Journal of Nanoparticle Research **4:** 511–524, 2002.

Simulation on the effect of Brownian motion on nanoparticle trajectories in a pulsed microplasma cluster source

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Received 30 May 2002; accepted in revised form 6 October 2002

Key words: Brownian motion, cluster beam, aerodynamic focusing, supersonic flow, nanostructured materials, aerosols, control volume method, particle tracking method

Abstract

We describe a simulation of the nanoparticle trajectories in a pulsed cluster beam source. Clusters, formed by condensation of atomic vapor in a helium bath, and considered here as rigid spheres having a diameter of 1.5 nm, were tracked during their travel inside the source cavity, an aerodynamic lens, and a cylindrical nozzle. Steady state supersonic laminar flow of helium is considered in an axi-symmetric geometry aiming to simulate, within some limitations, the conditions under which cluster formation takes place in a pulsed microplasma cluster source. In spite of the unsteady nature of the pulsed source, the time scale characterizing particle motion in the flow field is significantly smaller than the characteristic time constant for the evolution of gas pressure in the source. For this reason, a steady simulation can shed some light on the understanding of processes governing nanoparticle motion in a pulsed vaporization source. The extent to which the Brownian diffusion can affect the particle extraction from the source is investigated. Simulations have shown that the Brownian motion perturbs the clusters from the trajectories dictated by the carrier gas and increases the rate of cluster deposition on the source internal walls. However, it does not hinder the aerodynamic focalization produced by the lens even in nano-size cluster regime. This result is qualitatively confirmed by experiment.

Introduction

The rapid development of nanotechnology and the increase of potential applications of nanostructured materials have stimulated the demand for large-scale production of nanoparticles with well-defined size, structure and stoichiometry (Roco, 2001).

Inert gas condensation (IGC) processes are very promising for an efficient production of contamination-free aggregates with controlled mass distribution (Siegel, 1993). The critical parameter for IGC is the residence time of the condensation nuclei in the particle nucleation and growth region. For mass production and nanostructured material assembling, it is very important to understand and to control the extraction of the particle from the growth region. Gas phase particle extraction and manipulation based on free convection have several disadvantages as discussed in detail by Haas et al. (1997). Transition from the free convection to the forced convection regime improves the particle extraction yield. It has stimulated different versions of flow condensers and extractors for mass production, manipulation and deposition of nanoparticles (Tsantilis et al., 1999).

Supersonic cluster beams (SCBs) occupy a particular position among gas-phase methods for the production of nanoparticles. The condensation of droplets in an expanding nozzle flow was first observed in