Elaboration of Nanocomposite Coatings by Coupling Aerosol Jets and Physical Vapour Deposition

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We propose a generic method for the elaboration, in a single step and in a confined chamber, of nanocomposite coatings consisting of nanoparticles (NP) from 4 to 100 nm, homogeneously distributed in a matrix. The process combines the jet of nanoparticles in vacuum (JNV) technology and Physical Vapor Deposition (PVD). The hybridization of these two techniques is made possible by routing nanoparticles in the aerosol form to the substrate, either immediately after their synthesis in the gas phase, or from colloidal suspensions. The simultaneous deposition of the particles and the matrix is achieved on the same face of the same substrate. The process is innovative in that it allows an unlimited selection in the respective chemical compositions of nanoparticles and the matrix, and a moderate temperature of the substrate. The general scheme of the process is presented in Figure 1a. A laser-driven pyrolysis reactor can be used for in-situ synthesis of nanoparticles. Laser pyrolysis is an efficient method to synthesize various high purity nanopowders, oxides and non-oxides, in a gas phase bottom-up approach [1]. An atomizer that produces aerosol from colloidal suspension of previously synthesized nanoparticles can also be used.

The JNV is obtained by the use of an aerodynamic lens system, which is composed of chambers separated by diaphragms, which produces a collimated beam of nanoparticles under vacuum [2]. This kind of beam is currently used for gas phase characterization of freestanding nanoparticles or for precision 3D printing with a high deposition rate. We show that it is possible to obtain an angle-controlled divergent and homogenous jet of nanoaerosols, as well, by changing the geometry of a classical lens. We demonstrate the adaptation if the JNV technique with pressure environment required for running a classical magnetron sputtering device. The later is used for depositing, on the same substrate and in the same time, the material constituting the matrix of the composite film.

The possibility to elaborate large and homogenous nanostructured films were investigated with different types of nanoaerosols with different sizes and densities. Samples composed of gold and silicon nanoparticles (see Figure 1b) will be shown. Many applications are already considered for this type of coatings, including photovoltaic, aesthetic coatings for luxury industry, hard covering for tools or self-healing films. The development of the process is carried out in the frame of the HYMALAYAN project funded by the Agence Nationale de la Recherche under Grant No ANR-14-CE07-0036, and is open to new potential end-users.

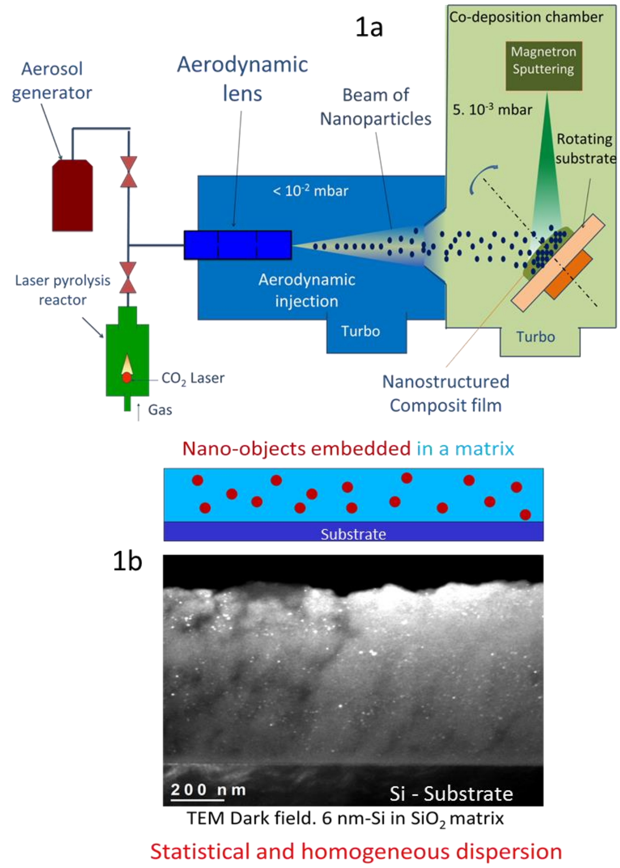

Figure 1a. General scheme of the co-deposition process.
Figure 1b. Dark field TEM micrograph of Si nanocrystals embedded in a SiO_2 matrix.

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[2] Zhang, X.F. et al. (2004), *Aerosol Science and Technology* **38**, 619.

[3] Sublemontier, O., Kintz, H., Lacour, F (2011). *Kona powder and Particle Journal* **29**, 236.