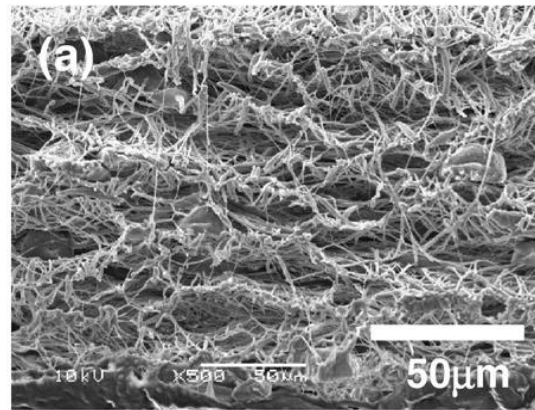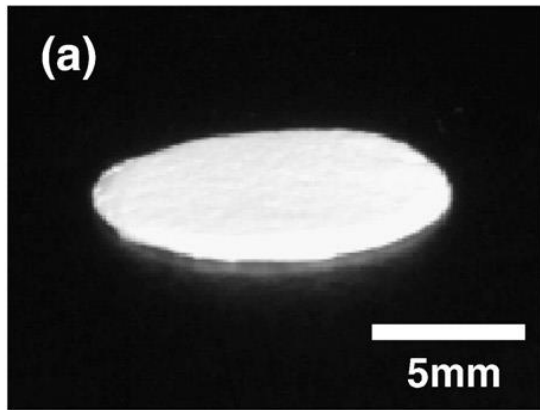
Photos and SEM images of PGA non-woven mat prepared by traditional system (a) and spongiform PGA fabric with solvent system (b).
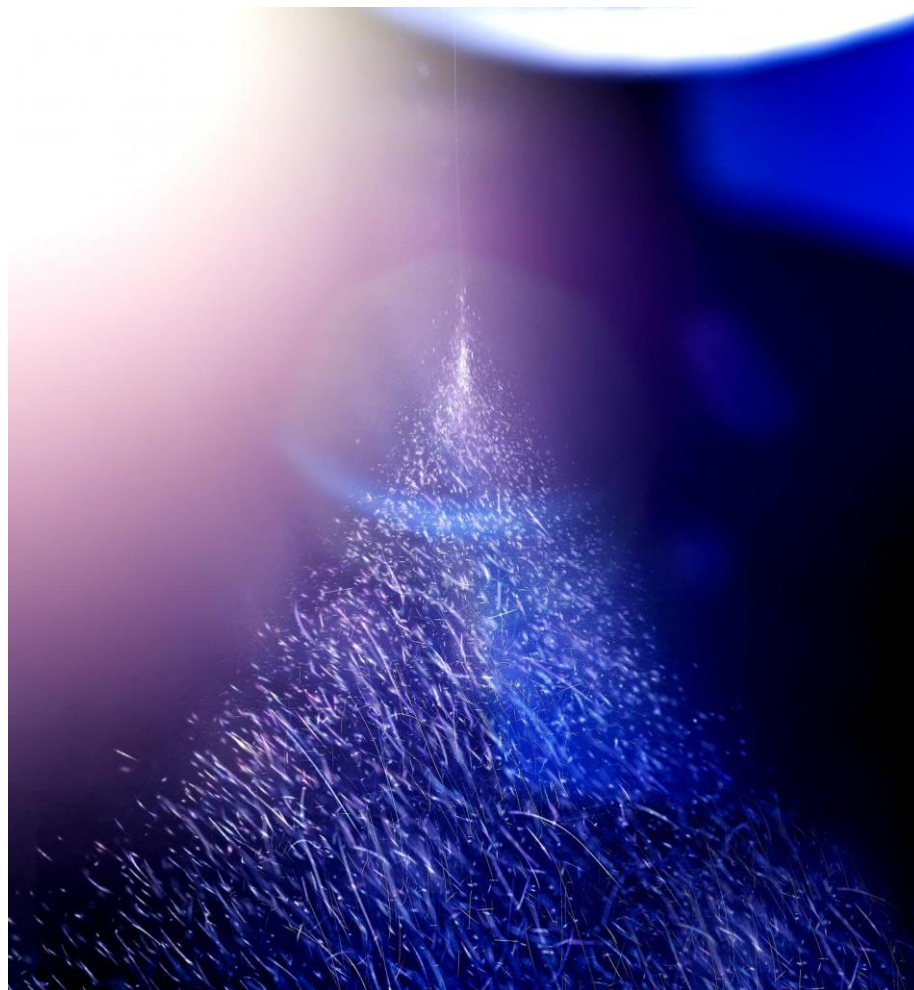
Scanning electron images of electrospun materials: PCL fibers (from chloroform/ethanol 9:1 solution) wet electrospun into different liquid collectors described above each image.

Collector
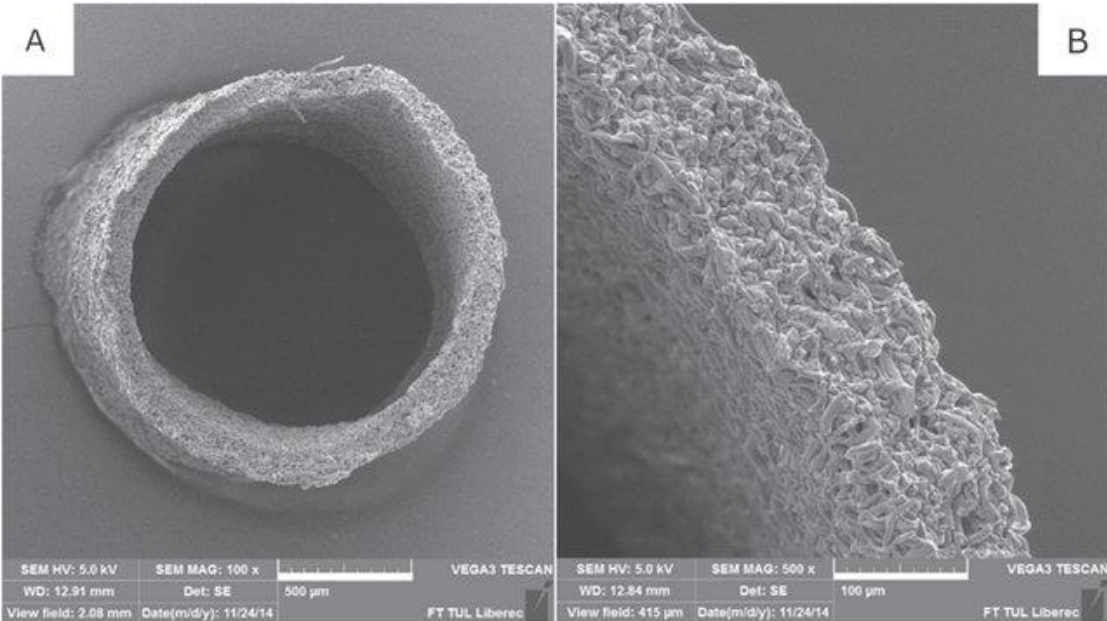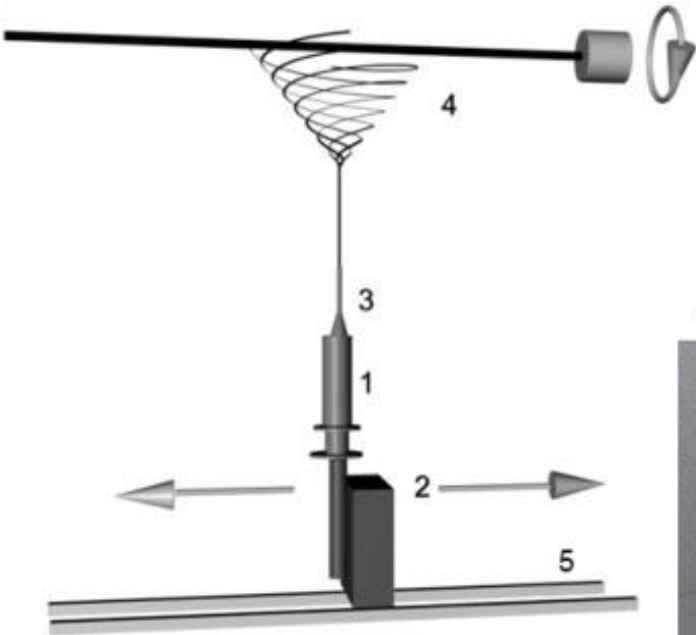
Thank you for your attention!

TEST

- What material conditions affect the spinning process?

- What process conditions affect the spinning process?

- What is the relationship between the electrical voltage and the distance from the collector?

- How does ambient humidity affect the electrospinning process?