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Nanoparticle Synthesis in a Plasma Downstream Reactor – From Plasma Parameters to Nanoparticle Properties

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The plasma downstream reactor is normally used for the surface modification of fine-grained powder substrates by the controlled deposition of nanostructured SiO_x on the substrate particle surface. The deposited nanostructures reduce the attractive interparticle forces and thus, improve the powder flowability. This kind of plasma reactor consists basically of a 1.5m long glass tube with a gas and precursor feed unit on the top and a particle-gas separation unit at the lower end. An inductive coil on the outside of the tube couples the power into the discharge. In order to understand the process of nanoparticle synthesis in this continuous reactor, we performed a detailed study of plasma parameters and nanoparticle growth without any addition of substrate powder into the reactor. Silica-like particles were produced from four different organosilicon monomers HMDSO, TMDSO, TEOS, and TMOS, in argon-oxygen gas mixtures. The chemical composition and morphology of the emerging particles and its production rate were studied as a function of process pressure (100 – 400 Pa), plasma power (200 – 350 W), gas velocity (5 – 16 m/s) and gas composition. Langmuir double probe and calorimetric probe measurements allowed determining the axial profiles of electron temperature, positive ion density and energy influx along the tubular reactor at these conditions. The carbon content of the orthosilicate derived particles was generally lower compared to disiloxane derived particles and it decreased with rising oxygen to monomer ratio, plasma power and process pressure. The conversion from monomer to nanoparticles was favoured by high pressure, short residence time, and high monomer content in the process gas. The morphology of the produced amorphous particles was similar to fumed silica, with primary particles in the size range of 10 nm building hard-agglomerates of several hundred nanometres during the synthesis. Finally an adapted particle growth model for a continuous plasma reactor is introduced which explains the influence of the different process parameters on the particle evolution.

Keywords
Nanoparticle Synthesis
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