

Integrated MEMS force sensors in medical technologies

PhD Report – 2nd semester

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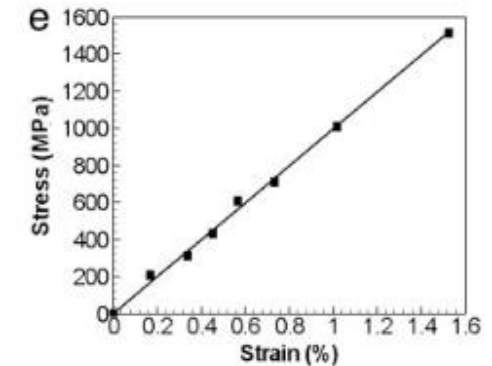
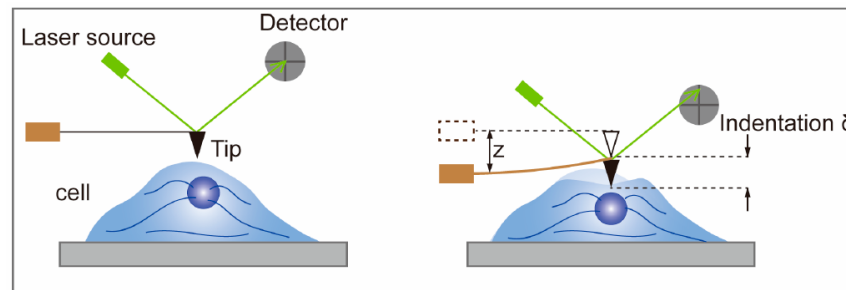
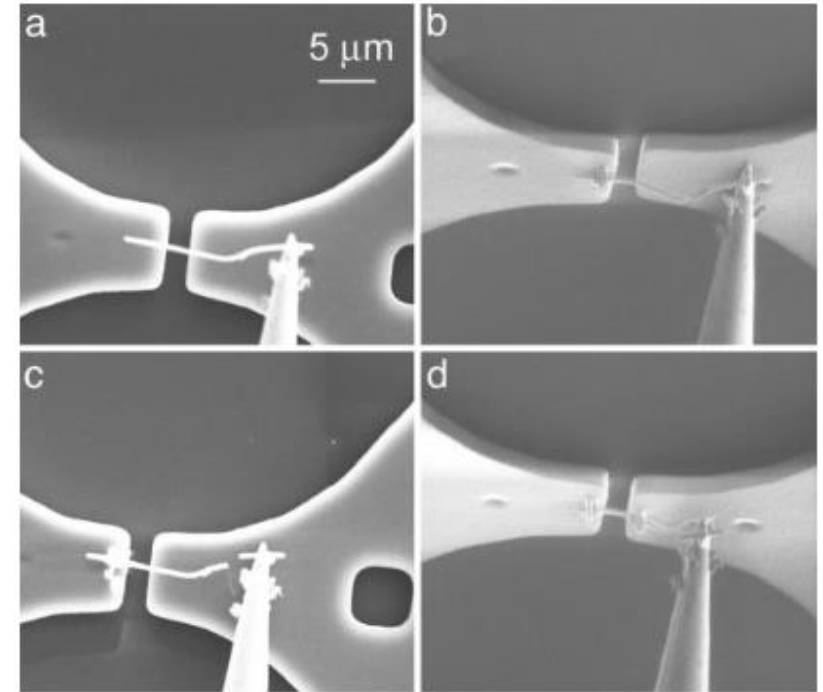
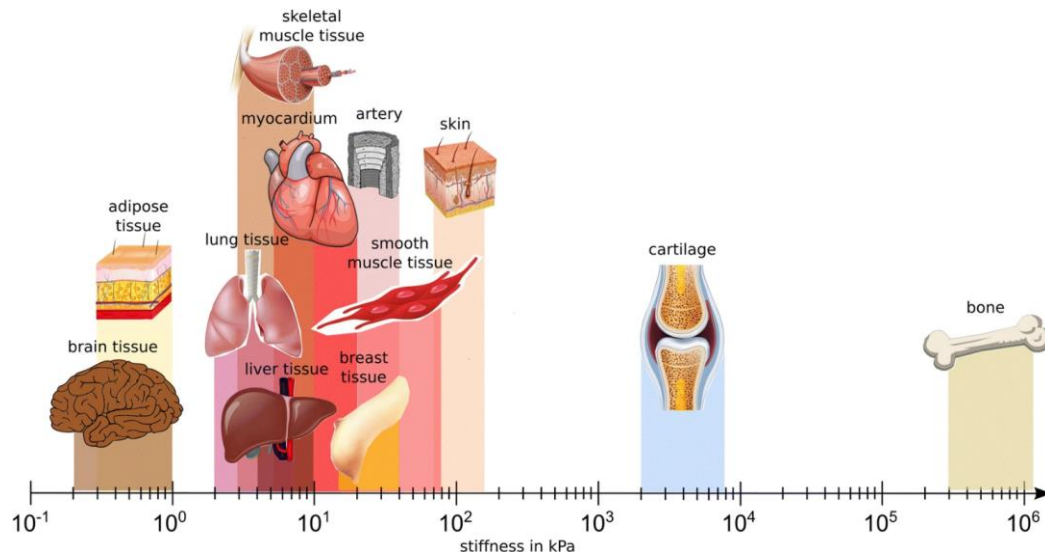
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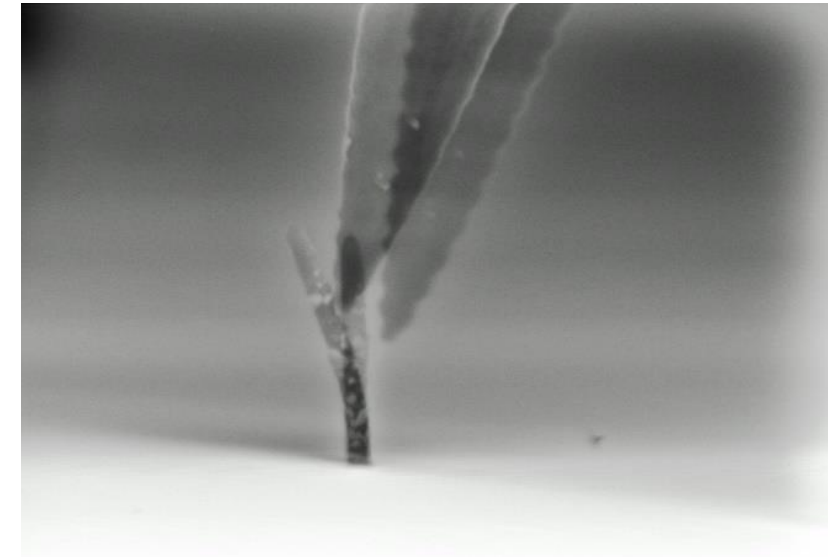
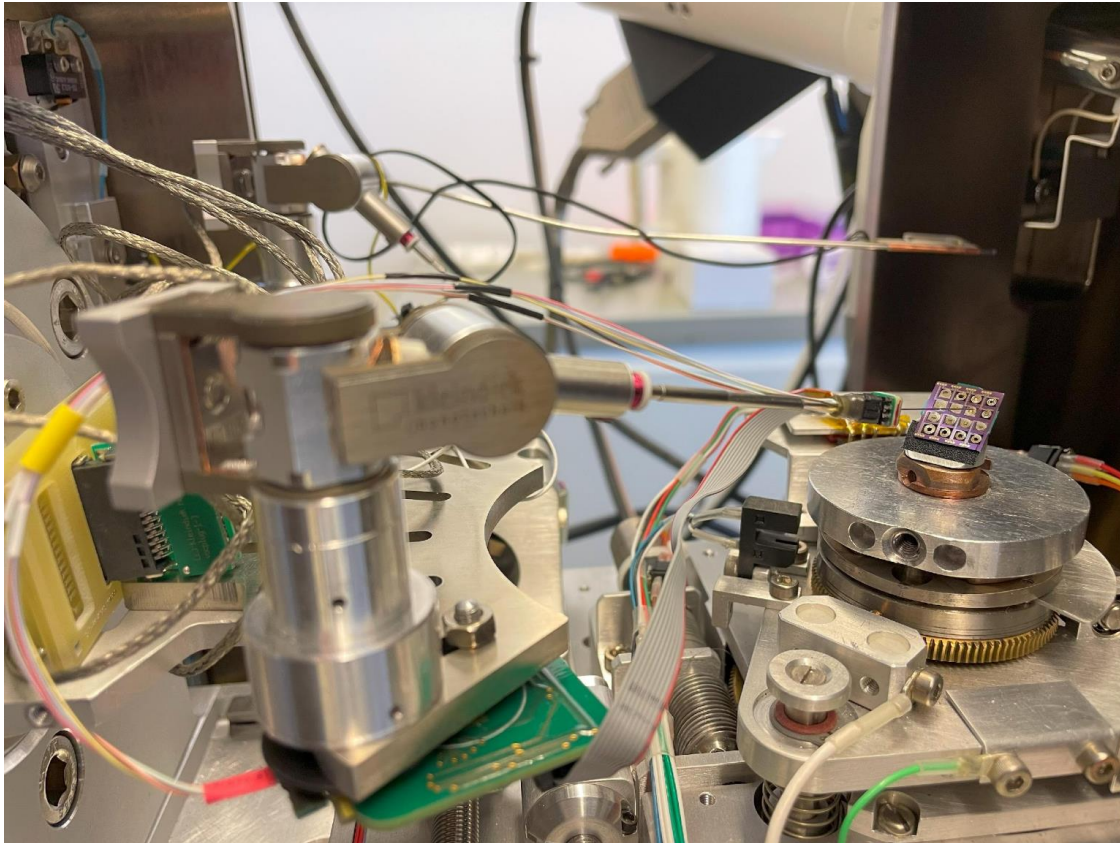
In-situ mechanical testing

Application areas:

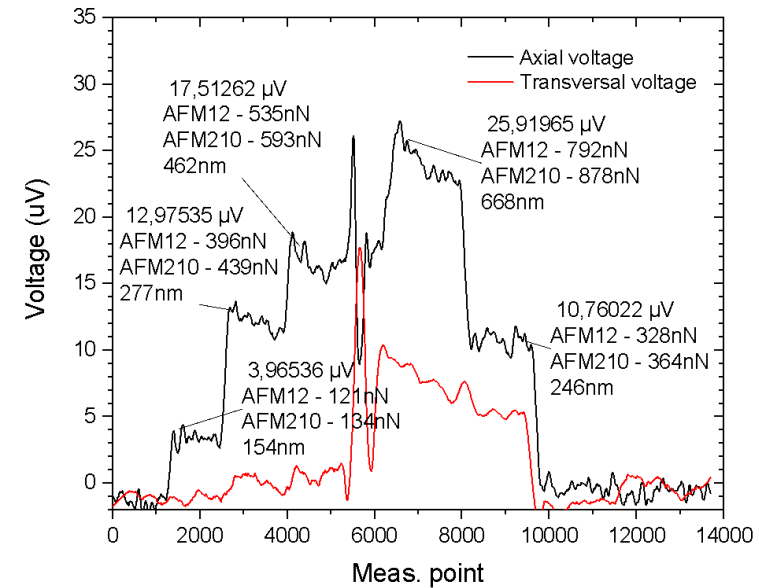
- Nanomechanics
- Tissue mechanics - nerve systems, minimal invasive surgery
- Single cell mechanics



In-situ nanomechanical test in SEM

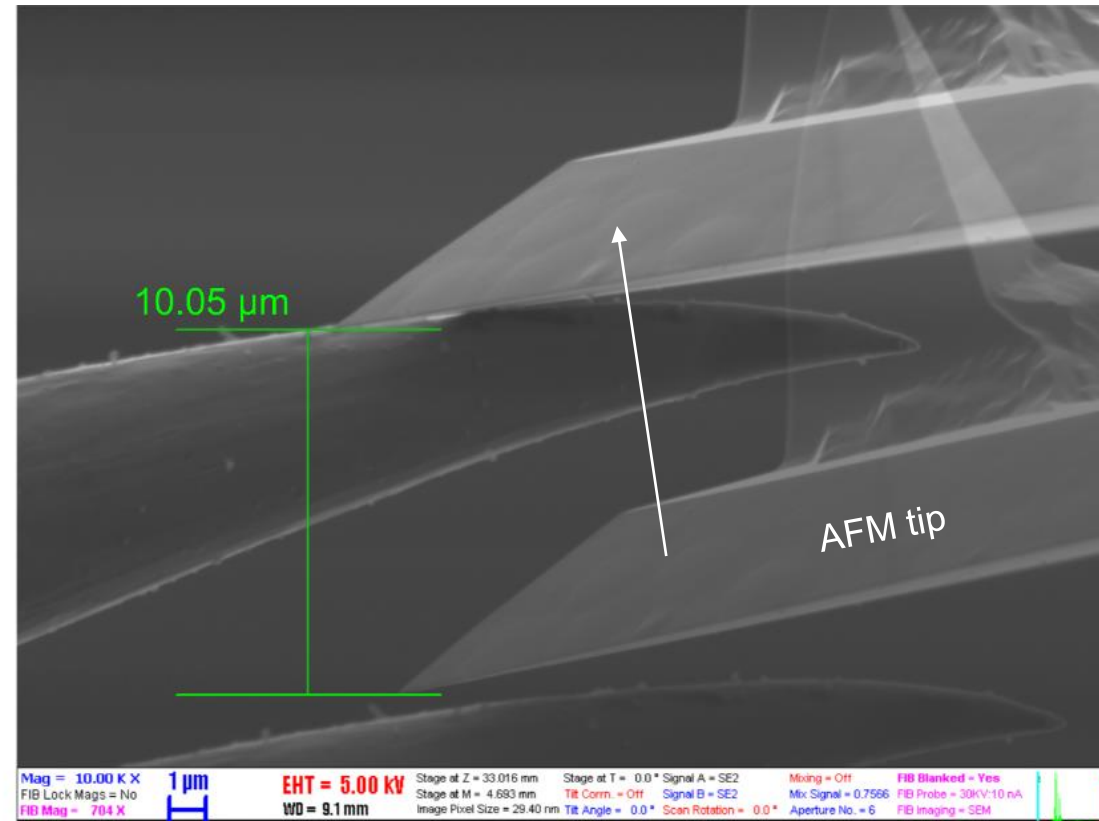
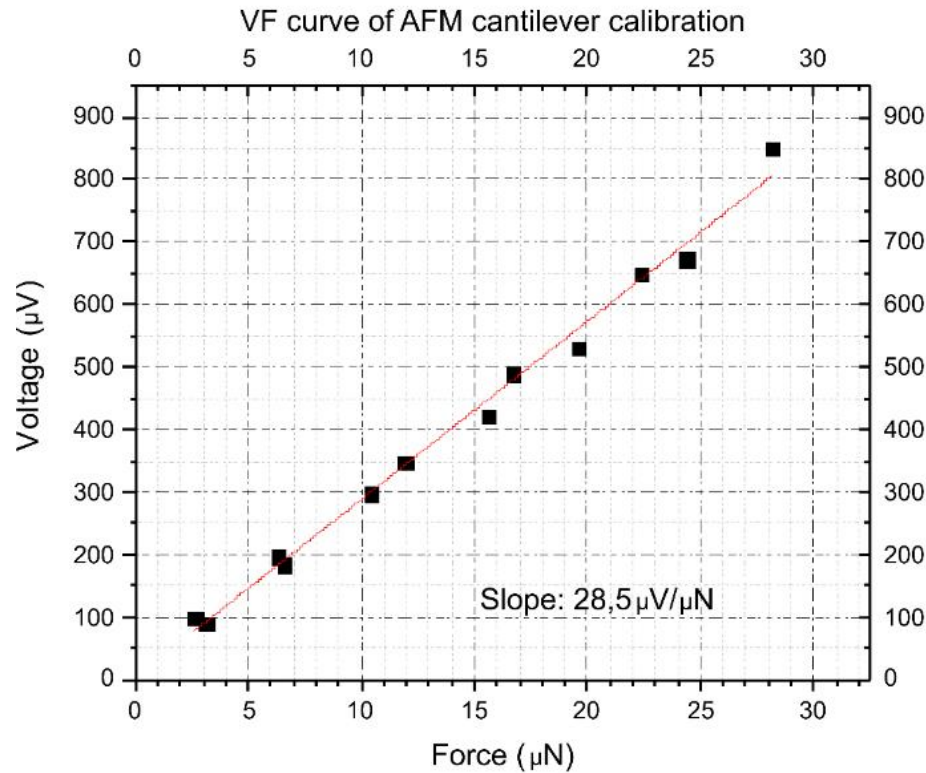
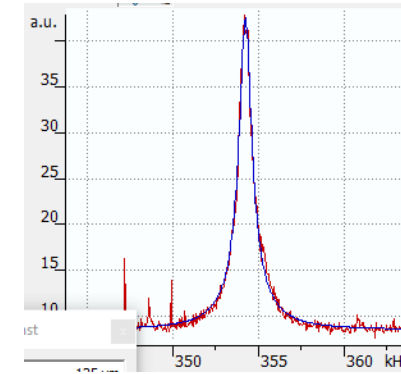


Mag = 20.60 K X 1 μm EHT = 5.00 kV Stage at Z = 39.341 mm Stage at T = 5.0 Signal A = InLens Working = Off FIB Blanked = Yes
 FIB Lock Mags = No FIB Mag = 704 X WD = 5.9 mm Stage at M = 9.937 mm TR Conn = Off Signal D = SEC Mo Signal = 0.7568 FID Probe = 30kV-10 nA
 Image Pixel Size = 10.20 nm Tilt Angle = 0.0° Scan Rotation = 129.0° Aperture No. = 8 FIB Imaging = SEM



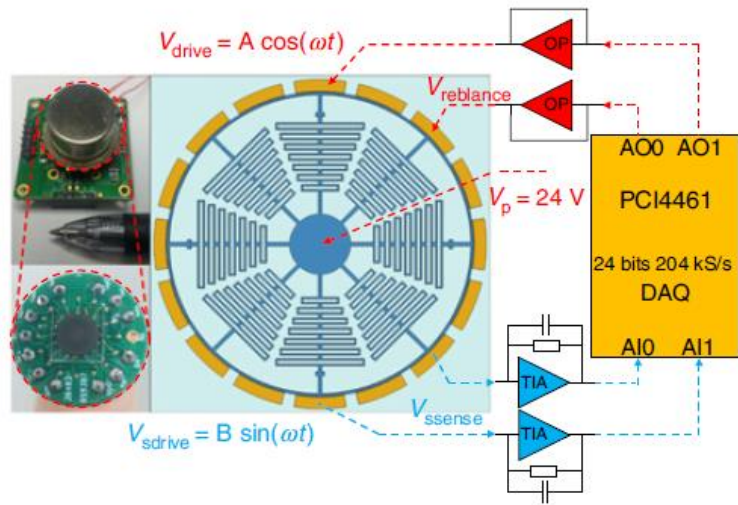
In-situ nanomechanical test in SEM

Calibration with AFM probe AFM self calibration via Sader method

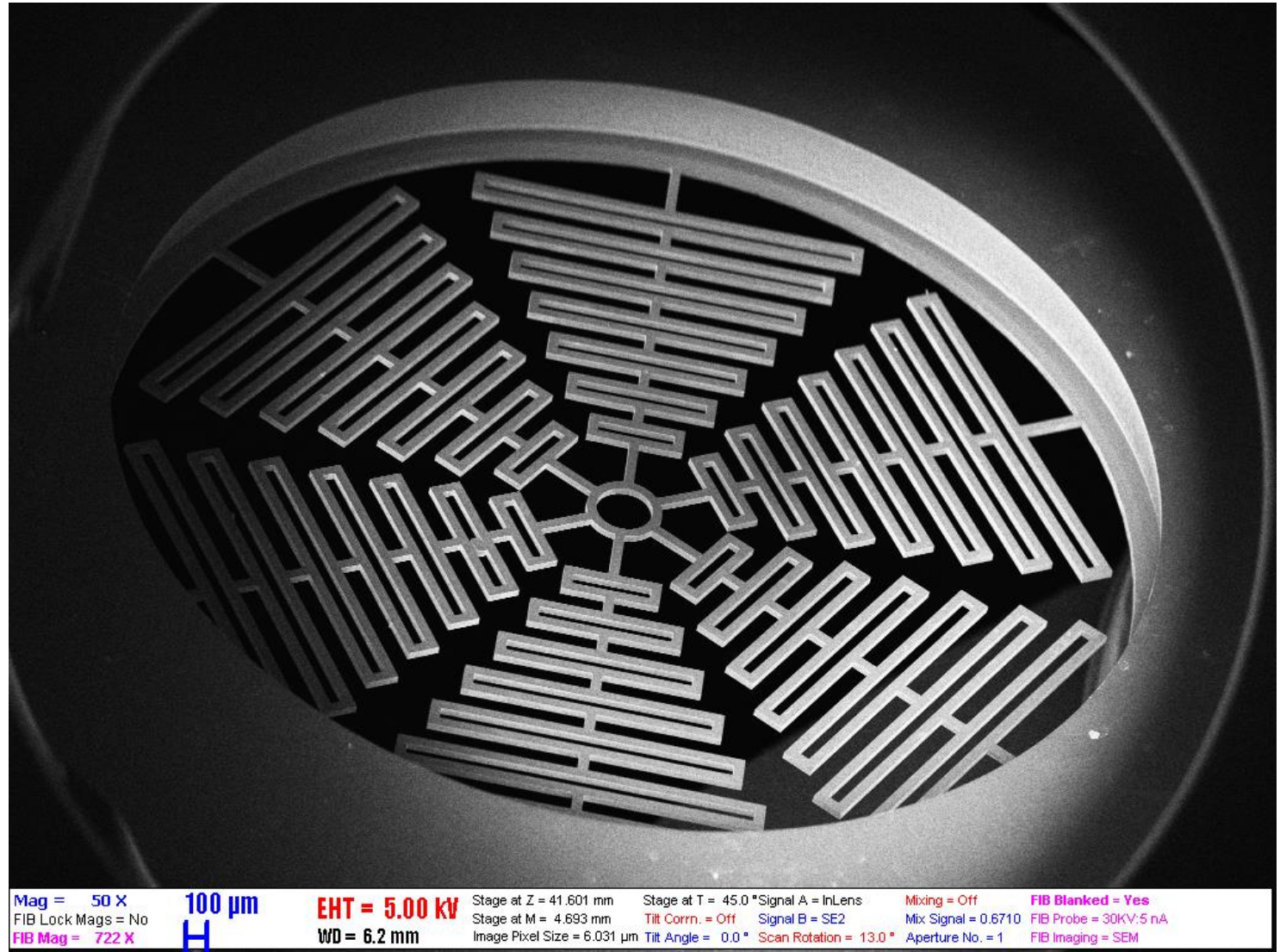


Deformation tester design

Originally a ring MEMS gyroscope, we plan to use the structure for „calibrator” and possibly a new sensor design.



Zesen Bai et al.
<https://doi.org/10.1049/el.2019.1356>

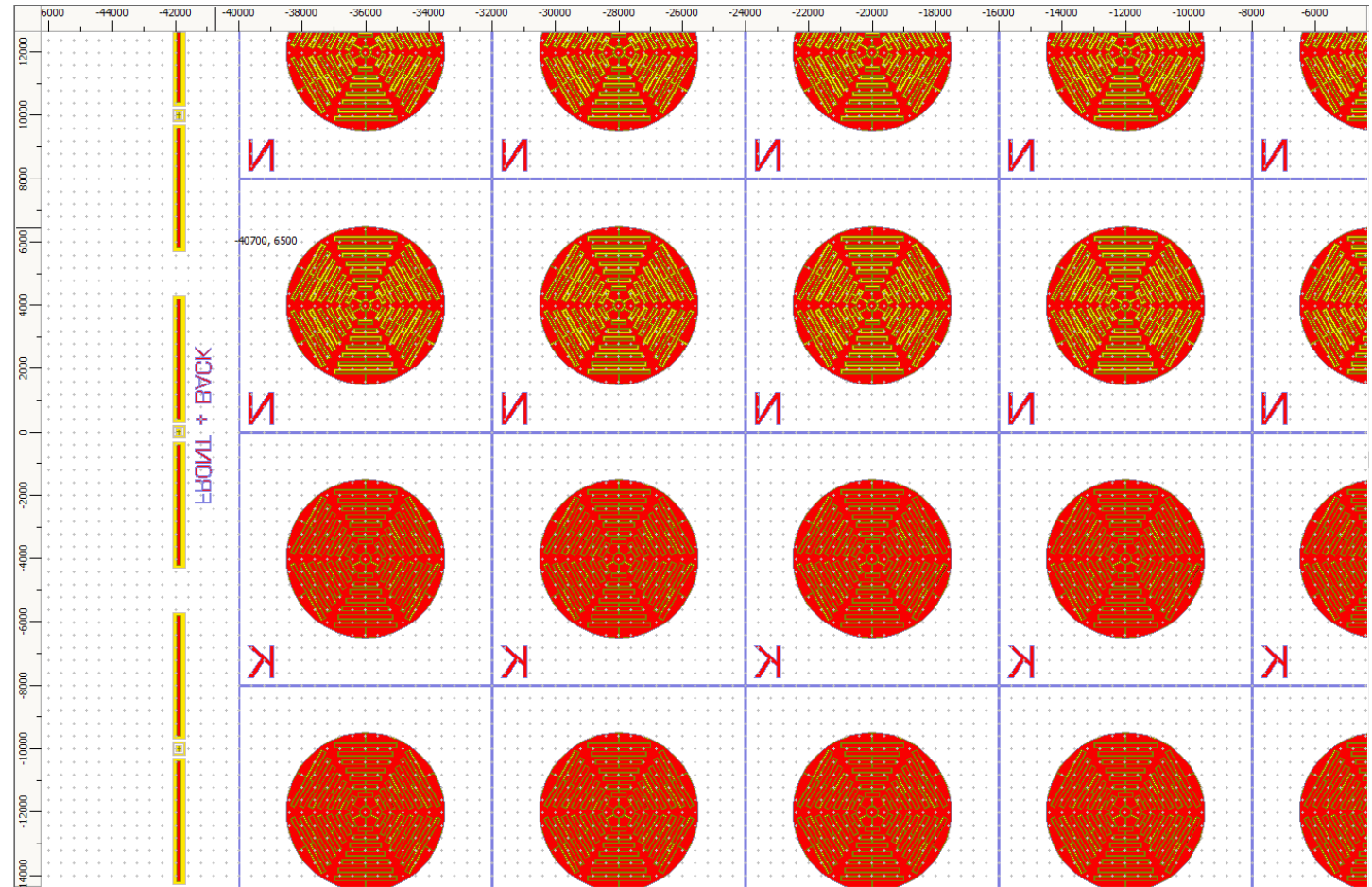
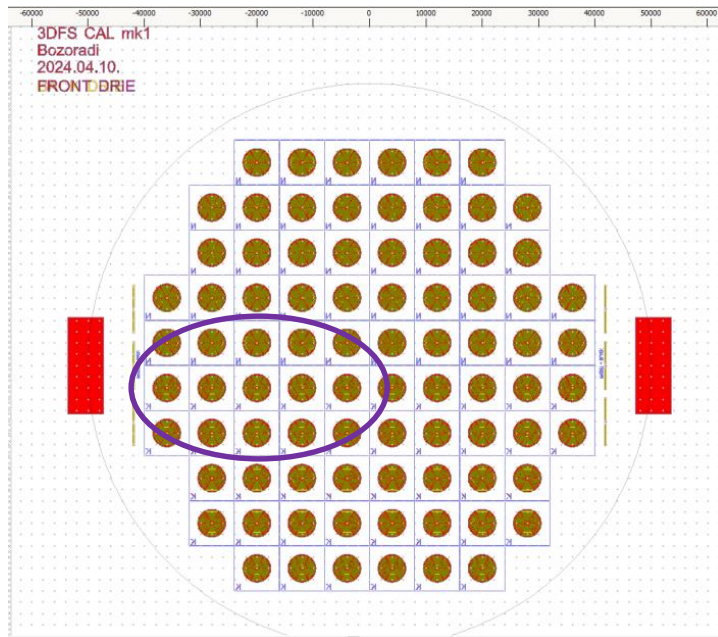


Mag = 50 X 100 µm EHT = 5.00 kV Stage at Z = 41.601 mm Stage at T = 45.0° Signal A = InLens Mixing = Off FIB Blanked = Yes
 FIB Lock Mags = No FIB Mag = 722 X WD = 6.2 mm Stage at M = 4.693 mm Tilt Corr. = Off Signal B = SE2 Mix Signal = 0.6710 FIB Probe = 30KV:5 nA
 Image Pixel Size = 6.031 µm Tilt Angle = 0.0° Scan Rotation = 13.0° Aperture No. = 1 FIB Imaging = SEM

Deformation tester design

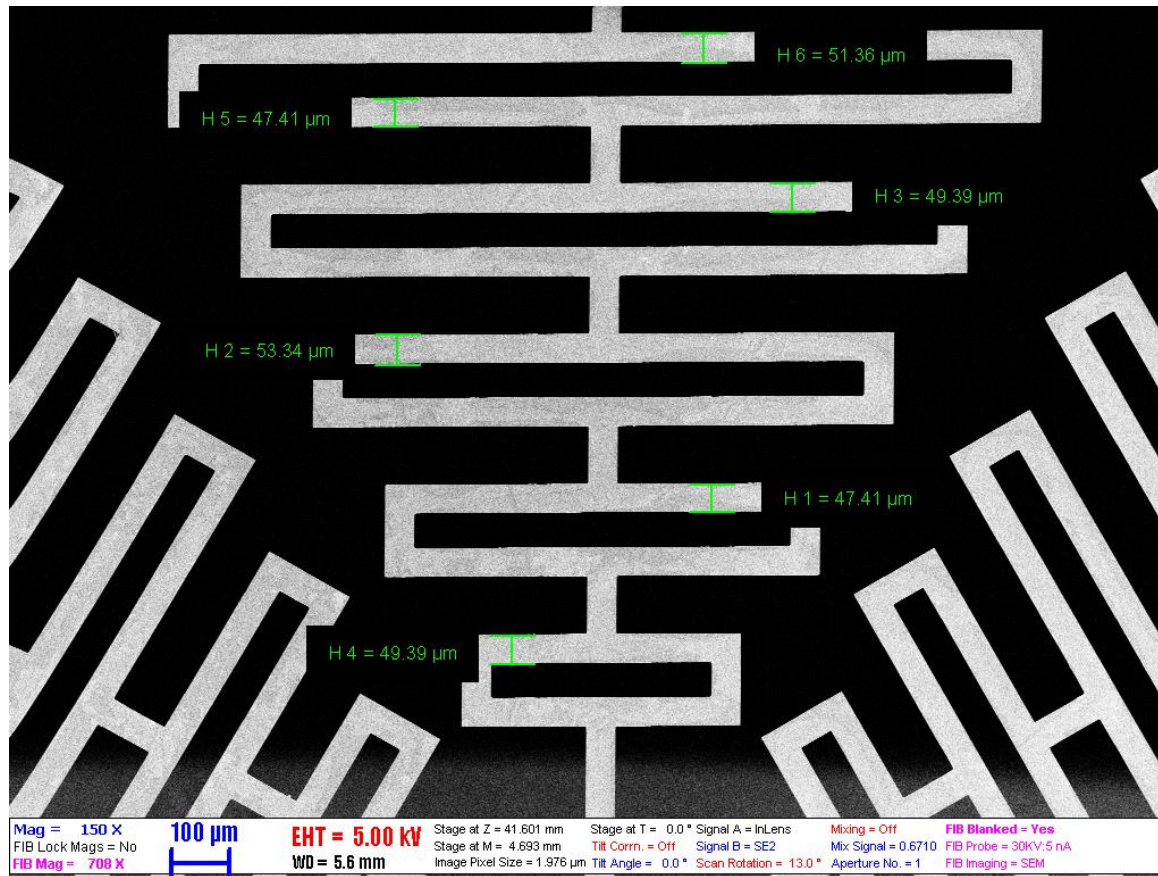
Practice in micromechanical technologies

- Lithography mask design
- The use of process management system
- Design of multi-step micromachining process sequence
- **Lithography and DRIE**

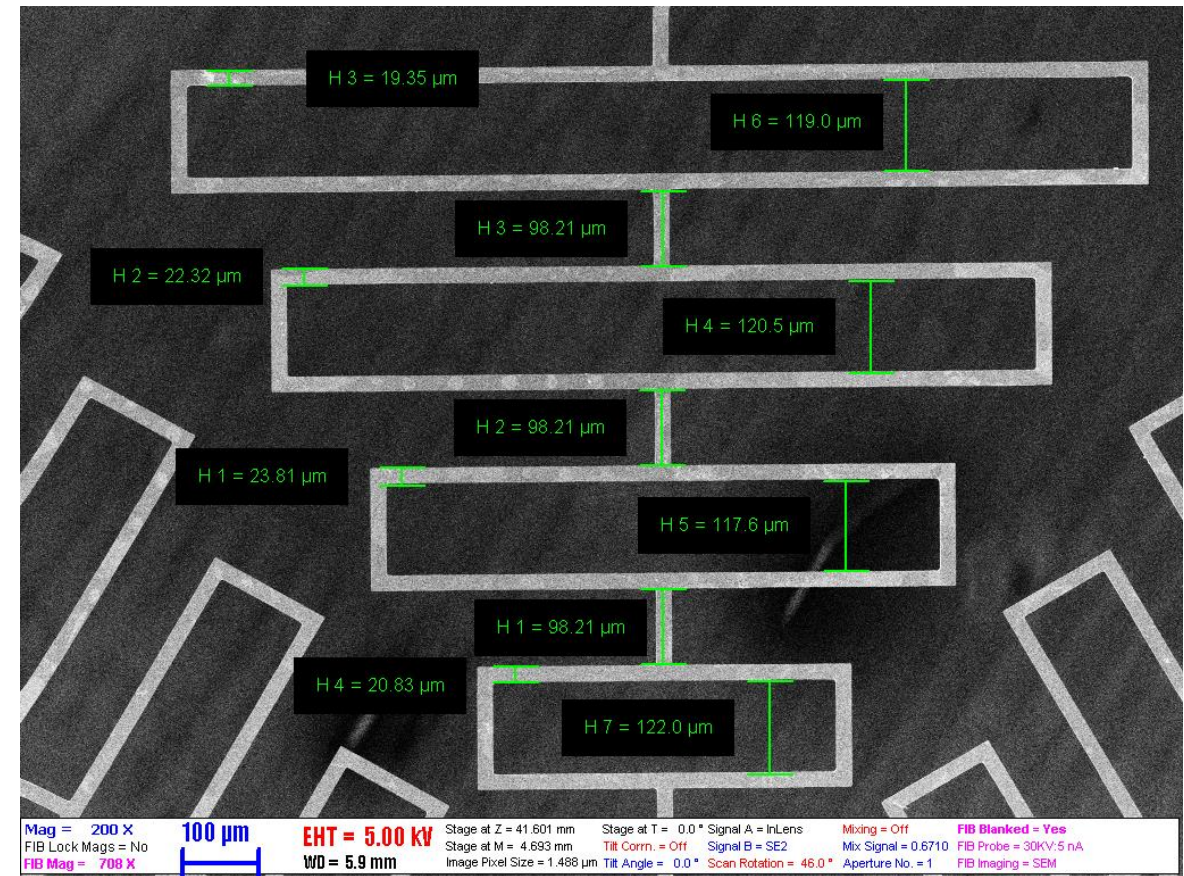


Deformation testers

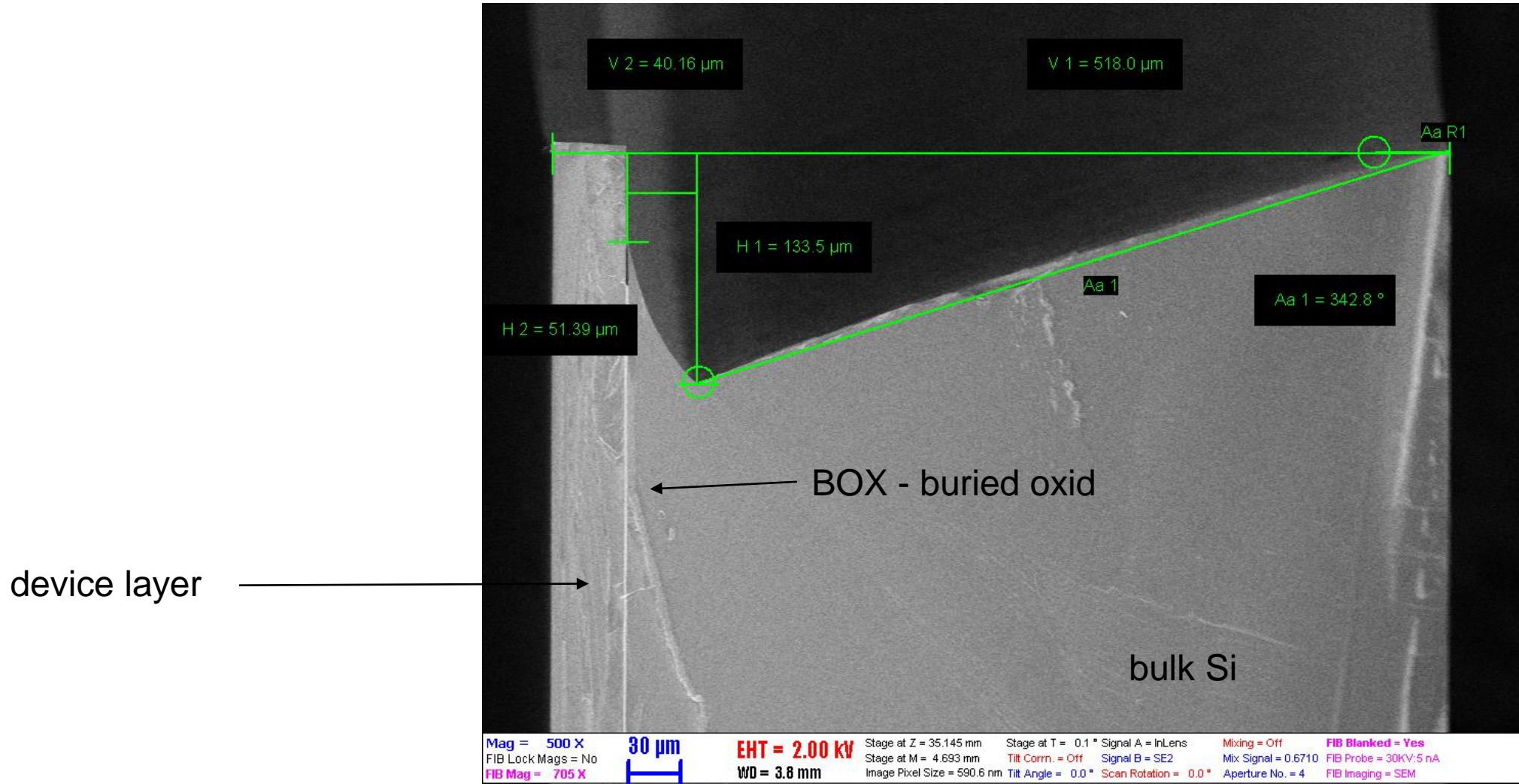
50 μm wide / 40 μm thick spring system



20 μm wide / 40 μm thick spring system

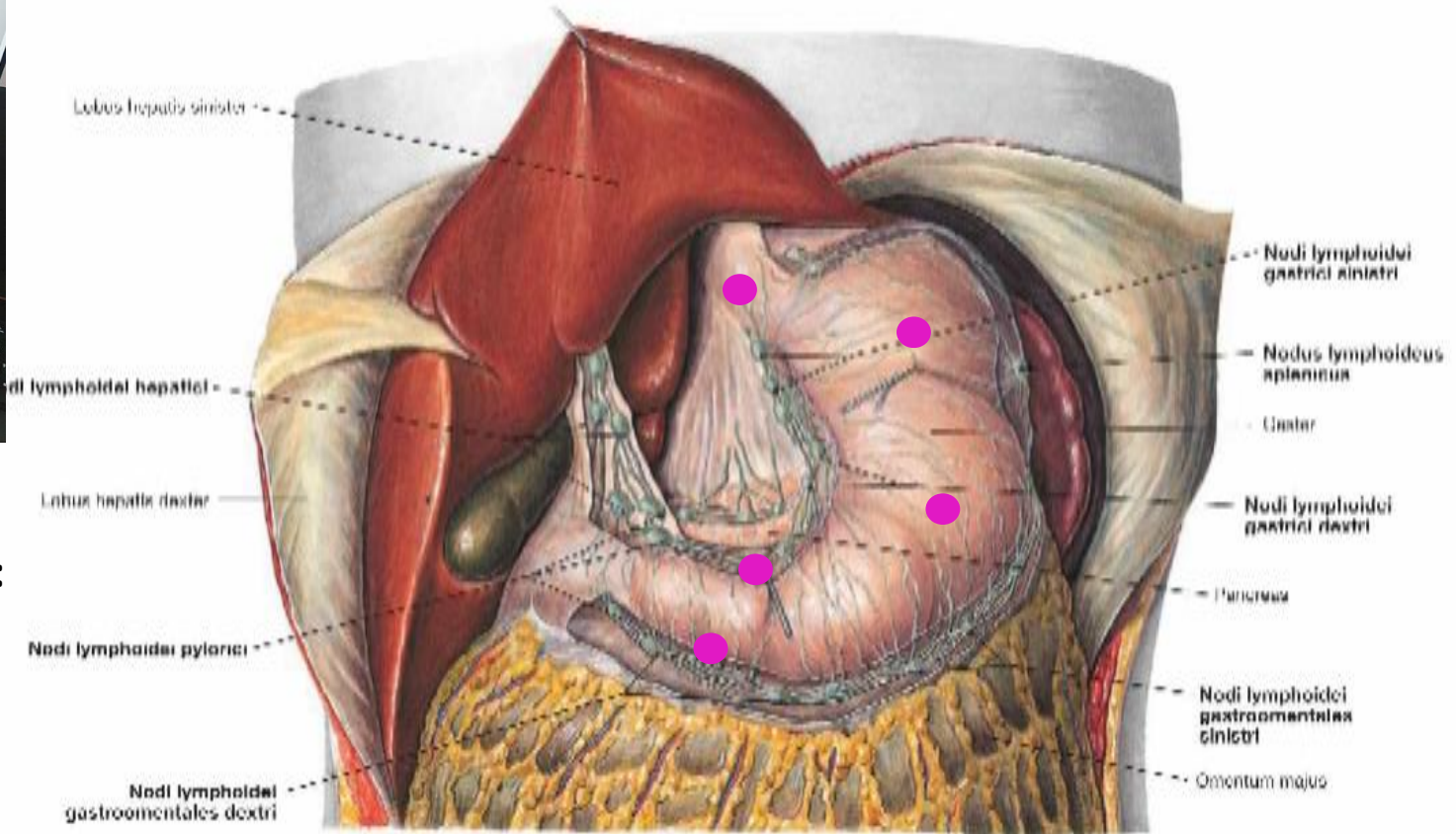
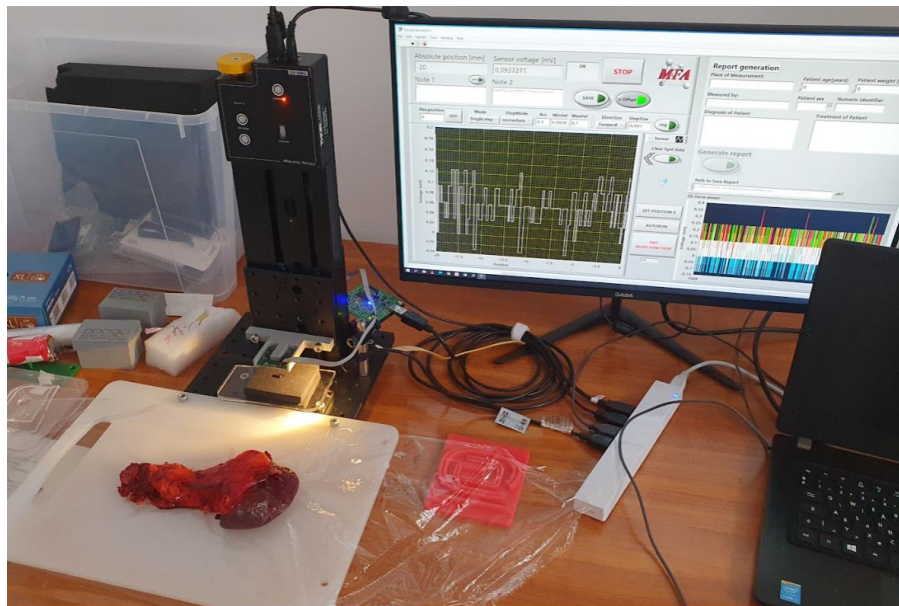
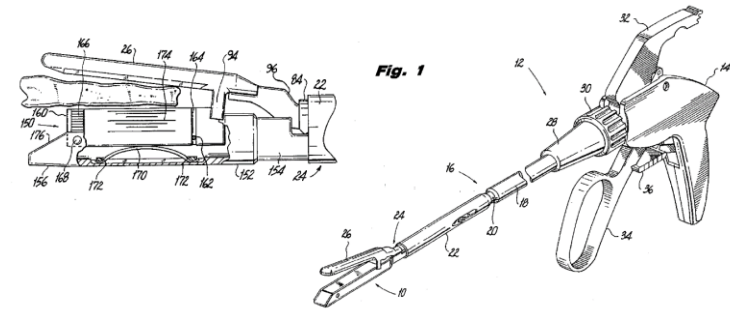
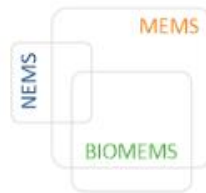


Over etching near the device layer



Biomechanical tissue testing

Quantitative and qualitative testing of mechanical properties of tissues



Ex-vivo measurements on surgical leftovers:

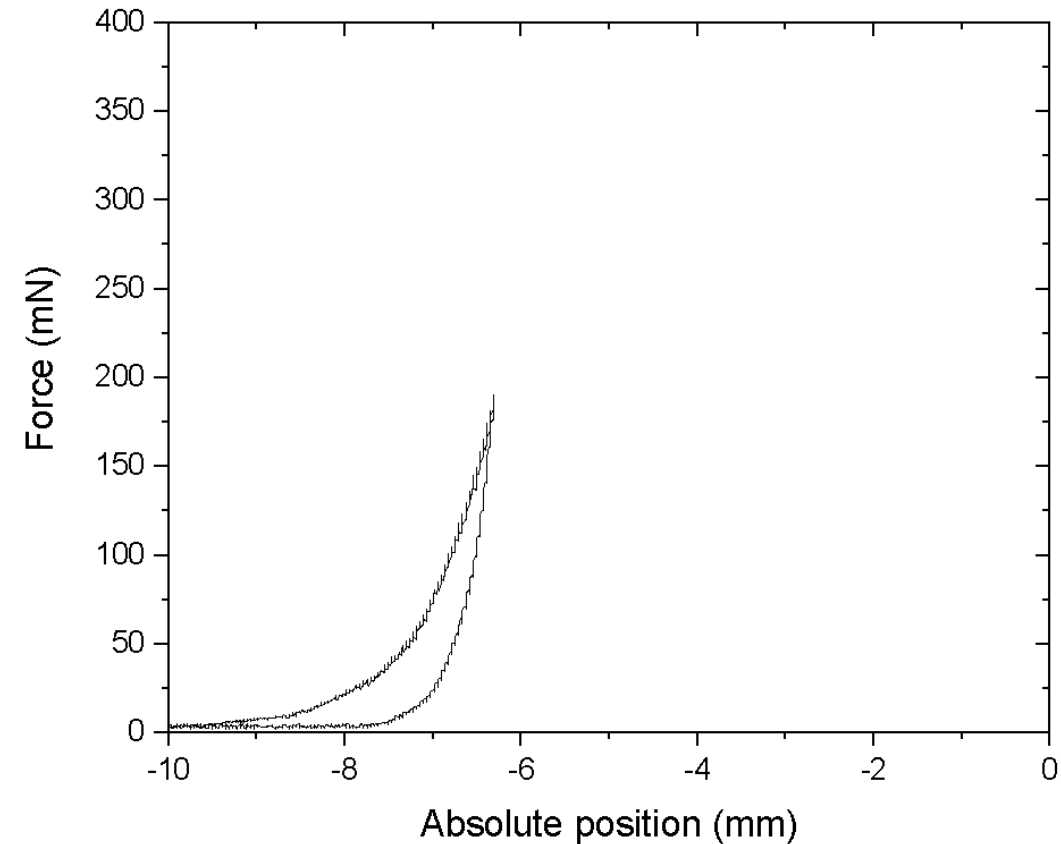
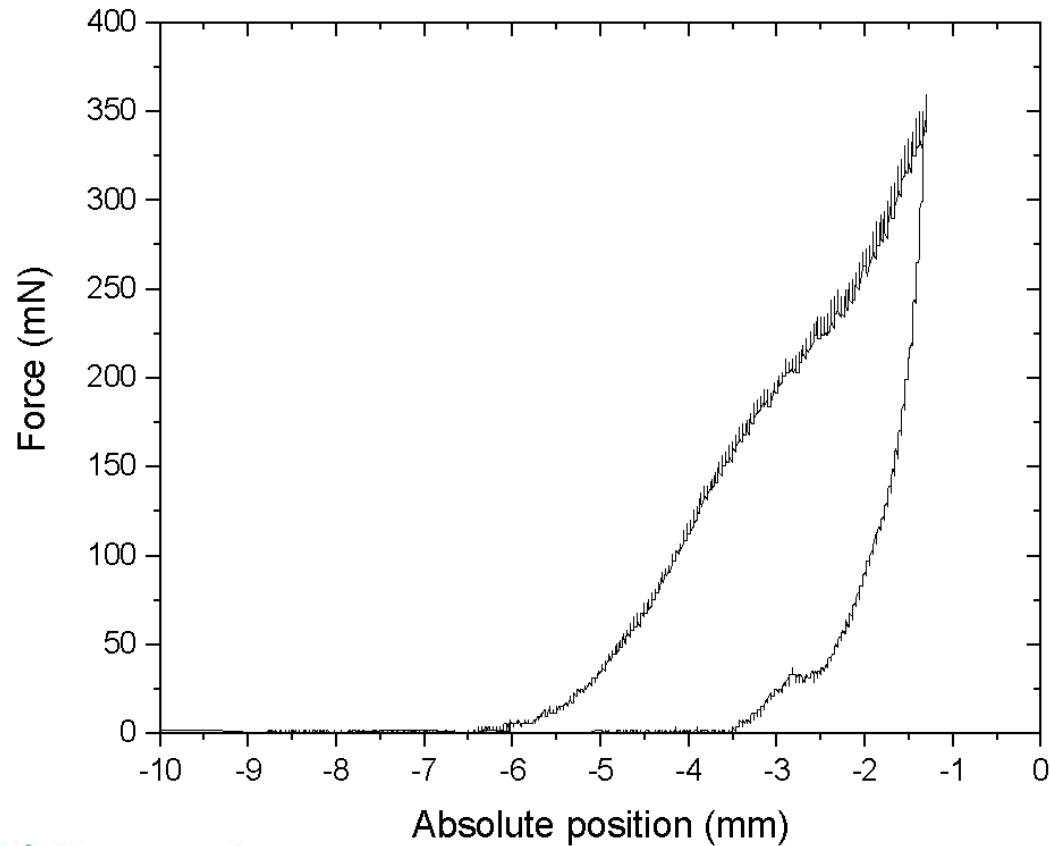
- Gaster
- Pancreas

Ethical clearance number: IV/174- 2 /2022/EKU

Ex-vivo tissue mechanical measurements

2 different pancreas samples

- Different patients
- Different samples
- Only two samples altogether

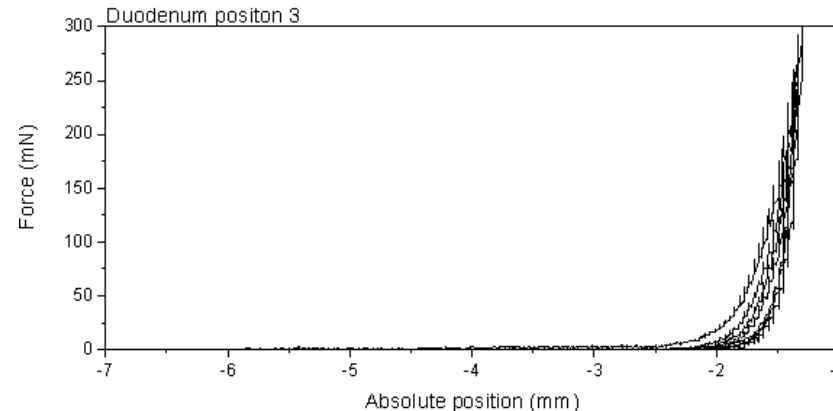
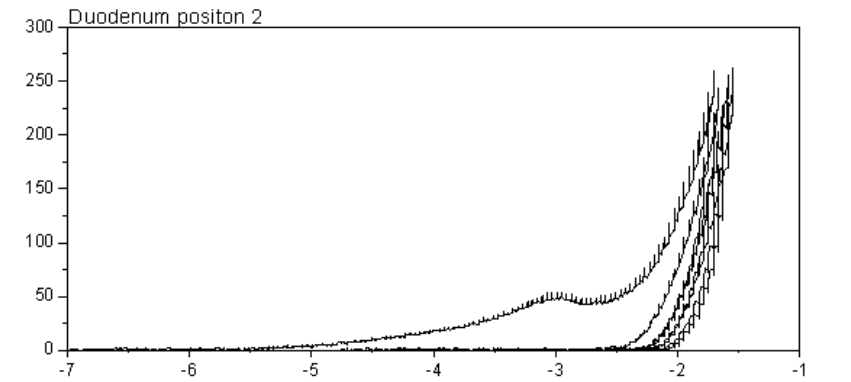
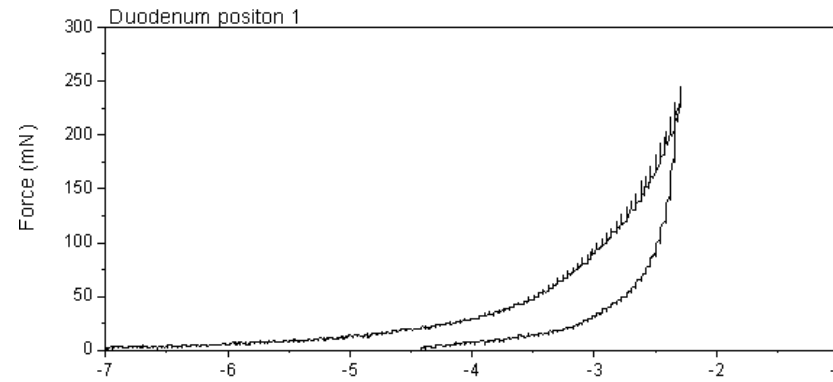
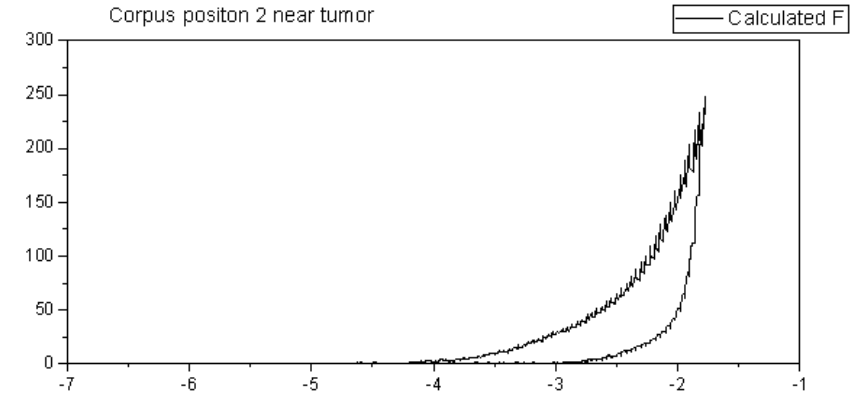
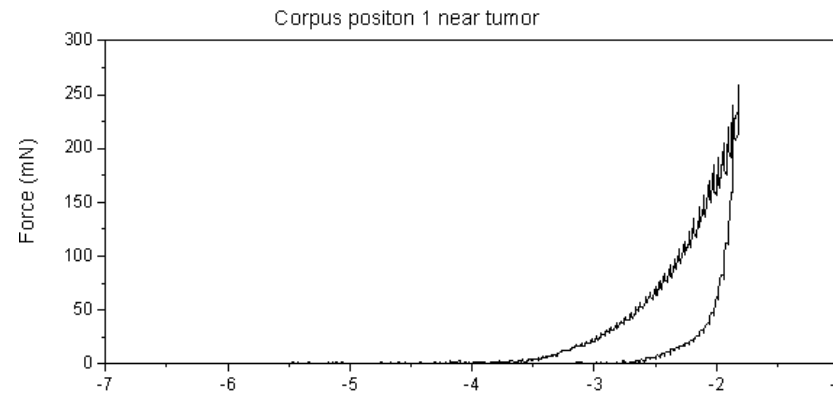


Ex-vivo tissue mechanical measurements

Gastric samples

- Single patients
- Single organ
- Too many points to measure on a single organ

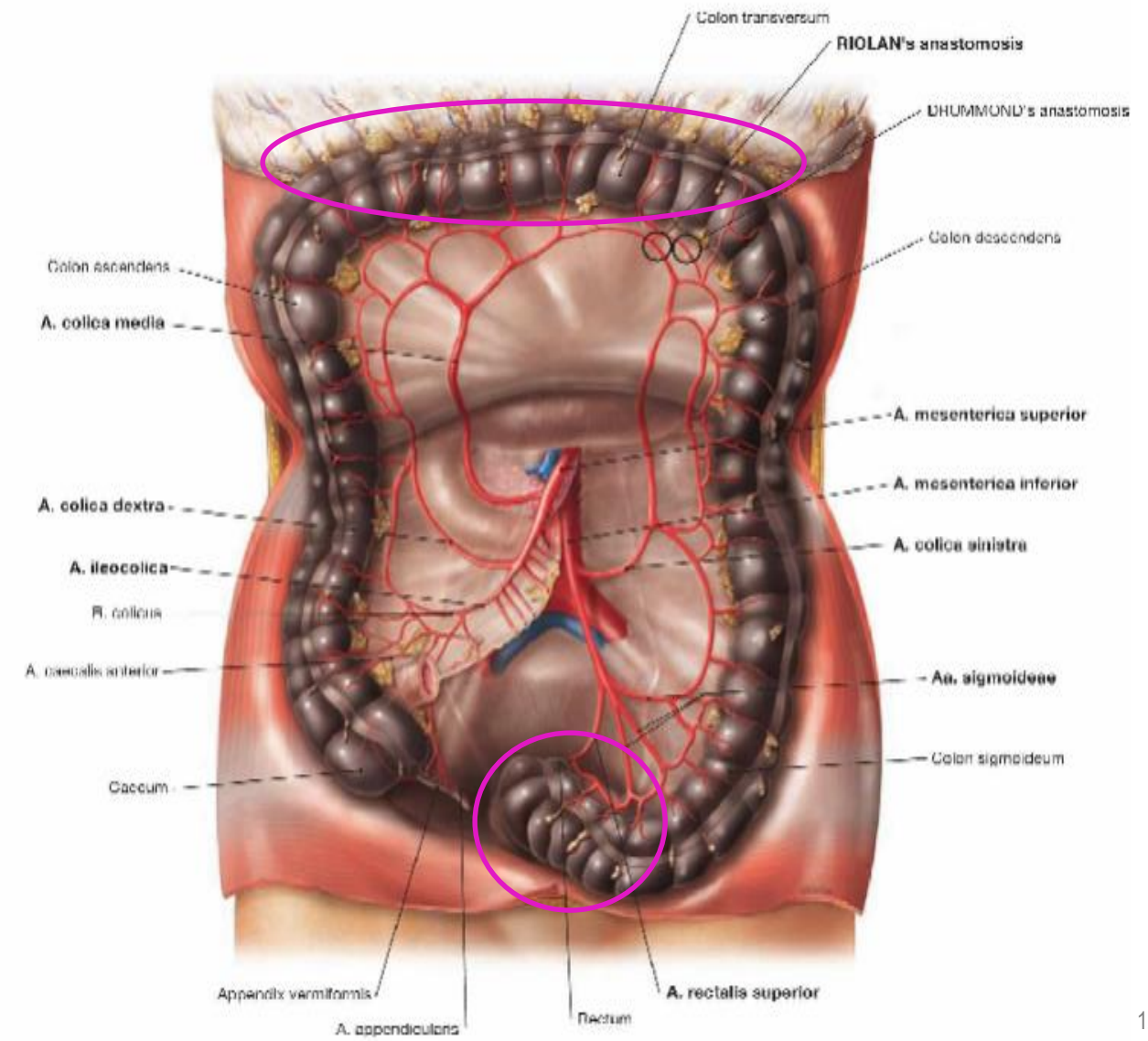
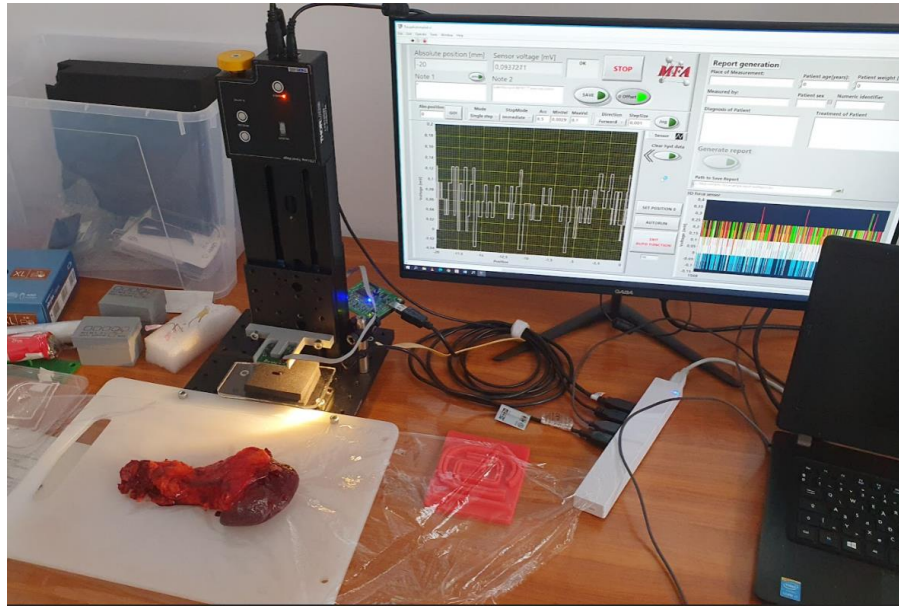
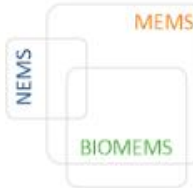
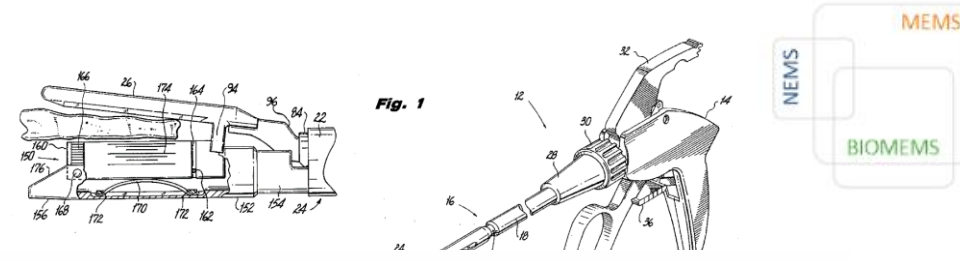
- Small sample number
- High variety of samples (generally true to all)



84 y.o., female

Biomechanical tissue testing

Quantitative and qualitative testing of mechanical properties of tissues



Ex-vivo measurements on surgical leftovers:

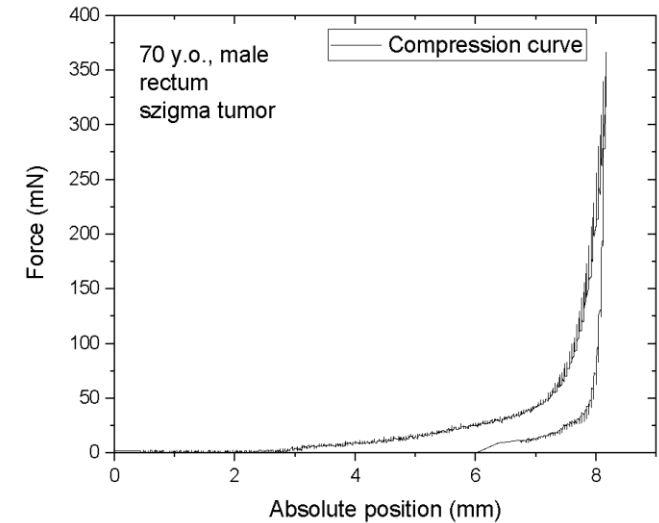
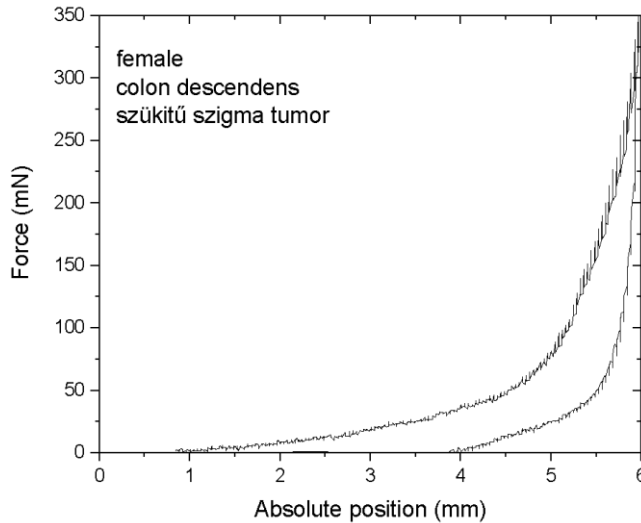
- Different sections of the colon

Ethical clearance number

Ex-vivo tissue mechanical measurements

Colon samples

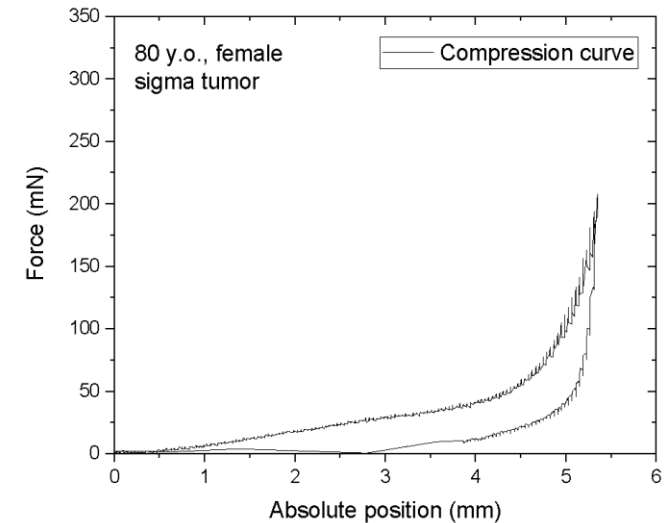
- „Only” 30 samples
- Different patients
- Different samples
- High variety in colon partition
- Small sample number
- High variety of samples (generally true to all)



Overall:

- Multiple organs of interest ? More partners needed
- Different state of patients ? Large sample pool
- High number of samples ? More focused measurement protocol

**AI based
data processing
and classification**



Future plans

1. Overview the complete fabrication process of the already existing MEMS force sensors + further miniaturisation by VIA connections
2. Form a new measurement method for larger number of tissue characterization
3. Develop new, faster, smaller measurement instruments for easy use, including a new sensor head
4. Publishing the results of the past year's advancement

Publications

1. P. L. Neumann, J. Radó, J. M. Bozorádi, J. Volk, AlGa_N/Ga_N heterostructure based 3-dimensional force sensors, MICRO AND NANO ENGINEERING 19, 100198 , 8 p. (2023)
2. Zs. Szomor, J. M. Bozorádi, B. Beiler, Z. Szabó, P. Fürjes, In-situ optical characterisation of droplet generation in two-phase microfluidic system, MNE-ES 2022 - Micro and Nano Engineering (MNE) & Eurosensors 2022 Conferences, Leuven, Belgium, 2022
3. J. M. Bozorádi, A. Nagy, J. Radó, P. Földesy, I. Bársony, G. Papp, Cs. Dücső, P. Fürjes, Characterisation tissue elasticity by MEMS force sensors, MNE-ES 2022 - Micro and Nano Engineering (MNE) & Eurosensors 2022 Conferences, Leuven, Belgium, 2022
4. Zoltán Szabó, Kitti Pankász, János Márk Bozorádi, Orsolya Hakkel, Szabolcs Bella, Bianka Fabinyi, Sandro Meucci, Péter Fürjes, Microfluidic Cuvette for Near Infrared Spectroscopy, Proceedings of Eurosensors 2023 Conference, Lecce, Italy, 2023 (oral presentation) Proceedings 2024, 97(1), 209; <https://doi.org/10.3390/proceedings2024097209>

1. **Bozorádi János Márk:** 3D MEMS erőmérő szenzorok alkalmazása biomechanikai vizsgálatokra, 36. OTDK Műszaki Tudományi Szekció, Egészségtudomány 1 Tagozat, II. HELYEZÉS

Courses completed:

- | | |
|---------------|------------------------|
| 1. OATFETE1ND | Félvezető technológiák |
| 2. OATFEFV1ND | Félvezető eszközök |

Thank you for your attention!