Controlled droplet transport through an atmospheric pressure plasma.

P Maguire[1], C. Mahony[1], C Kelsey[1], N Hamilton[1], E Bennet[2], D Rutherford[1], DA McDowell[1], H Potts[2], D Diver[2], D Mariotti[1],

[1]Engineering Research Institute, University of Ulster, Shore Road, Newtownabbey, BT37 0QB
[2]SUPA, School of Physics and Astronomy, University of Glasgow
*Contact e-mail: pd.maguire@ulster.ac.uk

1. Introduction

Plasma-liquid interactions are complex but offer considerable scope for fundamental study and for use in applications from plasma medicine to nanomaterials synthesis. The introduction of individual microdroplets into a steady-state low temperature plasma at atmospheric pressure, with control of size, speed and separation would offer advantages for fundamental investigations and simulations of plasma chemistry. Droplet chemistry offers the potential for gas-phase microreactors similar to liquid bubble microfluidics current under intense research but with enhanced opportunities for scale-up. For nanomaterials and quantum dot synthesis, the addition of a liquid phase within the plasma expands considerably the scope for core-shell and alloy formation. The remote delivery of plasma activated media to living tissue and the study of plasma interactions with isolated biological elements such as cells or DNA are immediate areas of interest. Apart for the impact of the liquid particles on the plasma and gas temperature, we report initial findings on droplet generation and interface to the plasma, flow and thermal effects during transport and preliminary measurements which indicate the occurrence of (i) in-situ microreaction chemistry, (ii) nanoparticle formation, (iii) remote delivery of chemistry and (iv) biological interactions.

2. Plasma-droplet system

We have developed a system for entraining micron-sized droplets within a narrow rf-driven (13.56 MHz) cylindrical He-Ne microplasma operated at atmospheric pressure. The measured droplet size distribution at exit is log-normal with a count median diameter of 14µm. Diameter reduction due to plasma exposure is < 3µm. Transport times can be varied between 20µs to >100µs. Droplets exit the plasma with a velocity distribution within a parabolic envelope, figure 1(a), and droplets with net charge have been observed up to ~20 mm from the plasma exit. The plasma induced evaporation results in an average diameter reduction of < 3µm. Au nanoparticle synthesis has been observed within $AuHCl_4$ droplets as they pass through the plasma. Downstream Ag nanoparticle synthesis, with plasma-activated H_2O onto $AgNO_3$, is shown, fig. 2.

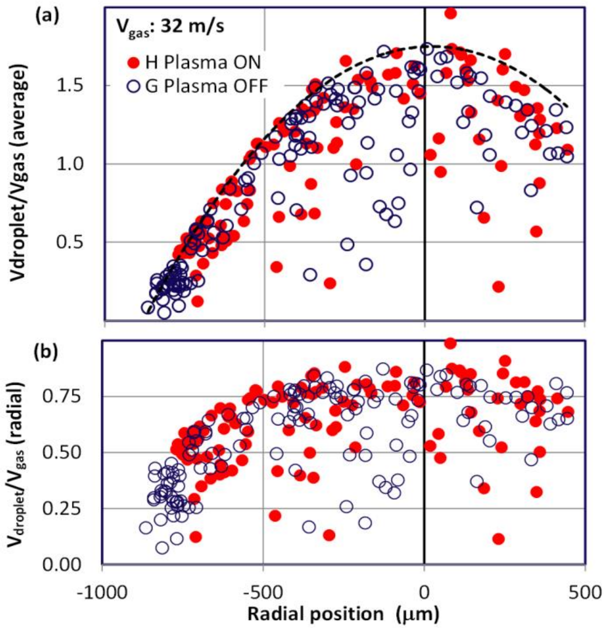

Fig 1: *(a) droplet velocity distribution at ~1.5mm from plasma exit with (filled) and without (empty) plasma, (b) velocity distribution normalised to radial gas speed.*

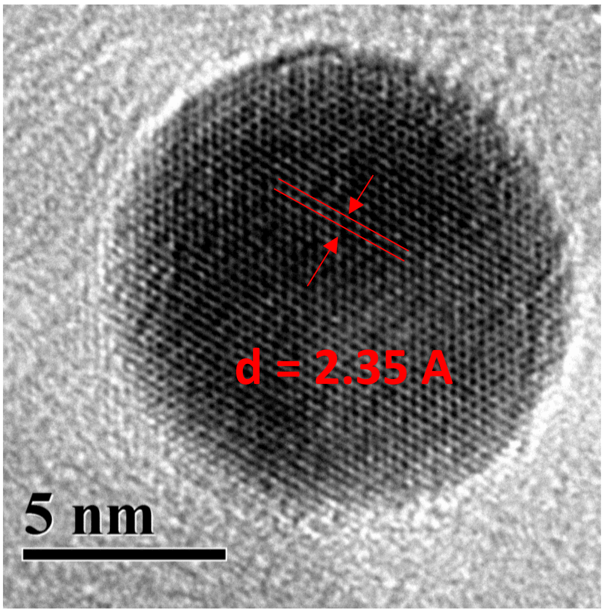

Fig 2: *TEM image of Ag nanoparticle formed through plasma-droplet downstream interaction with $AgNO_3$.*

Acknowledgements: Engineering & Physical Sciences Research Council (EPSRC: EP/K006088/1 EP/K006142, EP/K022237/1)