Some Results on Micro- and Nanoscience at Res. Inst. Tech. Phys. and Matl. Sci., MFA

Presented by

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http://www.mfa.kfki.hu/en

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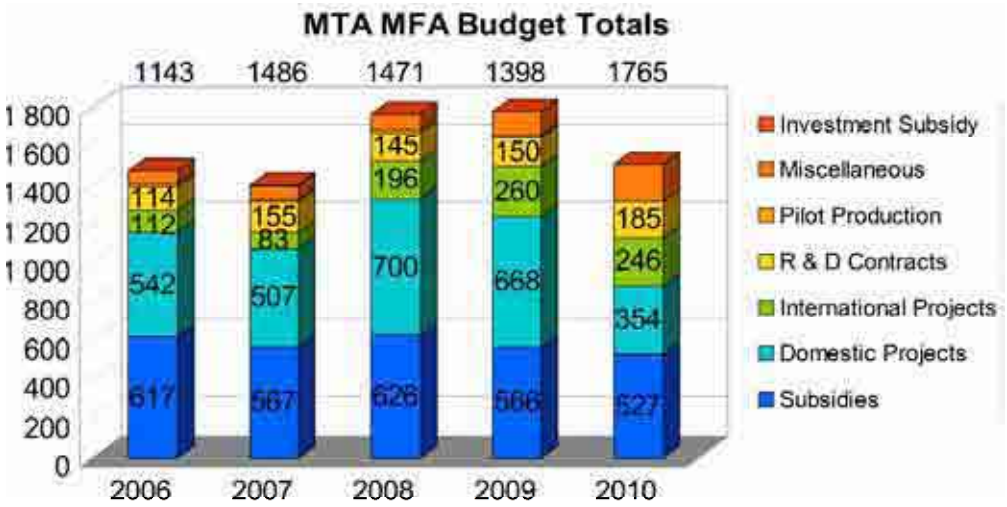
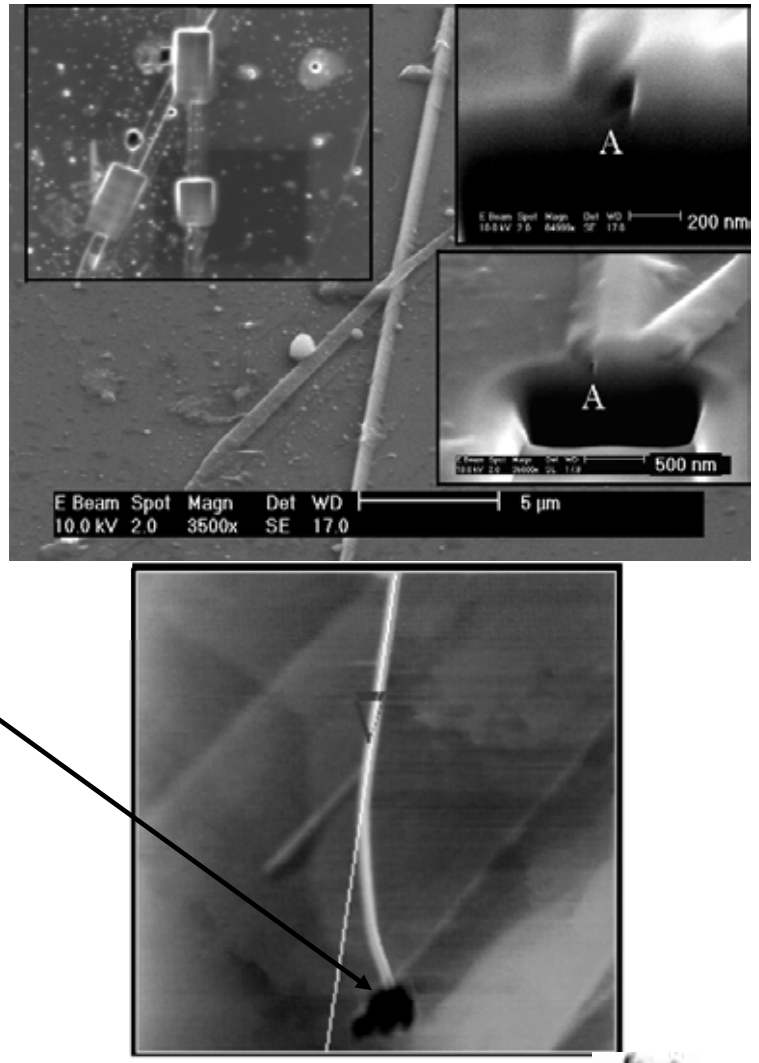


Strategy shift

- Clean lab – only up to 100 mm wafers
- Approx. 1 µm lithography and mask shop
- FIB, ALD, Deep Reactive Ion Etch, e-beam lithography was added to the arsenal
- Analytical tools
    - Electrical characterization, testing
    - TEM, SEM, AFM, RBS
- Strategy shift – move towards sensors and actuators, where the “1 µm” still allows leading edge results.
- We believe in synergism of micro- and nanodevices
- Nano-structuring with Scanning Probes enabled work with CNT and graphene

Our road to nanoscience

- Our road to nanotubes (CNT) through swift ion irradiation (in Dubna, Russia, 1992), also into HOPG
- Still a miracle: explosive crystallization by ≈200 MeV, multiply charged Kr ions?
- Growth rate approx. (μm/≈100ps)
- Sound velocity? Why tubes?…
- No. of atoms in CNT equal to missing atoms in exit crater
- Cascade density also seems important:
  - Ne ions produce MWCNT (multiple wall),
  - Xe ions SWCNT (single wall) nanotubes

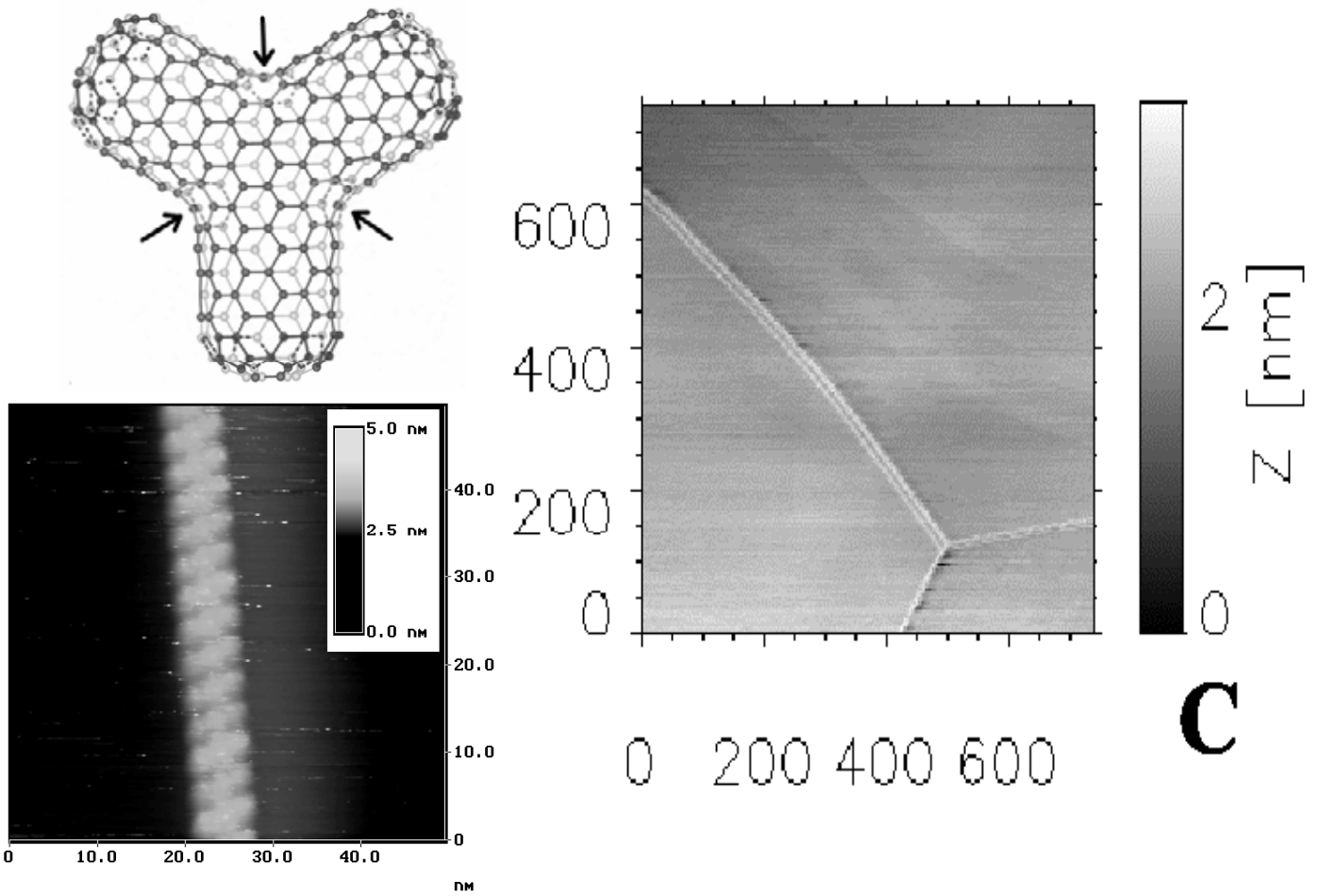


Department of Nanostructures (L.P. Biró) (http://www.nanotechnology.hu/)

- CNT production later
  - Under water spark
  - CVD
- Tailored build-in 5 and 7-member rings

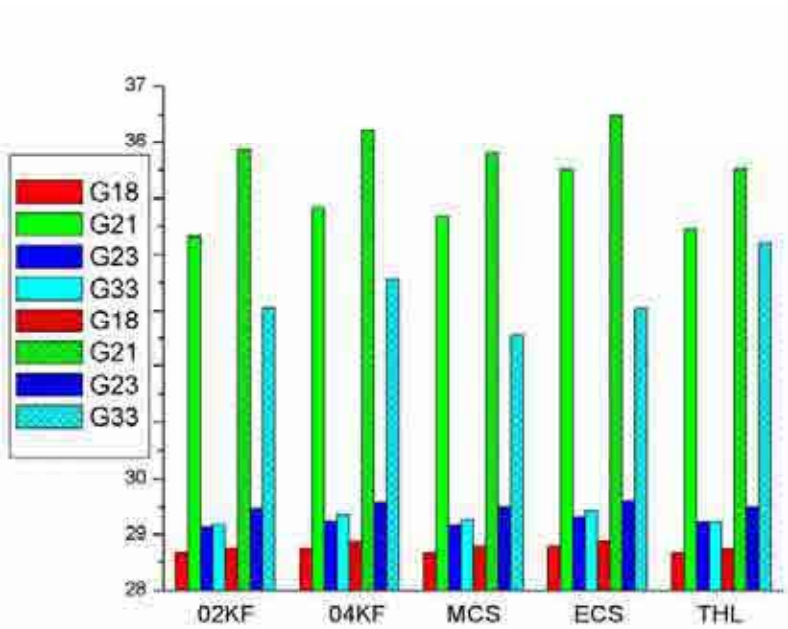
- Moved to graphene
- Towards structuring
- Lithography

Next step: Y-shaped and helical SWNT-s



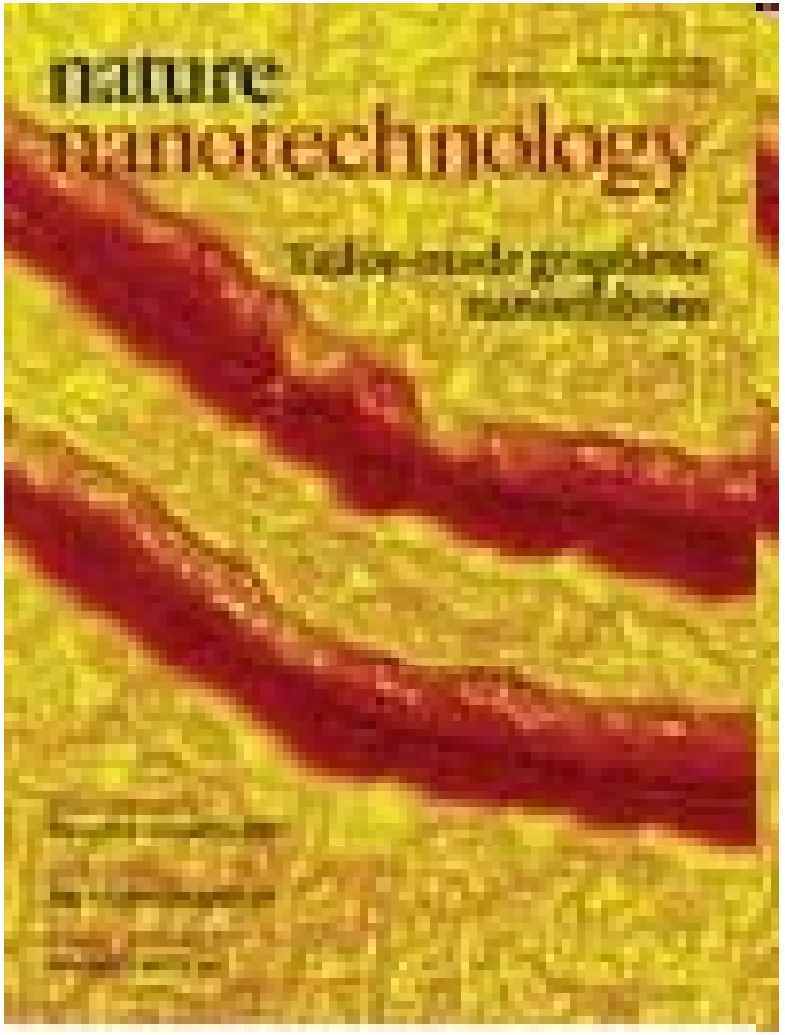
”Artificial nose” with CNT, elec. conductivity

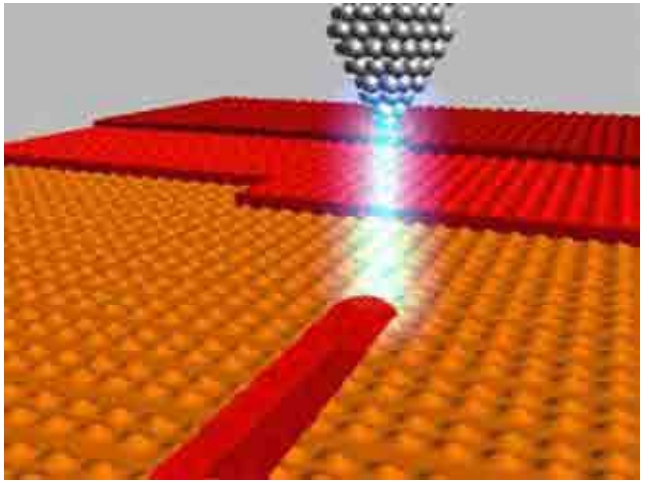
Chance to detect differences in wine…



02KF: 2002 Blaufränksch of a winery, 04KF: 2004 vintage of the same,
CS: Cabernet sauvignon, M and E two wineries
THL: Lindenblätter of Tokaj
Needs build-up of an intelligent databank
Combined with our MEMS-based nose, further improvement

Graphene lithography, I





SPM: „Plasma nanotorch”

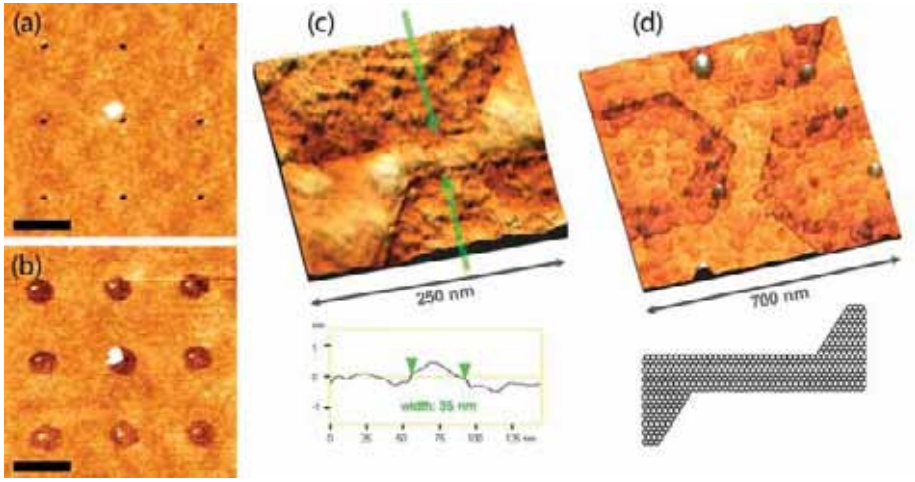
8 nm wide, oriented stripes.

Junior Prima Prize, 2008:
L. Tapasztó, MFA

http://www.mfa.kfki.hu/int/nano/

Graphene lithography, II

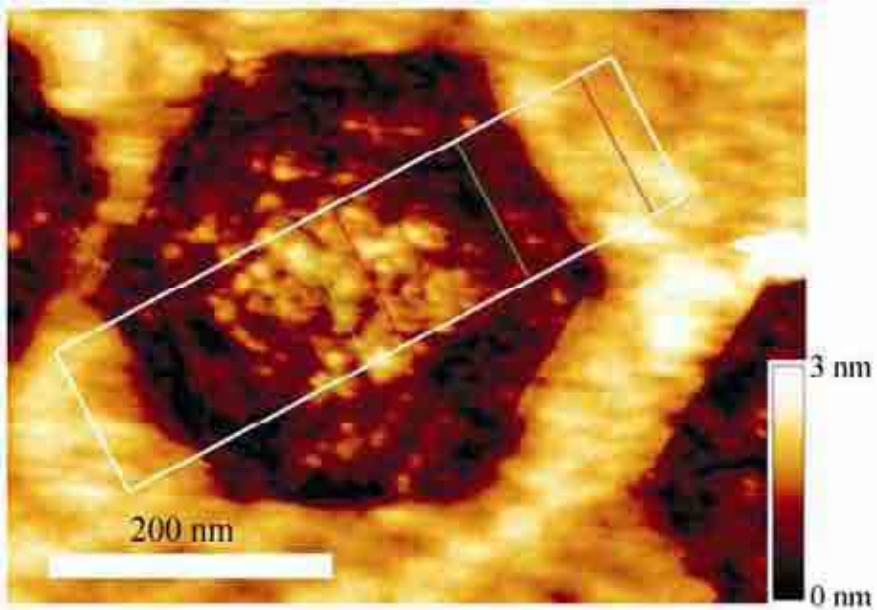
- Local, oriented oxidation of graphene on SiO_2
- Perimeter can be controlled

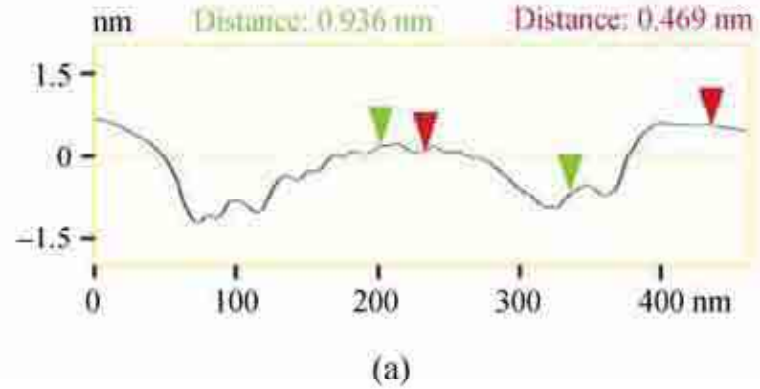


Péter Nemes-Incze

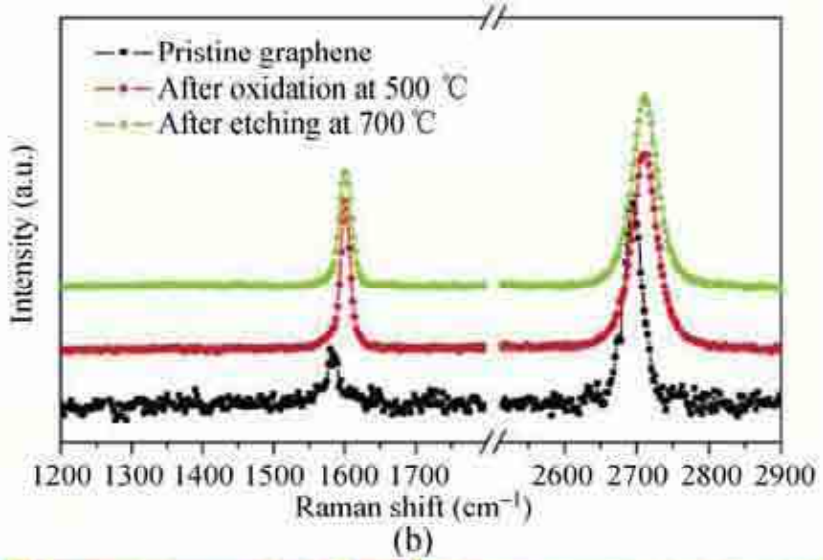
Junior prima, 2010

Graphene lithography, III

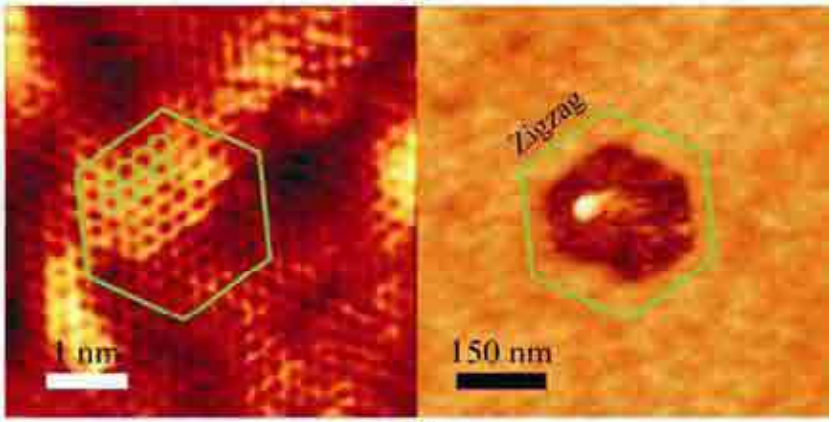




(a)

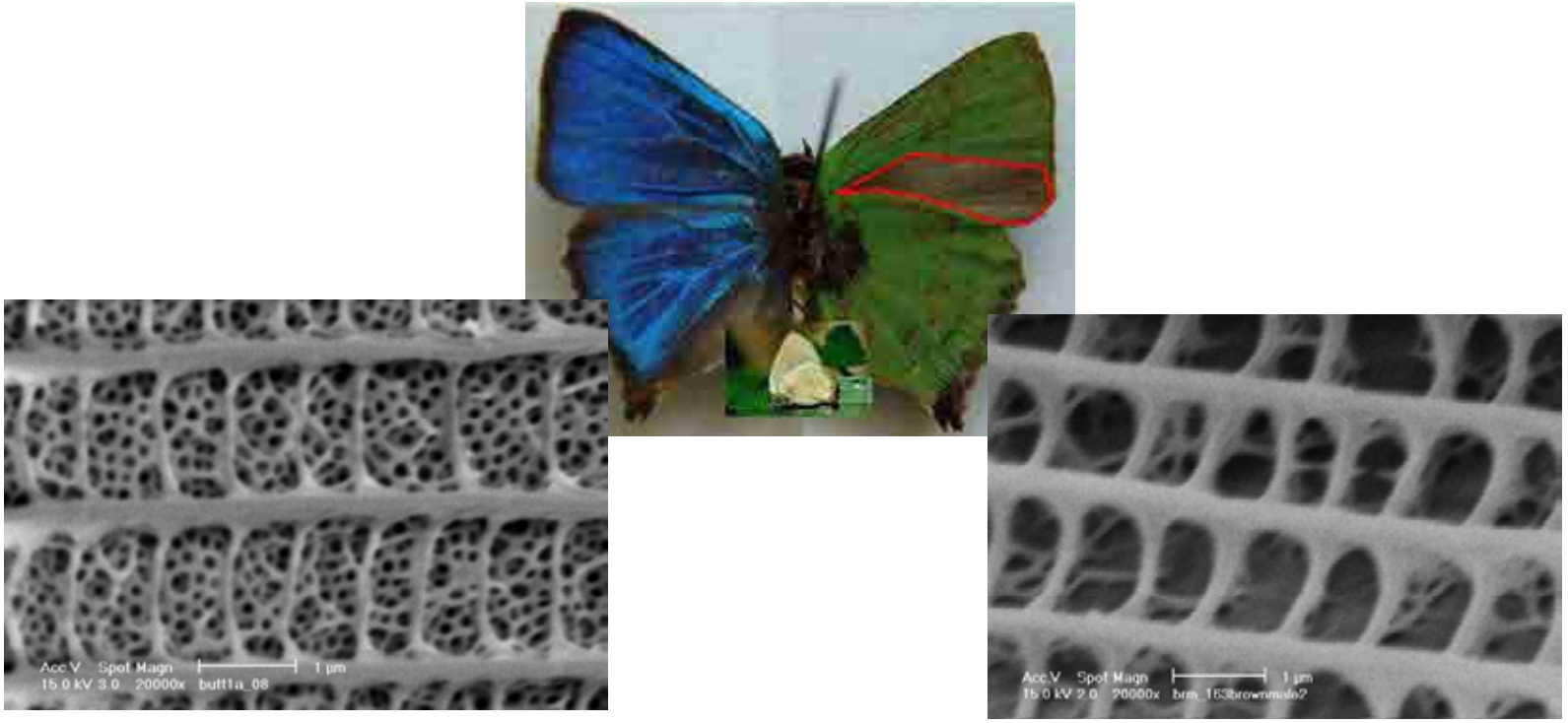


(b)



(c)

Photonic crystals – natural and towards artificial



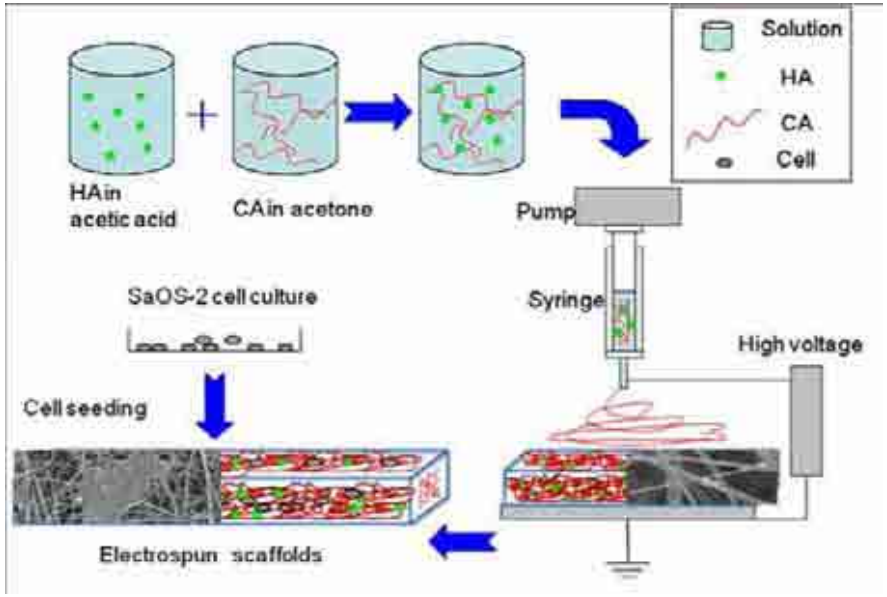
L.P Biró and Zs. Bálint.: Born under non-favouring conditions, e.g.,
at high altitude, no fine structure –
but, body temperature few degrees higher

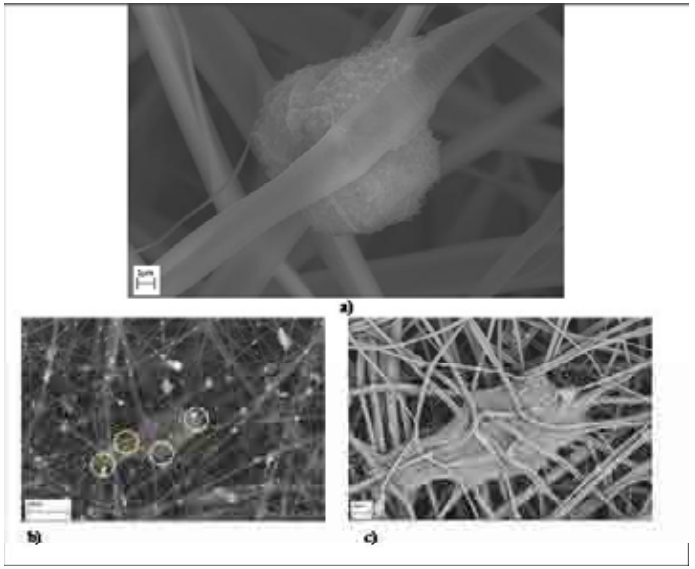
Department of Ceramics and nanocomposites (Cs. Balazsi, J. Volk)

- Nano hydroxyapatite and polymer based bio-compatible nanocomposites
- Artificial bone tissue scaffolds based on natural hybrids of cellulose acetate (CA) and nano-hydroxyapatite (nHA) in a bio-mimicking 3D matrix architecture (SUNY SB)

- ZnO nanorods

Artificial bone scaffolds





HA: Hydroxyapatite

CA: Cellulose acetate

Artificial bone scaffolds, II

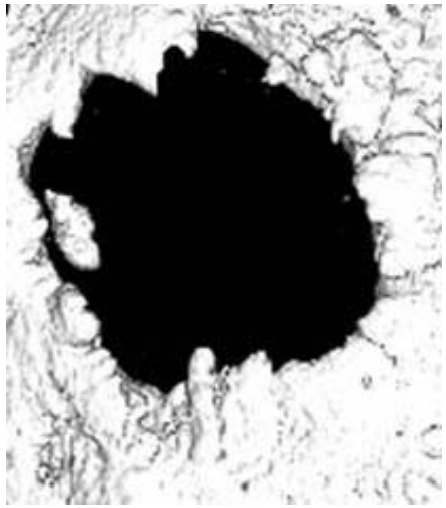
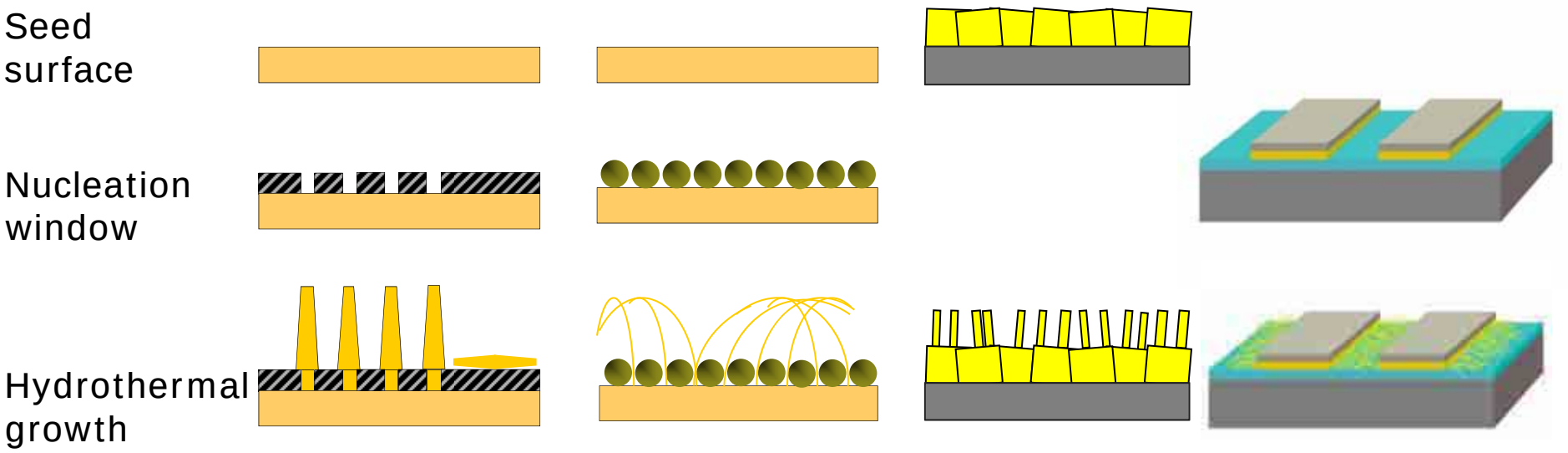


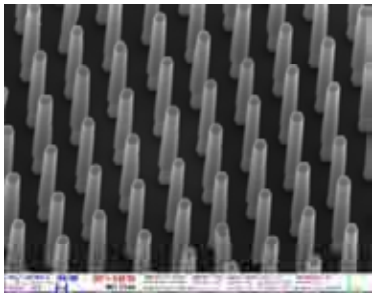
Figure a. *μCT images of unfilled control group at 8 weeks.*

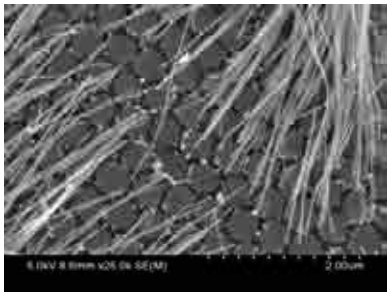
Figure b. *μCT images of nano-HAp grafted group at 8 weeks.*

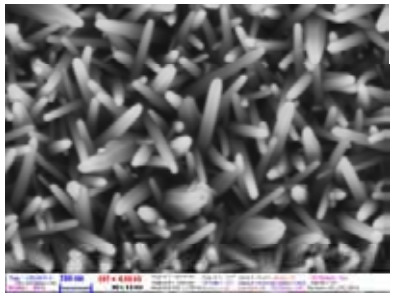
Figure c *Implants installation. The gap between implant and bone was restored by bone graft (nHA from Hungary). There was no infection in the graft site.*

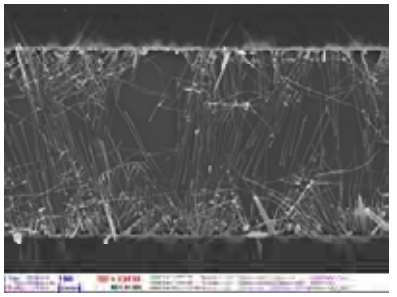
Engineered ZnO nanowires (J. Volk)



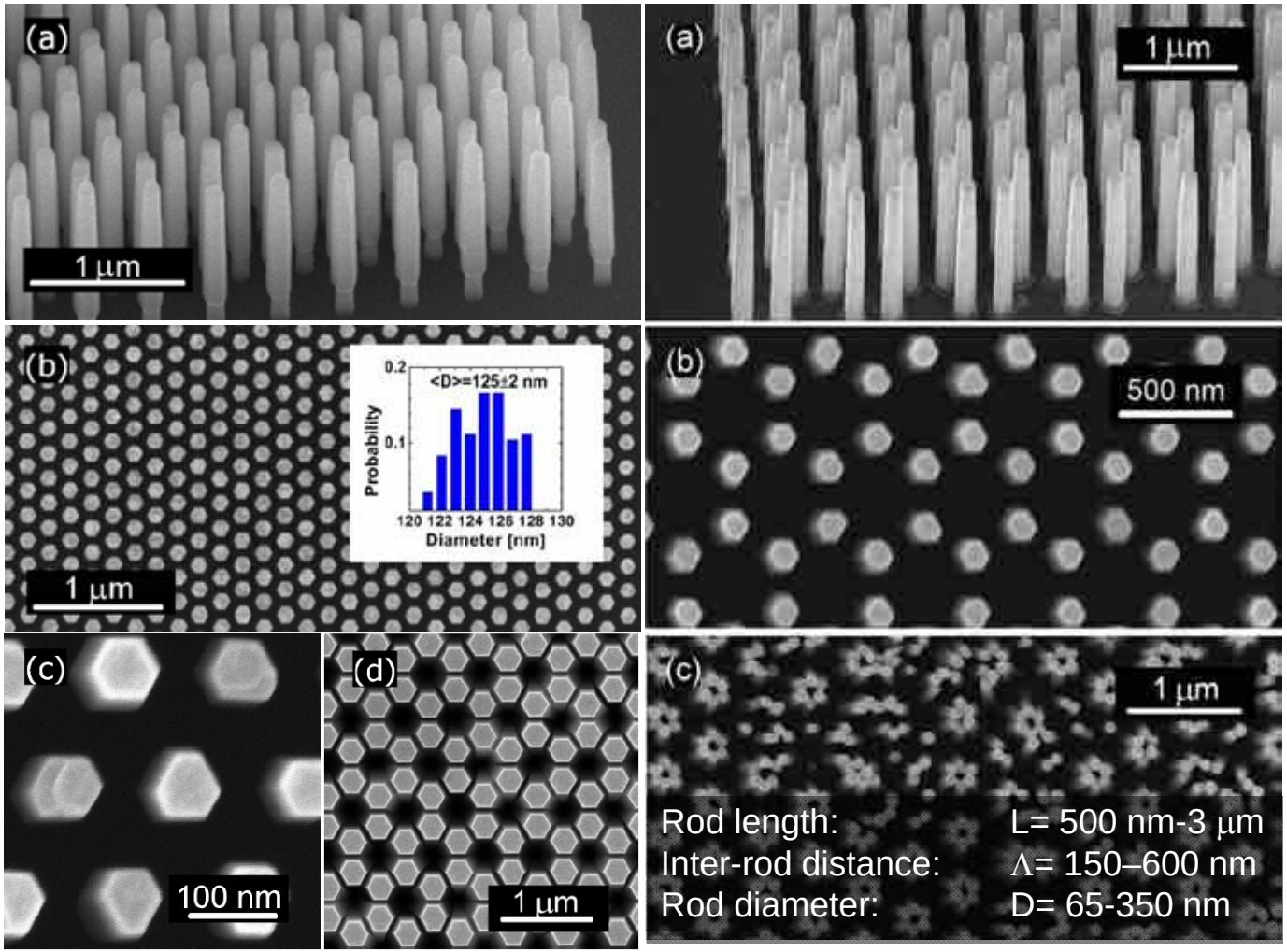








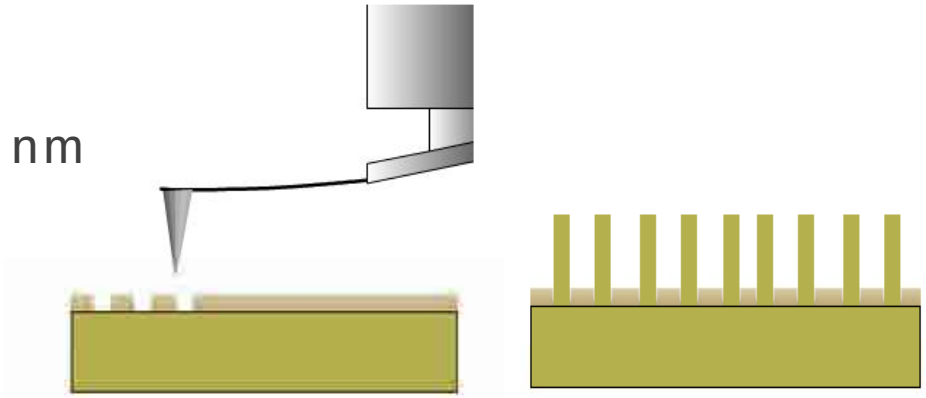
…by e-beam lithography

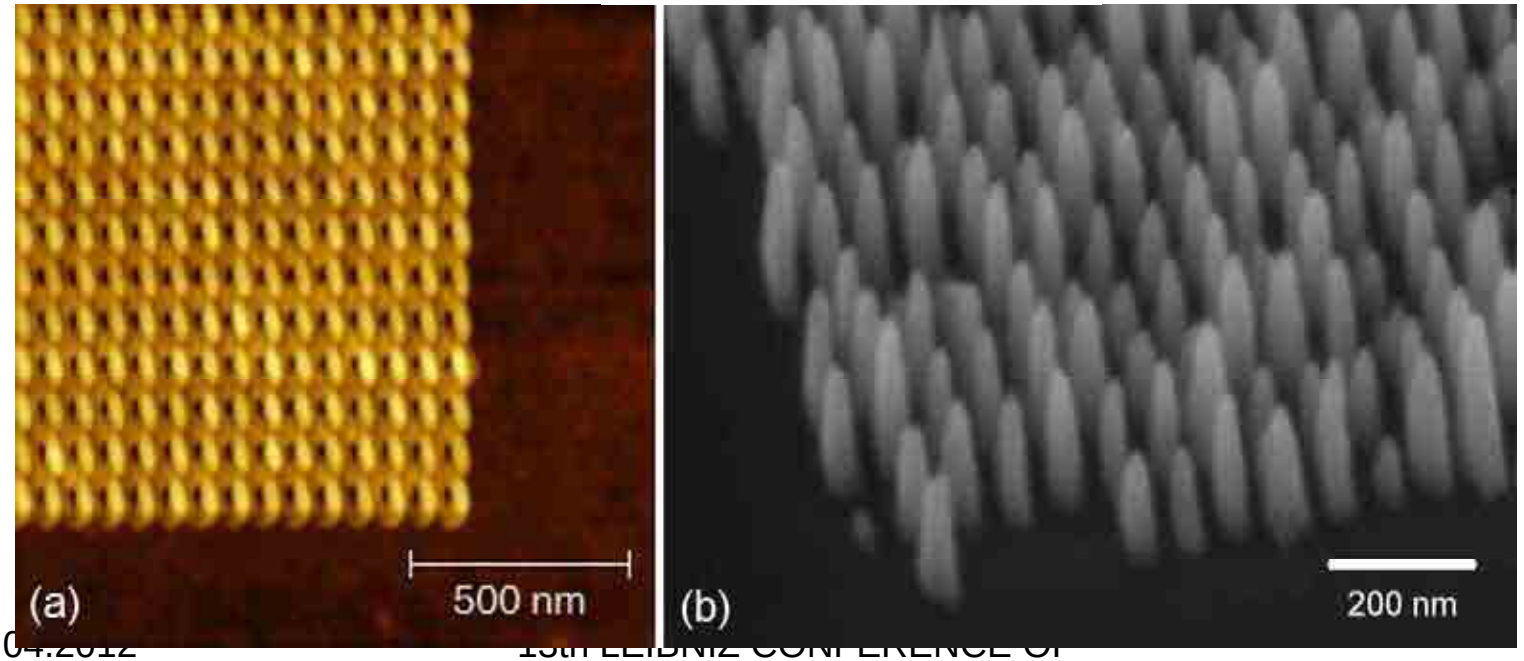


J. Volk et al., Nanoscale Res. Lett. 4, 699 (2009)

...by AFM nanolithography

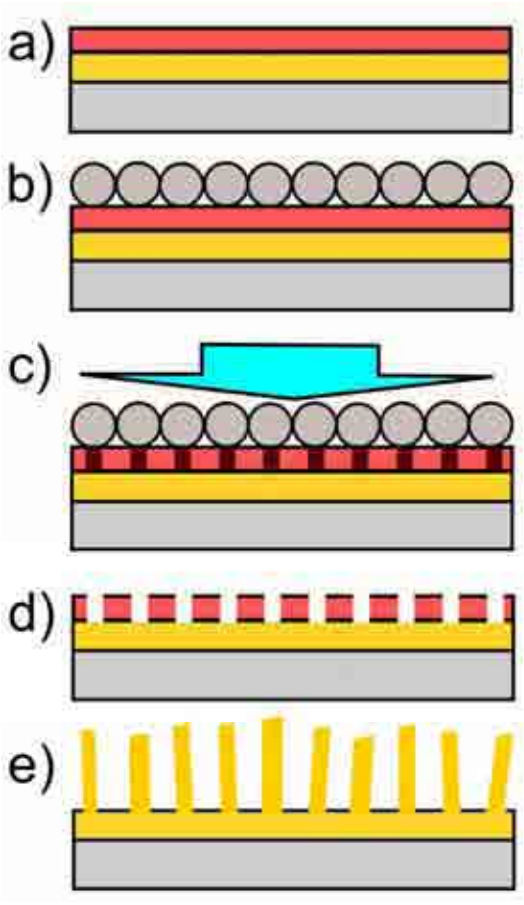
- 15 nm PMMA
- pulse shift value of 100 nm



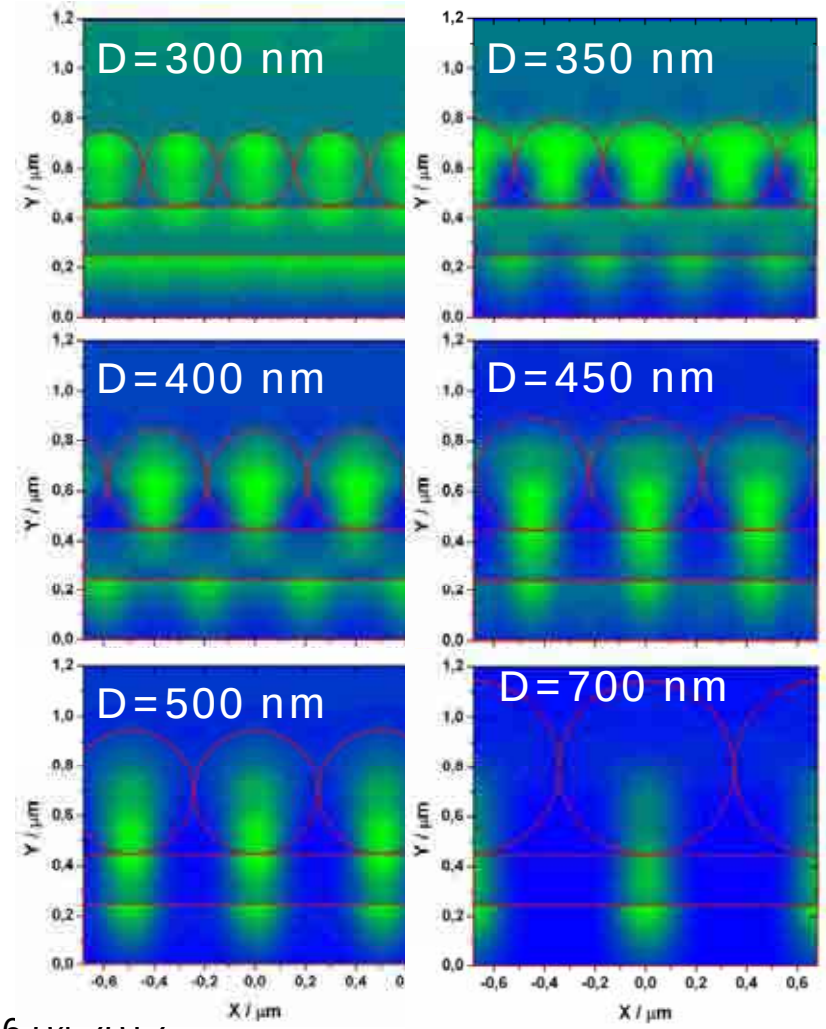


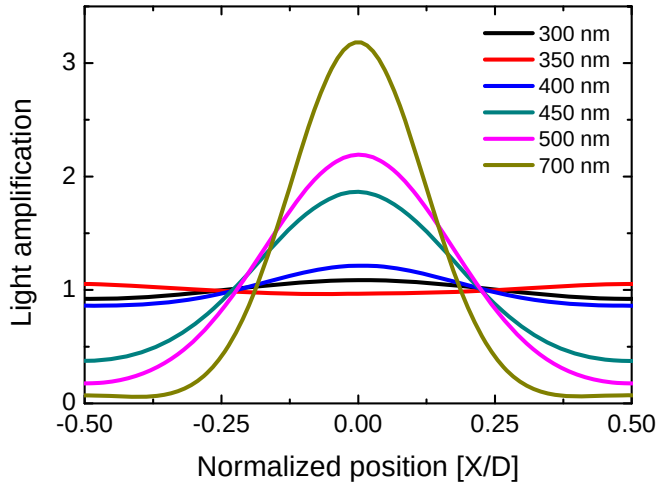
...by nanosphere photolithography

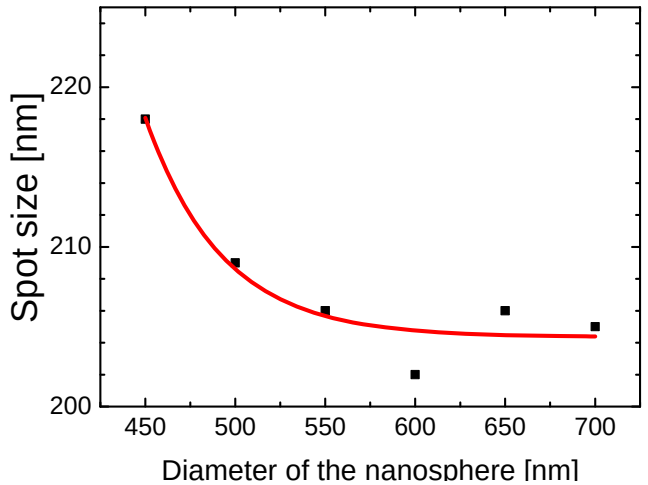
- Spin coating of photoresist
- Langmuir-Blodgett film of polysterene nanospheres
- UV illumination of 405 nm
- Developement
- Hydrothermal growth of nanopillars



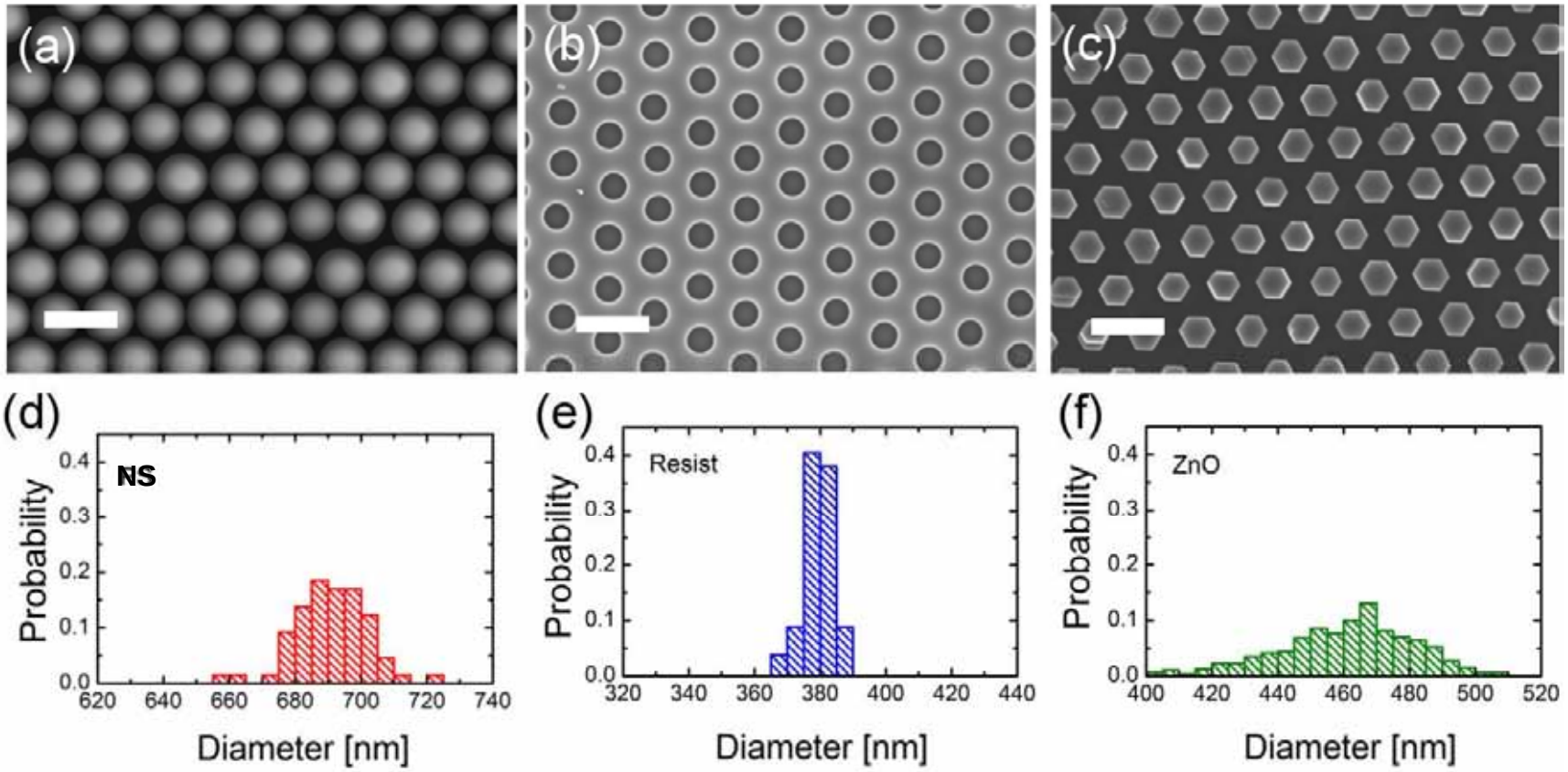
...by nanosphere photolithography – finite-difference time-domain (FDTD) simulation λ= 405 nm



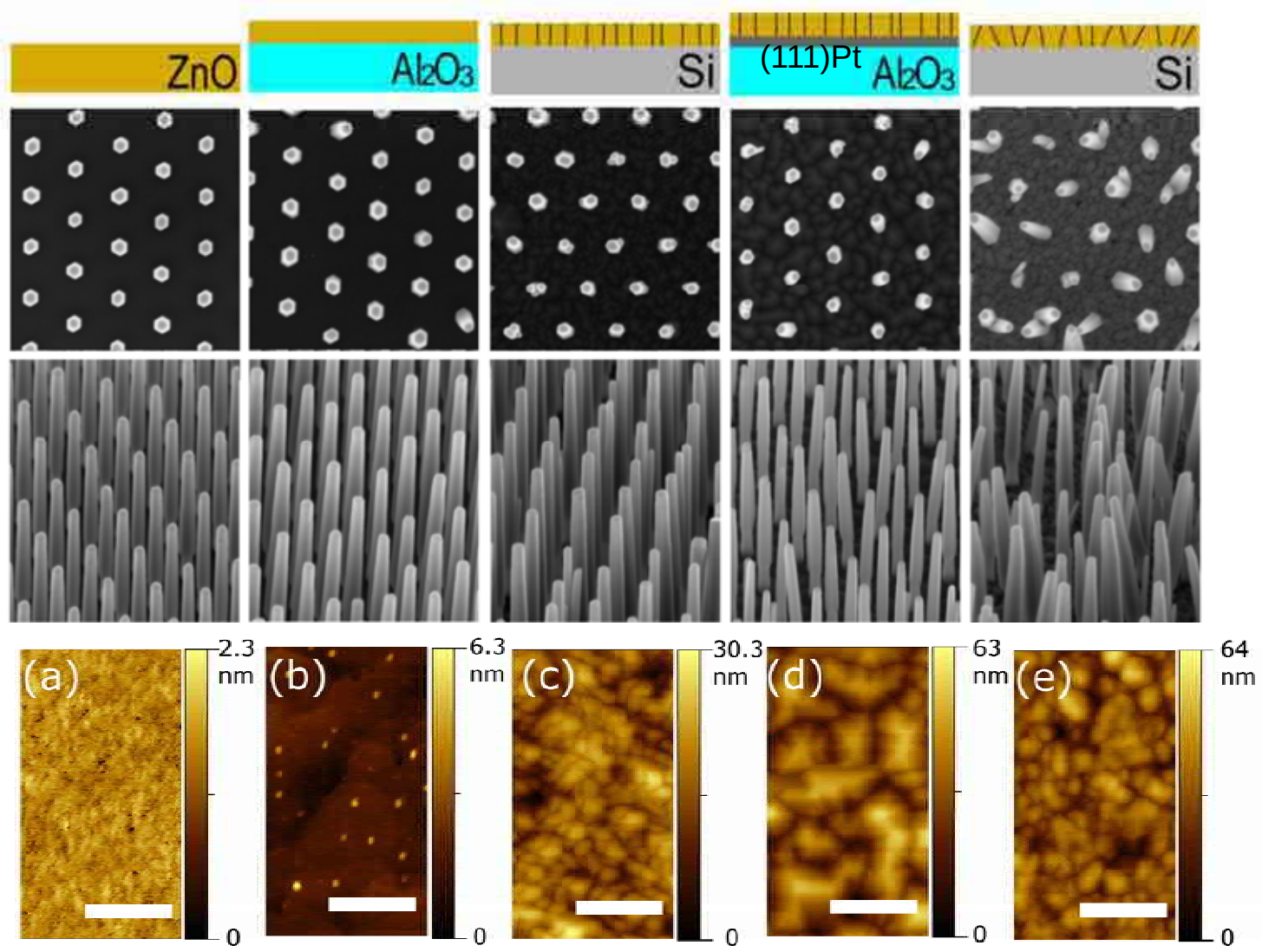




...by nanosphere photolithography

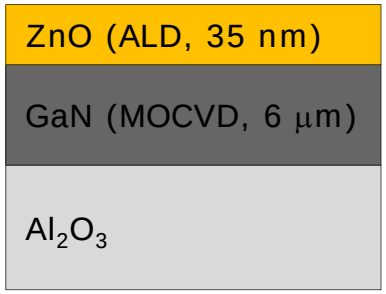


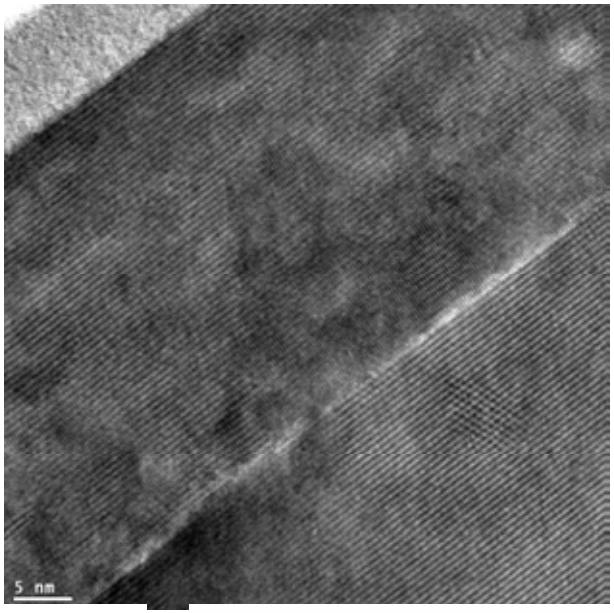
Seed surface effect

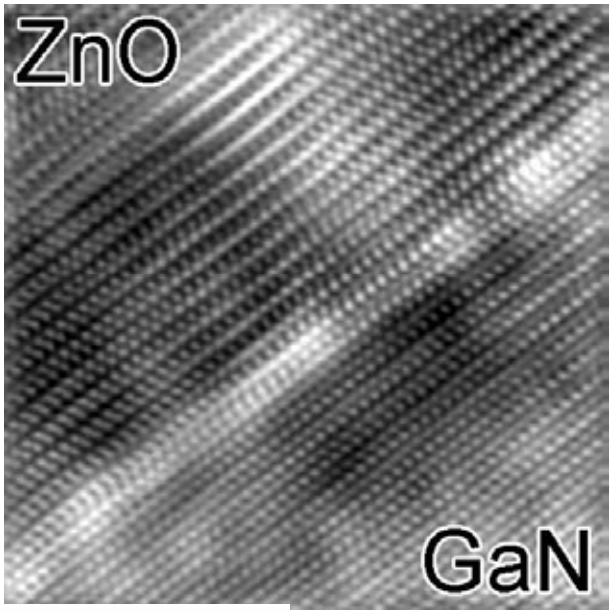


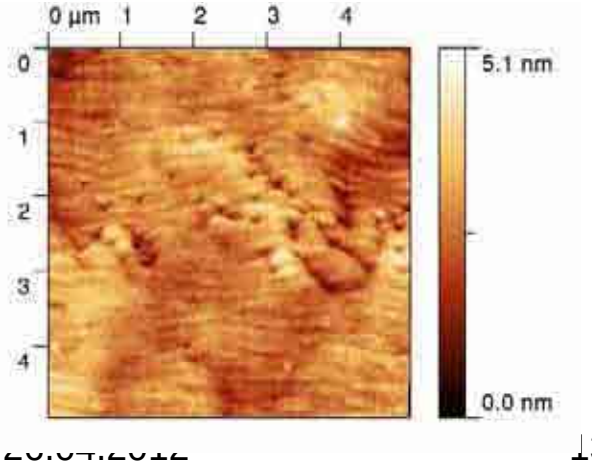
R. Erdélyi et al., Cryst. Gr. & Des., 2011, 11, 2515

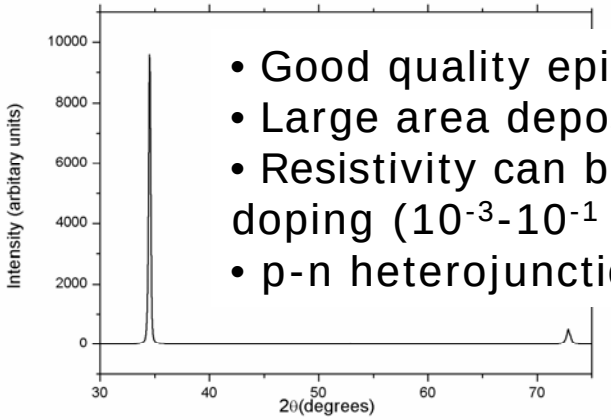
Nanowires, NWs on ALD ZnO template





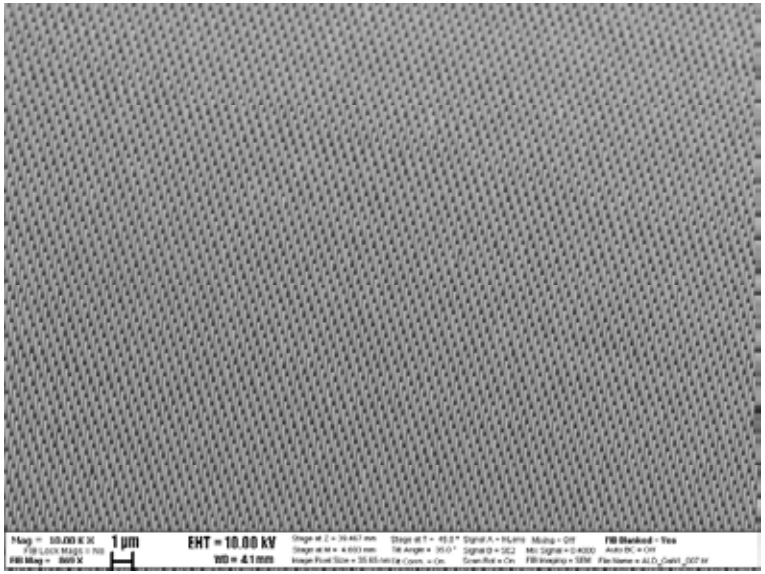


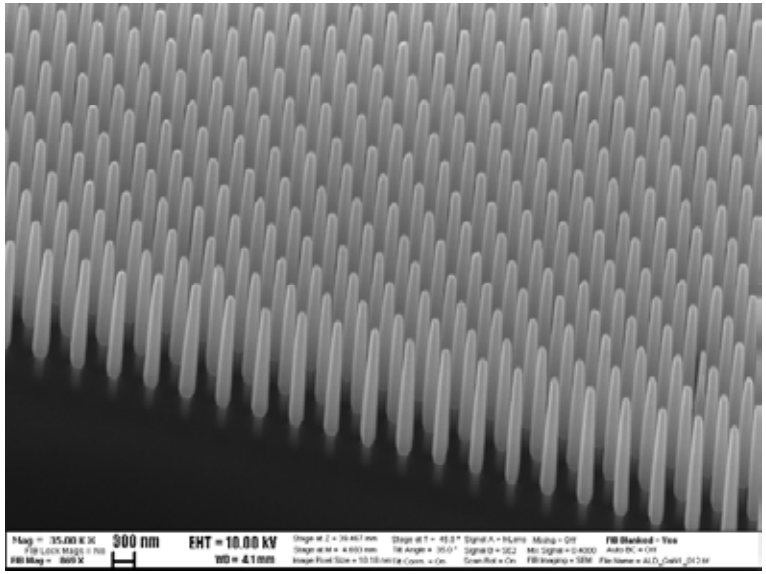


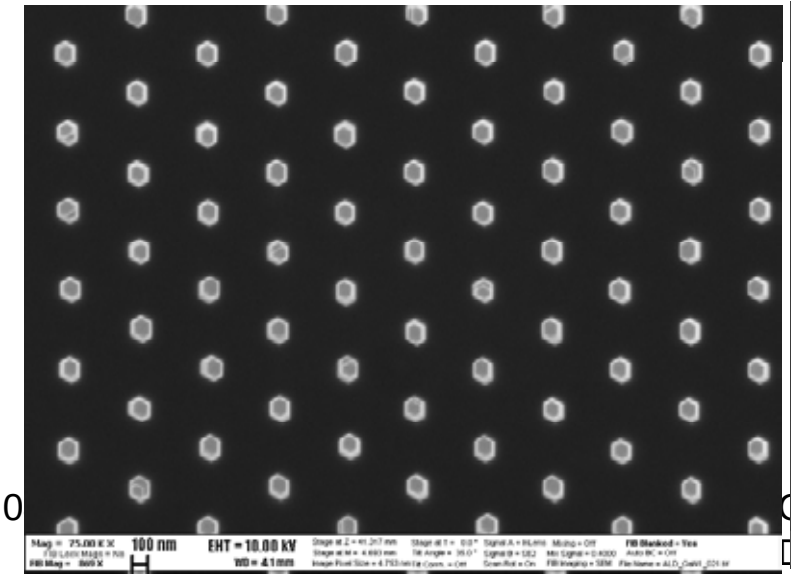


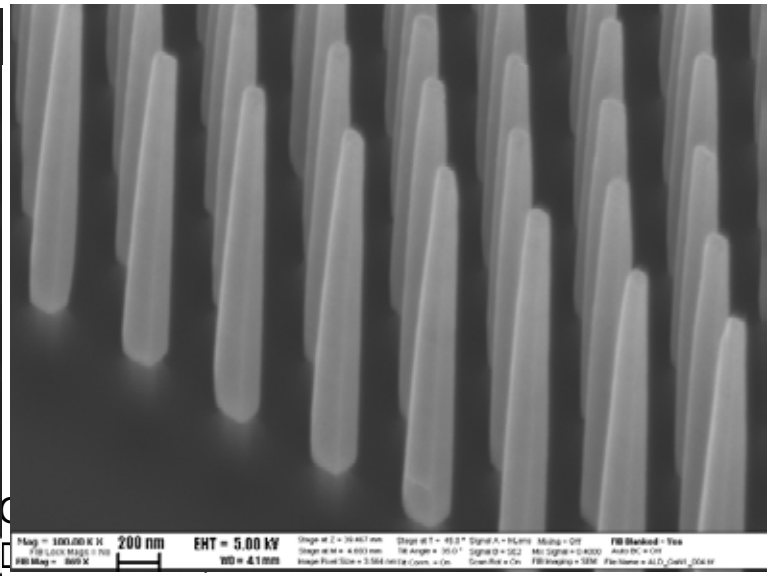
- Good quality epitaxial layer
- Large area deposition technique
- Resistivity can be controlled by Al doping (10^{-3}-10^{-1} Ωcm)
- p-n heterojunction at the interface

NWs on ALD ZnO template

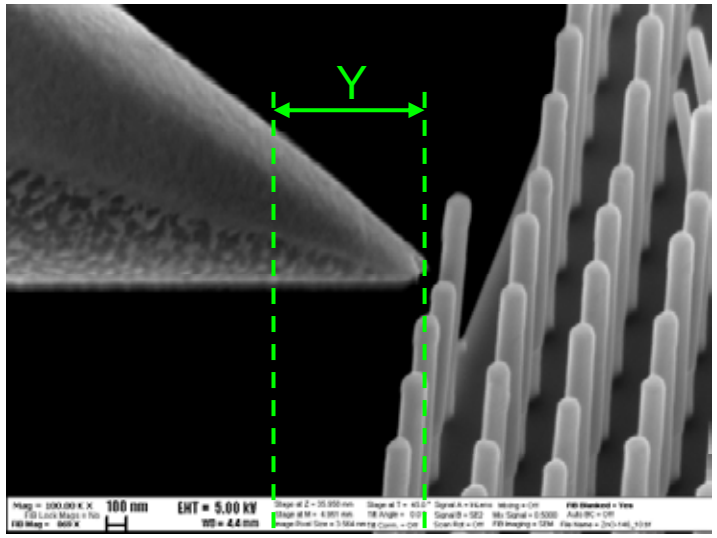


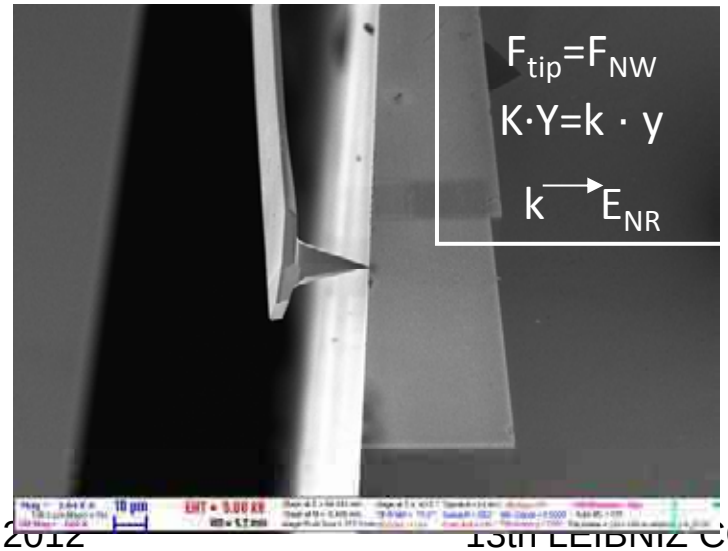






Static nanomechanical characterization

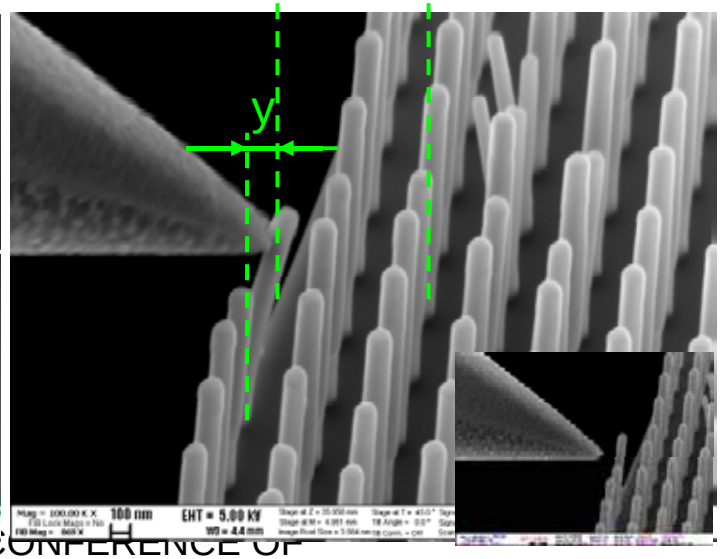




$F_{tip}=F_{NW}$

$K \cdot Y = k \cdot y$

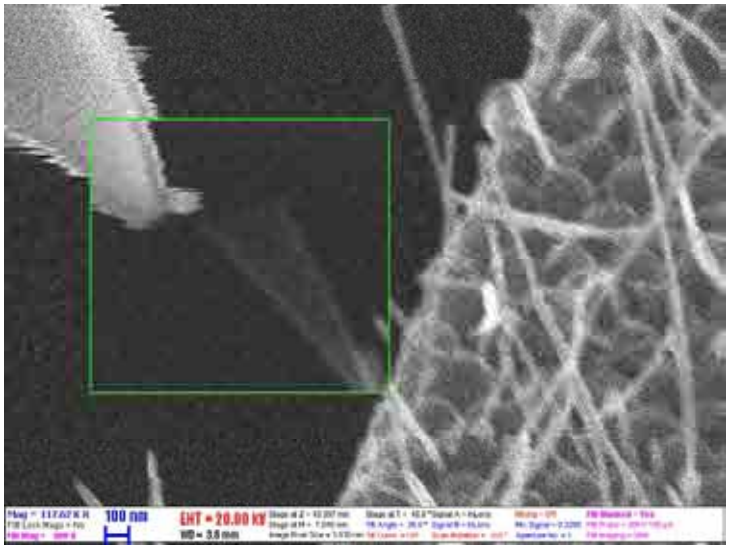
$k \rightarrow E_{NR}$

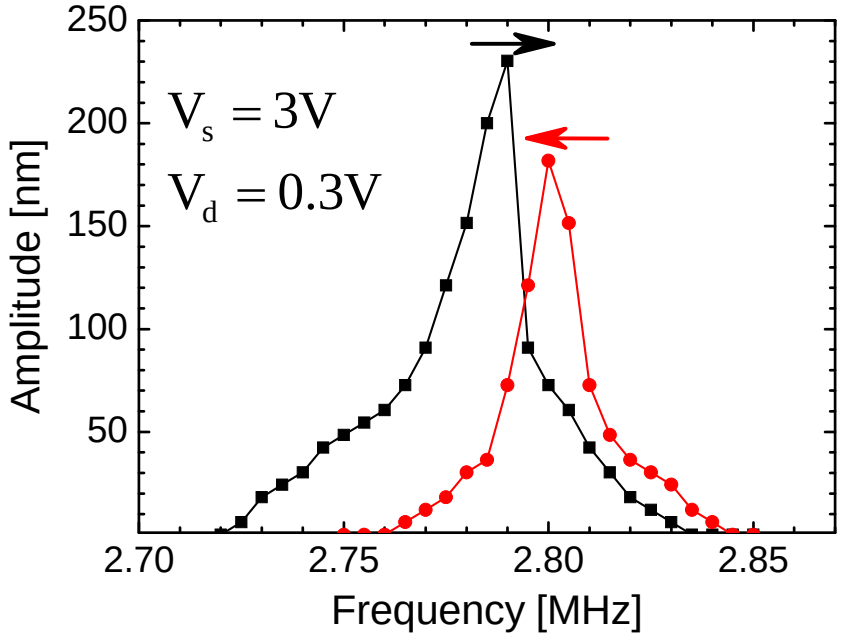


Resonance excitation method

$$V(t) = V_s + V_d \cos(\omega t)$$
$$q = \alpha[\Delta V + V(t)]$$
$$F(t) = \beta[\Delta V + V(t)] \cdot q$$

$$F(t) = \alpha\beta\left[\Delta V + V_S + V_d \cos(\omega t)\right]^2$$

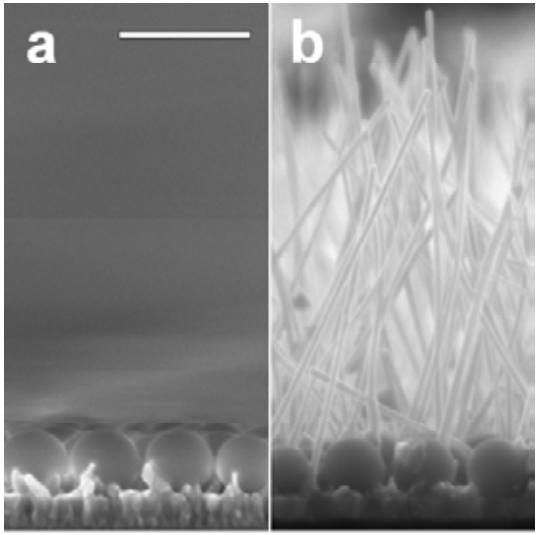


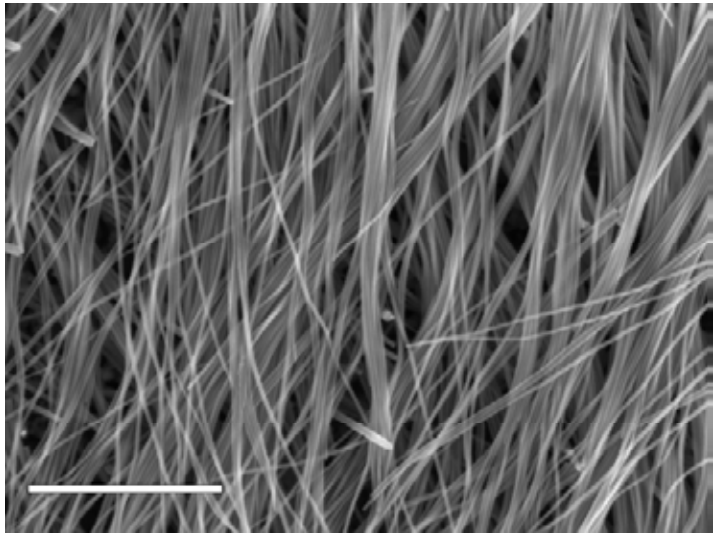


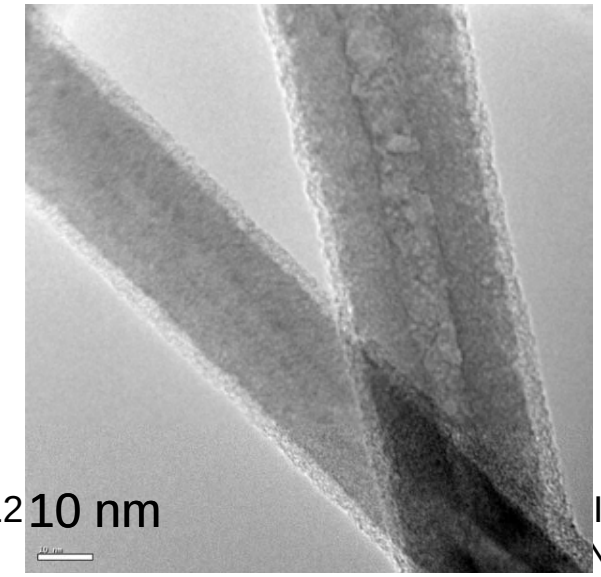
$$\upsilon = \frac{\beta_i^2}{8\pi}\sqrt{\frac{E}{\rho}} \cdot \frac{D}{L^2}$$

Demonstration with CNT: P. Poncharal, Science 283, 1513 (1999)

Possible application: Integrated chemical/biological sensor



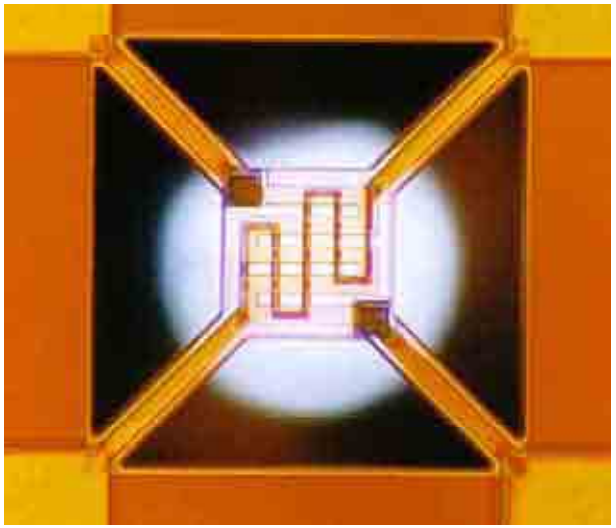


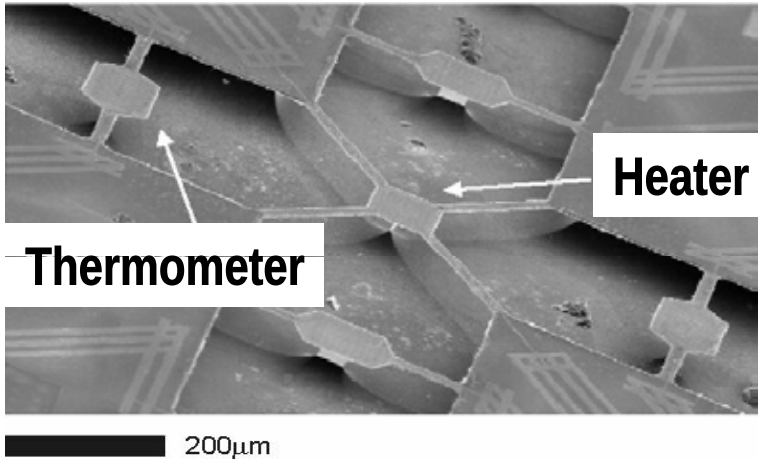


Microtechnology Department (I. Barsony, G. Battistig, P. Fürjes)

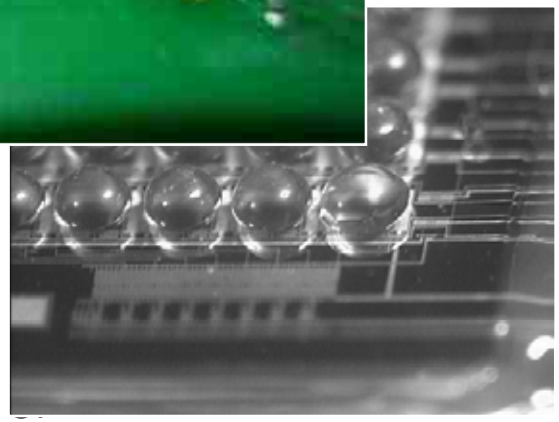
- Early technology with sacrificial layers, mainly porous silicon
- Taguchi sensors
- Gas flow meter

- Now, rather DRIE employed





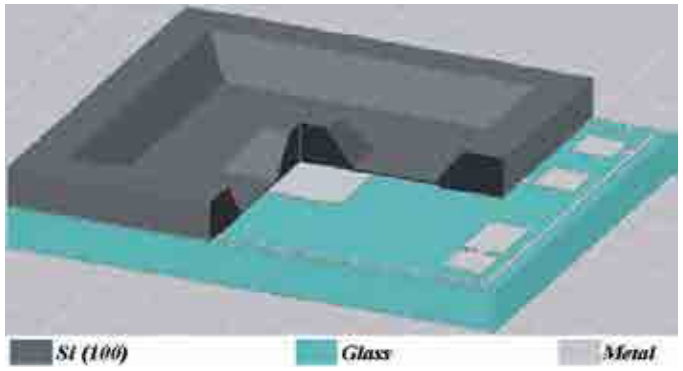
Tactile sensor, sensitivity approx. that of the fingertip

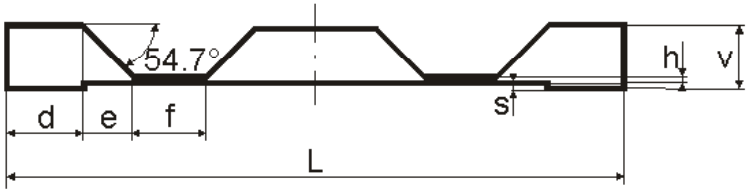


MFA - PPKE – Tactologic, Inc.

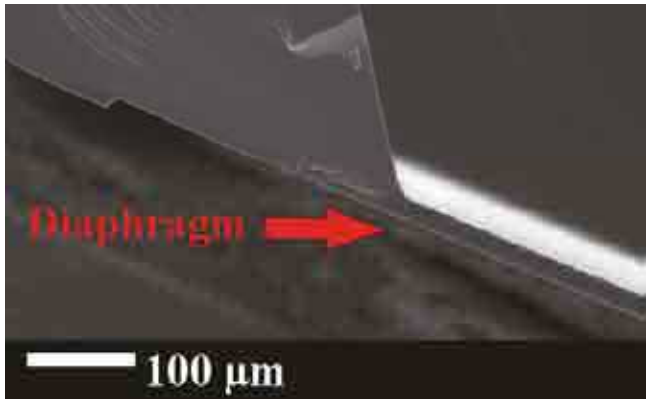
Project ENIAC SE2A 2009-2011

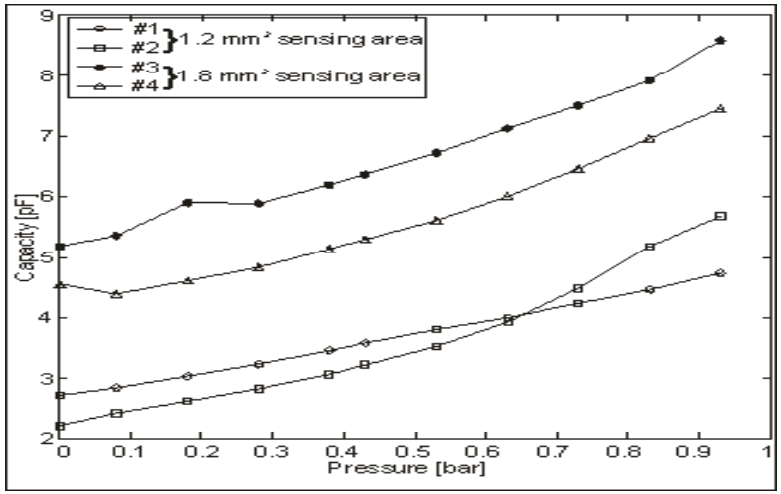
Capacitance pressure sensor – with wafer bonding





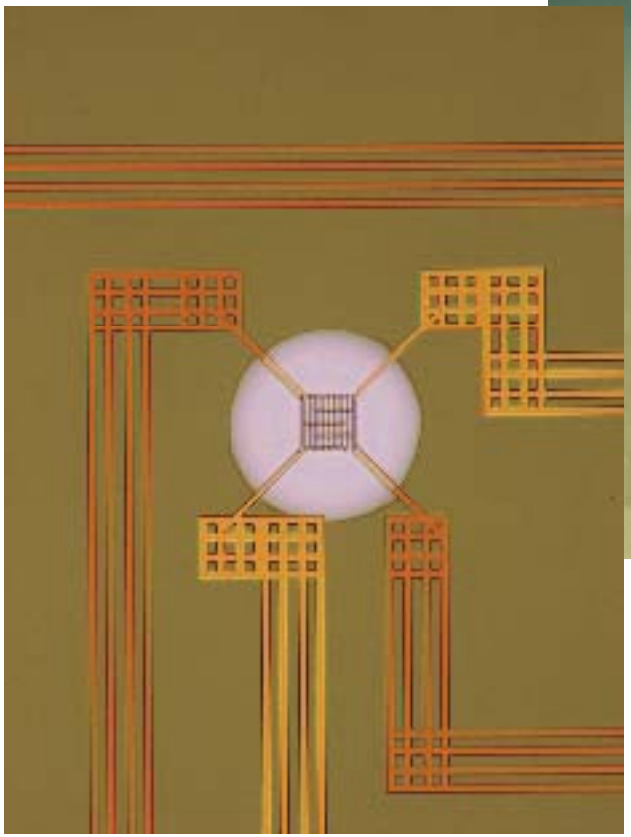
d=500 µm; e=340 µm; f=1 mm; L=5 mm;
s=10 µm; h=10 µm; v=500 µm;

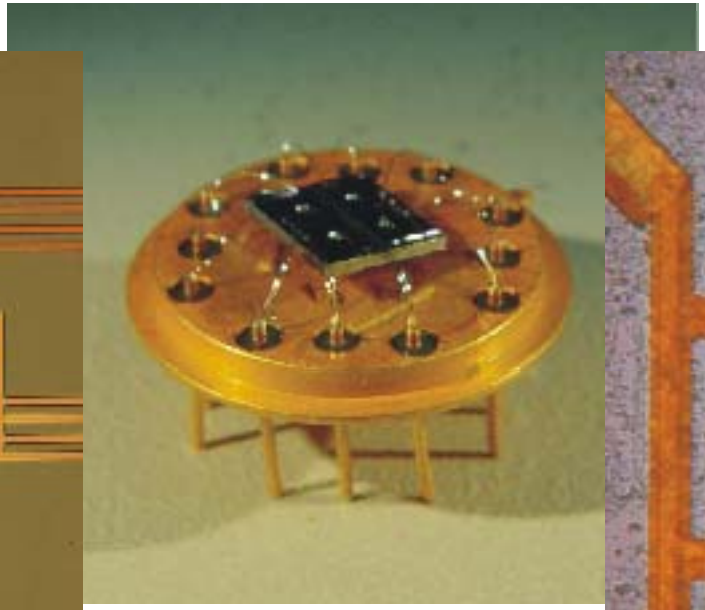


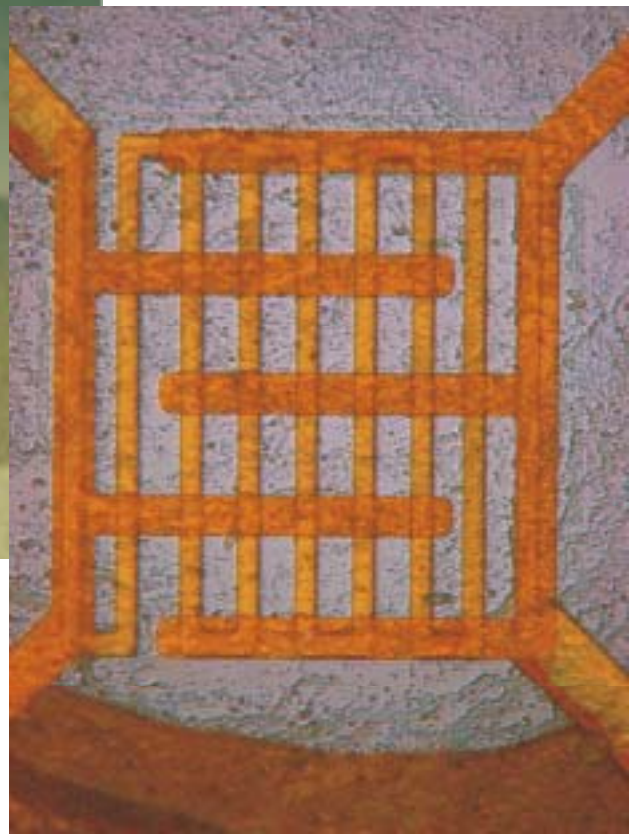


Projects ENIAC SE2A 2009-2011

Gas sensor – membrane – h-WO_3

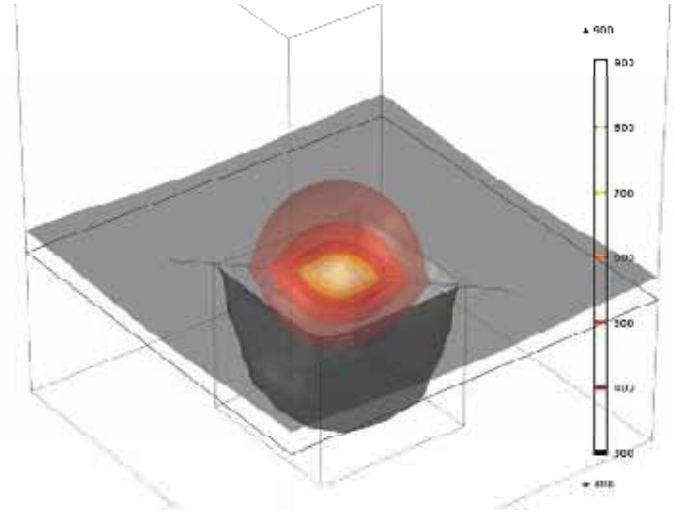


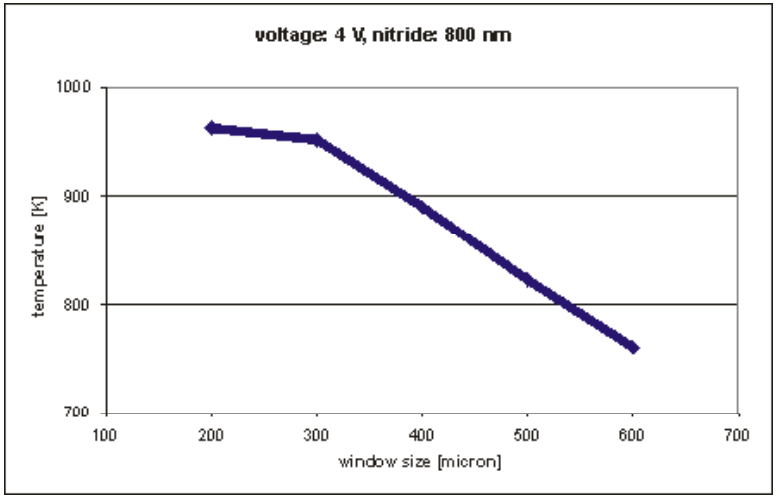


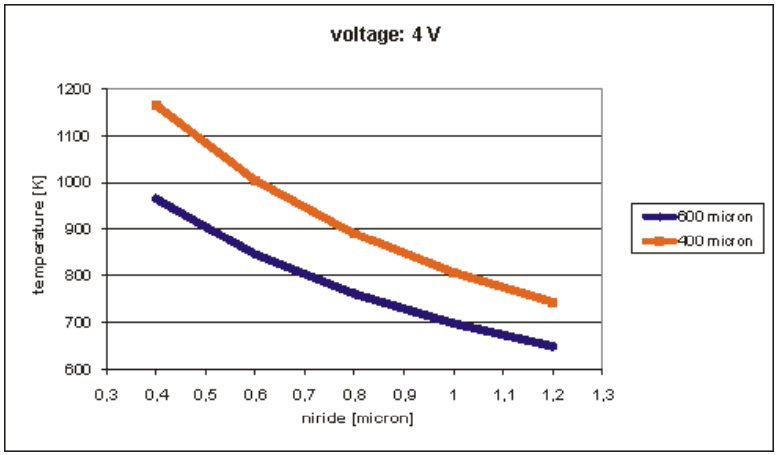


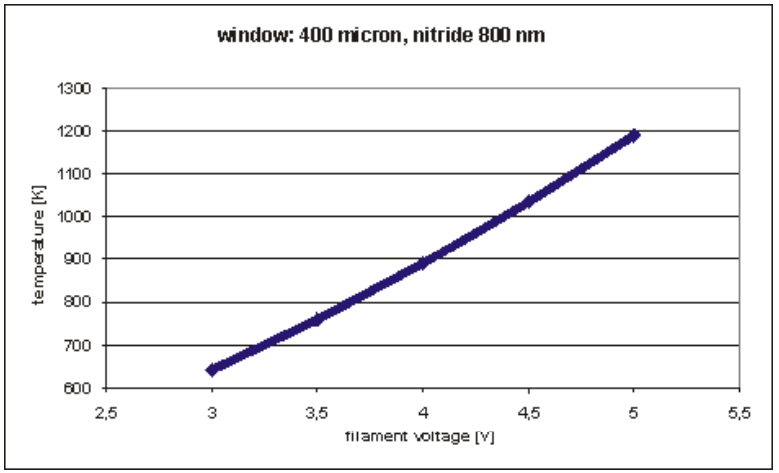
Projektek ENIAC SE2A 2009-2011

Gas sensor – membrane – WO_3; FE modelling – Heat distribution



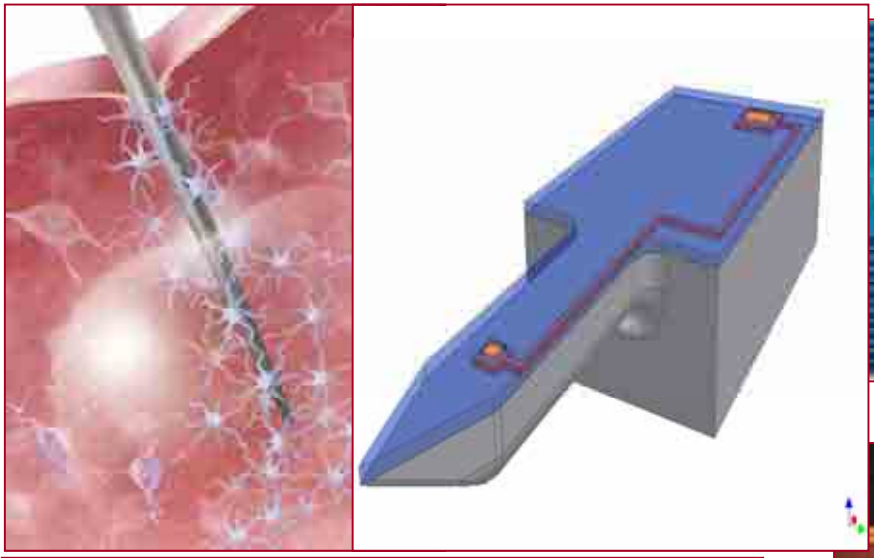


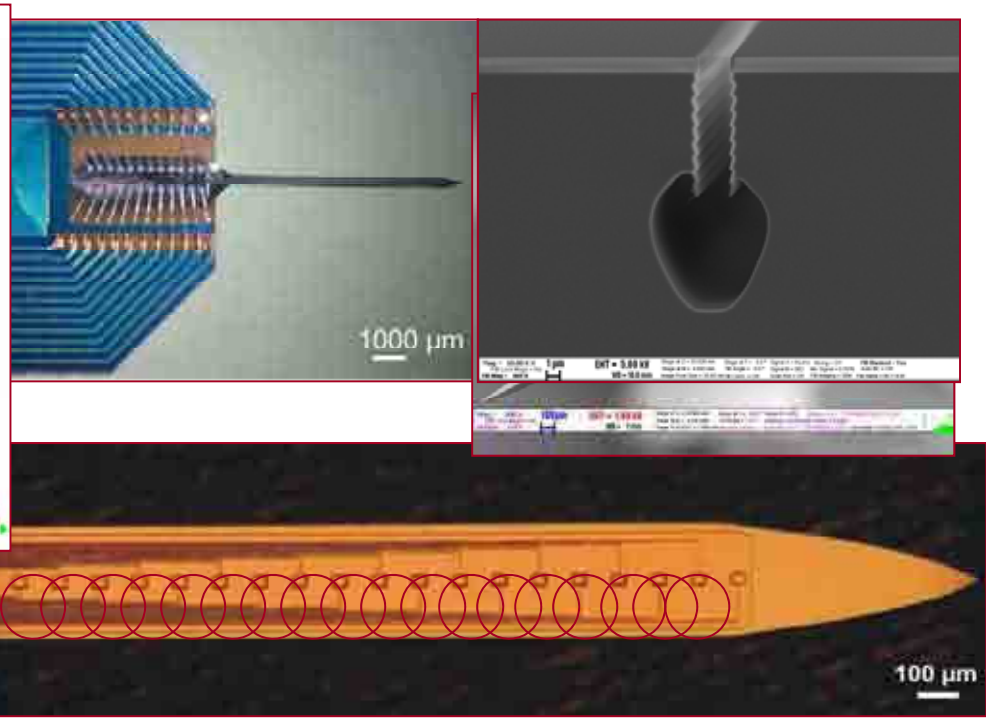


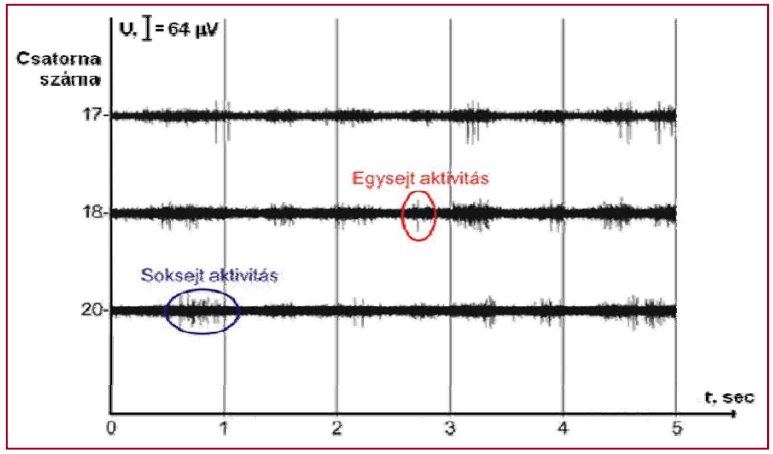


In-vivo multichannel brain electrode with canule

For monitoring extracellular electric processes





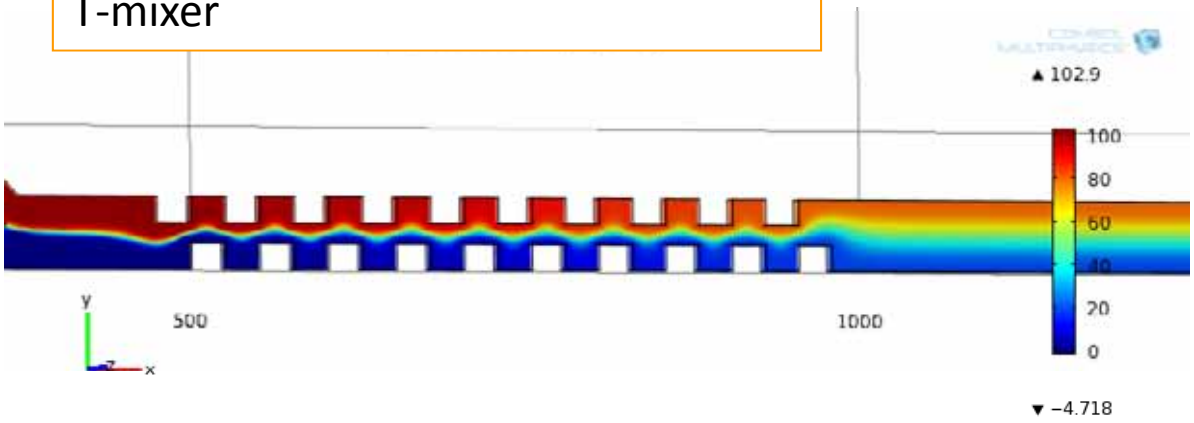


Goal: monitoring neural processes (Parkinson, epilepsy…)

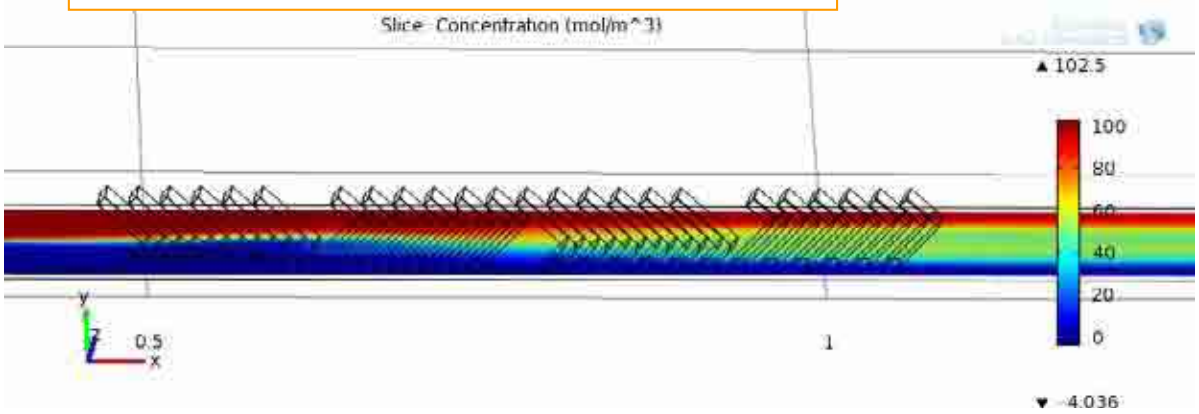
Partners: Pazmany Cath. Univ.,
Res. Inst. Psychology, Hung. Acad. Sci.

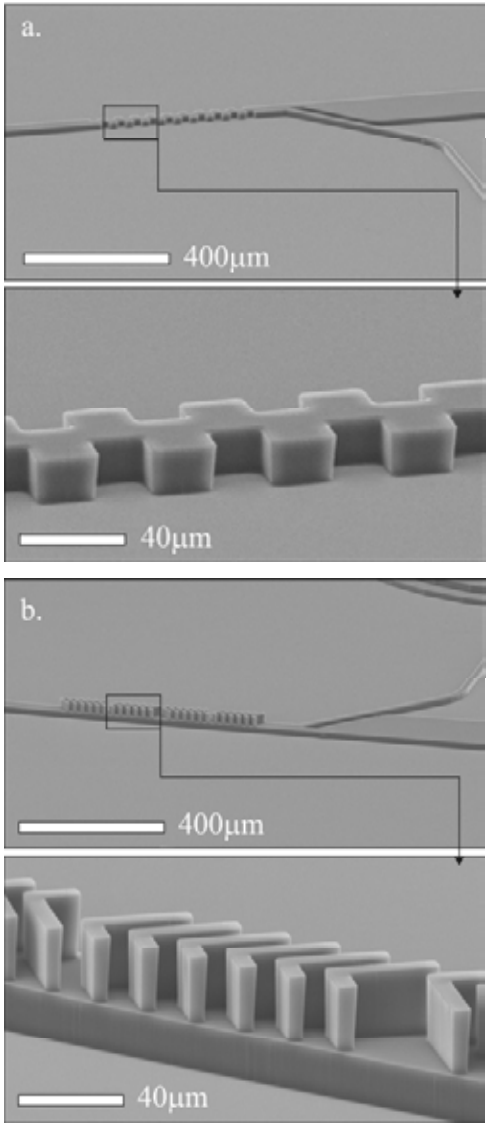
Mixing in micron quantities

T-mixer

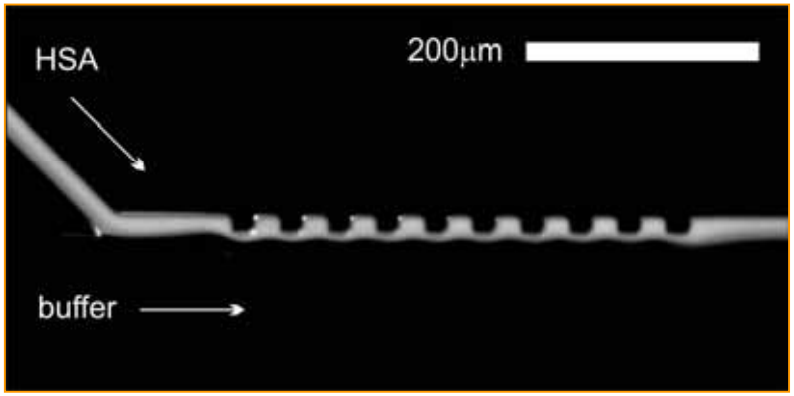


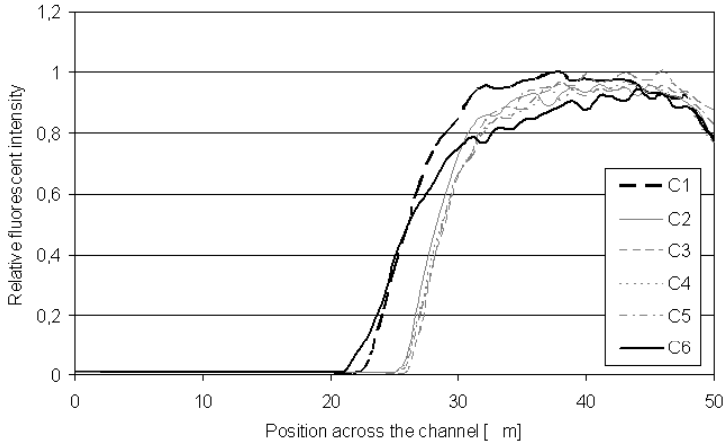
Herring-bone type mixer

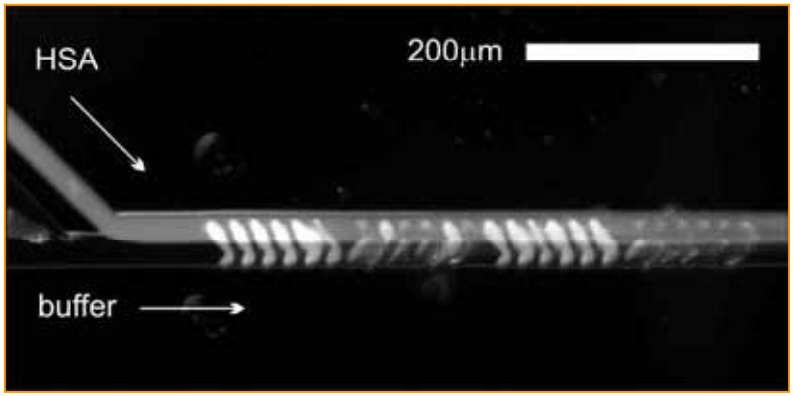


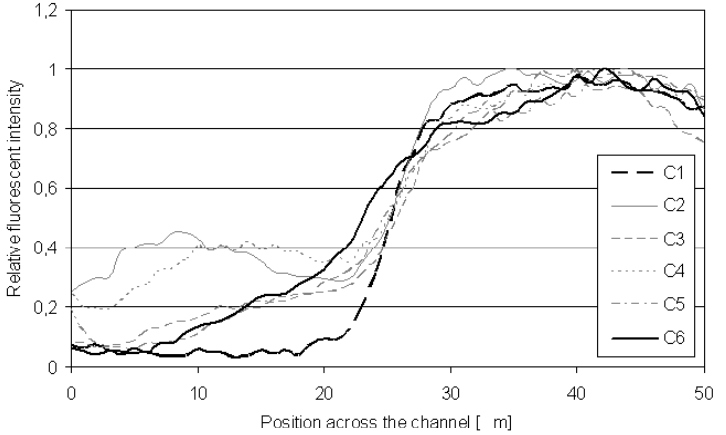


Mixing in micron quantities









Projects ENIAC CAJAL4EU 2010-2012

Chip Architectures by Joint Associated Labs for EUropean diagnostics

… develop semiconductor-based biosensor technology platforms enabling *in-vitro* diagnostic test manufacturers to rapidly build a variety of new multi-parameter test applications in a robust, user-friendly and cost-effective way …

… rapid, highly sensitive multiplexed detection of biomolecules in a ***label-free*** sensing approach …

Nanopores

… selective recognition of proteins and nucleic acids …

… chemically modified single nanopores and nanopore arrays with multiplexing capabilities …

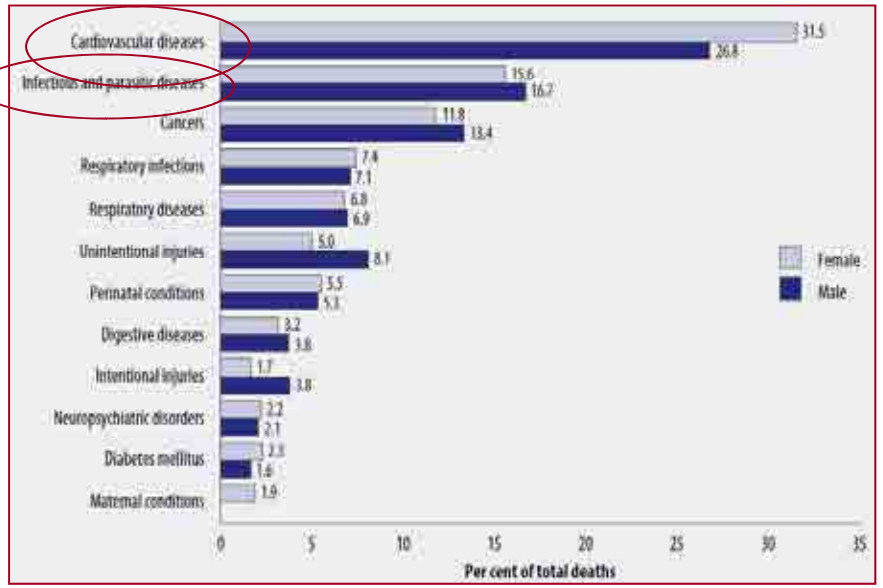
… interfaced with microelectronic readout and addressable microfluidics …

Partners:
BME (TUB) +
SOTE (Semmelweiss Med. Univ.)

Micro- and nanosystems for bioanalytical purposes

Motivation: large thruput and cheap, disposable systems

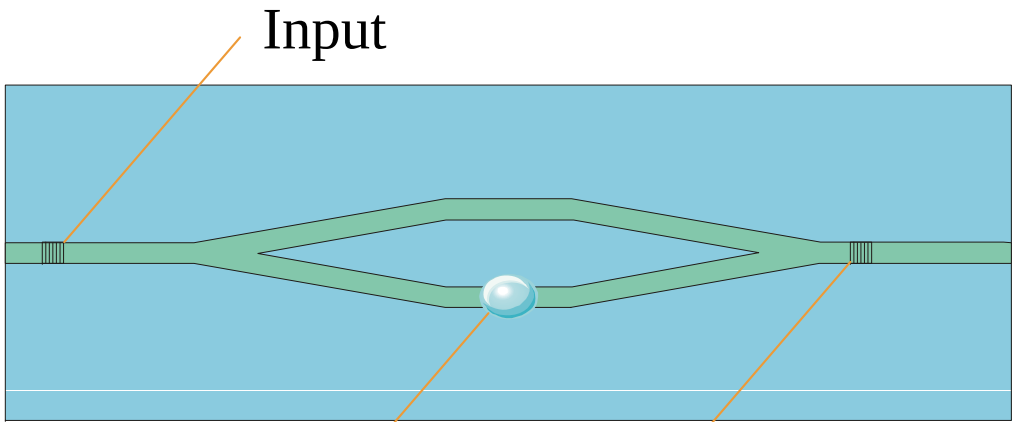
- Multi-parametric tests - antibody, DNS or marker protein detection
- Quick, discard
- Blood or plasma



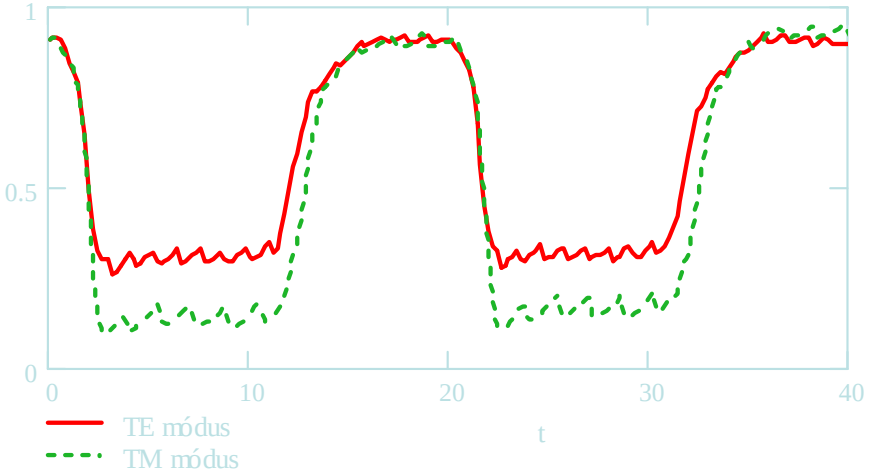
Projects:

1. Polymer Photonics Multiparametric biochemical SENSor for Point of care diagnostics – **P3SENS (FP7 project no.: 248304)**
2. Chip Architectures by Joint Associated Labs for EUropean diagnostics – **CAJAL4EU (ENIAC JTI – 2009-1)**
3. Chemically modified nanapore sensors for investigations of biomolecular interactions **(OTKA NF69262, Hungary and patents)**

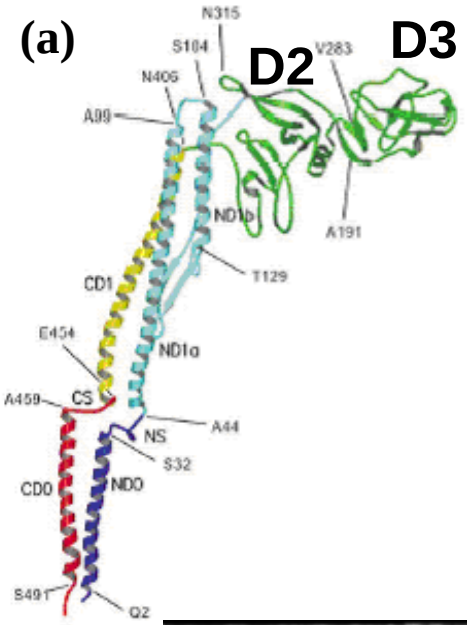
Bioreceptors on Mach-Zender interferometer (M. Fried, F. Vondervizst)



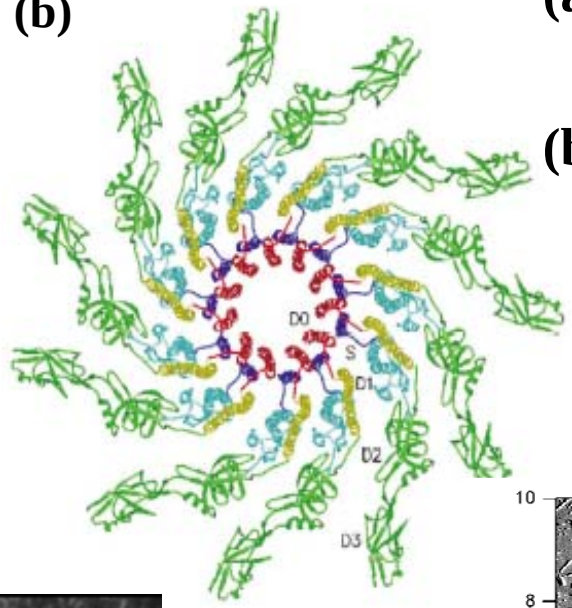
Interferometer signal



(a)

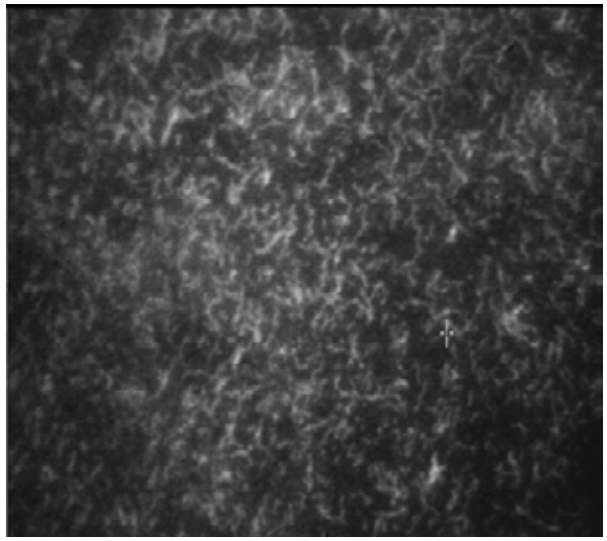


(b)

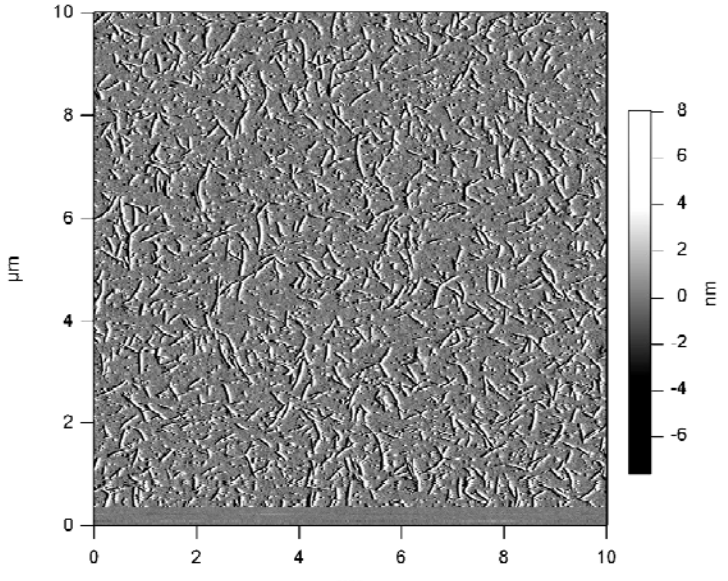


(a) Ni sensitized flagelline (D2, D3)

(b) Flagelline distribution on surfaces, glass and Nitrocellulose

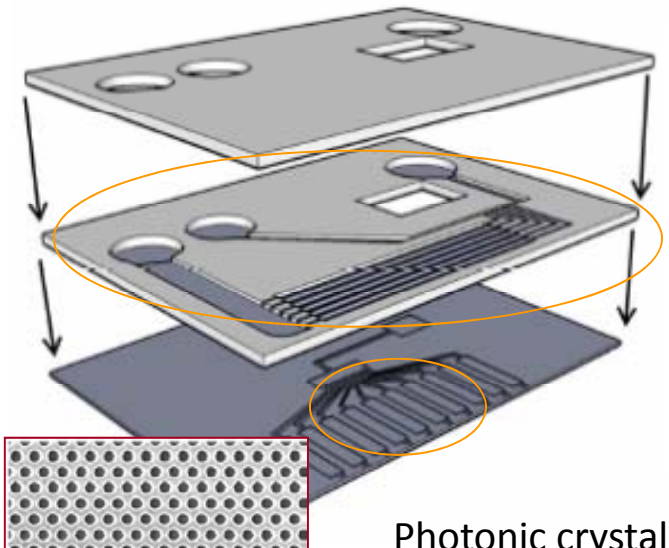


Glass



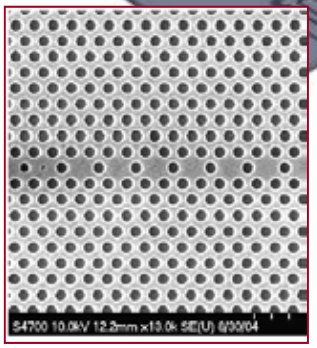
Nitrocellulose

Complex system to detect label-free biomarker proteins (R. Horvath)



Cover

Transport microfluidics
SU-8 vagy PDMS polymers



Photonic crystal:

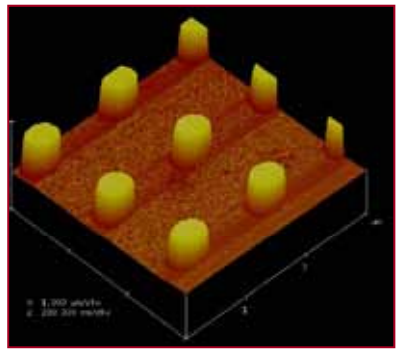
Polymer photonic crystal (PhC) based multichannel biosensor

Polymer Photonics
Multiparametric biochemical SENSor for Point of care diagnostics

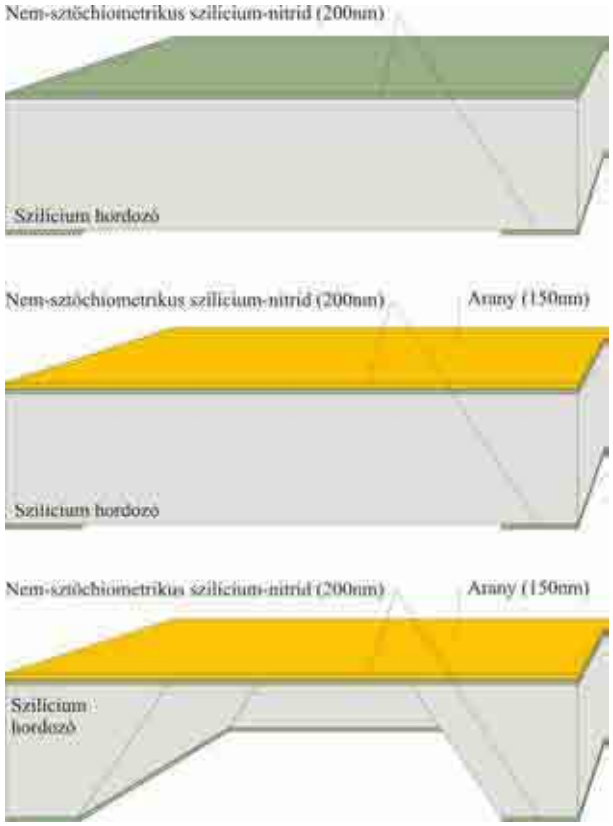
P3SENS

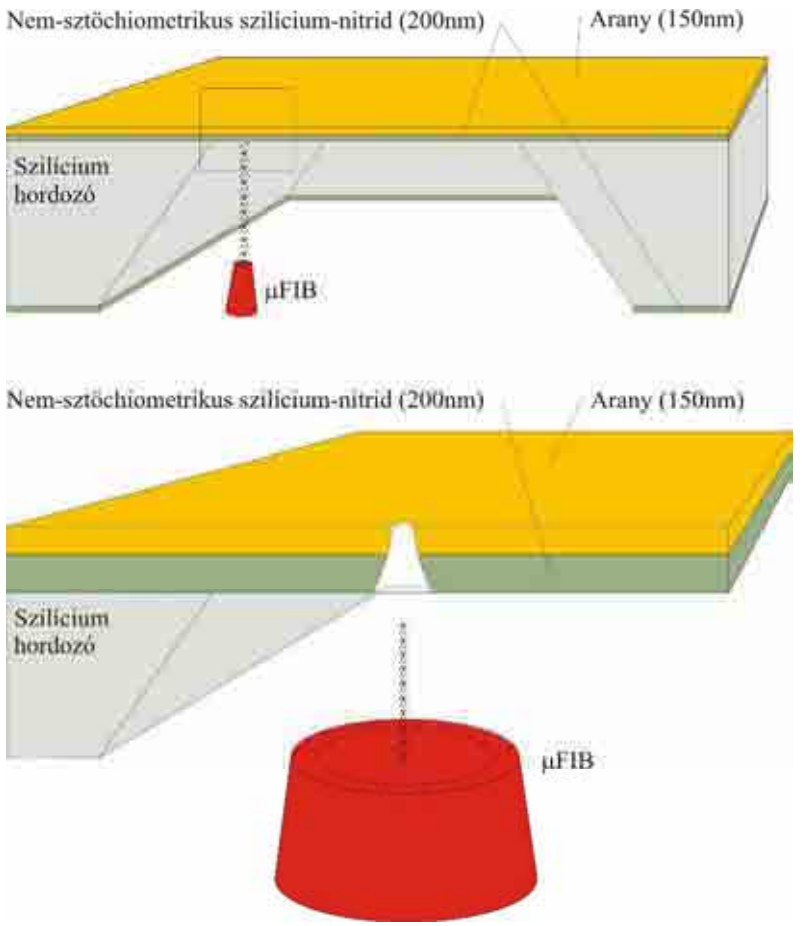
Polymer forming:
nanoimprint lithography

SiC stamp

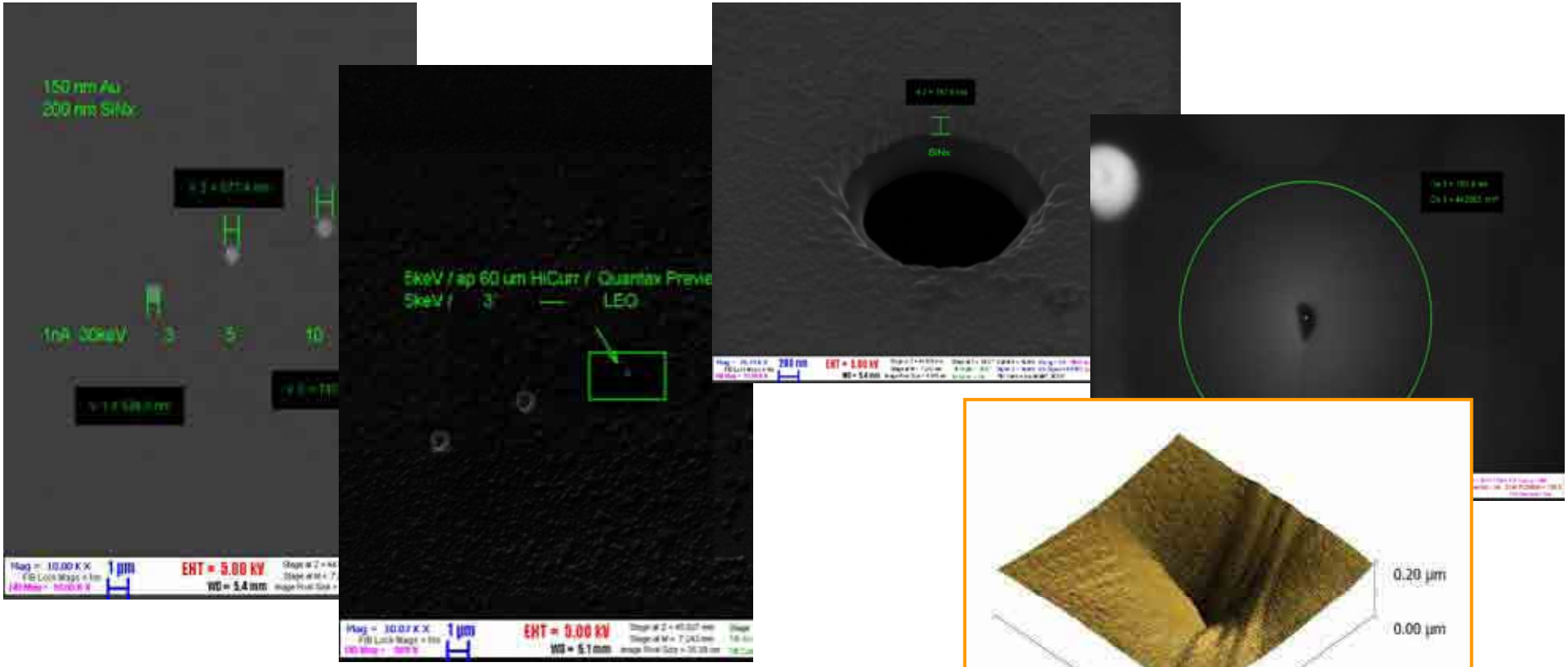


Nanopore structures with FIB
– cooperation with Faculty of Chemistry TUB (Robert E. Gyurcsanyi)





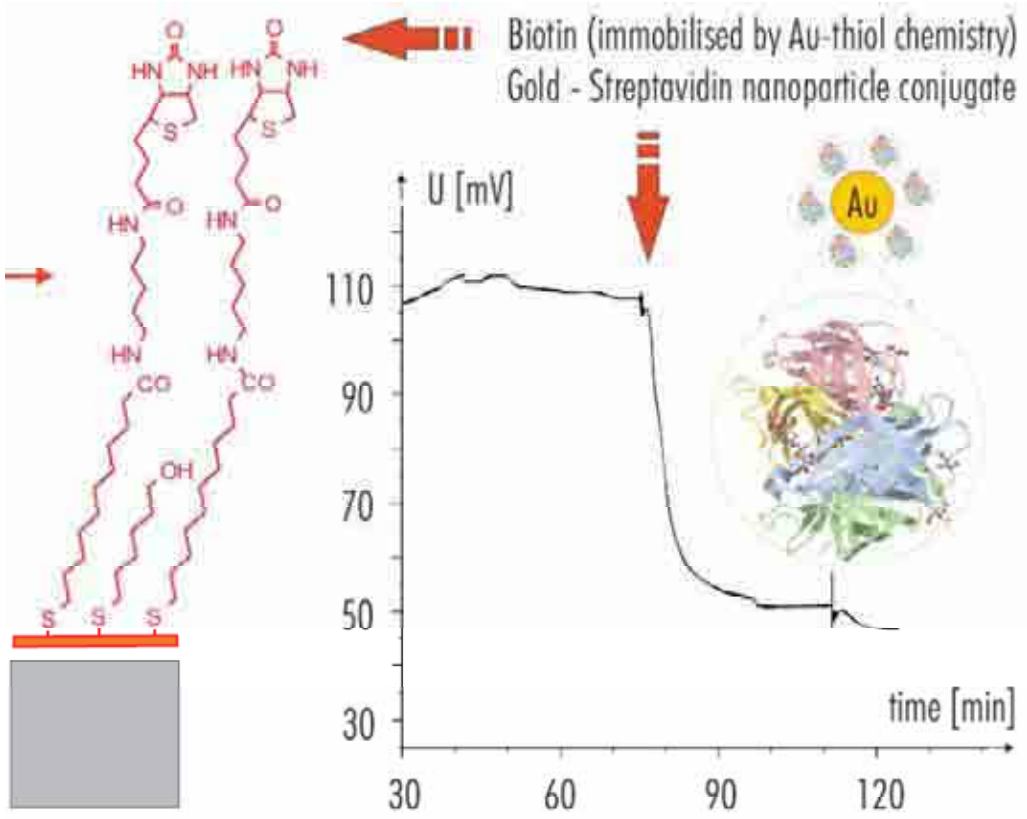
Nanopore with selective, e-beam enhanced TEOS-oxide deposition and FIB



AFM picture

Selective detection in nanopores

Chemically modified polymer in the pore



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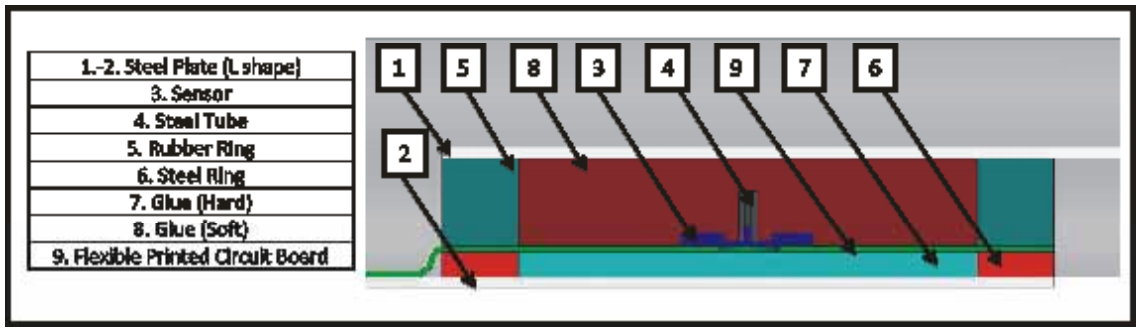
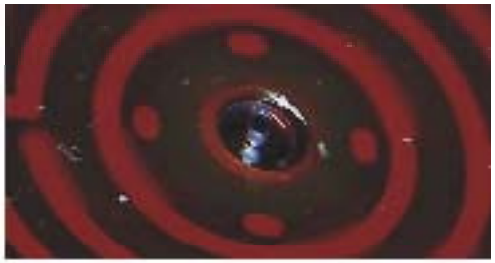
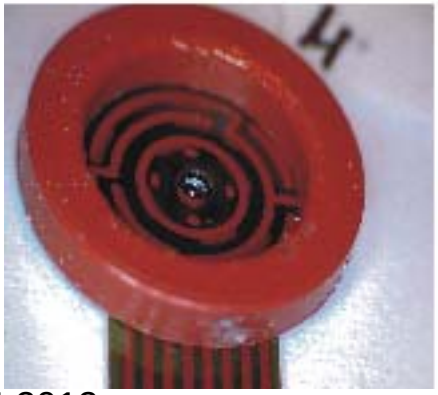
3D Force sensor integrated into tire – into repair patch





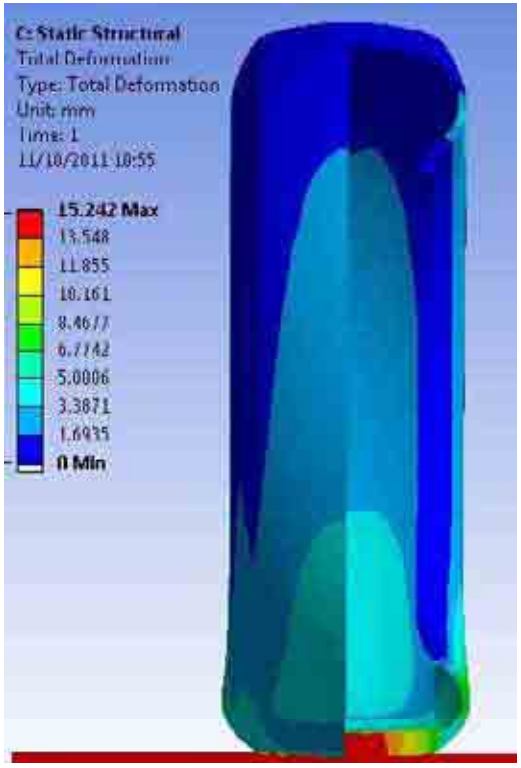


Projects ENIAC SE2A 2009-2011

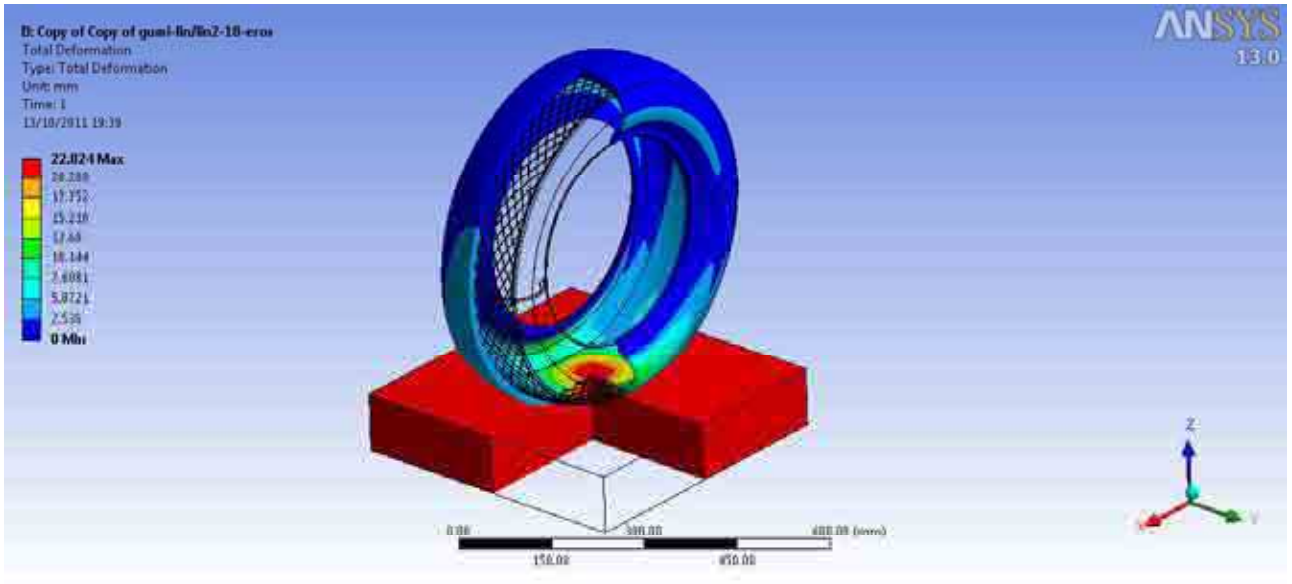
Nanoelectronics for Safe, Fuel Efficient and Environment Friendly Automotive Solutions

… developing nanoelectronics solutions for automobile manufacturers enabling higher fuel efficiency, lower CO2 emission and enhanced safety …

3D Force sensor integrated into tire - FEM modelling

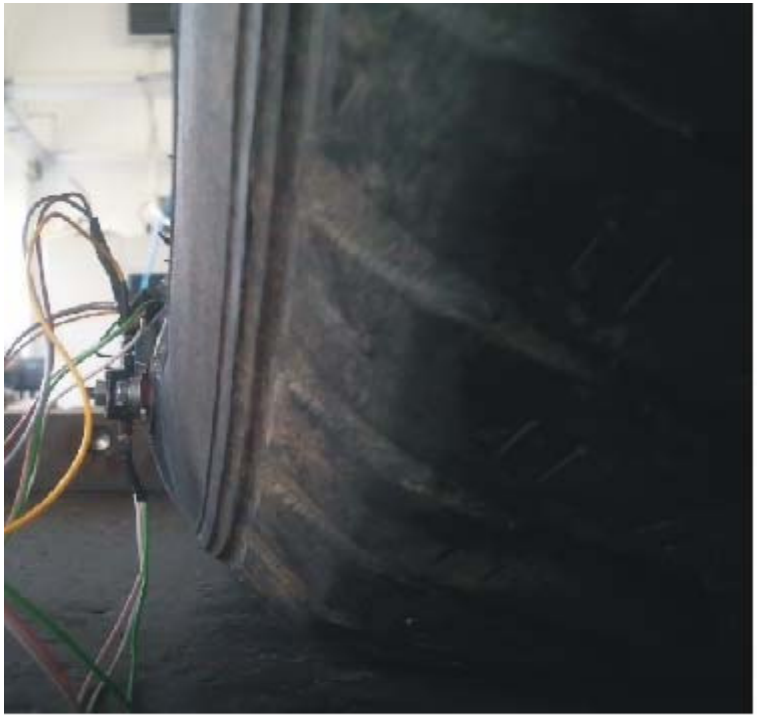


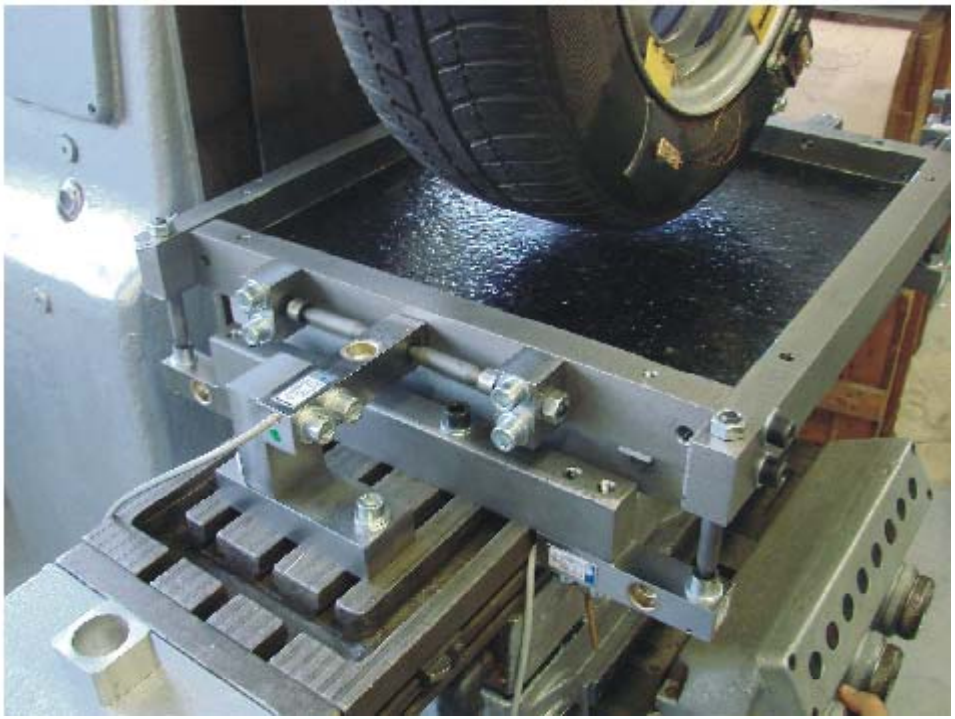
Coopoeration with WESZTA-T, Inc.



Projektek ENIAC SE2A 2009-2011

3D Force sensor integrated into tire – Measurement





Conclusions

- Great success of my successor, Prof. Barsony that out of 80 scientists, over twenty are below 35 years – we became attractive to young people,
- What is remarkable, that young people still return

- (e.g., Andras Deak was part of the work of usage of nanoparticles as „microphon” (A. Lutich, München) is now back…

- Home funding idling since two years
- EU-dependent, mainly cooperative work
- Only few industrial partners and contracts
- Often ”Project dragged” research
- Hard times – serious risk of loosing young people
- Recently, a restructuring was performed resulting in a potential and later merger with chemists and enzymologists – wait and see…
- I hope though that a later review will not be a step backwards

- Thank you for the invitation – a few copies of our Yearbook is also available