Electrospray Applications for Applying CNT Solutions

Shannon O Connor¹, John Veracka², Riley Flanagan³, Christopher Rivera⁴, Sahil Ghate⁴, Virginie Rollin⁴, Daewon Kim⁴ and Foram Madiyar¹

¹Department of Physical Science, ²Human Factors and Behavioral Neurobiology, ³Department of Mechanical Engineering, ⁴Department of Aerospace Engineering, Embry-Riddle Aeronautical University, Daytona Beach, FL

Introduction

Liquids readily interact with electric fields. In 16th century, William Gilbert observed that a drop of water deformed into a cone in the presence of charged piece of amber. This was due to instabilities of a charged liquid drop which was studied by Lord Rayleigh in 1882. This physics of interaction of a liquid in capillaries with electric field is related to electrosprays. In 1882, Rayleigh observed that an excessive charge q on the droplets would disintegrate the droplets as the repulsive force between the charges on the droplet surface exceeds the surface tension of the droplet. Using this concept we hope to apply electrospray to the application of nanomaterials. Particularly, that of carbon nanotube solutions (CNT’s)

Mechanism of Electrospray

The mechanism of electrospray is to form a very fine tip of the conductive solution by application of a high voltage between the capillary containing the conductive liquid charged at high electric potentials and a nearby-grounded substrate. A pump pushes the fluid through a capillary where the electric field is applied. The applied electric field induces mutually opposite forces (surface tension and viscoelastic forces) on the fluid that help to retain the hemispherical shape of the droplet formed while the charge induced through the electric field wants to deform the droplet into a conical shape called a Taylor cone. Once the voltage breaches a threshold value the electric forces are overwhelmed, and a charged jet emerges from the Taylor cone. It has been observed that low viscosity fluids are those that break up into particles when an electric field is applied and leave the capillary as very fine mist in electrospray.

Comparison of Standard Coating Methods

<table>
<thead>
<tr>
<th></th>
<th>Low Cost</th>
<th>Scalable</th>
<th>Highly Uniform</th>
<th>Efficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spin Coating</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Dip Coating</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>High-Volume Low-Pressure Spray</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Electrospray</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Results

Preliminary testing of our electrospray set up has shown proof of concept that electrospray works. Using a testing solution of 10% NaCl, we were able to get the water to be pulled from the syringe tip towards a charged aluminum plate. So far, we have been able to manipulate our solution application from a stream to a light mist, however the mist has not been deemed light enough to justify using the CNT solutions yet. Spray characterization will continue through a series of tests independently controlling voltage, volumetric flow, and conductivity. The most promising direction so far leans towards larger spray orifice to create a more stable Taylor cone.

Conclusion

In conclusion, electrospray is a proven concept. We look next to improving upon the concept by experimenting further with the needle size as well as changing the voltage and flow rate of our experiment setup. We wish to improve upon this to the point where we can apply our concept to the application of nanotubes.

References and Acknowledgements


Acknowledgements: We thank the financial support by Office of the undergraduate research, Embry Riddle Aeronautical University, Daytona Beach, FL 32114