Carbon Nanofibers:Polycarbonate Urethane Composites as a Neural Biomaterial

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Abstract— **Chronic neural implants are usually made from silicon materials and are subject to scar tissue formation at the tissue/implant interface, which interferes with their functionality. Carbon nanofibers are an example of a material that may improve neural implant interactions with native cell populations since these nanofibers have promising cytocompatibility, mechanical, and electrical properties. Neural implants may achieve better tissue interactions simply by incorporating carbon nanofibers into a polymer matrix. Polycarbonate urethane and carbon nanofiber composites have induced neurite extension during in vitro studies. The objective of the present study was to use an electrical field to align carbon nanofibers in a polycarbonate urethane matrix. Polycarbonate urethane was dissolved in chloroform, and then mixed with carbon nanofibers of high and low surface energies separately. When the solution was viscous, it was pored into a parallel copper plate capacitor chamber. Alignment occurred after exposure to 500 to 700 volts. The aligned nanofiber structure was maintained after the polymer cured. These materials have been prepared to determine if neuron axonal extension will be affected by the carbon nanofiber alignment. These materials have promising tunable properties for neural implants such as electrical, nanoscale structure and organization, and surface energy characteristics.**

I. Introduction

Biomaterials for neural applications have been implemented in many ways including tissue bridges and probes. Since such implants require unique biocompatibility properties to function successfully in the presence of native tissue, new formulations of biomaterials are currently being investigated to customize materials for these neural applications. A key design parameter is the reduction of scar tissue interference at the site of the implant. This gliotic response is mediated largely by astrocytes in the central nervous system [1,2]. Design of synthetic biomaterials that mimic the properties of natural tissues is a promising method to minimize adverse reactions such as the foreign body response and scar tissue formation. Cells of the body are accustomed to interacting with surfaces with a large degree of nanostructured surface roughness due to the size of proteins that compose the extracellular matrices in vivo. In vitro studies with nanophase biomaterials have indeed shown that cells respond differently to materials with nanoscale roughness when compared to those with micron-sized roughness [3,4].

Carbon fibers have been shown to be compatible with physiological tissues, and nano-dimensioned fibers have excellent conductivity and high strength to weight ratios [3,5-7]. The size of carbon nanofibers contributes to their strength and high conductivity, but since their size is also in the nanometer regime, they are on the same scale as physiological proteins. Alignment of nanoscale features is an attractive approach for directing axonal extension [8]. The objective of this present in vitro study was to synthesize a polycarbonate urethane (PU) matrix with aligned carbon nanofibers to facilitate neural biomaterial design.

II. Materials and Methods

Multiwalled carbon nanofibers (CN) that had been synthesized using catalytic and chemical vapor deposition were acquired from Applied Sciences, Inc./Pyrograf Products, Inc. Composites were formed from 100 nm, low surface energy fibers (25-50 mJ/m^2) or 60 nm, high surface energy fibers (125-140 mJ/m^2) and poly carbonate urethane (Thermedics Polymer Products, PC3575A). Polycarbonate urethane pellets were allowed to dissolve in chloroform at 25 °C for 40 min with sonication, then carbon nanofibers were added and sonication continued for another hour. This mixture, when viscous, was poured into wells of a microscope slide fashioned with parallel copper plate electrodes. Voltage was applied to the solution to create a homogeneous electric field. Voltages up to 700 were applied to the wells until the composite had cured.

III. Results

As can be seen in Figure 1, the present study provides evidence of aligned carbon nanofibers in a polymer matrix. Note the random agglomerated carbon nanofibers in the polymer matrix before the application of the electric field. In contrast, note the aligned carbon nanofibers in the polymer matrix in the presence of an electrical field.

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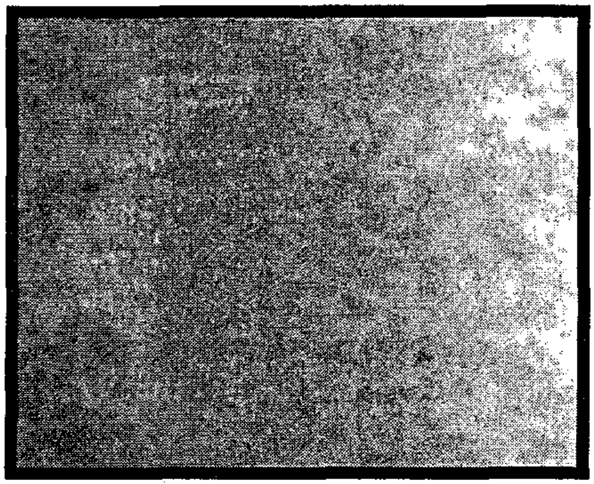
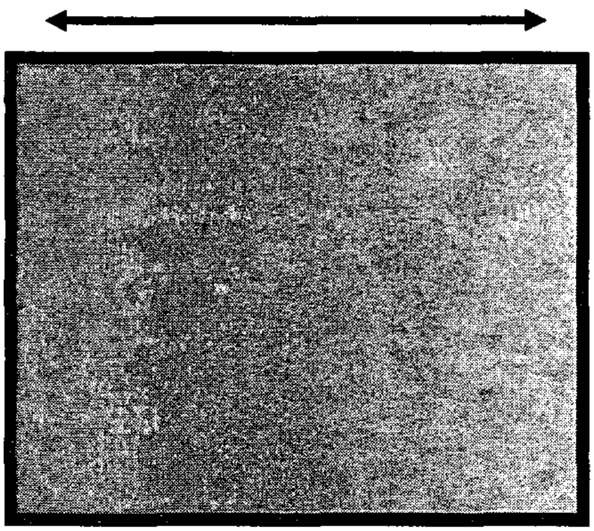


High surface energy carbon nanofibers in polymer without an applied electric field



High surface energy carbon nanofibers in polymer with an applied electric field

Figure 1. Alignment of carbon nanofibers for neural applications. Arrow indicates alignment. Similar results were obtained for low surface energy carbon nanofibers.

IV. DISCUSSION AND CONCLUSIONS

The present results provide a valid synthesis technique to align a material previously shown promising for neural applications (carbon nanofibers) in a polymer matrix. Previous studies have shown decreased glial scar tissue formation and increased interactions of neurons (such as increased neurite extension) on carbon nanofibers [9,10]. It is anticipated that the through the alignment of carbon nanofibers in a polymer rmatrix, the ability to control axon extension in neurons will be achieved. Further studies will be needed to verify this.

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