Diverse morphologies of amorphous nanostructures by electrospraying

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Electrospray is a liquid atomization technique of interest in diverse applications. For example, it is capable of producing nano- to micro-particles with biomedical and pharmaceutical functions (Boda et al., 2018). A precursor solution is fed through the exit of an electrified capillary where it forms a Taylor cone meniscus, which emits a thin liquid jet (Rosell-Llompart et al., 2018). The electrical charge allows overcoming surface tension forces and thus produce tiny structures. Different scenarios produce different morphologies. The jet tends to break up into droplets that become particles after the solvent evaporates. The charged droplets have initially repeatable sizes, but later, after some solvent evaporation, they can undergo Coulombic instabilities (CIs), leading to progeny submicrometric particles (Bodnár et al., 2018). On the other hand, the jet breakup may be incomplete for high solution viscosity. In this case, thin nanofilaments remain between the particles. Only general understanding exists on these regimes and on the roles played by the different many (process, solution, ambient) variables. Here, we present systematic research aimed at clarifying those roles, more specifically, how the morphologies depend on the solution physico-chemical properties such as viscosity and electrical conductivity, while varying solute concentration and molecular weight (MW).

With very dilute polystyrene (PS) in butanone (MEK) solutions, CIs arise and progeny particles are visible. With increased concentration, progeny particles disappear, while size-monodisperse globular main particles form (Figs. 1a, 1b), as well as satellite particles at the periphery of the collection (not shown). Further rising the solution viscosity, the collected residues are linked by filaments (Figs. 1c, 1d) due to incomplete jet breakup. High solution viscosity with low electrical conductivity led to incomplete jet breakup; so, it became critical to use a solvent-saturated gas co-flow for highly viscous solutions to prevent drying of the Taylor cone and obtain stable electrospraying. We also found that the filaments get thinner when the co-flow speed around the Taylor cone is increased, as shown in Figs. 1e and 1f for the same solutions as in Figs. 1c and 1d, respectively. The sizes of the particles remained nearly unchanged by the co-flow increase. Particles with low MW are spherical whereas, high MW forms deflated shells. Blended solutions produced particles with in-between shapes. For different molecular weights, the boundary between these regimes correlated is predicted by viscosity.

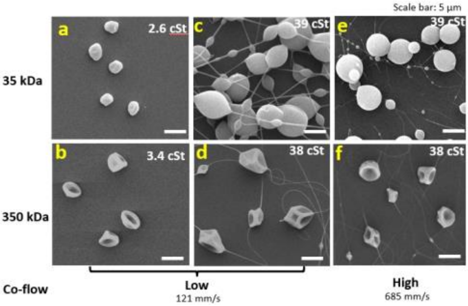

Figure 1: Electrosprayed particles from PS/MEK solutions at: (a) 15, (b) 5, (c) 40, (d) 14 wt.%, with low co-flow, and (e) 40, (f) 14 wt.%, both with high co-flow. Left panels are for Mw 35 kDa PS, right ones for 350 kDa. Top panels show the solution viscosity (at 22°C).

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