Polarization Mechanisms in AC Electro-Sprays

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Two distinct polarization mechanisms are found experimentally to be responsible for ejecting drops and jets in AC electro-sprays. At high frequencies ($>$ 100 KHz), low-mobility anions, generated by gas-phase ionization reactions, are entrained near the drop to produce a net Maxwell force, whose magnitude is sensitive to the frequency but is independent of the liquid conductivity. The drops are ejected from elongated drops and jets at a frequency much lower than the AC frequency. The drops are electro-neutral and retain a dimension close to the capillary radius. At frequencies lower than the inverse anion entrainment time in the gas phase, liquid polarization occurs and ejects charged drops through the classical Taylor cones at an ejection frequency much higher than the AC frequency. The required voltage and Maxwell force for this low-frequency ejection is highly sensitive to the liquid conductivity, suggesting a double-layer polarization mechanism. The charged drops undergo Rayleigh fission into nano-meter sized drops as in the classical DC sprays. Exciting this low-frequency mechanism at the resonant frequency of the drop produces pointed polyhedral drops and multi-Taylor cones with high ejection throughputs. We exploit the distinctly different charge, dimension and ejection frequency of these two different polarization and ejection mechanisms to carry out precision coating of nano-colloids, drug encapsulation in tissues and capsules of tunable dimension, and high-throughput mass spectrometer interface. Some preliminary asymptotic and scaling theories will also be offered to delineate and collapse the data from these two mechanisms, as well as deciphering the formation dynamics of Taylor cones at low frequencies.