

Plasma-based aerosol processes for the production of nanoscale materials

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The presentation first depicts the objectives and the outlines of this special session on plasma-based aerosol processes. Recent developments of atmospheric pressure plasmas for the production of nanoparticles and coated nanoparticles by nucleation, either from cooling of expanding vapour plumes produced by plasma-surface interaction, like in spark generators (Deppert, 2012) or from injection of gaseous precursors in or downstream the plasma for reactive nucleation and subsequent coating of particles or substrates (see fig. 1). Besides, the transport of so-formed nanoparticles for deposition on surfaces as well as integration into nanocomposite thin films will also be addressed (Massines, 2012).

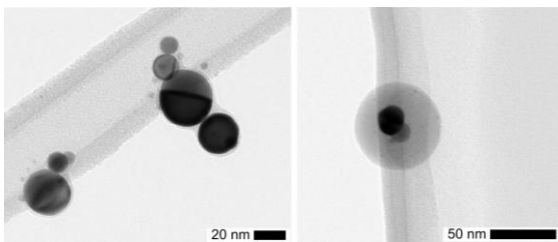


Figure 1. TEM micrographs of SiO_x coatings from 2 to 20 nm, formed by post-DBD TEOS injection (0.7 ppmv) for 83 and 185 sec post-DBD reaction duration (Weber et al 2016).

Then, the second part of the presentation will focus on a plasma process for the production of nanoparticles with tunable size and the same composition than the electrode in Dielectric Barrier Discharges (DBD). Such nanoparticles with narrow size distribution are targeted for their size-dependent properties. However, classical ablation/vaporization processes by laser and spark discharges (1-100 mJ per spot) usually leads to 10-100nm agglomerates of nanoparticles.

Here, a compact, inexpensive and simple DBD design is presented for the production of such targeted tailored nanoparticles. The production of nanoparticles by nucleation of the electrode material vaporized by plasma filament interaction with the surface of electrodes and dielectric materials are depicted from TEM and size distributions measurements, with chemical composition and crystalline structure from Small Angle Electron Diffraction (SAED).

With smaller energy per filament in DBD (0.1-100μJ), it is first confirmed that the initial local vapor flux is produced from the spots of interaction between plasma filaments and different materials (Al₂O₃, Au, Ag, and Cu, Si, polymers).

Then, as an example with a metal electrode, amorphous and crystalline pure primary metal nanoparticles are produced by physical nucleation in expanding vapors jets (see Fig. 2). Finally, small agglomerates with diameters still below 5 nm are formed by agglomeration of these primary particles at the end of the vapor jet expansion, as well as after the production during the transit between subsequent filaments in the DBD. The first local agglomeration step can be limited at reduced energy per filament by lowering the initial vapor flux, while the second growth step depends on the transit time in DBD.

Hence, DBD were successfully tested for the production of tailored nanoparticles with tunable size and the same composition than the electrode (Borra et al. 2015).

This plasma-based aerosol processes represent an alternative for nanotechnologies, since it is performed at atmospheric pressure and can be used to reach size-dependent properties of nanomaterial, without any precursor or solvent.

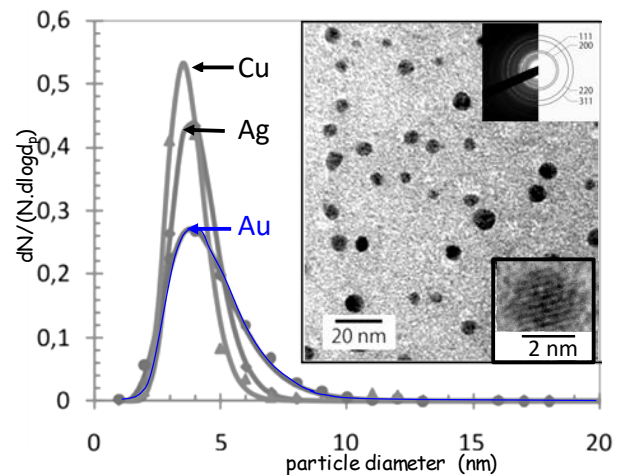


Figure 2. TEM micrographs of Metal nanoparticles produced by atmospheric pressure DBD (a) gold particles and corresponding SAED figure of Au fcc crystalline structure (Upp=11kV, gap=1.65mm)

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