SYNTHESIS OF NANOPARTICLES IN INDUCTIVELY COUPLED PLASMA REACTOR

Silvania Lopes, Portugal
Supervisor: Prof. P. Rambaud & Prof. P. Proulx (Sherbrooke University, Québec)
Promoter: Prof. J.-M. Buchlin (ULB, Belgium)

Nanoparticles materials have been shown to have enormous potential for many industrial applications, because of their often singular optical, mechanical, catalytic and electronic properties. The product purity, particle size, size distribution, and morphology are determined by the processes used to generate the nanoparticles. Therefore, to promote use of such material requires well-controlled synthesis and materials processing techniques to be developed.

In particular, inductively couples plasma (ICP) offer unique advantages over other synthesis methods for nanoparticles, due mainly to their high temperature, large plasma volume and long residence/reaction time allowing the evaporation of particles with high melting/boiling point at high production rates, and the possibility to work under a controlled atmosphere. Moreover, the final product depends strongly on the temperature history in the reactor which can be controlled by the quenching mechanism.

The purpose of this thesis is to design an inductively coupled plasma reactor for efficient and controlled production of nanoparticles at industrial scale. A coupled model for synthesis of nanoparticle is developed for the optimization of an industrial reactor. The complete model describes the evaporation of the micron-sized precursor particles in the plasma and the formation of the nanoparticles. The plasma flow is described by a coupled system of the fluid mechanical equations of continuity, momentum, and energy with the vector potential formulation of the Maxwell's equations. The solid particles precursors are treated following the Lagrangian approach, taking into account the vapor production field in the plasma. An Eulerian model based on the method of moments with interpolative closure[1] is used to describe the nanoparticles formation by simultaneous nucleation and growth by coagulation and condensation. The effects of the plasma operating parameters and quenching design (quench type, position and rate) on the contribution of the different formation mechanisms and on the generated particle size and distribution are studied. *Figure 1-2* represent the temperature and the average numerical diameter after nucleation and coagulation, respectively, using one quench unit.
The setup is tested in the VKI Minitorch plasma facility, in order to perform validations of the numerical model.

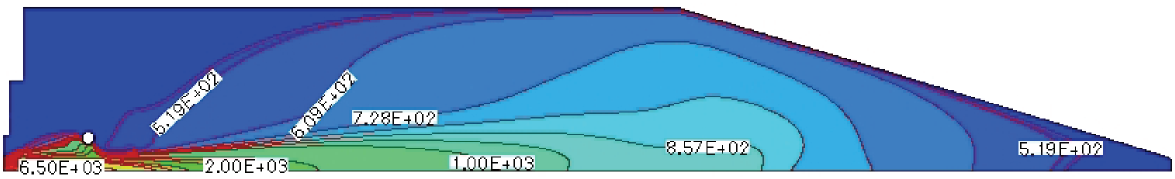

Figure 1: Temperature contours in the reactor (K): 1 quench rate with 30slpm

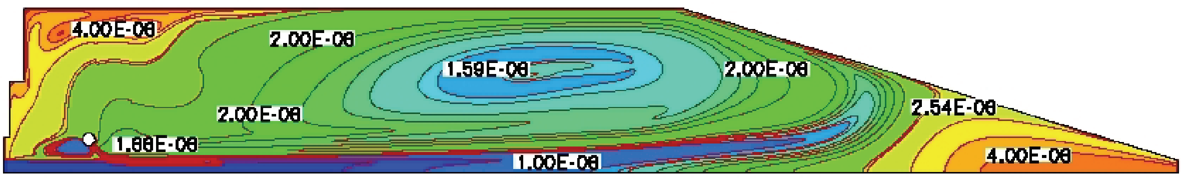

Figure 2: Average diameter (m) after nucleation+ coagulation: 1 quench rate with 30slpm

[1] FRENKLACH M. Method of moments with interpolative closure. Chemical Engineering Science, 57 (12):2229-2239.