Universidade do Minho

Escola de Engenharia

Semana da Escola de Engenharia
October 24 - 27, 2011

IMPLANTABLE FLEXIBLE SENSOR BASED ON ALIGNED-CARBON NANOTUBES FOR BLOOD PRESSURE MONITORING

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KEYWORDS
Implantable pressure sensor, aligned-carbon nanotubes.

ABSTRACT

This paper presents a carbon nanotube (CNT)-based flexible capacitive sensor to measure the pressure within an aneurysm sac after an EVAR (endovascular repair) procedure. Given the specifications of EVAR, the device must be foldable, extremely flexible and characterized by a very small profile. Aligned-CNTs embedded in a flexible substrate of polydimethylsiloxane (PDMS) are used to fabricate the elements of the capacitive sensor. Fabricated sensors prototypes validate our approach and show that A-CNTs/PDMS layered composites can be used to create highly flexible pressure sensors.

INTRODUCTION

Research on CNT-based sensors has been very active in the past years whereas the work on nanocomposites for microsystems has been primarily focusing on materials technology, with little work reported on nanocomposites-based sensors. MEMS-scale pressure sensors are devices of great interest for biomedical applications mostly due to the small scale of the devices. Pressure sensors have been proposed for permanent implant through minimally invasive procedures. These sensors are typically silicon-based, have limited high-temperature operation, require internal power sources and have limited biocompatible packaging technologies (Fonseca et al. 2006). Also, long-terms pressure sensors currently available in the market still present some communication difficulties and the results are not always accurate, causing false-positive findings. New solutions are focusing on the development of flexible technologies for the sensor fabrication. This work presents the development of a flexible sensor for blood pressure measurement after EVAR procedure. The research work presented here only addresses the development and characterization of the pressure sensor. Details about the sensor system can be found in (Sepúlveda et al. 2011).

FLEXIBLE SENSOR DEVELOPMENT

The pressure sensor is based on two square-plate electrodes separated by a dielectric at pressure P_0. Bending of the square-plates, caused by variations in outside pressure, P_{out}, generates capacitive changes proportional to the pressure changes. A schematic of the fabrication process of the pressure sensor is presented in Figure 1. PDMS flexible membranes were obtained using acrylic moulds (Fig.1a). The electrical components were built with forests of vertically A-CNTs, grown via an atmospheric chemical vapor deposition (CVD) process(Fig.1b) (Bello et al. 2008). The next consists of embedding the polymeric matrix (PDMS) into the A-CNTs (Fig.1c). The final step is the curing of the elastomer (Fig.1d). Uncured PDMS adhesive technique approach (Eddings et al. 2008) was used for the bonding and has proven successful in our work, see Figure 2.

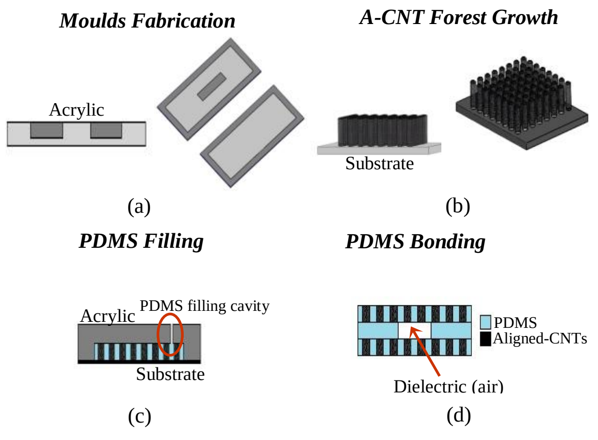

Figure 1: Fabrication process flow for the development of a flexible pressure sensor of A-CNTs/PDMS.

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EXPERIMENTAL RESULTS

Measurements of a set of polymer nanocomposites samples show an electrical conductivity of 0.35 $S.m^{-1}$ with a standard deviation of 0.37 $S.m^{-1}$. Other samples were tested in tension to obtain the Young's modulus in both axial and transverse directions.

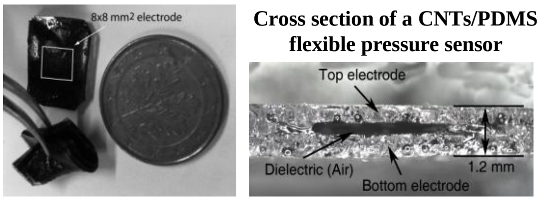

Figure 2: A-CNTs/PDMS flexible pressure sensors.

The nanocomposites, molded into rectangular shapes with dimensions of $32x14x0.4mm^3$ (LxWxH), present an increase in the Young's modulus in the transverse direction (1.7MPa). In the axial direction, the increase is very high (up to 8MPa). Fabricated A-CNTs/PDMS prototype sensors were tested in a vacuum chamber. The results were compared with the respective sensor analytical model and a finite element modeling. The simulation results compare relatively well with the experimental data for large pressures differences.

CONCLUSIONS

We demonstrate that a technology based on A-CNTs embedded in a flexible matrix of PDMS has proven successful in the development of flexible pressure sensors. Future work includes the development of an inductor embedded in the nanocomposite using conductive fibers that enables the fabrication of a LC network for passive telemetry.

ACKNOWLEDGMENTS

The first author wishes to thank FCT - Fundação para a Ciência e Tecnologia, Portugal, for the financial support provided by the grant SFRH/BD/ 42922/2008. This work is supported by FCT under the project MIT-PT/EDAM-EMD/0007/2008.

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