INVESTIGATION OF LINEAR ELECTROSPINNING JETS

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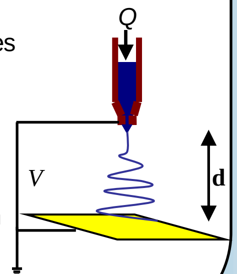
ELECTROSPINNING

- Create nano-scale polymer fibers through the use of electric charge
  - Induce charge on polymer solution through applied voltage
  - When electrostatic forces overcome solution surface tension, a charged jet erupts from needle
  - Normally undergoes 3 phases
    - Taylor Cone
    - Linear extension
    - Bending Instability
  - Different collection methods based on desired orientation
  - Current methods that yield oriented fibers are low output

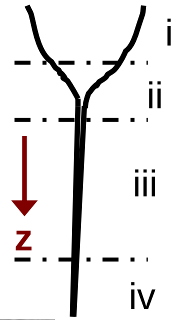


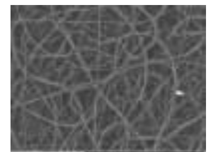
ELECTROHYDRODYNAMIC MODELING

- Motivation: Numerous potential applications
  - Tissue scaffolds, multi-functional composites, filtration, sensors, drug delivery…
- No model that can successfully link processing parameters with fiber diameter for multiple polymer-solvent systems!
- Helgeson et al. electrohydrodynamic model
  - Reduce dimensionless balance equations based on analogy to traditional uni-axial flow
    - Identify important forces in different sections of stable jet region
    - Experimentally verified for poly(ethylene oxide)-water system through high speed velocimetry

STABLE JET REGIONS

- i. Taylor Cone
- ii. Jet Initiation
  - Strain Hardening
  - Large increase in extensional viscosity
- iii. Jet Stretching
  - Reach pseudo-steady state extensional viscosity
  - $R \sim z^{-1/2}$, $v \sim z$
- Jet Thinning
  - $R \sim z^{-1/4}$, $v \sim z^{1/2}$

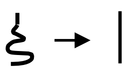


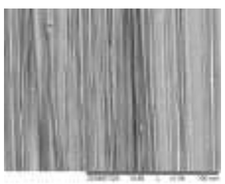


Representative non-woven mat, x1000

EXPERIMENTAL

- **Goal:** Explicitly verify observed scaling laws for a completely different electrospinning system
- Poly(ethylene oxide)-Chloroform
  - Linear jet—No bending instability!
  - Collection of highly spatially oriented fibers

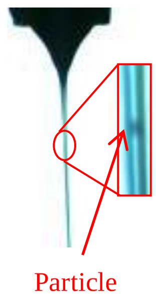




PEO-Chloroform, x1000

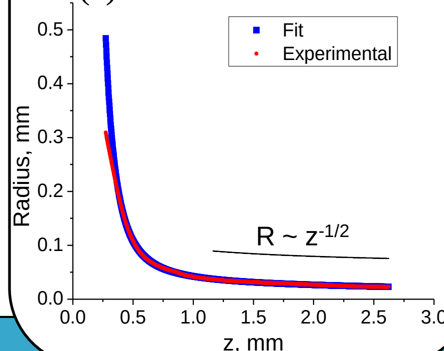
HIGH SPEED IMAGING

- High speed images to track particles in the jet
  - Hollow silica (10 μm)
  - 2000 fps
  - 250 μs exposure
- Observations:
  - Solvent evaporation seemed to play large role
  - Formation of polymer 'skin' on cone region
  - Steady jet difficult to achieve

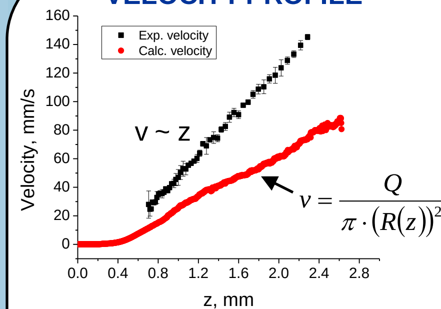


RADIUS FITTING

$$R(z) = Az^{n} + Bz^{-1/2} + Cz^{-1/4}$$



VELOCITY PROFILE



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