Fabrication and application of 3D force sensors based on piezoelectric and piezoresistive effects

János Radó

MTA EK MFA MEMS labratory

First semester

Supervisor: Csikósné Papp Andrea Edit

Introduction

3 part of my work

- *Piezoresistive 3D force sensors*
- *Piezoelectric ZnO nano-rods*
- *Piezoelectric AlN thin films*

Piezoresistive 3D force sensors

Applications

- *Integration in a surgery robot's laparoscope*

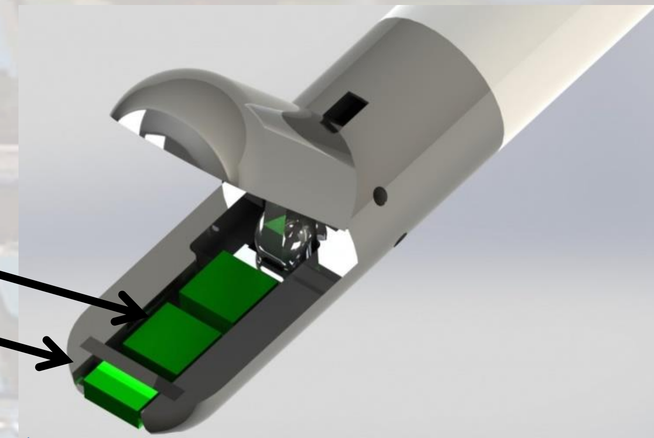
- *Integration in a vehicle tyre*

Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Means

Measurement and online feed-back of

-gripping force inside the tweezer head
- tactile sensing at the tip of the tool



Piezoresistive 3D force sensors - Integration in a laparoscopic tool

3D force sensor chip

Specific requirements:

- Reduced size (down to $1x1mm^2$) to enable integration
- Sensitivity: 1-20N for gripping force, 10-1000mN for tactile sensing
- Robustness (vs. sensitivity)
- Biocompatible coating can withstand sterilization

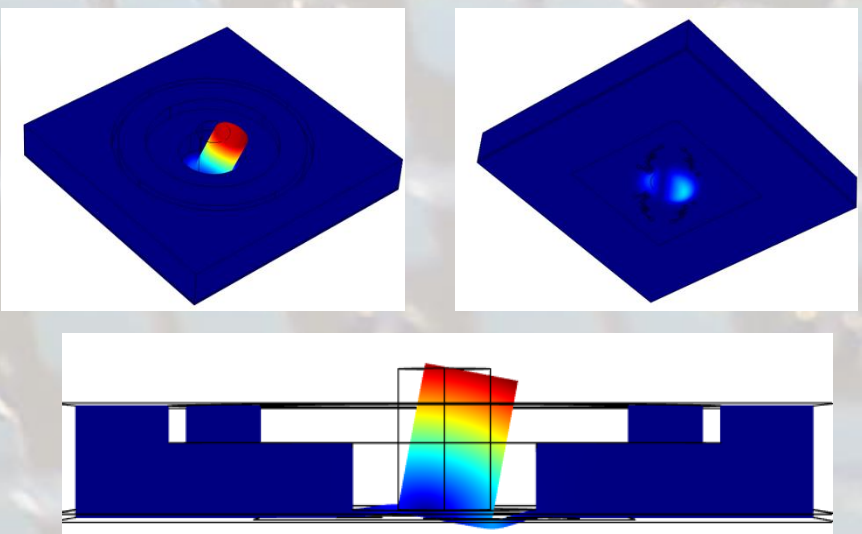
Operation:

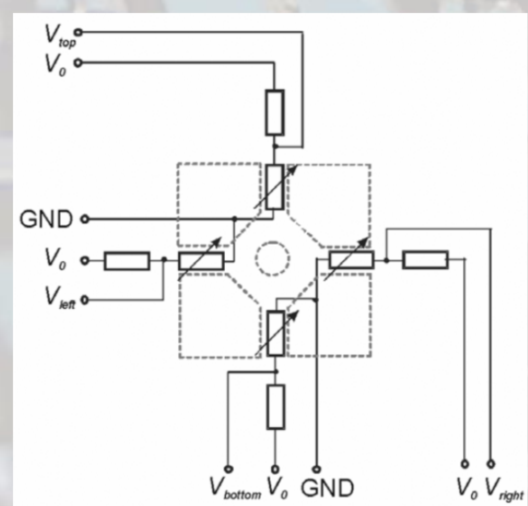
- Deforming c-Si membrane
- 4 embedded piezorezistors
- 4 Voltage dividers or Wheatstone-bridges
- Calculation of vectorial components:

$$F_x = \frac{1}{V_0 \alpha_{ls} \pi_{44}} \left(\Delta V_{right} - \Delta V_{left} \right),$$

$$F_y = \frac{1}{V_0 \alpha_{ls} \pi_{44}} \left(\Delta V_{top} - \Delta V_{bottom} \right),$$

$$F_z = \frac{1}{V_0 \alpha_{ln} \pi_{44}} \frac{\left(\Delta V_{left} + \Delta V_{right} + \Delta V_{top} + \Delta V_{bottom} \right)}{2}$$

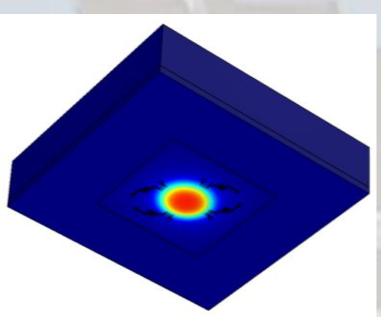


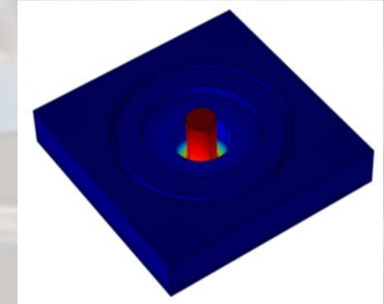


Piezoresistive 3D force sensors - Integration in a laparoscopic tool

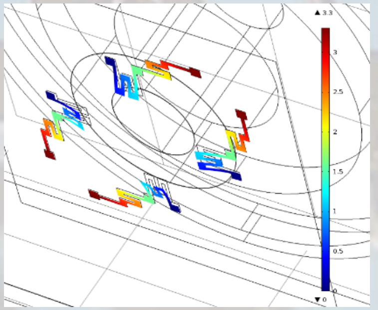
Previous work

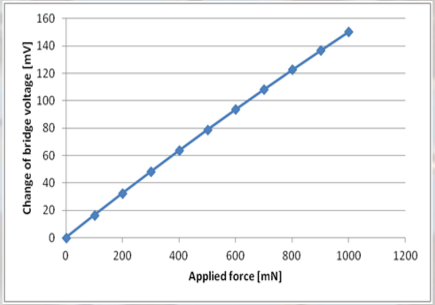
- Design



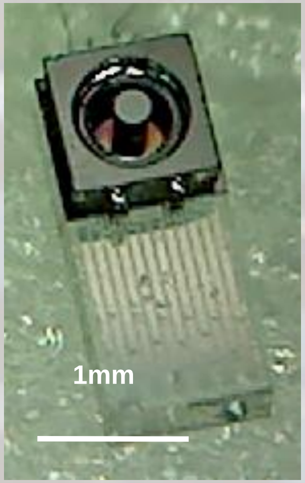


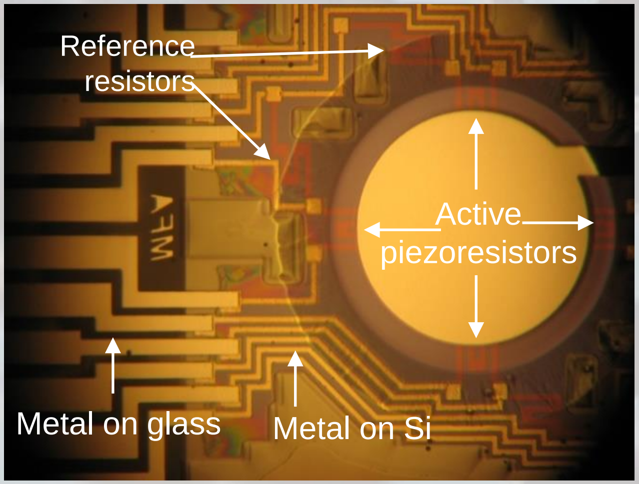
- Simulation





- Fabrication

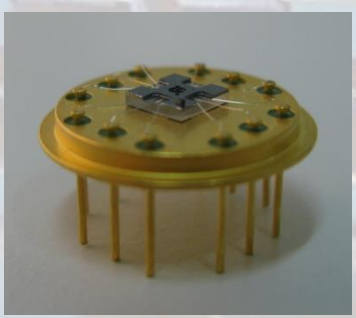




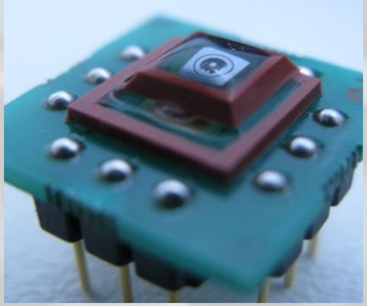
Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Current work

- Bare sensor for testing

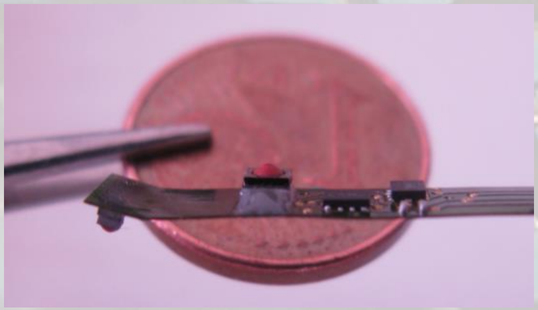


- Covered sensor for testing



- Test device of circuit functionality

- Final PCB



Piezoresistive 3D force sensors - Integration in a laparoscopic tool

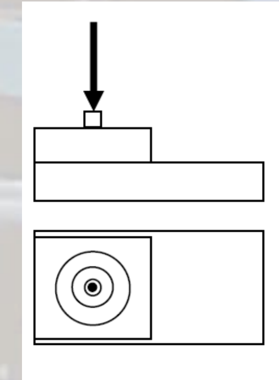
Current work

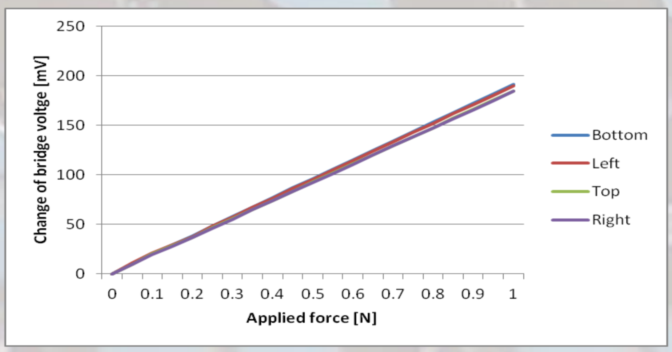
- Measurements

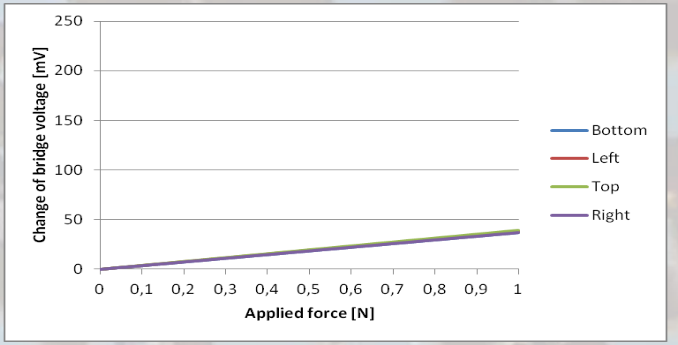
Effect of membrane thickness

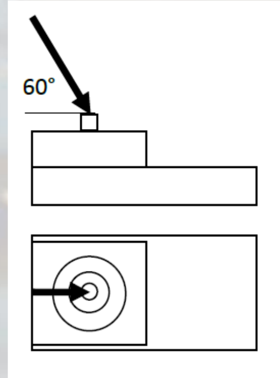
20 µm

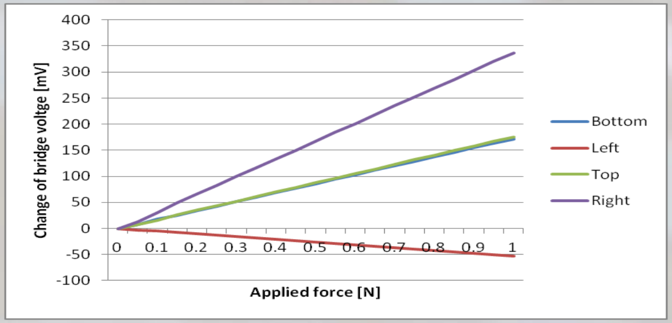
50 µm

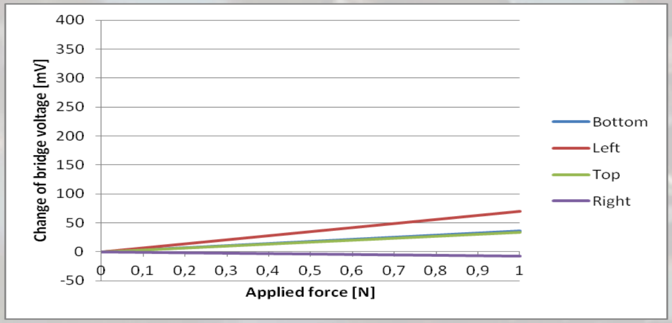












Piezoresistive 3D force sensors - Integration in a laparoscopic tool

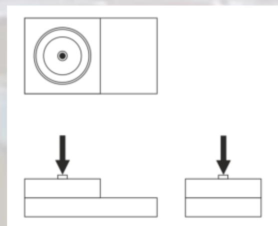
Current work

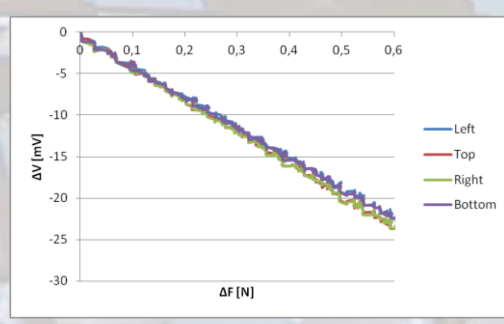
- Measurements

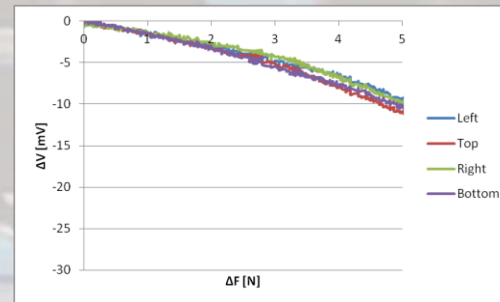
Effect of elastic coating

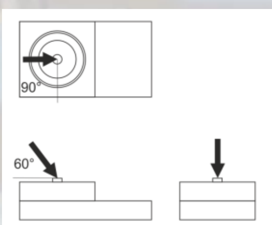
Bare sensor

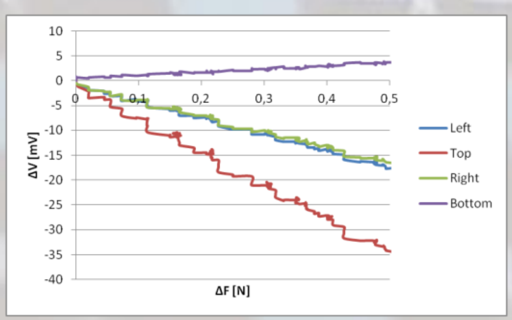
Covered sensor

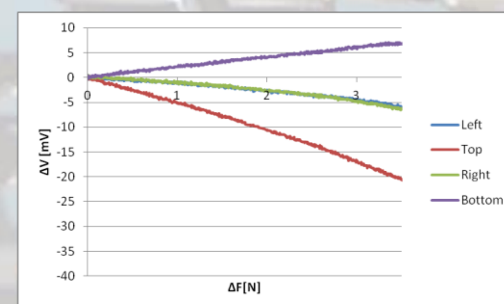


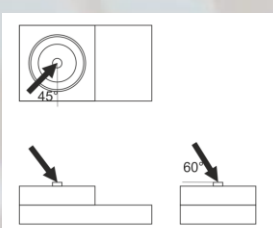


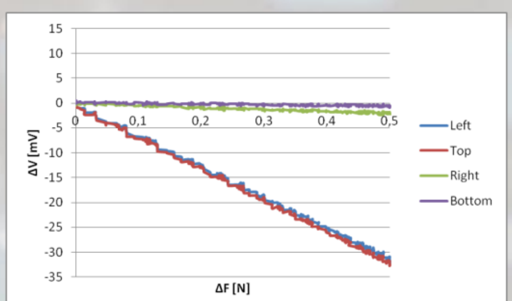


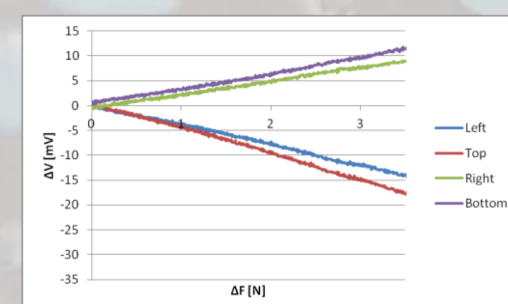








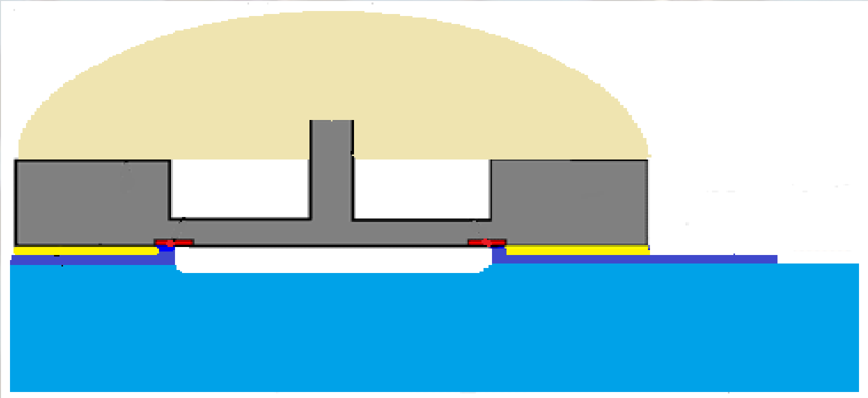


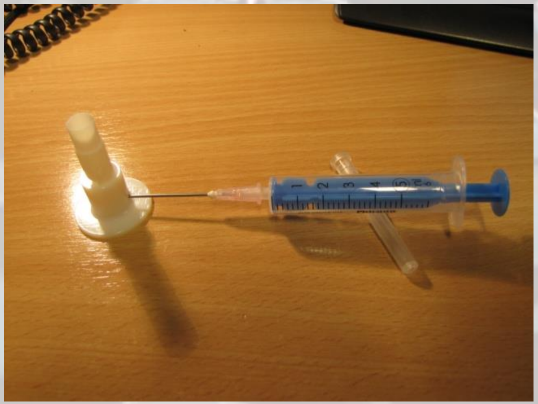


Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Future work

- Integration of the final PCB in a 3D printed tweezers
- Covering of the tool
- Further measurements





Piezoresistive 3D force sensors - Integration in a laparoscopic tool

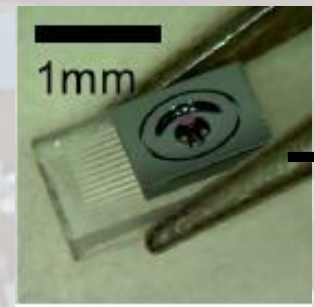
Publications in this topic

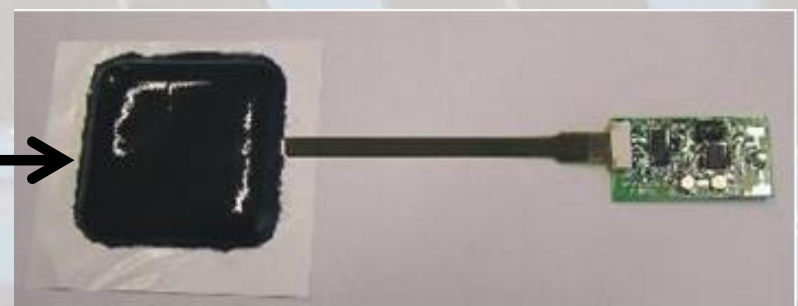
- János Radó, Csaba Dücső, Gábor Battistig, Gábor Szebényi, Zbigniew Nawrat, Kamil Rohr, Péter Fürjes: **3D force sensors for laparoscopic surgery tool,** DTIP 2016, oral presentation in English **(my own presentation)**
- Kamil Rohr, Lukasz Mucha, Péter Fürjes, János Radó, Csaba Dücső, Péter Földesy, Gábor Szebényi, Zbigniew Nawrat: **Robin Heart Force Feedback/Control,** MEDICAL ROBOTS 2015, oral presentation in English
- Radó János, Dücső Csaba, Battistig Gábor, Fürjes Péter: **3D mikro-erőmérő sebészrobot alkalmazáshoz,** ORSZÁGOS ANYAGTUDOMÁNYI KONFERENCIA 2015, poszter szekció, magyar nyelvű Covering of the tool **(my own presentation)**

Piezoresistive 3D force sensors - Integration in a vehicle tyre

Current work

- Implantation of 3D force sensor in a special rubber



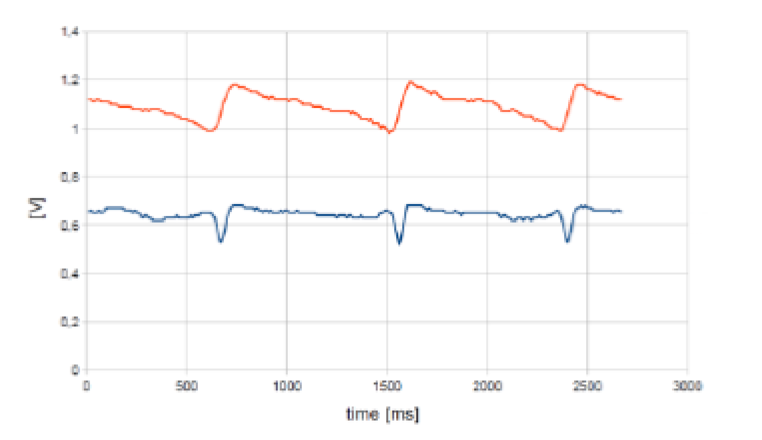


- Integration of test tool in a vehicle tyre

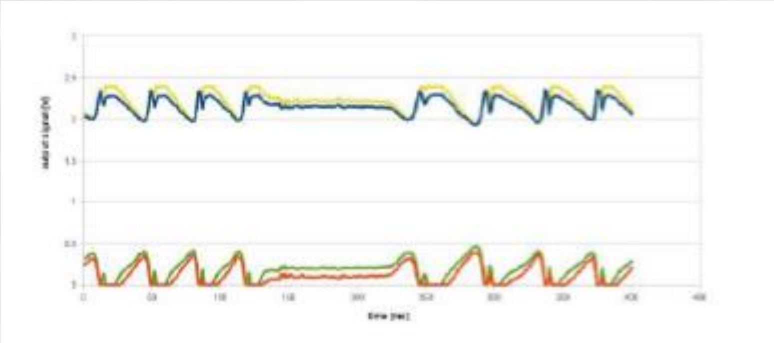
Piezoresistive 3D force sensors - Integration in a vehicle tyre

Current work

- Measurements – normal road conditions



- Measurements – the wheel is blocked



Piezoresistive 3D force sensors - Integration in a vehicle tyre

Future work

- Building a special test station
- More tests in real circumstances

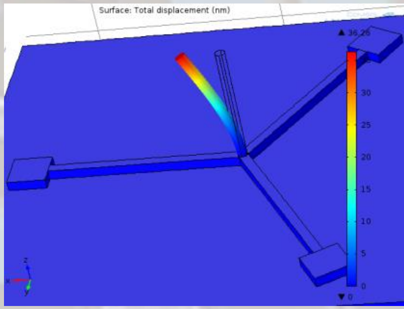
Publications in this topic

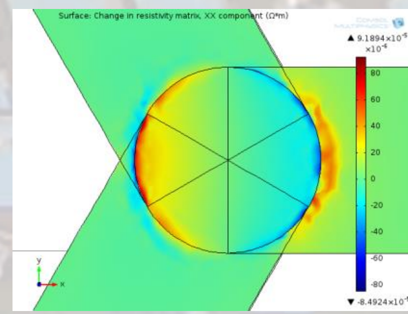
- J. Radó, G. Battistig, S. Kuliniy, R. Végvári, I. Bársony: **Monitoring the tyre deformation on a vehicle on the run,** EUROSENSORS 2016, oral presentation in English **(my own presentation)**

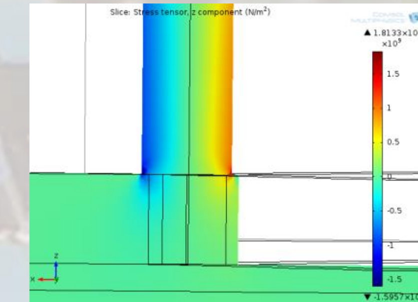
Piezoelectric ZnO nano-rods

Curent work

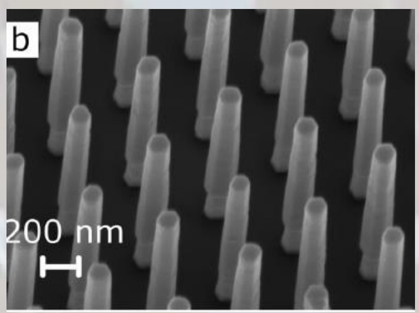
- Simulation

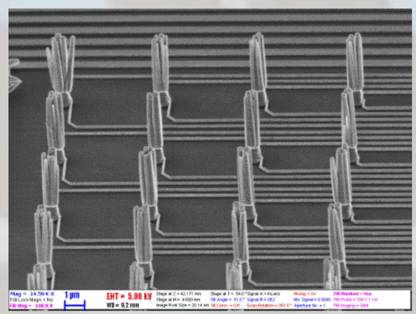


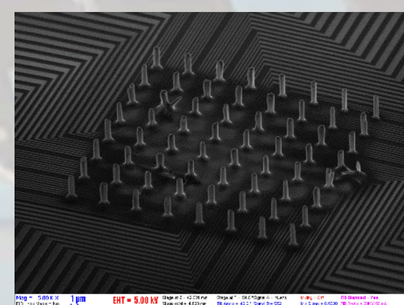




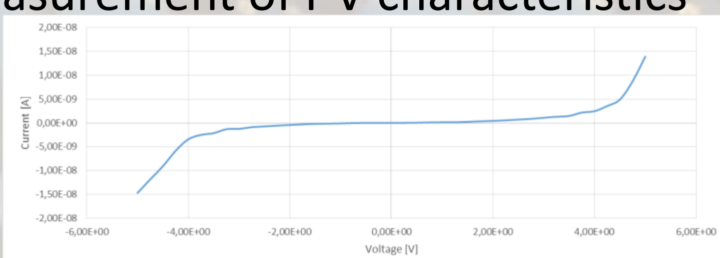
- Growing of the rods (hydrothermal growing: Zinc-nitrate hexahydrate and hexamethylen tetramin)

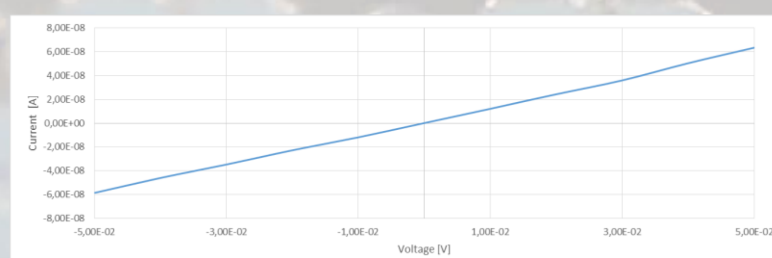






- Measurement of I-V characteristics

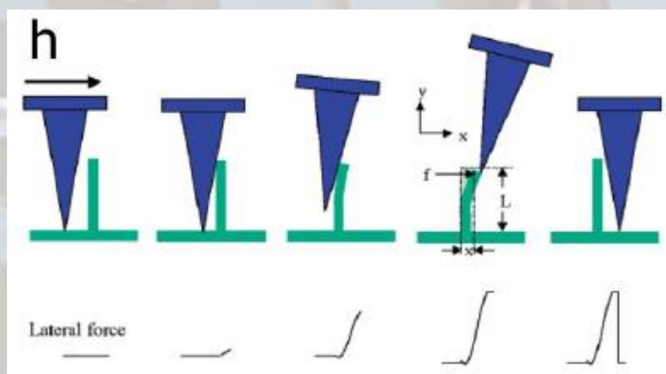


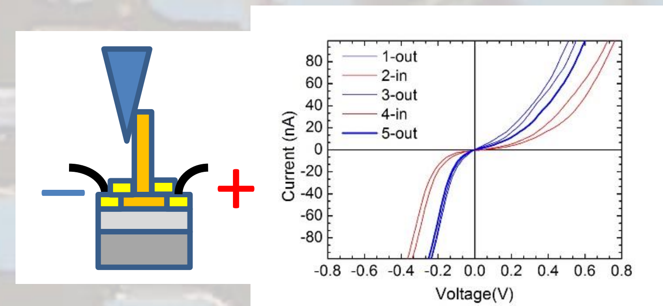


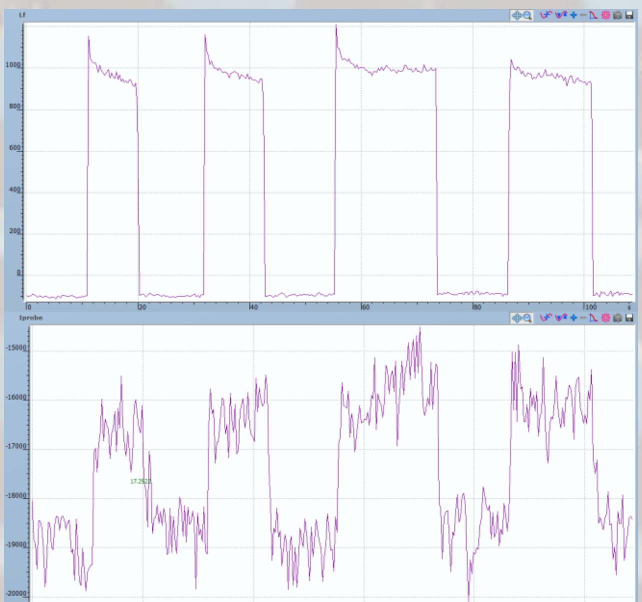
Piezoelectric ZnO nano-rods

Curent work

- Bending and measurement in Atomic Force Microscope







Piezoelectric ZnO nano-rods

Future work

- Experience of phenomenon in details
- Separation of the piezoelectric effect from the piezoresistive effect
- Measurement of the entire array in the same time

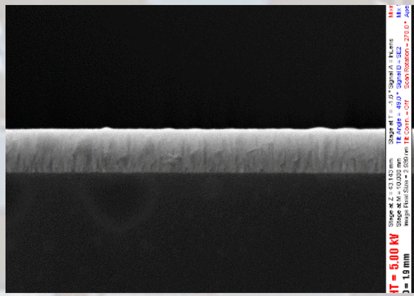
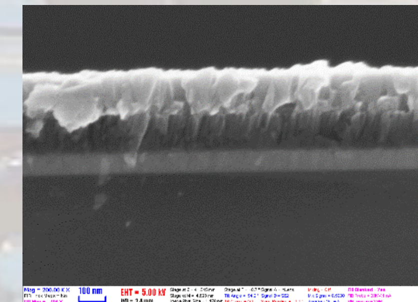
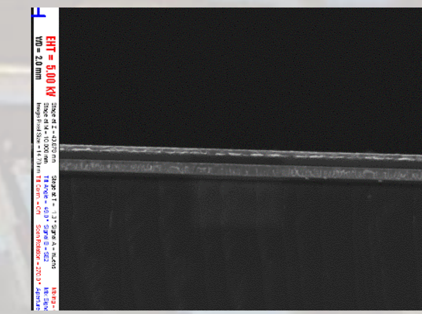
Publications in this topic

- János Volk, István E. Lukács, Nguyen Quoc Khánh, János Radó, Róbert Erdélyi: **Bottom contacted piezoelectric nanowire arrays,** NGPT 2016, oral presentation in English
- J. Volk, J. Radó, I. E. Lukács, N. Q. Khánh, R. Erdélyi, G. Battistig, C. Sturm, M. Grundmann, A. Graillot, C. Loubat: **Integrated piezoelectric nanowire arrays for high resolution tactile mapping,** EUROSENSORS 2016, oral presentation in English (**my own presentation)**

Piezoelectric AlN thin film

Current work

- Test deposition with different parameters
- Qualification of complete thin films

There is no publications in this topic.

Further information

Completed courses

- Solid state chemistry

Teaching activity

- I gave practice lessons for electric engineer students.

Thank you for your attention!