Electrospinning – introduction

Introduction to the problematic of electrospinning technology, basic terminology. Introduction of physical principles of electrospinning technology (Taylor cone, Rayleigh instability, needle electrospinning, needle-less electrospinning, etc.)

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KNT, FT, TUL
Human hair

Cotton fiber
Very simple nanofiber production method is so called ELECTROSPINNING

- Known from the beginning of the 20th century

*Schematic diagram of Zeleny’s set up apparatus.*

J. Zeleny Physical Review 3 (1914) 69
A polymer solution is injected at a constant feed rate though a nozzle or needle which is charged to a high voltage, typically 10 to 30 kV (positive or negative). The applied voltage induces a charge on the surface of the liquid droplet and when this is sufficiently high, the hemispherical surface of the fluid elongates and a Taylor cone is established. On increasing the applied voltage further, a charged liquid jet is ejected from the Taylor cone and attracted to the earthed collector, which is positioned at a fixed distance from the needle. During this process the solvent evaporates from the polymer solution, leaving dry polymer fibres on the collector.

http://www2.warwick.ac.uk/services/rss/business/analyticalguide/electrospinning/
Basic principle – needle electrospinning

Taylor cone

Whipping

http://www2.warwick.ac.uk/services/rss/business/analyticalguide/electrospinning/
Basic principle – **needle** electrospinning
Basic principle – *needle* electrospinning

Figure 1. Two electrospinning units were positioned on opposite sides of a spinning collector. Electrospinning parameters for each apparatus could be controlled independently. The spinning grounded collector mixed the fibers in the resulting nonwoven fabric.

Basic principle – needle electrospinning

SELF ORGANIZATION !!!
Basic principle – needle electrospinning

Electrospinning/electrospraying schematic with variations for different processing outcomes
Basic principle – needle-less electrospinning

1- high voltage source
2- metal cylinder,
3- drop of polymer solution or melt,
4- creating nanofibers
5- grounded collector
**Basic principle – needle-less electrospinning**

**NANOSPIDER**

**WORLD PATENT**


[Links](www.elmarco.cz; www.nanospider.cz)
Basic principle – needle-less electrospinning

**NANOSPIDER**

Makroskopický pohled na vrstvu elektrostaticky zvlákněných nanovláken
Basic principle – needle-less electrospinning

Basic principle – needle-less electrospinning

NANOSPIDER

Overview
Overview

http://www.youtube.com/watch?v=7ix0EIGHTGY
TUL – laboratory nanofiber production

http://www.youtube.com/watch?v=9_7bevTse4E
Electrospinning- Nanospider smooth and wire cylinder

http://www.youtube.com/watch?v=oR_z54vV9Os
Electrospinning – Nanospider wire electrode

http://www.youtube.com/watch?v=Pac1M6D9dus
TUL – hand made nanofibers
From a physical point of view electrospinning resembles a tree with unusually manifold external morphology starting with its roots in a tiny surface layer of a polymer solution serving as one of a couple of electrodes, continuing with a stem represented by stable part of a jet. A whipping zone of the jet creates branches of the tree. Its fruits, i.e. nanofibres, are collected on one of electrodes connected to a high voltage source (David Lukáš 2007).
Needle Electrospinning

1. Taylor cone
2. Stable jet
3. Whipping
4. Solvent evaporation

Self-organized nanofibrous layer

d = 200 nm

Self-organization
Scaling up the technology

Theron, Yarin, Zussman (2005) Polymer, 46
Properties

- High specific surface
- High porosity
- Small pore size
- Fiber diameter 50 – 1000 nm
Material parameters of electrospinning

- polymer type
- molecular weight and molecular weight distribution
- solvent and concentration (for polymer solutions)
- temperature (for polymer melts)
- Aditives
- Electric conductivity of polymer solution or melt
- Surface tension
- Viscosity
- ....
The most used polymers for electrospinning

Z roztoku: PA 6, PVA, PVB, PUR, PAN, PVDF, PVP, …

Z taveniny: PE, PP
**Process parameters of electrospinning**

- **Spinner set-up**
- **Used high voltage**
- **Spinning distance (distance between electrodes)**
- **Room temperature**
- **Humidity**
- **Properties of support material (antistatic treatment)**
- **...**
Polymer concentration and fiber diameter

Concentration of polymer solution influenced mainly its viscosity.

Polymer concentration in polymer solution increasing means increasing of creating fiber diameter.

Relationship between polymer concentration, solution viscosity and diameter of electrospun polyacrylonitrile (PAN) fibres.
Pearl effect – electrospinning of solutions with very low polymer concentration

*Plateau – Rayleigh instability*

Extremelly = *elektrospraying*

http://phd.marginean.net/regimes.html
Huang, et al., A review on polymer nanofibers by electrospinning and their applications in nanocomposites, Composites Science and Technology, 63 (2003), 2223-2253.

Fig. 5. SEM photographs of electrospun nanofibers from different polymer concentration solutions [48].
Pearl effect (beads)

Polymer solution viscosity increasing
= nanofibrous layer without beads
Polycaprolactone fibers with [A] beads for electrospinning at a voltage of 6kV and [B] beadless fibers at 22kV. [Courtesy of W.E. Teo and S. Ramakrishna, National University of Singapore].

Increasing of applied high voltage
Increasing of polymer solution concentration
Increasing of feed rate (at needle-electrospinning process)

Polycaprolactone fibers with increasing beads size with increasing feedrate at [A] 0.5 ml/hr and [B] 2 ml/hr. [Courtesy of Teo and Ramakrishna, National University of Singapore].
PA 6.6 (a) spinning distance 2cm, (b) spinning distance 0.5cm.

Needle- electrospinning