Plasma Techniques for Nanostructured Materials

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Nanostructured materials are revolutionizing many fields of science and technology and are finding their way in many commercial products. Their interest is due to the fact that nanostructured films present functional (tribological, biological, electrical, optical) properties which are new, or of superior quality, compared to non-nanostructured ones. Indeed, plasma sources are essential for the synthesis of new molecules yielding very high purity materials, allowing in addition the control of formation and transport of the synthesized building blocks for the nanofabrication of thin layers and multilayer composited films, as well as the synthesis of nanoparticles (NPs). A large variety of nanostructured materials and their applications have been already demonstrated in different fields. So far, plasma-based methods have been employed for the precursor dissociation, the most relevant of which is the expanding thermal jet (1995) enabling purity control of the growth process, and more recently, the Pulsed Laser Deposition (PLD) technique working at ultra-high vacuum has been developed to control both purity and nanostructured morphology. A novel technique was designed to assemble high purity materials at the nanoscale over a larger area and higher flexibility, allowing to work with many kind of chemicals, and less severe operational conditions due to the possibility of working at higher pressures. The method is based on a non-thermal supersonic plasma jet where independent control over plasma chemistry, dissociation and molecule aggregation, nanoparticle assembly and film growth, are achieved by fluidodynamic segregation of the two processes in a unique remote plasma configuraton. The method for producing nanostructured films and NPs with controlled morphology, particularly of a hierarchically organized type, is suitable to a scale-up for industrial processing. The technique denominated Plasma Assisted Supersonic Jet Deposition (PA-SJD) is the segmentation of the gas phase material synthesis in two separate steps: Chemistry control in a reactive cold plasma environment of several precursors; and secondly, nucleation and assembling of the building blocks by means of a supersonic inseminated plasma jet where particle collisions can be controlled. By acting on the jet parameters, the active control of the synthesis of NPs is able to produce cluster sizes varying from few nm to 100 nm. These nanomaterials (NPs and films) have a broad range of applications in diverse fields such as photovoltaics, photoelectrochemistry, energy storage, photonics and biomedicine.