Nanostructured Biomaterials based on Carbon Nanotubes: Electroactive Support for Cells Regeneration

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Statement of Purpose: Surface morphology and electrical charge are principal factors dictating biomaterial-cell interactions. In this work, we report, for the first time, the variability in responsiveness of a new biomaterial as function of cumulative effect of electrical characteristics and morphologic features. Using nanomaterials such as carbon nanotubes (CNTs) we have formulated new fibbers as support for cells regeneration [1]. The synthesis of these biomaterials was realised by applying Particle Coagulation Spinning (PCS) method [2] which forms macroscopic fibers with a very good alignment of nanotubes, intercalated in a polymer network: polyvinyl alcohol (PVA) and polylactic-co-glycolic acid copolymer (PLGA). The CNTs we used are single wall (SWNT) and multi wall (MWNT) with different electrical behaviour.

Method: The CNTs alignment in macroscopic materials is essential to ensure electrical conductivity of fibers and this is one of main characteristics. Eight types of samples were analysed and are identified as following: SWA1/MWA1 and SWA2/MWA2 containing CNT, PVA and PLGA (M_w= 28 kDa) in different concentrations; SWB1/MWB1 and SWB2/MWB2 containing CNT, PVA and PLGA (M_w=12 kDa) in different concentrations. We used a PVA 98% hydrolysed polymer with M_w=150 kDa. The PLGA was produced by Bohentingher Inghelheim and the choice of molecular weight was based on specific considerations. The SWNTs were purchased from Carbon Nanotechnologies Inc., in the form of purified powder while the MWNT were produced by Attofina. The samples were presented as yarn with a diameter ranging in 50-60μm and a length of 70-100 mm.

Surface morphology of fibers was investigated for identification of nanoscale characteristics by using the Low-Vacuum Scanning Electron Microscopy (LV-SEM) in both Secondary Electron (SE) and Back Scattering Electrons (BSE) mode without applying a conductive layer. Hence, this technique enables us to obtain nanoscale details regarding external topography as well as CNTs alignment. Moreover, we are able to identify morphological characteristics in relation with variation of molecular weight of copolymer and its two different concentrations. Complementary morphological information is provided by Atomic Force Microscopy (AFM). Observation of surface morphology was carried out with an AFM, Digital Multimode Scanning Probe Microscope, in contact mode using a tip with a radius of 40 nm, in order to obtain submicrometer morphological features of section.

Electrical activity of CNT fibers was established by using the Impedance measurements and Cyclic Voltametry. These values are used as indicator for the capacity of fibres to display specific charge in simulating body environment.

Results/Discussion: Our morphological observations reveal the variation of external surface as function of SWNT versus MWNT; these differences are identified by both SE and BSE mode. The use of different molecular weights copolymer generates structural differences in the case of the same type of NT (A formulation versus B formulation). The variability between formulation 1 and formulation 2 is also visible. Using higher magnification we are able to identify different alignment degrees of CNTs depending on the type of nanotube used. The presence of MWNT on the surface of fibers is more visible than the SWNT one. The information provided by AFM analysis strengthens the results present herein. In fact, using contact mode we are able to follow lateral surface profile at a level of 20 nm. These data, revealing surface morphology and texture describe fiber microstructure and significant changes induced by using third component, the PLGA copolymer.

Impedance measurements provide data on electrical resistivity of fibers and the variation of these values is directly determined by the CNT contribution. Moreover, the differences induced by copolymer contribution are visible and they prove the role of copolymer to internal structure of fiber as well as its presence on the surface. This information indicates a consistent dispersion of carbon nanotubes in fibers as well as a good interconnection of the three components resulting in material homogeneity. The cyclic voltametry shows the specific contribution of different species to the electrochemical phenomena taking place. Hence, we are able to identify not only the influence of molecular weight of copolymer but also its chemical configuration. The values of electrical conductivity are presented accompanied with the explanation related to formulation. We will particularly emphasise the differences induced by electrical behaviour of CNT as well as the impact of copolymers.

Conclusions: Based on these measurements we established a relationship between fiber external structure and its electrical behaviour in simulating body conditions. This correlation is a potential tool to predict the interactions of fibers with a biologic environment. We use this study to perform the *in vitro* biocompatibility studies for different cell lines.

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