CARBON NANOTUBES, CARBON NANOFIBERS - *IN VITRO* STUDY

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Introduction

Fibrous carbon nanomaterials, i.e. carbon nanotubes (CNT) and carbon nanofibers (CNF) have found a number of applications in environmental protection and in medicine [1]. The reaction of cells to a material depends on its physical and chemical properties and has a decisive influence on the type of application in the field of medicine. CNT and CNF constitute also valuable initial materials for the manufacture of biosensors, electrodes and fibrous substrates in the form of 2D or 3D structures that meet the requirements of regenerative medicine. In each of these materials biocompatibility of degradation products is a key element.

The aim of the study was to investigate *in vitro* carbon nanomaterials in contact with cells. It is already well recognized that carbon nanotubes after an oxidative treatment are particular useful materials for medical purposes, whereas the as-received (non-functional) nanotubes may have a toxic impact on living systems [2]. By introducing certain quantities of materials into the cell culture, efforts were made to demonstrate differences in the behavior of cells in contact with CNT or CNF and to explain their essence based on the characteristics of individual nanomaterials.

Materials and Methods

Carbon nanotubes from Nanostructured & Amorphous Materials, USA and carbon nanofibers manufactured from PAN-Zoltek, Hungary nanofibers precursor made in the electrospinning process followed by carbonization at 1000^{o}C were investigated. Carbon nanomaterials were characterized using FTIR spectroscopy and SEM microscopy. Multiwalled carbon nanotubes (MWCNT), nanotubes functionalized in a mixture of acids (MWCNTf), carbon nanofibers (CNF) and oxidized nanofibers (CNFf) (after grinding process), were immersed in PBS (1 mg / 1 ml) and homogenized. The *in vitro* tests were performed in contact with RAW 264.7 macrophage and L929 fibroblasts lines. Biological evaluations of carbon nanomaterials were conducted using the following in vitro tests; viability cells (PrestoBlue), the cytotoxicity (Toxi Leight) and detection of active oxygen (DCFH-DA.

Results and Discussion

SEM studies indicate that both carbon groups, i.e. CNT and CNF, have significantly different geometry and particle sizes (FIG. 1). Nanomaterials, which are the subject of research, also differ in the structure and chemical state of the surface. CNT are materials with a precisely defined structure in which the graphene layers form a series of coaxial rolled sheets, while carbon nanofibers, formed from the electrospun PAN precursor, constitute a fine crystalline carbon phase performing characteristic turbostratic structure. The surface of CNTf, contains oxygen-containing chemical groups, e.g. hydroxyl and carboxyl groups, and due to presence of nitrogen from polymer precursor in carbon residue after annealing to 1000^{o}C, nitrogen containing functional groups. Biological studies have shown that the functionalized materials, both nanotubes and nanofibers, are characterized by improved biocompatibility compared to the initial materials. The highest cytotoxicity was found for carbon nanofibers that have not been pre-oxidized. On the other hand, all the materials tested induced low oxidative stress, significantly lower than that manifested by control (FIG. 2).

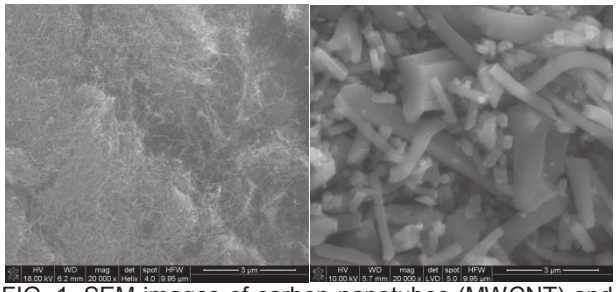

FIG. 1. SEM images of carbon nanotubes (MWCNT) and carbon nanofibers (ESCNF) after grinding process.

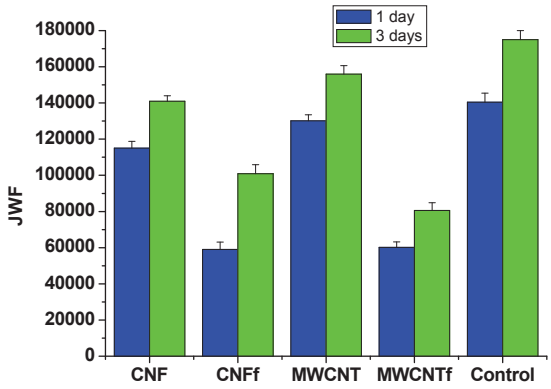

FIG. 2. The level of all reactive oxygen species produced by macrophages in contact with carbon nanomaterials.

Conclusions

Fibrous carbon nanomaterials are valuable materials for a number of medical applications. However, these materials require post-manufacture processing that changes the chemical nature of the surface and removes elements that can significantly reduce their biocompatibility.

A high relative cytotoxicity of the nanofiber degradation products formed during the carbonization of the PAN nanofibers precursors may be due to the presence of some chemical groups on the nanofibers surface that may be toxic to cells.

Acknowledgments

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References

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