Electrosprays, the unique aerosols emitted by conical liquid menisci

J. Rosell-Llompart[1,2]

[1]Catalan Institution for Research and Advanced Studies ICREA, Barcelona, E-08010, Spain
[2] Department of Chemical Engineering, Universitat Rovira i Virgili, Tarragona, E-43007, Spain
Keywords: droplets, monodisperse, Taylor cone, cone-jet, EHDA.
Associated conference topics: 1.5
Presenting author email: joan.rosell@urv.cat

We give an overview of past and current research on electrospray technology and how it has impacted Aerosol Science and Technology, while identifying opportunities for future research.

Electrified conical menisci, known as Taylor cones, emit droplets with unique properties; mainly, precise size adjustability from micro-meters down to nano-meters, size mono-dispersion, and high electrical charge near the Rayleigh limit value (Rosell-Llompart *et al*, 2018). Such attributes have made electrosprays famous for diverse applications: from mass analysis of biomolecules in Analytical Chemistry (ESI-MS) to colloid thrusters for spacecraft propulsion, to high-brightness liquid metal ion sources (LMIS), as used in focused ion beam lithography.

Electrosprays have also been a powerful aerosol technology, having been used

I. for liquid atomization to generate test aerosols for aerosol instrumentation;
II. as sources of ions, macro-ions and charged nanoparticles (including biologically composed, e.g., proteins, DNA, viruses, etc.), enabling the development of high-resolution differential mobility analysis (DMA) of diffusive aerosols, which in turn has driven the study of such aerosols;
III. as sources of particles by (1) the spray-drying route, for pharmaceutical and biomedical applications, and by (2) the pyrolysis route for ceramics;
IV. as sources of "building blocks" (droplets/particles) to make coatings/films and print patterns for catalysis, energy devices, medical implants, biosensing, etc.; and
V. as dense sources of electrostatically mobile droplets, with uses in wind to electrical energy conversion, or in electrostatic precipitation (in lieu of corona discharges).

Such uses of electrospraying have in turn stimulated intense engineering developments, as well as research on the underlying physics mechanisms.

With respect to physics research, the large number of variables needed to describe the system and intervening forces, and the coexistence of disparate length and time scales make it challenging to predict the aerosol microscopic properties from the basic parameters of the problem (composition and process variables), and therefore, despite an impressive body of theoretical knowledge, many questions still remain unsolved.

On the engineering axis, important developments include:

a) multi-fluid configurations (e.g., coaxial flows) to achieve complex droplet compositions (e.g., core-shell),
b) opposite-polarity electrospraying for bipolar coagulation to trigger chemical micro-reactions between dissimilar droplets,
c) multiplexing of emitting sources to scale up the throughput of the electrospraying process, and
d) *in situ* droplet neutralization with gas-phase ions to overcome issues caused by the electrical charge.

These inventions have uncovered new capabilities of the technology, and overcome limitations; while many opportunities lie ahead for developing, perfecting, and modelling them.

The author will aim to give a clear perspective of this rather broad topic, while highlighting developments in which he participated.

Acknowledgements. Most of the ideas have in one way or another been borne out of discussions on this topic with my mentors, many colleagues and coworkers, including students. Research funding leading up to this activity is kindly acknowledged from the Government of Spain and the EU European Regional Development Fund programme through various grants which have been essential to my professional development, as well as from the Catalan Government through its Consolidated Research Groups program, currently with grant 2021SGR-00978.

Rosell-Llompart, J., Grifoll, J., and Loscertales, I.G. (2018) *J. Aerosol Sci.* **125**, 2-31.