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EIROPAS SAVIENĪBA

International conference

FM&NT

Functional materials and nanotechnologies 2012

Institute of Solid State Physics
University of Latvia

April 17 - 20

Riga

2012

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Po-144	J. Zicans	**Mechanical and Electrical Properties of Pe Nanocomposites with Carbon Nanotubes**
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Completely Hyperelastic Pressure Sensing Mat with Structurally Integrated Piezoresistive Sensors

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Previous studies of polyisoprene nanostructured carbon black composites (PNCBC) have proven that this material could be used to produce cheap pressure, impact or vibration detection units – sensors [1]. Depending on the carbon black concentration and filler dispersing methods PNCBC revieals higher or lower piezoresistive properties as well as good electrical conductivity [2]. In this article we try to elaborate completely hyperelastic pressure sensitive mat (CHPSM) capable of large scale pressure mapping using layered composite approach.

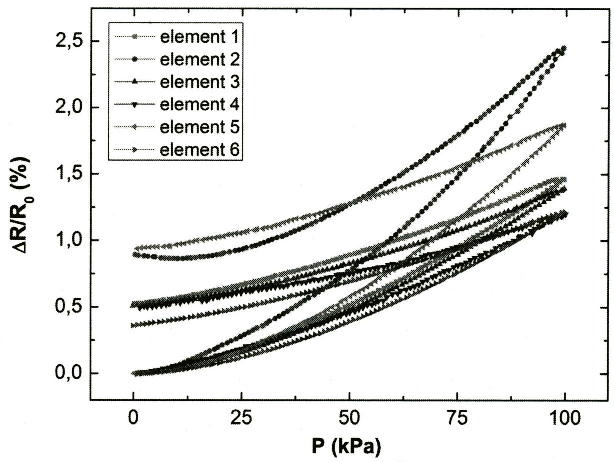

Fig.1 Piezoresistive behavior of separate similar CHPSM elements under 1 atmosphere of pressure

The CHPSM were made from raw PNCBC compositions with variable electroconductive carbon black concentrations. Each element of CHPSM was semi-vulcanized separately so it could maintain its shape during final vulcanization when these elements were cured together to form a uniform sensor. The CHPSM consists of 6 separate piezoresistive elements with hyperelastic electrodes incorporated into non-conductive natural polyisoprene rubber shell. The piezoresistivity of each CHPSM element was determined under operational pressures up to 1 and 10 atmospheres. Dimensions of the elaborated CHPSM are 100x70x5 mm but they can be easily tailored for a specific requirement.

References

1. M.Knite, V.Teteris, A.Kiploka, J.Kaupuzs, Sensor.Actuator A **110**, 142 (2004)
2. J. Zavickis, A. Linarts and M. Knite, Energetika **8**, 44 (2011)

Completely hyperelastic pressure sensing mat with structurally integrated piezoresistive sensors

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Functional materials and nanotechnologies

ABSTRACT

Previous studies of polyisoprene nanostructured carbon black composites (PNCBC) have proven that this material could be used to produce cheap pressure, impact or vibration detection units – sensors [1]. Depending on the carbon black (CB) concentration and filler dispersing methods PNCBC reveals more or less distinctive piezoresistive properties as well as good electrical conductivity [2]. In this article we try to elaborate completely hyperelastic pressure sensitive mat (CHPSM) capable of large scale pressure mapping using layered composite approach. The CHPSM were made from raw PNCBC compositions with variable concentrations of electroconductive carbon black. Each element of CHPSM was semi-vulcanized separately so it could maintain its shape during final vulcanization when these elements were cured together to form a uniform sensor. The CHPSM consists of 6 separate piezoresistive elements with hyperelastic electrodes incorporated into non-conductive natural polyisoprene rubber shell. Dimensions of the elaborated CHPSM are 100x70x5 mm but they can be easily tailored for a specific requirement.

INTRODUCTION

Majority of the conventional pressure sensors are brittle systems made from solid materials therefore their usage is limited due to vulnerability to withstand impact, vibrations or large scale deformations. However industries like automotive, civil engineering, medical equipments and robotics are interested in cheap, liable, various shape and elastic pressure sensors. In our previous research we approved that PNCBC with variable filler concentrations can be used to produce entirely hyperelastic pressure sensor system consisting of one sensitive element (Fig. 1) using functional multi-layer approach [3]. Using the same method we now try to produce larger sensor system consisting of six sensitive elements capable of planar pressure mapping.

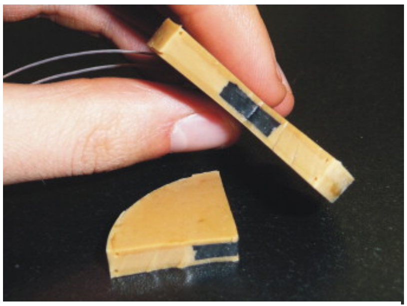

Fig. 1 Radial cross-cut of one sensitive element sensor system [3].

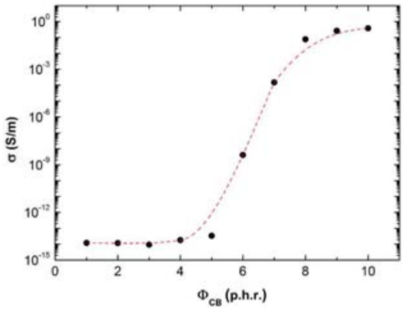

Fig 2 The electrical percolation transition of PNCBC.

Evaluation of raw materials

Polyisoprene – natural caoutchouc was mixed with necessary curing ingredients and various high structure carbon black (Degussa Printex Xe2 - specific surface area of 950m^2/g, average primary particle diameter 30nm) concentrations were made using roll mixing in Baltic Rubber factory (BRF). Carbon black concentration further is expressed in mass parts per hundred rubber (p.h.r.). To determine electrical as well as piezoresistive properties of each PNCBC composition we made flat, round shaped samples (diameter of 18mm, thickness of 1mm) with brass foil electrodes by curing the raw rubber in stainless steel mould for 15 minutes under 30 atmospheres of pressure at 150 °C. After moulding the samples were kept at room temperature for at least 24 hours before any measurements were made. Afterwards the electrical conductivity of each PNCBC sample was measured using Keithley 6487 Picoammeter/Voltage source (Fig. 2) and piezoresistive effect was determined using Zwick/Roell Z2.5 universal material testing machine coupled with Agilent 34970A data acquisition/switch unit. Due to technical limitation of measuring equipment PNCBC samples with conductivity lower than 10^{-8} S/m were not tested for piezoresistivity (Fig. 3). Obtained results determined the selection of materials for elaboration of CHPSM.

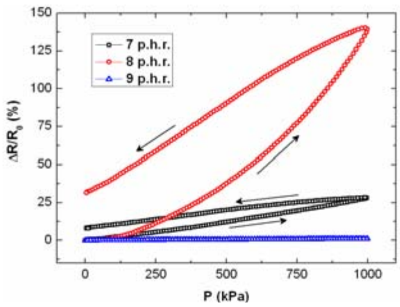

Fig 3 Piezoresistive behavior of PNCBC with various concentrations of CB under 1 MPa of pressure.

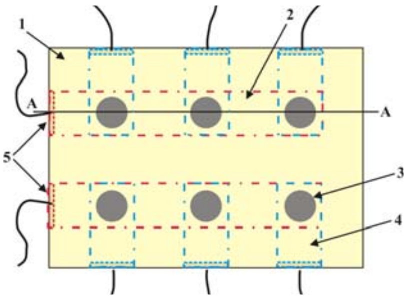

Fig 4 Planar schematic view of CHPSM consisting of: 1 – non conductive outer shell, 2 – piezoresistive PNCBC, 3 – upper layer of conductive PNCBC, 4 – lower layer of conductive PNCBC, 5 – wires with soldered small brass foil plates.

Elaboration of CHPSM

The CHPSM archetype was made using layered composite design where six pressure sensitive elements were joint with electrode elements and incorporated into protective non-conductive natural rubber shell without CB filler. The pressure sensitive elements was made form PNCBC with 8 p.h.r. CB since the piezoresistive sensitivity of this composition under 1 MPa of pressure was the highest (see Fig. 3). PNCBC with 10 p.h.r. CB was used in hyperelastic electrode elements on both sides of sensitive elements. The placement of electrode layers in CHPSM was designed to insure that the sensitive elements are electrically separated from each other so we could determine the piezoresistive behavior of each sensitive element individually under external pressure therefore it is possible to use this sensor system for pressure mapping. All CHPSM elements initially were semi-vulcanized separately for 11 minutes under 3 MPa of pressure at 140 °C to insure that they could maintain their shape during final vulcanization when all elements where assembled in designate positions and cured together under 3 MPa of pressure at 150 °C for 20 minutes. To connect EHPS to measuring equipment eight small wires with soldered brass foil extensions were added to the side electrode layers. Figure 4 shows schematic placement of electrode and sensing elements in protective rubber shell. Figure 5 shows schematic cross section view A-A of Figure 4. Figure 6 shows digital image of CHPSM and Figure 7 shows piezoresistive behavior of each sensitive element of CHPSM under 1 atmosphere of pressure. As we can see from Figure 7 piezoresistive behavior of each separated sensitive element is more or less distinct and the relative change of resistivity under 1 atmosphere is quite low.

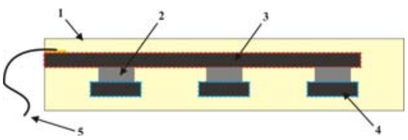

Fig 5 Schematic A-A cross section of CHPSM in Fig. 4.

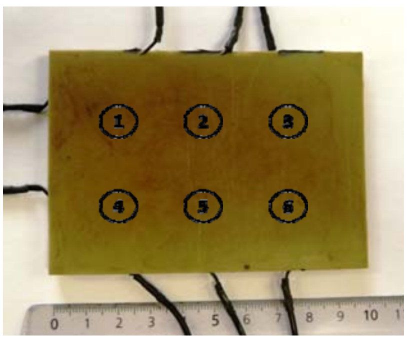

Fig 6 Digital image of CHPSM with approximate sensitive element placement.

Conclusions

1. The CHPSM has been succesfully elaborated by using functional multilayer approach. The raw materials for CHPSM was chosen from PNCBC with various CB concentrations after examining of their electro-mechanical properties.
2. The CHPSM is capable of large scale pressure mapping, however the piezoresistive behavior of each element is distinct.
3. The sensor needs technical improvements because the piezoresistive sensitivity is quite low.

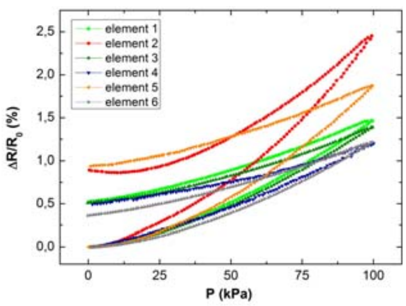

Fig 7 Piezoresistive behavior of each pressure sensitive element of CHPSM.

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