Valsts ZP programmas 3. projekta sadaļa

Invatīvi polimēra/nanostrukturēta oglekļa kompozīti multifunkcionāliem sensoriem: dizains, izgatavošana un īpašību izpēte

Māris Knite*, *Juris Zavickis*, *Gita Šakale*, *Kaspars Ozols*, *Velta Tupureina*, *Valdis Teteris*, *Artis Linarts*, *Juris Adams*, *Elīna Liepa*, *Santa Stepiņa

Rīgas Tehniskā universitāte,
Materiālzinātnes un lietišķās ķīmijas fakultāte
Tehniskās fizikas institūts

Mūsu zinātniskā grupa

Velta Tupureina
Researcher
Chemical engineering

Valdis Teteris
Researcher
Electrical engineering

Juris Zavickis
PhD pretendent
Materials science

Gita Šakale
PhD student
Materials science

Kaspars Ozols
PhD student
Materials science

Artis Linarts
Mg student
Materials science

Elīna Liepiņa
Bc student
Materials science

Santa Stepiņa
Bc student
Materials science

Apakšprojekta galvenais mērķis:

1) izstrādāt inovatīvu hibrīdo polimēra nanokompozītu materiālu dizainu;
2) izstrādāt iegūšanas tehnoloģijas;
3) izgatavot šos materiālus un
4) izpētīt to īpašības, ar mērķi pielietot tos elastoplastisku elektronisko sensoru izstrādē.

Šīs prezentācijas mērķis ir iepazīstināt ar VZPP izpildes pirmajā gadā paveikto:

Apakšprojekta 1. gada uzdevumi:

1) Izgatavot pilnībā superelastīgu spiediena sensora elementu;
2) Izstrādāt jaunus etanola sensormateriālus ;
3) Panākt OŠT sensora efekta jutības un ilgdarbības parametru uzlabošanu.

Saturs:

1. Motivācija un daži principiāli jēdzieni

2. Spiedes deformācijas sensorefektu uzlabošana

3. Ķīmisko sensorefektu uzlabošana

4. Sensorefektu modeļa attīstīšana

5. Pilnībā superelastīgs spiedes sensors

6. Patenti un publikācijas

Motivation is to develop completely flexible (hyper-elastic) pressure sensor, for example, soft mater tactile sensors for robotics.

Always and anywhere ready to work!

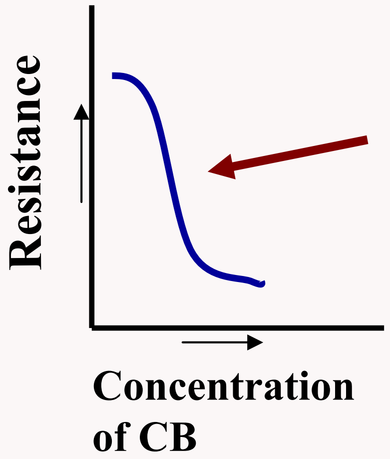
Designer Eric De Nijs

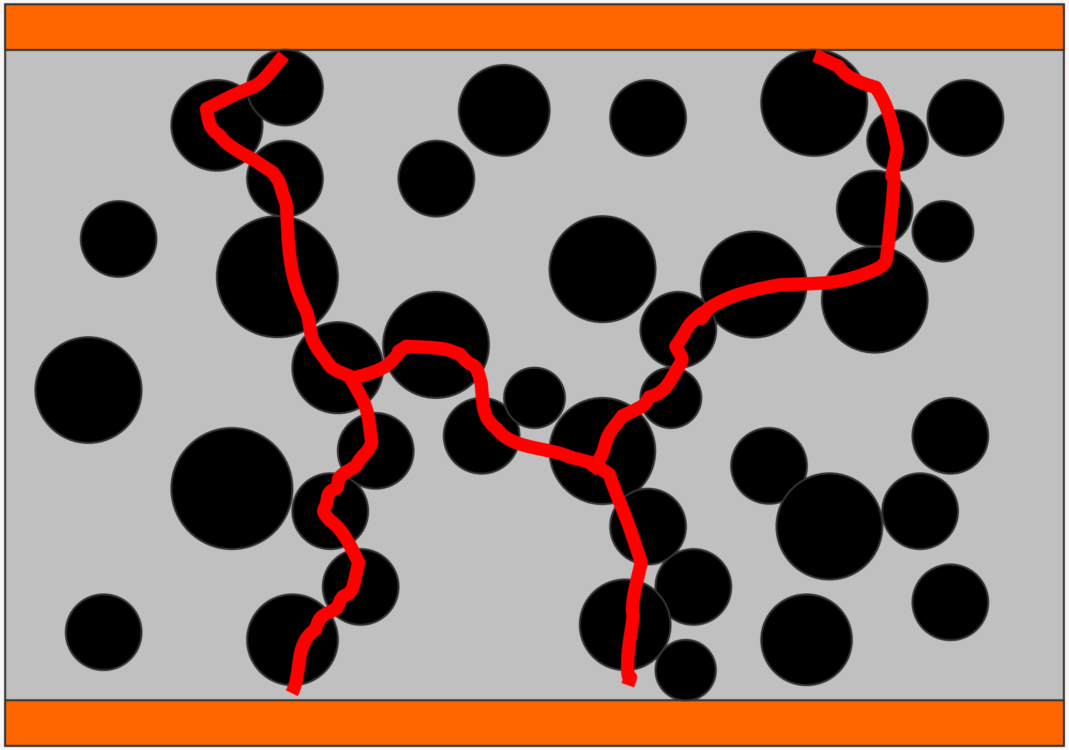
Designer Zach Hoeken

http://www.gadgets.co.uk/item/USBRK/USB-Flexible-Portable-Rubber-Keyboard.html

1. Some general concepts

Mechanism of electrical percolation





Percolation – formation of infinite conductive particle cluster

Piezoresistivity – changes of conductive network under pressure that results in changes of electrical resistance of composite

Tensoresistivity – changes of electrical resistance under tension

Positive piezoresistivity effect: electrical resistance rises versus uniaxial pressure.

$$\frac{\Delta R}{\Delta p} > 0$$

Negative piezoresistivity effect: electrical resistance decreases versus uniaxial pressure.

$$\frac{\Delta R}{\Delta p} < 0$$

Positive tensoresistivity effect: electrical resistance rises versus uniaxial tension.

$$\frac{\Delta R}{\Delta F_{tens}} > 0$$

Negative tensoresistivity effect: electrical resistance decreases versus uniaxial tension.

$$\frac{\Delta R}{\Delta F_{tens}} < 0$$

Gauge factor:

$$G = \frac{\Delta R / R_0}{\Delta l / l_0} = \frac{\Delta R / R_0}{\varepsilon}$$

Saturs:

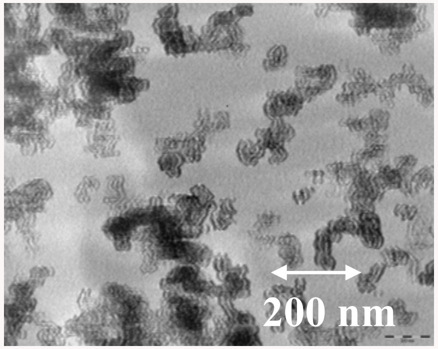
Design and preparation of our first samples

(~ 7 years ago)

Components:

1) Polyisoprene (PI) matrix (Thick Pale Crepe No. 9 Extra, MARDEC Inc.)

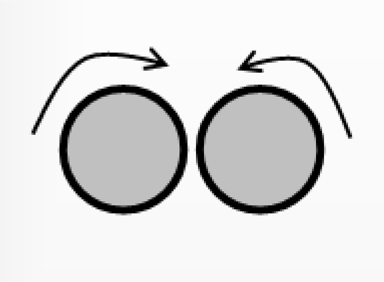
2) High structure nano-size carbon black (CB) filler, extra-conductive (Printex XE2, DEGUSSA AG): mean particle size: 30 nm; surface area: 950 m^2/g; DBP absorption: 380 ml/100g



3) Additional ingredients (S, ZnO...)

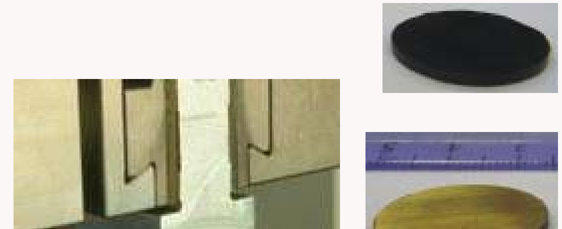
Processing:

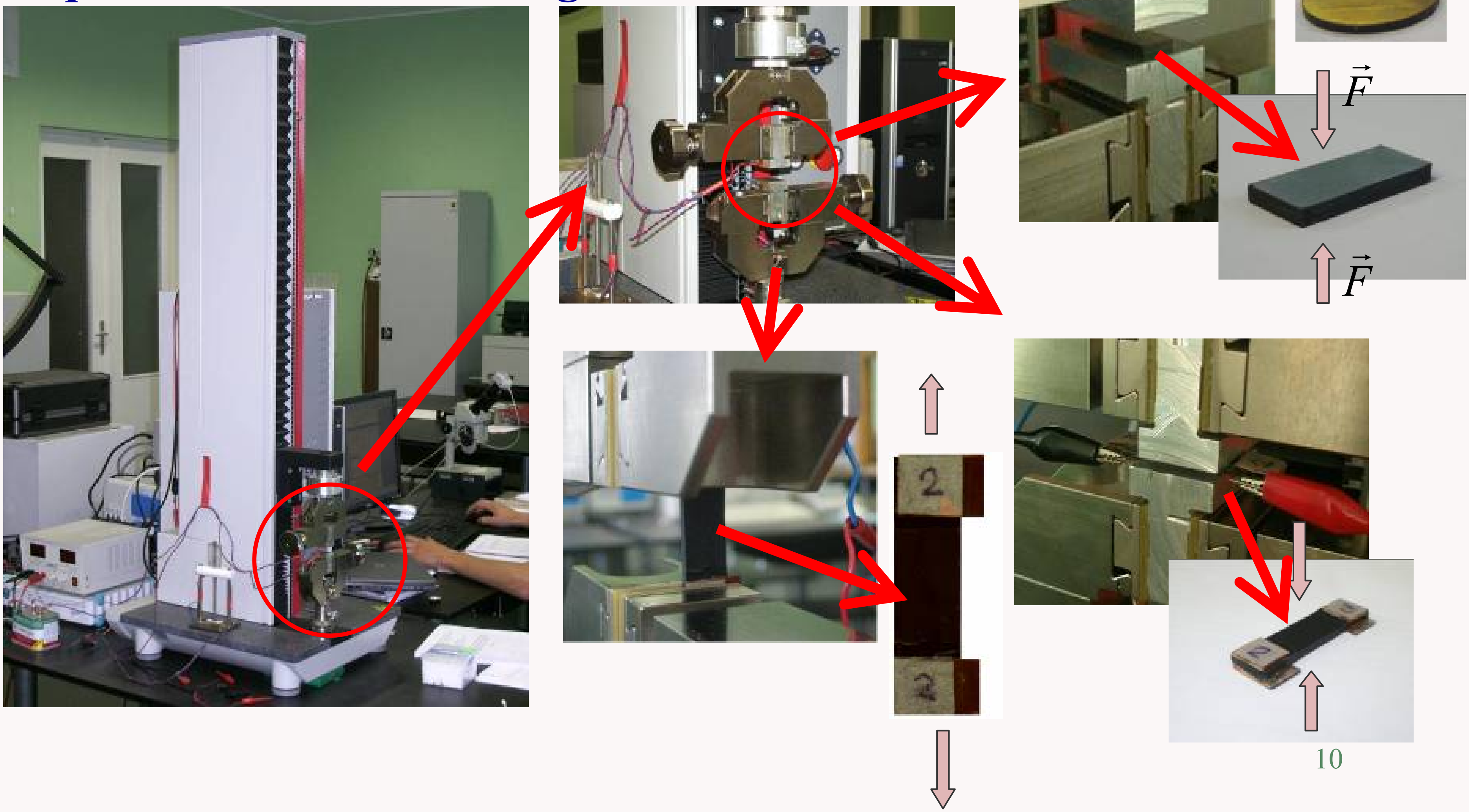
Polyisoprene, Printex XE2 and additional ingredients were mixed by cold rolls.



Plates 1.5x10 cm^2, 1÷2.5 mm thick, were vulcanised at 140ºC for 15 min under pressure $30x10^5$ Pa.

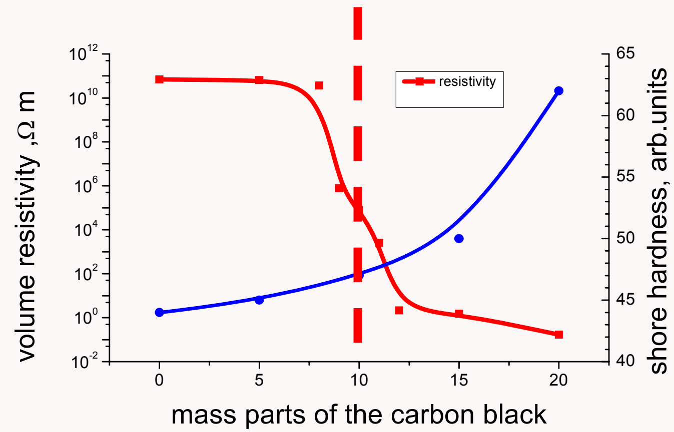
Setup for investigation mechanical sensing properties based on ZwickRoell Z2.5 and data acquisitions switch unit Agilent 34970A

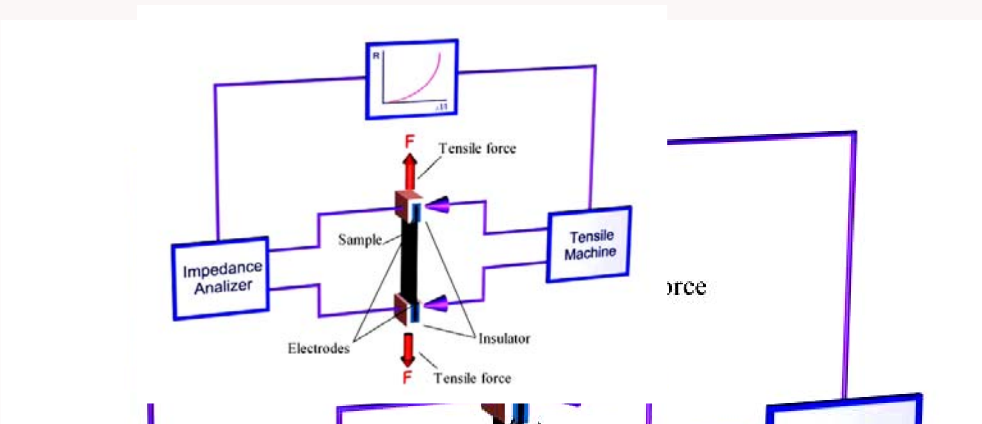




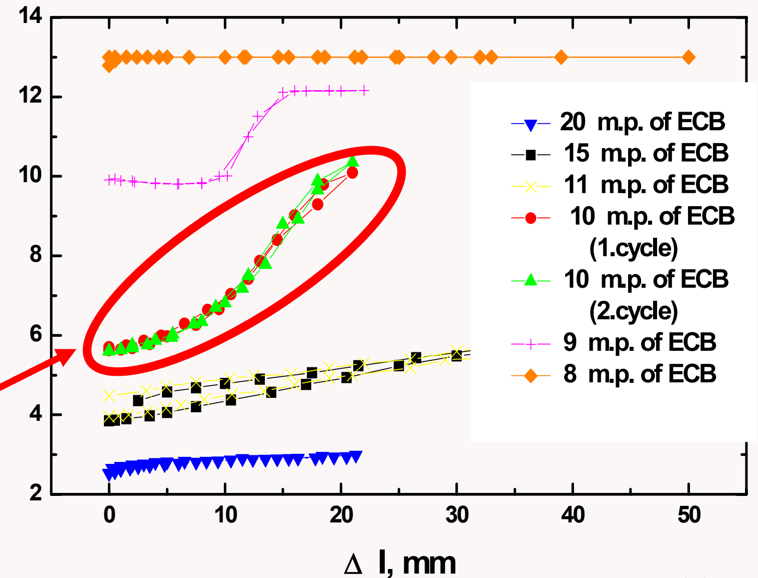
First results: Positive tensoresistivity effect

Electric resistivity as function of HSCB concentration





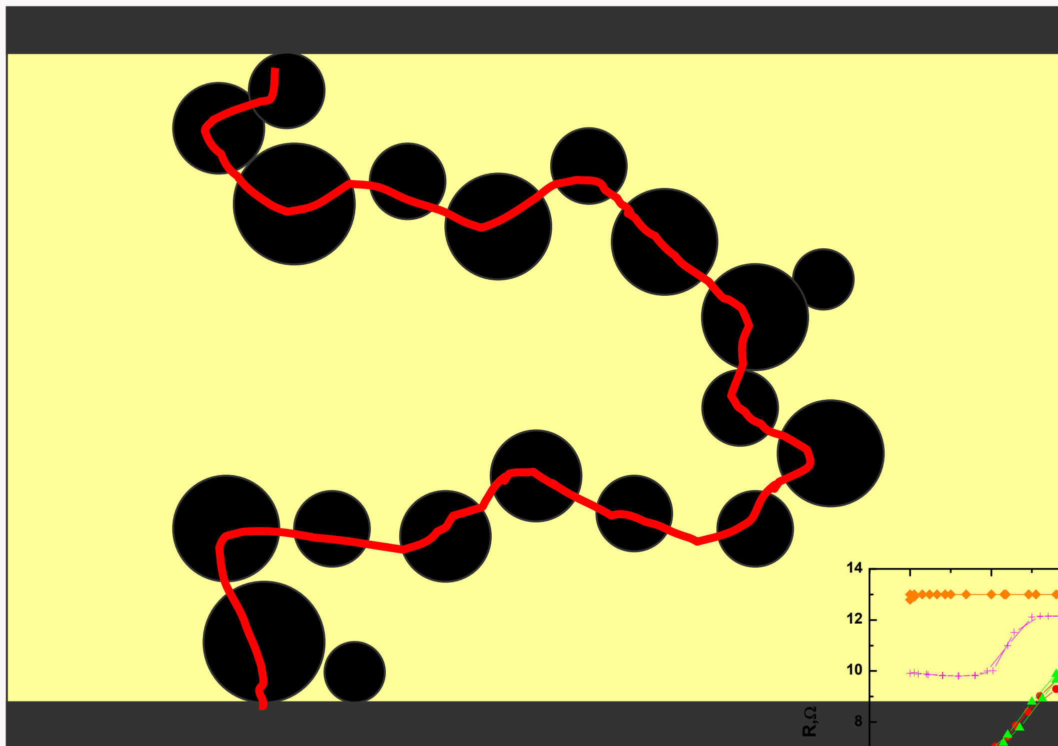
Electric resistance ***R*** as function of tensile strain ***Δ l*** at different mass parts of HSCB, l_0=50 mm, T=293K.

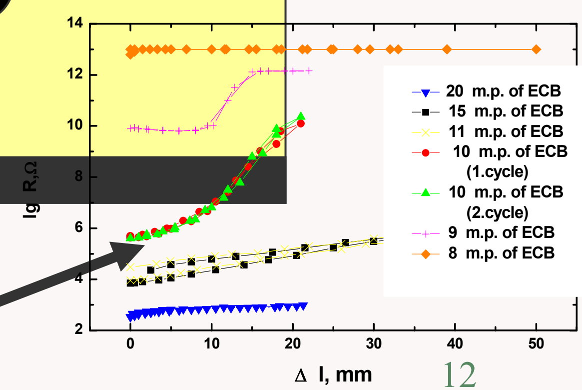


Conclusion: Best reversible tensoresistivity effect exists slightly above percolation threshold

M.Knite et al, ***Sensors and Actuators. A: Physical,*** V110/1-3, **2004**, p.142-149.

Explanation of positive tensoresistivity effect



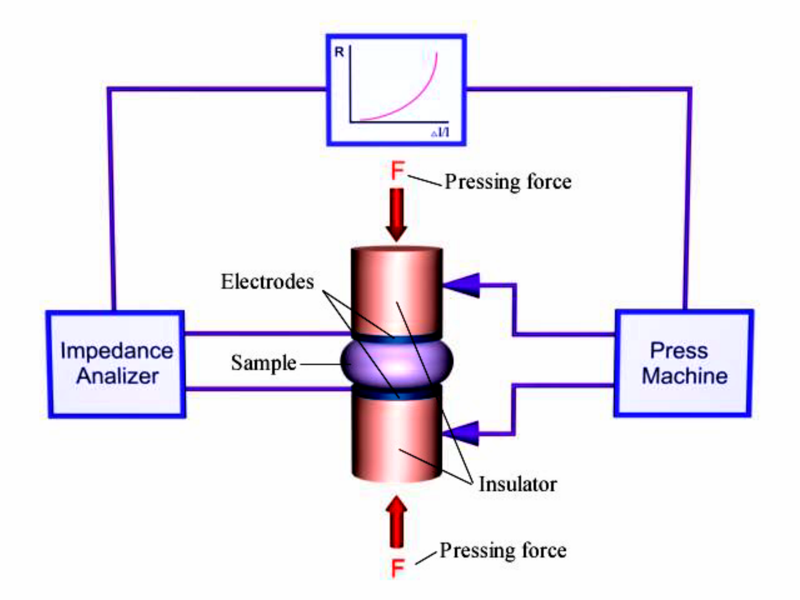


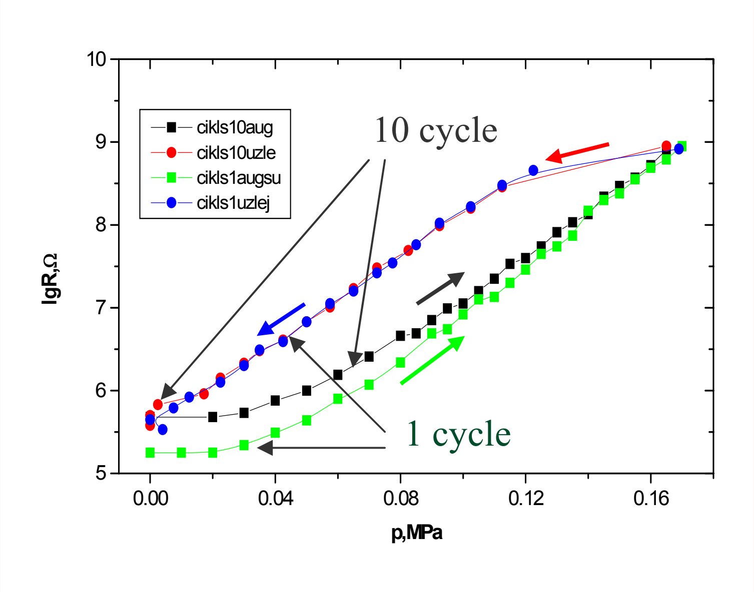
Conductive CB channels are destroyed under uniaxial tension: resistivity raises

First results:

Unexpected for us a positive piezoresistivity effect has been observed.

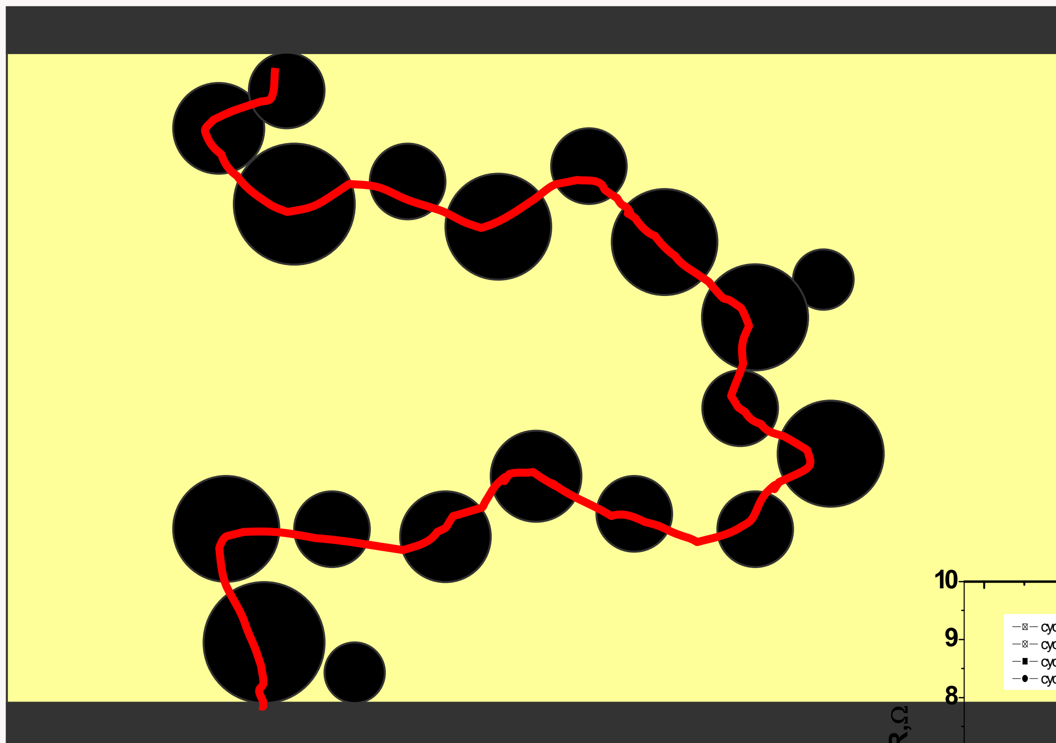
Why?

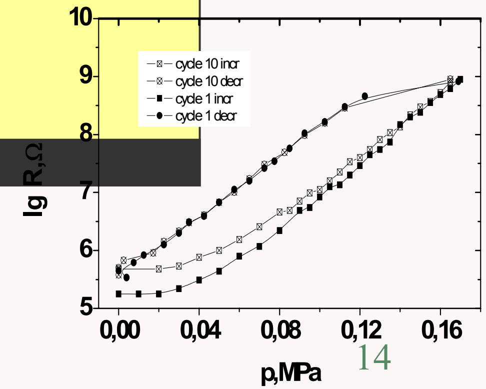




M.Knite et al, ***Sensors and Actuators. A: Physical,*** V110/1-3, **2004**, p.142-149.

Explanation of positive piezoresistivity effect





Conductive CB channels are destroyed under uniaxial pressure: resistivity raises

Our first papers in this field:

ELSEVIER
Materials Science and Engineering C 19 (2002) 15–19
MATERIALS SCIENCE & ENGINEERING C
www.elsevier.com/locate/msec

Electric and elastic properties of conductive polymeric nanocomposites on macro- and nanoscales

Maris Knite[a,*], Valdis Teteris[a], Boris Polyakov[b], Donats Erts[b]
[a] Technical Physics Institute, Riga Technical University, 14/24 Azenes Str., LV-1048, Riga, Latvia
[b] Institute of Chemical Physics, University of Latvia, 19 Rainis blv. LV-1586, Riga, Latvia

Knite, M., Teteris, V., Polyakov, B., Erts, D.
Electric and elastic properties of conductive polymeric nanocomposites on macro- and nanoscales
(2002) *Materials Science and Engineering C*, 19 (1-2), pp. 15-19. Cited 25 times.
doi: 10.1016/S0928-4931(01)00410-6

Abstract + Refs | View at Publisher

ELSEVIER
Available online at www.sciencedirect.com
SCIENCE DIRECT®
Sensors and Actuators A 110 (2004) 142–149
SENSORS AND ACTUATORS A PHYSICAL
www.elsevier.com/locate/sna

Polyisoprene-carbon black nanocomposites as tensile strain and pressure sensor materials

Maris Knite[a,*], Valdis Teteris[a], Aleksandra Kiploka[a], Jevgenijs Kaupuzs[b]
[a] Institute of Technical Physics, Riga Technical University, 14/24 Azenes str. LV-1048 Riga, Latvia

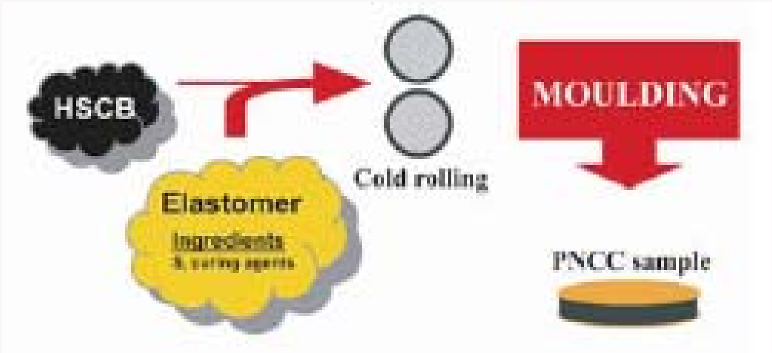
Knite, M., Teteris, V., Kiploka, A., Kaupuzs, J.
Polyisoprene-carbon black nanocomposites as tensile strain and pressure sensor materials
(2004) *Sensors and Actuators, A: Physical*, 110 (1-3), pp. 142-149. Cited 52 times.
doi: 10.1016/j.sna.2003.08.006

Abstract + Refs | View at Publisher

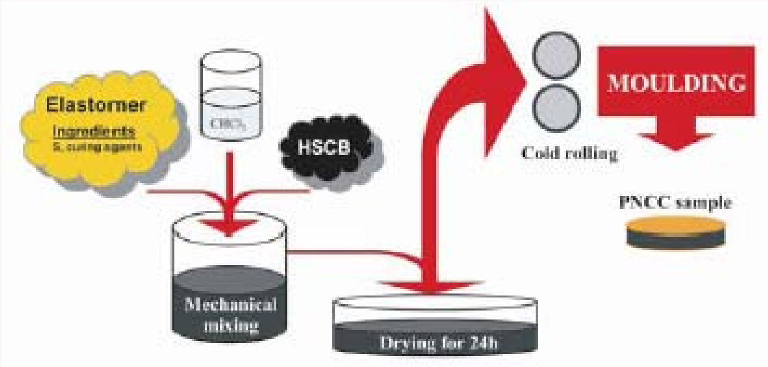
SCOPUS data

II. Development of composite design and technology

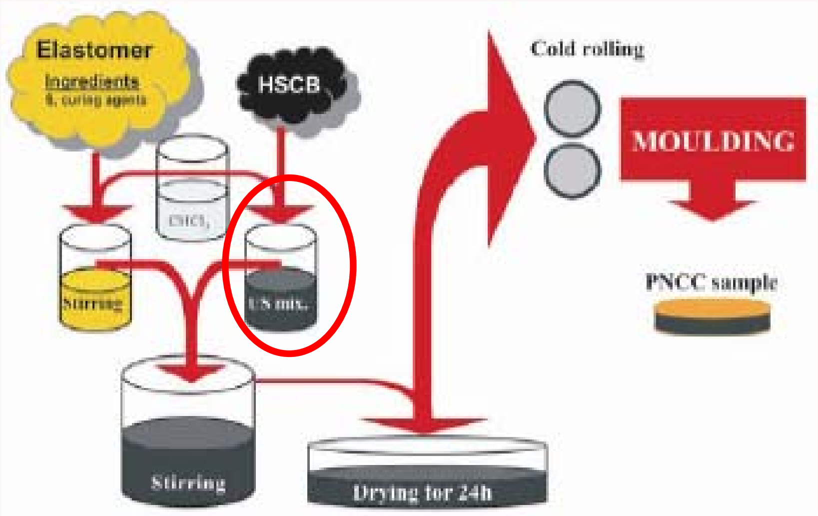
1) *Improvement of nanoparticle dispersion methods in matrix*



Only cold roll mixing of HSCB in polyisoprene



Mechanical mixing of HSCB in chloroform solution of polyisoprene



US mixing of HSCB in chloroform liquid

J.Zavickis, A.Linarts, M.Knite, Proc. of Scient. Conf. of Young Scientists on Energy Issues 2010, Kaunas, Lithuania, May 27-28, 2010, p.408-415, ISSN 1822-7554

1) Improvement of nanoparticle dispersion methods in matrix

CYSENI 2010, May 27–28, Kaunas, Lithuania
ISSN 1822-7554, www.cyseni.com

THE ELECTRICAL PERCOLATION SHIFT IN POLYISOPRENE – NANOSTRUCTURED CARBON COMPOSITE

J. Zavickis, A. Linarts, M. Knite
Riga Technical University
Institute of Technical Physics

CYSENI 2010, May 27–28, Kaunas, Lithuania
ISSN 1822-7554, www.cyseni.com

The critical concentrations (Φ_c) corresponding to the percolation threshold were found out for all types of PNCCs (Fig. 6.).

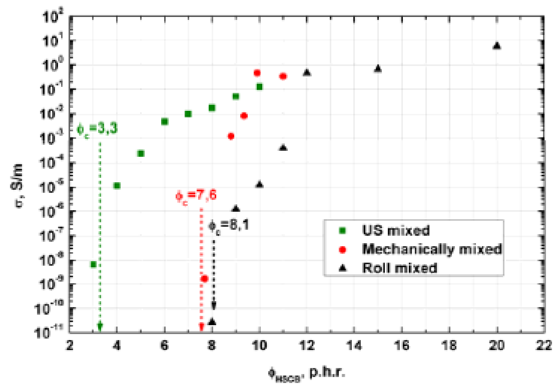


Fig. 6. The specific electrical conductivity as a function of filler fraction for differently prepared PNCCs and their critical concentrations Φ

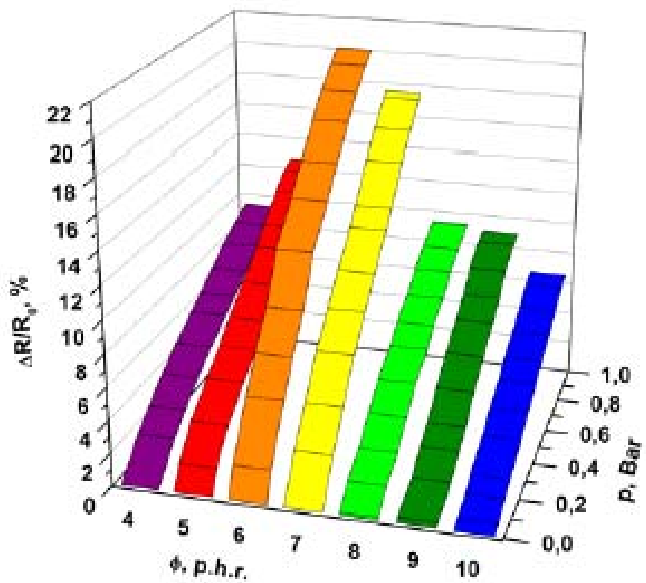
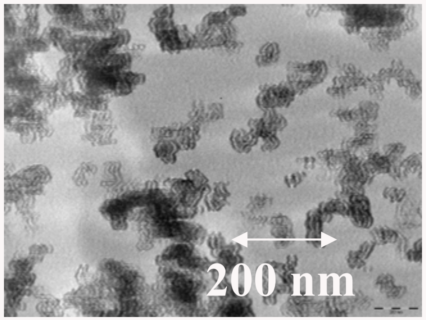


Fig. 10. The piezoresistive behavior of US mixed PNCCs

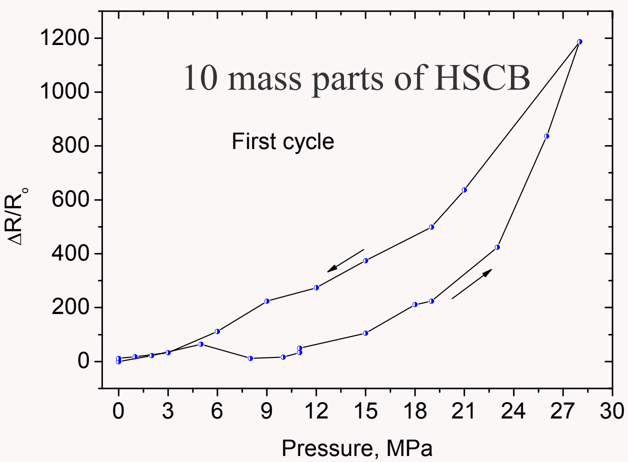
J.Zavickis, A.Linarts, M.Knite, Proc. of Scient. Conf. of Young Scientists on Energy Issues 2010, Kaunas, Lithuania, May 27-28, 2010, p.408-415, ISSN 1822-7554

2) *New filler - multi wall carbon nanotubes MWCNT*

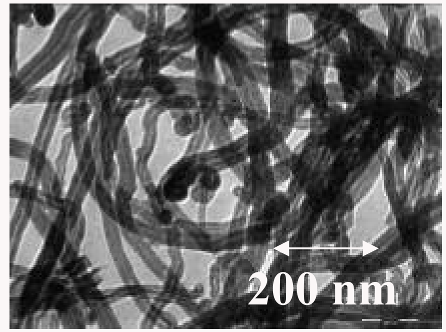
Carbon black
(Printex XE2, DEGUSSA AG)



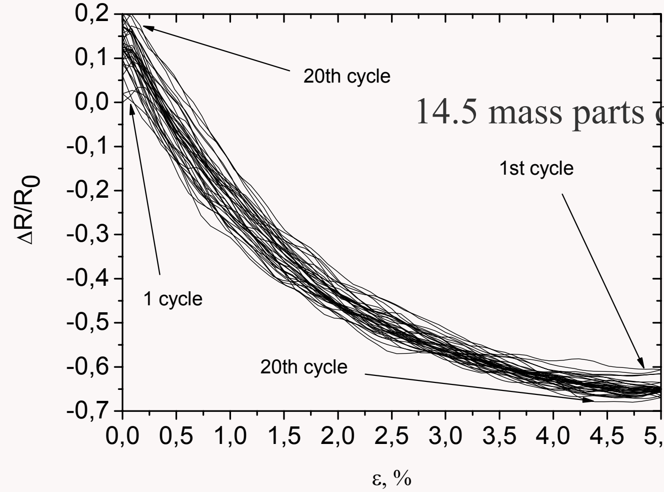
Positive piezoresistance effect



Carbon nanotubes **(Aldrich 636835),**
OD = 60-100 nm, ID = 5-10 nm, length = 0,5-500 μm.



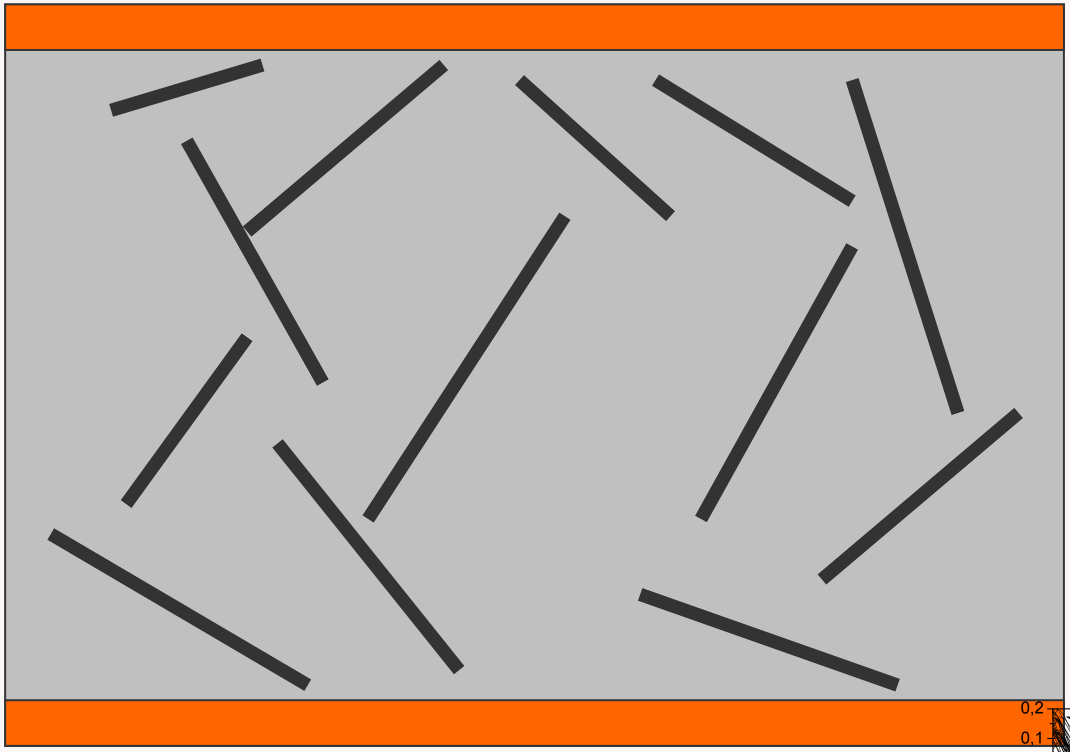
Negative piezorezistance effect

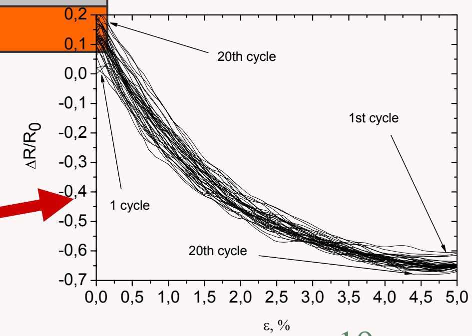


Cold roll mixed

M. Knite, K. Ozols, J. Zavickis, V. Tupureina, I. Klemenoks, R. Orlovs,, ***Journal of Nanoscience and Nanotechnology***, 2009 V9, N6, 3587-3592

Explanation of negative piezoresistivity effect in polyisoprene/carbon nanotube composites





New electric channels are built up under pressure: resistivity decreases

Journal of Nanoscience and Nanotechnology
Vol. 11, 1–5, 2011

Polyisoprene-Multi Wall Carbon Nanotube Composite Structure for Flexible Pressure Sensor Application

M. Knite, J. Zavickis*, V. Teteris, and A. Linarts

Institute of Technical Physics, Riga Technical University, 14-322, Riga, Latvia, LV-1007

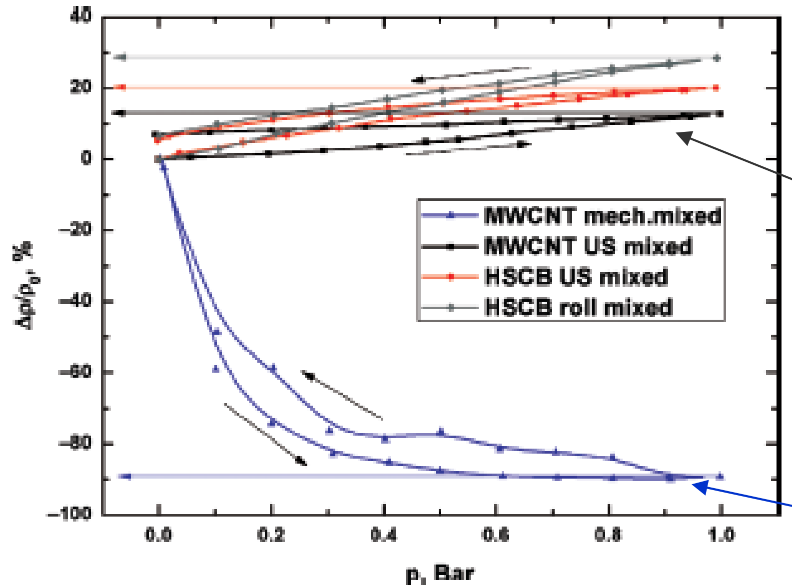


Fig. 7. The best obtained piezoresistive behavior comparison (relative change of electrical resistivity versus operational pressure) for differently prepared polyisoprene MWCNT/HSCB composites.

Inversion of the character of the piezoresistivity effect !!!

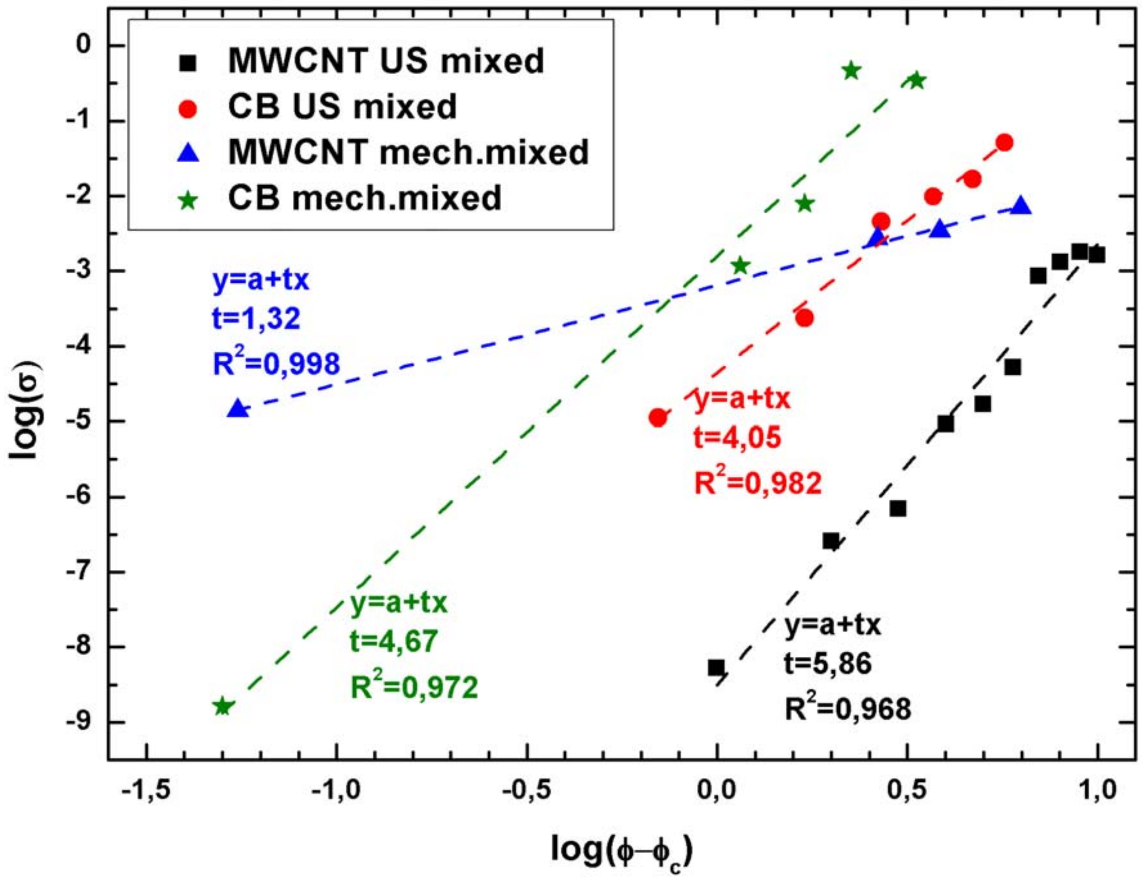
US mixing of MWCNT in chloroform liquid – **positive piezoresistivity**

Mechanical mixing of MWCNT in chloroform solution of polyisoprene – **negative piezoresistivity**

M.Knite, J.Zavickis, V.Teteris, A.Linarts,, ***Journal of Nanoscience and Nanotechnology***, accepted 01.03.2010

2) *New filler - multi wall carbon nanotubes MWCNT*

Kritiskā indeksa ***t*** noteikšana: $\sigma = \sigma_0 (\Phi - \Phi_C)^t$



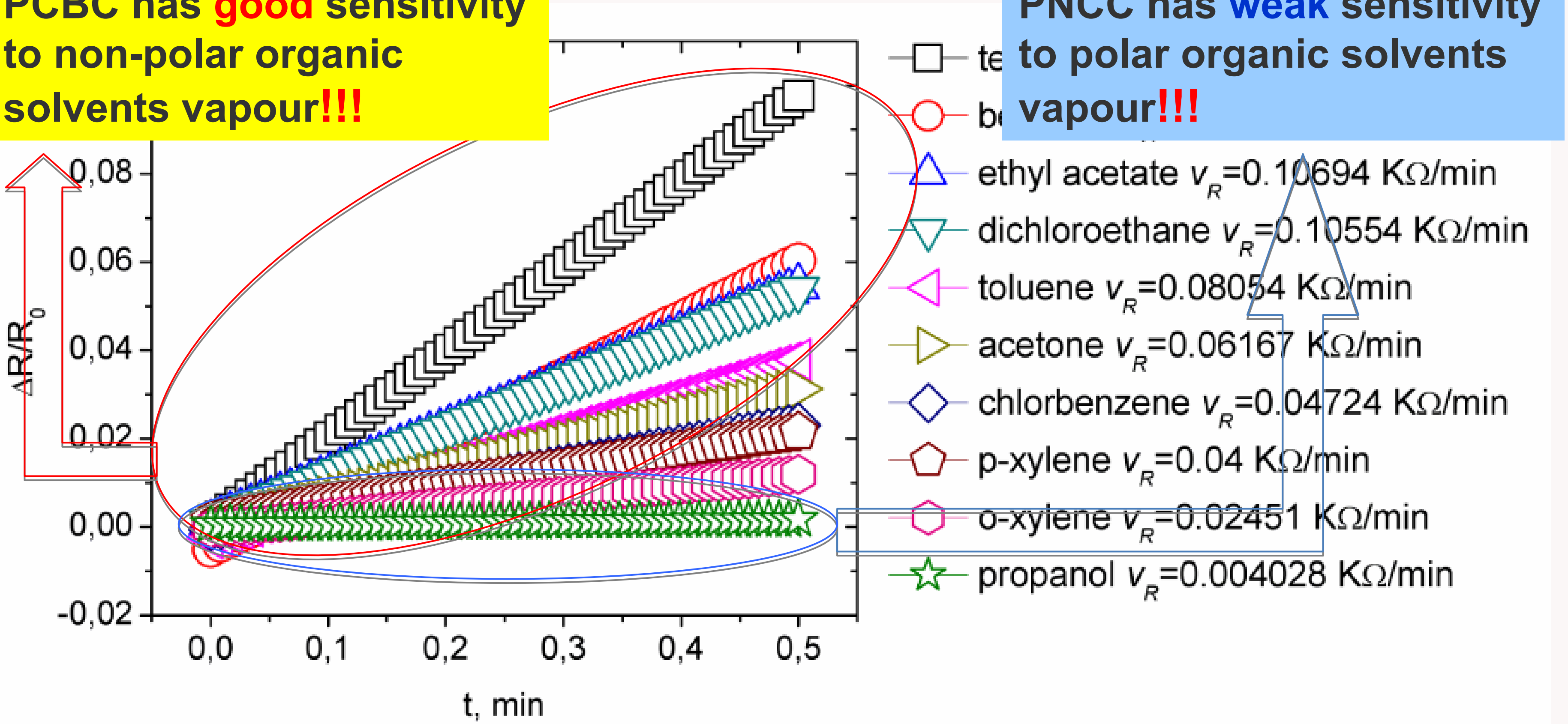
M.Knite, J.Zavickis, V.Teteris, A.Linarts,, ***Journal of Nanoscience and Nanotechnology***, accepted 01.03.2010

Saturs:

3. Polyisoprene/HSCB composite (PCBC) organic solvent vapour sensor effect

PCBC has good sensitivity to non-polar organic solvents vapour!!!

PNCC has weak sensitivity to polar organic solvents vapour!!!

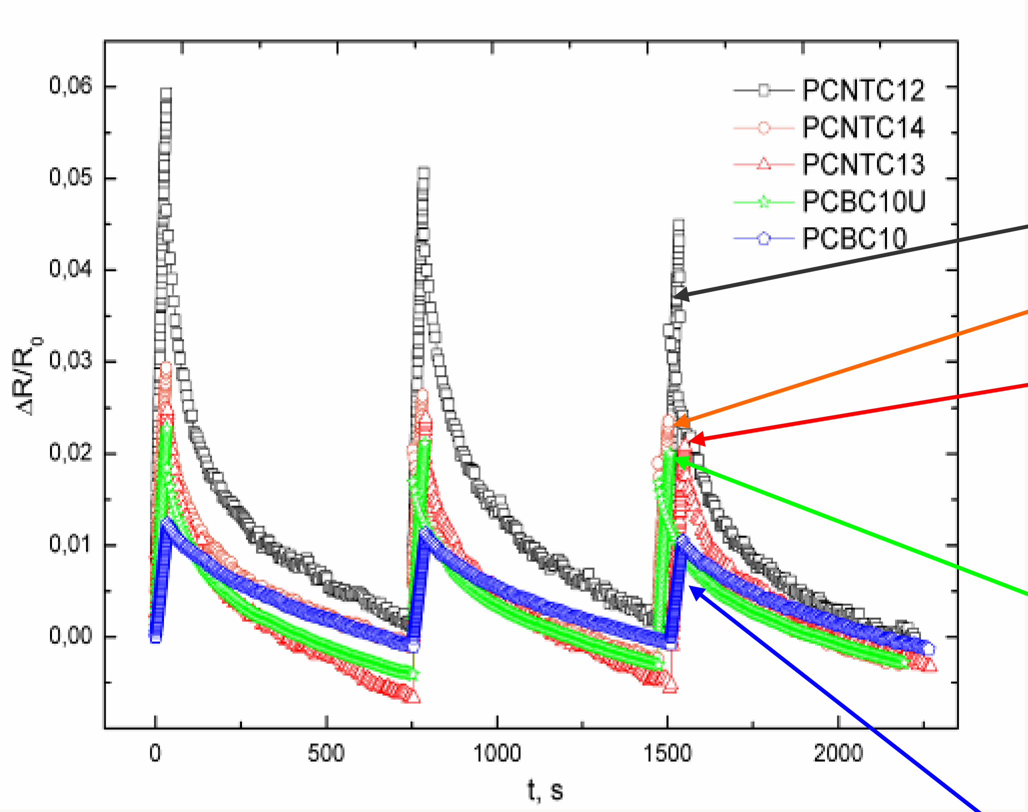


The change of relative electric resistance versus time for the sample held in saturated vapours of different solvents.

M.Knite, K.Ozols, G.Sakale, V.Teteris, ***Sensors and Actuators B Chemical***, 2007, V126, 209-213

Polyisoprene/MWCNT nanocomposites for chemical sensing

Ethyl acetate vapour sensing effect in polyisoprene/MWCNT composites



US mixing of MWCNT in chloroform liquid:

12 phr MWCNT

14 phr MWCNT

13 phr MWCNT

US mixing of HSCB in chloroform liquid:

10 phr PRINTEX XE2

Cold roll mixing of HSCB in polyisoprene

10 phr PRINTEX XE2

Electric resistance reversibility and response repeatability (0,109ml/l)

M.Knite, G.Sakale, V.Teteris, ***Journal of Nanoscience and Nanotechnology***, pieņemts publicēšanai 19.11.2010

Ethanol sensing effects in polyethylene glycol (PEG), polyvinilacetate (PVAc) and ethilene vinylacetate copolymer (EVA) / NC composites

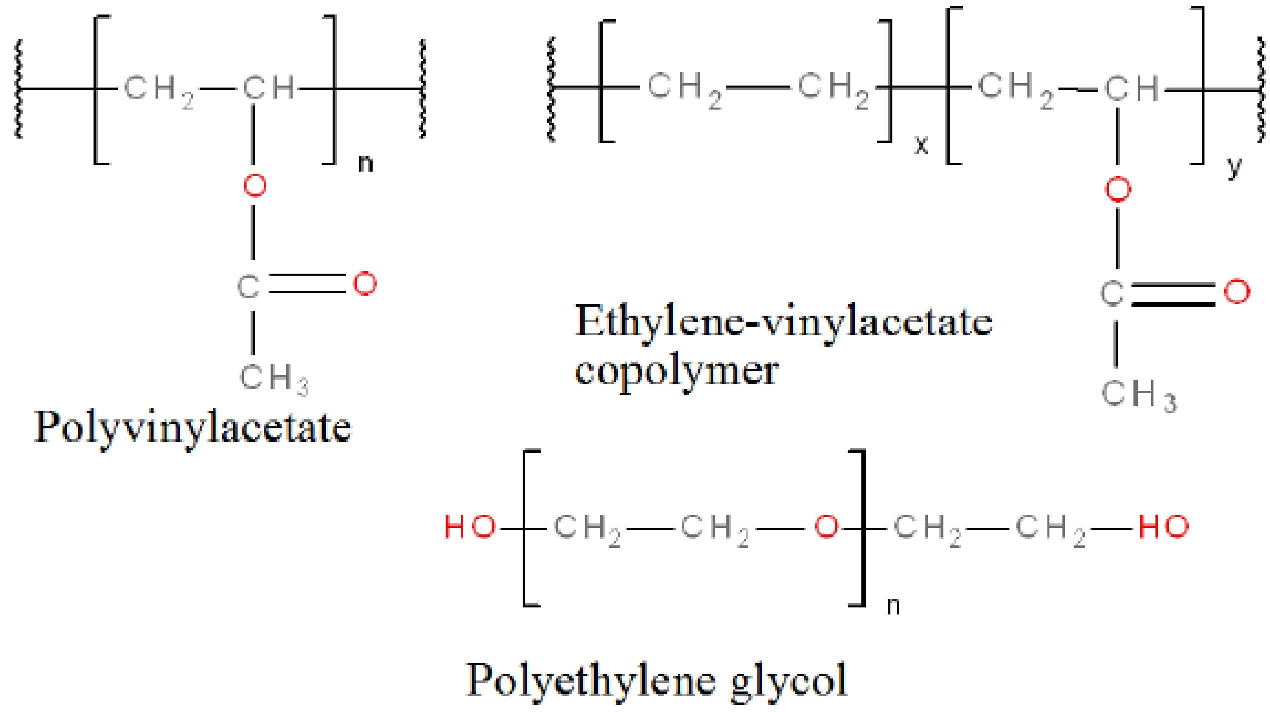
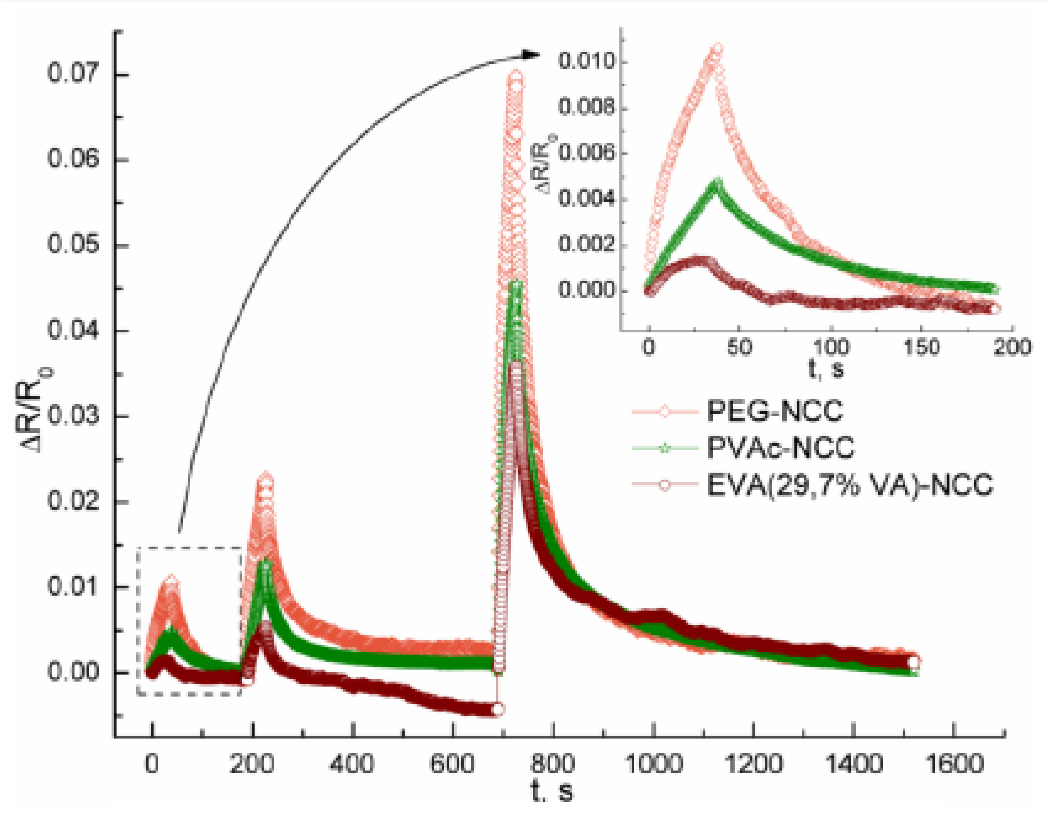


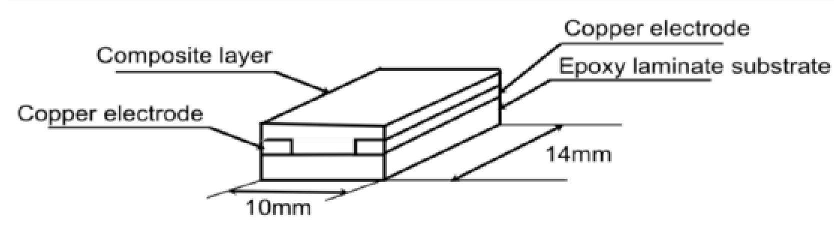
Figure 2. Chemical structure of PVAc, EVA and PEG.

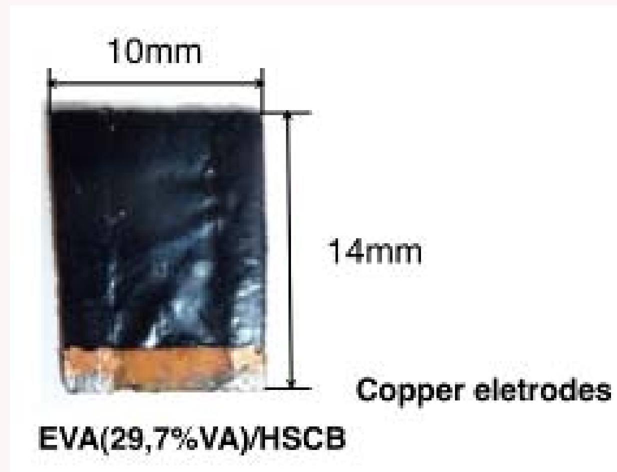
G.Sakale, M.Knite, V.Teteris, V.Tupureina, S.Stepina, E.Liepa, ***Central European Journal of Physics***, accepted 18. 10. 2010

Ethanol sensing effects in polyethylene glycol (PEG), polyvinilacetate (PVAc) and ethilene vinylacetate copolymer (EVA) / NC composites



Relative electrical resistance versus time of PEG-NCC (◇), PVAc-NCC (⋆) and EVA(29.7%VA)-NCC (○) in ethanol vapour with concentration 0.022 ml/l (1st peak), 0.043 ml/l (2nd peak) and 0.065 ml/l (3rd peak). Thickness of PEG-NCC layer 24 μm, PVAc-NCC - 20 μm, EVA(29.7%VA)-NCC - 108 μm.





Dispersion of 10 phr PRINTEX XE2 in chloroform liquid by US homogenizer.

G.Sakale, M.Knite, V.Teteris, V.Tupureina, S.Stepina, E.Liepa, ***Central European Journal of Physics***, accepted 18. 10. 2010

Ethanol sensing effects in polyethylene glycol (PEG), polyvinilacetate (PVAc) and ethilene vinylacetate copolymer (EVA) / NC composites

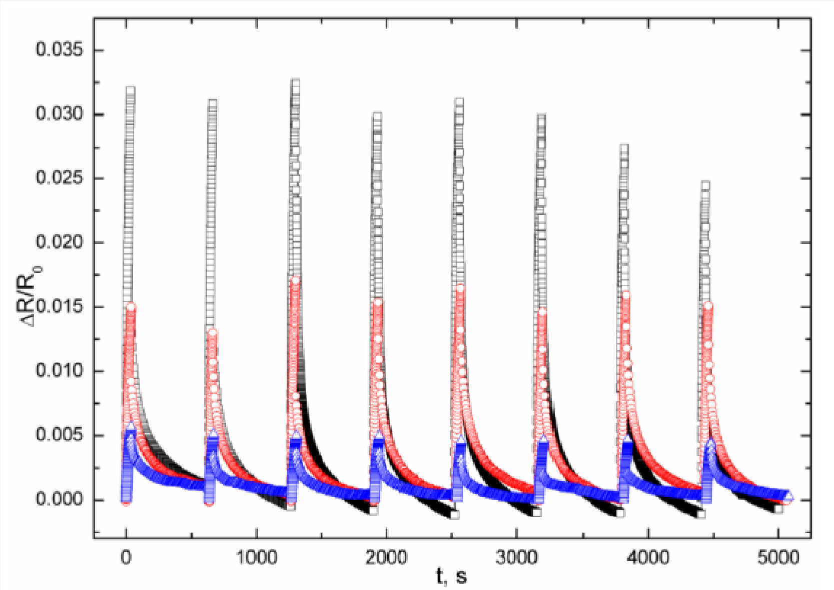


Figure 4. EVA(29.7%VA)-NCC (□), EVA(25.0%VA)-NCC (○) and EVA(11.6%VA)-NCC (Δ) relative electrical resistance change versus time in ethanol vapour (0.11 ml/l).

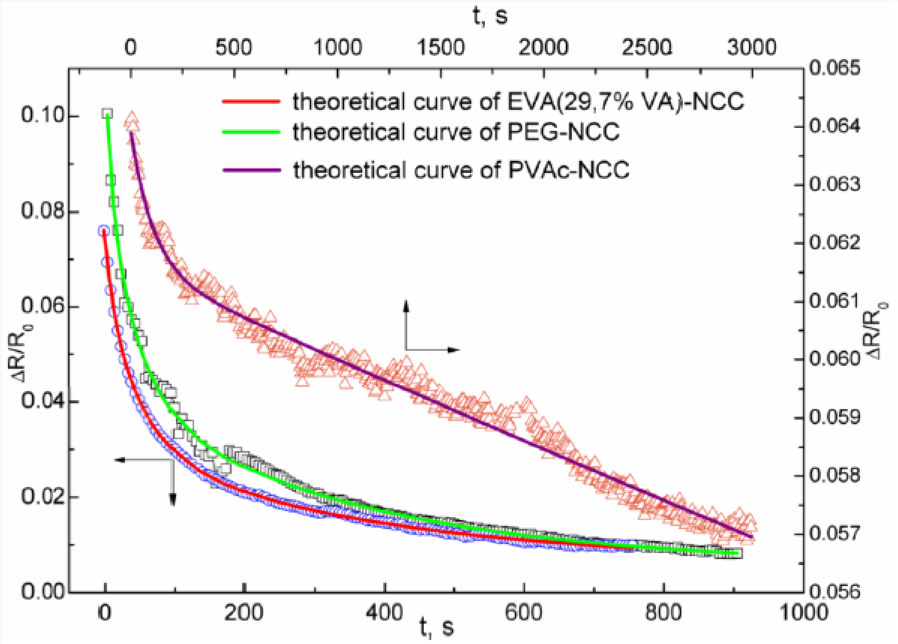


Figure 6. Electrical resistance relaxation of PVAc-NCC (Δ), EVA(29.7%VA)-NCC (○) and PEG-NCC (□) in air.

$$\Delta R / R_{0(t)} = \Delta R / R_{0(\infty)} + A_1 \cdot \exp\left(\frac{t}{\tau_1}\right) + A_2 \cdot \exp\left(\frac{t}{\tau_2}\right) + A_3 \cdot \exp\left(\frac{t}{\tau_3}\right)$$

τ_1 (etanola redifūzija) , τ_2 (polimēra virkņu relaksācija), τ_3 (nanostrukturētā C režģa relaksācija)

G.Sakale, M.Knite, V.Teteris, V.Tupureina, S.Stepina, E.Liepa, ***Central European Journal of Physics***, accepted 18. 10. 2010

Cent. Eur. J. Phys. • 1-6
Proofreading version

Central European Journal of **Physics**

The investigation of sensing mechanism of ethanol vapour in polymer-nanostructured carbon composite

Research Article

Gita Sakale[1]*, Maris Knite[1], Valdis Teteris[1], Velta Tupureina[2], Santa Stepina[1], Elina Liepa[1]

1 *Institute of Technical physics, Riga Technical University, Azenes street 14/24, Riga, LV-1048, Latvia*

2 *Institute of Polymer materials, Riga Technical University, Azenes street 14/24, Riga, LV-1048, Latvia*

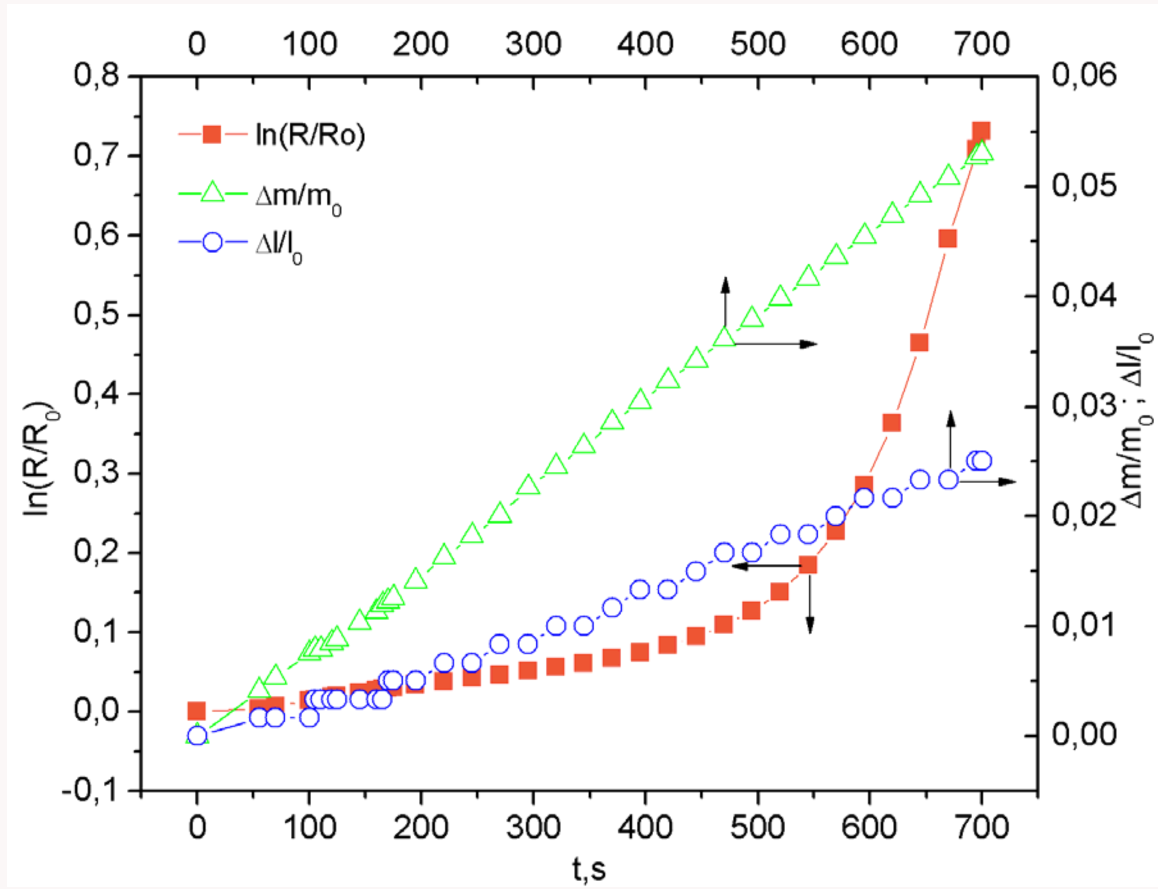
Received 19 July 2010; accepted 18 October 2010

Abstract: Polymer-nanostructured carbon composites (PNCC) using three different polymers as composite matrix

Saturs:

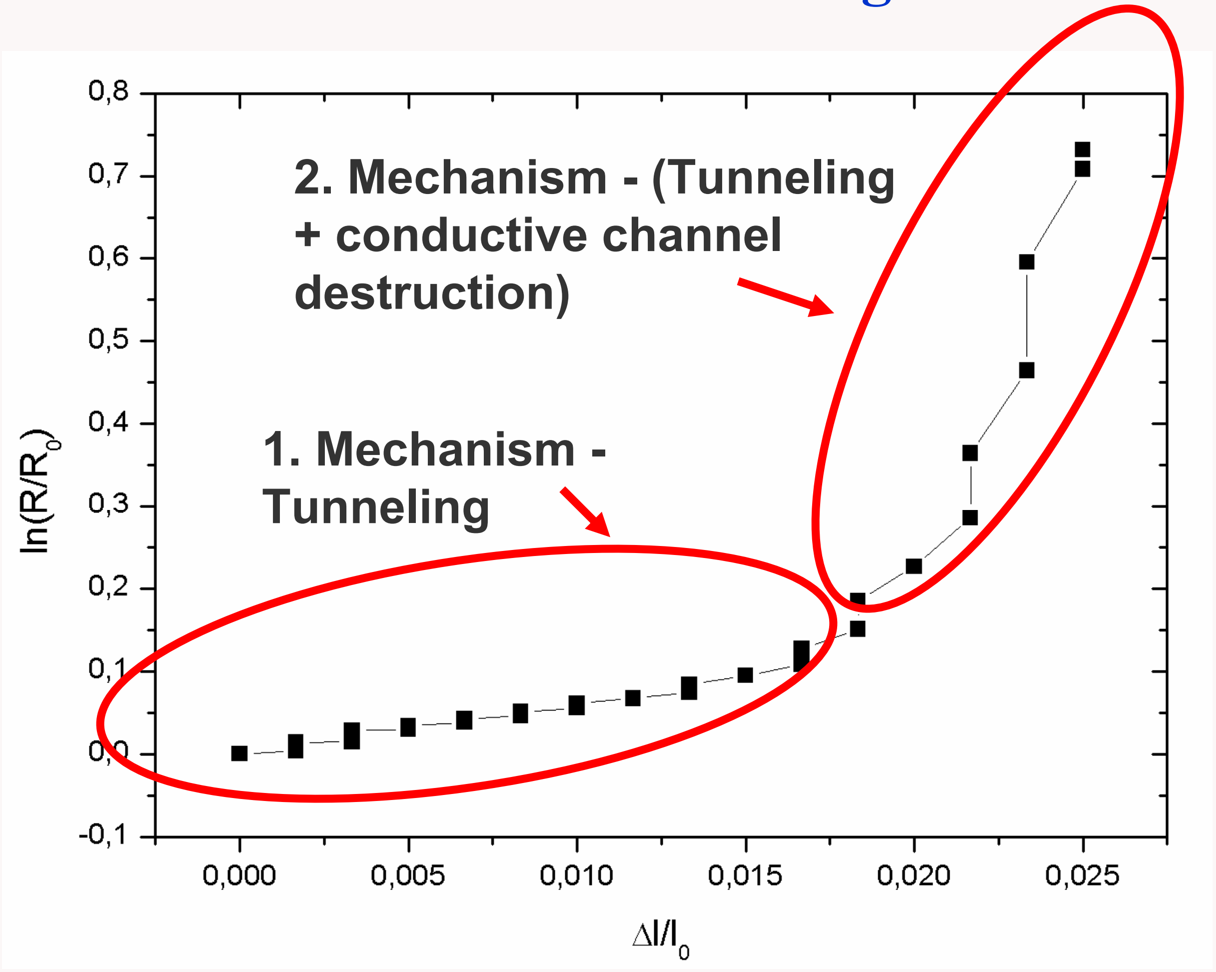
Some theoretical aspects of the effect of chemical sensing

To prove the developed theory of sensing effect in-situ electric resistance, mass and length change measurements were made



Polyisoprene/HSCB composite electric resistance, mass and length simultaneous change versus time in toluene vapour (concentration 595ppm).

The composite material electric resistance change mechanism in case of matrix swelling



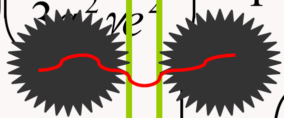
Electric resistance of the composite versus relative elogation of the composite, when it is held in toluene vapour (595ml/l) for 700 seconds.

The 1st electric resistance increase mechanism: tunneling current existence in the composite material

Tunneling effect in thin elastomer layers betveen CB aggregates can be described by:

Simplified swelling model

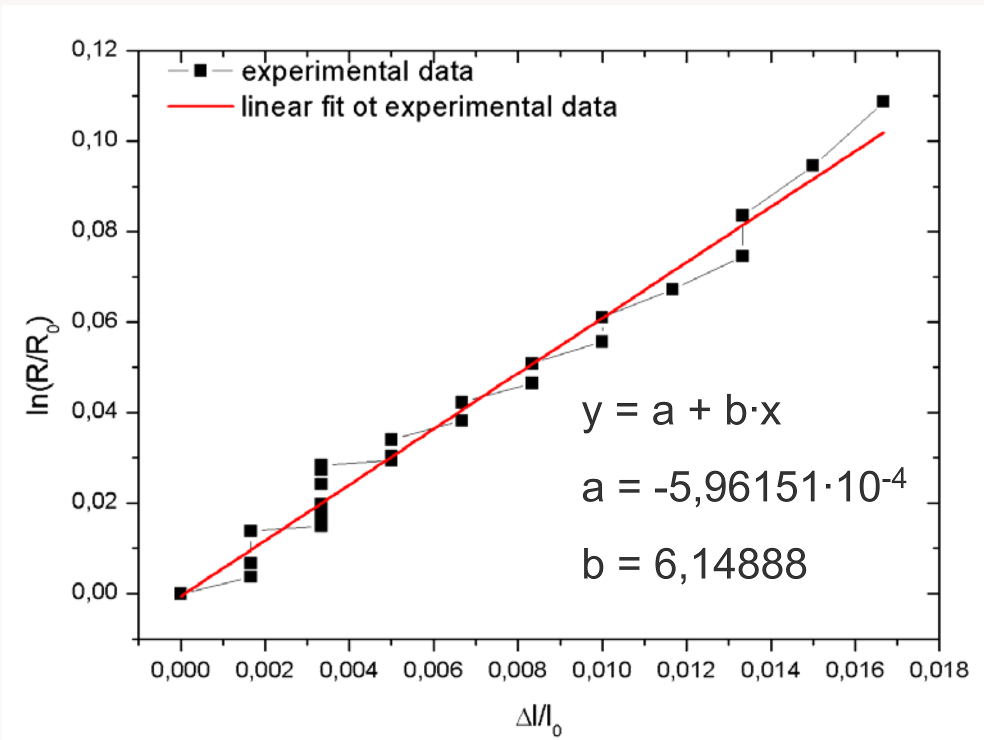
$$R = \left(\frac{L}{N}\right)\left(\frac{8\pi h s}{3a^2\gamma e^2}\right)\exp(\gamma s) \qquad \gamma = \frac{4\pi(2m\phi)^{0,5}}{h} \qquad \frac{R}{R_0} = \left(\frac{s}{s_0}\right)\exp[\gamma(s - s_0)]$$



$$s = s_0(1+\varepsilon) = s_0\left[1 + \left(\frac{\Delta l}{l_0}\right)\right]$$

$$\ln R = \ln R_0 + \ln\left[1 + \frac{\Delta l}{l_0}\right] + A_0\left[\frac{\Delta l}{l_0}\right]$$

at deformations $\Delta l/l_0 < 0,1$ tends to 0.



L – the number of particles forming a single conducting path

N – the number of conducting channels

h – Plank's constant

s – the least distance between conductive particle aggregates

s_0 – initial particle separation

a^2 – the effective cross-section, where tunneling occurs

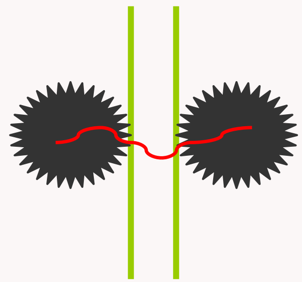
e – electron charge

R_0 – the initial resistance

Model is developed basing on *X.W.Zhang et al. J. of Polym. Sc. B, 38 (2000) p.2739-2749*

The 2nd electric resistance increase mechanism: tunneling + destruction of conductive channels

Simplified swelling model 2



The high rate of increase of R/R_0 at deformations ($\Delta l/l_0$) larger than 0,018 is related to destruction of the conducting network. The decrease of conductive channels is described by equation:

$$N = \frac{N_0}{\exp\left[A_1\left(\frac{\Delta L}{L_0}\right) + B\left(\frac{\Delta L}{L_0}\right)^2 + C\left(\frac{\Delta L}{L_0}\right)^3 + D\left(\frac{\Delta L}{L_+}\right)^4\right]} \rightarrow R = \left(\frac{n}{N}\right)\left(\frac{8\pi hs}{3a^2\gamma e^2}\right)\exp(\gamma s)$$

$$\rightarrow \ln R = \ln R_0 + \ln\left[1 + \frac{\Delta l}{l_0}\right] + A\left(\frac{\Delta l}{l_0}\right) + B\left(\frac{\Delta l}{l_0}\right)^2 + C\left(\frac{\Delta l}{l_0}\right)^3 + D\left(\frac{\Delta l}{l_0}\right)^4$$

Theoretical fit of experimental results of chemical sensing

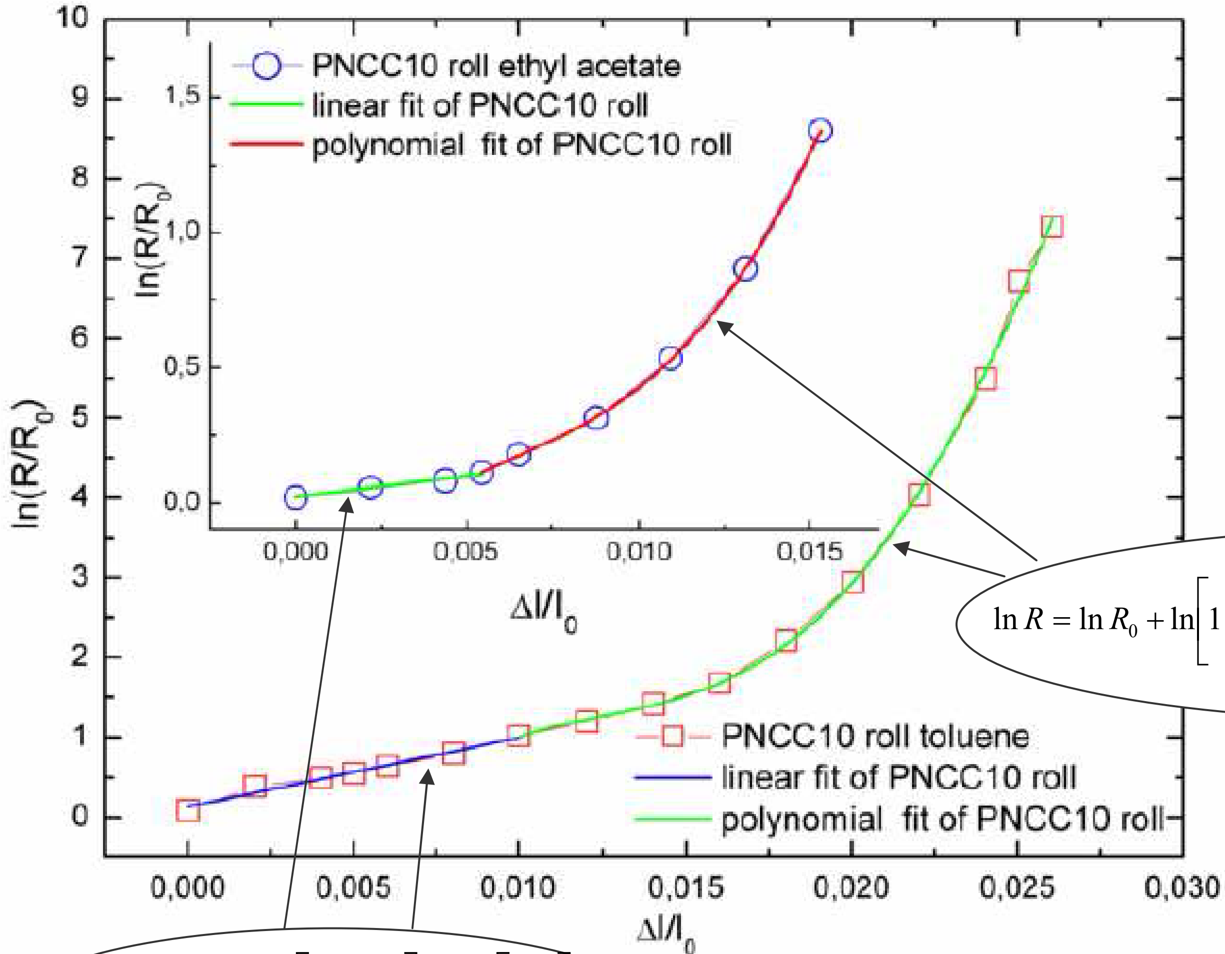


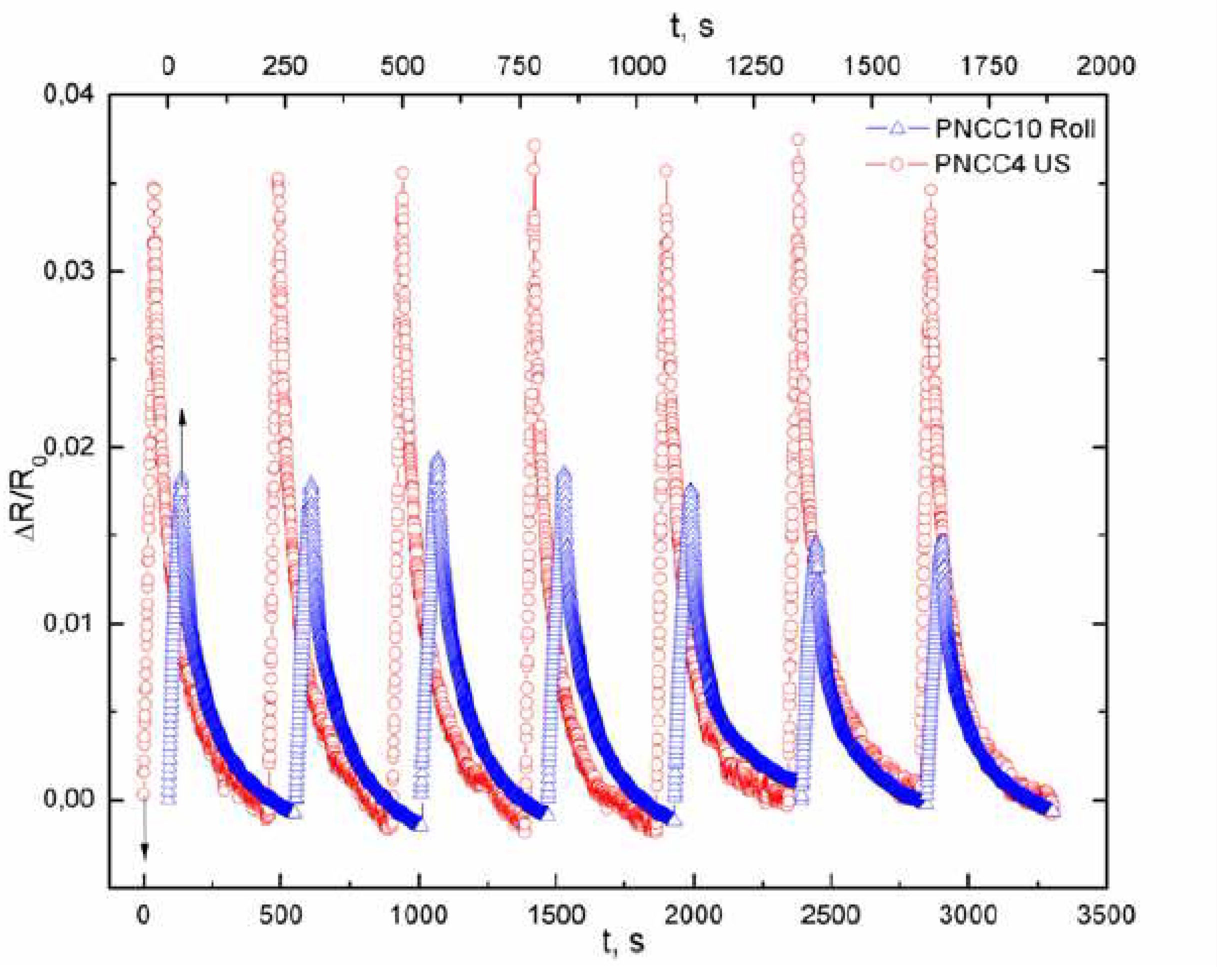
Fig.4. Electrical resistance increase (*ln(R/Ro)*) versus relative elongation (*Δl/lo*) of sample held in **toluene** and **ethyl acetate** vapour. Solid line denotes theoretical fitting of experimental data (symbol) by polynomial equation (line) .

$$\ln R = \ln R_0 + \ln\left[1+\frac{\Delta l}{l_0}\right] + A\left(\frac{\Delta l}{l_0}\right) + B\left(\frac{\Delta l}{l_0}\right)^2 + C\left(\frac{\Delta l}{l_0}\right)^3 + D\left(\frac{\Delta l}{l_0}\right)^4$$

$$\ln R = \ln R_0 + \ln\left[1+\frac{\Delta l}{l_0}\right] + A_0\left[\frac{\Delta l}{l_0}\right]$$

G.Sakale, M.Knite, V.Teteris,, ***Sensors and Actuators. A: Physical,*** iesniegts 19.08.2010

Improvement of repeatability of chemical vapor sensing

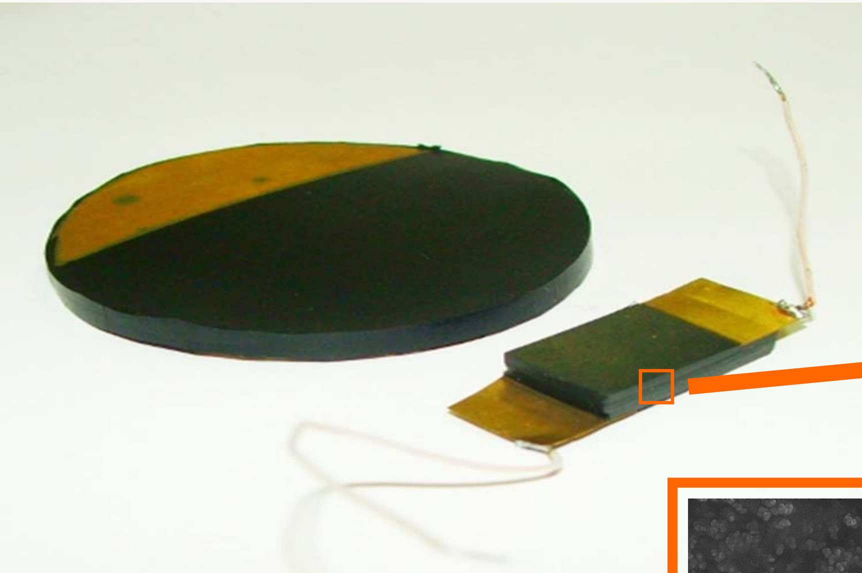


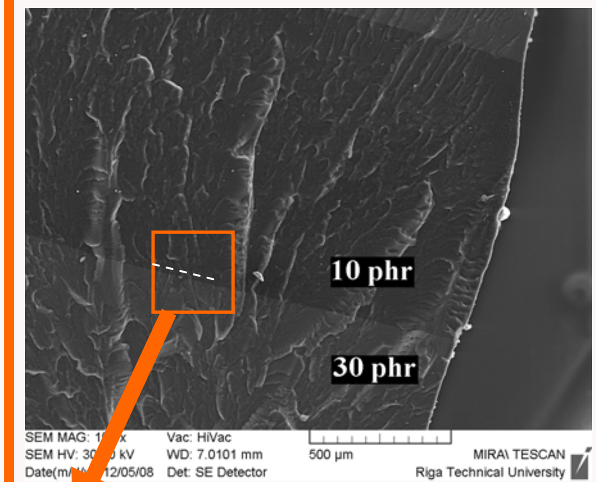
G.Sakale, M.Knite, V.Teteris,, ***Sensors and Actuators. A: Physical,*** iesniegts 19.08.2010

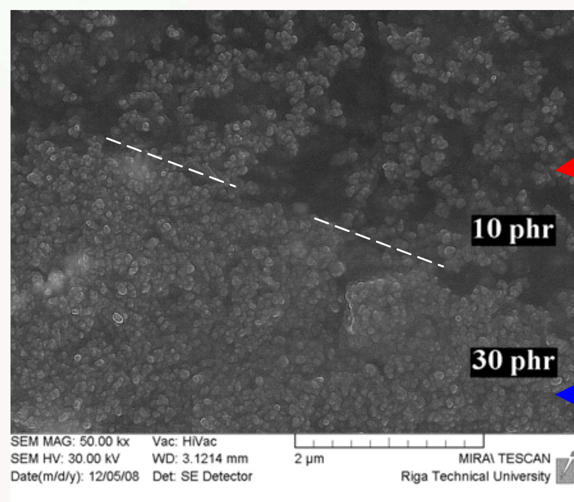
Saturs:

1. **Motivācija un daži principiāli jēdzieni**
2. **Spiedes deformācijas sensorefektu uzlabošana**
3. **Ķīmisko sensorefektu uzlabošana**
4. **Sensorefektu modeļa attīstīšana**
5. **Pilnībā superelastīgs spiedes sensors**
6. **Patenti un publikācijas**

Completely hyper-elastic pressure sensor





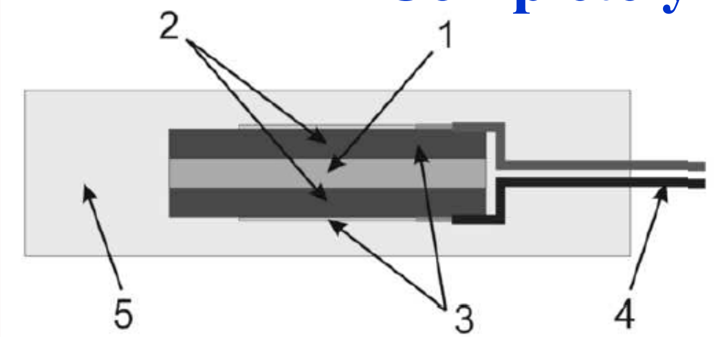


Piezoresistive composite

Electrode composite

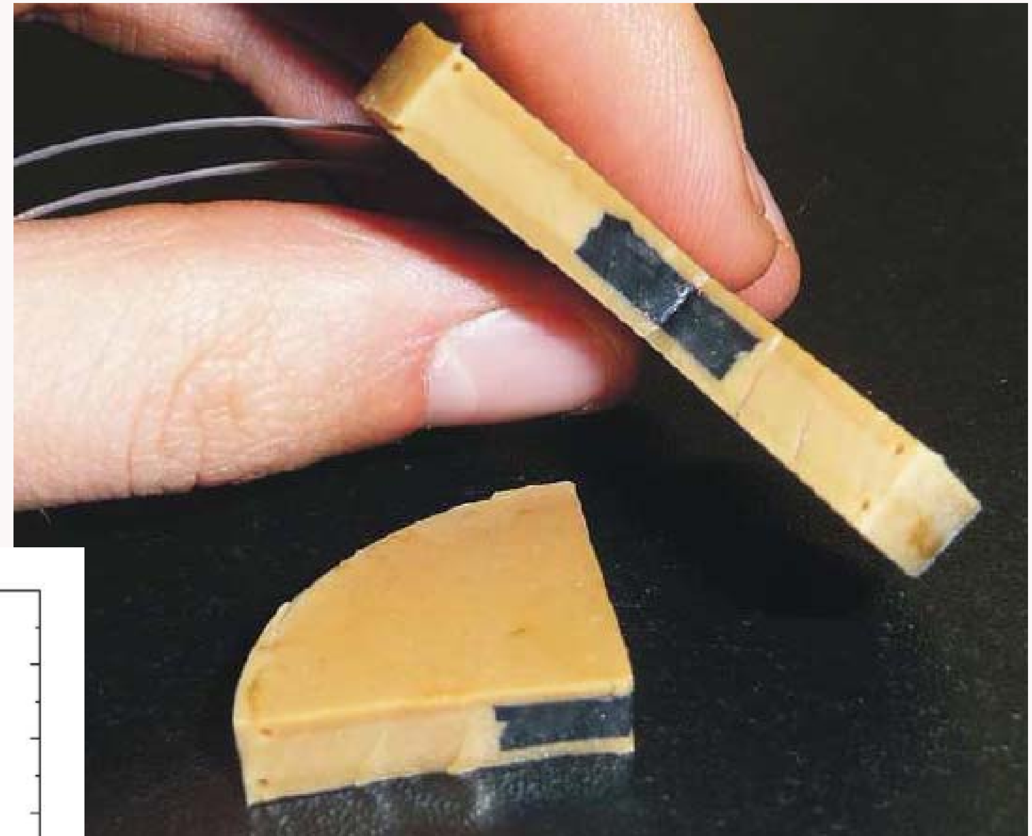
Patent of Latvia: Nr. 14085, J.Zavickis, M.Knite, G.Podins, 20.04.2010

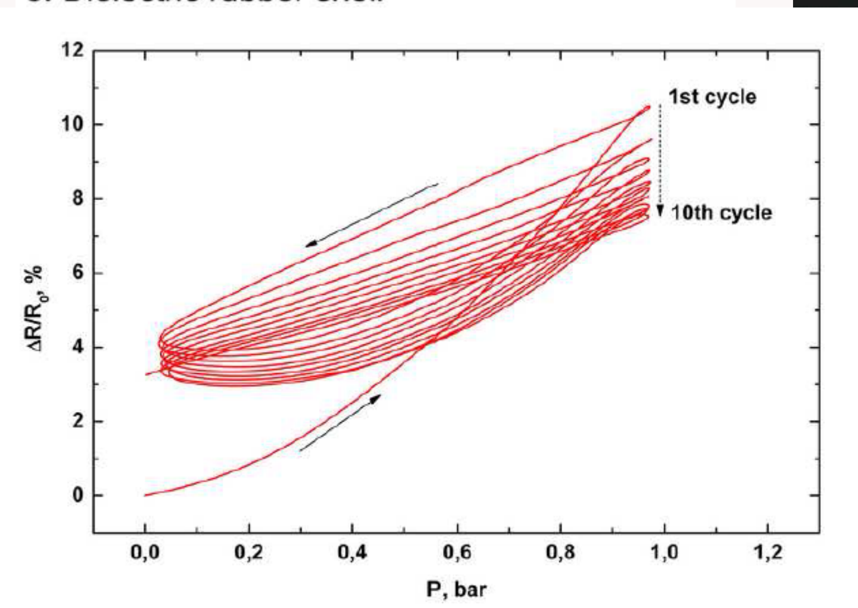
Completely hyper-elastic pressure sensor



Legend:

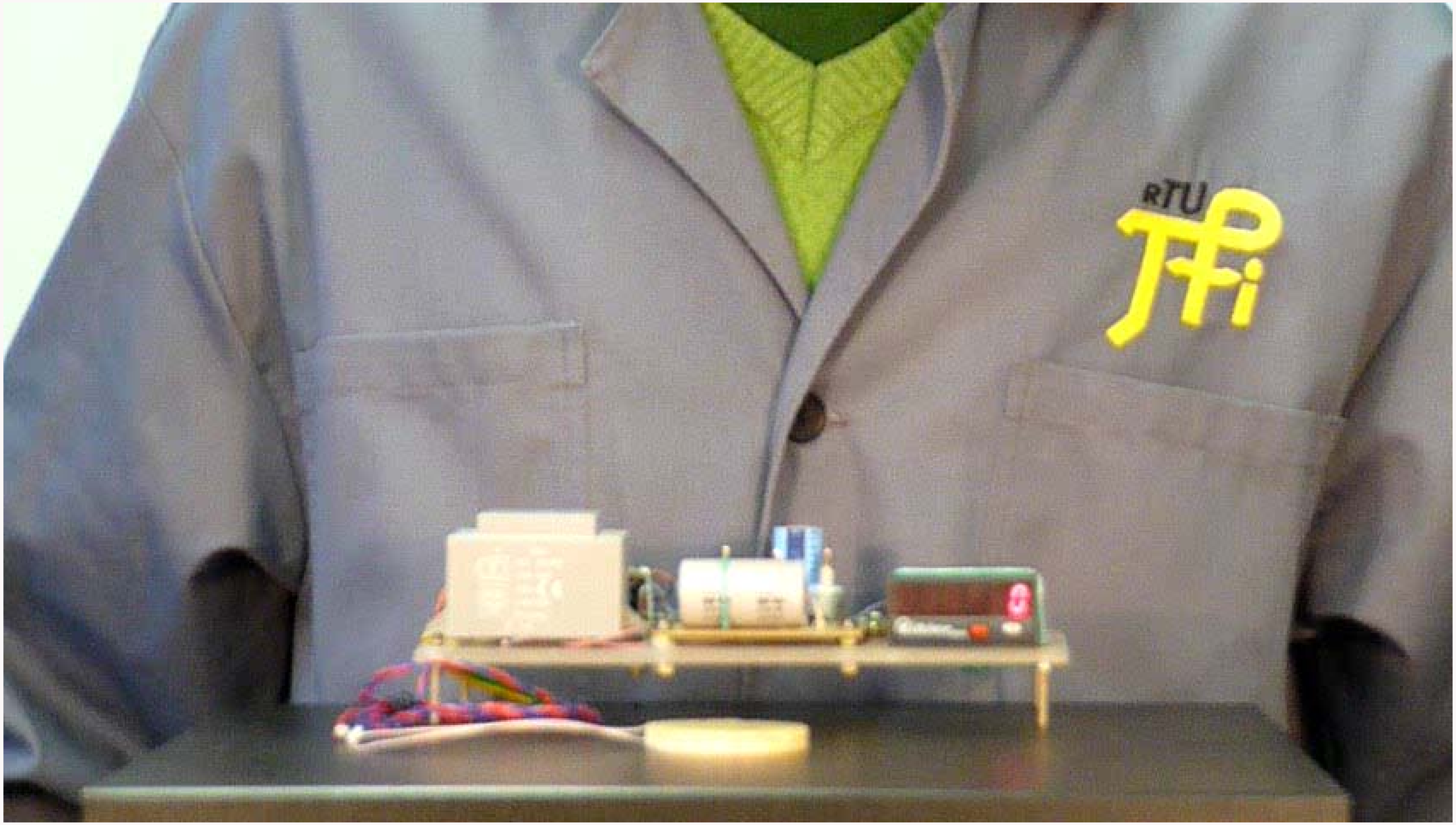
1. Piezoresistive layer of PNCC
2. Two electro-conductive layers of PNCC
3. Thin wire brass electrodes
4. Flexible cupper wire extensions
5. Dielectric rubber shell





Patent of Latvia: Nr. 14085, J.Zavickis, M.Knite, G.Podins, 20.04.2010

J.Zavickis, M.Knite, G.Podins, A.Linarts, R.Orlovs, ***Sensors and Actuators. A: Physical,*** iesniegts pēc revīzijas 18.11.2010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5. Pilnībā superelastīgs spiedes sensors
6. Patenti un publikācijas

Patenti un raksti (publicētie vai akceptētie)

1. Latvijas Patents Nr. 14085 „Viscaur superelastīgs spiediena sensorelements”, autori J.Zavickis, M.Knite, G.Podiņš. 2010

1. J.Zavickis, A.Linarts, M.Knite, The electrical percolation shift in polyisoprene – nenostructured carbon composites, Proceedings of scientific Conference of Young Scientists on Energy Issues 2010, Kaunas, Lithuania, May 27-28, 2010, p.408-415, ISSN 1822-7554
2. M.Knite, J.Zavickis, V.Teteris, A.Linarts, Polyisoprene – multi wall carbon nanotube composite structure for flexible pressure sensor application, , ***Journal of Nanoscience and Nanotechnology***, accepted 01.03.2010
3. G.Sakale, M.Knite, V.Teteris, V.Tupureina, S.Stepina, E.Liepa, The investigation of sensing mechanism of ethanol vapour in polymer-nanostructured carbon composite, ***Central European Journal of Physics***, accepted 18. 10. 2010
4. J.Zavickis, M.Knite, K.Ozols, G.Malefan, Development of percolative electroconductive structure in piezoresistive polyisoprene-nanostructured carbon composite during vulcanisation, ***Materials Science & Engineering C***, accepted 12.11.2010.
5. (M.Knite, J.Zavickis, Prospective polymer composite materials for applications in flexible tactile sensors (*chapter No. 7 in book “**Contemporary robotics – challenges and solutions**”),* In-Teh, India: **2009**, p.99-128. ISBN 978-953-307-038-4)

Patenti un raksti (pieņemtie vai iesniegtie)

1. J.Zavickis, M.Knite, G.Podins, A.Linarts, R.Orlovs Polyisoprene – nanostructured carbon composite – a soft alternative for pressure sensor application, ***Sensors and Actuators. A: Physical***, iesniegts pēc revīzijas 18.11.2010
2. M.Knite, G.Sakale, V.Teteris, Diffusion, swelling and electrical properties of polyisoprene/multiwall carbon nanotube composites in organic solvent vapours, ***Journal of Nanoscience and Nanotechnology***, pieņemts publicēšanai 19.11.201, jāveic revīzija
3. G.Sakale, M.Knite, V.Teteris, Polyisoprene-nanostructured carbon composite (PNCC) organic solvent vapour sensitivity and repeatability, ***Sensors and Actuators. A: Physical,*** iesniegts 19.08.2010

Konferenču tēzes

1. J.Zavickis, M.Knite, K.Ozols, A.Linarts, G.Malefan, The polyisoprene – nanstructured carbon composite as flexible pressure sensor materials – properties and practical applications. Abstracts of International Conference **“Functional materials and nanotechnologies 2010”, Riga, Latvia, March 16 – 19, 2010, 72**
2. G.Sakale, M.Knite, V.Teteris, The investigation of organic solvent vapour sensing mechanism of polymer-nanostructured carbon composite. Abstracts of International Conference “Functional materials and nanotechnologies 2010”, Riga, Latvia, March 16 – 19, 2010, 73
3. J.Zavickis, M.Knite, G.Podins, A.Linarts, R.Orlovs, Polyisoprene – nanostructured carbon composite – a soft pressure sensor alternative, Abstracts of **E-MRS Spring Meeting 2010, Strasbourg, France, June 7-11, 2010**, A-3/A0
4. G.Sakale, M.Knite, V.Teteris, J.Zavickis, Polyisoprene nanostructured carbon composite (PNCC) organic solvent vapour sensitivity and repeatability, Abstracts of E-MRS Spring Meeting 2010, Strasbourg, France, June 7-11, 2010, A-3/A0
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6. Sakale G., Knite M., Teteris V, Sensing element performance analyses using in-situ measurements of electric resistance, mass and the sample length change, Abstracts of **20th Anniversary World Congress on Biosensors 2010. May, Great Britain, Glasgow. P1.7.007.**
7. M.Knite, G.sakale, V.Teteris, Electrical, Swelling and Diffusion Properties of Polyisoprene/Multiwall Carbon Nanotube Composites in Atmosphere of Organic Solvent Vapours. Abstract book of the **6th International Conference on Diffusion in Solids and Liquids (DSL 2010), Paris, France, July 5-7, 2010**, 176
8. G.Sakale, M.Knite, V.Teteris, Filler dispersion method effect on polyisoprene-nanostructured filler composite (PNFC) vapour sensitivity, Digest of the **9th International Conference on Global Research and Education (Inter-Academia 2010), Riga, Latvia, August 9-12, 2010**, 170-171
9. J.Zavickis, M.Knite, K.Ozols, A.Linarts, R.Orlovs, V.Teteris, V.Tupureina, Piezoresistive rubber nanocomposites for pressure sensing, Digest of the 9th International Conference on Global Research and Education (Inter-Academia 2010), Riga, Latvia, August 9-12, 2010, 202-203
10. M.Knite, I.Aulika, A. Mrzel, A.Fuith, J.Zavickis, G.Sakale, A.Linarts, M.Dunce, Polyisoprene composites with conductive tubular nanostructures for multifunctional sensing: fabrication and properties, Abstracts of **1st COINAPO Topical Meeting “Polymer composites with inorganic tubular nanomaterials Fabrication. Properties and Technical Applications, Zaragoza, Spain, 25th -26th of October,** 2010, 27

Dalība komercializācijas pasākumos

Latvijā patentētais “Pilnībā superelastīgais spiediena sensors” prezentēts:

Izstāde-gadatirgus **„Ražots Latvijā 2010”**,
25.-27.03.2010. Rīgā, Olimpiskajā Sporta centrā.

3 rd Commercializetion Reactor, 9-11.11.2010., Riga Latvia, supported by *Latvian Agency of Investigations and Development, Virtual CEO Ltd, Air Baltic, Baltic International Bank, Swedbank and Riga City Council*. http://www.tvnet.lv/online_tv/8866

Starptautiskā izstāde **„Tech Industry 2010”** 25-27.11.2010., Rīgā, Starptautiskajā izstāžu centrā Ķīpsalā

Aizstāvētie bakalaura darbi:

1) **Artis Linarts**, *„Poliizoprēna – nanostrukturēta oglekļa kompozītu elektrovadāmības perkolācijas parametru izmaiņas atkarībā no oglekļa disperģēšanas metodes."* 2010. , vadītāji: Juris Zavickis; M.Knite

2) **Juris Adams**, *„Ultraskaņas homogenizētāja iedarbība uz poliizoprēna - nanostrukturēta oglekļa kompozīta elektriskajām īpašībām"*. 2010. , vadītāji: Juris Zavickis; M.Knite

Tiek izstrādāti promocijas darbi:

1) **Juris Zavickis**, "*Multifunkcionālu elastomēra – nanostrukturēta oglekļa kompozītu izstrāde un fizikālo īpašību izpēte*", vadītājs M.Knite

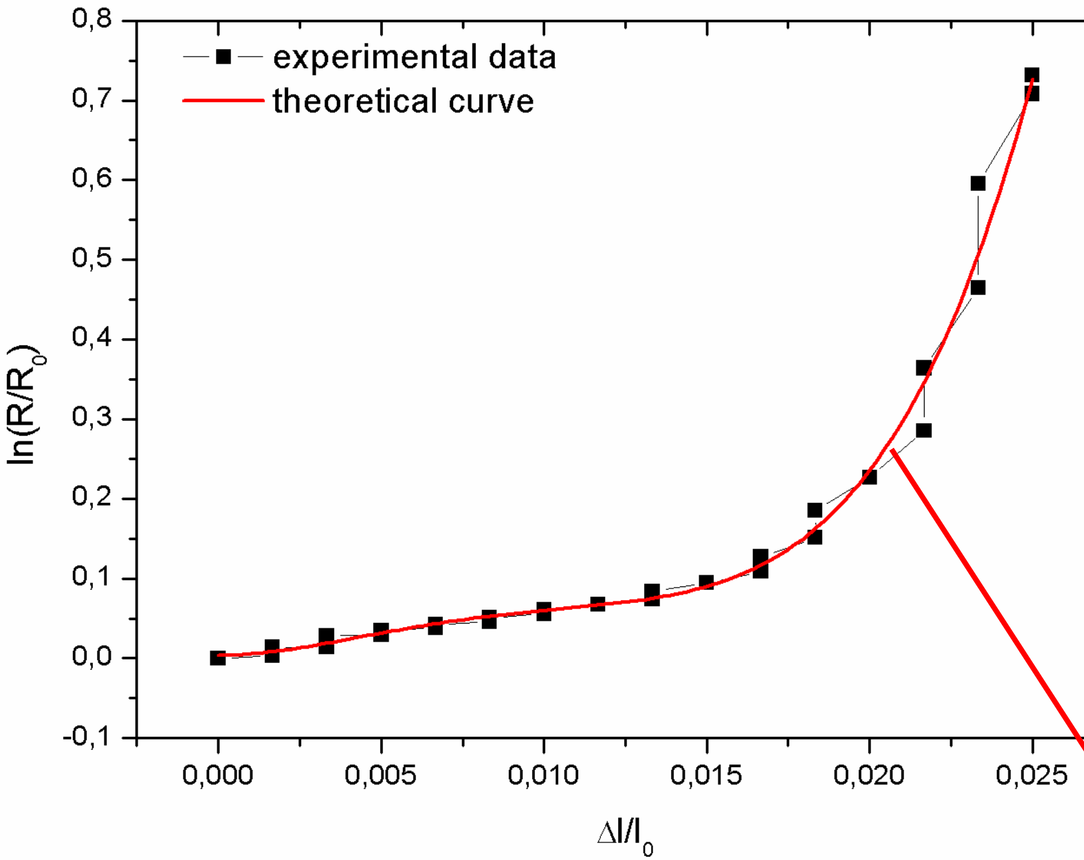
2) **Gita Šakale**, "*Ķīmisko sensoru materiālu izstrāde un īpašību izpēte*", vadītājs M.Knite

3) **Kaspars Ozols**, "Polimēra/neorganisku nanodaļiņu kompozītu elektriskās un optiskās īpašības", vadītājs M.Knite

Visi trīs doktoranti saņem stipendijas **RTU ESF** projekta ietvaros:
Nr.2009/0144/1DP/1.1.2.1.2/09/IPIA/VIAA/005 *„Atbalsts RTU doktora studiju īstenošanai"*

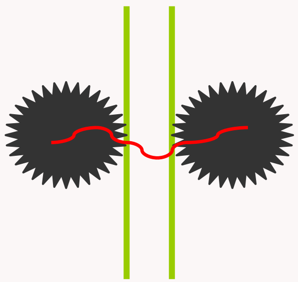
Paldies par uzmanību!

The 2nd electric resistance increase mechanism: tunneling + destruction of conductive channels



Electric resistance change vs. relative elongation.

Simplified swelling model 2



The high rate of increase of R/R_0 at deformations ($\Delta l/l_0$) larger than 0,018 is related to destruction of the conducting network and can be well described by equation:

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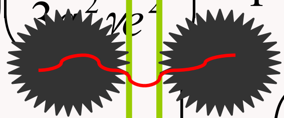

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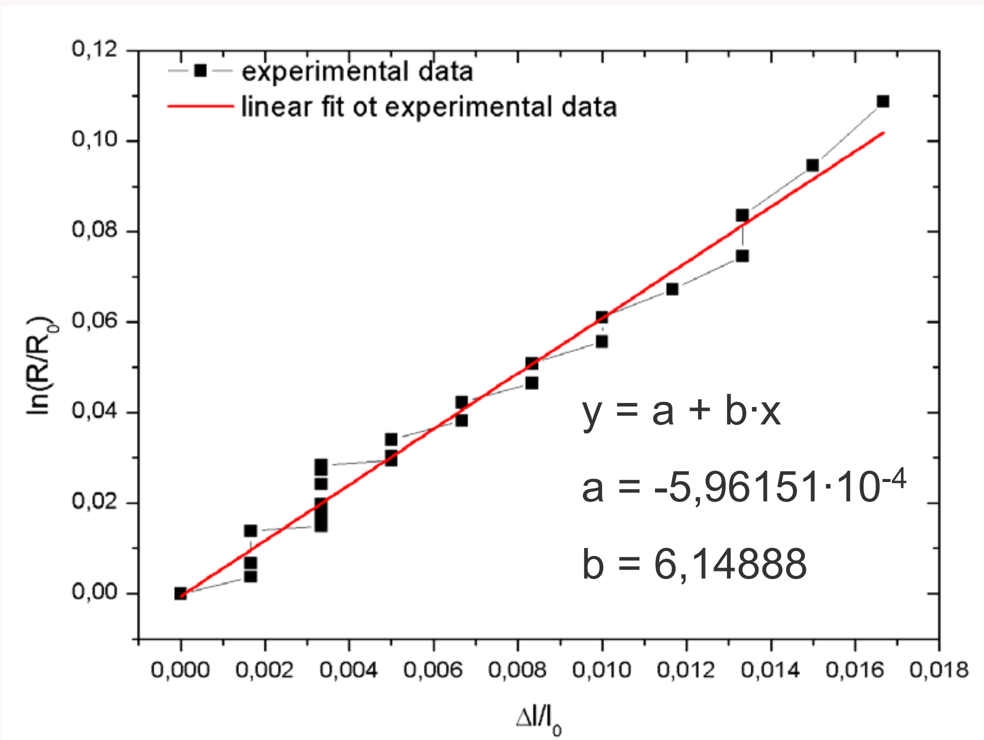

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