# SPM workshop 2025

## seminář o metodách blízkého pole

Lednice 23.–25. 4. 2025

Main sponsor:

Sponsors:

Program TREND

# Wednesday 23. 4.

| | | |
|---|---|---|
| 13:55 – 14:00 | | *Welcome* |
| 14:00 – 14:18 | Matěj Hývl ......... | Contact force in current-detecting atomic force microscopy |
| 14:18 – 14:36 | Ján Šoltýs .......... | MFM tip-controlled magnetization of magnetic nanostructures |
| 14:36 – 14:54 | Elena Arbelo ........ | Park Systems company presentation |
| 14:54 – 15:12 | Petr Klapetek ....... | Advanced measurement modes in Gwyscope controller |
| 15:12 – 15:30 | Dominik Badura .... | Scanning probe microscope with active piezoresistive cantilever for versatile surface metrology |
| 15:30 – 15:50 | Dušan Novotný ..... | News from MT-M (Měřicí technika Morava s.r.o. company presentation) |
| 15:50 – 16:20 | | *Coffee break* |
| 16:20 – 16:56 | **Teodor Gotszalk** .. | **Metrology with MEMS devices** |
| 16:56 – 17:14 | Bartosz Pruchnik ... | Higher eigenmode atuation of active piezoresistive cantilevers for surface nanometrology |
| 17:14 – 17:32 | Iwo W. Rangelov .... | Active Probe Atomic Force Microscopy with Quattro-Parallel Cantilever Arrays for High-Throughput Large-Scale Sample IC Inspection |
| 17:32 – 17:50 | Władysław Kopczyński ................ | Active piezoresistive cantilevers in nanorobotics |
| 17:50 – 18:15 | Jakub Horák ........ | News from Bruker (Měřicí technika Morava company presentation) |
| 18:15 – 19:00 | | *Dinner* |
| 19:00 – 20:00 | Exhibitors .......... | Experience the AFM: practical demonstration of instruments and free discussion with company representatives |

# Thursday 24. 4.

| | | |
|---|---|---|
| 9:00 – 9:36 | **Martin Setvín** ..... | **Imaging and tracking polarons in $Fe_2O_3$ and $SrTiO_3$ by atomic force microscopy** |
| 9:36 – 9:54 | Pavel Jelínek ........ | Observables in STM: can we see molecular orbitals? |
| 9:54 – 10:12 | Egor Ukraintsev ..... | AFM, FFMD simulations and CD analyses of [7]-helicene assembly on ZnO polar and non-polar facets |
| 10:12 – 10:30 | Martin Rejhon ...... | Exploring ABC-stacked graphene domains in untwisted epitaxial graphene |
| 10:30 – 10:50 | Karel Šec ........... | Nanoscale optical and chemical characterization of nanomaterials using s-SNOM technology (Nicolet CZ company presentation) |
| 10:50 – 11:20 | | *Coffee break* |
| 11:20 – 11:56 | **George Heath** ..... | **Localization atomic force microscopy** |
| 11:56 – 12:14 | Berta Papulová ..... | Use of Localized Atomic Force Microscopy to improve imaging resolution |
| 12:14 – 12:32 | Pavel Klok .......... | Nanoscale Time-Resolved Photoluminescence Mapping of $CsPbBr_3$ Nanocrystals via Near-Field Optical Microscopy |

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|---|---|---|
| 12:32 – 12:50 | Marek Černík ....... | Correlative Raman-AFM (Uni-Export Instruments company presentation) |
| 12:50 – 14:00 | | *Group photo, Lunch* |
| 14:00 – 14:36 | **Georg Fantner** .... | **Scanning Ion Conductance Microscopy and Spectroscopy** |
| 14:36 – 14:54 | Bart Hoogenboom ... | Surface roughness analysis by atomic force microscopy (Nanosurf company presentation) |
| 14:54 – 15:12 | Ondřej Novotný ..... | Development of an in-situ methodology for the measurement of sensitive materials (Nenovision company presentation) |
| 15:12 – 15:30 | Jakub Hruška ....... | Atomic force microscopy combined with scanning electron microscopy in life sciences |
| 15:30 – 16:00 | | *Coffee break* |
| 16:00 – 16:18 | Jan Přibyl .......... | Multiscale Analysis of Biological Systems: Integrating Imaging, Mechanical Characterization, and Chemical Profiling |
| 16:18 – 16:36 | Jakub Máčala ....... | Dual-Organoid Biosensor for Monitoring Cardiac Conduction Disturbances In Vitro |
| 16:36 – 16:54 | Barbora Brázdilová . | Standardization of methods for characterization of mechanical properties of soft samples at nanoscale |
| 16:54 – 17:12 | Radka Obořilová .... | AFM Spectroscopy for the Study of Lipid Bilayer Stability and Morphology |
| 17:12 – 17:30 | Daria Kondrakhova . | Use of advanced scanning probe spectroscopy techniques and phycical techniques for analyzing dessicated tear fluid |
| 17:30 – 17:48 | Lukáš Fojt .......... | AFM as a tool for visualization of biopolymer adsorption onto the carbon electrode surface |
| 19:30 – 23:00 | | *Social evening* |

# Friday 25. 4.

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|---|---|---|
| 9:00 – 9:18 | Jan Martinek ....... | Two probe SThM diffusivity |
| 9:18 – 9:36 | Anna Charvátová Campbell ........... | Calibration of scanning thermal microscope using optimal estimation of function parameters by iterated linearization |
| 9:36 – 9:54 | Mykhailo Khytko ... | Perovskite Degradation Study Using AFM: Insights into Stability and Surface Morphology |
| 9:54 – 10:12 | Swarnendu Banerjee | Light-induced Degradation of MAPI Perovskite Thin Films Probed by AFM |
| 10:12 – 10:30 | Andrzej Sierakowski . | Piezoresistive technology as universal tool for various self-sensing microstructures |
| 10:30 – 10:50 | Dušan Novotný / Bruker application scientist ................. | Měřicí technika Morava company presentation |
| 10:50 – 11:20 | | *Coffee break* |
| 11:20 – 11:38 | Šimon Řeřucha ...... | Development of monolithic interferometric assembly for two-axis coordinate positioning with sub-nanometer precision |
| 11:38 – 11:56 | Radek Šlesinger ..... | Gaussian processes prediction for directing measurement strategy in Gwyscope |
| 11:56 – 12:14 | Daniel Haško ........ | Influence of preparation conditions on the surface morphology of thin perovskite films |

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|---|---|---|
| 12:14 – 12:32 | Aniket Mukherjee . . . | Graphite nanoparticles in amine plasma polymer film: AFM based study |
| 12:32 – 12:50 | Vilma Buršíková . . . . | to be specified |
| 12:50 – 14:00 | | *End of the workshop, lunch* |

Wed 14:00 – 14:18 **Matěj Hývl** hyvl@fzu.cz

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M. Hývl, M. Ledinský

### Contact force in current-detecting atomic force microscopy

Development of new microscopic techniques for characterization of nanostructured materials and devices goes hand in hand with the recent progress in fields like photovoltaics, nanoelectronics, batteries and other technologies that exhibit large variations in electronic properties on small scales. SPM made a good name for it self as a versatile technique that can be utilized in many different fields. In regards to mentioned domains of nanoelectronics and photovoltaics, current-detecting AFM (C-AFM) is gaining traction as a characterization tool able to visualize current flows and electrically active elements on unparalleled scale. However, the question whether the technique is ready to make a next step to become a common characterization technique on a larger scale or even toward the industrial applications is yet to be answered. During any current-detecting AFM measurement, measured current flows through a circuit including the microscope, the probe tip, the cantilever and chip, the sample, and all the interfaces between them. From all these elements, tip-sample contact has been pin-pointed as a dominant factor of the resulting current signal1. Besides being affected by the environmental conditions such as humidity, atmosphere composition etc.2, it also changes in time due to a simple, yet substantial, effect of sample-geometry induced tip-sample contact force fluctuations.
In this series finale of my current-detecting AFM lectures for SPM workshop, I would like to offer a comprehensive summary of the effect of the sample geometry on the detected current and share a gwyddion-run experiment generating synthetic current based on the sample geometry. With python scripting, I was able to synthetize a theoretical current channel on the home-made testing sample and compare it with the actual result of C-AFM measurement. Results of this experiment show the validity of my approach and open doors to both further studies on the tip-sample contact and increasing future C-AFM reliability and repeatability.

(1) Schulze, A.; Cao, R.; Eyben, P.; Hantschel, T.; Vandervorst, W. Outwitting the Series Resistance in Scanning Spreading Resistance Microscopy. Ultramicroscopy 2016, 161, 59–65. https://doi.org/10.1016/j.ultrami
(2) Lanza, M.; Porti, M.; Nafría, M.; Aymerich, X.; Whittaker, E.; Hamilton, B. Note: Electrical Resolution during Conductive Atomic Force Microscopy Measurements under Different Environmental Conditions and Contact Forces. Review of Scientific Instruments 2010, 81 (10), 106110. https://doi.org/10.1063/1.3491956.

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Wed 14:18 – 14:36 **Ján Šoltýs** jan.soltys@savba.sk

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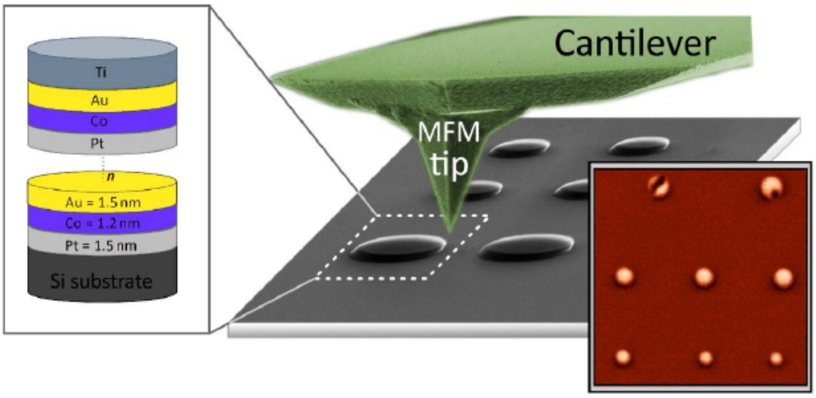
Ján Šoltýs, Iuliia Vetrova, Tomáš Ščepka, M. Zelent, Juraj Feilhauer, Sergei Krylov, Jaroslav Tóbik, J. Dérer, Michal Mruczkiewics, Tetiana Kalmykova, Vladimír Cambel

### MFM tip-controlled magnetization of magnetic nanostructures

Atomic Force Microscopy is a versatile tool that goes far beyond surface imaging. It enables the active manipulation and modification of materials at the nanoscale. For instance, by applying a higher force with the AFM tip, the material can be displaced or removed, creating precise patterns. It can also locally deliver chemicals to a surface, causing a reaction that changes the surface properties. Besides the AFM tip, the MFM tip can also be used for sample property modification. The stray field of the MFM tip can induce changes in the magnetization of the sample. This can be used to study the magnetic properties of materials and to create specific magnetic patterns on the surface.
Here, we present three examples of MFM tip modification. In the first, the MFM tip's local magnetic field influences a magnetic state in nanodisks. The experimentally measured disks were remagnetized from

the multi-domain state to the single-domain state [1]. In the second case, we demonstrate the control of magnetization circulation of the closure domain state in permalloy squares divided diagonally into four dipolar-coupled isosceles triangles. The control over the magnetization circulation was achieved by the mutual application of a suitable external in-plane magnetic field and interaction with the MFM tip [2]. The last example shows a system with a periodic array of permalloy squares, each with the same circular magnetization. Using a high momentum MFM tip, we can locally break the symmetry at a desired location within the array. The results of this study demonstrate a possible technique for controllable local magnetization of ferromagnetic elements in magnonic crystals or artificial spin ices.




*Schematic illustration of modifying the magnetic state in Co based multi-layered nanodisks using an MFM tip. The MFM inset on the right shows that most disks were magnetized to a single-domain state.*

References:

[1] M. Zelent et al., Skyrmion formation in nanodisks using MFM tip, Nanomaterials 11, 2627 (2021)

[2] T. Ščepka et al., Control of closure domain state circulation in coupled triangular permalloy elements using MFM tip, J. Appl. Phys. 134, 213902 (2023)

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Wed 14:36 – 14:54 **Elena Arbelo** elena.arbelo@parksystems.com

*Park Systems*

**Park Systems company presentation**

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Wed 14:54 – 15:12 **Petr Klapetek** petr.klapetek@cmi.gov.cz

*Czech Metrology Institute*

Petr Klapetek, Anna Charvátová Campbell, Miroslav Valtr, Václav Hortvík

**Advanced measurement modes in Gwyscope controller**

Gwyscope is an open hardware SPM controller which can be used to set up SPM experiments focusing on adaptive and non-regular scans. In this contribution we present implementation of off-resonance tapping (ORT) technique in this controller, including motivation for this development, practical aspects of implementation on Field Programmable Gate Array and measurement results. Presentation focuses on use of ORT to reduce sensing anisotropy and reduce the measurement uncertainty in non-regular scans and on uncertainties in determining the mechanical properties using ORT data, both in real-time and offline analysis.

Wed 15:12 – 15:30 **Dominik Badura** dominik.badura@pwr.edu.pl

*Nanometrology Department, Wroclaw University of Science and Technology*
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Dominik Badura, Władysław Kopczyński, Bartosz Pruchnik, Ivo W. Rangelow, Teodor Gotszalk

**Scanning probe microscope with active piezoresistive cantilever for versatile surface metrology**

Atomic Force Microscopy (AFM) is a powerful tool for nanoscale imaging and manipulation. However, conventional AFM setups often suffer from limitations in accurately controlling the cantilever's angular orientation relative to the substrate, impacting imaging consistency and nanomechanical interactions. We present a novel AFM head design that enables precise control of the cantilever angle, unlocking new capabilities in large-area imaging and nanoscratching applications. Our custom AFM head incorporates an innovative mechanical alignment mechanism that precisely determines and stabilizes the cantilever-substrate angle. This control minimizes artifacts in topographical measurements, enhances tip-sample interaction accuracy, and ensures reproducible force application during nanoscratching. Experiments demonstrate that precise angle control significantly improves large-area imaging fidelity, reducing distortions and enhancing resolution across extended scan fields. Additionally, nanoscratching tests confirm the system's ability to generate well-defined, controlled modifications on surfaces with high repeatability. The novel approach opens new possibilities for material characterization and nanofabrication. The proposed AFM head design overcomes limitations of traditional systems by offering precise cantilever angle control. This advancement enhances imaging capabilities over large fields of view and enables highly controlled nanoscratching, making it a valuable tool for research in nanomechanics, surface engineering, and beyond.

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Wed 15:30 – 15:50 **Dušan Novotný** dusan.novotny@mt-m.eu

*Měřicí technika Morava, s.r.o*

**News from MT-M (Měřicí technika Morava s.r.o. company presentation)**

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Wed 16:20 – 16:56 **Teodor Gotszalk** teodor.gotszalk@pwr.edu.pl

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*Janiszewskiego 11/17, 50-372 Wroclaw, Poland*

Teodor Gotszalk, Bartosz Pruchnik, Andrzej Sierakowski, Andrew Yacoot, Ivo W. Rangelow

**Metrology with MEMS devices**

Micro-electromechanical systems (MEMS) are micromachines, whose dimensions are of the order several micrometers. They integrate three basic components: a mechanical movable structure, its deflection actuator and position/movement detector. MEMS devices can operate in ambient conditions, air, vacuum and liquids. As MEMS structure are small the energy needed to activate the device is in the range of several electronvolts. The high resonance frequencies make MEMS devices insensitive to external measurements disturbances and reduce their response time. From that point of view the technology of such micromachines is an attractive option for investigation of nanoscale phenomena such as ultralow mass measurements or molecular force interactions. As every MEMS device can be calibrated, they pave the way to metrological (traceable) investigations, which is important for the development and dissemination of nanotechnology. In this talk, the architecture of a family of MEMS structures fabricated in the silicon technology will be presented. The actuation principle of the metrological MEMS structures will be based on electromagnetics.

The advantage of such a solution is the precise control of the excited force, which is only the function of the current flowing in the Lorentz loop, the magnetic field and Lorentz loop geometry. The piezoresistive scheme and/or optical interferometry are used to measure the displacement of the MEMS mechanical structure. The measurement resolution is limited by the thermomechanical vibration noise of the MEMS device. The resolution the structure displacement actuation is far smaller than the noise detection limit. Experiments demonstrating measurement of photon pressure in a current balance setup and calibration low-stiffness scanning probe microscopy cantilevers will be described as examples of applications of this technology.

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Wed 16:56 – 17:14 **Bartosz Pruchnik** `bartosz.pruchnik@pwr.edu.pl`

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Bartosz Pruchnika, Dominik Badura, Władysław Kopczyński, Dariusz Czułek, Ivo W. Rangelow, Andrzej Sierakowski, Andrew Yacoot, Virpi Korpelainen, Teodor Gotszalk

**Higher eigenmode atuation of active piezoresistive cantilevers for surface nanometrology**

We present recent advances in the field of nanometrology performed with active piezoresistive cantilevers as a probes for atomic force microscopy (AFM). We introduce quantitative calibration samples with determined relief height and geometrical reference shaping imprinted. We discuss on sensitivity and resolution of introduced changes and impact onto modern quantitative (metrological) scanning probe microscopy methods.

Active piezoresistive cantilevers are complete micro-electromechanical systems (MEMS). They universally serve as a versatile measurement tool, including multimodal scanning probe microscopy (SPM) – primary for AFM. Thanks to embedded actuation mechanism, they are off-the-shelf ready both non-contact and contact line of imaging. The silicon cantilever body is implanted and processed to fabricate piezoresistors for deflection detection [1]. As probes, active piezoresistive cantilever are supreme in sensitivity and offer competitive bandwidth (approx. 100 kHz). However, fabrication technology doesn't enable much improvement due to required minimal size of the cantilever body.

We therefore employ higher transverse eigenmodes of vibration. In each consecutive mode the resonant frequency rises significantly ( 6 for second,  17 for third etc.). The issue is the sensitivity, which gets inhibited in higher eigenmodes by relatively shift of the region of maximal stress. To counteract that, we introduce non-linear modification of the cantilever. We perform a local milling with focused ion beam (FIB). By that, we locally reduce stiffness and improve strain in the sensor proximity.

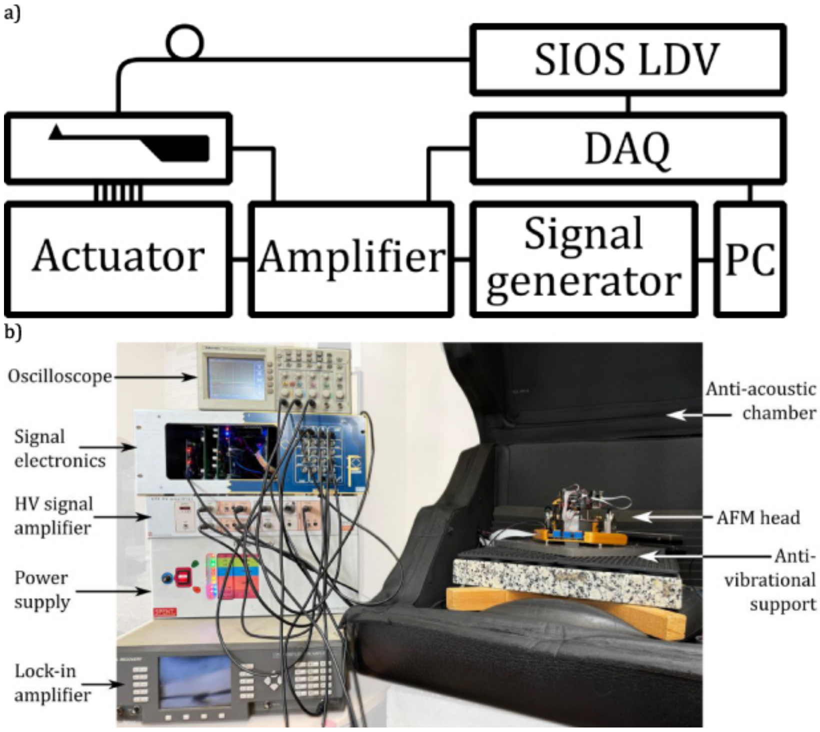
We show modelling and theoretical analysis of the active piezoresistive cantilever and the effect of modification. We perform sensitivity analysis on 2nd and 3rd eigenmode to prove the increase of sensitivity by the means of thermomechanical noise spectral analysis [2]. We present the imaging capabilities on the surface of SiO2 20 nm relief calibration sample and SiC 1.5 nm steps sample [3]. We discuss on possibilities of modifications and improving sensor performance towards higher eigenmodes, enabling imaging in a bandwidth above 1 MHz.

We acknowledge support of the Joint Research Project within the European Metrology Research Programme EMPIR 20IND08 'Traceability of localised functional properties of nanostructures with high speed scanning probe microscopy" – MetExSPM and E-COST action "Focused Ion Technology for Nanomaterials – fit4nano".

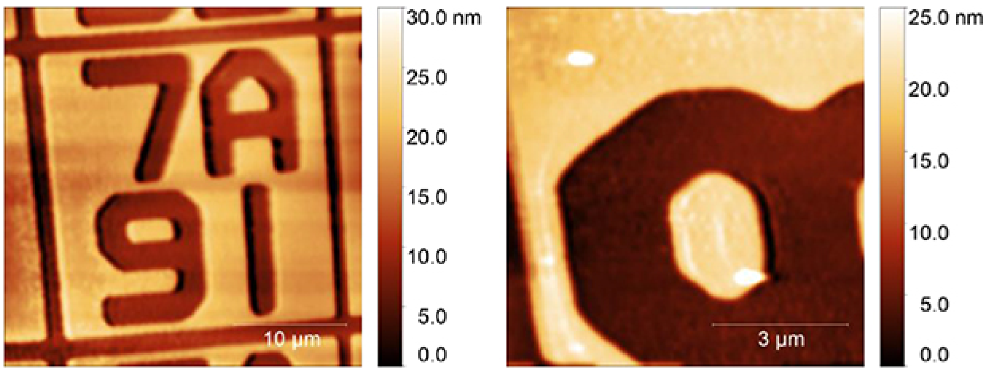
References:

[1] I.W. Rangelow, P. Grabiec, T. Gotszalk and K. Edinger, Nanoprobe maskless lithography, Surf. Interface Anal. 33, 59–64 (2002), http://dx.doi.org/10.1117/12.852265
[2] G. Jóźwiak, D. Kopiec, P. Zawierucha, T. Gotszalk, P. Janus, P. Grabiec and I.W. Rangelow, The spring constant calibration of the piezoresistive cantilever based biosensor, Sens. Actuators B 170, 201–6 (2012),

https://doi.org/10.1016/j.snb.2012.02.007
[3] B. Pruchnik, D. Badura, W. Kopczyński, D. Czułek, I.W. Rangelow, V. Korpelainen, A. Sierakowski, A. Yacoot and T. Gotszalk, Application of active piezoresistive cantilevers in high-eigenmode surface imaging, Meas. Sci. Tech. 36, 016020 (2025), https://doi.org/10.1088/1361-6501/ad8cf9




*AFM setup with high-frequency equipment for higher eigenmode imaging [3]*




*Images acquired by imaging with modified active piezoresistive cantilever probe [3]*

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Wed 17:14 – 17:32 **Iwo W. Rangelov** rangelow@nanoanalytik.net

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Fabian Dietrich, Hans-Georg Pietscher, Jav Basseri, Katia Ivanova, Mirosław Woszczyna, Ivo W. Rangelow, Bartosz C. Pruchnik, Teodor P. Gotszalk, Fangzhou Xia

**Active Probe Atomic Force Microscopy with Quattro-Parallel Cantilever Arrays for High-Throughput Large-Scale Sample IC Inspection**

Atomic force microscopes (AFMs) are a powerful and versatile tool for nanoscale surface studies to capture

3D topography images of samples. However, due to their limited imaging throughput, AFMs have not been widely adopted for largescale inspection purposes. Researchers have developed high-speed AFM systems to record dynamic process videos in chemical and biological reactions at tens of frames per second, at the cost of a small imaging area of up to several square micrometers. In contrast, inspecting large-scale nanofabricated structures, such as semiconductor wafers, requires nanoscale spatial resolution imaging of a static sample over hundreds of square centimeters with high productivity. Conventional AFMs use a single passive cantilever probe with an optical beam deflection system, which can only collect one pixel at a time during AFM imaging, resulting in low imaging throughput. This work utilizes an array of active cantilevers with embedded piezoresistive sensors and thermomechanical actuators, which allows simultaneous multi-cantilever operation in parallel operation for increased imaging throughput. When combined with large-range nano-positioners and proper control algorithms, each cantilever can be individually controlled to capture multiple AFM images. In order to accelerate the response of the cantilever to DC-z-actuation (off-resonance), a lag-lead compensator was designed and implemented in a control system that generates operated DC-input on the thermomechanical actuator to attain a desirable fast response (deflection output) of the active cantilever in high dynamic bandwidth in the kHz range. This compensator was used and was able to increase the cantilever bandwidth from 321 Hz to 2550 Hz. With data-driven post-processing algorithms, the images can be stitched together, and defect detection can be performed by comparing them to the desired geometry. This paper introduces principles of the custom AFM using the active cantilever arrays, followed by a discussion on practical experiment considerations for inspection applications. Selected example images of silicon calibration grating, highly-oriented pyrolytic graphite, and extreme ultraviolet lithography masks are captured using an array of four active cantilevers ("Quattro") with a 125 $\mu$m tip separation distance. With more engineering integration, this high-throughput, large-scale imaging tool can provide 3D metrological data for extreme ultraviolet (EUV) masks, chemical mechanical planarization (CMP) inspection, failure analysis, displays, thin-film step measurements, and roughness measurement dies.

ACKNOWLEDGEMENTS
The authors would like to acknowledge the Eurostars programme for supporting parts of the presented methods by funding the projects Eurostars-3 - Call 6, 6,208 PSISPM. The team of nano analytik GmbH has received funding from the Federal Ministry of Education and Research (BMBF) under Grant Agreement DiaTip_13N16578 and support from TAB of the Free State of Thuringia in the frame of FEE-2024 FEE 0007 project.

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Wed 17:32 – 17:50 **Władysław Kopczyński** wladyslaw.kopczynski@pwr.edu.pl

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**Active piezoresistive cantilevers in nanorobotics**

Modern Applications of Scanning Probe Microscopy (SPM), including advanced nanofabrication techniques, precise nanomanipulation and surface property measurements (with atomic resolution), form the basis of the rapidly evolving field of nanorobotics. The key component of such systems are cantilevers, performing both sensing and actuation functions. Currently, their traditional design, based on auxiliary deformation readout, may limit the speed of a given system's response, it's precision of operation and integration with more complex control systems, e.g. in the form of multi-effector nanomanipulators.
Active piezoresistive cantilevers, which integrate the detection function directly into the probe structure (in the form of piezoresistive semiconductor layers, e.g., silicon), address these limitations. The compact design of these cantilevers allows for the complete elimination of optical components from the system, which translates into increased measurement stability, reduced system size and the ability to operate in environments inaccessible to optical methods (e.g., small SEM chambers or EM-sensitive environments).
In light of these properties, active piezoresistive cantilevers represent a promising tool for nanorobotic

platforms, combining compactness, precision and operational autonomy. Their ability to function simultaneously as actuator and sensor enables the implementation of advanced real-time control mechanisms, opening new prospects for automated nanoscale operations. The use of active piezoresistive cantilevers is already gaining particular recognition in processes requiring high resolution and reliability, such as single-object nanomanipulation, selective surface modification, micro- and nanolithography or precise mechanical and electrical measurements.
This presentation will provide an overview of the current applications of active piezoresistive cantilevers in nanorobotics as well as a nanorobotic solution being developed at the Department of Nanometrology, with particular emphasis on their role in implementing nanomanipulation, nanofabrication, and precise mechanical and electrical measurements at the level of single structures.

*Project financed from the state budget, allocated by the Minister of Science and Higher Education under the Programme "Student science clubs create innovations"*

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Wed 17:50 – 18:15 **Jakub Horák** jakub.horak@mt-m.eu

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**News from Bruker (Měřicí technika Morava company presentation)**

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Wed 19:00 – 20:00 **Exhibitors** \protect\unhbox\voidb@x\hbox{}

**Experience the AFM: practical demonstration of instruments and free discussion with company representatives**

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Thu 9:00 – 9:36 **Martin Setvín** martin.setvin@matfyz.cuni.cz

*Department of Surface and Plasma Science, Charles University, Prague, Czech Republic*

**Imaging and tracking polarons in $Fe_2O_3$ and $SrTiO_3$ by atomic force microscopy**

Noncontact atomic force microscopy (nc-AFM) has recently proven to be a powerful tool for manipulating and imaging single electrons at surfaces. Single electrons could be localized at trapping sites such as Au atoms on thin NaCl films [1], small molecules on oxide surfaces [2], or larger organic molecules on thicker NaCl films [3].
This talk will focus on the possibilities of investigating polarons in materials: Polarons are electrons or holes that self-localize in ionic lattices due to electron-phonon interaction [4]. Such charge carriers can move to adjacent lattice positions, provided they are given certain activation energy. Polarons play a key role in many applications and materials properties, such as electrical conductivity, optical properties, catalysis and photocatalysis, and they stand behind exotic properties such as colossal magnetoresistance or

high-temperature superconductivity. The successful imaging of polarons in hematite $Fe_2O_3$ [5] and $SrTiO_3$ will be shown, and the new possibilities offered by this technique will be discussed.
The work was supported by projects MSMT CZ.02.01.01/00/22_008/0004572 and LL2324.
[1] L. Gross et al., Science 324, 1428 (2009)
[2] M. Setvin et al., PNAS 114, E2556 (2017)
[3] S. Fatayer et al., Science 365, 142 (2019)
[4] C. Franchini et al., Nature Reviews Materials 6, 560 (2021)
[5] J. Redondo et al., Science Advances 10, eadp7833 (2024)

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Thu 9:36 – 9:54 **Pavel Jelínek** jelinekp@fzu.cz

*Institute of Physics, Czech Academy of Sciences*
*Cukrovarnická 10, Prague, Czech Republic*

Manish Kumar, Diego Soler, Pavel Jelínek

### Observables in STM: can we see molecular orbitals?

The interpretation of experimental spatially resolved scanning tunneling spectroscopy (STS) maps of molecules on surfaces is usually interpreted within the framework of one-electron molecular orbitals. Although this standard practice often gives relatively good agreement with experimental data, it contradicts one of the basic assumptions of quantum mechanics, postulating the impossibility of direct observation of the wave function, i.e., individual molecular orbitals. The STM community often considers this contradiction about observing molecular orbitals as a philosophical question rather than a genuine problem. Moreover, in the case of polyradical strongly correlated molecules, the interpretation of STS maps based on one-electron molecular orbitals often fails. Thus, for a precise interpretation of STS maps and their connection to the electronic structure of molecules, a theoretical description, including non-equilibrium tunneling processes going beyond one-electron molecular orbitals, is required.
In this contribution, we first show why, in selected cases, it is possible to achieve good agreement with experimental data based on one-electron canonical molecular orbitals and Tersoff-Hamann approximation [1]. Next, we will show that for an accurate interpretation of strongly correlated molecules, it is necessary to describe the process of removing/adding an electron within the formalism of many-particle wave functions for the neutral and charged states. This can be accomplished by the concept of so-called Dyson orbitals [2]. We will discuss the examples where the concept of Dyson orbitals is mandatory to reproduce experimental STS data. Finally, we critically review the possibility of the experimental verification of the so-called SOMO/HOMO inversion effect using STS maps in polyradical molecules [3]. Namely, we will demonstrate that experimental STS measurements cannot provide any information about the ordering of molecular orbitals and, therefore not about the SOMO/HOMO inversion.
[1] J. Tersoff and D.R. Hamann, Phys. Rev. Lett. 50, 1998 (1983); Phys. Rev. B 31, 805 (1985)
[2] J.V. Ortiz, J. Chem. Phys. 153, 070902 (2020).
[3] Sh. Mishra et al, ACS Nano 18,, 15898 (2024).

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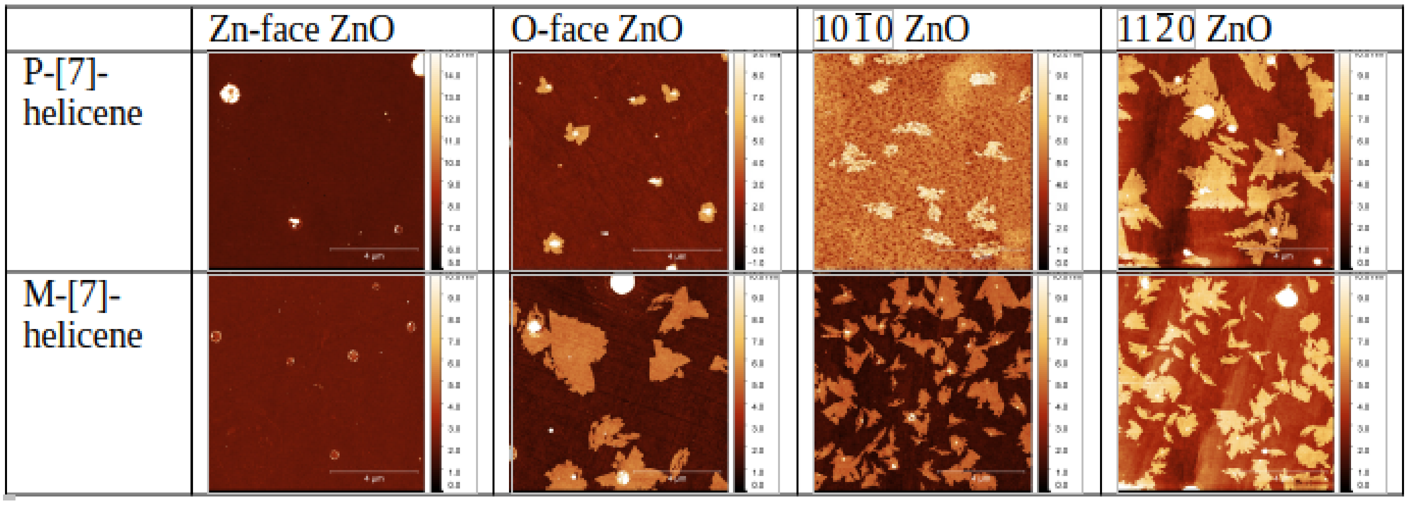
Thu 9:54 – 10:12 **Egor Ukraintsev** ukraints@fzu.cz

*Faculty of Electrical Engineering, Czech Technical University in Prague*
*Technická 2, Prague 6, 166 27, Czech Republic*

Egor Ukraintsev, Pin-Qian Yang, Hua Shu Hsu, Bohuslav Rezek

### AFM, FFMD simulations and CD analyses of [7]-helicene assembly on ZnO polar and non-polar facets

Interaction of organic molecules with semiconductor surfaces is key to many applications from energy conversion to electronic sensors and catalysis. Despite the importance of [7]-helicene as a small chiral molecule, its interactions with zinc oxide (ZnO) nanomaterials that are prospective in photocatalysis and spintronics have not yet been sufficiently explored. Here the impact of surface polarity of different ZnO facets on P/M-[7]-helicene adsorption is studied both experimentally by atomic force microscope (AFM), circular dichroism (CD) and theoretically by force field molecular dynamics (FFMD). Nonpolar ZnO surfaces cause self-assembly into layered nanoislands with characteristic 4 nm layer thickness. Polar O-face ZnO surface causes the formation of similar nanoislands, while polar Zn-face ZnO surface is practically clean with few circular objects. CD measurements cannot detect the presence of sub-monolayer helicene structures but can be used for determining the ZnO orientation. Theoretical FFMD simulations show the impact of surface dipole electric field orientation on helicene self-assembly. The results thus also show a way for controlling the assembly of [7]-helicene and other molecular nanomaterials for diverse applications. Carbon nanostructures, molecular adsorption, polar and non-polar surfaces, helicene molecules, ZnO, AFM, CD, MD simulations.




Thu 10:12 – 10:30 **Martin Rejhon** martin.rejhon@matfyz.cuni.cz

*Charles University, Faculty of Mathematics and Physics, Institute of Physics*

### Exploring ABC-stacked graphene domains in untwisted epitaxial graphene

In graphene, emergent properties such as superconductivity to ferroelectricity have been observed in ABC-stacked domains, typically obtained by exfoliation followed by expert mechanical twisting and alignment with the desired orientation, a process very challenging and nonscalable.

Here, we demonstrate that graphene in the ABC stacking domain can be obtained using a scalable growth technique, namely, the thermal decomposition of silicon carbide. Using conductive atomic force microscopy (Fig. 1a), we identified distinct conductivity patterns in untwisted three-layered epitaxial graphene on silicon carbide. These patterns revealed the presence of ABA and ABC domains, matching the conductivity differences observed in twisted exfoliated graphene and those predicted by density functional theory. The size and geometry of the stacking domains depend on the interplay between strain, solitons crossing, and shape of the three-layer regions. Interestingly, we demonstrate the growth of three-layer regions in which the ABA/ABC stacking domains self-organize in stable stripes of a few tens of nanometers (Fig. 1b). This study demonstrates the potential of the thermal decomposition method for producing ABA/ABC domains, paving the way for future applications in electronic and optoelectronic devices.

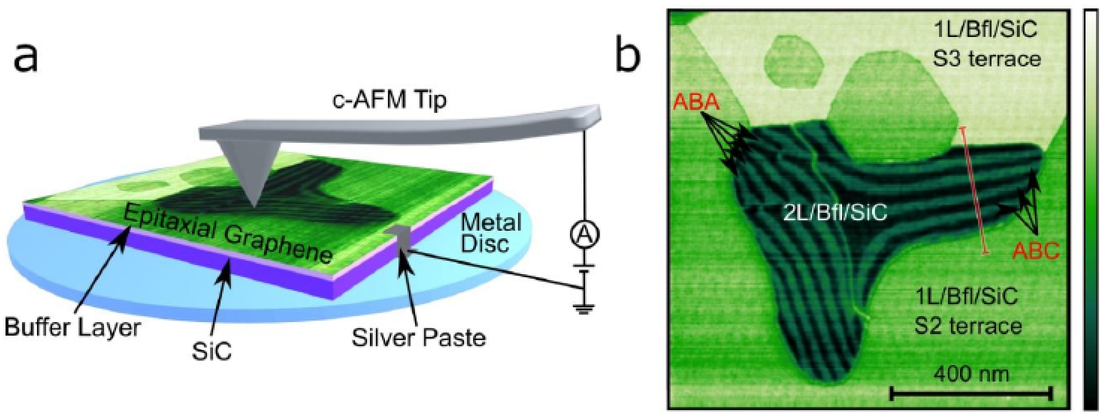



*Figure 1: a) Setup of conductive AFM experiment. b) c-AFM image of an epitaxial graphene film with visible stripes in conductivity on a three layeref epitaxial graphene.*

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Thu 10:30 – 10:50 **Karel Šec** info@nicoletcz.cz

*Nicolet CZ, s.r.o*

**Nanoscale optical and chemical characterization of nanomaterials using s-SNOM technology (Nicolet CZ company presentation)**

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Thu 11:20 – 11:56 **George Heath** G.R.Heath@leeds.ac.uk

*Faculty of Engineering and Physical Sciences, University of Leeds*

**Localization atomic force microscopy**

Understanding structural dynamics of biomolecules at the single-molecule level is vital to advancing our knowledge of molecular mechanisms. Currently, capturing dynamics at the sub-nanometre scale and in physiologically relevant conditions is challenging. Atomic force microscopy (AFM) has an advantage of analysing unlabelled single molecules in physiological buffer and at ambient temperature and pressure, but its resolution can limit the assessment of conformational details of biomolecules. Localization AFM (LAFM) is a technique developed to overcome current resolution limitations. By applying localization image reconstruction algorithms to height fluctuations in high-speed AFM and conventional AFM data, we increase the resolution beyond the limits set by the tip radius and resolve single amino acid residues on soft protein surfaces in native and dynamic conditions. LAFM enables the calculation of high-resolution maps from either images of many molecules or many images of a single molecule acquired over time, facilitating single-molecule structural analysis. Here we present the localization AFM method and our recent advances to optimize resolution, localization and the general analysis workflow.

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Thu 11:56 – 12:14 **Berta Papulová** 533700@mail.muni.cz

*Central European Institute of Technology, Masaryk University*
*Kamenice 5, 625 00 Brno, Czech Republic*

Berta Papulová, Jan Přibyl

**Use of Localized Atomic Force Microscopy to improve imaging resolution**

Atomic Force Microscopy (AFM) is a type of scanning probe microscopy that obtains information about

the structure and mechanical properties of a sample through interactions between the nanoscale probe tip and the surface of a biomolecule. An advantage of AFM is its ability to measure unlabeled molecules under physiological conditions. However, the resolution and accuracy of AFM topography images are influenced by factors such as molecular motion in liquid environments, tip geometry and other imaging artifacts. Localization Atomic Force Microscopy (LAFM) enhances the resolution of surface structures beyond conventional AFM capabilities when localization algorithms are applied to analyze the spatial fluctuations of topographic features in AFM images. Development of this method was inspired by stochastic optical reconstruction microscopy and photoactivated localization microscopy, achieve super-resolution imaging by accurately identifying and isolating fluorescence signals over multiple frames.
In the presentation, the application of LAFM to biomolecules of fibrillar structure, such as DNA and Tau protein fibrils, measured in a liquid environment will be demonstrated. The image processing was performed using open-source software.

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Heath, G.R., Micklethwaite, E., Storer, T.M., 2024. NanoLocz: Image Analysis Platform for AFM, High-Speed AFM, and Localization AFM. Small Methods 8, 2301766.

Acknowledgment:
We acknowledge CF Nanobiotechnology of CIISB, Instruct-CZ Centre, supported by MEYS CR grant numbers LM2023042 and LUC24105. And European Regional Development Fund- Project No. CZ.02.01.01/00/23_015/0008175. Masaryk University is acknowledged for its support by the interdisciplinary fund MUNI/G/1125/2022.

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Thu 12:14 – 12:32 **Pavel Klok** `208733@vutbr.cz`

*Institute of Physical Engineering, Faculty of Mechanical Engineering, Brno University of Technology Technická 2, 61669 Brno, Czech Republic*

P. Klok, P. Viewegh, P. Liška, V. Křápek, Z. Nováček, M. Kratochvíl, F. Ulč, J. Čecháček, J. Spousta, T. Šikola

### Nanoscale Time-Resolved Photoluminescence Mapping of $CsPbBr_3$ Nanocrystals via Near-Field Optical Microscopy

We demonstrate time-resolved photoluminescence (tr-PL) mapping with sub-diffraction resolution ($\sim$150 nm) in aperture-type scanning near-field optical microscopy (a-SNOM) of $CsPbBr_3$ nanocrystals. This method allows to correlate structural and optoelectronic properties, revealing the impact of nanoscale heterogeneities on recombination dynamic and enhancing nanoscale characterization for optoelectronic applications.
Lead halide perovskites (LHPs), particularly $CsPbBr_3$ nanocrystals, have emerged as highly promising materials for optoelectronic applications [1], exhibiting exceptional optoelectronic properties, such as high photoluminescence quantum yield [2], long non-radiative recombination lifetimes [3]. However, a detailed understanding of these properties necessitates advanced characterization techniques capable of resolving spatial and temporal dynamics at the nanoscale [4].
Traditional far-field photoluminescence (PL) and tr-PL spectroscopy methods provide insights into charge-carrier dynamics and recombination mechanisms but are diffraction-limited. Consequently, they fail to resolve nanoscale heterogeneities that significantly impact the optoelectronic behavior of LHPs. This limitation underscores the necessity of a non-destructive, high-resolution optical technique for nanoscale characterization.
To address this challenge, we present an approach that integrates aperture-type scanning near-field optical microscopy (a-SNOM) with tr-PL to achieve sub-diffraction-limited resolution in the study of carrier recombination dynamics in $CsPbBr_3$ nanocrystals. Our experimental setup enables pixel-by-pixel correlation

of structural topography, PL intensity, and tr-PL decay dynamics within a single scan, providing a comprehensive nanoscale characterization framework.

Using this technique, we demonstrate tr-PL mapping of $CsPbBr_3$ nanocrystals with a spatial resolution of ∼150 nm. This multimodal approach allows direct visualization of charge-carrier recombination dynamics, revealing significant spatial variations in lifetime distributions, spectral shifts, and carrier diffusion. By directly correlating these findings with structural features, we gain critical insights into morphology-dependent optoelectronic behavior.

This study establishes near-field excited tr-PL as a powerful tool for nanoscale characterization of perovskites. By enabling simultaneous nanoscale mapping of topography, PL, and tr-PL dynamics, this method provides essential insights into local recombination mechanisms, paving the way for the optimization of perovskite-based devices. By advancing nanoscale characterization capabilities, our approach contributes to the broader goal of developing high-performance perovskite-based optoelectronic technologies.

The author acknowledges the support of the Brno Ph.D. Talent Scholarship, funded by the Brno City Municipality, financial support from the Czech Science Foundation (grant No. 25-17500S), CzechNanoLab Research Infrastructure supported by MEYS CR (LM2023051), and the Light Microscopy Core Facility, IMG, Prague, Czech Republic, supported by MEYS – LM2023050 and RVO – 68378050-KAV-NPUI, for their support with the FLIM (Leica Stellaris 8 Falcon) presented herein.

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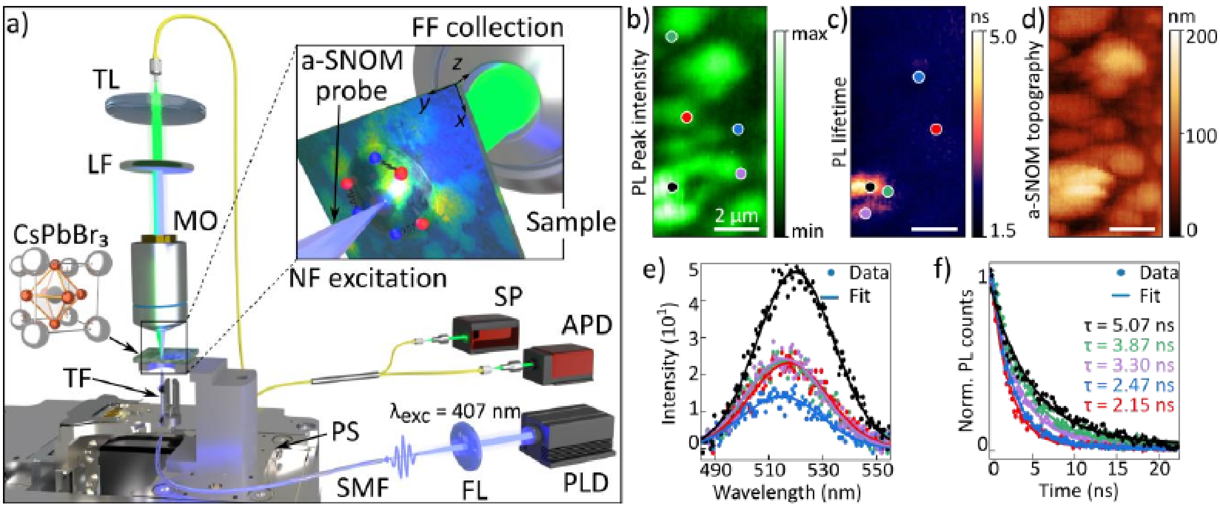


*Figure 1: (a) Schematic of the experimental setup, integrating a pulsed laser diode (PLD), single-mode optical fiber (SMF), piezo stage (PS), tuning fork (TF) with an a-SNOM probe, 50× magnifying objective (MO), longpass filter (LF), tube lens (TL), avalanche photodiode (APD), and spectrograph (SP). The inset illustrates near-field (NF) excitation of photoluminescence (PL) in $CsPbBr_3$ nanocrystals. (b) NF excited PL intensity map fitted using a Gaussian function. (c) tr-PL lifetime map revealing spatial variations in carrier lifetimes. (d) Topographic map obtained via a-SNOM probe using shear-force feedback. (e) Representative PL spectra at selected locations, fitted with Gaussian functions. (f) tr-PL decay curves at corresponding points, fitted using a single-exponential decay model.*

Thu 12:32 – 12:50 **Marek Černík** `uniexport@uniexport.co.cz`

*Uni-Export Instruments, s.r.o*

**Correlative Raman-AFM (Uni-Export Instruments company presentation)**

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Thu 14:00 – 14:36 **Georg Fantner** `georg.fantner@epfl.ch`

*École polytechnique fédérale de Lausanne, Switzerland*

**Scanning Ion Conductance Microscopy and Spectroscopy**

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Thu 14:36 – 14:54 **Bart Hoogenboom** `hoogenboom@nanosurf.com`

*Nanosurf*

**Surface roughness analysis by atomic force microscopy (Nanosurf company presentation)**

Atomic force microscopy (AFM) provides surface roughness measurements at (nanometer) length scales that are not readily accessible for other techniques. This can make it hard to provide direct comparisons to standard roughness values (e.g., Ra, Rq, Sa, Sq) as provided by other methods. Moreover, length scale-dependent information may get lost by capturing roughness in a single number. I will discuss the use of various power spectral densities, and their respective merits for quantification of roughness by AFM, exemplified by data recorded with Nanosurf's DriveAFM.

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Thu 14:54 – 15:12 **Ondřej Novotný** `info@nenovision.com`

*Nenovision*
*Purkyňova 127, 612 00, Brno*

**Development of an in-situ methodology for the measurement of sensitive materials (Nenovision company presentation)**

Keywords: AFM-in-SEM, LiteScope, in-situ characterization, semiconductors, battery materials, self-sensing probes, correlative microscopy, NenoVision

The precise characterization of modern materials is essential for advancing research in semiconductors and battery technologies. However, a persistent challenge in these fields lies in ensuring the repeatability and accuracy of measurements while minimizing external factors such as oxidation and contamination. Traditional ex-situ analytical methods frequently alter surface properties, leading to inconsistencies and limiting the reliability of acquired data. To address these limitations, in-situ correlative microscopy, which integrates Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM), presents a robust solution for high-resolution, multimodal characterization under controlled conditions.
NenoVision has developed a vacuum sample transfer system to safeguard sample integrity throughout the preparation and measurement process, recognizing the need for enhanced in-situ analysis. This system effectively minimizes environmental exposure, mitigating oxidation and contamination risks compromising measurement reliability. Additionally, we developed new optimized workflows and implemented several changes in the user interface. This makes measurement more time efficient and unlocks new insights into

battery and semiconductor materials that were previously impossible or hard to get.
To strengthen the capabilities of our AFM-in-SEM, we have expanded our portfolio of self-sensing probes, with a primary focus on advanced electrical measurement modes in high-end applications. These enhancements enable precise characterization of electrical properties while fully leveraging the advantages of high-resolution correlative imaging.
With these advancements, AFM-in-SEM technology is now more powerful than ever, providing accurate, repeatable, and high-quality in-situ data for semiconductor failure analysis, battery material research, and a wide range of other applications in materials science and nanotechnology. These innovations mark a significant step forward in streamlining complex workflows, enhancing measurement precision, and broadening the scope of AFM-in-SEM applications for academic and industrial research.

**Company introduction**
NenoVision is a technology company based in Brno, Czech Republic. We were the first spin-off from the Brno University of Technology and the Central European Institute of Technology (CEITEC). Over 30 % of world production of electron microscopes is manufactured in Brno. The city has a long tradition in the development of scientific instruments and is also referred to as the world center of electron microscopy. Our goal is to move microscopy to the next level by continuing with the established tradition and expertise within the field and bringing innovative Correlative Probe and Electron Microscopy Technology to the market.

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Thu 15:12 – 15:30 **Jakub Hruška** `499596@mail.muni.cz`

*CEITEC Masaryk University*
*Kamenice 5, 625 00 Brno, Czech Republic*

Jakub Hruška, Radka Obořilová, Šimon Vrana , Jakub Máčala, Jiří Nováček, Jan Přibyl

**Atomic force microscopy combined with scanning electron microscopy in life sciences**

Correlative microscopy, in general, is a powerful technique that combines multiple imaging methods to analyse a single sample in-situ. Integrating data from different imaging techniques allows for the identification of sample features that might be difficult or even impossible to detect with each method individually. The in-situ approach also minimises complications associated with transferring samples between microscopes, preserving the sample's integrity and maintaining precise spatial correlations. Correlative Probe and Electron Microscopy (CPEM) is a specialised form of correlative microscopy that integrates two commonly used techniques in the life sciences: Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). The combination of these methods provides a comprehensive analysis of the sample. SEM offers a broad view of the sample as specific SEM channels, such as secondary electrons and backscattered electrons. On the other hand, AFM uses an atomically sharp probe to scan the surface, enabling high-resolution topographical mapping. The synchronisation of those techniques allows precise data correlation that integrates multiple channels from both techniques. The outcome is a more time-efficient and detailed analysis of complex samples, enabling a deeper understanding of their structure and properties. This presentation will give the audience a brief insight into the use of CPEM on biological samples.

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Thu 16:00 – 16:18 **Jan Přibyl** `jan.pribyl@ceitec.muni.cz`

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Jan Přibyl, Radka Obořilová, Šimon Vrana, Jakub Máčala, Jakub Hruška

**Multiscale Analysis of Biological Systems: Integrating Imaging, Mechanical Characterization, and Chemical Profiling**

Scientific Core Facilities are pivotal within research institutions, providing access to advanced technologies,

equipment, and expertise. They empower researchers and students through training, technical support, education, and consultation. Our facility specializes in atomic force microscopy (AFM) applied to biological samples, combined with advanced correlative microscopy techniques such as optical and Raman microscopy, uniquely complementing more established methods.
By fostering interdisciplinary collaborations and emphasizing meticulous experimental planning, we have successfully applied force microscopy in diverse modes to achieve significant results in bio-related projects. Notable applications include imaging single molecules to elucidate their structure and interactions [1], exploring the mechanical properties of microenvironments on cellular behavior [2], assessing the effects of nanoparticles on cell growth and function [3], and investigating pathological phenomena such as liver fibrosis formation and treatment [4]. These studies have provided valuable insights into molecular mechanisms and cellular dynamics.
Our facility also integrates correlative approaches to combine complementary data from different modalities. For instance, hybrid techniques like AFM coupled with optical or Raman microscopy allow simultaneous acquisition of mechanical, structural, and chemical information. This multimodal strategy enhances our ability to analyze complex biological systems at multiple scales.

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**Acknowledgement:**
The authors acknowledge funding from CIISB, Instruct-CZ Centre, supported by MEYS CR grant numbers LM2023042 (CF Nanobiotechnology) and LUC24105. European Regional Development Fund-Project No. CZ.02.01.01/00/23_015/0008175. Masaryk University is acknowledged for its support by the interdisciplinary fund MUNI/G/1125/2022.

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Thu 16:18 – 16:36 **Jakub Máčala** macala@mail.muni.cz

*Central European Institute for Technology, Masaryk University*
*Kamenice 5, 625 00 Brno, Czech Republic*

Jakub Máčala, Filip Svěrák, Daniil Kabanov, Šimon Vrana, Deborah Beckerová, Jan Máchal, Martin Pešl, Vladimír Rotrekl, Jan Přibyl

### Dual-Organoid Biosensor for Monitoring Cardiac Conduction Disturbances In Vitro

Atomic Force Microscopy (AFM) is traditionally employed as a high-resolution imaging tool to analyze surface morphology and mechanical properties by scanning a sharp tip mounted on a flexible cantilever. Robust feedback system and micromechanical transducers are responsible for the constant adjustment of tip-sample interaction; however, it can be utilized to monitor the contraction dynamics of cardiomyocytes. Moreover, by distinguishing vertical and lateral contractile movements, AFM enables precise differentiation between focal and conductive arrhythmic contractions. This presentation introduces an AFM-based biosensor using a dual-beating human pluripotent stem cell (hPSC)-derived organoid. The high biosensor sensitivity allows detailed analysis of contractile behavior under pharmacological modulation with cardiomodulating drugs. The dual-organoid system enhances model robustness by minimizing variability inherent in single-cell studies, thereby improving its translational relevance for cardiotoxicity assessment.

**Acknowledgement:**
We acknowledge CF Nanobiotechnology of CIISB, Instruct-CZ Centre, supported by MEYS CR grant numbers LM2023042 and LUC24105. And European Regional Development Fund-Project No. CZ.02.01.01/00/23_015/0008175. Masaryk University is acknowledged for its support by the interdisciplinary fund MUNI/G/1125/2022.

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Thu 16:36 – 16:54 **Barbora Brázdilová** 520913@mail.muni.cz

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Barbora Brázdilová, Jan Přibyl

### Standardization of methods for characterization of mechanical properties of soft samples at nanoscale

Soft materials, including biopolymers, hydrogels, and biological tissues, exhibit highly dynamic and unique mechanical behaviors. Their viscoelastic properties, structural heterogenity, and sensitivity to external factors lead to challenges in precise evaluation. A deeper understanding of these properties at the nanoscale is crucial for various fields, including biomedical engineering, materials science, and nanotechnology, as it can lead to advancements in biomaterials and tissue engineering. This presentation presents measurement techniques, particularly atomic force microscopy (AFM) and nanoindentation and how standardization improve the reproducibility and reliability of the assessment of soft materials mechanical properties. To validate the robustness and accuracy of these standardized techniques, both intra-laboratory and inter-laboratory comparisons will be presented. By improving measurement accuracy and reproducibility, this research aims to provide a strong basis for future studies on soft material mechanics, facilitating their integration into advanced biomechanical and nanotechnological applications. This work contributes to international scientific collaboration through participation in the COST MecaNano consortium.

**Acknowledgement:**
We acknowledge CF Nanobiotechnology of CIISB, Instruct-CZ Centre, supported by MEYS CR grant numbers LM2023042 and LUC24105. And European Regional Development Fund-Project No. CZ.02.01.01/00/23_015/0008175. Masaryk University is acknowledged for its support by the interdisciplinary fund MUNI/G/1125/2022.

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Thu 16:54 – 17:12 **Radka Obořilová** oborilovaradka@seznam.cz

*Central European Institute for Technology, Masaryk University*
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Radka Obořilová, Jakub Hruška, Rahul Deb, Robert Vácha, Jan Přibyl

### AFM Spectroscopy for the Study of Lipid Bilayer Stability and Morphology

Atomic Force Microscopy (AFM) allows visualization of nano-objects, biomolecules and cells while simultaneously investigating their mechanical properties. Force-distance curves derived from indentation experiments provide insight into the elastic and viscoelastic properties of macromolecules and living cells. Supported phospholipid bilayers can be another example of an object of study that serves as a mimic of cell membranes. And they can be used to simulate cellular processes in vitro. In addition to the usual measurements of mechanical properties, the penetration of the bilayer by an AFM tip with a small radius creates a characteristic peak in the force-distance curve. The location of this break is called a "rupture event" and provides valuable information about the phospholipid membrane, its thickness, fluidity or composition, etc. AFM can also capture protein-membrane interactions and the effects of specific agents on lipid bilayers or cell membranes, for example demonstrated here on pore-forming peptides with antimicrobial and anti-cancer potential. Or the effect of lipid oxidation on the structure and properties of lipid membranes and exploring the protective role of flavonoids against these changes.

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**Acknowledgement:**
This work is supported by CIISB, Instruct-CZ Centre of Instruct-ERIC EU consortium, funded by MEYS CR infrastructure project LM2023042 and European Regional Development Fund-Project „Innovation of Czech Infrastructure for Integrative Structural Biology" (No. CZ.02.01.01/00/23_015/0008175).

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Thu 17:12 – 17:30 **Daria Kondrakhova** daria.kondrakhova@student.upjs.sk

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**Use of advanced scanning probe spectroscopy techniques and phycical techniques for analyzing dessicated tear fluid**

Tear fluid is a complex biofluid with metabolic and immunological protective functions, reflecting both local and systemic dysregulations. In this study, non-invasive advanced physicochemical techniques were applied to analyze structural and biochemical changes in tear fluid associated with inflammatory and neurodegenerative diseases. These evolving diagnostic methods offer valuable insights into various diseases. Our study identified significant differences in crystal formation, ion composition, and surface morphology between healthy individuals and those with diseases such as dry eye syndrome, glaucoma, multiple sclerosis, and diabetes. AFM imaging revealed structural alterations in dendritic formations. While AFM-IR identified variations in protein and glucose levels, with shifts in Amide I and II indicating protein glycation related to diabetes. EDS detected ion dysregulation with lower potassium ($K^+$) and higher sodium ($Na^+$) levels, along with alterations in $Cl^-$ concentrations."An increased $Na^+/K^+$ ratio could act as a potential biomarker for ocular diseases. XRD results suggested that sodium ions might interact with proteins in pathological conditions, affecting crystallization behavior. These findings emphasize the diagnostic potential of tear fluid analysis as a promising non-invasive tool for disease screening.

We acknowledge the support of the Slovak Research and Development Agency under the contract No APVV-23-0049.

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Thu 17:30 – 17:48 **Lukáš Fojt** fojt@ibp.cz

*The Czech Academy of Sciences, Institute of Biophysics*
*Královopolská 135, 612 00 Brno, Czech Republic*

Lukáš Fojt, Daniel Dobrovodský, Marcela Hrušková, Miroslav Fojta

**AFM as a tool for visualization of biopolymer adsorption onto the carbon electrode surface**

We have used AFM for (a) the detection of guanine quadruplex formation (part of human telomeric sequence) in the presence of Li, K anions, and (b) the confirmation of layered electrochemical biosensor structure. All measurements were performed on the ZYH grade highly oriented pyrolytic graphite (HOPG). Our measurements demonstrated the capability of AFM to (a) detect the layers created by the DNA oligonucleotides capable of forming guanine quadruplexes and (b) evaluate the presence of different layers of biopolymers on the HOPG surface, thus serving as a powerful tool for proof-of-concept validation methodology.

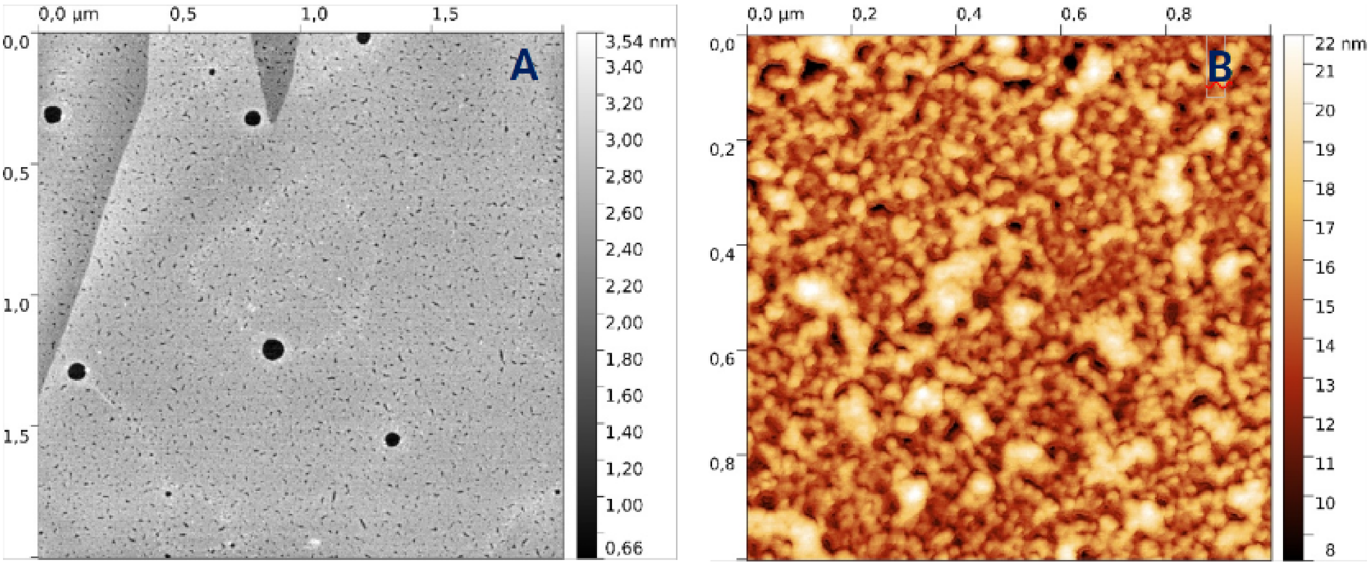


*Figure 1. The guanine quadruplex-forming sequence (A) and streptavidin plus biotinylated DNA oligo (B) on the HOPG surface.*

The Czech Science Foundation, project No. 23-05688S, has supported this research.

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Fri 9:00 – 9:18 **Jan Martinek** `jan.martinek@cmi.gov.cz`

*Czech Metrology Institute*
*Okružní 31, 638 00 Brno, Czech Republic*

**Two probe SThM diffusivity**

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Fri 9:18 – 9:36 **Anna Charvátová Campbell** `anna.charvatovacampbell@cmi.gov.cz`

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Anna Charvátová Campbell, Petr Klapetek, Radek Šlesinger, Jan Martinek, Václav Hortvík, Viktor Witkovský, Gejza Wimmer

**Calibration of scanning thermal microscope using optimal estimation of function parameters by iterated linearization**

Scanning thermal microscopy is a unique tool for the study of thermal properties at the nanoscale. However, calibration of the method is a crucial problem. When analyzing local thermal conductivity, direct calibration is not possible and reference samples are used instead. As the calibration dependence is non-linear and there are only a few calibration points, this represents a metrological challenge that needs complex data processing. In this contribution we present use of the OEFPIL algorithm for robust and single-step evaluation of local thermal conductivities and their uncertainties, simplifying this procedure. Furthermore, we test the suitability of SThM calibration for automated measurement.

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Fri 9:36 – 9:54 **Mykhailo Khytko** khytko@fzu.cz

*Czech Academy of Sciences, Institute of Physics*
*Na Slovance 2, 182 00 Prague, Czech Republic*

Mykhailo Khytko, Swarnendu Banerjee, Lucie Landova, Antonín Fejfar, Martin Ledinský

### Perovskite Degradation Study Using AFM: Insights into Stability and Surface Morphology

Organic halide perovskites (OHPs) have revolutionized photovoltaics, with power conversion efficiencies (PCEs) reaching 34.6% for perovskite/Si tandem cells and 26.7% for single-junction devices. Despite these advancements, the long-term stability of perovskite thin films remains a critical barrier to commercial viability. Methylammonium lead iodide (MAPI) perovskites, while promising due to their high absorption coefficient, tunable bandgap, and low-cost processing, degrade rapidly under environmental stressors such as light, moisture, oxygen, and temperature.
In this study, atomic force microscopy (AFM) was employed to investigate the degradation mechanisms of MAPI thin films. AFM provides high-resolution visualization of surface morphology changes, offering insights into features such as grain roughening and overall surface evolution over time. Controlled experiments were conducted under specific ambient conditions of temperature, humidity, and light exposure, enabling precise monitoring of degradation pathways.
Our findings reveal heterogeneous degradation patterns, with individual grains displaying pristine, partially degraded, and fully degraded regions. Surface roughness analysis shows broadening of the root mean square (RMS) roughness distribution as degradation progresses, reflecting increased surface heterogeneity. Grains with layered, step-terrace structures degrade faster than smoother, featureless grains, highlighting the impact of grain morphology on stability.
Additionally, substrate material strongly influences degradation rates. Films on ITO-coated glass substrates exhibited significantly slower degradation compared to those on quartz or bare glass, suggesting that interfacial properties between the perovskite and substrate play a pivotal role in stability.
These results underscore the importance of grain morphology and substrate engineering in improving the longevity of perovskite-based devices. This work provides critical insights for optimizing synthesis techniques and ensuring the stability of high-performance perovskite solar cells.

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Fri 9:54 – 10:12 **Swarnendu Banerjee** banerjee@fzu.cz

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### Light-induced Degradation of MAPI Perovskite Thin Films Probed by AFM

Perovskite thin films show excellent optoelectronic properties for next-generation solar cells. However, their long-term stability under operating conditions remains a critical challenge. We investigate the degradation mechanisms of Methylammonium Lead Iodide (MAPI) perovskite thin films, using AFM in controlled nitrogen atmospheres. Based on prior research on light-induced degradation in ambient conditions,[1,2] this study isolates the role of light under controlled nitrogen environments.
We aimed to assess the degree to which the degradation caused by light alone differs in nitrogen compared to ambient conditions. Surface morphology, roughness, and any potential variations were compared across both conditions. MAPI thin films exposed to a controlled nitrogen environment exhibited negligible morphological changes under AFM analysis, both in darkness or under low light intensity. This is due to the absence of moisture and oxygen in the nitrogen environment, which contributes additionally to degradation. Thus, this approach facilitates the isolation of light-induced degradation from moisture and oxygen.
We observed a light intensity threshold and a minimum exposure time initiating perovskite film degradation within a nitrogen environment. This suggests even in inert atmospheres, photochemical pathways remain active, albeit potentially slowed. To isolate the effects of light and other environmental factors, we

quantify the degradation in ambient darkness and under illumination in nitrogen, exceeding the established threshold light intensity and time. This highlights the independent or synergistic contributions of light and other factors to perovskite film degradation, further validating nitrogen's protective role in enhancing solar cell longevity.

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Keywords: Perovskite, thin film, degradation, AFM, nitrogen environment.

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Fri 10:12 – 10:30 **Andrzej Sierakowski** `andrzej.sierakowski@ite.lukasiewicz.gov.pl`

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### Piezoresistive technology as universal tool for various self-sensing microstructures

In this paper, we present solutions that use piezoresistive technique for detection of microsctuctures deflection. Various manufacturing technologies of piezoresistors developed by our group will be presented. It includes implantation and/or diffusion of silicon substrate,doping of polycrystalline silicon layers and hybrid FEBID postprocessing technique.

### Introduction

The piezoresistive detection is an attractive technique compared to the optical and the thermal beam deflection ones [1, 2]. The principal advantage is that no external alignment of optical source and detector needed. First work about pieozoresistors read-out was published in 1992 by Tortonese, Barrett and Quate [3]. Over the last few years many groups have provided researches on piezoresistive read- out cantilever for many applications, e.g. as a biological and chemical sensor [4], force transducers [5], atomic force microscope probes [6], self-sensing and self-actuated array of cantilevers [7, 8]. In the area of special manufacturing technologies for custom microelectronic components, IMiF (previously ITE) in cooperation with the Wrocław University of Technology developed and manufactured the family of piezoresistive, self-sensing microstructures (AFM cantilevers, micro-bridges).

### Piezoresistive, self-sensing AFM microstructures

Technologies developed at IMIF enable the production of deflection sensors on various microstructures with different shapes and for various applications. In the case of integrated deflection sensors in the form of piezoresistors, the correct design taking into account the stress distribution in the structure is of particular importance. Proper design defines two main contradictory parameters of the sensor: displacement sensitivity and force sensitivity. Depending on the application, there are two methods of manufacturing sensors on the lever: bulk and polysilicon. The technology of monolithic piezoresistors allows for obtaining high sensitivities (above 2uV/nm). PolySi sensors, despite their slightly lower sensitivity, allow for galvanic isolation of the blade from the piezoresistor system, which is particularly important in CAFM and EFM/KPFM techniques. In addition, sensors manufactured in the added layer enable the production of thinner cantilevers (c.a. 2um). Advanced sharpening technology developed at IMIF is used to obtain ultra-sharp tip. (approx. 2 nm).

Fig. 2 presents results of experiments performed with piezoresistive probes developed at IMIF.
Fig. 3 presents a self-sensing dielectric cantilever with a PtC nanowire defined in FEBID process serving as a piezoresistor between the gold paths.
Authors present technology that can be useful for manufacturing of various self-sensing microstructures. The flexibility of the technological concept described in work enables fabrication of a variety of cantilever-based devices.


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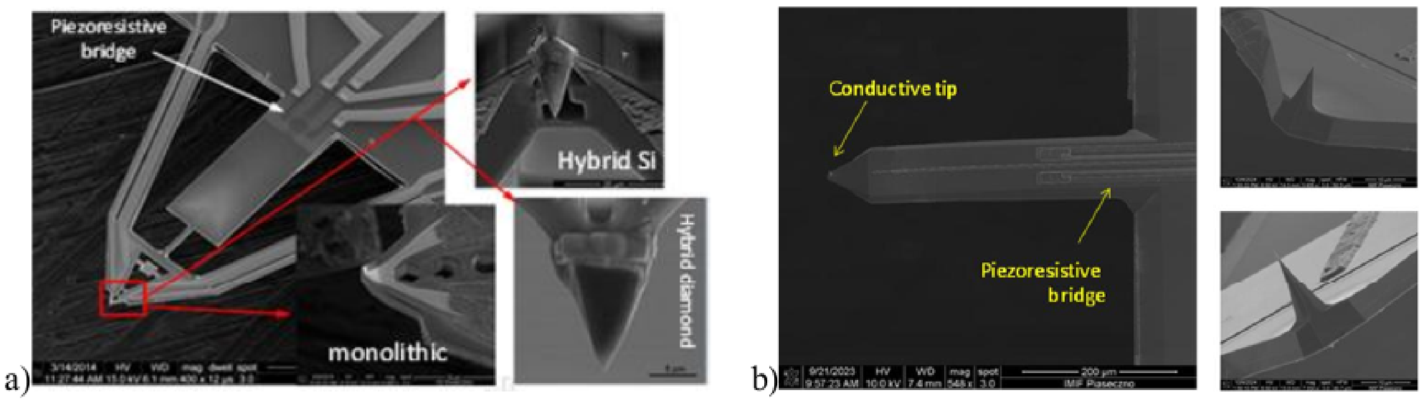


*Fig.1 Examples of piezoresistive AFM probes manufactured at IMIF a) with monolithic Pt or hybrid Si or diamond tips (FP7 NANOHEAT) b) with PoliSi deflection sensor and galvanically isolated, conductive tip (for electrical experiments)*

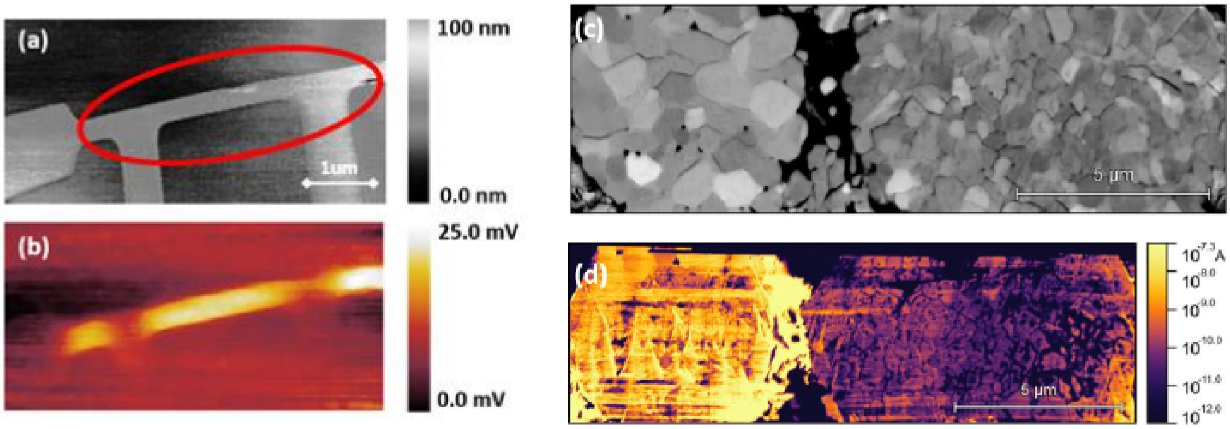


*Fig.2 Left: Topography (a) and results of thermal scan (b) on 450nm wide platinum resistor with SThM piezoresistive AFM probe. Right: SEM (c) and conductive map (d) of liquid electrolyte NCA NCM grain.*

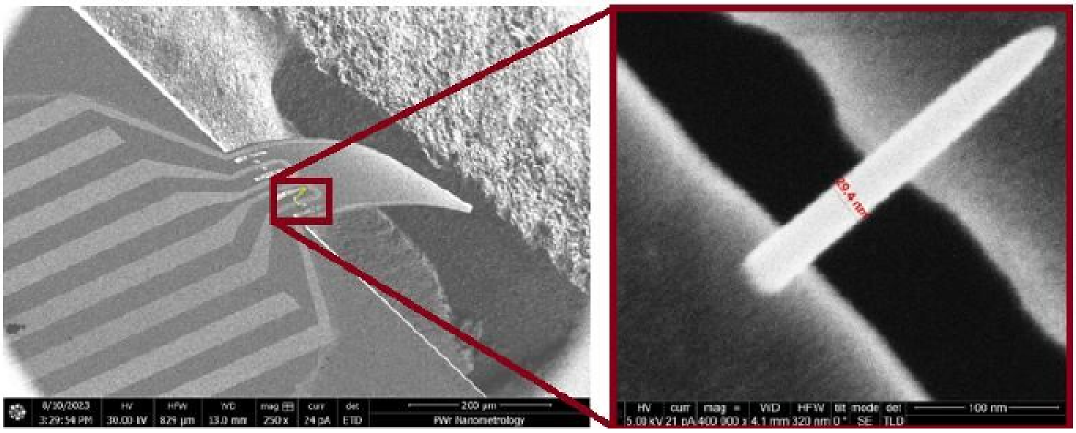

*Fig.3 Dielectric, soft cantilever with PtC nanowires defined in FEBID process.*

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Fri 10:30 – 10:50 **Dušan Novotný / Bruker application scientist** dusan.novotny@mt-m.eu

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**Měřicí technika Morava company presentation**

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Fri 11:20 – 11:38 **Šimon Řeřucha** res@bespin.cz

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**Development of monolithic interferometric assembly for two-axis coordinate positioning with sub-nanometer precision**

We report on the development and validation of a compact, monolithic laser interferometric as- sembly designed for high-precision two- and three-axis displacement measurement in coordinate po- sitioning. This design is specifically tailored for OEM integration into advanced precision motion platforms, including nanometrology instruments, semiconductor manufacturing equipment, and ultra- high vacuum (UHV) applications. Utilizing a single laser source, the assembly incorporates two or three interferometers, achieving sub-nanometer linear error in X-Y motion systems. The monolithic construction enhances stability and reduces thermal drift, crucial for achieving and maintaining sub- nanometer accuracy. It also enables easy integration and adjustment, and prevents geometric errors, streamlining the assembly process and ensuring consistent performance. The assembly's vacuum com- patibility makes it ideal for high-precision, clean environments. Its design and testing suggest potential improvements for precision motion systems, pushing the boundaries of miniaturized, high-accuracy in- terferometry.

Authors acknowledge support from: the Technology Agency of the Czech Republic (TN02000020) and Czech Academy of Sciences (RVO:68081731).

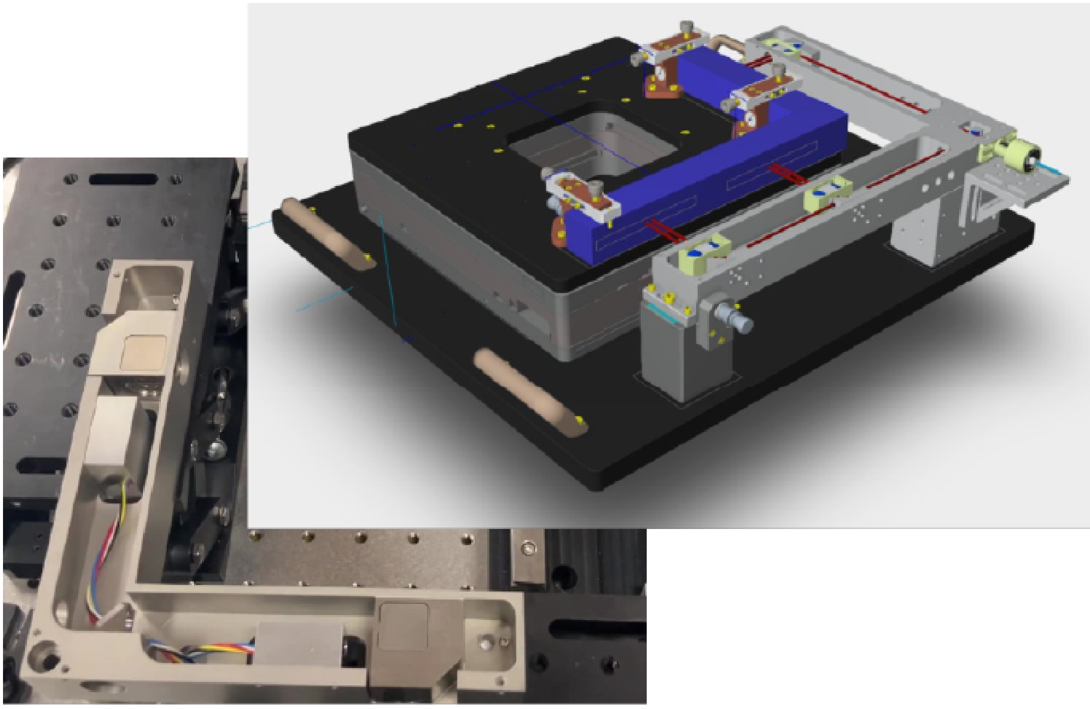

*Figure 1: A prototype of a two-axis system and a CAD model visualisation of a three-axis system.*

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Fri 11:38 – 11:56 **Radek Šlesinger** `radek.slesinger@cmi.gov.cz`

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### Gaussian processes prediction for directing measurement strategy in Gwyscope

Detailed mapping of (not only) mechanical properties using techniques such as instrumented indentation or scanning probe microscopy techniques, can be a very lengthy process, however, acquiring the complete image might not be needed e.g. when looking for a specific feature. We present a custom software tool, which, when combined with a suitable measuring instrument, enables to quickly identify regions containing possible anomalies, and to gather information from suspect regions in the first place. The foundation for the tool is provided by iteratively employing Gaussian processes (GP), which can be considered a form of machine learning, and can be applied as an interpolation tool, able to predict the function value as well as the variance (uncertainty) of the prediction at a given point. GP can be implemented in computer using standard tools for linear algebra and optimization without need for large computation toolboxes. With our tool in each iteration, a GP is constructed and trained using data already acquired, and then used to suggest unmeasured points where uncertainty of the prediction is greatest – this typically corresponds to areas in which the measured quantity changes noticeably. Performing the measurement at the suggested points provides quick reduction of the overall uncertainty on the whole unmapped area. The procedure is then repeated until sufficient amount of information is gathered.

Acknowledgement
This work was performed under the support of the project LUASK22008 "Efficient computational methods

for materials characterization at the nanoscale" funded by the Ministry of Education, Youth and Sports of the Czech Republic.

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### Influence of preparation conditions on the surface morphology of thin perovskite films

Perovskite materials, particularly organometallic hybrids, are among the most promising materials for photovoltaic solar cell applications because of their excellent characteristics, like high crystallinity, high carrier mobility, and direct band gaps. In our experiments, we prepared two sets of samples on FTO substrates through spin coating of $CH_3NH_3PbI_{3-x}Cl_x$ precursor solution in dimethyl formamide (from Ossila Ltd.) to observe how the preparation process influences their surface morphology. The first set of samples was prepared by spin coating of 50 µl $CH_3NH_3PbI_{3-x}Cl_x$ at 4000 rpm for 30 seconds, then after 15 seconds followed by applying 50, 75, and 100 µl of antisolvent (chlorobenzene) by dropping, and finally spin coated again at 4000 rpm for 30 seconds. Subsequently, samples were annealed at 110 °C for 10 minutes in glove box in $N_2$ atmosphere. For second set of samples an equal quantity of $CH_3NH_3PbI_{3-x}Cl_x$ was spin coated onto FTO substrates using different spin coating speeds ranging from 1000 to 5000 rpm for 30 seconds, then after 15 seconds followed by applying 100 µl of chlorobenzene and additional spin coating at the same speeds for 30 seconds. As well as previous, samples were annealed at 110 °C for 10 minutes in glove box in $N_2$ atmosphere. The prepared thin films were measured by AFM and analysed. Further experiments will concentrate on assessing the electrical characteristics of the developed thin films.

**Acknowledgement**
This work was financially supported by the Slovak Research and Development Agency under contract No. APVV-23-0083.

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Fri 12:14 – 12:32 **Aniket Mukherjee** mukherjeea@vutbr.cz

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### Graphite nanoparticles in amine plasma polymer film: AFM based study

Herein we present analysis of crystalline fluorescent graphite nanoparticles present in amine plasma polymer (PP) films. Amine PP films are thin coatings created through the plasma polymerization of amine-containing monomers or from the mixture of nitrogen-containing and hydrocarbon gases. Films with varying nitrogen content, functional groups, and cross-linking leading to their amorphous nature are prepared under varying plasma processing conditions. In addition, these films are reported to be partially water soluble. Recently after a discovery of the presence of fluorescent particles in the extract from immersing the amine PP films in water for 72hrs, we analysed the extracts with AFM. In this current work we determined the size and height profile of the material with the help of AFM images and analysis using python code, showing that these extracts contain the particles of size around 10 nm along with the liquid which when drop cast on Si substrate showed fractal patterns under optical microscope. Subsequently observing this we tried to separate the particles from the liquid in the extract using dialysis. These particles behave optically similar with previously synthesized N-doped GQDs. With 0.34 nm d-spacing these particles were confirmed to be crystalline and graphitic by HRTEM. Upon elemental analysis it was found that C, N, O are the major components of the particle. Thus, we conclude the presence of crystalline particles in amorphous thin film.

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**to be specified**

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