Producing Highly Aligned Nanofibers by Electrospinning without Whipping Motion

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Electrospinning is a fast-developing method for production of polymeric and composite nanofibers with diameters ranging from few micro-meters down to tens of nanometers. It is based on applying a high electrostatic potential (typically kilo-volts) on a polymer solution or a polymer melt as it flows out of a nozzle (typically a capillary tube). High charge density on the electrospun jet leads to extensive stretching, which is responsible for such low final diameters, and also believed to be responsible for the unstable trajectory and development of semi-chaotic motion called *whipping instability* (also, bending instability). This work shows how elimination of the whipping motion of electrospinning fibers leads to nearly perfect alignment of fibers.

The whipping motion is eliminated by (i) using more uniform electrical fields (by means of a "back electrode", a planar electrode place slightly upstream of the nozzle) and (ii) by pulling the fiber mechanically by a fast-rotating cylindrical collector. This process is demonstrated for two types of polymeric fibers, solid fibers of poly(ethylene oxide) and porous fibers of polystyrene. They were collected at collector surface speeds ranging from 2 to 15 m/s. Over this range, a transition is observed in the arrangement of the collected fibers: from either non-aligned or wavy fibers at the lower collector speeds, to straight fibers with nearly perfect alignment at an intermediate speed of about 6 m/s (over 95% of the fibers within 1º and 100% within 4º). At the highest collection speeds the electrospun jet developed flailing motion, apparently due to the air turbulence created by the cylinder rotation, which led to worsening of alignment.

The degree of fiber stretching has been quantified as a function of the collector surface speed. A 50% decrease in average diameter was measured for PEO fibers, while in porous PS fibers it decreased by less than 30% for the same change in collection speed.

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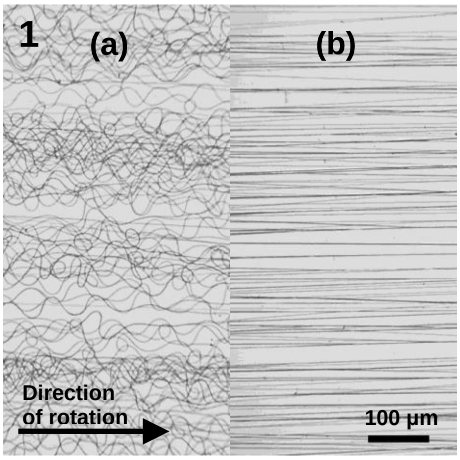
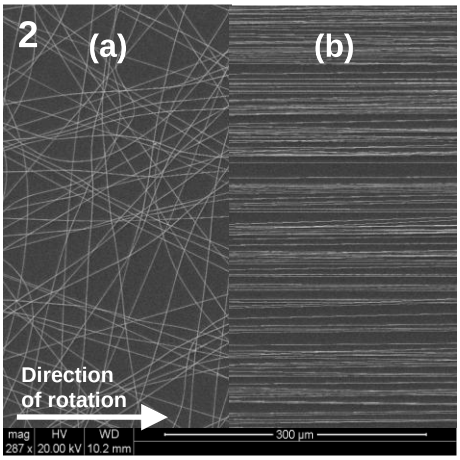
Figures





1 – Optical images of PEO fibers collected on 3 cm cylinder at collector surface speeds of (a) 2.07 m/s and (b) 4.71 m/s; 2 – SEM images of PS fibers collected at collector surface speeds of (a) 2.0 m/s and (b) 6.5 m/s