

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

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Third semester

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Introduction

3 parts of my work

- Piezoresistive 3D force sensors***
- Piezoelectric ZnO nano-rods***
- Piezoelectric AlN thin films (for 3D force sensor)***

Piezoresistive 3D force sensors

Applications

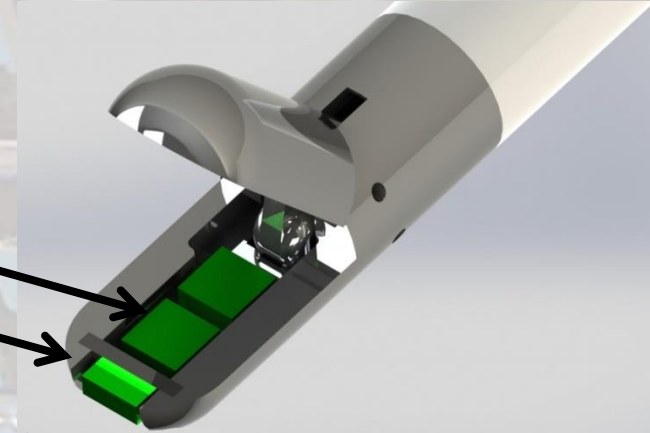
- Integration in a surgery robot's laparoscope***
- Integration in a vehicle tyre***

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

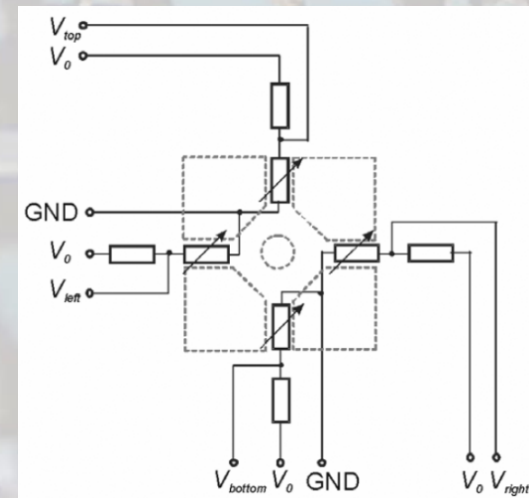
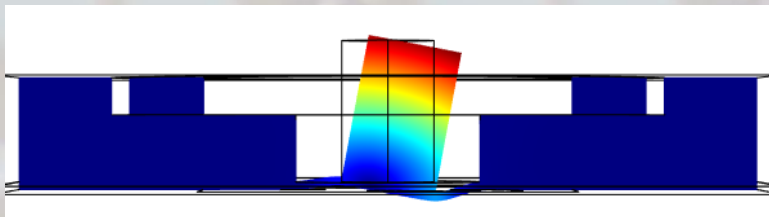
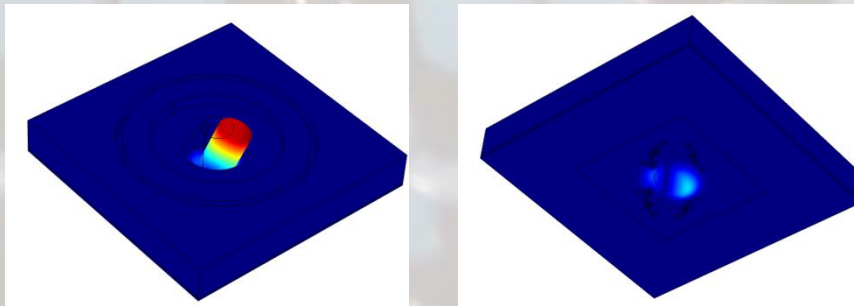
Specific requirements:

- Reduced size (down to $1 \times 1 \text{mm}^2$) 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 piezoresistors
- 4 Voltage dividers or Wheatstone-bridges
- Calculation of vectorial components:

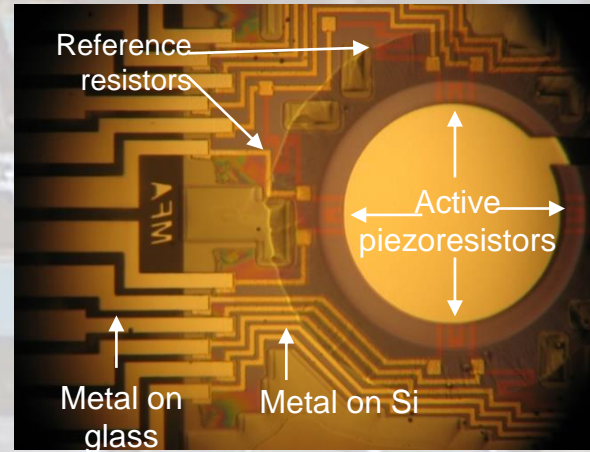
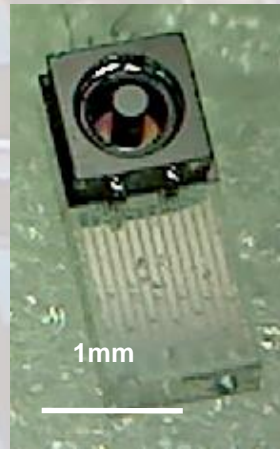
$$F_x = \frac{1}{V_0 \alpha_{ls} \pi_{44}} (\Delta V_{right} - \Delta V_{left}),$$
$$F_y = \frac{1}{V_0 \alpha_{ls} \pi_{44}} (\Delta V_{top} - \Delta V_{bottom}),$$
$$F_z = \frac{1}{V_0 \alpha_{ls} \pi_{44}} \frac{(\Delta V_{left} + \Delta V_{right} + \Delta V_{top} + \Delta V_{bottom})}{2}$$



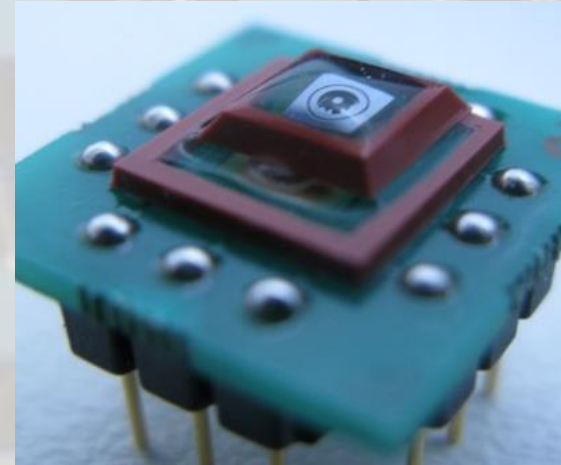
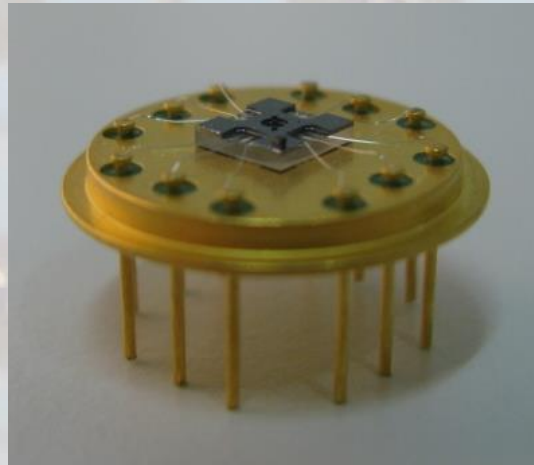
Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Previous work

- Fabrication



- Testing



Piezoresistive 3D force sensors - Integration in a laparoscopic tool

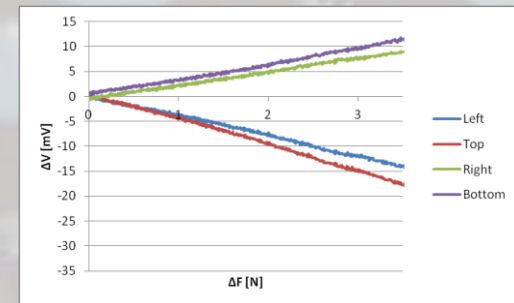
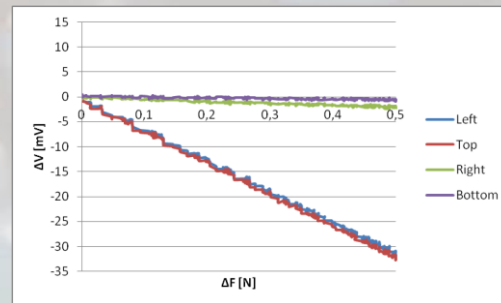
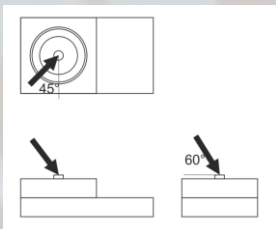
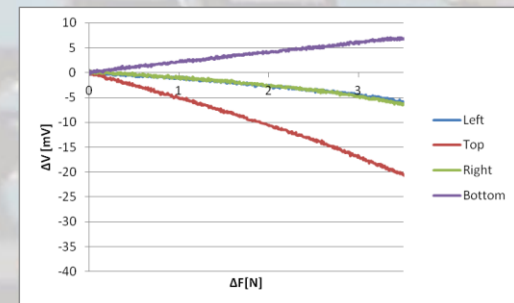
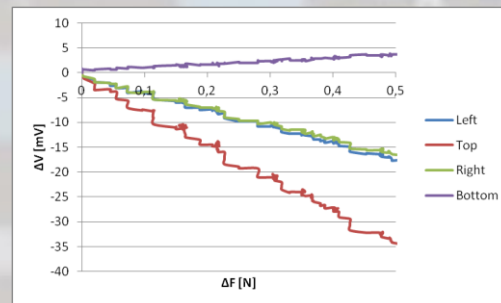
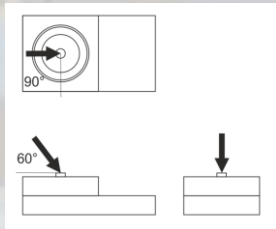
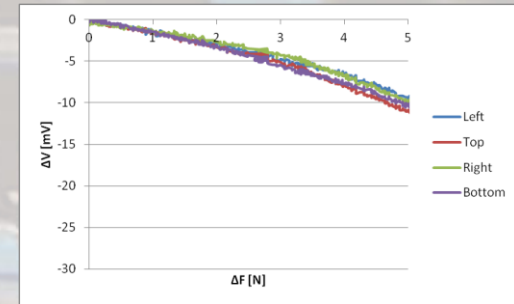
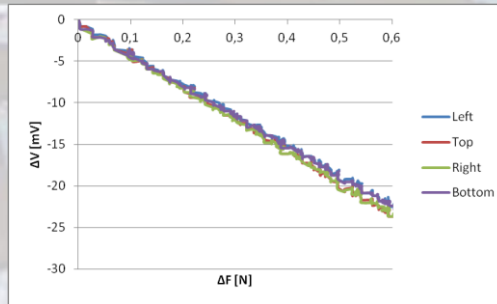
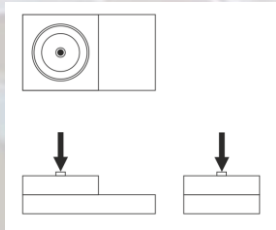
Previous work

- Measurements

Effect of elastic coating

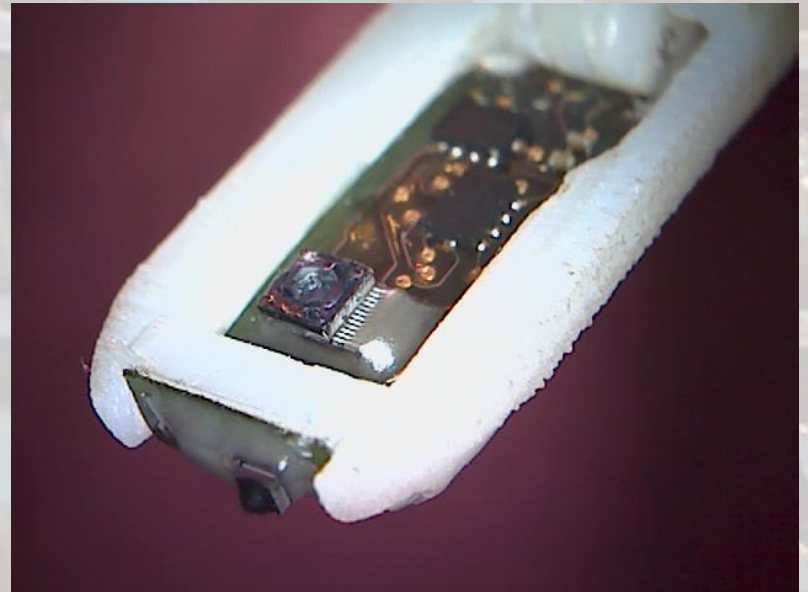
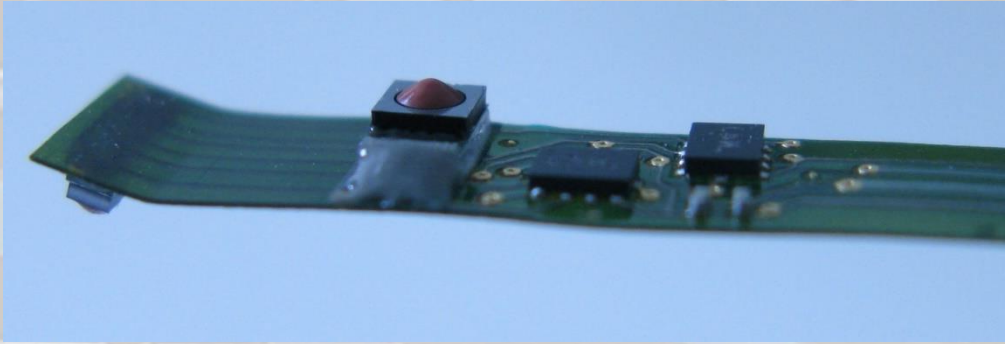
Bare sensor

Covered sensor



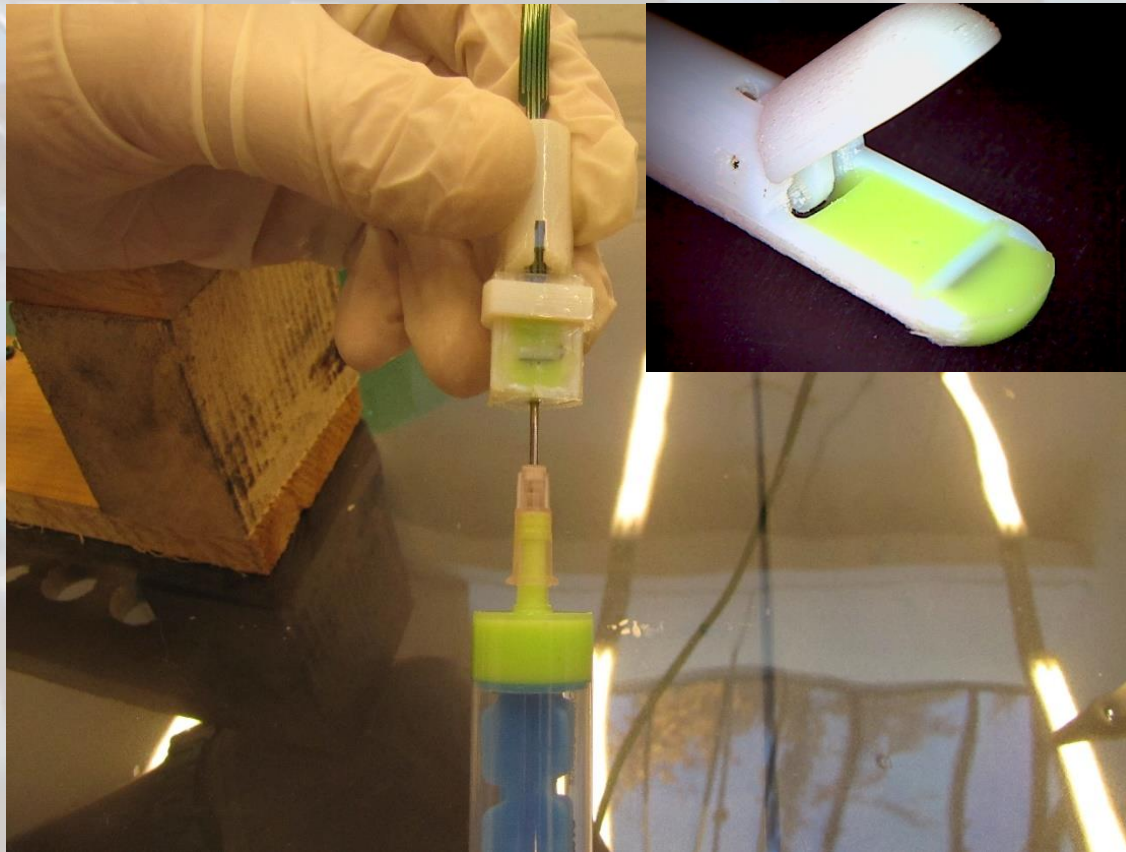
Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Previous work



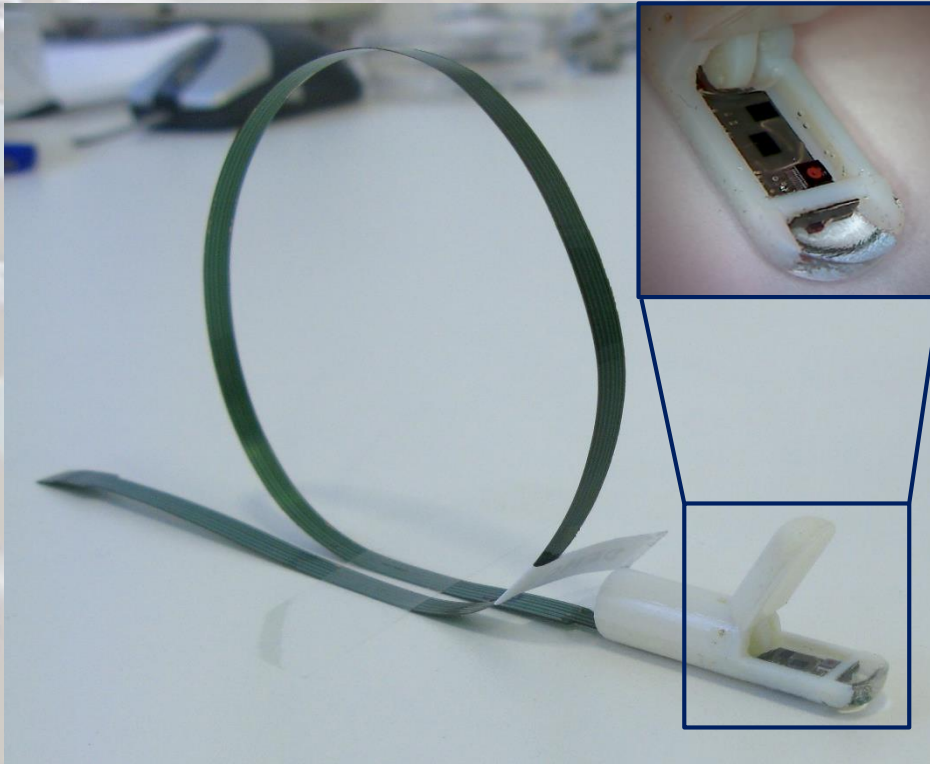
Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Previous work – elastic covering



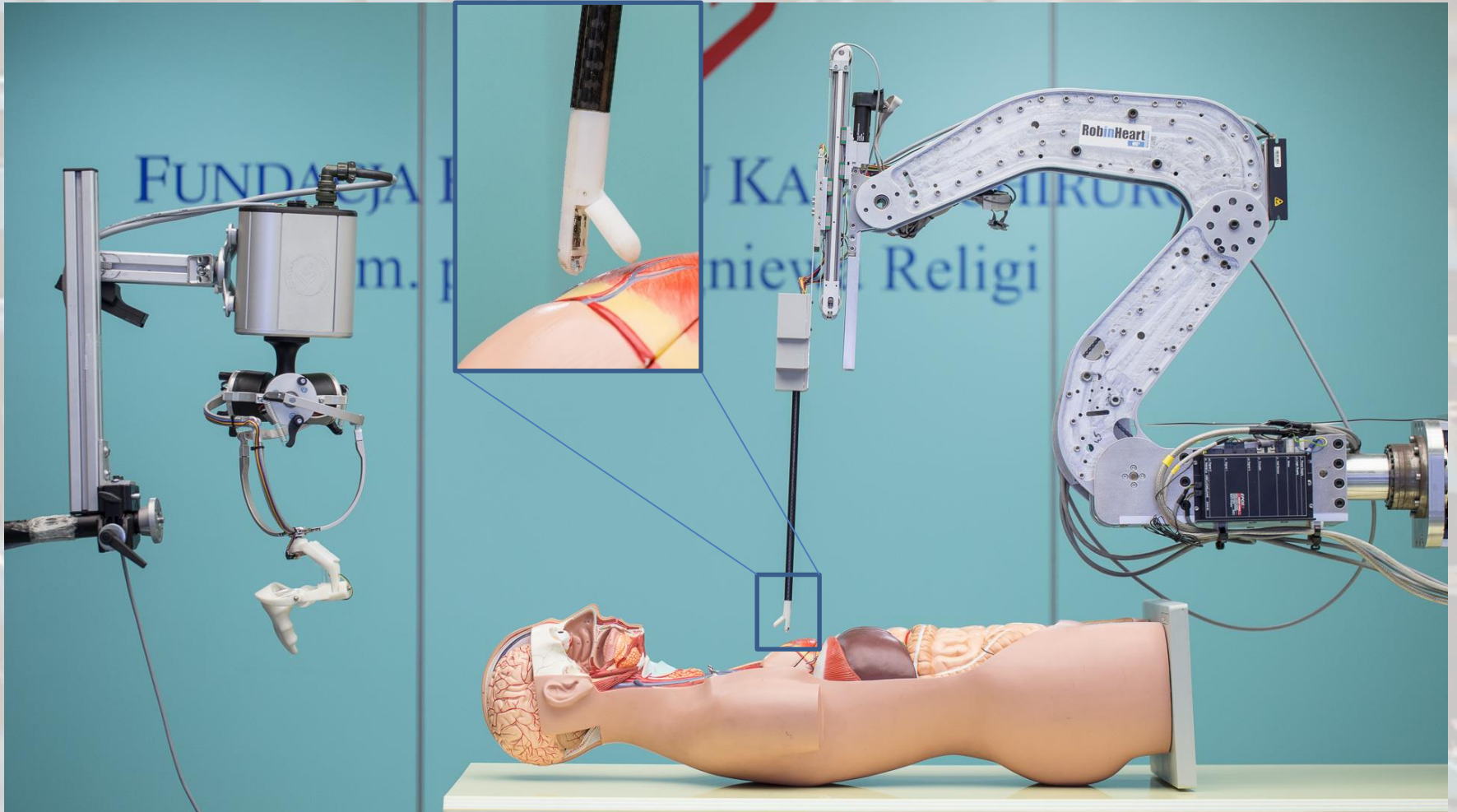
Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Previous work – completed test device



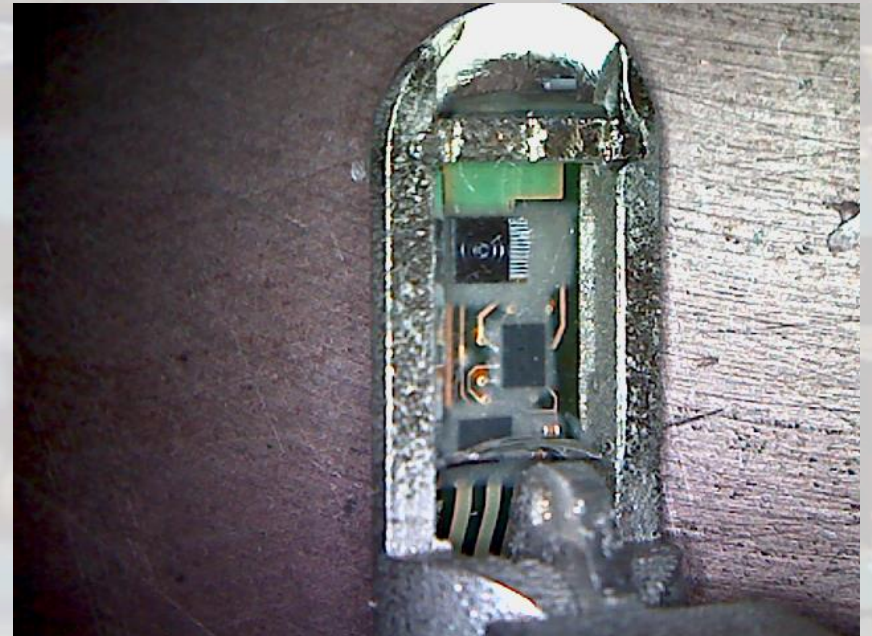
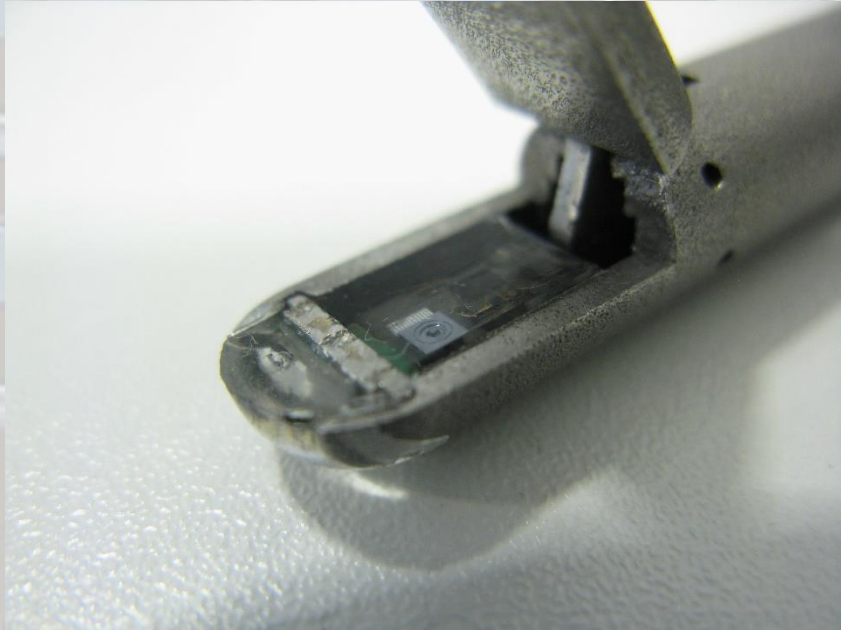
Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Previous work – completed test device



Piezoresistive 3D force sensors - Integration in a laparoscopic tool

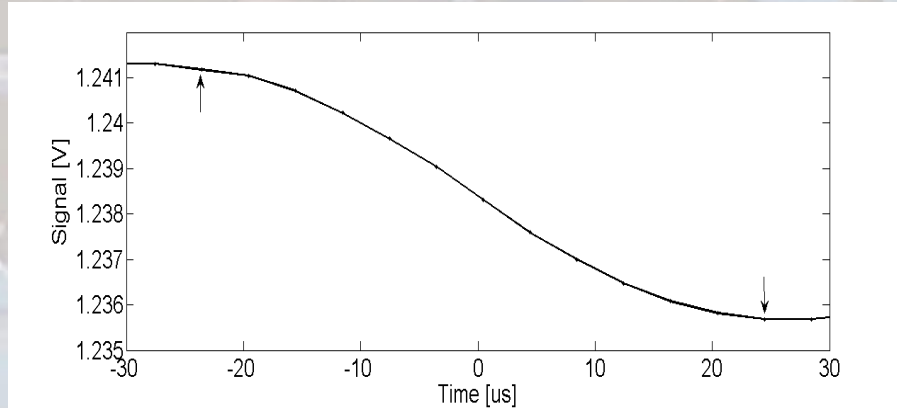
Current work – metal gripper and biocompatible coating (Nusil MED-6215)



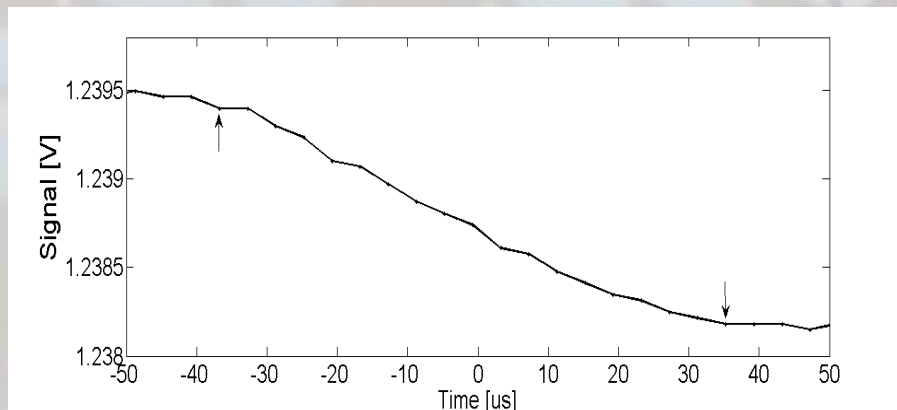
Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Current work – new measurements, new results

Response time



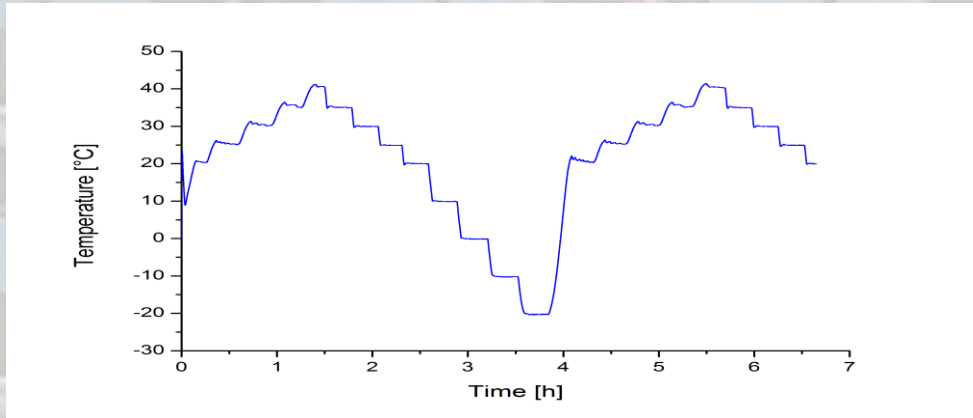
Bare sensor



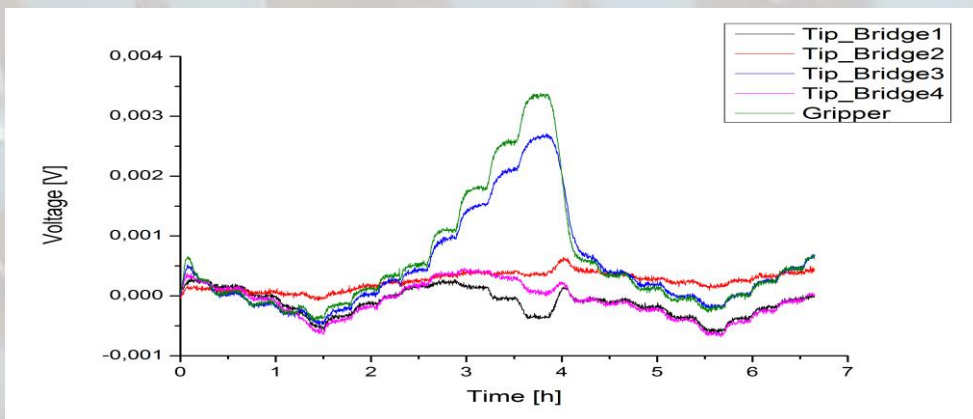
Covered sensor

Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Current work – temperature tests



Temperature profile



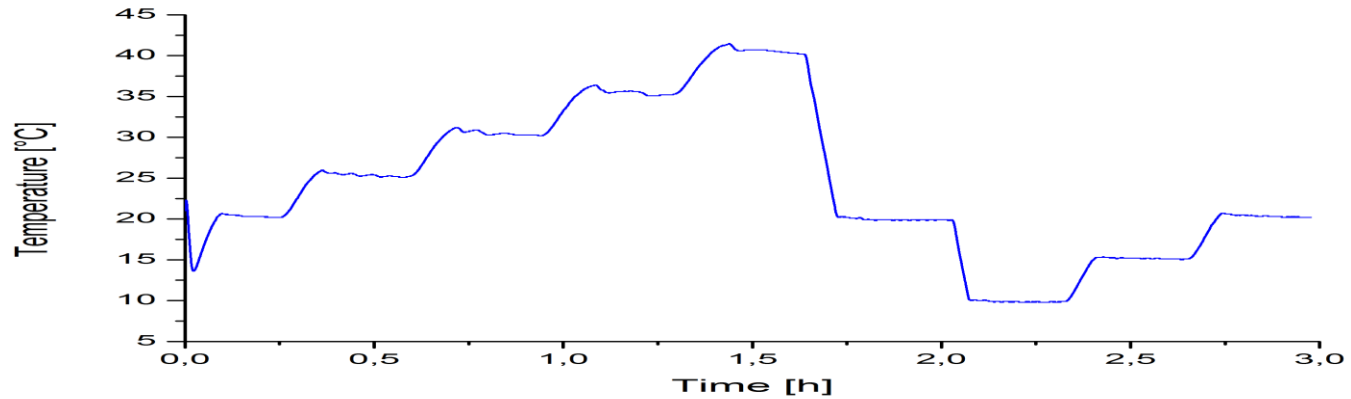
Offset signals



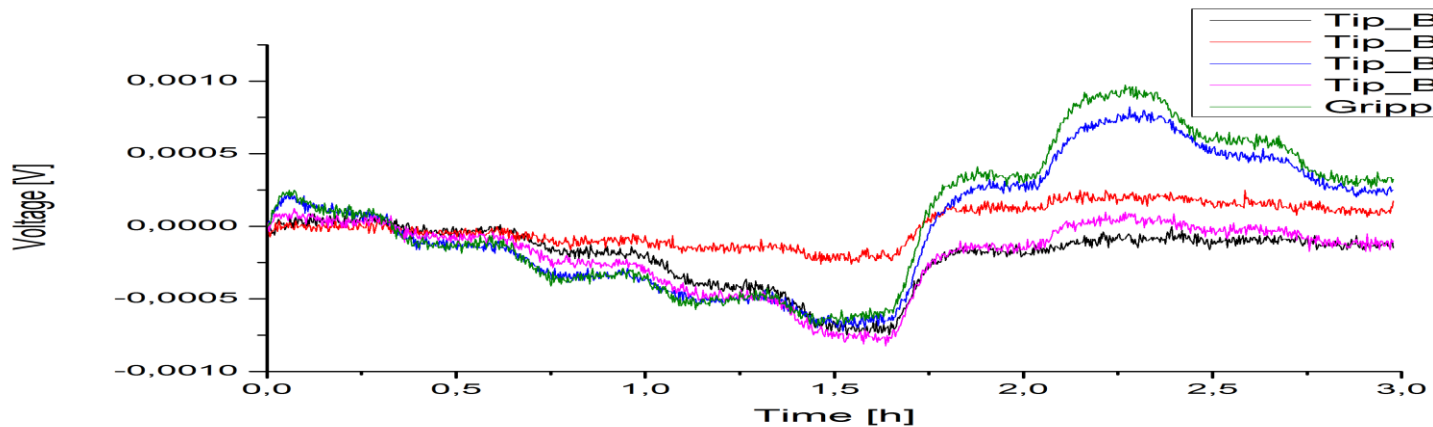
Climate chamber

Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Current work – temperature tests



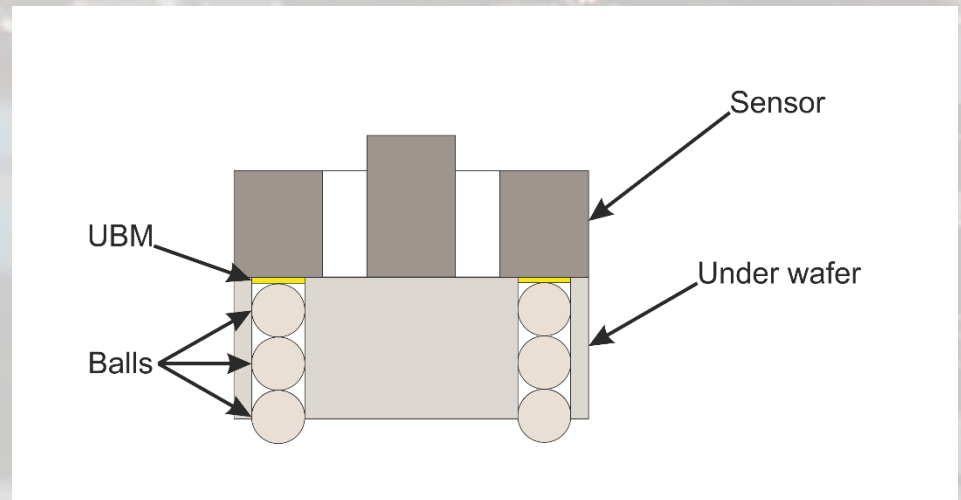
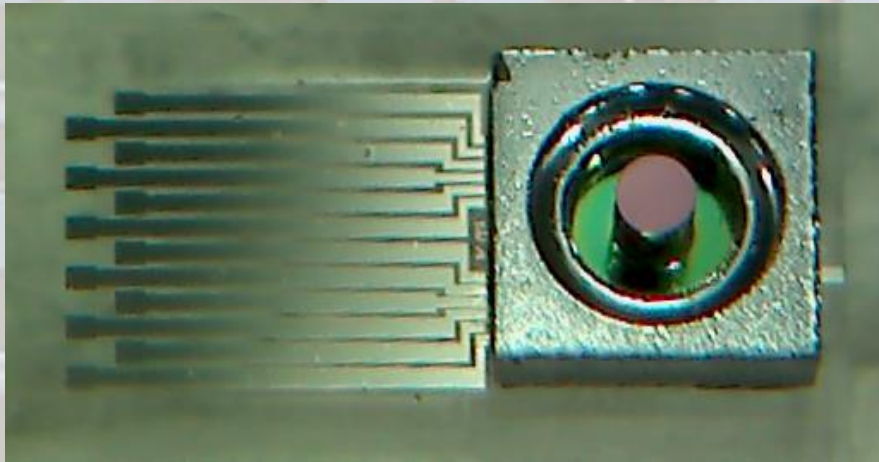
Temperature profile



Offset signals

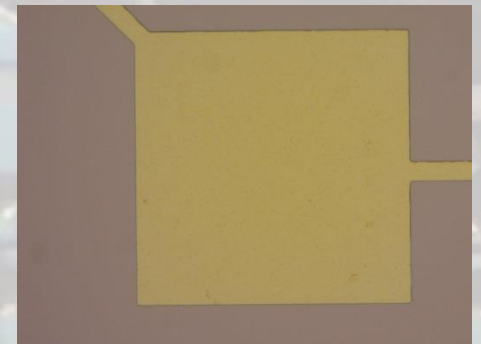
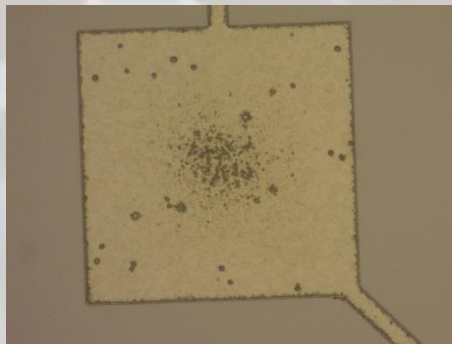
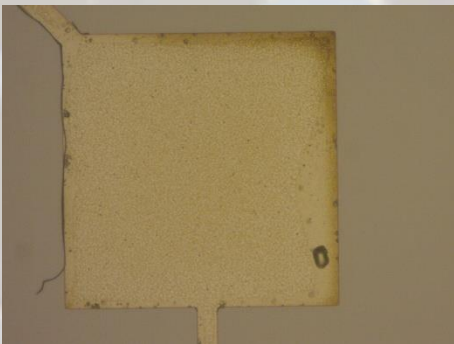
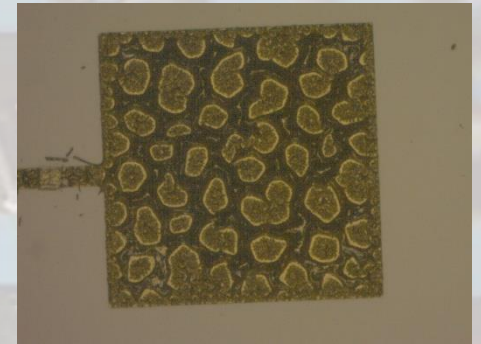
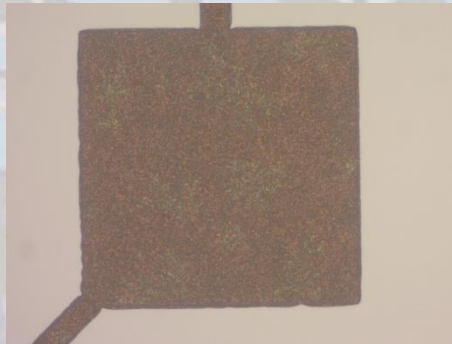
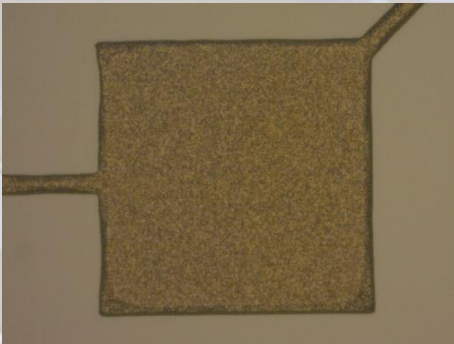
Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Current work – TSV for reduced size



Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Current work – first step: UBM



Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Future work

- FRK integration and tests
- Final demonstration
- Keep on reducing chip size and integrating into a catheter head

Piezoresistive 3D force sensors - Integration in a laparoscopic tool

Publications in this topic

Paper:

- János Radó, Csaba Dücső, Gábor Battistig, Gábor Szabényi, Zbigniew Nawrat, Kamil Rohr, Péter Fürjes: **3D force sensors for laparoscopic surgery tool**, Microsystem Technologies, ISSN 0946-7076 - accepted
- K.Rohr, P.Fürjes, L.Mucha, J.Radó, K.Lis, Cs.Dücső, W.Sadowski, P.Földesy, D.Krawczyk, P.Kroczek, Z.Malota, G.Szabényi, Z.Nawrat, **Robin Heart Force Feedback/Control System**, Medical Robotics Reports, Volume 4, 2015, ISSN 2299-7407

Oral presentation (in English):

- J.Radó, Cs.Dücső, P.Fürjes, P.Földesy, G.Szabényi, Z.Nawrat, **3D force sensors for laparoscopic surgery tool/for surgery robotics**, ROBOTY MEDYCZNE 2016, Zabrze, Poland (**my own presentation**)
- János Radó, Csaba Dücső, Gábor Battistig, Gábor Szabényi, Zbigniew Nawrat, Kamil Rohr, Péter Fürjes: **3D force sensors for laparoscopic surgery tool**, DTIP 2016, Budapest, Hungary (**my own presentation**)
- Kamil Rohr, Lukasz Mucha, Péter Fürjes, János Radó, Csaba Dücső, Péter Földesy, Gábor Szabényi, Zbigniew Nawrat: **Robin Heart Force Feedback/Control**, MEDICAL ROBOTS 2015, Zabrze, Poland

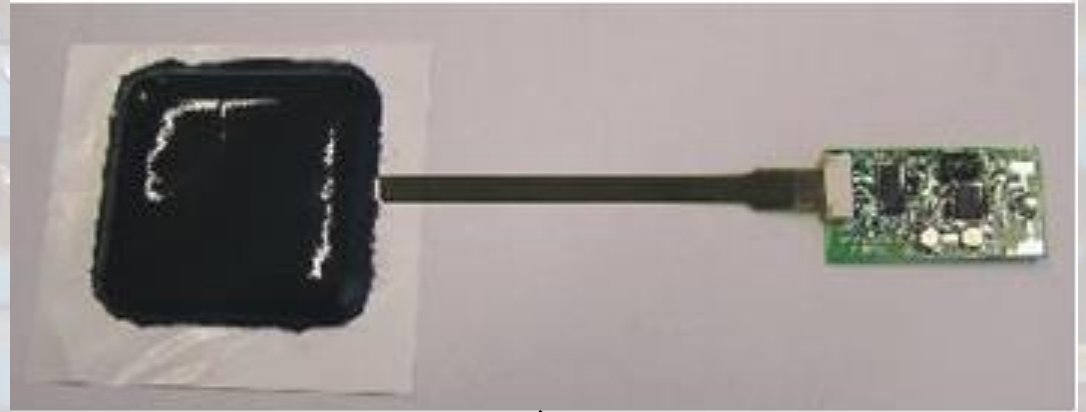
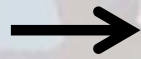
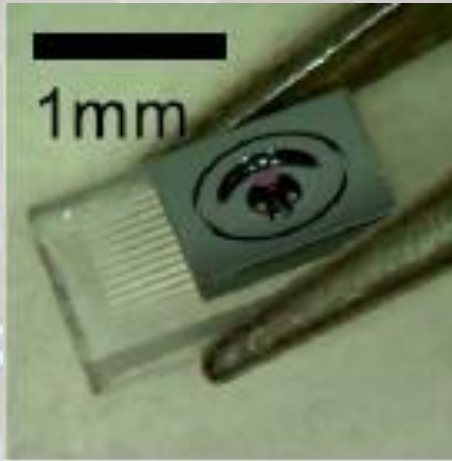
Poster:

- 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

Piezoresistive 3D force sensors - Integration in a vehicle tyre

Previous work

- Implantation of 3D force sensor in a special rubber



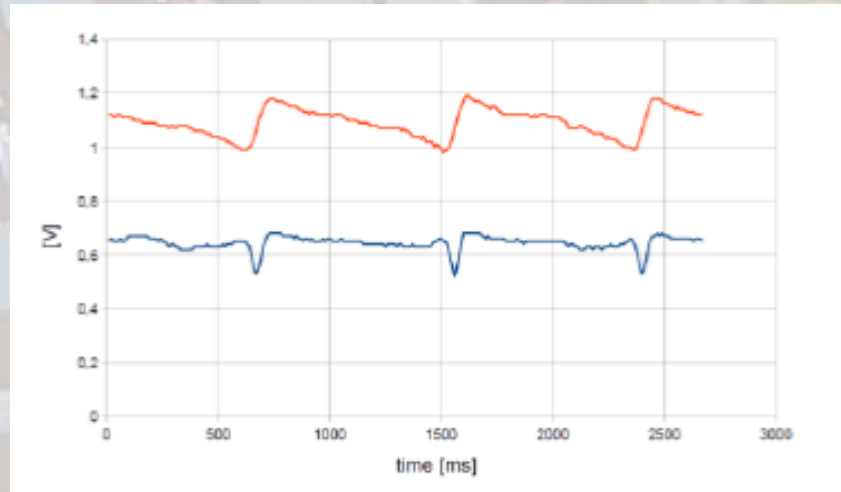
- Integration of test tool in a vehicle tyre



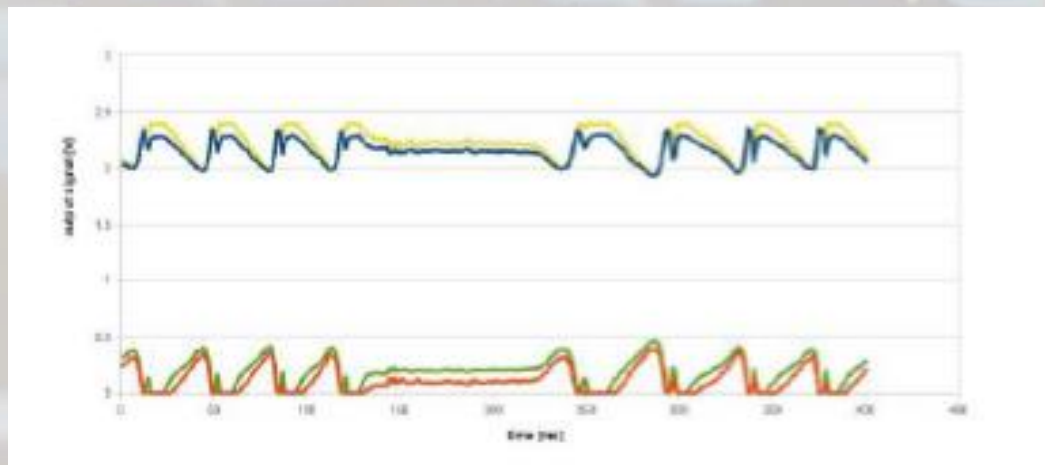
Piezoresistive 3D force sensors - Integration in a vehicle tyre

Previous work

- Measurements – normal road conditions



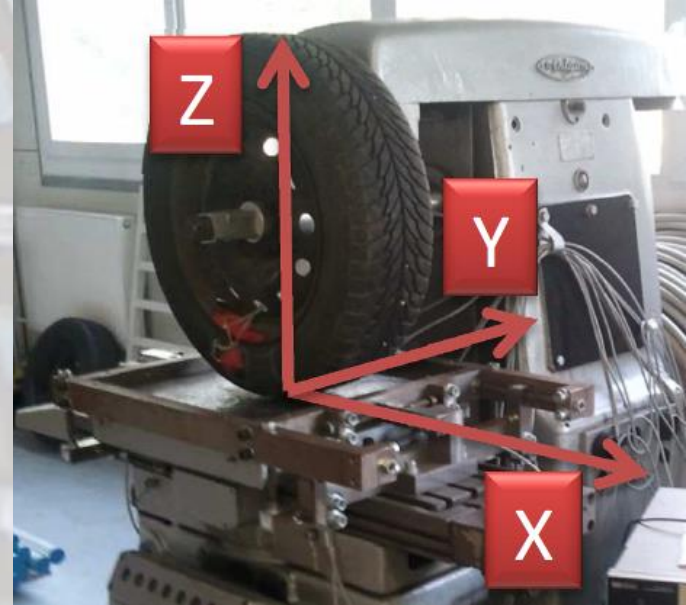
- Measurements – the wheel is blocked



Piezoresistive 3D force sensors - Integration in a vehicle tyre

Previous work

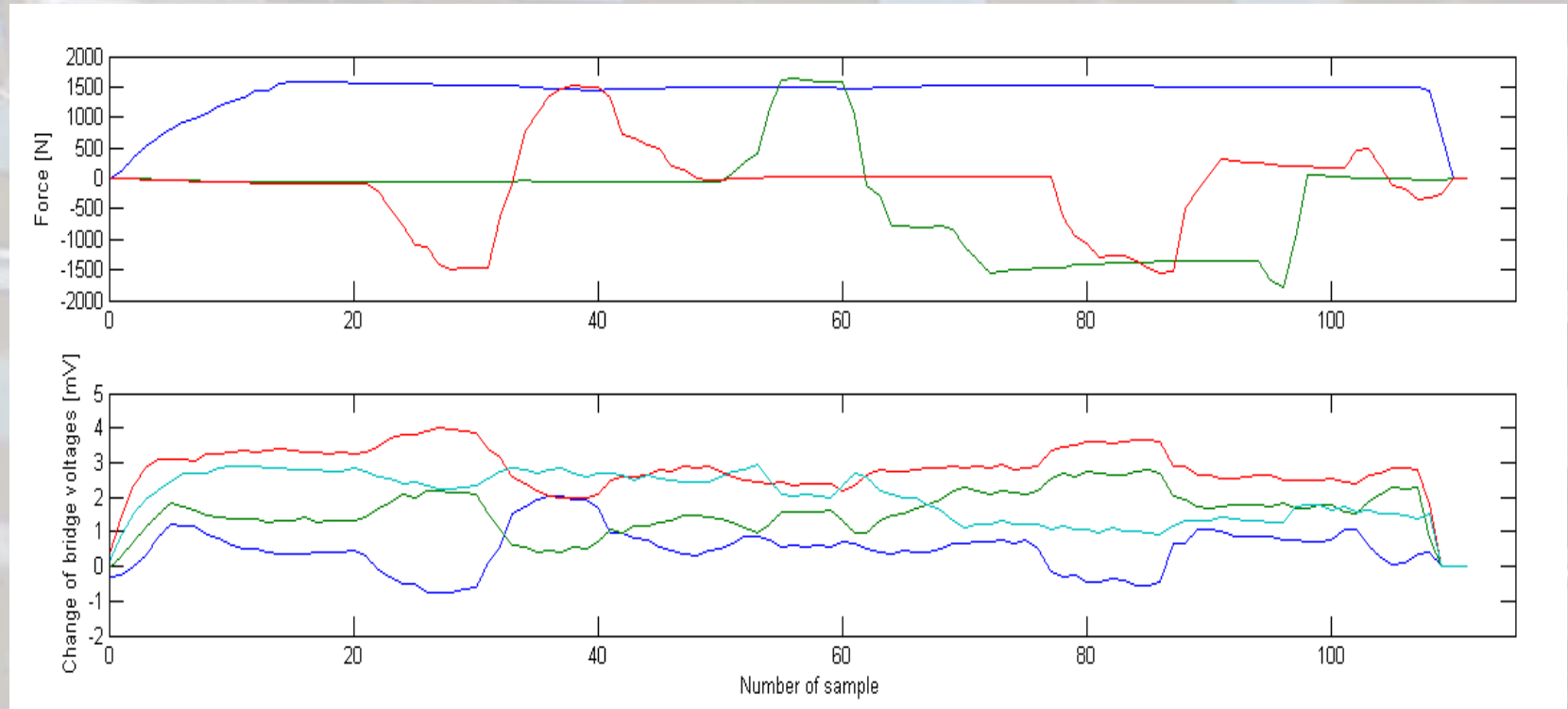
- Functional test: static loading



Piezoresistive 3D force sensors - Integration in a vehicle tyre

Current work

- Results of static measurement

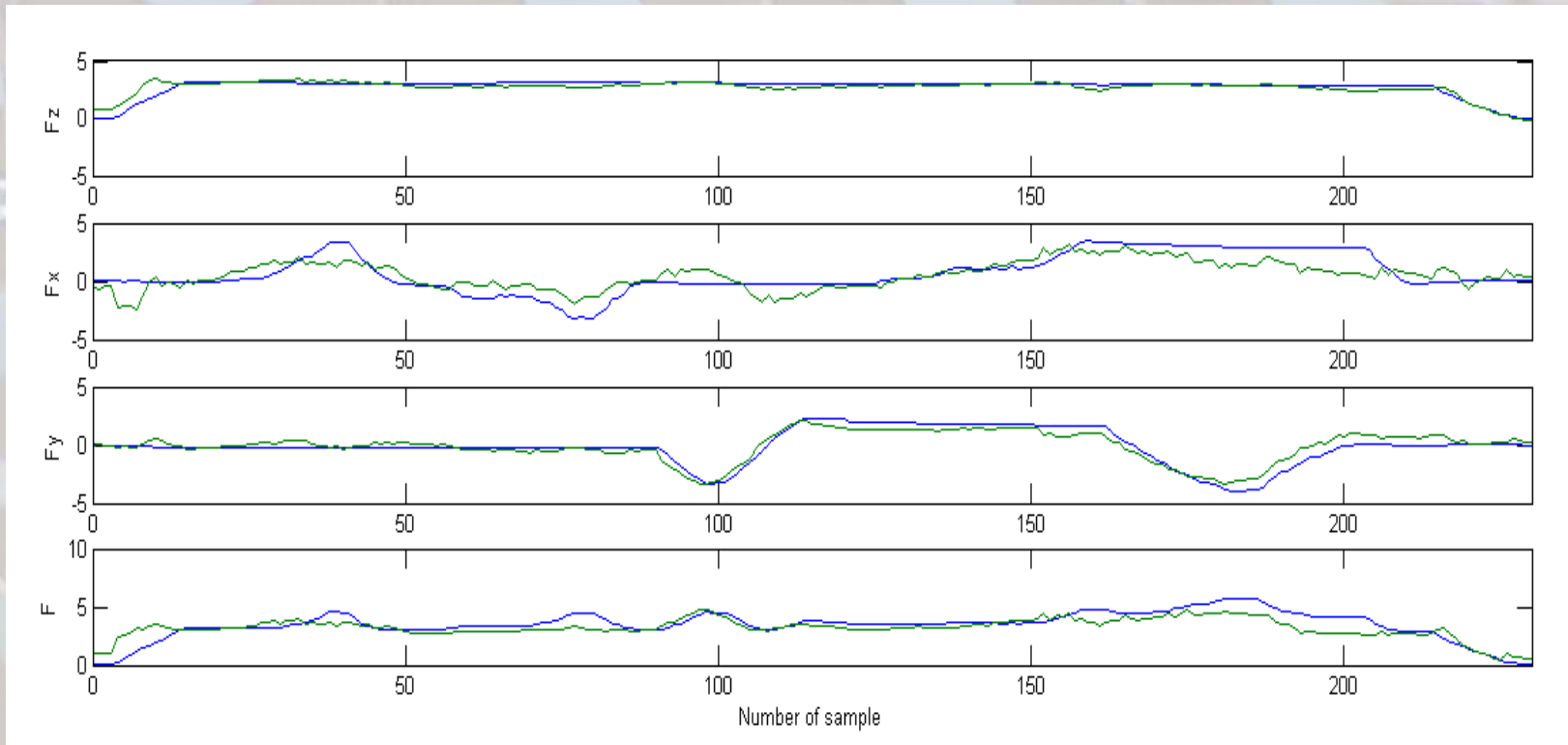


F_x ———
 F_y ———
 F_z ———

Piezoresistive 3D force sensors - Integration in a vehicle tyre

Current work

- **Multiple regression:** demonstration of proportional relationship between tyre deformation and acting forces on the wheel



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

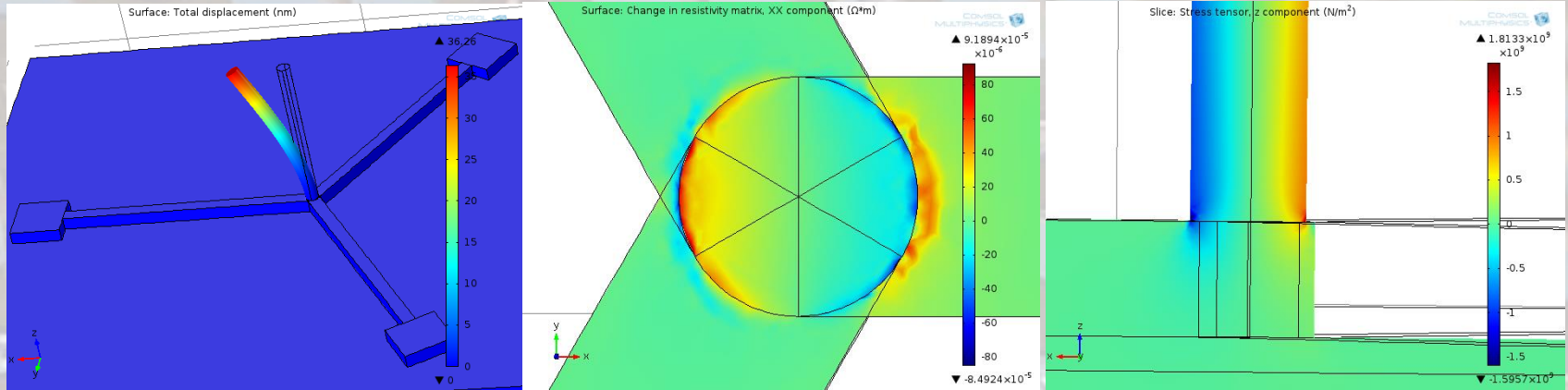
Oral presentation (in English):

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

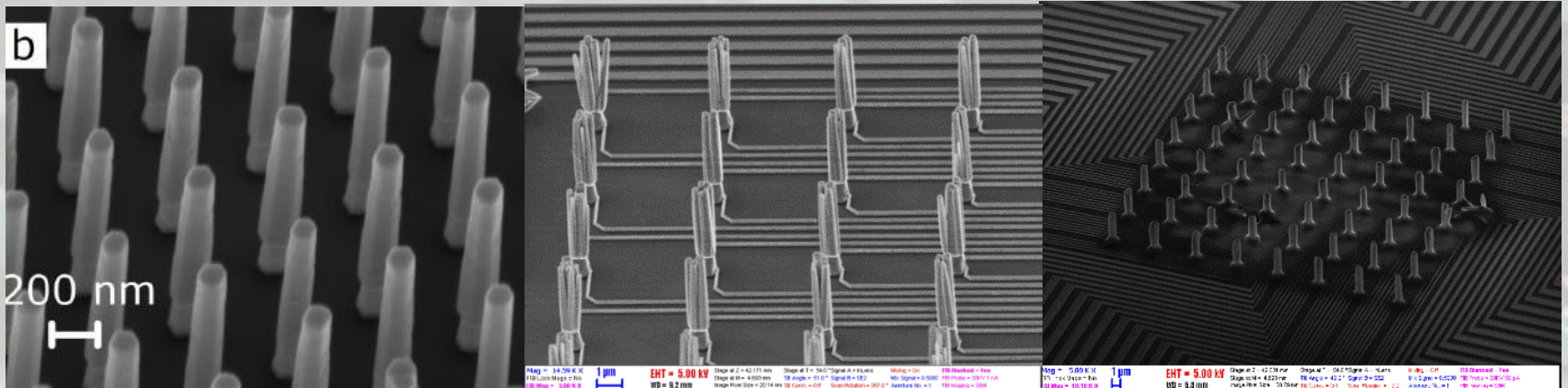
Piezoelectric ZnO nano-rods – for high-resolution fingerprint sensing

Previous work

- Simulation



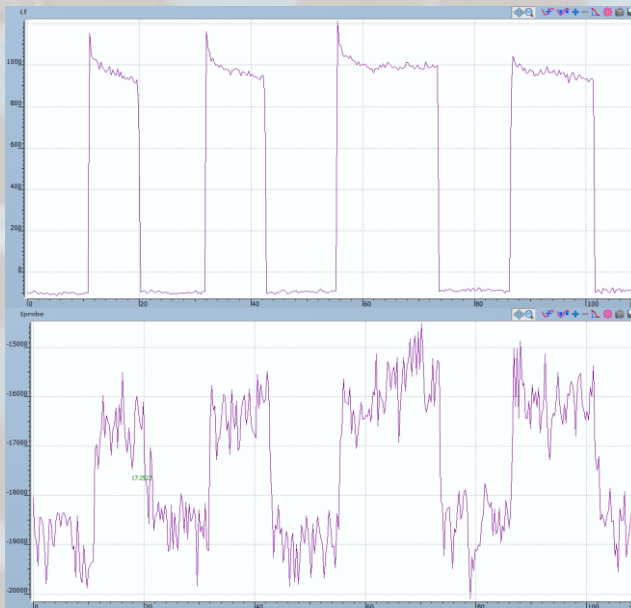
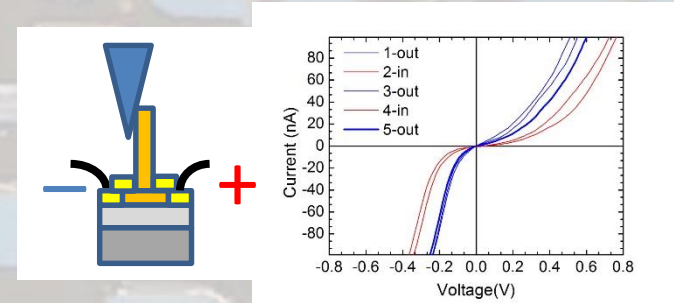
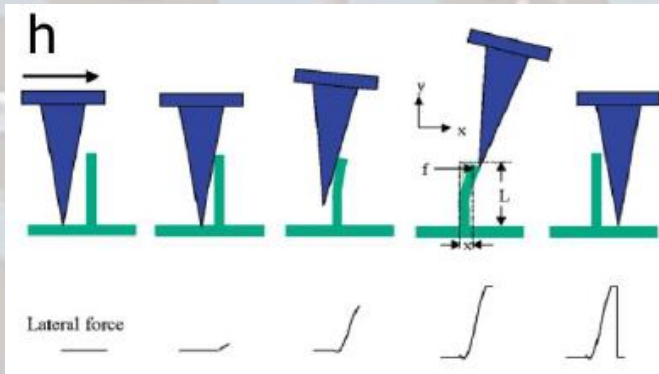
- Growing of the rods (hydrothermal growing: Zinc-nitrate hexahydrate and hexamethylen tetramin)



Piezoelectric ZnO nano-rods – for high-resolution fingerprint sensing

Previous work

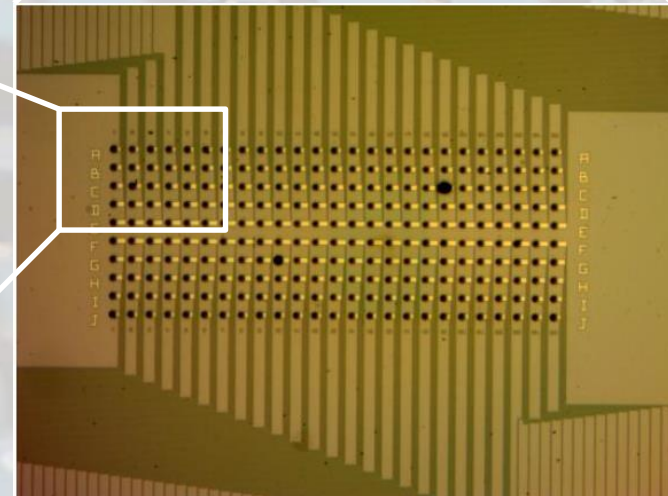
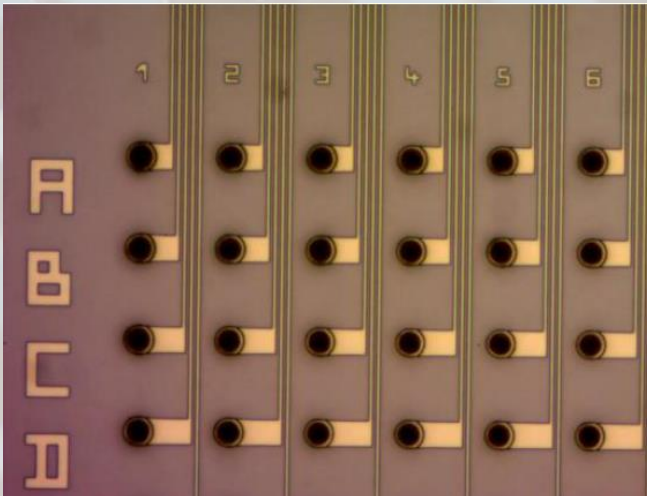
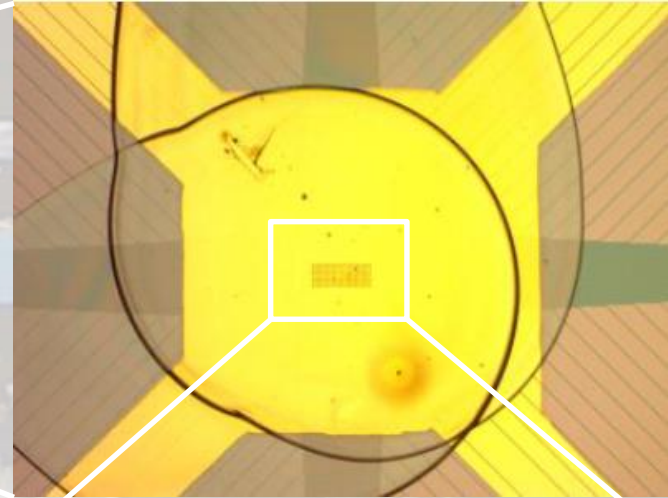
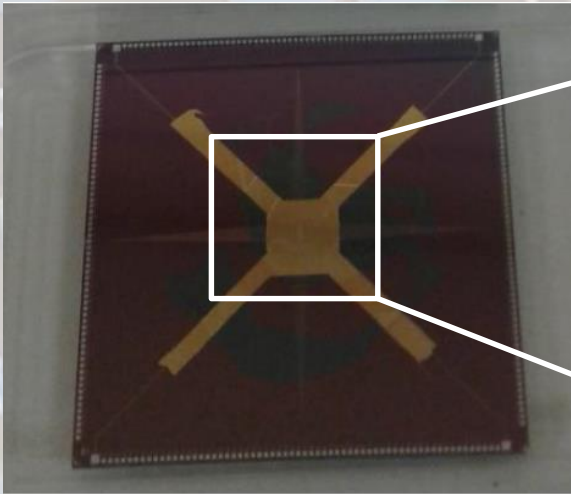
- Bending and measurement in Atomic Force Microscope



Piezoelectric ZnO nano-rods – for high-resolution fingerprint sensing

Current work

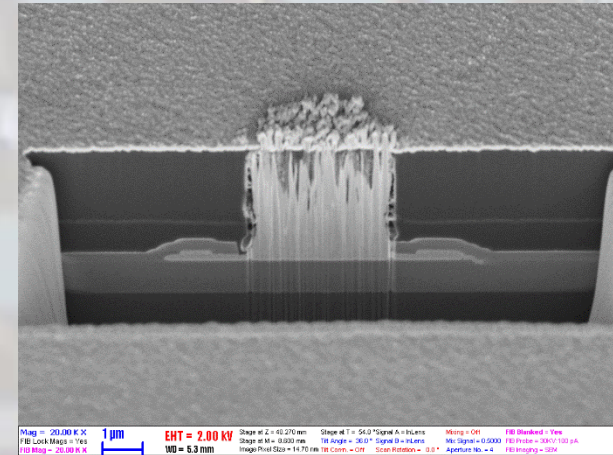
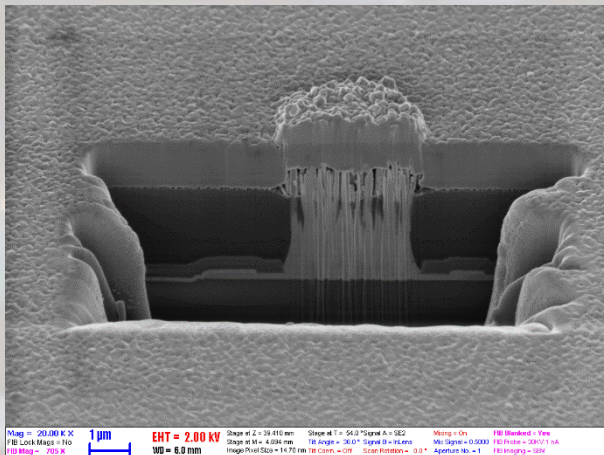
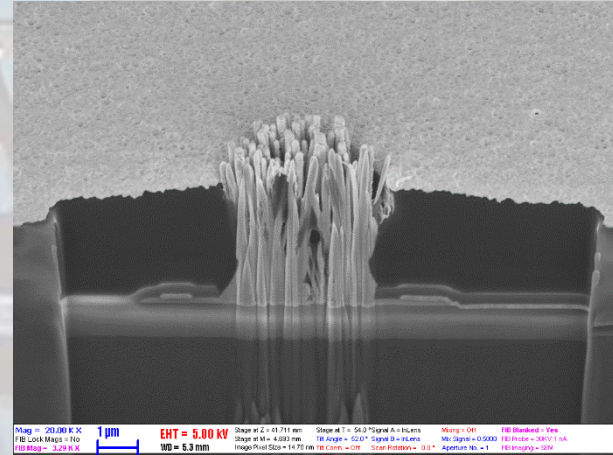
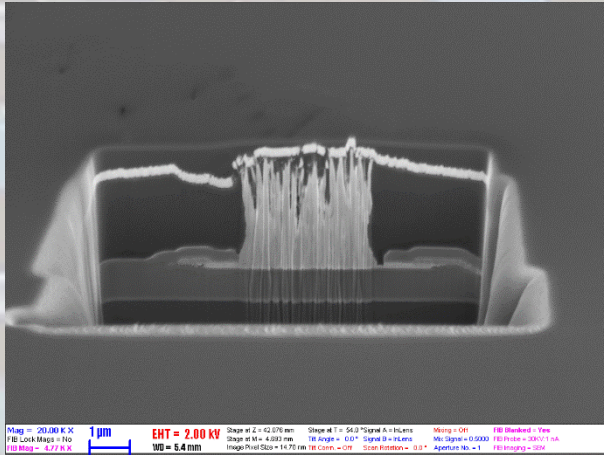
- Design and fabrication a 25x10 nano-array



Piezoelectric ZnO nano-rods – for high-resolution fingerprint sensing

Current work

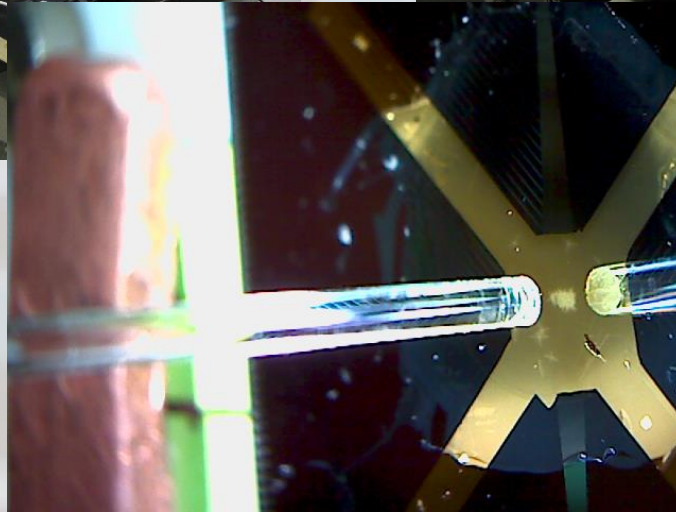
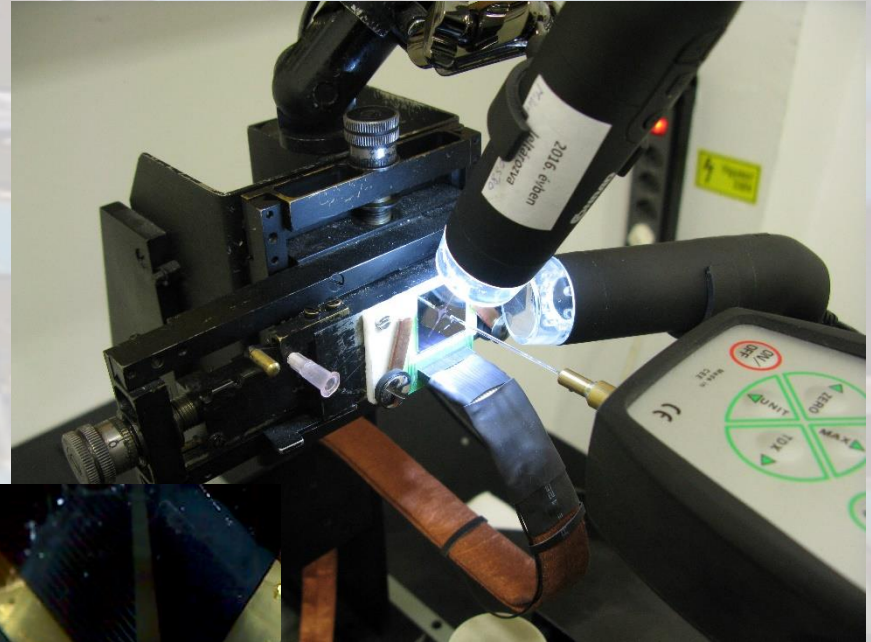
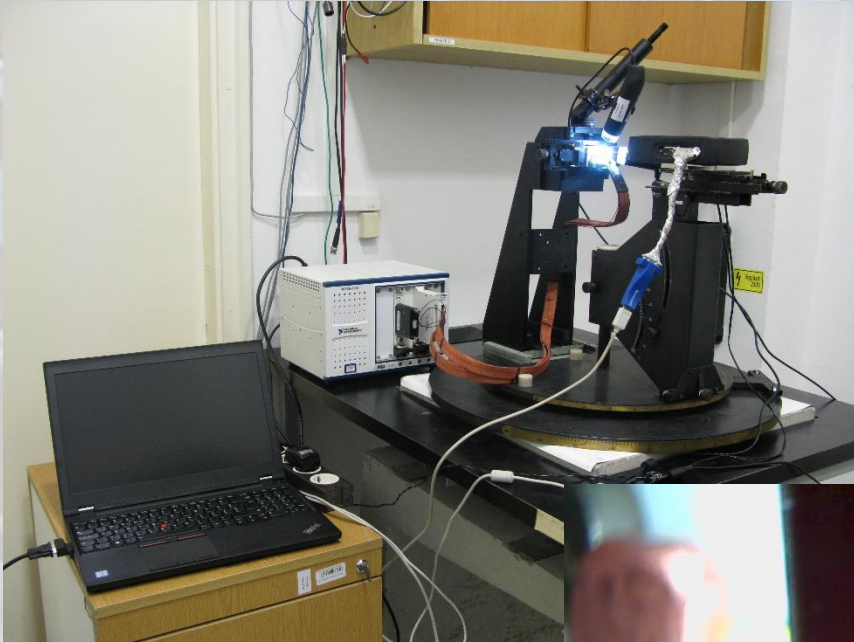
- Design and fabrication a 25x10 nano-array



Piezoelectric ZnO nano-rods – for high-resolution fingerprint sensing

Current work

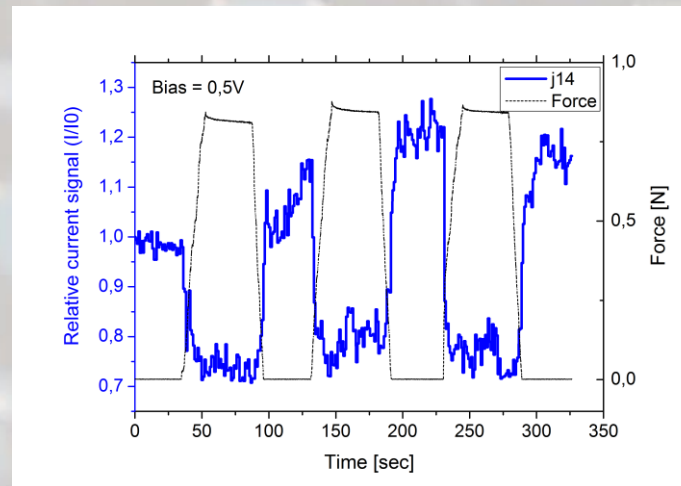
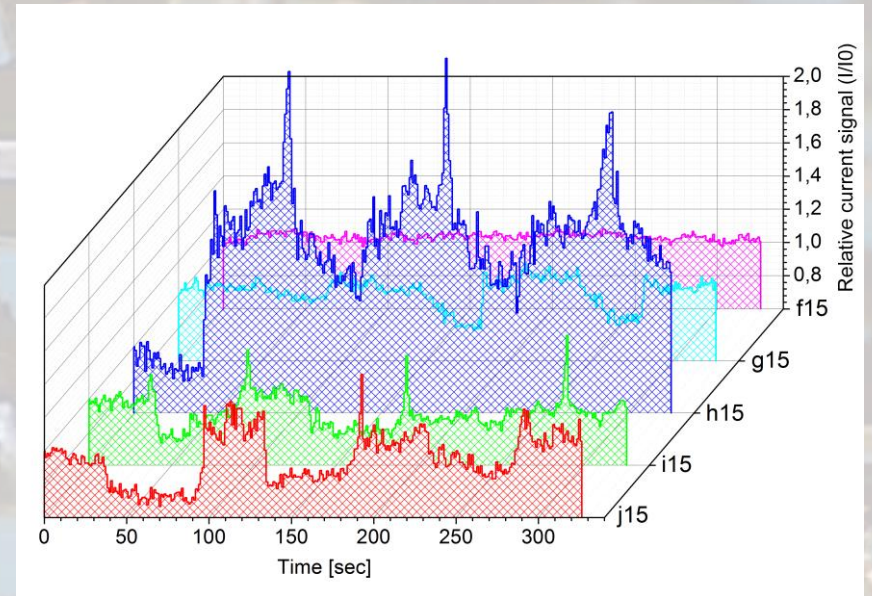
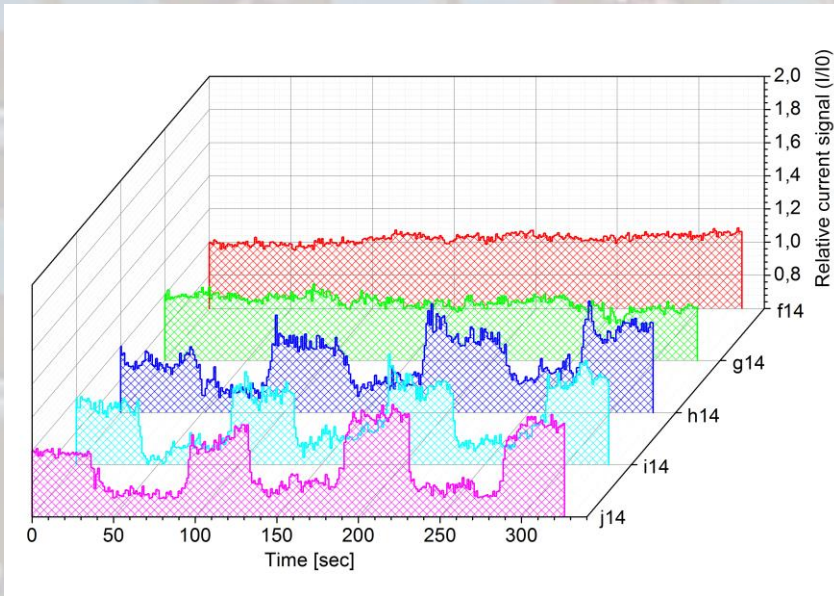
- Assembling a new measurement setup



Piezoelectric ZnO nano-rods – for high-resolution fingerprint sensing

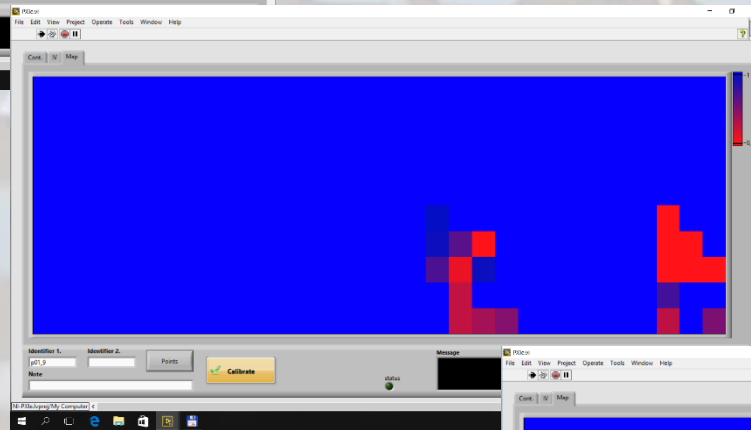
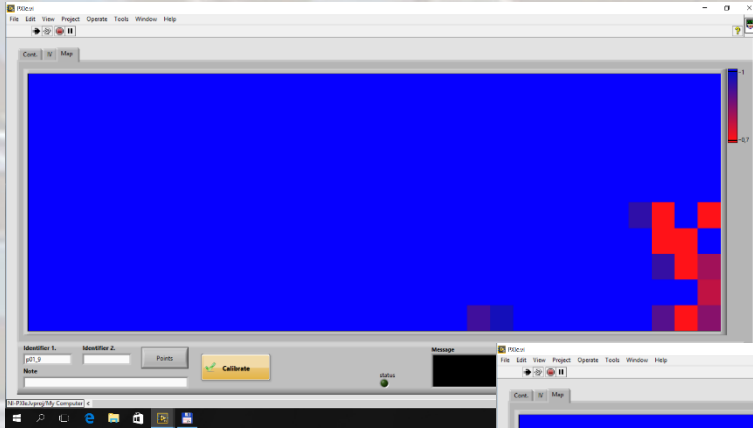
Current work

- Results



Piezoelectric ZnO nano-rods – for high-resolution fingerprint sensing

Current work



Piezoelectric ZnO nano-rods

Publications in this topic

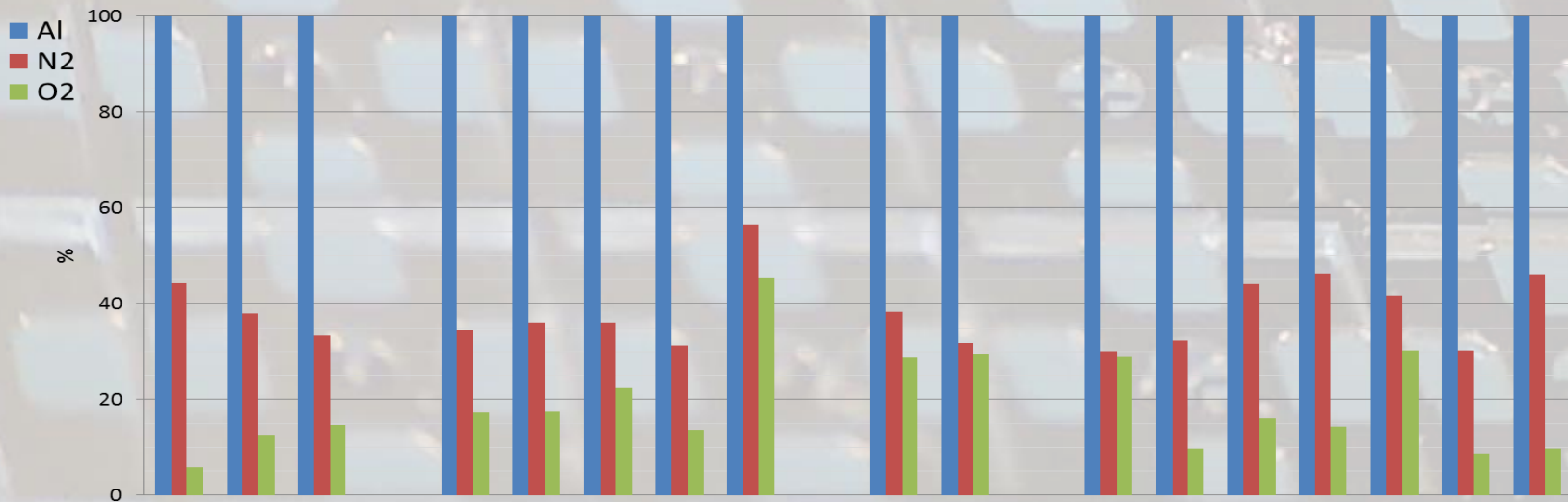
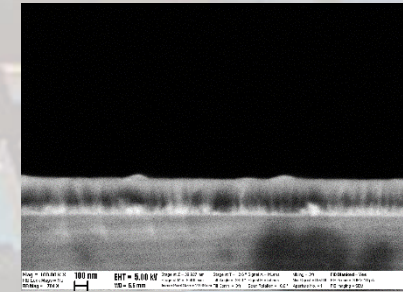
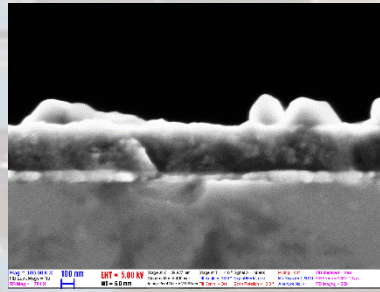
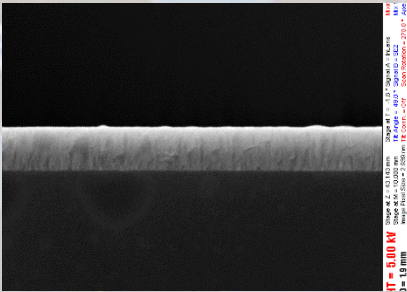
Oral presentation:

- János Volk, István E. Lukács, Nguyen Quoc Khánh, János Radó, Róbert Erdélyi: **Bottom contacted piezoelectric nanowire arrays**, NGPT 2016, Rome, Italy
- J. Volk, J. Radó, I. E. Lukács, N. Q. Khánh, R. Erdélyi, G. Battistig, C. Sturm, M. Grundmann, A. Graillet, C. Loubat: **Integrated piezoelectric nanowire arrays for high resolution tactile mapping**, EUROSENSORS 2016, Budapest, Hungary

Piezoelectric AlN thin film for 3D force sensor

Previous work

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



There is no publications in this topic.

Further information

Completed courses

- Szilárdtest kémia
- Nanotechnológia
- Polimerek kémiája és fizikája
- Mikroelektronikai anyagok és szerkezetek vizsgálati módszerei

Participation in projects:

- Incite Eniac (Call 2013-1/621278-2)
- PiezoMat (grant no. 611019)

***Thank you for your
attention!***