THE EFFECT OF ELECTRICAL FIELD SHAPE ON THE ELECTROSPINNING PROCESS

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INTRODUCTION AND GOALS

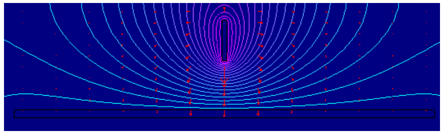
- Scaling up the electrospinning process
  - Traditional methods of electrospinning are slow with respect to output (hours/gram!)
  - Scale-up through use of multiple needles is problematic due to difficulty in achieving a high density of needles/unit area
  - Multiple electrodes in a pool of fluid as opposed to infusion of fluid through a needle provides a possible solution
- Question: How does the shape of an electrode effect the local field strength?
  - Local field strength distorts the fluid surface and governs the formation of a jet in solution.
- Using FEA models and a high speed imaging camera we want to try and show the relation between electrode geometry and electrical field shape.

CONTROL MODEL

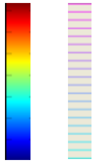
- Using COMSOL Multiphysics FEA modeling program, we can model the electric field shape and strength for each type of electrode geometry.

Needle and Plate Control Model*

Surface: Electric Field, norm [V/m]; Contour: Electrical Potential [V]; Arrow: Electric Field [V/m]



6.626e6 V/m | 5362.5 V



0 V/m | 137.5 V

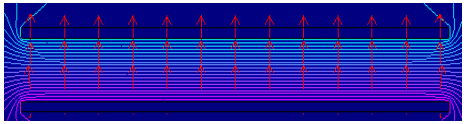
Dimensions: tip to plate – 10cm; plate width – 2mm; plate length – 10cm; needle width – 1.27mm; needle length – 1cm;

- To have jet initiation using the traditional needle and plate model at 5.5kV, a critical field strength of 4.09e5 [V/m] must be reached. (3% solution of 400k MW PEO in water)
- This field strength can be reached with different geometries by applying different potentials.

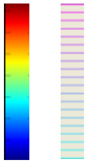
EXPERIMENTAL MODELS

Parallel Plates*

Surface: Electric Field, norm [V/m]; Contour: Electrical Potential [V]; Arrow: Electric Field [V/m]



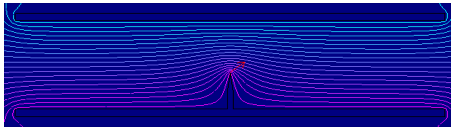
1.11e7 V/m | 5362.5 V



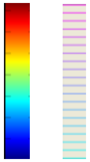
0 V/m | 137.5 V

Dimensions: plate to plate – 1.4cm; plate width – 2mm; plate length – 10cm

Sharp Tipped Geometry*



4.631e7 V/m | 5362.5 V

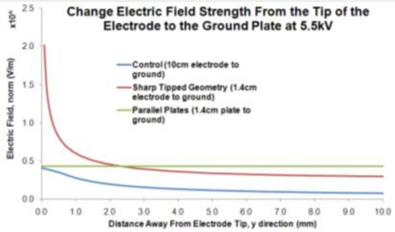


0 V/m | 137.5 V

Dimensions: tip to plate - 1.4cm; plate width - 2mm; plate length - 10cm; tip width – 1.27mm; tip length – 1cm

**Conditions: The potential applied is 5.5kV and material used for modeling the electrodes is aluminum.*

ELECTRIC FIELD STRENGTH

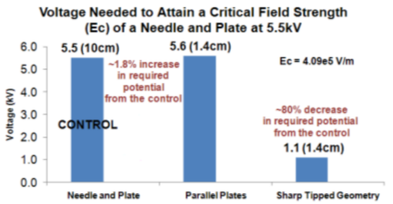


PREDICTED CRITICAL FIELD STRENGTH FOR JET INITIATION

- To attain jet initiation, the field strength must be large enough to overcome the surface tension and viscoelasticity of the fluid.
- Using the COMSOL software, the voltage needed to attain this field strength can be estimated.

PREDICTED CRITICAL FIELD STRENGTH FOR JET INITIATION (CON'T)

- We anticipated that the sharp tipped geometry will require a significantly smaller amount of voltage to induce jet propagation. (~80% decrease)

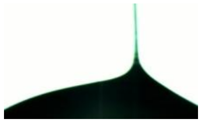


EXPERIMENTAL SET UP

- Following the COMSOL modeling conditions, we constructed two rectangular plates out of aluminum foil. We then used the Redlake Motionxtra HG 100K high speed camera to take images of the droplet at different potentials.

EXPERIMENTAL RESULTS

- *When jet initiation occurred, electrical arcing was observed between the two plates.*
- *Jet initiation should theoretically occur at 5.6 kV according to the modeled system*



Parallel Plates, 3% solution PEO/water, 15kV

- **Distortion of drop surface started at ~5.6kV, but jet initiation occurred at ~2.7 times the predicted value for the spinning potential.**
  - Significant electrical arcing between electrodes was observed during the experiment . Possibly due to high relative humidity (RH) ~64%.
- As RH increases, dielectric breakdown voltage decreases. The increased moisture in the air will cause an increase in the conductivity of the air and subsequently arcing at lower voltages.** The arcing decreases the amount of available surface charge, requiring a higher potential to induce initiation.

FUTURE WORK

- The next step is to lower the RH of the atmosphere to see if arcing will still hinder jet initiation.
- Our future goal is to compare images of jet propagation for many different electrode geometries to the geometries modeled.
- We also want to incorporate the characteristics of fluid and fluid shape into our modeling.

***K. P. Morales, et. al., "Pulsed Dielectric Surface Flashover in Nitrogen at Atmospheric Conditions," IEEE Trans. on Dielectrics and Electrical Insulation, 803-809, 2006.*

ACKNOWLEDGEMENTS

This work is supported by ONR BAA 07-037: Pseudocapacitor with High Energy and Power Densities Based on Nickel Oxide Nanostructures

Special Thanks:

Xing Chen and Prof. John Xiao UD Dept. of Physics and Astronomy