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LIQUID MICRODROPLETS IN A MICROPLASMA: PHENOMENA AND TECHNOLOGICAL APPLICATIONS

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Abstract. The acceleration of chemical reactions in confined microvolumes has inspired considerable interest in the potential of charged microdroplets as chemical microreactors with further enhanced capability. The use of plasma-generated free electrons as a charge source opens the possibility of generating very high levels of surface charge and high interfacial electric fields in such microdroplets. To fully exploit their potential as gas-phase reactors, microdroplets need to be relatively long-lasting in order to deliver a continuous stream of reaction products to a remote target and therefore evaporation during plasma exposure needs to be optimised. Potential applications of charged liquid microreactors are many and varied, including direct medical treatment by delivering elevated levels of radicals, e.g. $OH^{\bullet}$, or on-demand synthesised nanoparticles to target cancers, possibly in-vivo via endoscopic access. Other nanomaterials advances include on-demand ink-jet patterns for photonic sensors, surface catalysis, biocides, nanofertilisers and polymer nanocomposites. Plasma physics and chemistry of such a multiphase system comprising gas, plasma, saturated vapour, gas-phase clusters, solid nanoparticles and liquid are extremely complex and little explored.

Free electron fluxes to liquid provide a rich source of solvated electrons capable of initiating rapid reduction reactions in precursor-loaded droplets. To supply such electrons requires a high density but low temperature plasma operating at atmospheric pressure under non-equilibrium conditions and capable of tolerating droplet injection without excess evaporation or electron loss. Although, from theoretical considerations, microscale particles in such a plasma are expected to acquire a net charge, this has yet to be demonstrated. We report the first measurements of particle charge acquired by microparticles in a fully collisional atmospheric pressure low temperature plasma. Estimates of areal electron flux to the droplet surface were obtained from simulation coupled with experimental observation of in-droplet reduction reactions. Results demonstrate a 2 – 3 orders of magnitude increase in charge levels compared to ion charging in corona systems or electron charging in low pressure plasmas while electron fluxes are many orders of magnitude higher than in gamma radiolysis.