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TOPICAL REVIEW

Cluster beam deposition: a tool for nanoscale science and technology

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Abstract
Gas phase nanoparticle production, manipulation and deposition is of primary importance for the synthesis of nanostructured materials and for the development of industrial processes based on nanotechnology. In this review we present and discuss this approach, introducing cluster sources, nanoparticle formation and growth mechanisms and the use of aerodynamic focusing methods that are coupled with supersonic expansions to obtain high intensity cluster beams with a control on nanoparticle mass and spatial distribution. The implication of this technique for the synthesis of nanostructured materials is also presented and applications are highlighted.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

The presence of nanoparticles in industrial processes dates back well before the advent of nanotechnology [1, 2]: carbon nanoparticles as rubber additives for tyres [3] or titania nanoparticles for pigmentary applications [4, 5] represent a paradigm of mass production of nanoscale objects. In the last decade, the increasing understanding and control of the fundamental properties of nanoparticles has stimulated the interest in their use as building blocks of devices and systems with sophisticated properties and functionalities [6]. The ultimate goal of the nanotechnological approach is to provide new paradigms of production; however, it is reasonable to consider that the success of nanotechnology will rely on its capability of complementing actual technologies before substituting them [7].

The success of manufacturing approaches based on the assembling of nanoparticles is largely determined by the established infrastructure and customer base with cost reduction as a general benchmark. Other important parameters are for instance, the possibility of improvement in performance per unit cost and the compatibility with other production technologies (for example, in the semiconductor industry) [8].

The design and production of devices containing nanoparticles and nanomaterials require the capability of integrating different components at different length scales in terms of structure, chemical composition, packaging, etc. It is thus necessary to determine the structure and chemical status of nanoparticles and to transfer them onto suitable substrates or into matrices with a very precise control on positioning in an exactly defined area. Once deposited in a device, the nanoparticles should retain their properties and individuality.

A crucial point to be solved for a real technological breakthrough is the possibility of manipulating nanoscale objects [9]. The general term 'manipulation' is used here with special reference to the following meanings: (i) the ability to sort the objects in terms of a size or geometry classification; (ii) the ability to control the position and (iii) the ability to modify them physically or chemically. As most of the available nanoparticle synthetic routes are not able to produce

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