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Erasmus+ Programme Key Action 2 Cooperation Partnerships for Higher Education (KA220-HED)

Agreement number 2023-1-RO01-KA220-HED-000155412

European Network for Additive Manufacturing in Industrial Design for Ukrainian Context Staff Training (STTE) – Edibon International S.A., Madrid, Spain, 7-10 May 2024

Research realized concerning materials used in industry

Madrid, 2024

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Plan of presentation

1. Tribology and surface engineering laboratory
2. Research issues
3. Smart materials in industry
4. Our experience in smart material in industry

Laboratory

The lab is equipped with a range of modern test instruments for tribological and mechanical characterisation. Capabilities range from evaluation for lubricants, fuels and additives to unique friction, wear and tribo-corrosion testing capabilities for advanced materials and surface coatings, specialised tribometers for high temperature testing as well as testing in special environments.

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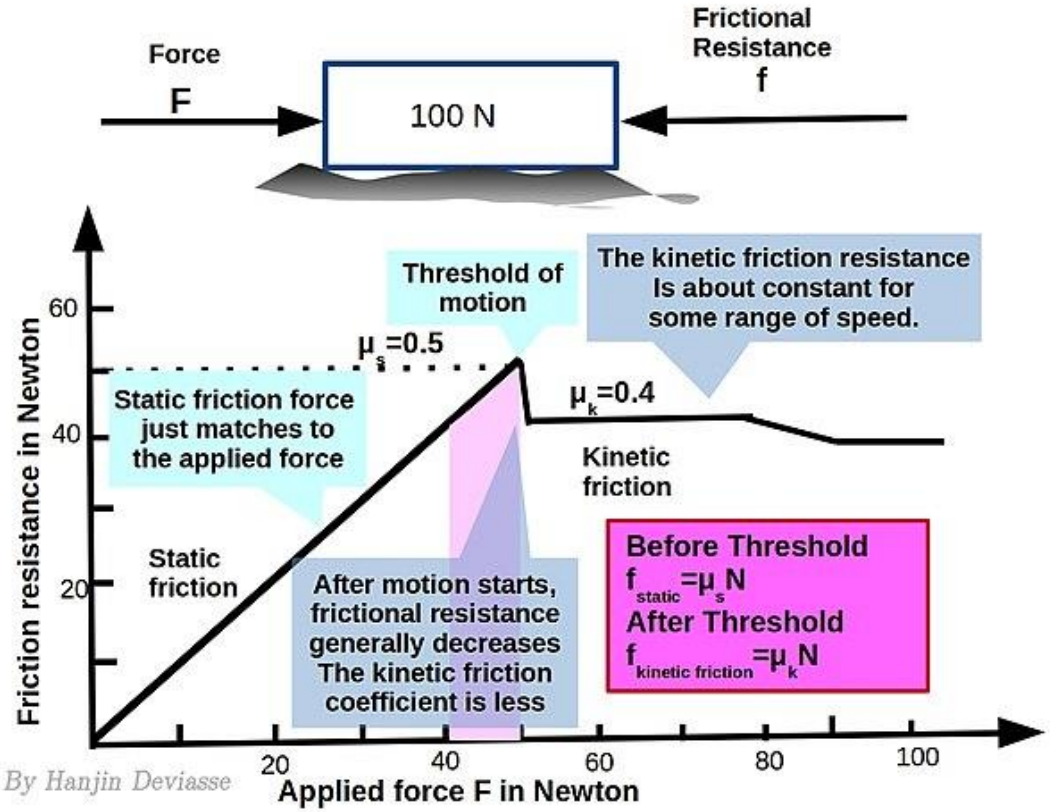
Tribology

Tribology is the science and engineering of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication and wear. Usually, measurement of the value coefficients of friction can be considered constant only within certain ranges of forces and velocities, outside of which there are extreme conditions that modify these coefficients and variables.



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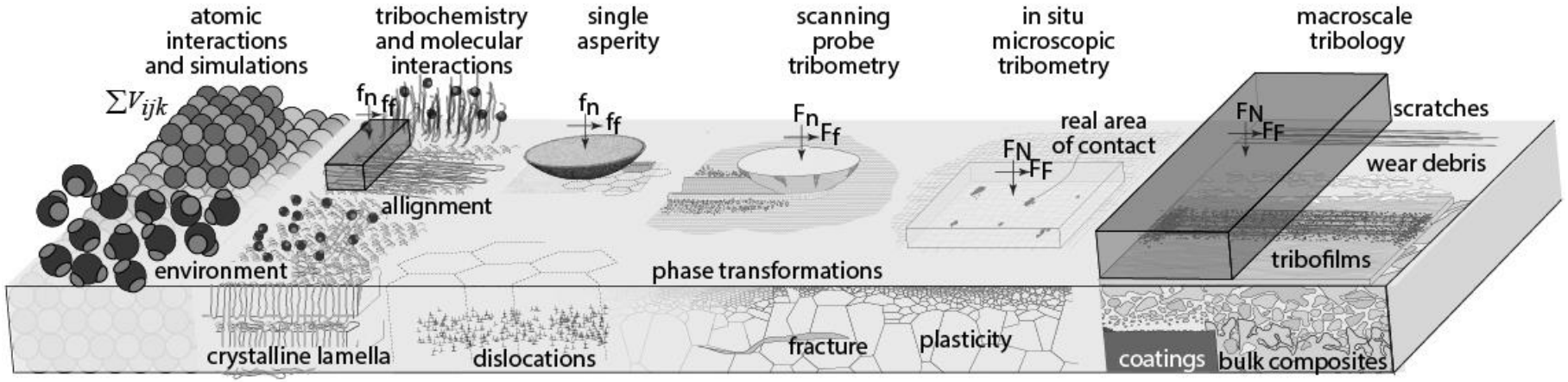
Possible research

- Linear reciprocating tribometer (high temperature testing up to 600°C, high sliding speed)
- Rotary tribometer (high temperature testing up to 800°C, humidity control)
- Block on ring tribometer
- Rheometer
- Micro-scratch tester
- Macro and micro-indentation testers
- 3D optical profilometer

- Scanning electron microscope
- XRF spectroscopy
- Hardness tester
- Thermographic measurements
- Adhesion tester



Our device

- Anton Paar step 700 with the micro-tribo tester MCT³ and the nano-scratch tester NST³
- Brucker UMT Tribometr
- Alemnis In-Sem Mechanical tester
- Fischer Picodentor HM500
- Fischer XRF Spectrometer
- Brookfield Viscometer
- Adhesion tester Positest AT-A
- Microhardness tester FM-700
- 3 original tribology testers

Brucker UMT Tribometr

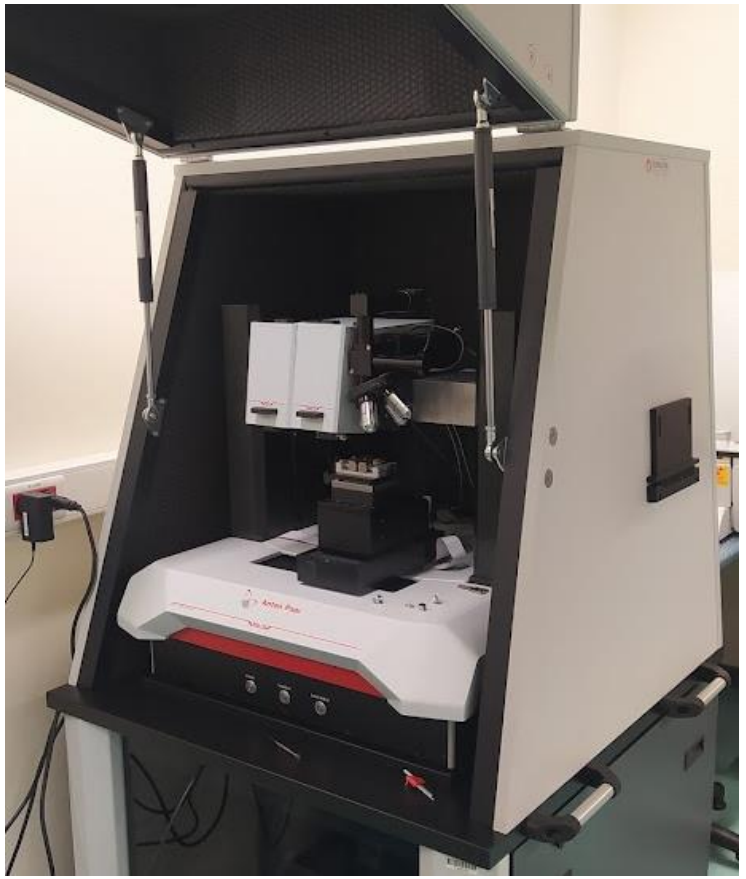
This station might be used for tribological testing of ferrous, nonferrous metals, plastics, ceramics, composites and various types of coatings, under “dry” and fluid or solid lubrication conditions. The tribological testing station can be programmed for motion in several axes. The ability to control of the trajectory of the sample and the countersample allow to use different methods of evaluation of wear, which are used for evaluation of engineering materials characteristics.

Standarized ASTM tests:

- Ball/Pin on disk
- Ball/Pin on flat
- Scratch test

Anton Paar step 700

- 2 measuring heads and motorized microscope
- micro combi tester MCT³ - allows the determination of adhesion, hardness, elastic modulus, friction, and wear for a wide range of samples.
- nano-scratch tester NST³ - can be used to analyze organic and inorganic coatings as well as soft and hard coatings - force acting from 5 mN



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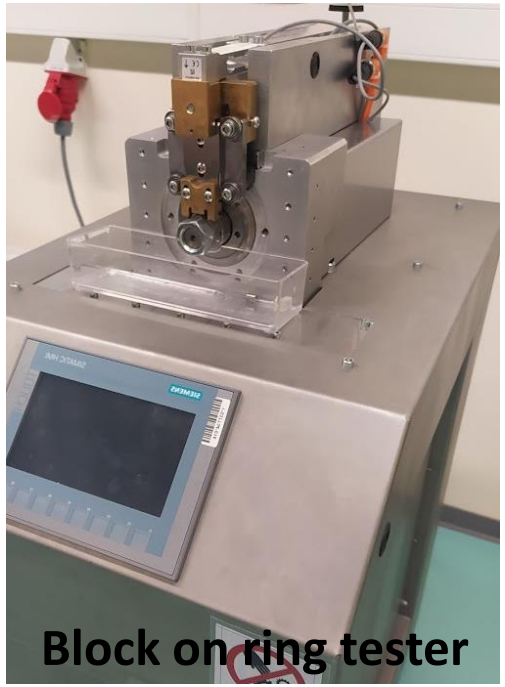
3 original tribology testers

Advantages of proprietary tribotesters: high-class Mitsubishi servo drives, Siemens automatics, very stiff device structure. Possibility of testing with high pressures.



Block on ring tester

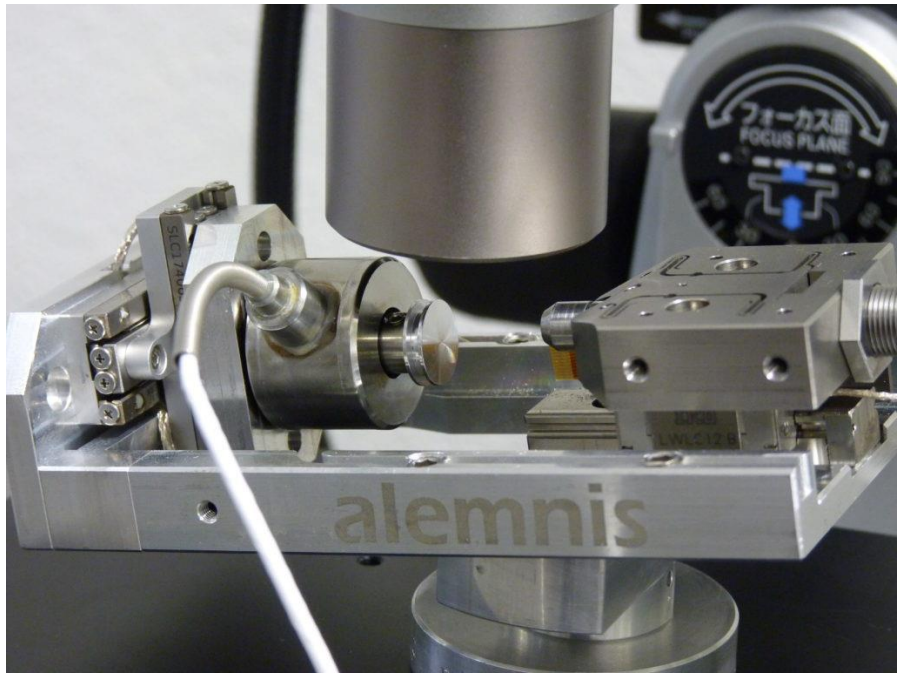
Rolling tester

Pin on disk tester

Alemnis

A universal system for micromechanical tests with the possibility of mounting an SEM microscope or a microtomograph in the space.

- Measurement range:
- Force measurement in two axes up to 1 N,
- Measurement of displacements in the Z axis up to 30 µm
- Measurement of displacements in the X and Y axes up to 100 µm



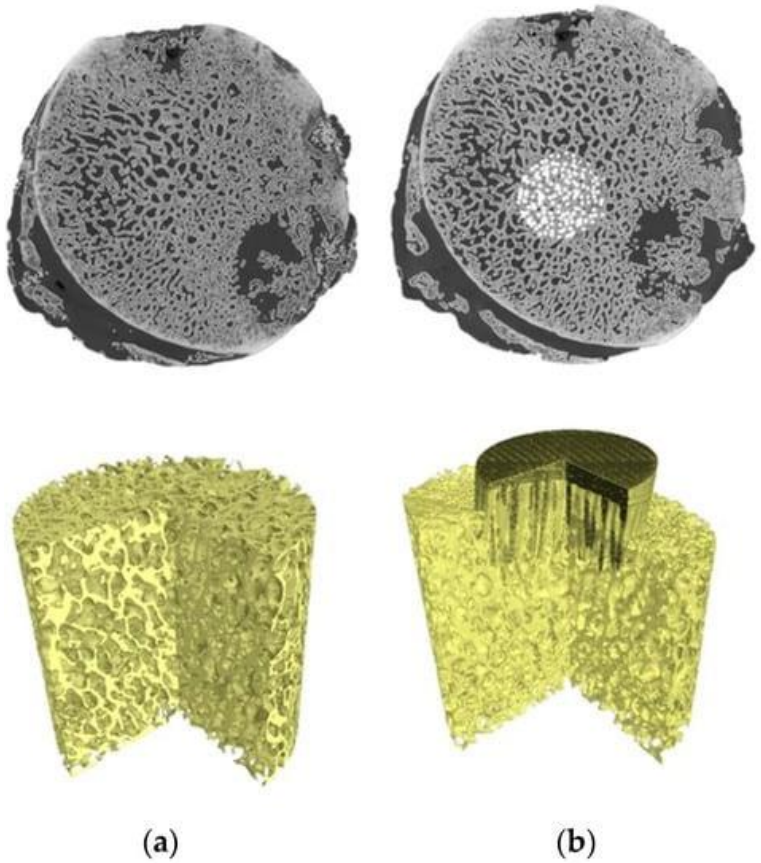
Research issues

- Tribological tests on a macro and micro scale
- Tribological tests of functional coatings on titanium alloys
- Mechanical behavior of porous coatings induced during scratch tests and pin-on-flat tests
- Structuring the surface microstructure using mechanical and laser methods
- Design of orthopedic implants
- Machining of bone and periarticular tissues

Design of orthopedic implants
Multi-spiked connecting scaffold

3D micro-CT reconstruction of femoral head bone samples: (a) before and (b) after embedding the prototype with a multi-pin scaffold connecting

Dąbrowski, M., Rogala, P., Uklejewski, R., **Patalas, A.,** Winiecki, M., Gapiński, B.. Subchondral Bone Relative Area and Density in Human Osteoarthritic Femoral Heads Assessed with Micro-CT before and after Mechanical Embedding of the Innovative Multi-Spiked Connecting Scaffold for Resurfacing THA Endoprostheses: A Pilot Study. J. Clin. Med. 2021



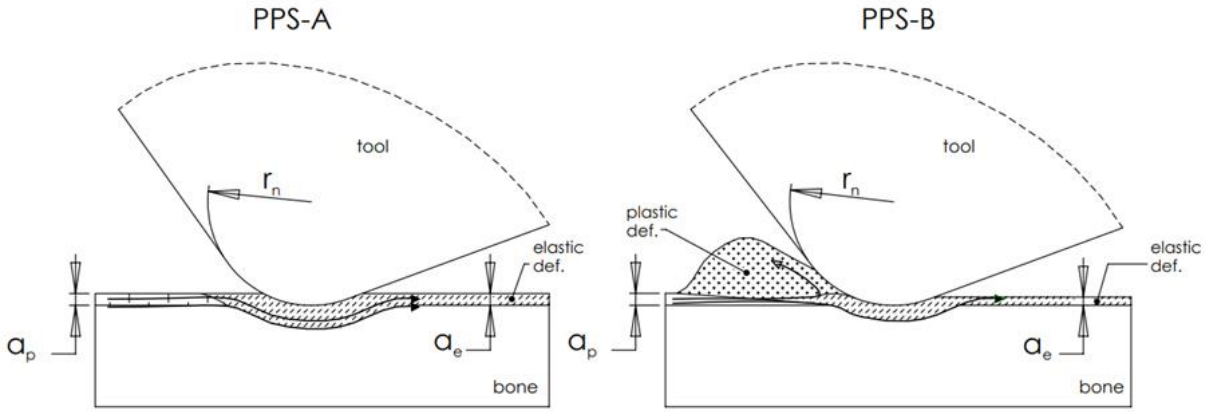
Design of orthopedic implants
Multi-pin connecting scaffold

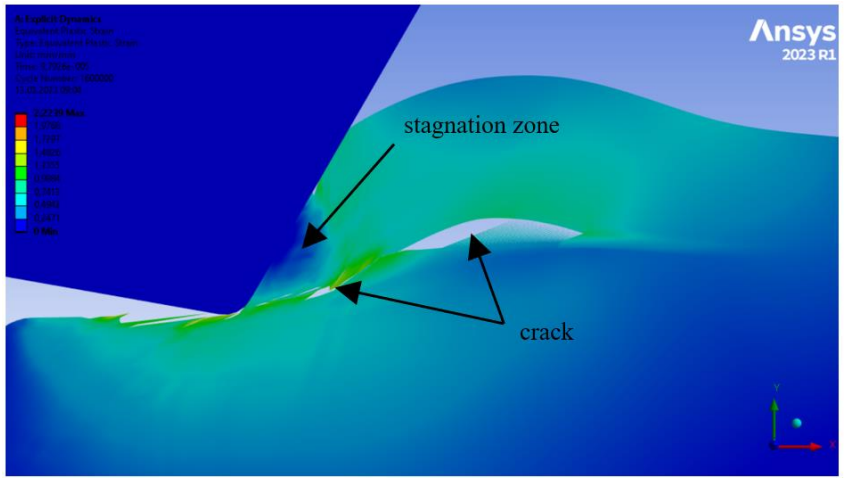
endomedic

An example of a working prototype of a partial RKA prosthesis with a multi-spiked connecting scaffold implanted in the lateral condyle of the femur in pigs.

Rogala P., Uklejewski R., Winiecki M., Dąbrowski M., Gołańczyk J., **Patalas A**. First Biomimetic Fixation for Resurfacing Arthroplasty: Investigation in Swine of a Prototype Partial Knee Endoprosthesis. BioMed Research International

Model of a chip formation mechanism of cortical bone using a tool with a negative rake angle - analysis, modelling, and validation



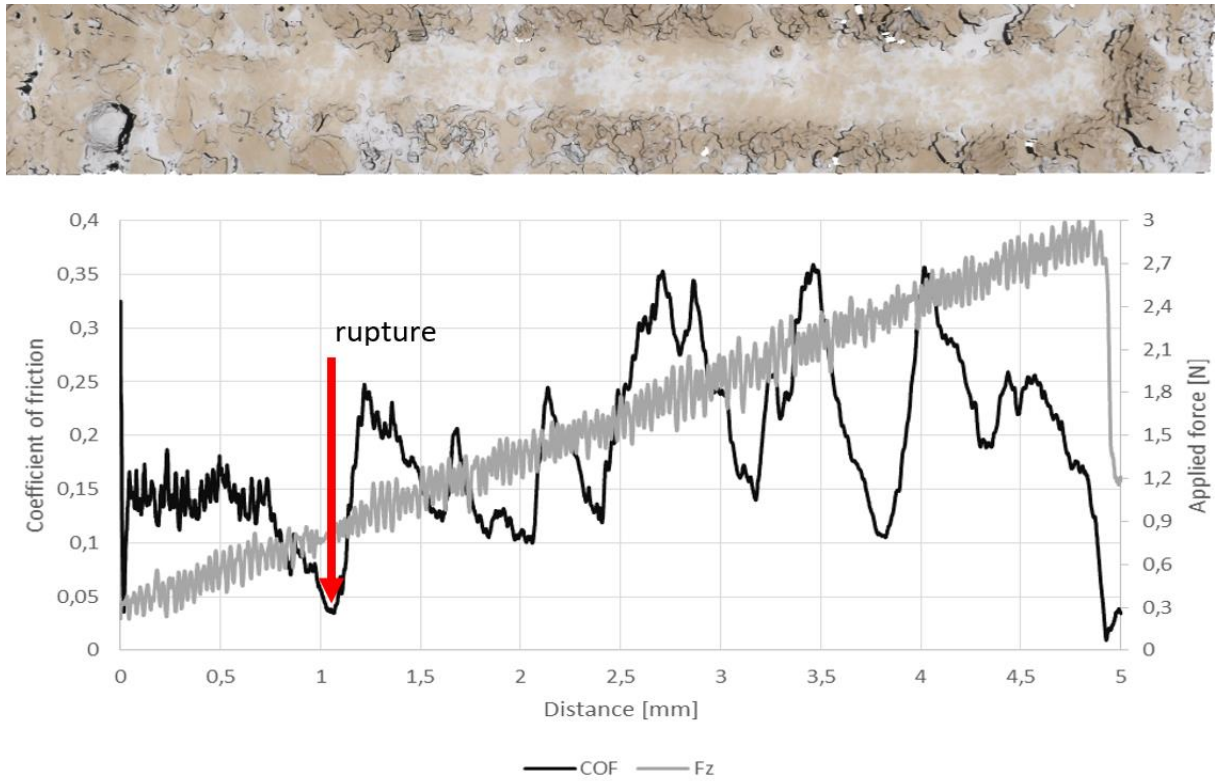


Zawadzki, P., Talar, R. Model of a chip formation mechanism of cortical bone using a tool with a negative rake angle — analysis, modelling, and validation. Int J Adv Manuf Technol 130, 4187–4205 (2024). https://doi.org/10.1007/s00170-023-12921-w

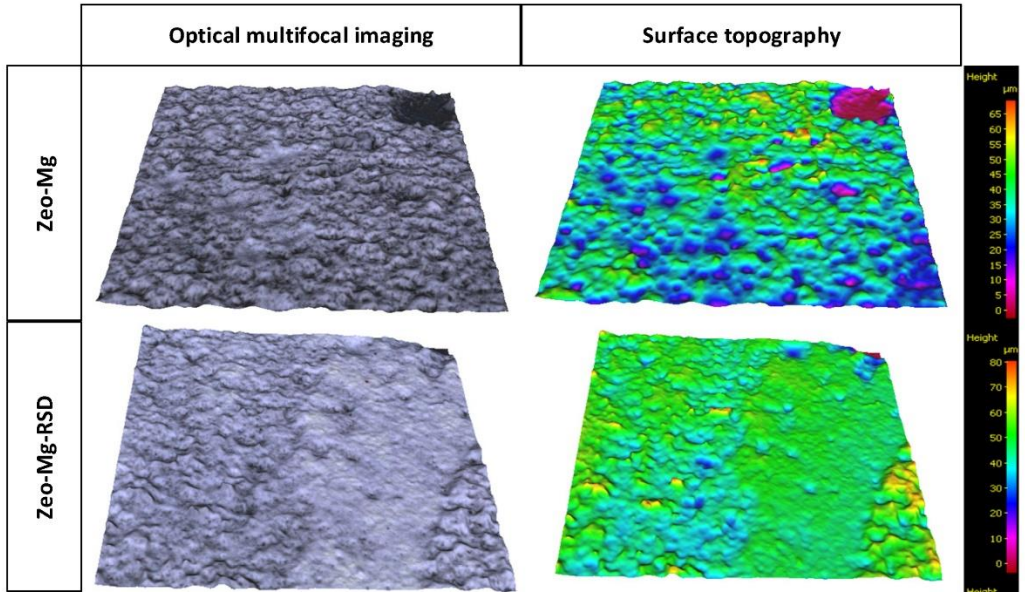
Mechanical behavior of porous coatings induced during scratch tests and pin-on-flat tests

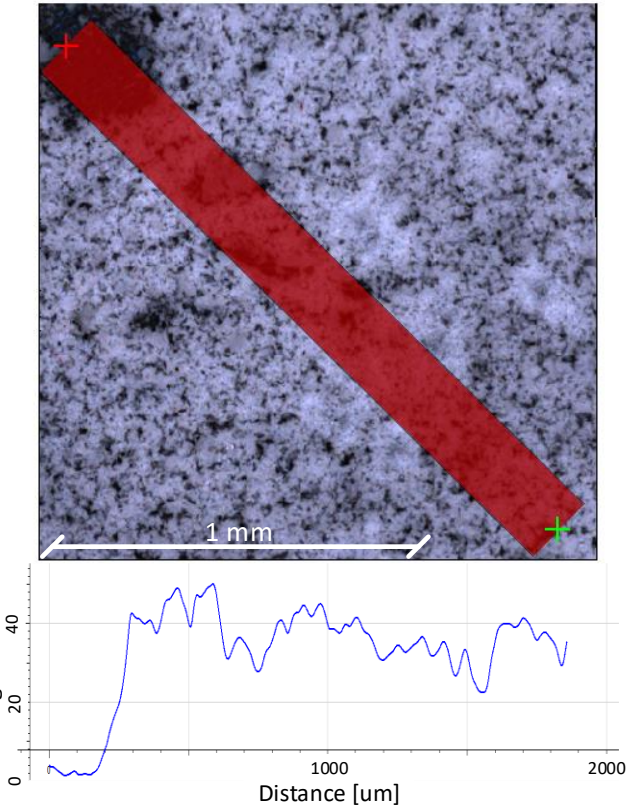
Scratch tests of zirconium oxide nanotube coating on zirconia ceramics

S. N. V. Raghu, P. Hartwich, **A. Patalas**, M. Marczewski, R. Talar, C. Pritzel, M. S. Killian. 2023. Nanodentistry aspects explored towards nanostructured ZrO2: Immobilizing zirconium-oxide nanotube coatings onto zirconia ceramic implant surfaces. Open Ceramics - 2023, vol. 14, s. 100340-1-100340-6



Tribological tests of functional coatings on titanium alloys



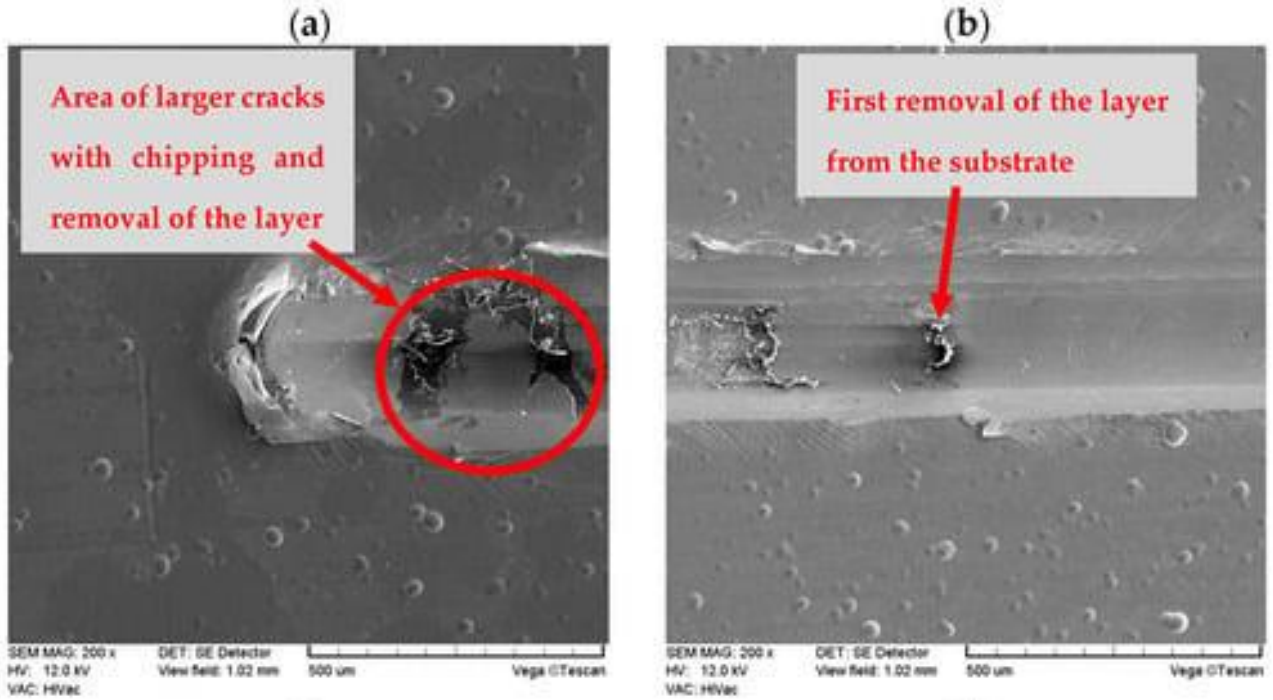


- M. Sandomierski, M. Zielińska, K. Adamska, **A. Patalas**, A. Voelkel. 2022. Calcium montmorillonite as a potential carrier in the release of bisphosphonates. New Journal of Chemistry - vol. 46, iss. 7, s. 3401-3408
- M. Sandomierski , M. Zielińska, T. Buchwald**, A. Patalas**, A. Voelkel. 2022. Controlled release of the drug for osteoporosis from the surface of titanium implants coated with calcium titanate. Journal of Biomedical Materials Research Part B, vol. 110, iss. 2, s. 431-437

Mechanical behavior of porous coatings induced during scratch tests and pin-on-flat tests

Mechanical tests of nanocomposite and hybrid Ni-P/Si3N4/graphite coatings deposited by chemical reduction on the AW-7075 aluminum alloy

Czapczyk, K.; **Zawadzki, P.; Wierzbicka, N.** Influence of Dispersed Phase Content on the Mechanical Properties of Electroless Nanocomposite Ni-P/Si3N4 and Hybrid Ni-P/Si3N4/Graphite Layers Deposited on the AW-7075 Alloy. Materials 2023, 16, 6100. https://doi.org/10.3390/ma16186100



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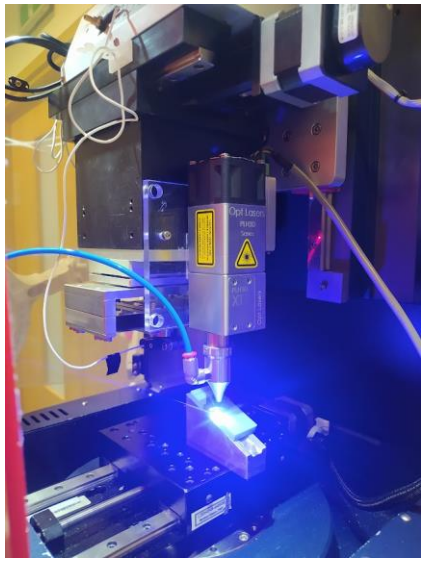
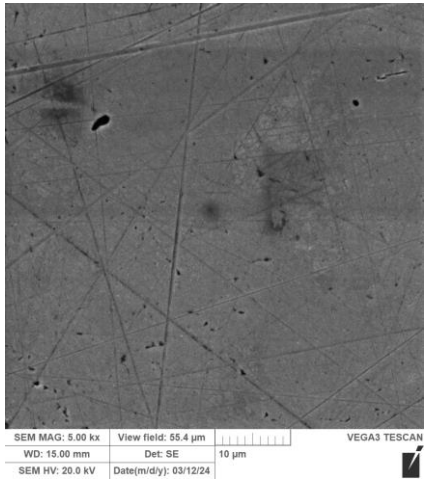
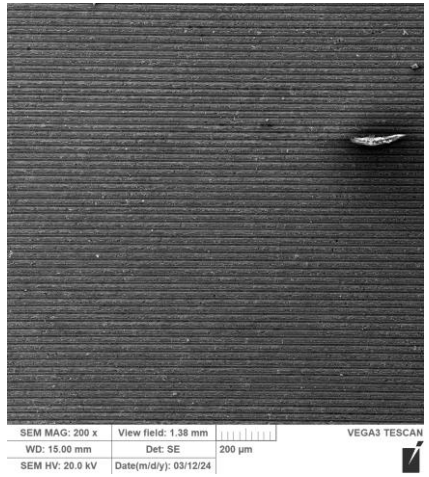
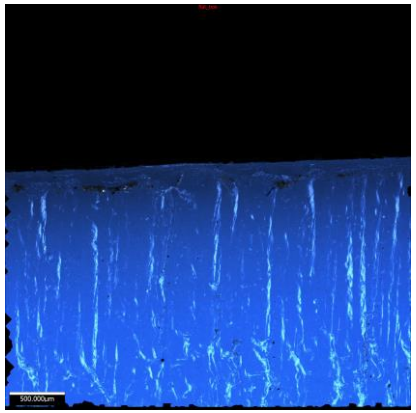
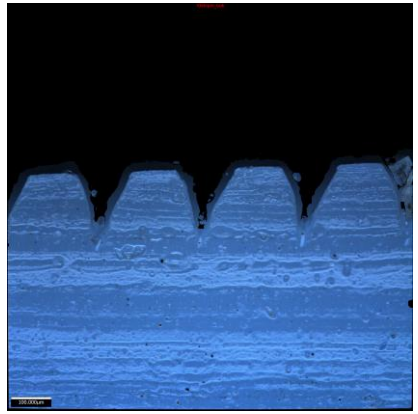








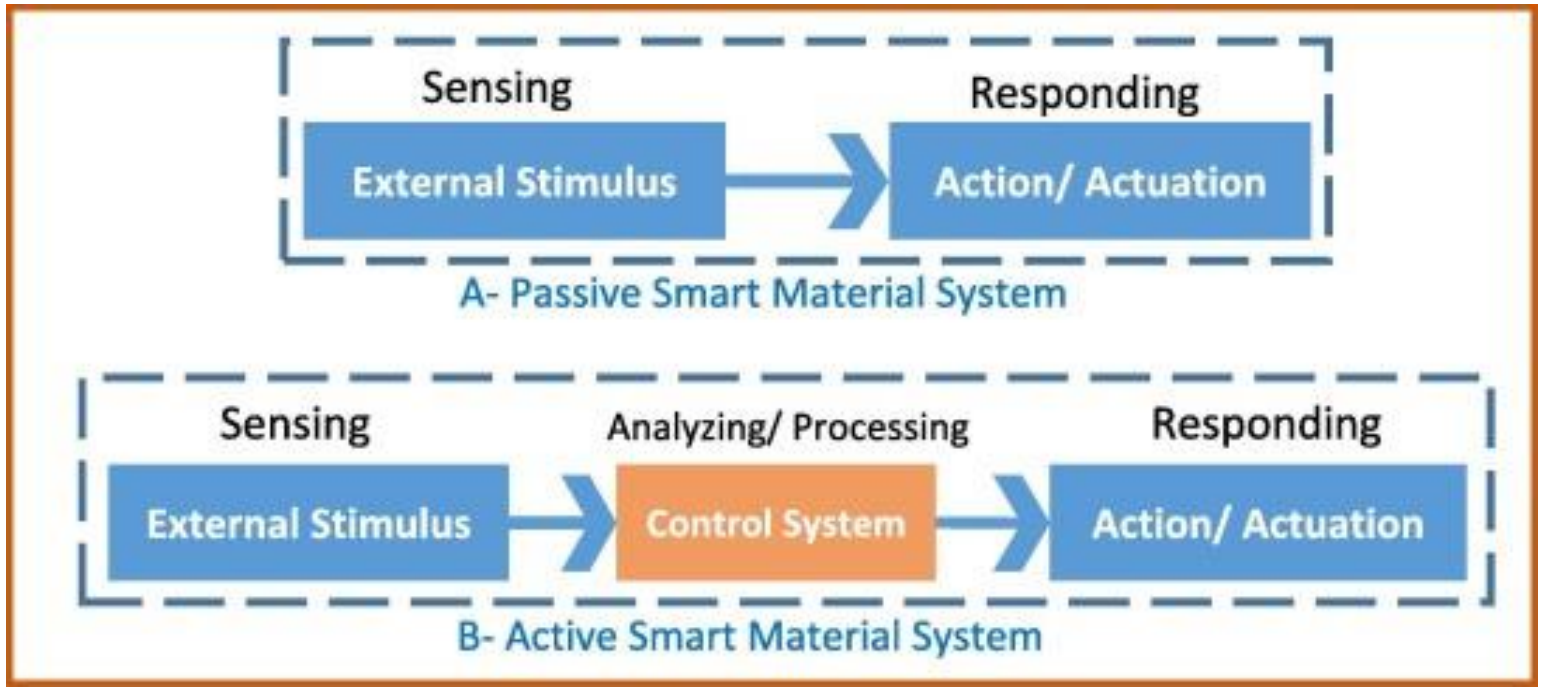


Structuring of surface microstructure using laser methods

Surface structuring to assess cell growth and secretion of pro-inflammatory cytokines (implants)
steel in order to obtain specific tribological characteristics

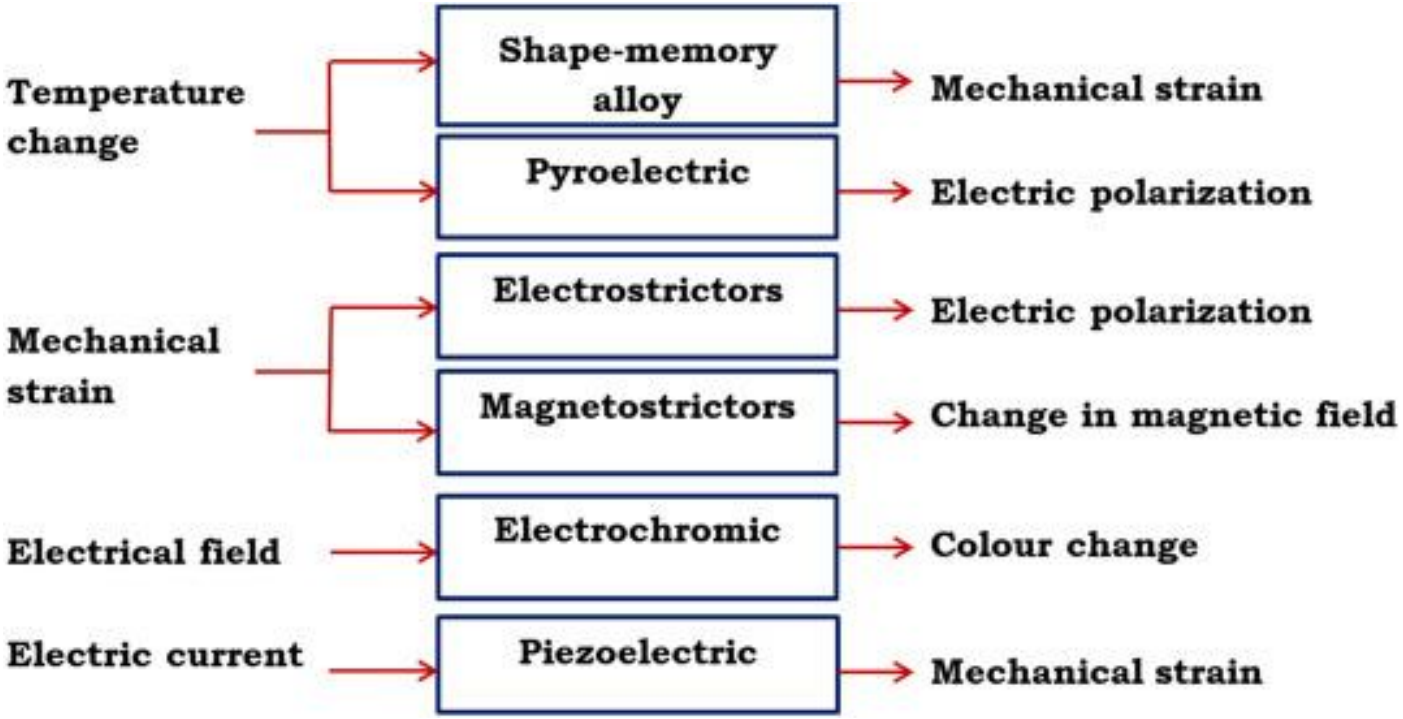
Surface structuring of medical silicone to induce anisotropic tribological features

Classification of Smart Materials by energy transduction capability

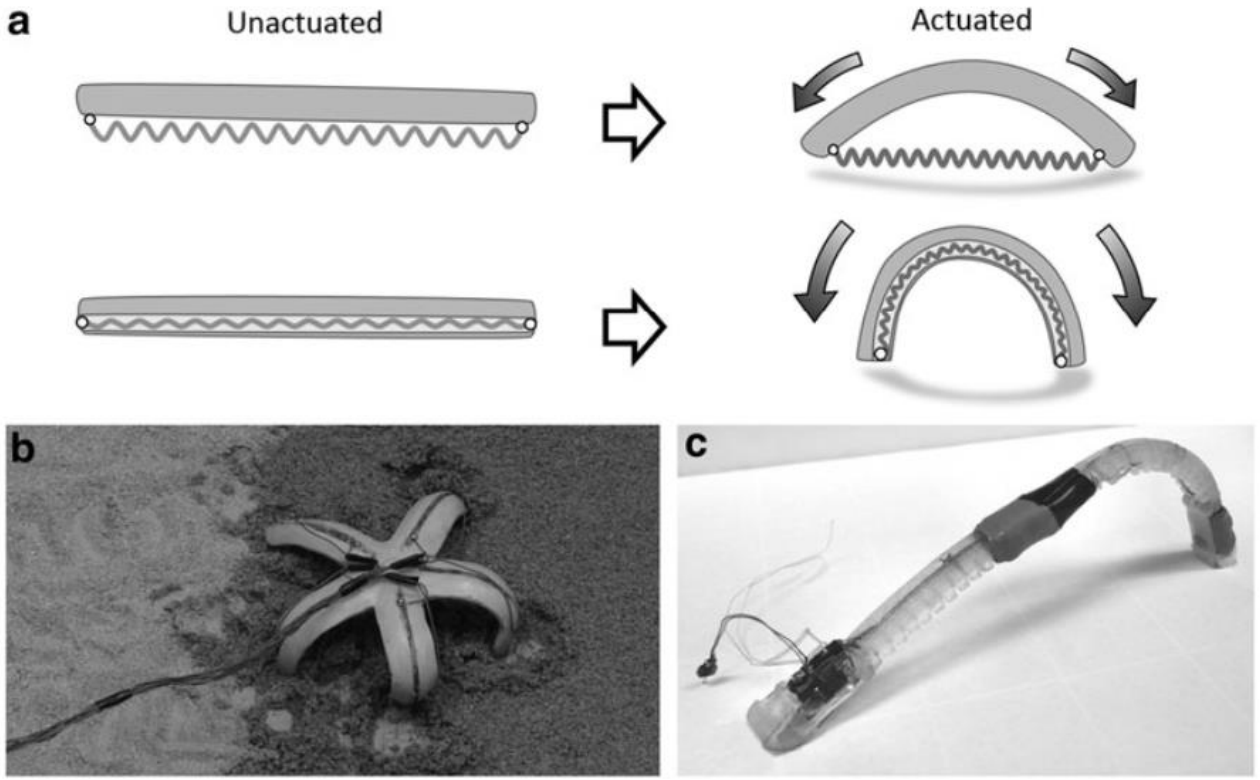


Yahya and Hoda, 2019

Smart Materials Types



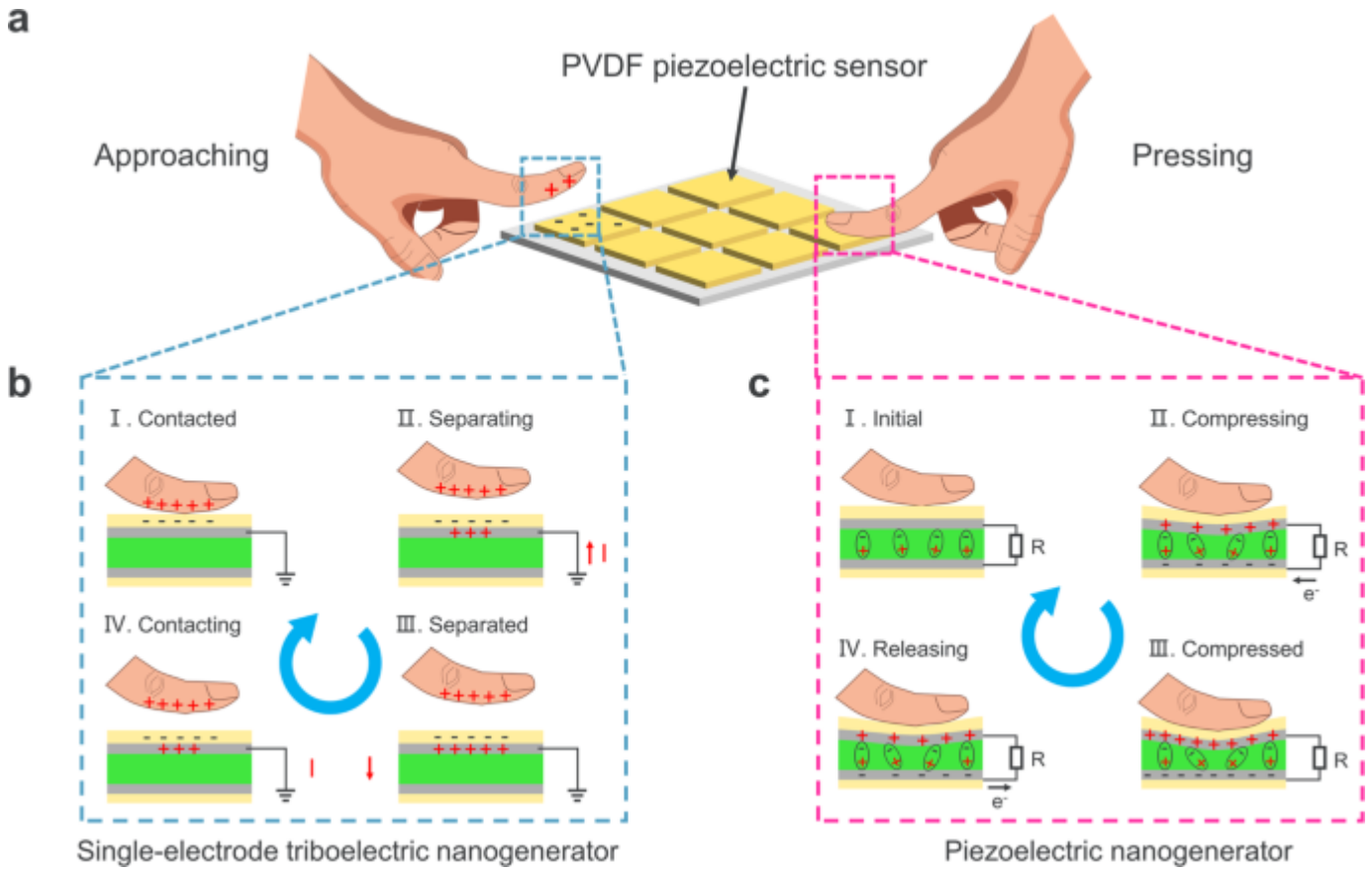
Shehata et al., 2022



Shape Memory Alloys (SMAs)

(**a**) Comparision of SMA element attached at both ends of the actuator and located outside versus inside, (**b**) starfish-like soft robot with flexible rays actuated by SMA spring located within the structure, and (**c**) spring-driven robot with a silicone polimer body (Huai-Ti and Trimmer)

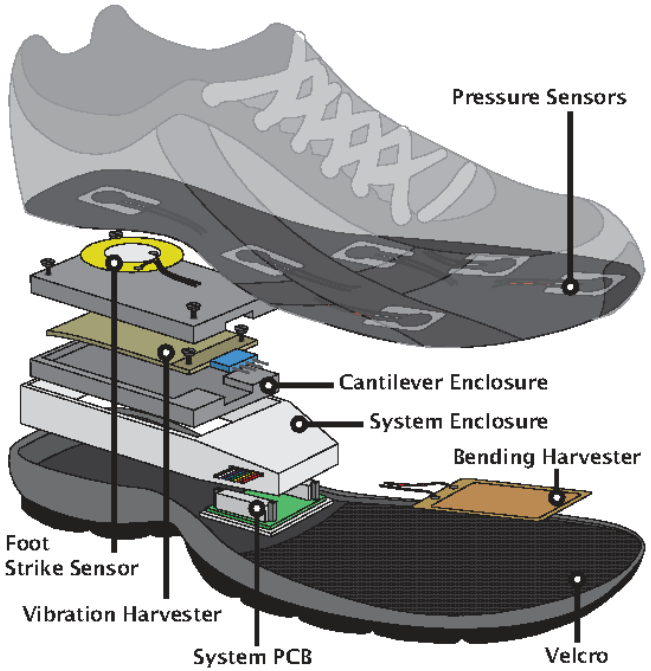
Rodrigue et al., 2022



Piezoelectric Materials

Examples of materials based on the piezoelectric effect allowing the generation and recovery of energy. This mechanism is mainly implemented by applying pressure to the material, which causes the reverse piezoelectric effect and the creation of a potential difference.

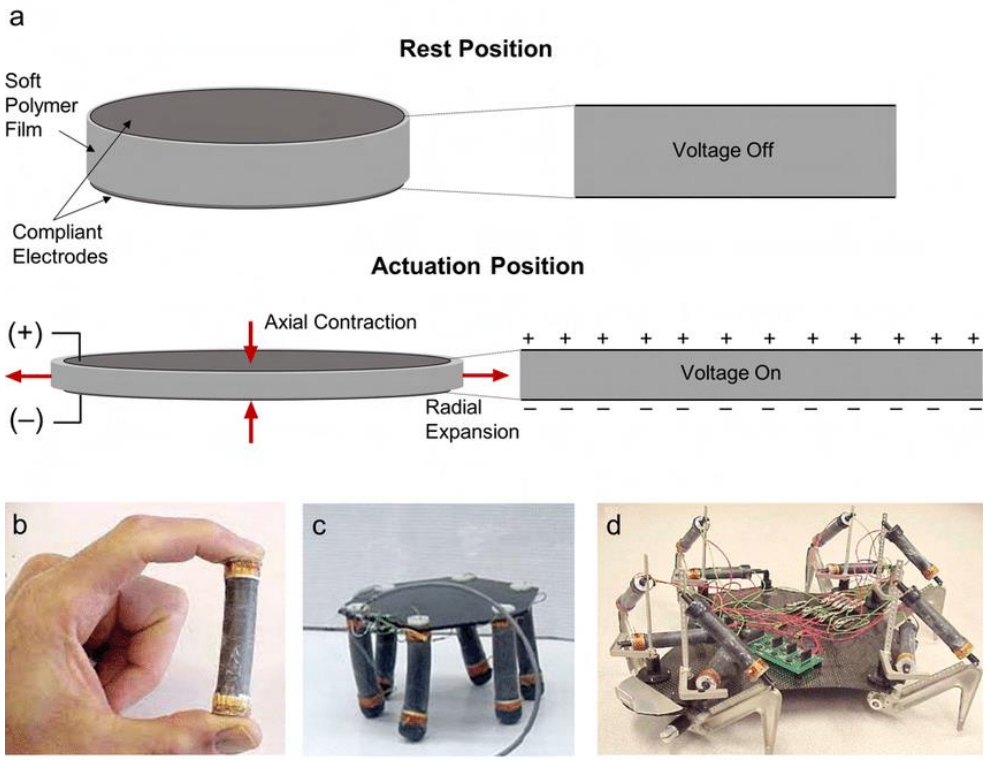
Chen, C. et al., 2022



Piezoelectric Materials

A piezoelectric energy-harvesting shoe system

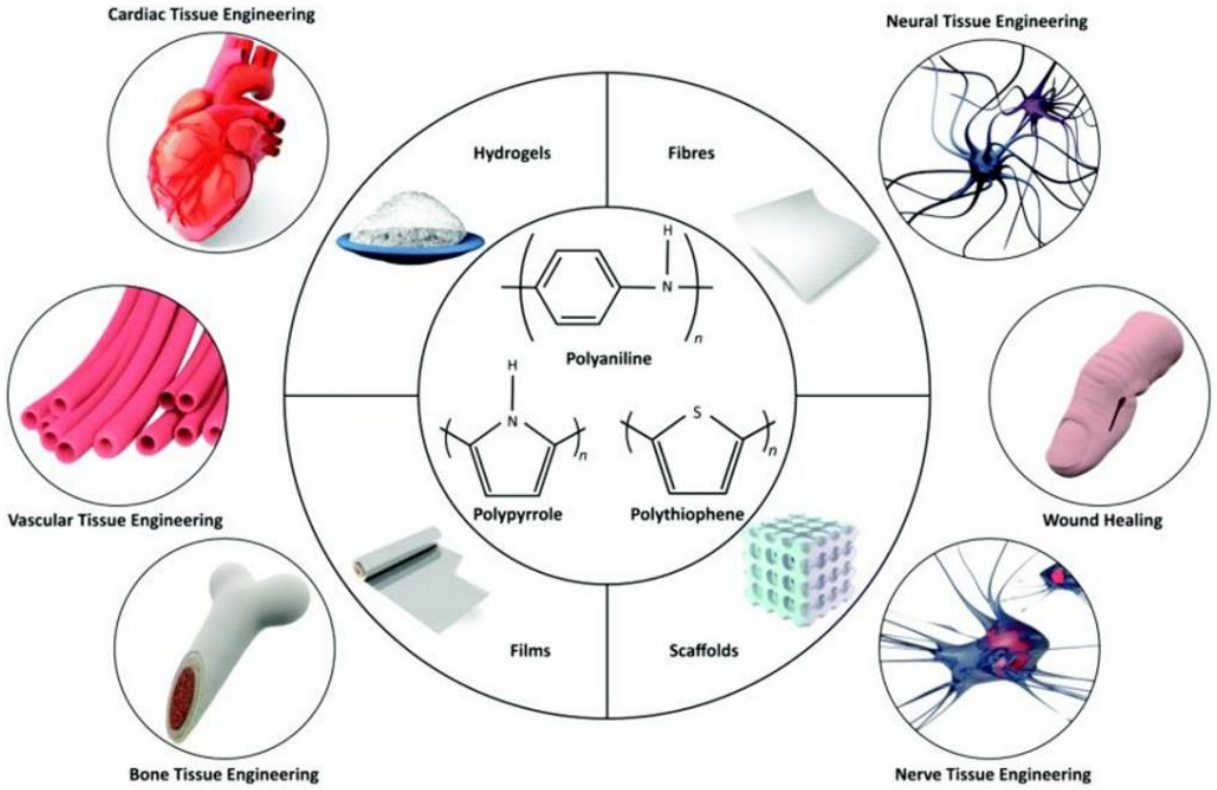
Meier, R. et al., 2014



Electroactive Polymers (EAPs) are polymers that change their size, shape or volume in response to a strong electrical field. They are extremely lightweight, inexpensive, fracture tolerant and compliant

(a) Operating principle of dielectric elastomer actuators (DEAs).
(b) (c) and (d) multifunctional electroelastomer roll (MER) and six legs MERbot

Higueras-Ruiz et al., 2021

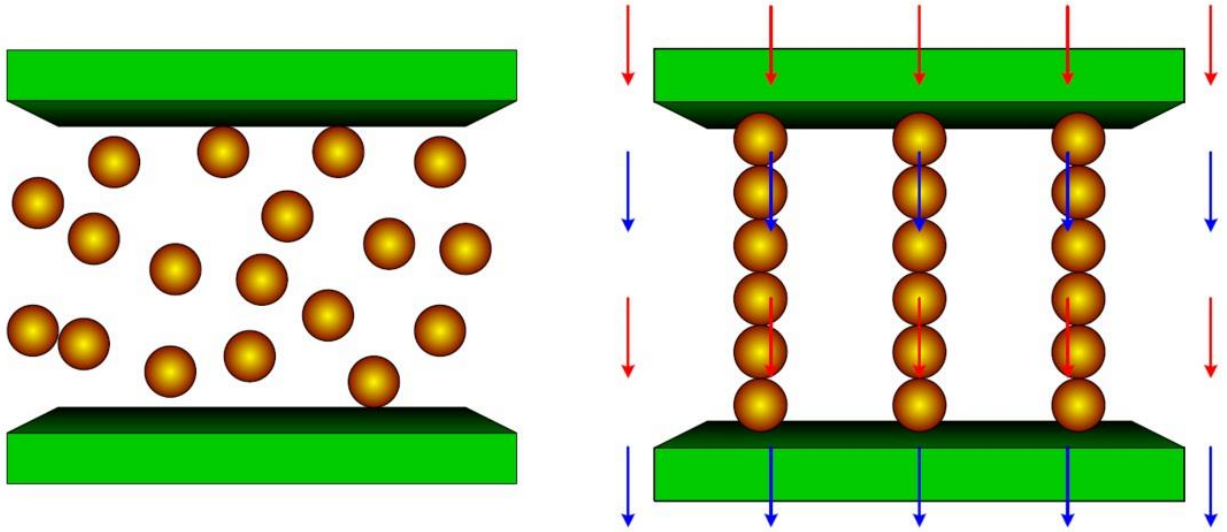


Smart Materials in Biomedical Engineering

- Self-Healing
- Multifunctional
- Adaptive
- Responsive
- Tunable

Additionally, responsive materials enable real-time health monitoring through wearable devices.

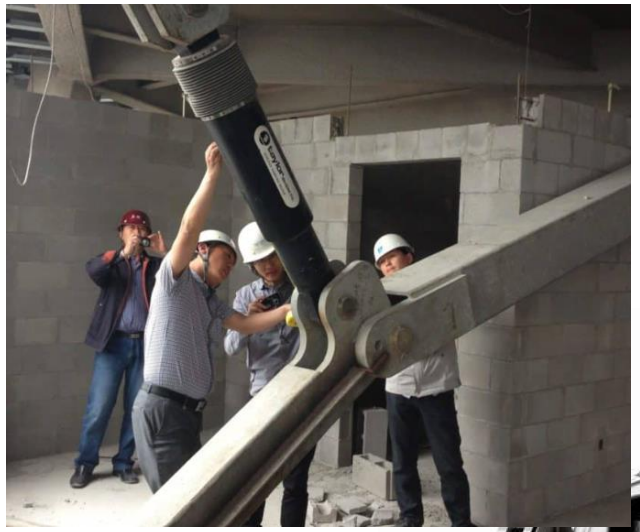
Fernandes et al., 2019

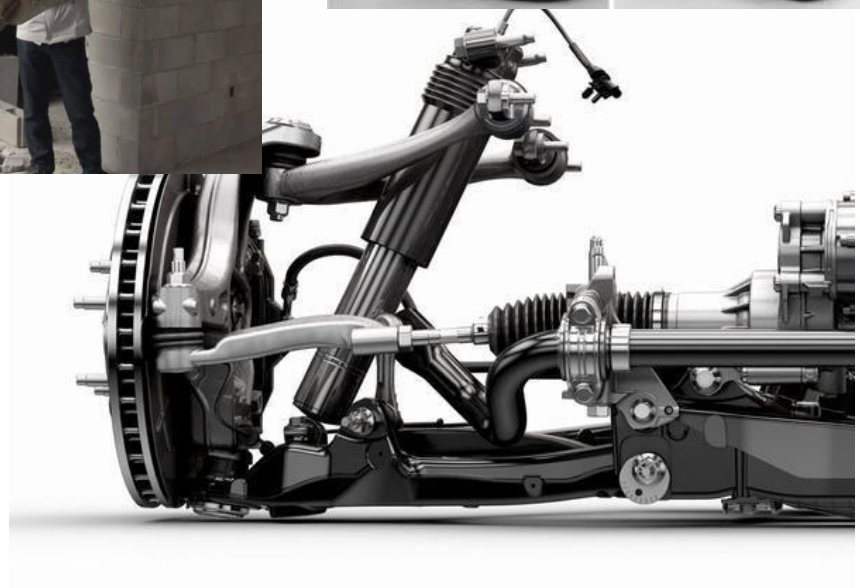


(a) Without Magnetic Field (b)With Magnetic Field

Magnetorheological fluid – MR fluid

Type of smart fluid that can change their viscosity or flow behavior in response to an applied magnetic field. These fluids consist of micron-sized magnetic particles suspended in a carrier fluid, typically oil. When subjected to a magnetic field, the magnetic particles align themselves along the field lines, causing the fluid to become more viscous and exhibit a semi-solid behavior.



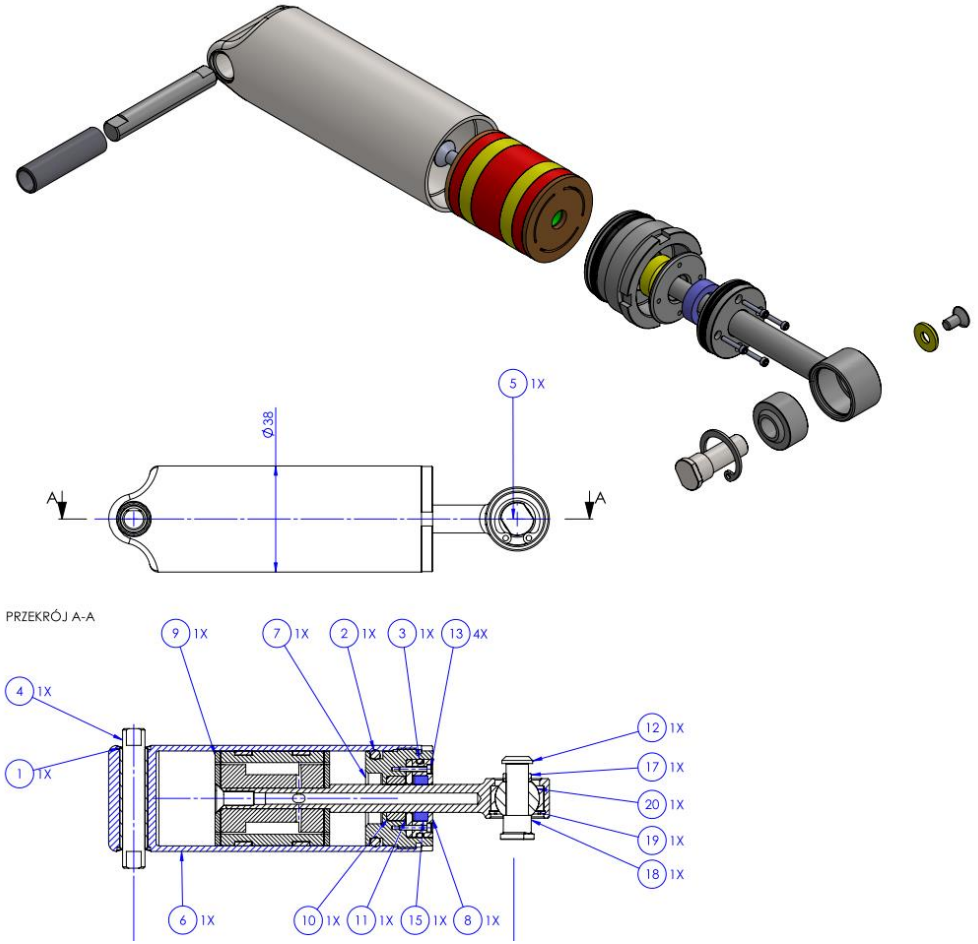


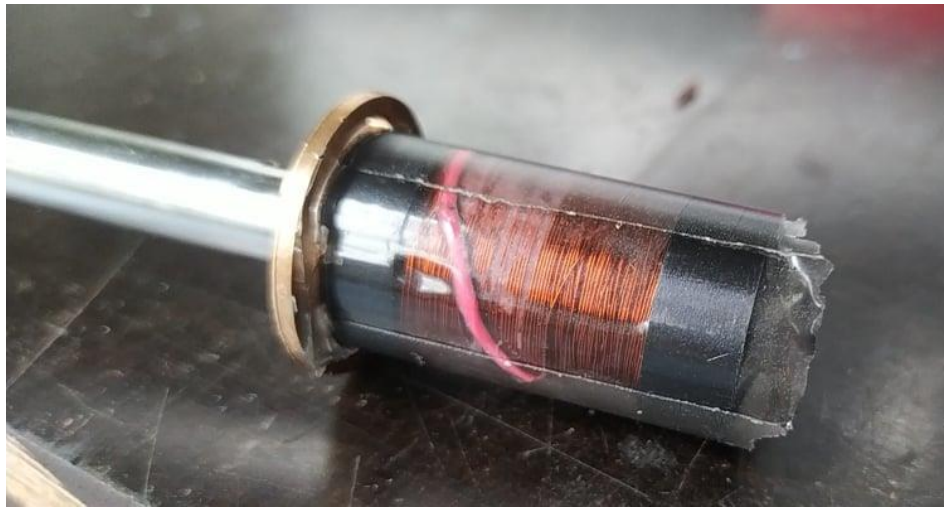
MR fluid - application

MR fluids are utilized in a wide range of applications across industries such as automotive, aerospace, civil engineering, robotics, and consumer electronics. Some common applications include adaptive suspension systems in vehicles, vibration dampers in buildings and bridges, haptic feedback devices, and damping systems for industrial machinery.

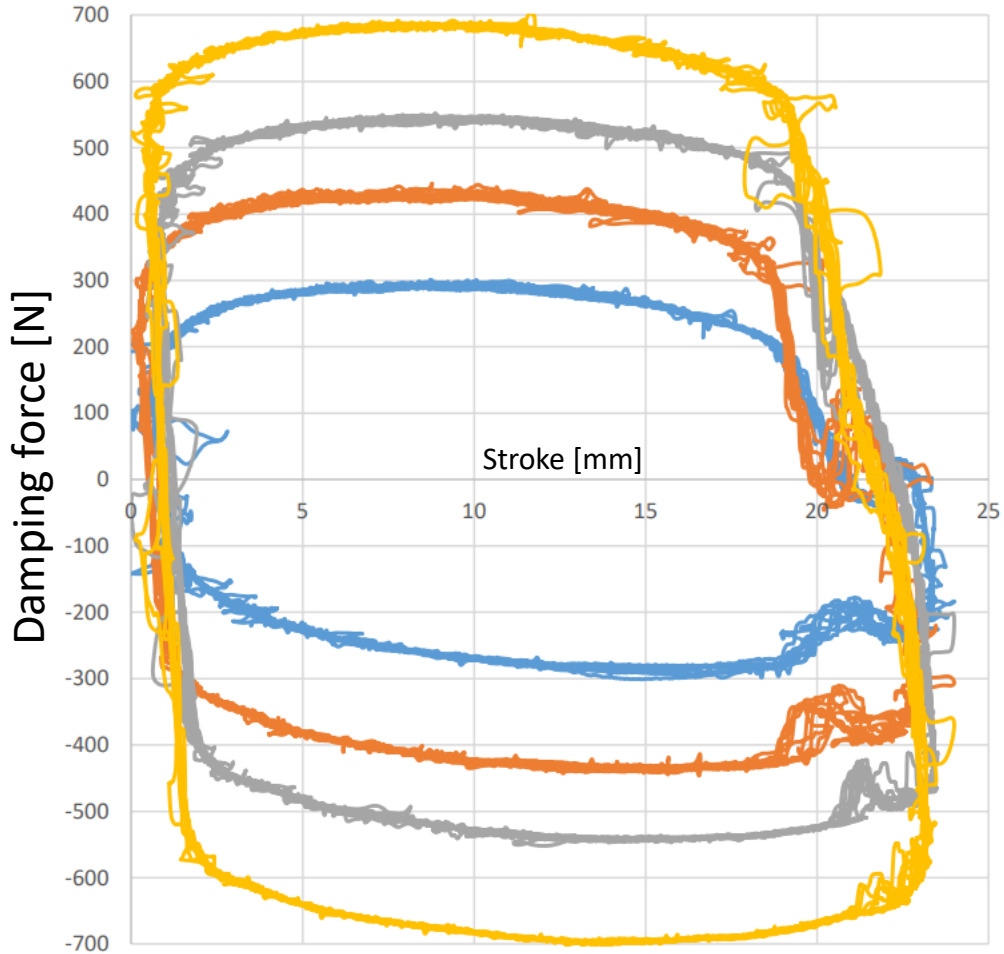
MR dampers – our experience

The prosthesis facilitates the ankle flexion to the extent corresponding to the natural one, which allows the user to maintain a smooth and dynamic movement during every step, regardless of the terrain.





Piston part of MR damper



Change of damping force depending on the current flow.

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