Supersonic Cluster Beam Deposition of Nanostructured Devices and Nanocomposites for Biomedical and Clinical Applications

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The development of analytical tools and smart prosthetics in biotechnology and medicine with improved performances, sensitivity and information throughput needs the capability of mastering integrated fabrication approaches where biological entities coexist with artificial nano- and microstructures.

It is well known that nanoscale topographical features of the cellular microenvironment determine cellular functions [1]. A major challenge consists in the fabrication and integration of artificial nanoscale cues able to control the cell fate with nanoelectronics, microsensors, micro/nano actuators, microfluidics in a unique platform. The need for bio and non-bio components coexisting in small packages implies the integration of hardware with different length scale features (from the millimeter to the nanometer range) and large material diversity [2].

This can be obtained by the convergence of top-down microfabrication with bottom-up assembling of nanoparticles to make compatible different length scales, architectures, materials, manufacturing methods. In particular the assembling of nanoparticles to form nanostructured layers on microfabricated platforms is the basis for the production of a novel class of miniaturized devices capable to meet the requirements for the high throughput in vitro study of cells [1]. Many applications in biomedicine, prosthetics, wearable electronics and robotics require also the integration of electronic, optical and actuation capabilities on soft and conformable polymeric substrates to form nanocomposites [3].

Gas phase routes for the production and assembling of nanoparticles can play a prominent role in the fabrication of this new class of devices and nanocomposites, however the convergence of different manufacturing processes is still hampered by the mismatch between the degree of maturity of top-down and bottom-up approaches in relation with production scale-up, cost effectiveness, reliability, compatibility with industrial and environmental standards [4].
Nanoparticle gas phase synthesis (aerosols in particular) is a well-established and versatile approach for the production of large quantities of nanoparticles with a high level of control on their physico-chemical properties, however top-down/bottom-up integration requires solutions able to deliver and integrate nanoparticles at precise addressable locations.

Here I will describe and discuss a nanofabrication method based on the use of supersonic cluster beam deposition (SCBD) [4, 5] demonstrating that this is a very effective enabling tool for the large-scale integration of nanoparticles and nanostructured films on microfabricated platforms and smart nanocomposites for applications in the field of cell biology, microfluidics devices for clinical analysis and for the fabrication of neuroprosthetics.

SCBD is a bottom-up additive technique able to produce nanostructured films by assembling clusters on substrate to obtain a nanoscale topography mimicking the structure of the extracellular matrix and integrating it into microfabricated platforms. This is obtained by exploiting the high intensity typical of gas phase aerosol sources with manipulation of the nanoparticles typical of supersonic expansions [6].

In particular I will describe the use of SCBD for the large scale fabrication of microfluidic devices for the analysis of chromosomal aberrations in cancer currently used in clinical diagnostic practice [7].

I will also concentrate on the use of supersonic cluster beam for the production of stretchable and compliant nanocomposites on elastomers such as PDMS to obtain stretchable conductive circuits and electrodes to be used in the realization of systems for neural electrical stimulation and recording [3].

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