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Riga Technical University
Institute of Polymer Materials, Riga Technical University
Liepaja Affiliation, Riga Technical University
Institute of Polymer Mechanics, University of Latvia
Latvian State Institute of Wood Chemistry
Faculty of Chemistry, University of Latvia
Department of Chemistry, Latvian University of Agriculture
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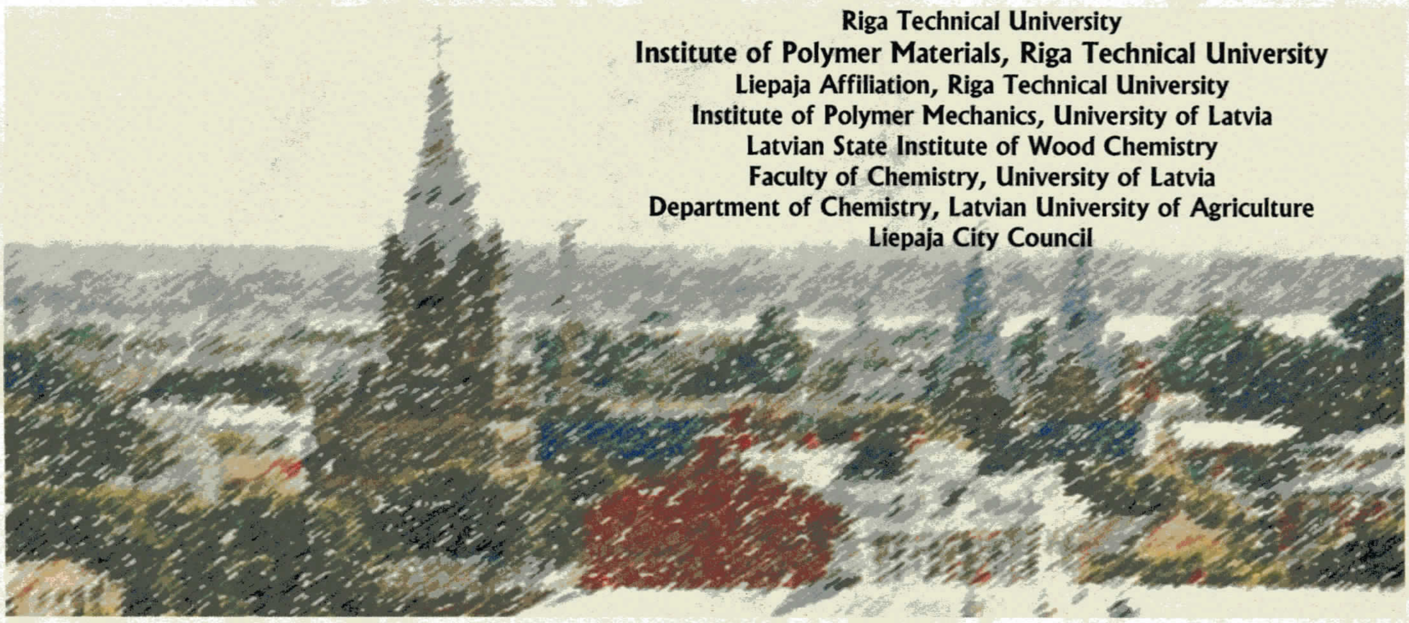

PIEZORESISTIVE BEHAVIOR OF POLYISOPRENE NANOSTRUCTURED GRAPHITE COMPOSITES

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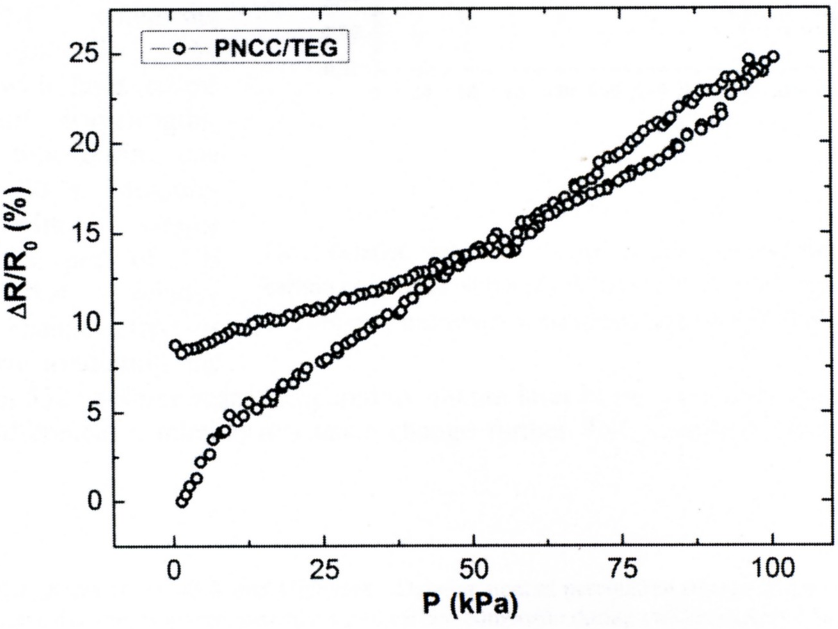
Previous research of polyisoprene nanostructured carbon black composites (PNCBC) have confirmed that, depending on the carbon black concentrations and filler dispersing methods, this composite has got higher or lower piezoresistive properties [1]. The main objective of this research is to achieve good composite homogeneity and remarkable piezoresistivty properties by using thermally exfoliated graphite (TEG) as the electrically conductive filler in polyisoprene nanostructured carbon composites (PNCC). TEG has been synthesized in Department of Physics of Kyiv National Taras Shevchenko University.

Afterwards the mechano-electrical properties of these composites has been determined in cyclic loading and unloading under 0,1 and 1 MPa of maximum pressure. By analyzing these results we can conclude that usage of TEG in PNCC to some extent improves the piezoresistive properties compared to PNCBC.



Piezoresistivity of polyisoprene nanostructured TEG composites

Reference

1. *Zavickis J., Linarts A. and Knite M.*. The downshift of the electrical percolation threshold in polyisoprene-nanostructured carbon composites // Energetika – 2011 – Vol. 8 – P. 44-49.

Piezoresistive behavior of polyisoprene nanostructured graphite composites

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ABSTRACT

Previous research of polyisoprene nanostructured carbon black composites (PNCBC) have confirmed that, depending on the carbon black concentrations and filler dispersing methods, this composite has got higher or lower piezoresistive properties [1]. The main objective of this research is to achieve good composite homogeneity and remarkable piezoresistive properties by using thermally exfoliated graphite (TEG) as the electrically conductive filler in polyisoprene nanostructured carbon composites (PNCC). TEG has been synthesized in Department of Physics of Kyiv National Taras Shevchenko University.

Afterwards the mechano-electrical properties of these composites has been determined in cyclic loading and unloading under 0,1 and 1 MPa of maximum pressure. By analyzing these results we can conclude that usage of TEG in PNCC to some extent improves the piezoresistive properties compared to PNCBC.

Samples and experimental

Polyisoprene/nanostructured graphite (PNGC) raw rubber composites were prepared using solution mixing method (Fig. 1). Polyisoprene (PI) with necessary curing ingredients was dissolved in chloroform and stirred in room temperature for 24h, afterwards TEG (Fig. 2.) powder, that was previously dispersed in pure chloroform solution using ultrasonic processor (specific power 1W*5min/1ml), was added to raw rubber solution in chloroform and stirred for another 24h at room temperature. Solution was then poured in to Petri dishes and left for 24h for chloroform to evaporate. Obtained films were homogenized using cold rolls with the smallest possible aperture. The TEG concentration in PI is expressed in mass parts per hundred rubber (p.h.r.). For determination of piezoresistive properties of each 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 shelf aged at room temperature before any measurements were made. Afterwards the piezoresistive behavior under 1 and 10 atmospheres of pressure were determined using Zwick/Roell Z2.5 universal material testing machine coupled with Agilent 34970A data acquisition/switch unit. Samples with initial resistivity higher than 100 MΩ where not tested for piezorezistivity due to technical limitation of measuring equipment.

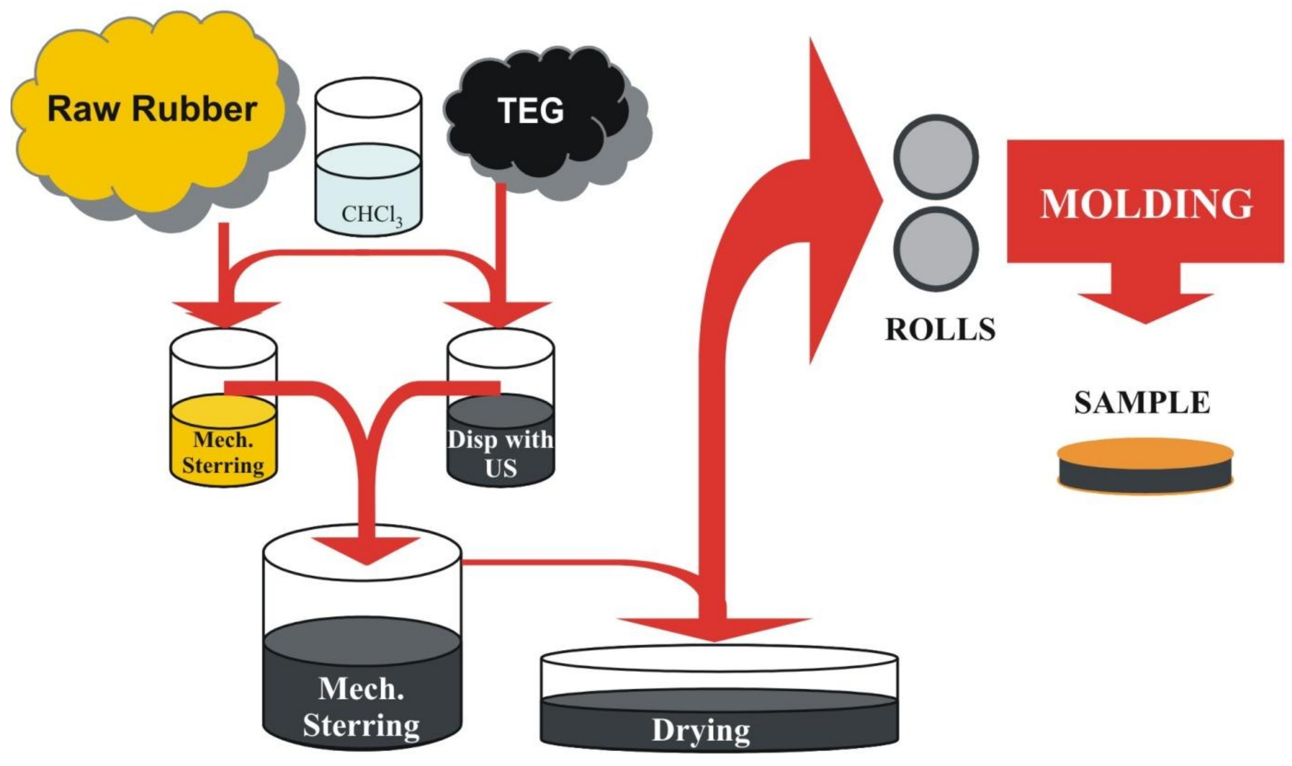

Fig. 1 Schematic picture of sample manufacture [2]

Results and discussion

The mechano-electrical properties were determined for each composition in cyclic loading and unloading test under 0,1 and 1 MPa of maximum pressure. The piezoresistive behavior of PNGC containing 13 p.h.r. TEG are shown in Figures 3 and 4. As we can see the piezoresistivity has almost linear behavior if the pressure doesn't exceed 0.1 MPa, however the resistivity does not returns to the initial value if the maximum pressure exceeds 0.1 MPa. This could be explained with relatively large size and flake like shape of TEG particles, that leads to restricted mobility in composite structure – under small pressures the displacement of particles are smaller, therefore it is more easier to reach initial structure, than in case of comparably higher pressures, when the displacement is much larger and the restricted mobility hinders particles to gain initial structure. The piezoresistive properties of all tested PNGC compositions under 0.1 MPa of maximum pressure are shown in Figure 5. We compared these results with previous results from PNCBC (Fig. 6), that where made with the same solution mixing method. As we can see from these results, by using TEG instead of carbon black (CB), it is possible to achieve much higher piezoresistive sensitity, but in the same time much larger filler concentrations are needed. The increase of piezoresistive change under pressure using TEG could be explained by larger volume occupied by TEG, therefore the change of tunneling currents under deformations plays a more significant role then in case of CB.

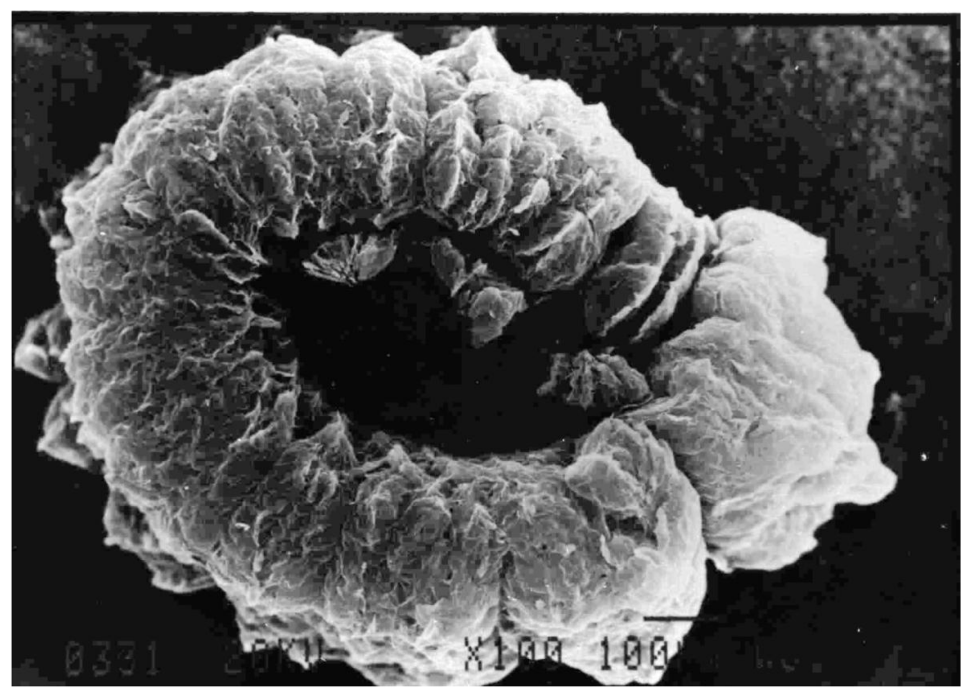

Fig. 2 SEM picture of TEG coated with 10 nm thick layer of Au

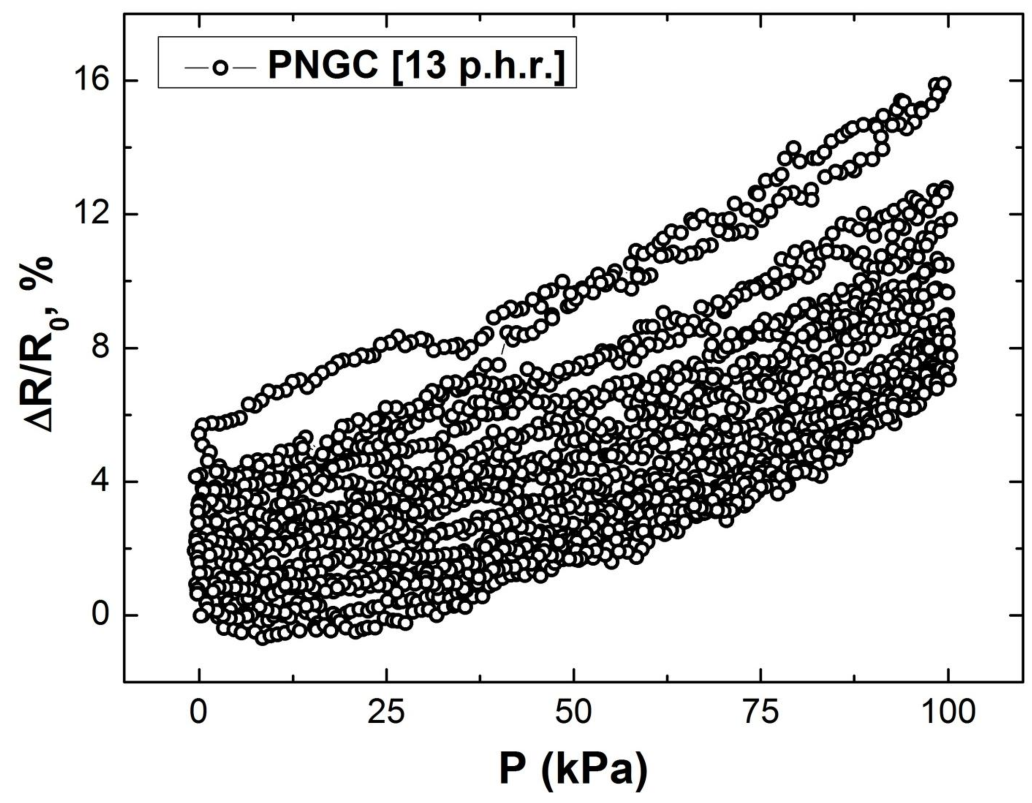

Fig. 3 Piezoresistive behavior under 0,1 MPa of pressure (PNGC with 13 p.h.r. TEG)

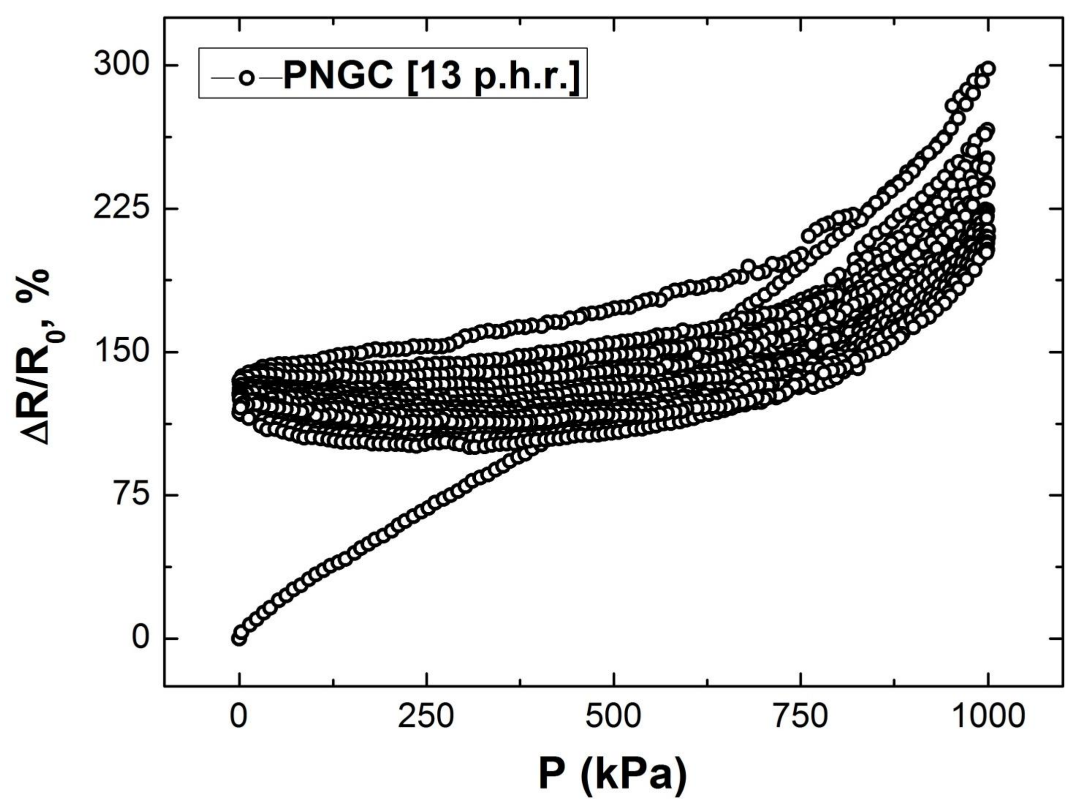

Fig. 4 Piezoresistive behavior under 1 MPa of pressure (PNGC with 13 p.h.r. TEG)

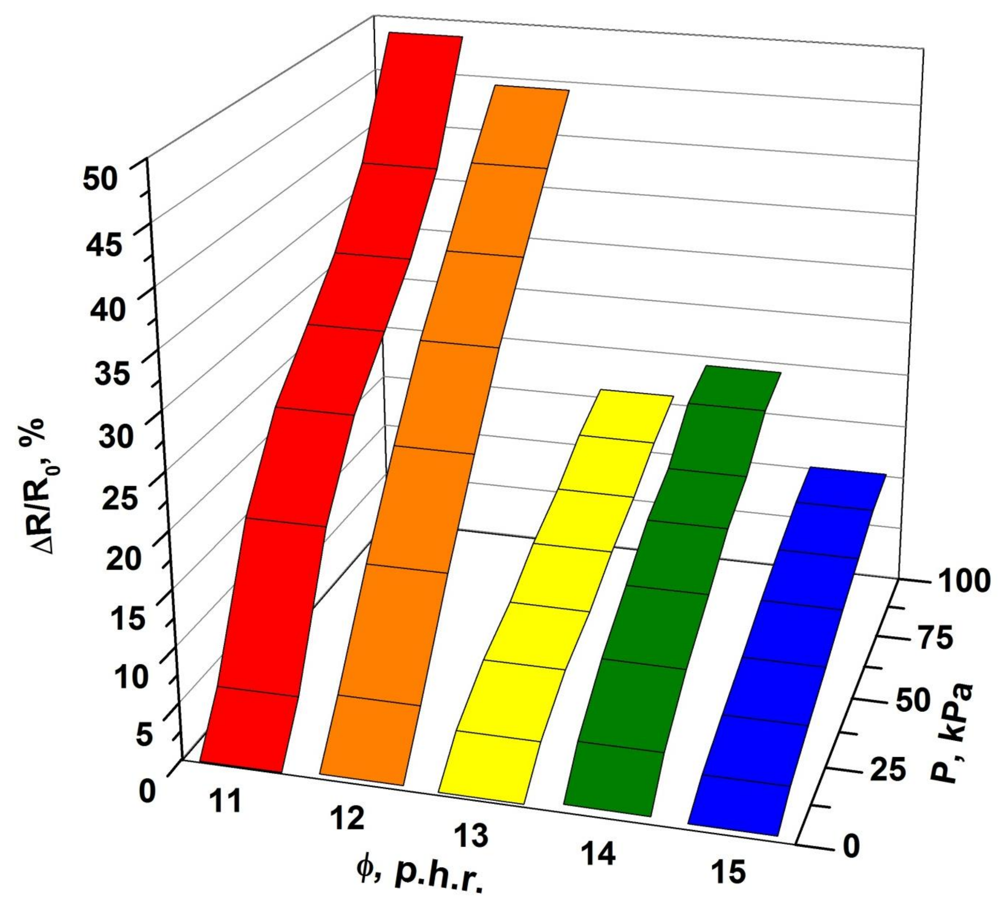

Fig. 5 The piezoresistive effect of PNGC

Conclusions

1. The piezoresistive behavior of PNGC depends on the value of external pressure. This could be explained with restricted mobility of TEG, therefore under higher pressures, when the displacement of particles is larger it is much harder to return to the initial structure.
2. It is possible to achieve much higher piezoresistive sensitivity at larger filler concentrations, if TEG is used as the filler instead of CB, this could be explained with larger volume occupied by TEG particles, therefore the change of tunneling currents between paticles under external deformations plays more significant role.

ACKNOWLEDGEMENTS

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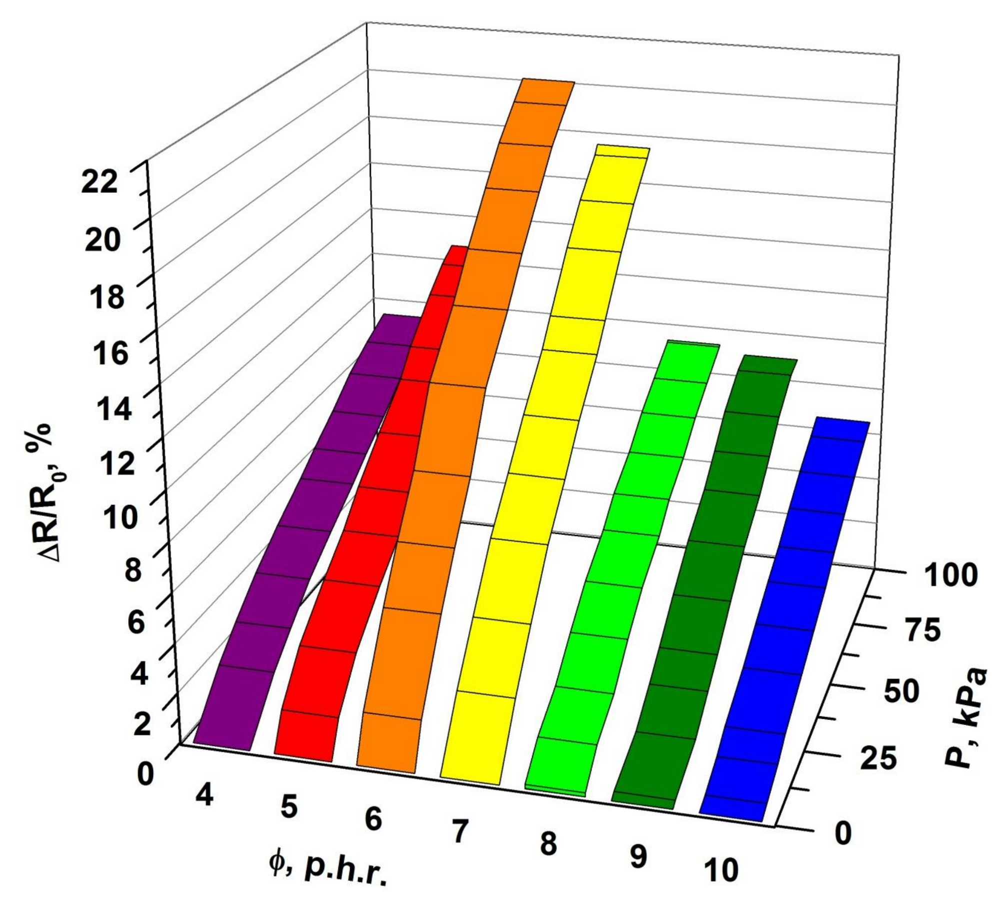

Fig. 6 The piezoresistive effect of PNCBC [1]

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1. J.Zavickis, A.Linarts, M.Knite, Energetika **8**, 44 (2011)