ELECTROSPINNING OF LIQUID JETS

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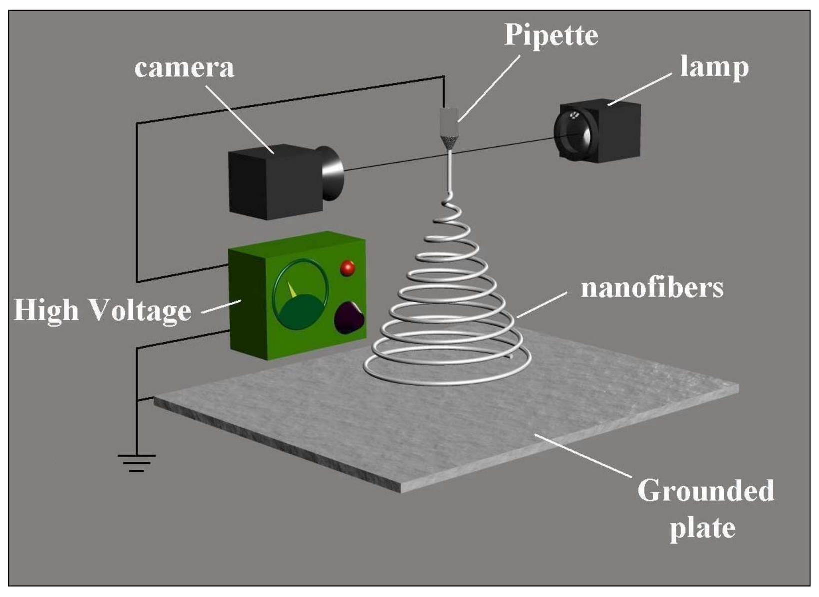
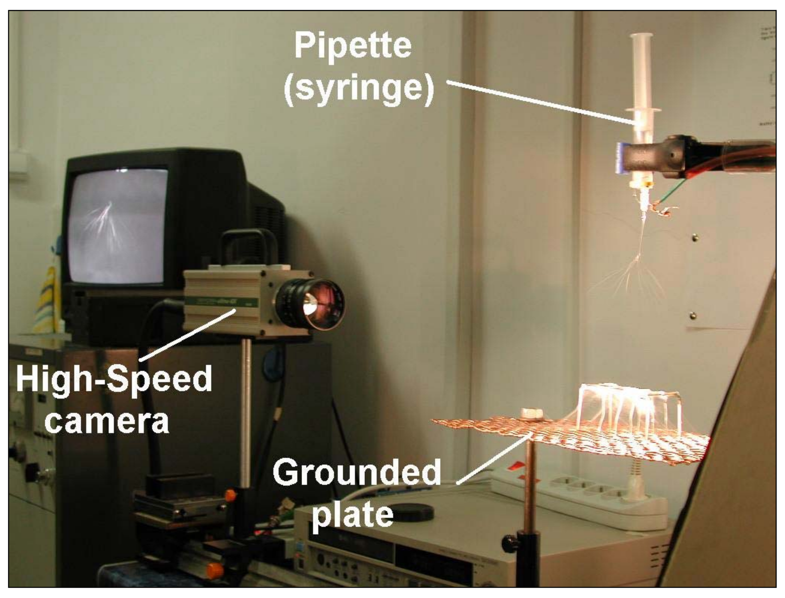
ELECTROSPINNING OUTLINE

- electrospinning is a modern and effective method of producing nanofibres
- fibre is pulled out due to electrostatic force between pipette and collector
- fibre is created from pendant droplet at the tip of pipette when electrostatic force overcomes surface tension
- the jet extends in a straight line for a certain distance and then bends and follows a looping and spiralling path
- in this process electrical forces elongate the jet thousands or even millions of times
- as a results 0.0003mm nanofibres is produced from polymer jet of 0.5mm in diameter

BASIC SETUP



Schematic drawing of the electrospinning process



Experimental setup of the electrospinning process

Basic equipment

- Pipette with polymer solution
- High voltage power supply (up to 30kV)
- Collector – grounded copper mesh
- High speed camera (up to 40500 fps)
- High resolution PIV camera (1280 x 1024 pixels)
- CW Argon laser
- Double pulse Nd-Yag laser

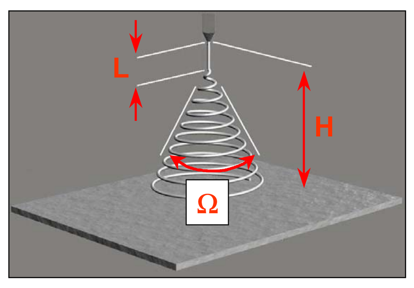
PARAMETRIC STUDY

Model validation varying following parameters:

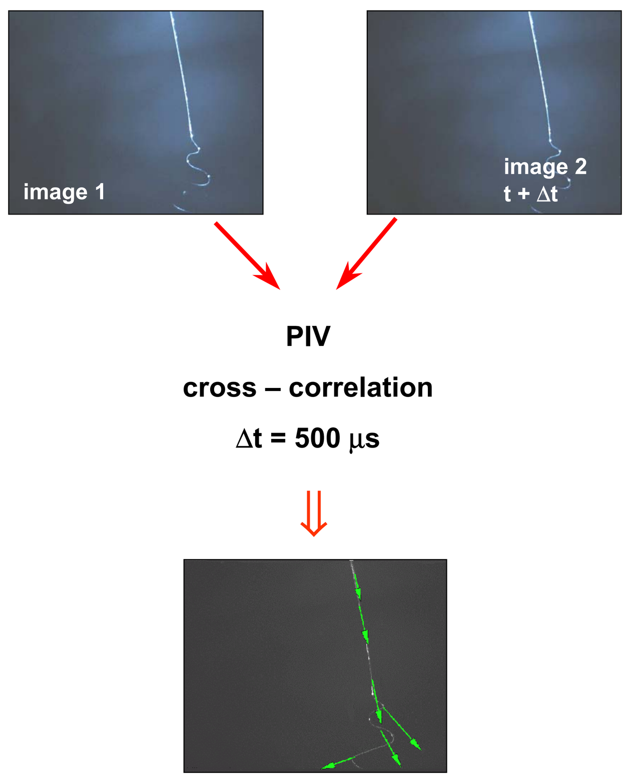
- L – length of the rectilinear part
- Ω – angle of the envelope cone (image analysis)
- U – velocity of the fibre by PIV method
- a – fibre diameter (image analysis)
- structure of collected woven
- elongation strength of single fibre measured by air jet

Effect of

- Electrostatic potential *V*
- Distance pipette-collector *H*
- Solution concentration *c*



PIV TECHNIQUE

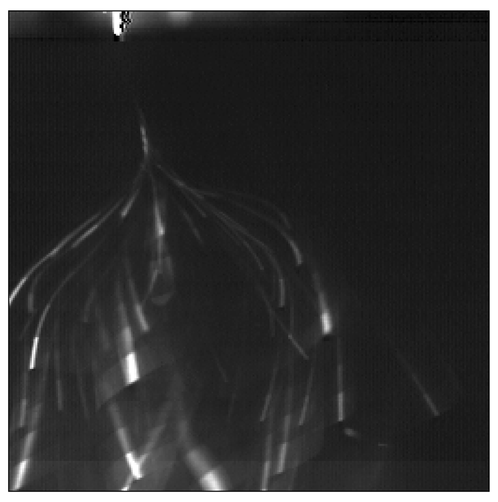


Average velocity of the fibres: 2 m/s

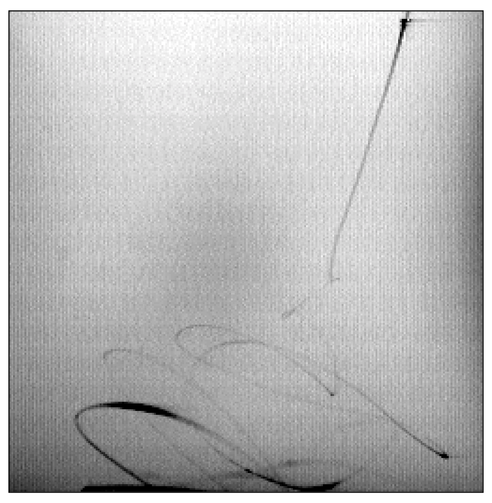
TESTED POLYMERS

Test	Polymer	Solvent	Concentration [% wt/v]	Voltage [kV]	Electrospinning
I	PEO poly(ethylene oxide)	40% water 60% ethanol mixture	3 – 4	3 – 12	good and stable process for voltage up to 10kV
II	DBC dibutyrylchitin	ethanol	9	6 – 16	fairly good
III	TAC cellulose triacetate	methylene chloride	20	3 – 30	polymer too viscous
			7	10 – 30	difficult
IV	PAN polyacrylonitrile	dimethyl-formamide (DMF)	15	5 – 25	very good
V	Glycerol	water	88	20 – 30	difficult; lack of solidification cause that the liquid jet is separated into small droplets (electrospray)

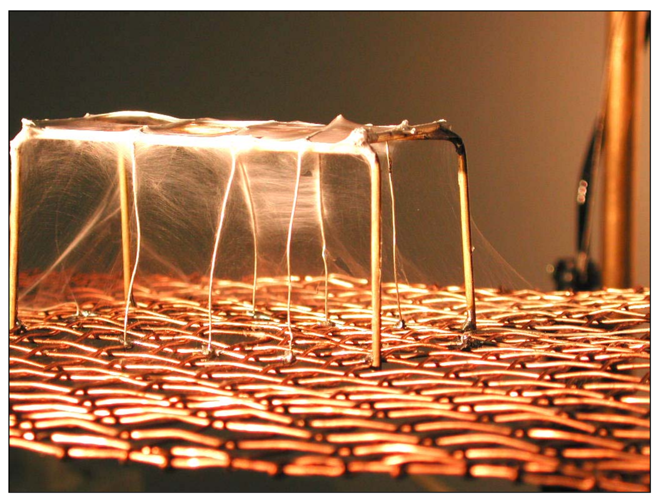
RESULTS



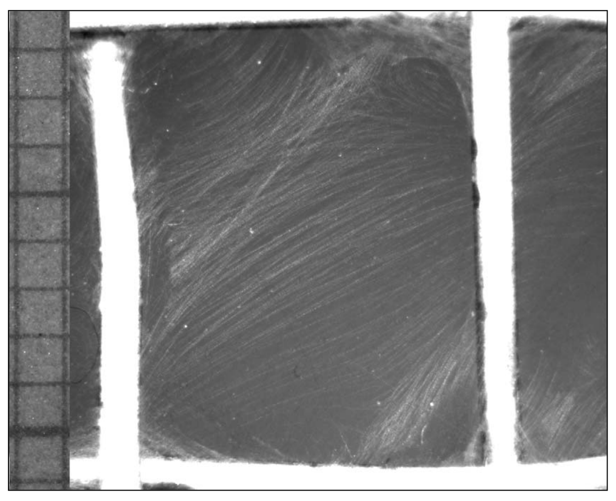
Electrospinning of PEO observed at 30 fps



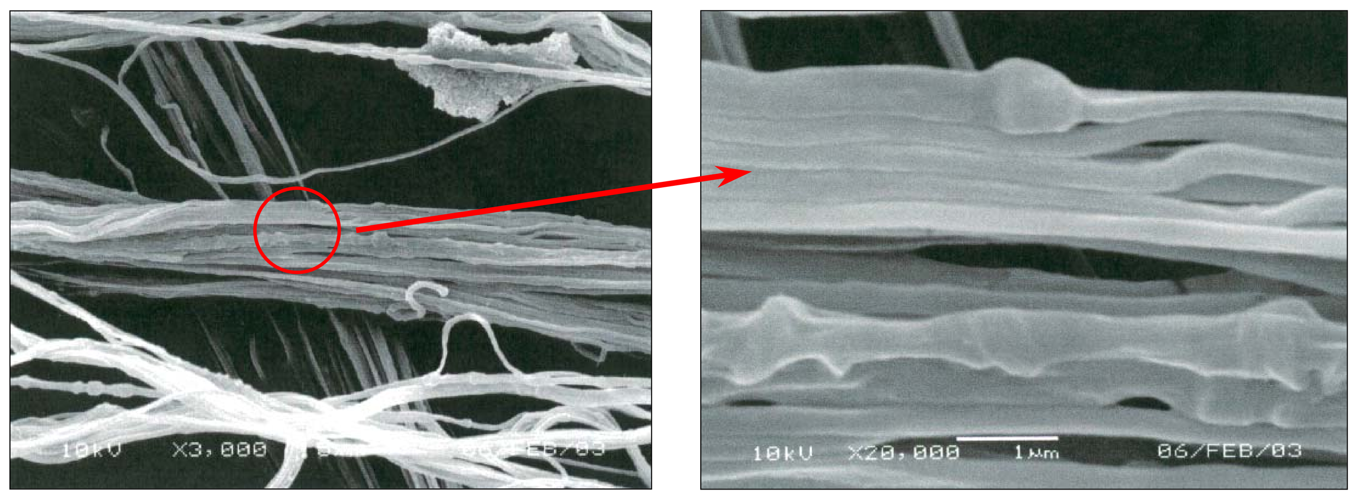
Electrospinning of PEO observed at 4500 fps



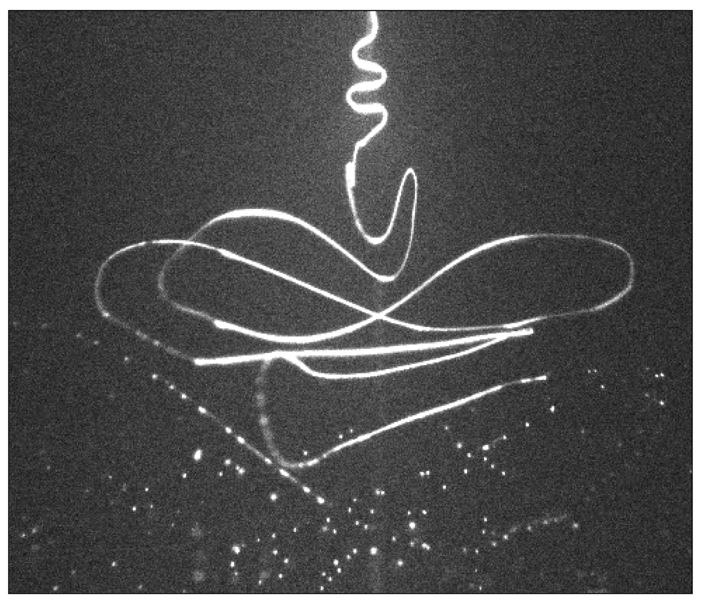
Nanofibres collection from PEO



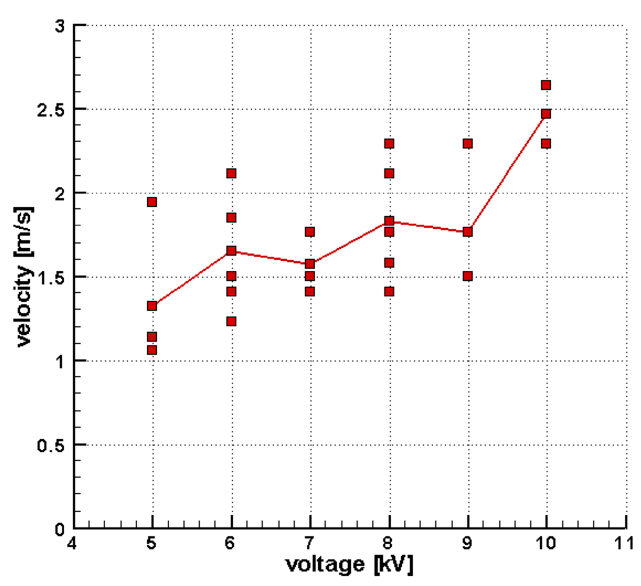
Nanofibres collection from PEO observed under microscope



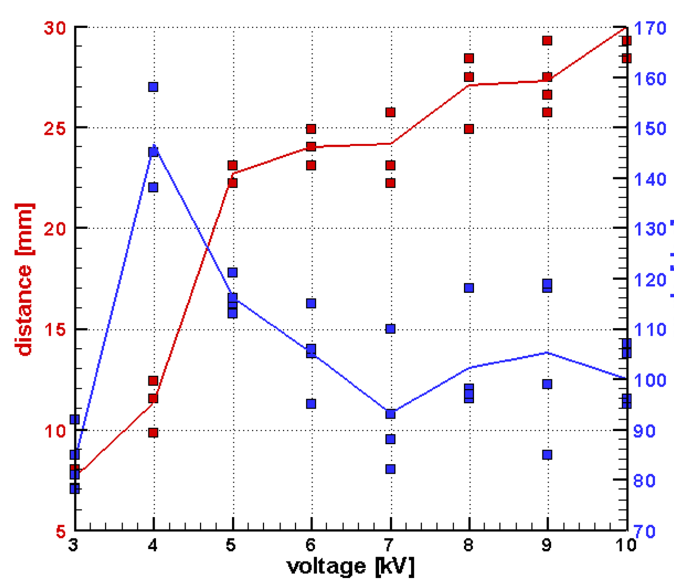
Nanofibres collection from PEO observed under electron microscope



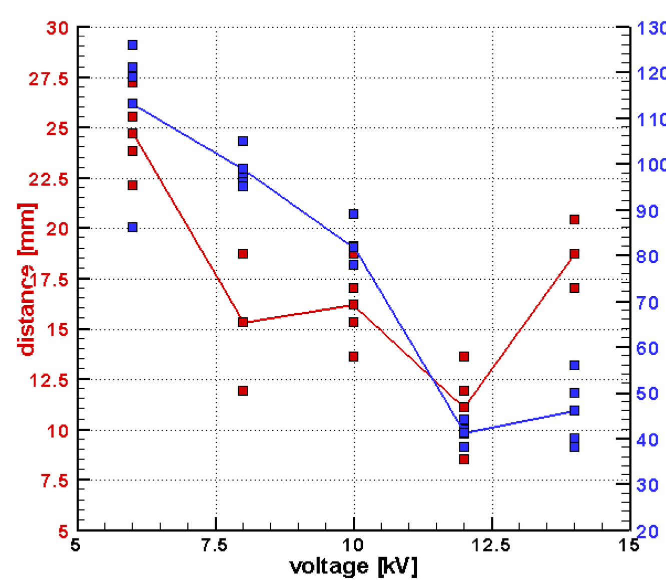
Electrospinning of 88% glycerol solution observed at 4500 fps



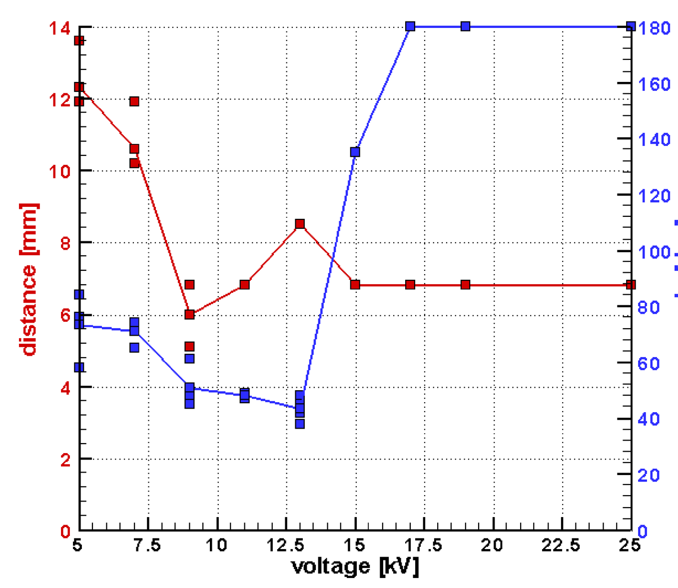
Velocity of the PEO fibre ate the rectilinear part



PEO - poly(ethylene oxide)



DBC - dibutyrylchitin



PAN - polyacrylonitrile

Variations of the straight segment (red line) and angle of the spiral cone (blue line) for tested polymers: PEO, DBC and PAN

ADVANTAGES AND APPLICATIONS

- Bending instability enormously increases path of the jet, allowing to solve problem: how to decrease jet diameter 1000 times or more without increasing distance to tenths of kilometres
- Nanofibres have numerous application in new materials sciences, chemical catalysts and electronic devices
- Collection of nonwovens of bio-active polymers, e.g. chitin finds practical application for tissue growth and new breathing bandages, protective clothing aimed for biological and chemical protection