Aerosol Science and Technology 36: 593–606 (2002)

Published by Taylor and Francis
0278-6826/02/$12.00 + .00

A Simple Nozzle Configuration for the Production of Low Divergence Supersonic Cluster Beam by Aerodynamic Focusing

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A nozzle configuration for the production of an intense and collimated supersonic cluster beam is presented and characterized by numerical modeling. A simple lens added to a cylindrical nozzle exploits aerodynamic focusing effects. The effect of the focalizing nozzle is an enrichment of the core of the jet with clusters of an arbitrary size interval depending on carrier gas pressure and temperature. The influence of the source and nozzle geometrical parameters and of the expansion conditions on the cluster focalization is simulated and compared to the experimental results. A collimating effect on particle velocities and the possibility of obtaining a cluster mass selection is also observed.

INTRODUCTION

The possibility of producing collimated beams of particles by the continuous expansion of an aerosol has been demonstrated by Murphy and Sears (1964) and systematically characterized in the seminal work of Israel and Friedlander (1967). The method is based on the expansion of a particle-gas mixture through a nozzle, generating a sonic or supersonic gas stream (Dahneke and Flachsbart 1972; Dahneke and Cheng 1979; Cheng and Dahneke 1979). One of the advantages of this method is the possibility of aerodynamically focusing particles of a selected size range (Fernandez de la Mora and Riesco-Chueca 1988; Rao et al. 1993)

On a parallel track, studies on supersonic expansions of gas mixtures showed aerodynamic effects leading to mass separation in the beam (Becker and Bier 1954; Waterman and Stern 1959). Reis and Fenn (1963) pointed out the analogy between aerosols and heavy molecules seeded beams. They suggested the common origin of the effects observed in aerosol impactors and in supersonic beams for isotope separation. The theoretical and practical consequences of these analogies have been extensively investigated and discussed by Fernandez de la Mora et al. (1984), Fernandez de la Mora (1985), Fernandez de la Mora and Rosell-Llompart (1989).

By the use of sheath air one can confine the aerosol particles to a very narrow beam (Dahneke and Flachsbart 1972; Dahneke and Cheng 1979), this method cannot be applied in every kind of geometry and condition. Liu et al. (1995a, b) have suggested a system of so-called aerodynamic lenses consisting of successive axial-symmetric contractions-enlargements of the aerosol flow passage. They have used thin-plate orifice nozzles that have been investigated by Fernandez de la Mora and Rosell-Llompart (1989), Rao et al. (1993), and Fuerstenau et al. (1994). The above-mentioned aerodynamic lenses have been used in a variable pressure impactor by Fernandez de la Mora (1996) and for sharp patterned microstructure deposition by Di Fonzo et al. (2000). In a recent work by Mallina et al. (2000), the capability of variable pressure inlets for producing beams of a selected size range is demonstrated.

Gas-phase generation of nano-particles is one of the most popular ways to produce bulk nanostructured materials (Siegel 1993). In particular, the production of clusters in supersonic beams allows us to study the properties of free aggregates and has been proposed as a technique of interest for the synthesis of nanostructured thin films (Milani and Iannotta 1999). Recently, we have demonstrated the cluster beam microfabrication of patterns of three-dimensional structures with a lateral resolution better than 0.5 μm by using a supersonic beam focused with a nozzle shaped to exploit aerodynamic focusing effects (Barborini et al. 2000).

In this paper we describe the working principles of this nozzle, called *focuser*, and analyze and model its influence, in terms of cluster focusing, on a seeded beam supersonic expansion. The focuser is designed to produce a sudden turn to the flow passage.

Received 29 December 2000; accepted 30 May 2001.
H.V.T. gratefully acknowledges the International Center for Theoretical Physics, Trieste, Italy, for a grant in the framework of TRIL Program. This work has been partially supported by INFM within the Advanced Research Project CLASS, by MURST within COFIN99, and by CILEA.
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