# ELECTRICAL AND BIOLOGICAL PERFORMANCE OF OXYGEN AND NITROGEN MODIFIED CNTs

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## Introduction

Functionalization of carbon nanotubes is the process that significantly improves their dispersability [1,2] and biocompatibility [3,4]. As some studies suggest, high level of oxidation yields materials that can be easily degraded in the human body [5,6].

For the individual CNTs, the process of covalent modification is known to deteriorate the electrical [7] and mechanical properties, by introducing structural defects. Still, the positive aspect here is the ability to conjugate the materials with various molecules to obtain substrates for drug delivery systems [8]. Meanwhile, the real potential of CNTs functionalization lies within their application as films and layers on the substrate of choice or as a composite fillers. While as films/layers, functionalization improves the CNTs/CNTs and CNTs/substrate adhesion and also act as hole dopant, enhancing electrical conductivity [9,10]. When used as modificators, functionalization enhances CNTs' dispersion within the matrix, resulting in improved mechanical and electrical properties [11]. It is also important to know, that cells are sensitive to surface chemistry of the materials they come in contact with, and different cell types favour [12-15] different conditions.

This study had three objectives: 1) to fabricate oxygen and nitrogen modified CNTs that are easily dispersible and can be used to prepare composite materials; 2) to fabricate and evaluate the physicochemical properties of the composite material, modified with CNTs with different functional groups; 3) to test if the obtained materials are biocompatible and if the fibroblasts prefer any particular morphology and/or functional groups. The tested materials' morphologies were layers and fibres, which are regarded promising in the field of tissue engineering applications.

## Materials and Methods

Oxidized CNTs were fabricated according to the procedure established in our previous studies [16,17]. DCC (used for induced amide coupling) and ammonia were used to fabricate the nitrogen modified CNTs.

From these, composite materials were fabricated via: 1) electrophoretic deposition to obtain well-adhered layers on the surface of biocompatible titanium plate and 2) electrospinning of PAN precursor, followed by carbonization, to obtain nanofibrous scaffolds with CNTs embedded inside the carbon nanofibers.

Physicochemical and electrical properties of the CNTs and their composites were evaluated via XPS, FTIR, SEM, 4-point probe measurement. Biological response was studied on L929 fibroblasts. PrestoBlue and Toxilight were used (according to manufacturer's instructions) to assess the materials' biocompatibility, while staining with acridine orange enabled to visualize their morphology.

## Results and Discussion

The applied methods of chemical functionalization enabled to obtain easily dispersible CNTs with high amounts of either oxygen or nitrogen atoms. These were used to fabricate composite materials of high quality: well adhered layers and carbon nanofibers with CNTs evenly distributed within the fibres, as manifested by reduced sheet resistivity.

All of the obtained materials were found to be highly biocompatible. During their initial growth, fibroblasts preferred smoother surface of CNTs layers over the fibrous scaffolds, manifested by higher initial adhesion, lower cytotoxicity and higher viability of cells at day 3 of culture. In this initial stage of growth, oxygen functional groups were preferred over nitrogen for both types of materials. At 7$^{th}$ day of culture, cells grown of fibres proliferated extensively, resulting in increased viability and reduced cytotoxicity. Still, the results were better for the layers. At day 7, fibroblasts were found to prefer nitrogen-modified CNTs, regardless of the morphology. The origin of such phenomena is yet to be defined.

## Conclusions

Covalent modification is an elegant way to obtain functionalized CNTs with high applicability potential in various fields of materials science, including biomedical. Highly conductive, biocompatible materials can be obtained and cellular reaction of desired cell type can be tailored to meet specific needs.

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