Bioinspired nano-architectures based on chemically functionalized carbon nanotubes

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Bio-nanotechnology is a branch of nanoscience that uses cellular basic building blocks or molecular design principles together with man-made nanomaterials for creating composites with life-science applications. The fact that the dimensions of man-made nanomaterials are analogous to those of natural biological materials greatly facilitates their development and the path to product application. Thus, the convergence between materials science and biomedicine enables the design of new devices that could play a central role in drug delivery or tissue engineering.
In the field of tissue engineering, carbon nanotubes (CNTs) are among the technologically most interesting nanoscale materials currently under investigation for medical application. CNTs are mechanically tough, chemically inert, and highly conductive and they are pure carbon. It is particularly noteworthy, that their diameters of molecular dimensions, and their potential for bio-interfacial engineering make them highly attractive tools for cell scaffold design.

Our research is mainly focused to reproduce at least partially, both the exceptional nanotopography and nanochemistry presented on the extracellular matrix (ECM) of bone utilizing for this purpose NSL technique combined with the layer-by-layer (LBL) assembly process. The complete network architecture consists of successive layers of cross-linked carbon nanotubes that self-assemble into orderly structures (Fig.1). The method enables controlled shaping and considerable chemical and mechanical stability of the self-assembled monolayers, allowing for high reproducibility in manufacturing. The films as free-standing substrates are characterized by controlled geometry, surface topography, and chemical composition (1).

To address the role of nano-sized features in complex nanostructured substrates, both texture and surface roughness of free-standing films were tested for their ability to promote cell growth. For these experiments, osteoblast-like cell were seeded onto nanostructured films to evaluate cell viability and proliferation (Fig. 2). The osteoblast cells were found to be viable in all nanostructured films. Remarkably, cells showed enhanced proliferate response to the interconnected nanotubes and nano-sized cavities.
We have further studied the biocompatibility of LBL film made up of CNTs modified by acids and polymer wrapping with Poly(allylamine hydrochloride)(PAH). Figure 3 shows fluorescent microscopy images of cells on the CNT-based nanostructures with carboxylate (Fig. 3A) and ammonium groups (Fig. 3B) after 7 days incubation and further labelled with luminescence probe. This clearly demonstrates the striking difference between the cell's adhesion and proliferation on differently functionalized carbon nanotubes. This observation indicates that the polymer-modified nanotube-based films support growth and proliferation of osteoblast cells. Solely for polyelectrolyte multilayer film made from PAH a very small number of cells were observed (not shown). The latter experiment reveals that CNTs significantly contribute to the biocompatible nature of the film, which can probably be attributed to the mechanical and structural properties of carbon nanotubes.

References:

[1] Firkowska I. et.al. ,Langmuir (2006), 5427- 34.

Figures:

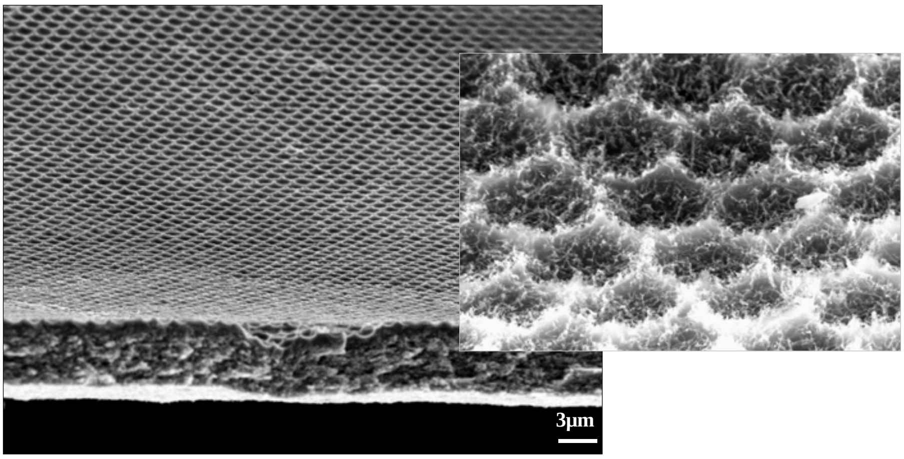

Fig. 1. SEM image showing a bioinspired free-standing substrate made up of carbon nanotubes arranged in a regular network of micro-cavities.

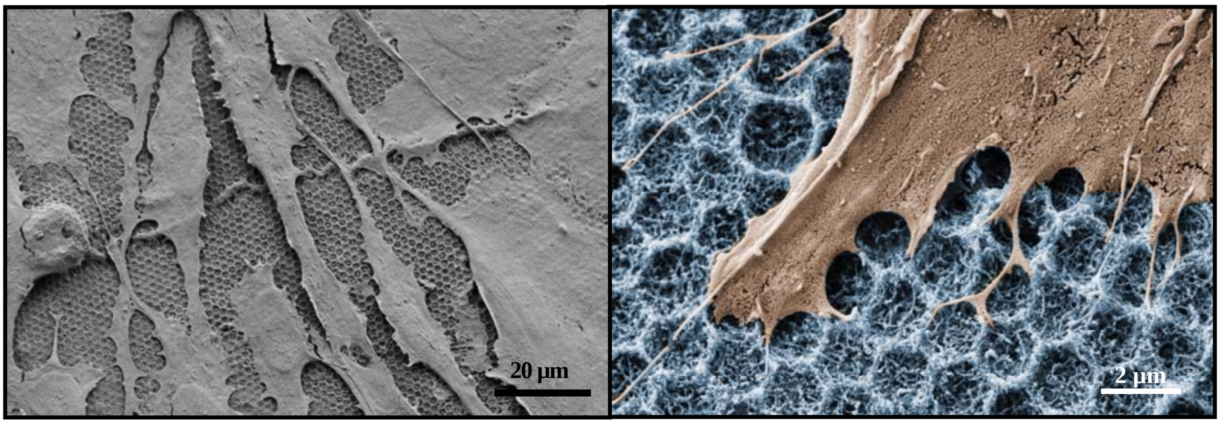

Fig. 2. SEM image depicting cell growth of osteoblast- like cells on bioinspired CNT-based substrates.

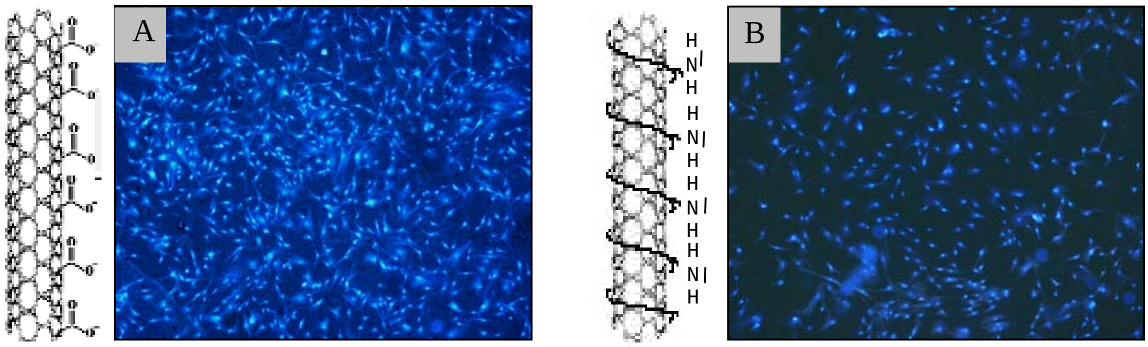

Fig. 3. Digital camera images showing the difference in the number of osteoblast-like cells growing onto nanostructured substrate made up of CNTs functionalized with carboxylate (A) and ammonium groups (B).