Electrospray Applications for Applying CNT Solutions

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Introduction

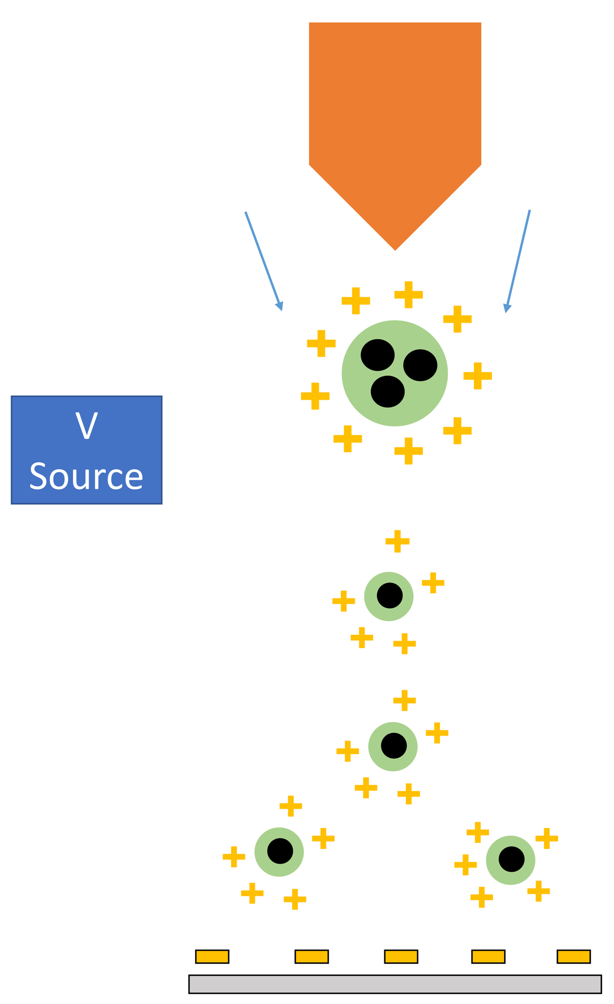
Liquids readily interact with electric fields. In 16th century, William Gilbert observed that a drop of water deformed into a cone in the presence of charged piece of amber. This was due to instabilities of a charged liquid drop which was studied by Lord Rayleigh in 1882. This physics of interaction of a liquid in capillaries with electric field is related to electrosprays.

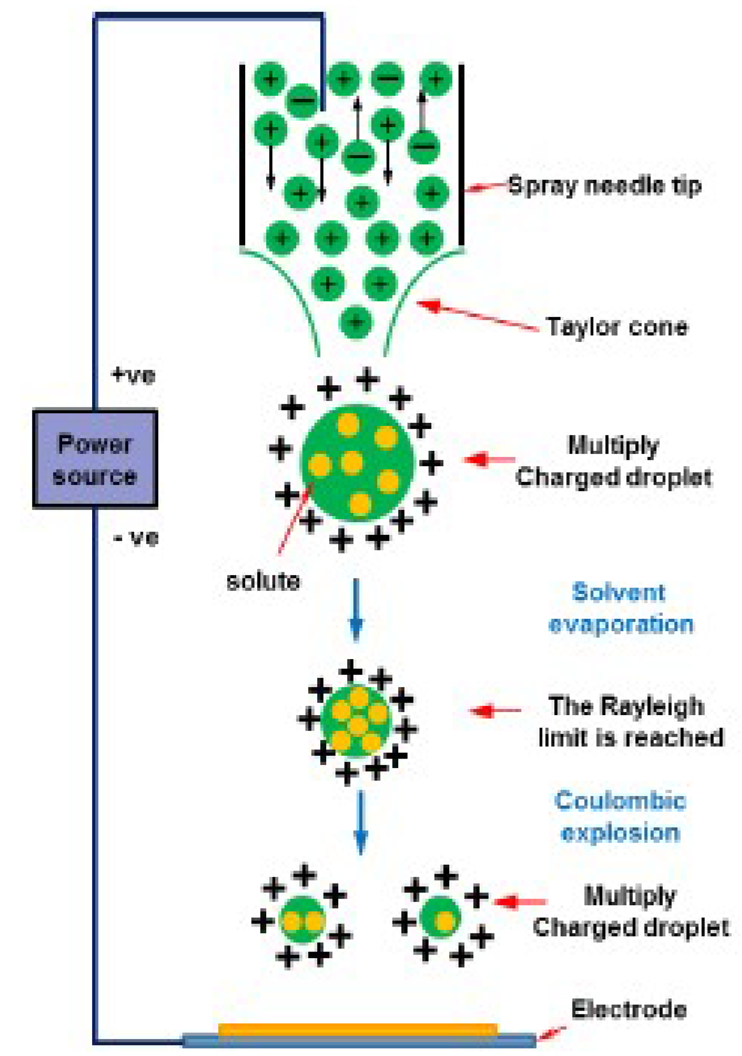
In 1882, Rayleigh observed that an excessive charge q on the droplets would disintegrate the droplets as the repulsive force between the charges on the droplet surface exceeds the surface tension of the droplet. Using this concept we hope to apply electrospray to the application of nanomaterials. Particularly, that of carbon nanotube solutions (CNT's)

Comparison of Standard Coating Methods

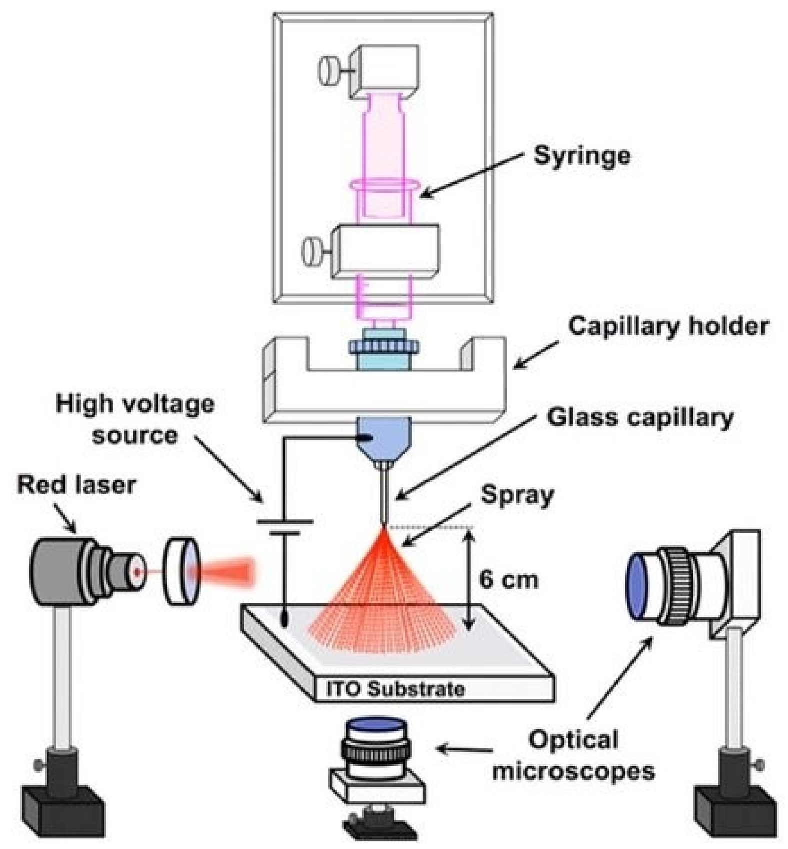
	Low Cost	Scalable	Highly Uniform	Material Efficient
Spin Coating	✓	X	✓	X
Dip Coating	✓	✓	X	X
High-Volume Low-Pressure Spray	✓	✓	X	✓
Electrospray	X	✓	✓	✓

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.



CNT Solution

The solution used with the electrospray platform was composed of Carbon nanotubes (CNTs), polyaromatic moieties, and the presence of a strong acid. Carbon nanotubes (CNTs) are an allotrope of carbon that is rolled into cylinders that can be used for a variety of purposes. A free-flowing solution of CNT nanoparticles was created using noncovalently bonding polyaromatic moieties that are further functionalized by the use of either fuming sulfuric acid or chlorosulfonic acid. The acid and the polyaromatic moieties are used together to minimize the presence of London Dispersion Forces (LDF) between the CNTs, diminishing the clumping of the nanotubes to each other. In addition, the conjunction of moieties and a strong acid allows for the mechanical flexibility and electrical properties of the CNTs to be unaffected, creating a solution with a high amount of resistance to be developed. The free-flowing properties of the CNT films allow for easy distribution amongst a surface, making it possible for a small amount of voltage to create an immense temperature change.

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 the 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

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