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Development and Application of a Model for Metallic Nanopowders Production in a Thermal Plasma Reactor

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Abstract- The type of technology used to generate nano-particles plays an important role in terms of particles size, morphology, crystalline phase and composition, which fundamentally determine the properties of the nano-structured material. Thermal plasma processing, and in particular the high-frequency inductively coupled plasma (ICP) reactor, consisting of a plasma torch for the evaporation of injected micro-sized precursor and a fast quench, is a route for nano-particle production that presents many advantages. Among these, the high temperatures and energy density, as well as the large plasma volume and relatively long residence/reaction time are very important. However the precise control of the particle size distribution and morphology in the mass production using this technique is very difficult due to the same characteristics. The effect of the plasma torch and reactor design as well as the quench configuration on the nano-particles characteristics are of great importance. Mathematical modeling is a very attractive way to complement the available experimental tools used to characterize the plasma reactors and nano-particles and to optimize the process. A complete model of the plasma reactor requires first the solution of the Navier-Stokes equations and the energy equation coupled with Maxwell's equations to describe the generation of the plasma. It further involves the description of micro particles evaporation in plasma flow, and gaseous species transport prior to nano-particles formation. Nano-particles are subsequently formed and grow due to numerous coexisting mechanisms, such as nucleation, condensation, coagulation and surface reaction. The complete model uses Computational Fluid Dynamics (CFD) techniques to solve the coupled plasma flow with the precursor particle evaporation, and a Population Balance Equation (PBE) solution method to obtain the prediction of the nano-particles' size distribution and morphology. The model is applied to an industrial unit of production of metallic nanoparticles.