XII Workshop on Applications of Scanning Probe Microscopy STM/AFM 2023

Book of Abstracts

November 29 – December 3, 2023
Zakopane, Poland

Faculty of Physics, Astronomy and Applied Computer Science
Jagiellonian University

XII Workshop on Applications of Scanning Probe Microscopy – STM/AFM 2023

Zakopane, 29 November - 3 December 2023

We have a great pleasure to invite you to the **XII Workshop on Applications of Scanning Probe Microscopy – STM/AFM 2023** which will be held in **Zakopane** from Wednesday, November 29 to Sunday, December 3, 2023, at the HYRNY Hotel (http://www.hyrny.pl/). The Workshop is organized by the **Centre for Nanometer-scale Science and Advanced Materials, NANOSAM**, of the Faculty of Physics, Astronomy, and Applied Computer Sciences, **Jagiellonian University** in Krakow, Poland.

The main goal of the Workshop series is to gather scientists who are or who would like to be involved in surface science research using **Scanning Probe Microscopy (SPM)**. These SPM methods include Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM), and other related techniques operating in ultra-high vacuum environment and liquid/gas atmospheres. We wish the Workshop to be an interdisciplinary meeting for participants representing different theoretical and experimental disciplines of scientific research.

More information can be found at https://nanosam.pl/stmafm2023/

With kind regards,

Franciszek Krok
Bartosz Such

Chairmen of the STM/AFM 2023 Workshop

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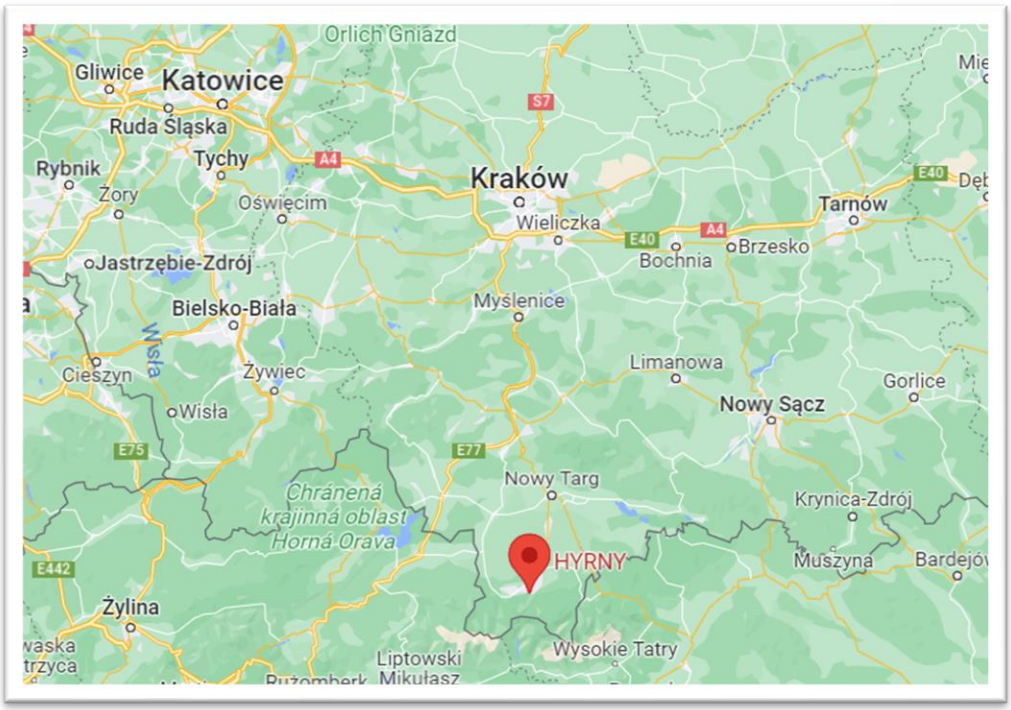
XII Workshop on Applications of Scanning Probe Microscopy will be held at the Conference and Recreation Center "HYRNY" in Zakopane, Poland, 20 Pilsudski Street

Location of Zakopane and the conference venue:



8th School of the Scanning Probe Microscopy and Spectroscopy

Following the example of previous years, the seminar is accompanied by the 8th School of SPM, which will take place on Wednesday, November 29, in the afternoon. This edition of the school aims to familiarize participants with advanced SPM techniques. Lectures (except the last one) will be delivered in polish. Lecturers at the SPM School in Zakopane 2023 and the scope of their lectures.

Program (Wednesday, 29th of November):

15.00 – 15.45:
dr hab. Ewelina Lipiec, Uniwersytet Jagielloński
„Mikroskopia ramanowska wzmocniona ostrzem (TERS)"

15.55 – 16.40:
dr hab. Szymon Godlewski, prof. UJ, Uniwersytet Jagielloński
„Spektroskopia tunelowa STS"

16.40 – 17.05:
coffee break

17.05 – 17.50:
dr Rafał Zuzak, Uniwersytet Jagielloński
„Funkcjonalizacja ostrza w niskotemperaturowej mikroskopii sond skanujących"

18.00 – 18.45:
dr Marcin Kisiel, Uniwersytet w Bazylei
„Pomiary bezkontaktowego tarcia" (in English)

Local information

Conference site

Conference and Recreation Center "*Hyrny",*
Józefa Piłsudskiego 20, 34-500 Zakopane

Conference and Recreation Center "Hyrny" is located on Pilsudski Street (running from Krupowki to ski jumping hill "Wielka Krokiew"). From the hotel windows there is a magnificent view of the Tatra Mountains and the surrounding area. There will be accommodation available in single and double rooms. The rooms are with bathrooms and toilets, equipped with satellite TV, telephones, internet, some of them are with balconies. There is a dining room, a cafe, a swimming pool, a conference room for 280 people, air-conditioned, equipped with state-of-the-art equipment, and four rooms each for about 30 people. There is also a Wellness Center.


Transportation

Arrival of participants for dinner on November 29 (Wednesday) at 7 pm. and departure on December 3 (Sunday) at 9 am. after breakfast. Transportation of the participants of the Workshop by bus from Cracow to Zakopane will be provided by the organizers.

Departure of the bus to Zakopane is scheduled for Wednesday, November 29, at approximately 16:00 from the building of the Institute of Physics, 11 Lojasiewicz Street. The bus will not go to the train/bus station.

On the way back from Zakopane (on Sunday, December 3, departure about 9.00 a.m.) the bus will go to the main railway station (Kraków Główny) and then continue to the Institute on Łojasiewicza street.

In Krakow, you can get from the train/bus station to the Institute of Physics - tram line 52 (every 5 min) from the stop "Teatr Słowackiego" (former name of the stop - "Main Railway Station") in the direction - "Czerwone Maki". Get off at the "Norymberska" stop. Travel time is about 25 minutes. From the tram stop to Institute building is approx. 350 m. The price of a regular tram ticket is PLN 6 (60-minute ticket) per person

The timetable is available at http://rozklady.mpk.krakow.pl

Excursions

Amidst the scientific conference, participants can engage in guided walking tours with seasoned mountain guides to the picturesque Tatra Mountains, departing from Zakopane, Poland. With the itinerary subject to weather conditions, one of the potential expeditions will lead eager explorers to the majestic Kasprowy Mountain, allowing them to immerse themselves in the region's awe-inspiring landscapes and natural beauty, while adapting to the prevailing weather for a safe and memorable adventure.

We kindly remind the participants that the weather may be harsh, therefore good shoes, warm jacket, gloves and cap are highly recommended to take.

Invited speakers

Lech Baczewski, Institute of Physics Polish Academy of Sciences

Magnetization switching of ferromagnetic thin film without applying a magnetic or electric field induced solely by adsorption of chiral molecules

Jan Čechal, Brno University of Technology

LEEM and STM - a strong combination for studying molecular systems on surfaces

Pavel Jelínek, Institute of Physics of the Czech Academy of Sciences

Advances in charge and spin characterization on the atomic scale using scanning probe microscopy

Maxime Le Ster, University of Lodz

Incommensurate STM image simulations with the moiré plane wave expansion model

Mikołaj Lewandowski, Adam Mickiewicz University Poznań

Identifying nanostructures at surfaces using STM/STS

Rafał Luchowski, Maria Curie-Sklodowska University Lublin

"Molecular blinds" in the retina of the eye

Ernst Meyer, University of Basel

Atomic friction experiments on 2D-materials

Emil Sierda, Radboud University

Quantum simulation on a surface

Ewelina Lipiec, Jagiellonian University

Probing the local chemical structure of artificial lipid membranes with Tip-enhanced Raman spectroscopy surfaces

Szczepan Zapotoczny, Jagiellonian University

Infrared scattering-SNOM for chemical mapping of soft matter

Ryszard Zdyb, Maria Curie-Sklodowska University Lublin

New class of massless fermions

Conference program

	THURSDAY	FRIDAY	SATURDAY	
9.00 - 9.10	**WELCOME**			**(FOR SATURDAY ONLY)**
09:10 - 09:40	**MEYER**	**EXCURSIONS**	**JELINEK**	**09:00 - 09:30**
09:40 - 10.00	**GNECCO**		**GODLEWSKI**	09:30 - 09:50
10.00 - 10:20	**MAJCHRZYCKI**		**GOŁĘBIOWSKI**	9:50 - 10:10
10:20 - 10:40	**WEISS**		**BUATIER DE MONGEOT**	10:10 - 10:30
10.40 - 11.00	**KHASAR**		**TOCZEK**	10.30 - 10.50
11:00 - 11:35	**COFFEE BREAK**		**COFFEE BREAK**	**10:50 - 11:20**
11:35 - 12:05	**LUCHOWSKI**		**ZDYB**	11:20 - 11:50
12:05 - 12:25	**LUPA**		**LEWANDOWSKI**	11:50 - 12:20
12:25 - 12:45	**BLACHARCZYK**		**PRUCHNIK**	12:20 - 12:40
12:45 - 13:05	**MARCINIAK**		**PALEWICZ**	12:40 - 13:00
13:05 - 13:25	**KUBISIAK**		**BERKOVICH**	13.00 - 13.20
13:30 - 14:30	**LUNCH**	**LUNCH**	**LUNCH**	**13:30 - 14:30**
15:00 - 15:30	**ČECHAL**	**LE STER**	**ZAPOTOCZNY**	
15:30 - 15:50	**PRZYBYSZ**	**CZAJKA**	**NOWAKOWSKI**	
15:50 - 16:10	**DRÓŻDŻ**	**KOPCIUSZYŃSKI**	**CEGIEŁKA**	
16:10 - 16:30	**ANTCZAK**	**NADOLSKA**	**DUNAL**	
16:30 - 16:50	**LAMCZYK**	**LABSOFT**	**RYSZ**	
16:50 - 17:20	**COFFEE BREAK**	**COFFEE BREAK**	**COFFEE BREAK**	
17:20 - 17:50	**SIERDA**	**LIPIEC**	**BACZEWSKI**	
17:50 - 18:10	**JAŁOCHOWSKI**	**KASARLA**	**MAJCHER-FITAS**	
18:10 - 18:30	**ALBONS**	**TWARDAWA**	**MARCINIAK**	
18:30 - 18:50	**RYŚ**	**SOFIŃSKA**	**CHUDZIK**	
18.50 - 19.10	**KULIK**	**KAWELSKI**	**KISIEL**	
19:30 - 20:30	**DINNER**	**DINNER**	**CONFERENCE DINNER**	
20:30 - 21:30	**POSTERS (ODD)**	**POSTERS (EVEN)**		

Thursday 30.11.2023		
9.00 - 9.10	**OPENING CEREMONY**	
09:10 - 09:40	Atomic friction experiments on 2d-materials	**Ernst Meyer**
09:40 - 10.00	Rolling and Sliding Migration of Manipulated Colloidal Glass Microspheres on Glass Surface	**Enrico Gnecco**
10.00 - 10:20	Influence of graphene oxide thermal reduction on its conductivity and tribological properties	**Łukasz Majchrzycki**
10:20 - 10:40	The study of dry friction between silane nanolayer and diamond crystal in ultra-high vacuum conditions	**Marek Weiss**
10.40 - 11.00	Investigating ripple formation during the scratch process using Atomic force microscopy	**Hesam Khasar**
11:00 - 11:35	**COFFEE BREAK**	
11:35 - 12:05	"Molecular blinds" in the retina of the eye	**Rafał Luchowski**
12:05 - 12:25	Topographical and Nanomechanical Properties of Coexisting Domains in Single and Multicomponent Lipid Layers	**Dawid Lupa**
12:25 - 12:45	Mechanobiology of liver sinusoidal endothelial cells on soft substrates	**Oliwia Blacharczyk**
12:45- 13:05	In silico approach to streptavidin-biotin unbinding: challenges, possibilities, and comparison to the in vitro experiment.	**Wojciech Marciniak**
13:05 - 13:25	Remodeling of intracellular architecture during SARS-CoV-2 infection of human endothelium	**Agata Kubisiak**
13:30 - 14:30	**LUNCH**	
15:00 - 15:30	LEEM and STM - a strong combination for studying molecular systems on surfaces	**Jan Čechal**
15:30 - 15:50	Simulation of the ARPES Experiment – First Steps In Chinook	**Przemysław Przybysz**
15:50 - 16:10	From Isolated Alpha and Beta Antimonene Phases to Their Heterostructures	**Piotr Dróżdż**
16:10 - 16:30	Bi-molecular layers of CoPc and F16CuPc on Ag(100): how the structure factor can be used to identify chiral domains	**Grażyna Antczak**
16:30 - 16:50	PIK-Instruments	**Marcin Lamczyk**
16:50 - 17:20	**COFFEE BREAK**	

17:20 - 17:50	Quantum simulation on a surface	**Emil Sierda**
17:50 - 18:10	Charge density waves and Friedel oscillations as seen by STM	**Mieczysław Jałochowski**
18:10 - 18:30	$BaTiO_3$ characterized at the atomic scale: surface structure and its ferroelectric behavior	**Llorenç Albons Caldentey**
18:30 - 18:50	Electronic structure investigations of Wyel semimetallic materials and hybrid systems	**Wojciech Ryś**
18.50 - 19.10	AFM and acoustics - an interesting marriage	**Andrzej Kulik**
19:30 - 20:30	**DINNER**	
20:30 - 21:30	**POSTER SESSION (ODD NUMBERS)**	

Atomic Friction Experiments on 2D-Materials

E. Meyer[1*], M. Kisiel[1], A. Ollier[1], Y. Song[1], S. Huang[1], A. Hinaut[1], Z. Liu[1] and T. Glatzel[1]

[1]Department of Physics, University of Basel, Klingelbergstr. 82, CH-4056 Basel

[*]Corresponding author: ernst.meyer@unibas.ch

Contact force experiments are performed on 2d-materials of graphene, twisted bilayer graphene and MoS_2. It is found that the formation of moiré patterns has profound effects on the friction response as a function of load and velocity. Depending on the size of the Moirée, one can observe different thresholds to a high friction regime [1,2]. It is found that the deformation of the moiré ridges play an essential role in this novel dissipation mechanism. Non-contact dissipation shows distinct features, which can be related to the filling of the mini-bands. Inhomogeneities due to variations of twist angle can be observed [3].

[1] Zhao Liu et al., Nanoletters 23, 4693−4697 (2023)
[2] Yiming Song et al., Nanoletters 22, 9529–9536 (2022)
[3] Alexina Ollier et al., Comm. Phys. (2023)

Notes:

Rolling and Sliding Migration of Manipulated Colloidal Glass Microspheres on Glass Surface

Enrico Gnecco[1], Roy Almog[2], Ronen Berkovich[1,2,3,*]

[1] M. Smoluchowski Institute of Physics, Jagiellonian University, ul. Lojasiewicza 11, Krakow, Poland

[2] Department of Chemical Engineering, Ben-Gurion University of the Negev, Beer Sheva, Israel

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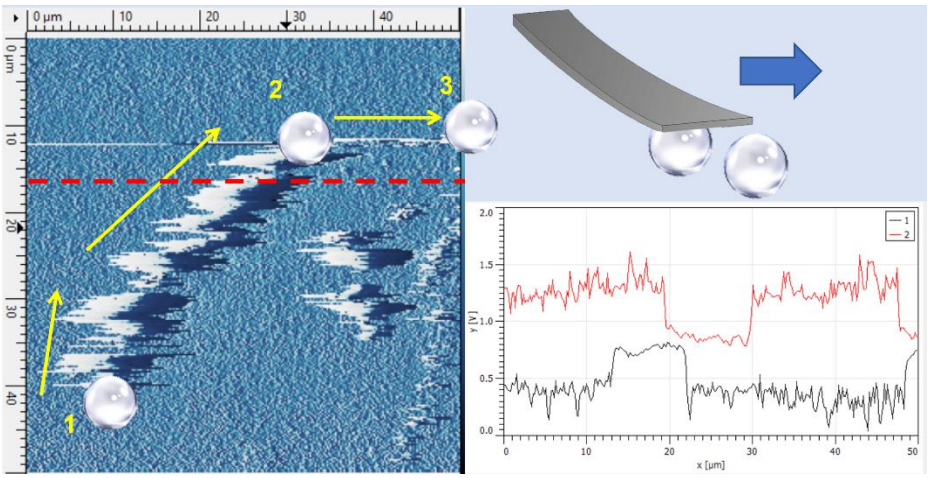
Resuspension of particles (e.g., radioactive, chemical, and biological) deposited on a surface poses health and environmental hazards, particularly when considering inhalable particles, which are smaller than ~20 µm. This phenomenon is comprised of multiple processes, ranging from the micro- to the macro- scales, which include particle-surface interactions (adhesion and friction forces) and hydrodynamics (near-wall turbulence). During the resuspension process, the particle motion was shown to occur via three main mechanisms: rolling, sliding, and lifting. Here we studied particle-surface interactions using atomic force microscopy (AFM), and focus on migration mechanisms through local adhesion, friction and manipulation of individual 10 µm in diameter glass colloids. We first characterize the adhesive interaction of the surface particle in the normal direction and study its motion mechanisms through lateral manipulation. Apart from the particle trajectories with respect to the velocity of the impact, we interestingly report on a reduction of friction during motion, which we attribute to rolling of the particle on the surface.



Notes:

Influence of graphene oxide thermal reduction on its conductivity and tribological properties

Łukasz Majchrzycki[1,*], Marek Weiss[1], Arkadiusz Ptak[1]

[1] Institute of Physics, Faculty of Materials Engineering and Technical Physics, Poznan University of Technology, Piotrowo 3, 60-965 Poznan, Poland

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The tribological properties of the surface are very important due to the high cost of the wear of the working surfaces. Thus, a lot of effort is made to limit the friction forces and surface wear as the result. Especially in the field of nano- and micromechanical systems, where the application of fluid lubricants is limited, other strategies, like thin film coatings, are highly expected [1]. One of the candidates for the anti-wear coatings is graphene oxide (GO). As it can be intentionally modified for tuning its properties by the reduction method, it gives the opportunity for GO applying as a thin film interface.

In this work, we present the effect of the influence of the GO thermal reduction process in the low-temperature range (90°C–150°C) on its conductivity and tribological properties in the nanoscale regime. Using the conductive-AFM (C-AFM) we indicated the reduction temperature range needed to increase the GO local conductivity. The calibrated friction force microscopy (FFM) and force spectroscopy (FS) measurements allowed us to analyze the adhesion with respect to the loading force and the friction force versus the sliding velocity. The threshold temperature obtained from all these experiment fits very well, suggesting a single source of observed changes. All this data leads us to the view of GO as an interface coating, whose properties can be tuned by simple, low-temperature annealing.

This work was supported by the National Science Centre in Poland under Project No. 2020/37/B/ST8/02023 (OPUS-19) and the Ministry of Education and Science in Poland under Project No. 0512/SBAD/2320.

[1] M. Weiss, Ł. Majchrzycki, E. Borkowska, M. Cichomski, A. Ptak, *Tribology International*, 2021, **162,** 107133.

Notes:

The study of dry friction between silane nanolayer and diamond crystal in ultra-high vacuum conditions

Marek Weiss[1,*], Bartosz Szczefanowicz[2], Michał Cichomski[3], Roland Bennewitz[2], Arkadiusz Ptak[1,*]

[1] Institute of Physics, Faculty of Materials Engineering and Technical Physics, Poznan University of Technology, Piotrowo 3, 60-965 Poznan, Poland
[2] INM–Leibniz Institute for New Materials, Campus D22, 66123 Saarbrücken, Germany
[3] Department of Materials Technology and Chemistry, University of Lodz, Pomorska 163, 90-236 Lodz, Poland

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In the work, nanoscale dry friction mechanisms are studied using atomic force microscopy (AFM) – particularly adhesive friction and stick-slip. The occurrence of the mechanisms such as adhesive friction and stick-slip strongly depends on the sliding velocity and loading force [1]. For instance, the adhesive friction predominantly manifests itself at near zero (and negative) loads, almost independently of the sliding velocity in the studied range. In contrast, rebinding processes are most probable at low sliding velocities. For larger loads, the stick-slip mechanism becomes more significant leading to higher energy dissipation and consequently – elevated friction force. These parameters, in conjunction with the chemical composition of the friction pair and other factors, influence the resultant friction force.

Here, we present nanotribology measurements conducted using lateral force microscopy in ultra-high vacuum (UHV) conditions, for the diamond (AFM tip) vs. trichloro(3,3,3-trifluoropropyl)silane (FPTS) friction pair. The UHV provides the best conditions for examination of dry friction, while the diamond single crystal AFM tip (supersharp AD-2.8-SS) was choosen due to its durability and small tip radius. The FPTS nanolayer was studied also in our previous paper [1]. For the near zero loads, the friction force is almost independent on the sliding velocity, while for larger loads it starts to change with the logarithm of sliding velocity.

This work was supported by the National Science Centre in Poland under Project No. 2020/37/B/ST8/02023.

[1] M. Weiss, Ł. Majchrzycki, E. Borkowska, M. Cichomski, A. Ptak, *Tribology International*, 2021, **162**.

Notes:

Investigating ripple formation during the scratch process using Atomic force microscopy

Hesam Khaksar[1]*, Chengfu Ma[2], Natalia Janiszewska[1], Kamil Awsiuk[1], Andrzej Budkowski[1] and Enrico Gnecco[1]

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[2]University of Science and Technology of China, 230026 Hefei, China

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Environmental plastic is a significant public concern, notably pollution from microplastics (MPs) and nanoplastics (NPs). Recently, questions about the consequences of such pollution have arisen and have become essential. Due to their small size, NPs are easily dispersed through the atmosphere, highlighting the importance of investigating their prevalence in the environment. NPs have been found in various consumer goods, including seafood, milk, salts, fruits, vegetables, tap and bottled water, and even beverages .As a result, NPs pose a potential hazard to both human health and the environment. Detecting MPs, particularly larger particles, in the environment is relatively less challenging. However, as particle size decreases, other factors, such as the total particle count, particle size distribution, morphology, color, chemical composition, and mass, become increasingly critical. Numerous methodologies have been proposed to detect NPs; however, an adequate approach that can satisfactorily identify these particles remains lacking. Using the atomic force microscope, it is possible to find the appearance of nanoparticles such as nanoplastics and nanopolymers due to forces and scratches. Based on this ability, We have investigated the formation of surface nanostructures caused by wear of polystyrene (PS) and poly(n-butyl methacrylate) (PnMBA) thin films as pure materials or mixed in the form of a 50%-50% blend. For scratching, atomic force microscopy (AFM) was used repeatedly, to measure the accompanying friction forces and image the resulting surface structures. In the very first stage, ordered ripples are formed in all cases. More irregular features replace the ripples as the disruptive process goes on. While the more compliant PnBMA is deformed more severely than PS, friction oscillations are larger on the stiffer PS. On the blend surface, a wider variety of features is observed, consistently with the fact that the linear size of the PS and PnMBA domains is only a few times the distance between the ripples. Quite noticeably, the wear damage increases if the surfaces are scanned only left to right, without reversing the scan direction. And the probability of forming nanoparticles increases.

Notes:

“Molecular blinds" in the retina of the eye

Rafal Luchowski[1,*], Wieslaw I. Gruszecki[1], Wojciech Grudzinski[1], Renata Welc-Stanowska[1], Maria Manuela Mendes Pinto[1], Alicja Sek[1], Jan Ostrowski[2], Karol Sowinski[1], Robert Rejdak[2]

[1] Department of Biophysics, Maria Curie-Sklodowska University, pl. M. Curie-Sklodowskiej 1, Lublin, Poland
[2] Department of General Ophthalmology, Medical University of Lublin, ul. Chmielna 1, Lublin, Poland

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In simple terms, the human eye has to work effectively in a wide range of light conditions, which is a tricky task. It needs to be both sensitive to detect low light and stable enough to handle bright light. To manage this, the eye has various mechanisms to control how much light reaches its light-sensing cells (photoreceptors). Recent research in our lab has found that two pigments called lutein and zeaxanthin, found in a specific part of the retina called the macula, play a similar role at the molecular level. We call this mechanism "molecular blinds" [1]. Essentially, these pigments act like a switch, blocking too much light from reaching the photoreceptors when it's very bright and allowing more light through when it's darker. This "molecular blinds" mechanism operates by changing the shape of these pigments when they are exposed to light. When there's a lot of light, they switch to one shape (*cis*), which blocks some light, and when there's less light, they switch to another shape (*trans*), which allows more light to pass through. During presentation, I will share the data about how lutein and zeaxanthin are specifically involved in this "molecular blinds" mechanism. I'll also discuss a map showing where these pigments are located in the macula and how they contribute to this dynamic process in regulating the eye's sensitivity to light.

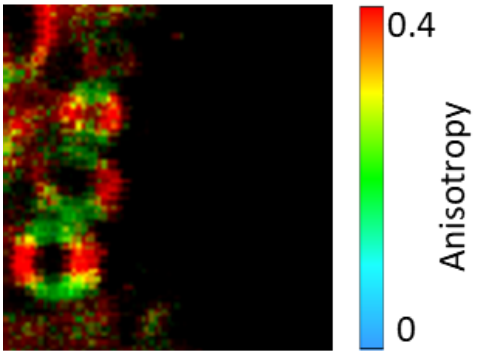

Figure 1. Cross-section of the human eye axons. Xanthophyll orientation in the axon lipid membrane.

[1] R. Luchowski, W. Grudzinski, R. Welc, M. M. Mendes Pinto, A. Sek, J. Ostrowski, L. Nierzwicki, P. Chodnicki, M. Wieczor, K. Sowinski, R. Rejdak, A. G. M. Juenemann, G. Teresinski, J. Czub, W I. Gruszecki, *J. Phys. Chem. B*, 2021, **125,** 6090.

Notes:

Topographical and Nanomechanical Properties of Coexisting Domains in Single and Multicomponent Lipid Layers

Dawid Lupa[1,*], Anna Chachaj-Brekiesz[2], Anita Wnętrzak[2], Ewelina Lipiec[1]

[1] Jagiellonian University, Faculty of Physics, Astronomy, and Applied Computer Science, M. Smoluchowski Institute of Physics, Łojasiewicza 11, 30-348 Kraków, Poland
[2]Faculty of Chemistry, Jagiellonian University, Gronostajowa 2, 30–387 Kraków, Poland

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Cell membranes are complex systems made of hundreds of different lipids and numerous proteins, and thus, the detailed structure of lipid bilayer remains elusive. The lateral distribution of lipids present in outer leaflet is highly nonuniform, which may lead to formation of lipid domains with different properties. [1] Coexistence of separated domains is of crucial importance for many physiological processes, such as protein trafficking and aggregation, membrane fusion, and signal transduction. [2] To fully understand the role of different lipid domains in these processes, a complex characterization of their physicochemical properties at the nanoscale is required.

To gain new insights into properties of lipid layers, we performed a comprehensive nanomechanical and topographical characterization of domains formed in single- and multicomponent lipid layers composed of dipalmitoylphosphatidylcholine (DPPC), 1,2-dipalmitoyl-*sn*-glycero-3-phosphoethanolamine (DPPE) and cardiolipin (CL). Lipid mono- and multilayers on gold and mica were obtained using Langmuir-Blodgett technique. Topographical and nanomechanical characterization of investigated systems was performed by applying atomic force microscopy (AFM) imaging working in PeakForce Tapping Quantitative Nanomechanical Mapping mode. Application of relatively low tip-sample forces allowed us to acquire a set of force – distance curves in each pixel of investigated area, and prevented the tip from damaging the delicate structure of lipid layers. From obtained force-distance curves, a maps of basic nanomechanical properties such as elastic modulus, adhesion, dissipation and deformation for single (DPPC, DPEE or CL) and mixed (DDPC, DPPE and CL) lipid layers were obtained. In this way, we have shown the coexistence of lipid domains that differ not only in topographical (height, roughness) but also nanomechanical properties. Interestingly, the formation of stiffer, more adherent and more viscoelastic domains was observed both for mixed and single component systems. From acquired maps of nanomechanical properties, we have derived the distribution of elastic modulus, adhesion and dissipation for coexisting lipid domains, and discussed the obtained results in terms of lipid segregation and ordering.

The results obtained in this work may be a useful reference for the proper interpretation of data obtained via application of other scanning probe microscopy techniques, such as tip-enhanced Raman spectroscopy.

[1] K. Sofińska et al., *Advances in Colloid and Interface Science*, 2022, **301**, 102614
[2] H. Ingólfsson et al., *Journal of the American Chemical Society*, 2014, **136**, 14554

Notes:

Mechanobiology of liver sinusoidal endothelial cells on soft substrates

O. Blacharczyk[1*], B. Zapotoczny[1], I. Czyżyńska-Cichoń[2], J. Kotlinowski[3], J. Kozieł[4], S. Chłopicki[2], M. Lekka[1]

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Liver sinusoidal endothelial cells (LSECs) are highly specialized cells involved in the exchange of substances between blood in sinusoids (the smallest blood vessels of the liver) and hepatocytes. They are the most permeable mammalian endothelial cells, due to fenestrations (transcellular pores 50 - 350 nm in size) and high endocytic activity [1, 2]. LSEC dysfunction is associated with increased extracellular matrix stiffness [3] and entails many consequences, leading to fibrosis and, eventually cirrhosis [4]. Research shows that chronic inflammation may contribute to developing the above-mentioned pathological conditions [5, 6]. Changes in LSEC observed in the development of the disease include a reduction in fenestration. During LSEC culture on glass, the disappearance of fenestration is also apparent. It was hypothesized that culturing LSECs on soft medium would prolong the culture time of fenestrated LSECs [7].

The effect of the soft substrate on the elasticity, porosity and actin cytoskeleton organizations of LSECs was evaluated. The studies used polyacrylamide hydrogels with defined stiffness: $E = 204{,}9 \pm 55{,}9$ kPa ($n = 3$), $E = 2.4 \pm 0{,}4$ kPa ($n = 3$), and a stiff glass. The elasticity of cells and culture media was measured using atomic force microscopy (AFM, Force Volume). Porosity was also measured by AFM (Quantitative Imaging). The actin cytoskeleton was imaged using fluorescence microscopy. In addition, a comparison was made between cells from control mice and genetically modified mice with deletion of Mcpip1 in myeloid leukocytes ($Mcpip1^{fl/fl}$ $LysM^{Cre}$), which displayed systemic inflammation [8].

Cells taken from $Mcpip1^{fl/fl}$ $LysM^{Cre}$ mice have a higher Young's modulus than cells obtained from control mice. The results suggest that the trend is independent of Young's modulus of the substrate on which the cells were cultured. The results of cell elasticity will be supplemented by fluorescence microscopy images of the actin cytoskeleton, and differences in the level of organization of the actin cytoskeleton between control and $Mcpip1^{fl/fl}$ $LysM^{Cre}$ mice will be discussed.

Research supported by the National Science Centre under the project SONATA 15, (UMO-2019/35/D/NZ3/01804)

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Notes:

In silico approach to streptavidin-biotin unbinding: challenges, possibilities, and comparison to the *in vitro* experiment

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One of the essential research topics in biochemistry is the protein–ligand interaction. Is is a key to understanding biomolecular proccesses, such as enzymes functioning and molecular signaling pathways. A deep comprehension of this topic is crucial in elucidating numerous factors involved in the proccesses studied in virology, cancer treatment and genetic disease prevention in multitude of organisms, including human, livestock and endangered species. An excellent model system regarding specific protein–ligand interaction is the streptavidin–biotin complex. It is a well-studied system, yet there is a room for better understanding of this biomolecular system mechanics [1].

Dynamic force spectroscopy (DFS) is a method applied to study protein-ligand interactions in both, *in vitro* and *in silico* approaches. It can be performed experimentally with the use of the atomic force microscope (AFM) or computationaly in nonequilibrium, or steered molecular dynamics (NEMD or SMD) approach. The benefits of such approach include the embarassing parallelism and readiness for implementation in heterogeneous cloud computing [2].

The possible practical implementations vary regarding the approach to the protein fixation and pulling force application. The protein can be fixed in place as a whole (rigid), by fixation of selected amino-acids, it can be restrained by aweak potential, or attached to a fixed atoms group by an explicitly or implicitly modeled linker. The ligand can be pulled as a whole, by a group of atoms or by a single atom; moreover it can be flexible or rigid. In some implementations, the protein can be pulled instead of the ligand. The applied simulation protocol can significantly influence the final results, namely the energetic and kinetic parameters describing the receptor-ligand interaction.

We present several different unbinding protocols with varying protein restraining potential stiffness (measured by theharmonic potential spring constant), ligand pulling potential stiffness (harmonic potential spring constant), and varying atom fixation approach. We explore the imposed errors and uncertainties introduced by each of the protocols.

The work has been funded by the Polish Ministry of Education and Science under the grant DI2017/007947 in the Diamond Grant program 2018 edition and grant No 0512/SBAD/2320.

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Notes:

Remodeling of intracellular architecture during SARS-CoV-2 infection of human endothelium.

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The clinical observations indicate the critical role of the endothelium in developing severe COVID-19 and potential cardiovascular sequelae, disregarding the severity of the disease. In this work, we explored the possibility that the SARS-CoV-2 infection of the endothelium may cause vascular dysfunction due to the modification of cell elasticity. We used human pulmonary endothelial cells (HPAECs) expressing ACE2 receptor as a model of the endothelium; this system mimics the in vivo conditions, as it allows for the virus entry, but the replication is abortive. As a reference, we used the A549 epithelial cell line expressing ACE2 and TMPRSS2 ($A549^{++}$), a well-described model that supports productive replication of SARS-CoV-2. We show that both the SARS-CoV-2 virus and the main Spike protein interact directly with the cellular cytoskeleton, and infection results in drastic changes in cellular elasticity and architecture. We observed that the infection of HPAECs results in the stiffening of the cell, correlating with an increased polymerization of actin filaments and an induction of the inflammatory response. Surprisingly, we observed the reverse effect (significant decrease in cellular stiffness) in $A549^{++}$ cells, which effectively supports viral replication. On the other hand, these changes in the cell may directly impact virus replication. Consequently, we believe that non-productive SARS-CoV-2 infection associated with stiffening of the endothelium may be clinically relevant and yield dysfunction and damage in this tissue.

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Notes:

LEEM and STM: a Strong Combination for Studying Molecular Systems on Surfaces

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In this contribution, I will focus on combining low-energy electron microscopy (LEEM) and scanning tunneling microscopy (STM) for studying molecular systems on surfaces, highlighting the areas where these methods work synergistically. I will introduce the working principle of LEEM and its modes of operation. I will demonstrate the real-time monitoring of surfaces in the bright field to study the kinetics and thermodynamics of molecular phase transformations. Then, I will introduce a local congruence approach for precisely determining molecular unit cells even from distorted diffraction images, which, combined with structural information from STM, gives a highly accurate starting point for theoretical calculations.

Notes:

Simulation of the ARPES Experiment – First Steps In Chinook

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To study low-dimensional materials and their heterostructures, we use theoretical calculations DFT (Density Functional Theory) and experimental ARPES (Angle-Resolved Photoemission Spectroscopy) to find interactions between layers and changes in band structure. The combination of these two methods gives us a greater understanding of the interactions occurring between heterostructure layers.

However, we are not always able to explain the complex band structure of the heterostructure using only DFT and ARPES. Therefore, in our research we used a third method, which is the simulation of an ARPES experiment by using the Chinook program. In our work, we want to present the application of the Chinnok program as a complement to the DFT and AEPRES techniques when studying low-dimensional materials.

This work was financially supported by the National Science Centre, Poland under projects 2018/30/E/ST5/00667 and 2018/31/B/ST3/02450.

The calculations were carried out on the Dutch national e-infrastructure with the support of SURF Cooperative (EINF-5312) and on the Hábrók high-performance computing cluster of the University of Groningen.

Notes:

From Isolated Alpha and Beta Antimonene Phases to Their Heterostructures

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Antimonene belongs to the Xenes mono-elemental subclass of two-dimensional materials. It belongs to the 15th group of period table among phosphorene, arsenene and bizmuthene. Antimonene was successfully synthesized in 2016 [1]. Antimonene has several theoretically predicted allotropic forms. But only two of them are energetically stable [2]. These are puckered alpha phase (α-Sb) and low buckled beta phase (β-Sb). The α-Sb is characterized by a rectangular unit cell, while β-Sb has a honeycomb structure. In both cases, a single layer of antimonene consists of two atomic sublayers.

In this work we show the structural properties of the α-Sb and β-Sb phases deposited on W(110) substrate. Antimonene layers were grown by molecular beam epitaxy (MBE) method. The experiment has been performed *in-situ* in a Low Energy Electron Microscope (LEEM). The structural properties were investigated by Low Energy Electron Diffraction (LEED). The obtained results indicate that the substrate temperature (T_{SUB}) during the deposition process has a major role in the phase composition of antimonene grown on the W(110) substrate. Depending on the temperature, the formation of isolated α-Sb and β-Sb islands (a) or β-Sb/α -Sb heterostructures (b) was observed.

This research was in part funded by the National Science Centre (Poland) under Grant No 2020/37/B/ST5/03540.

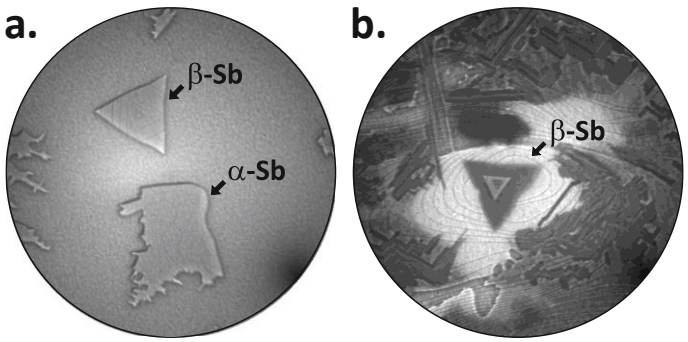

Figure 2. (a) Isolated α-Sb and β-Sb islands (T_{SUB} = 155°C) and (b) β-Sb/α -Sb heterostructure (T_{SUB} = 125°C).

[1] P. Ares, et al., Adv. Mater. 28, 6332 (2016).

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Notes:

Bi-molecular layers of CoPc and F_{16}CuPc on Ag(100): how the structure factor can be used to identify chiral domains

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The properties of the metal-organic interface are governed by the adsorbate-substrate and adsorbate-adsorbate interactions. Monolayer consisting of two molecular species, so called bi-molecular or binary monolayers, allow to control and – in future – tune the interaction between the constituting adsorbates. Phthalocyanine (Pc) molecules are a group of molecules intensively studied due to their interesting properties regarding applications in optoelectronics. We utilize low energy electron microscopy (LEEM) to characterize the bi-molecular domains composed of cobalt phthalocyanine (CoPc) and perfluorinated copper phthalocyanine (F_{16}CuPc) adsorbed on Ag(100) surfaces at room temperature and subsequently annealed at 470 K. After deposition of the two molecules in a 1:1 ratio, the first monolayer of the mixed phase is given by a $(5\sqrt{2} \times 5\sqrt{2})45^{o}$superstructure [1]. The phthalocyanine (Pc) molecules are adsorbed in this bi-molecular structure such that the molecular axes are rotated by 27° with respect to <011> directions of the substrate [2, 3]. This leads to development of two mirror domains, with opposite chirality. We will show that the structure factor of the constituting molecules enables the identification of these domains by LEEM, which is operated in either dark field or micro diffraction (μLEED) mode. Additionally, we will show that during the initial deposition of F_{16}CuPc up to a total coverage of more than 0.5 ML, a 2D gas phase is formed with discrete rotation angles of the molecule.

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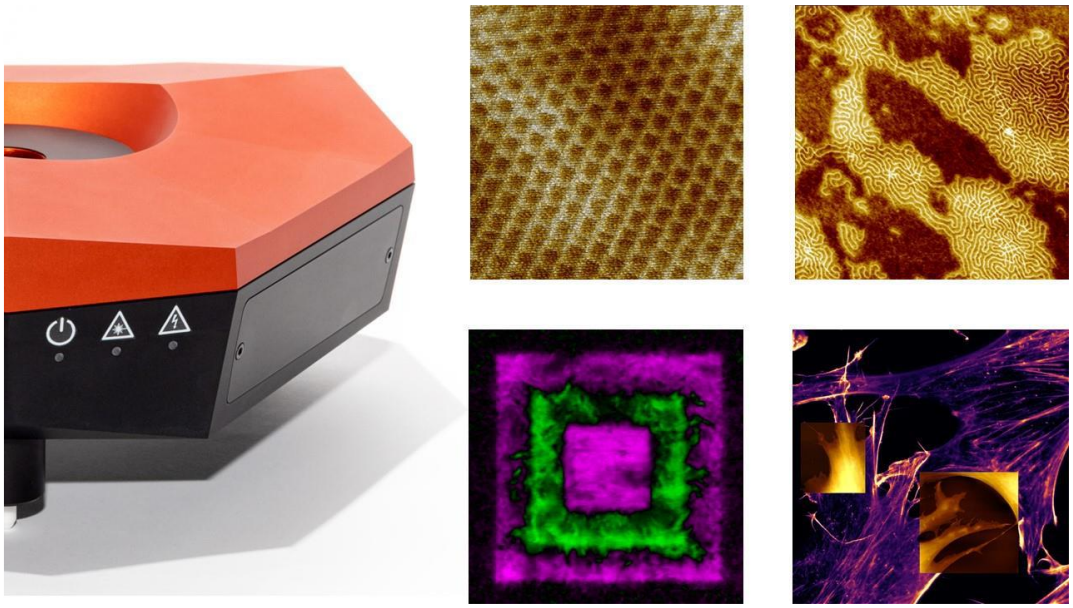
PIK Instruments is an innovative company that offers products from more than 25 manufacturers of laboratory equipment. We specialize in electron microscopy, preparation of biological and engineering samples, and atomic force microscopy. Our strengths also include metallography, digital microscopy and solutions dedicated to in-situ techniques. PIK Instruments' product portfolio also includes vacuum devices and advanced systems for imaging and preparation in medicine.

Our team is made up of a highly qualified group of passionate experts, who will professionally advise on any issue - not only the selection of suitable microscopes, but also in the field of preparation, or appropriate consumables for the laboratory.

Referring to the theme of the seminar, we would like to present the DriveAFM microscope, which represents the culmination of the continuous technical development of the Swiss company Nanosurf A.G., which since 1997 has been pushing the boundaries of what is possible in the study of interactions at close range. More information about the DriveAFM microscope can be obtained at our booth or during the presentation of the company PIK Instruments, to which we cordially invite you.



Notes:

Quantum simulation on a surface

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Designing materials with tailored physical and chemical properties requires a quantitative understanding of interacting quantum systems. In order to provide predictability, a promising route is to create bottom-up platforms, where the electronic properties of individual and interacting atoms can be emulated in a tunable manner. Here, we present a solid state quantum simulator based solely on patterned Cs atoms on the surface of semiconducting InSb(110), a system characterized by a dilute two-dimensional electron gas decoupled from the substrate's bulk bands. We use this platform to create electron traps that emulate artificial atoms by precisely positioning Cs atoms using atom manipulation in scanning tunneling microscopy (STM). Localized states of such artificial atom are expected based on ab initio calculations and confirmed by probing with scanning tunnelling spectroscopy (STS). These artificial atoms serve as building blocks to realize artificial molecular structures with different orbital symmetries which are probed by spatially dependent tunneling conductance maps. We find bonding and anti-bonding states for coupled dimers of artificial atoms and orbitals of higher symmetries (π orbitals) for a linear assembly of a few artificial atoms. Based on these artificial orbitals and various atomic patterns, we emulate the structure and orbital landscape of known planar organic molecules, including antiaromatic molecules. [1] In a different limit where Cs atoms are much closer, this quantum simulator can also be used to probe the effect of electron-electron interactions. Our experimental data suggest that dense structures exhibit many-body effects which can be extended to complex quantum states based on arbitrary lattices.

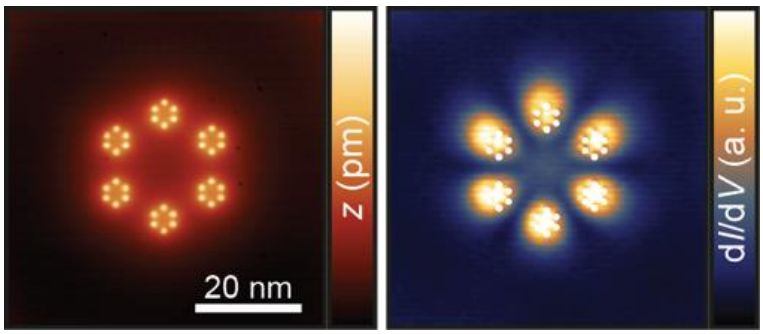

Figure 3. STM image of artificial atoms in hexagonal arrangement resembling benzene structure and spatial distribution of one of its orbitals probed in the experiment.

[1] E. Sierda, *et al.*, *Science*, 2023, **380**, 1048-1052. DOI: 10.1126/science.adf2685

Notes:

Charge Density Waves and Friedel Oscillations as Seen by STM

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We study the problems of charge density waves (CDW) and Friedel oscillations (FO) in atomic chains on the surface. Both CDW and FO concern spatial variability of the local density of states (LDOS) and overlap in most cases, leading to standing charge waves along the system. It is known that the periodicity of these waves is determined by the system Fermi energy. However, for the chain between two electrodes out of equilibrium or in the STM geometry, there are two Fermi energies that influence the charge oscillation period. Thus, we predict that the net charge modulation along the chain should depend on both Fermi energies and can be a combination of two periods.

This problem is also reflected in the interpretation of the STM results due to at least two reasons: firstly, for the constant current operation of the STM, the height profile carries data on both the topography and integrated LDOS modified by the tunneling transmission coefficient; secondly, a reliable interpretation can only be made for metallic systems where sample biases are close to zero and the bias energy window is small. For larger biases, the shape of the system LDOS in the bias window (between the surface and STM Fermi energies) should determine the chain occupancy and can significantly modify charge waves in the system leading to bias-dependent oscillation periods. In order to corroborate our predictions, we investigate Si atomic chains on a Si(553)-Au surface by means of the STM topography method. In this work, we resolve this problem and unambiguously identify the nature of voltage-dependent periodicities using the experimental studies and theoretical tight-binding calculations.

This work was supported by the National Science Centre, Poland, under Grant No. 2022/45/B/ST3/01123.

Notes:

$BaTiO_3$ characterized at the atomic scale: surface structure and its ferroelectric behavior

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$BaTiO_3$ is a promising material for prospective use in ferroelectric catalysis [1], as well as a model system for investigating fundamental properties of ferroelectricity at surfaces. Specifically, ferroelectric polarization may be used to separate or trap charges at the surface of the crystal, as well as to alter the surface structure and chemical properties. In this work we show that one can prepare a pristine $BaTiO_3$(001) surface by cleaving single crystals in UHV and characterize it with atomic resolution using the qPlus nc-AFM/STM. Moreover, by polarizing the crystals in preferential directions before cleaving, we have proven that the surface structure depends on the ferroelectric polarization and strain of the bulk crystal during cleave. We demonstrate that a reversible ferroelectric polarization of the surface at the atomic scale is possible with the electric field of the tip applied above a certain site.

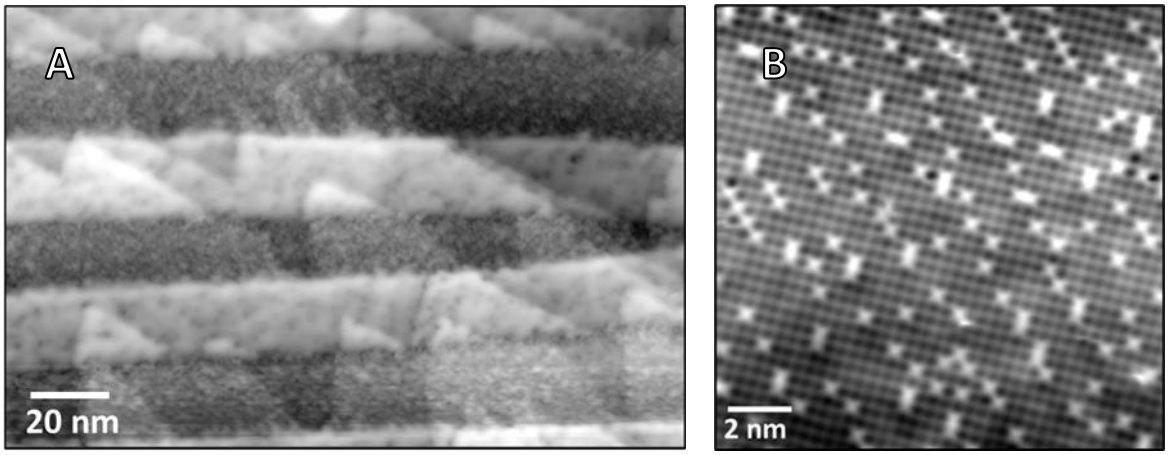

Figure 4. (A) Constant-frequency ncAFM map of the surface of a $BaTiO_3$(001) crystal with random ferroelectric polarization. (B) Constant-height ncAFM image of the atomic lattice of the BaO termination of $BaTiO_3$.

[1]: S. Assavachin, F. E. Osterloh, *J. Am. Chem. Soc.*, 2023, **145**, 34, 18825–18833.

Notes:

Electronic Structure Investigations of Wyel Semimetallic Materials and Hybrid Systems

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The Wyel semimetals are a novel group of materials that have not been experimentally proven until 2015. Their band structure is characterised by the crossing of valence and conduction bands thus forming Weyl nodes with electrons behaving as massless Weyl fermions with a strictly defined chirality. It leads to phenomena such as negative magnetoresistance, anomalous Hall Effect and unusual transport properties. Because of that, they may find applications in fields like electronics, spintronics, photonics, optoelectronics or quantum informatics. Alas, their easy applications are limited by oxidation and passivation processes occurring in the air.

In our research, we investigate fundamental properties of materials such as WTe_2 and TaAs. T_d-WTe_2 is an orthorhombic type-II Weyl semimetal whereas our MBE-grown TaAs is a mixture of standard tetragonal and previously unreported hexagonal phases, both being type-I Weyl semimetals. What is more, we have also researched a van der Waals (vdW) heterostructure made of WTe_2 and graphene. Such-created materials may exhibit properties different than what could be expected from a simple mix of given components, due to the proximity effects that modify their electronic structure. Nonetheless, the essential part is to secure one material from oxidizing with another one - an inert type like graphene. Complex electronic, chemical and surface structure examination was performed both to pristine materials and to WTe_2 graphene vdW heterostructure which was produced by covering the WTe_2 surface with graphene.

The properties of the pristine materials as well as a mutual influence of the hybrid components interactions in the heterostructure have been characterized using a variety of research techniques - both global and local, such as scanning tunnelling microscopy (STM), current imaging tunnelling spectroscopy (CITS), low-energy electron diffraction technique (LEED), Raman spectroscopy, X-ray photoelectron spectroscopy (XPS) and angle-resolved photoelectron spectroscopy (ARPES). The examined interfaces were found to be of exceptional purity. Moreover, the data obtained using the above-mentioned methods suggest the existence of interactions caused by the proximity effect in the heterostructure and a modification of the electronic structure of its components.

This work could be done thanks to financing from the National Science Center, Poland under the projects 2018/31/B/ST3/02450 and 2018/30/E/ST5/00667.

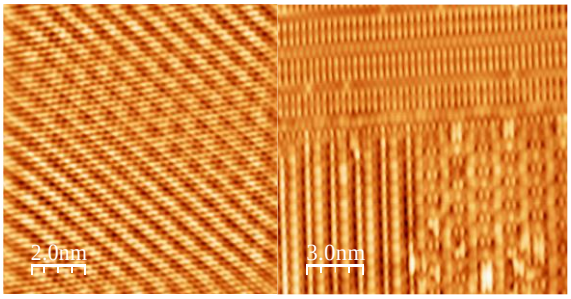

Figure 1. STM topography images for graphene / T_d-WTe_2 hybrid and TaAs.

Notes:

AFM and acoustics - an interesting marriage

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Quantitative nanoscale measurements of mechanical properties are of primary interest for physicists, biophysicists and material scientists. Acquisition of force-distance curves is the most popular method with inherent drawbacks: huge amount of data and ill-defined strain rate.

Adding small amplitude oscillations allows to perform well defined studies. Common misunderstanding is related to sample thickness to acoustic wavelenght ratio. Mostly, frequencies used do not exceed 2 MHz, so wavelenghts are in cm range. Therefore, analysis of the system should not be performed in terms of wave propagation but rather periodic or quasi-static tip-sample interactions.

Proper choice of the modulation frequency insures meaningful results [1]. Working well below mechanical resonances is the right choice for studying compliant biomolecules because stiffness can be extracted. However, dissipative properties are probably not measurable in our opinion [2]. High frequency ultrasonic wave packets can be detected using tip-sample nonlinearity. The last technique ("Ultrasonic Force Microscope - UFM) gives access to local adhesive properties [3]

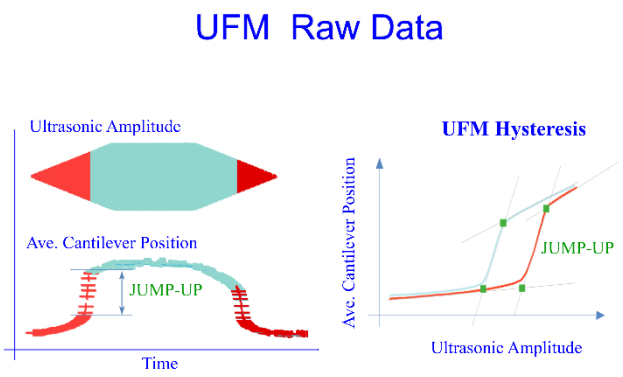

Figure 1. Waveforms observed in Ultrasonic Force Microscopy (UFM) experiment

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Notes:

Friday, 1.12.2023		
09:00 - 13:00	**EXCURSIONS**	
13:30 - 14:30	**LUNCH**	
15:00 - 15:30	Incommensurate STM image simulations with the moiré plane wave expansion model	**Maxime Le Ster**
15:30 - 15:50	Processing of PtSe2 ultra-thin layers using Ar plasma for applications in planar devices	**Ryszard Czajka**
15:50 - 16:10	Electrostatic gating of the Van der Waals heterostructures	**Marek Kopciuszyński**
16:10 - 16:30	Epitaxial MoO3 monolayer – manipulation and electrical properties study by atomic force microscopy	**Aleksandra Nadolska**
16.30 - 16.50		**Labsoft sp z.o.o.**
16:50 - 17:20	**COFFEE BREAK**	
17:20 - 17:50	Probing the local chemical structure of artificial lipid membranes with Tip-enhanced Raman spectroscopy	**Ewelina Lipiec**
17:50 - 18:10	Therapeutic strategies against melanoma skin cancer metastasis by targeting exosomes, cells, and tissues with the use of label-free methods	**Swamy Kasarla**
18:10 - 18:30	Nanomechanical Changes in Erythrocytes of Diabetic Patients Before and After Dapagliflozin Therapy	**Patrycja Twardawa**
18:30 - 18:50	Nanospectroscopy for Revealing Secrets of Protein Aggregation in Alzheimer's Disease	**Kamila Sofińska**
18.50 - 19.10	Technolutions	**Łukasz Kawelski**
19:30 - 20:30	**DINNER**	
20:30 - 21:30	**POSTER SESSION (EVEN NUMBERS)**	

Incommensurate STM image simulations with the Moiré plane wave expansion model

M. Le Ster[1], K. Palotás[2], J. Sławińska[3], P. Dąbrowski[1],P. Krukowski[1], I. Lutsyk[1], M. Rogala[1], W. Ryś[1] and P. J. Kowalczyk[1]

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Moiré systems have recently attracted a lot of attention in condensed-matter physics following the experimental discovery of superconductivity and correlated phases in twisted bilayer graphene [1]. Many other unique moiré quantum phases of matter have been since explored, with most theoretical investigations focusing on the emergence of flat bands and correlated electronics [2]. Scanning tunneling microscopy (STM) simulations of moiré systems have however been overlooked, despite moiré patterns almost always arising from the pairing of two-dimensional (2D) materials and the potential assistance that simulations could provide for scientists investigating van der Waals heterostructures. Indeed, moiré patterns can sometimes lead to complex STM images, which is especially true in the case of mixed symmetry coupling, i.e., hexagonal-rectangular symmetry pairing [3, 4]. In these systems, the moiré unit cell can be very large and even infinite in the case of incommensurability, excluding the application of methods based on periodic cells, e.g., density functional theory. Other approaches are thus required; in this talk, I will introduce a new method, the moiré plane wave expansion model, to simulate STM images, which simply requires a priori knowledge of the non-interacting STM images and a small set of intuitive parameters [5].

This project is supported by SONATA-18 grant No. 2022/47/D/ST3/03216 by Narodowe Centrum Nauki and IDUB 6/JRR/2021 by the Ministry of Science and Higher Education, Poland.

[1] Y. Cao et al., *Nature* **556**, 43-50 (2018)
[2] D. M. Kennes et al., *Nat. Phys.* **17**, 155-163 (2021)
[3] M. Le Ster et al., *Phys. Rev. B* **99,** 075422 (2019)
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Notes:

Processing of $PtSe_2$ ultra-thin layers using Ar plasma for applications in planar devices

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The systems containing the ultra-thin layers of TMD materials (e.g. $PtSe_2$) exhibit interesting physical properties and can be easily integrated into CMOS technology [1].We propose a procedure for the fabrication of simple electronic devices based on $PtSe_2$ ultra-thin layers using Ar plasma processing on commercially available $PtSe_2/Al_2O_3$ samples [2]. The report contains a detailed analysis of the influence of the Ar plasma treatment time on a system comprising thin $PtSe_2$ layers with a thickness of 1 to 3 monomolecular layers. The impact of the process on the physical properties of the system is also analyzed using Raman Spectroscopy and Atomic Force Microscopy techniques. The electrical properties of devices based on 3ML $PtSe_2$ are characterized using so called Transfer Line Measurements with electrical contacts consisting of the Ni buffer layer and an Au outer electrode contact (with thicknesses of 20 nm and 40 nm, respectively). The results confirm the effectiveness of the proposed approach in the fabrication of planar nano-electronic devices (1÷3 ML thickness of $PtSe_2$) [3].

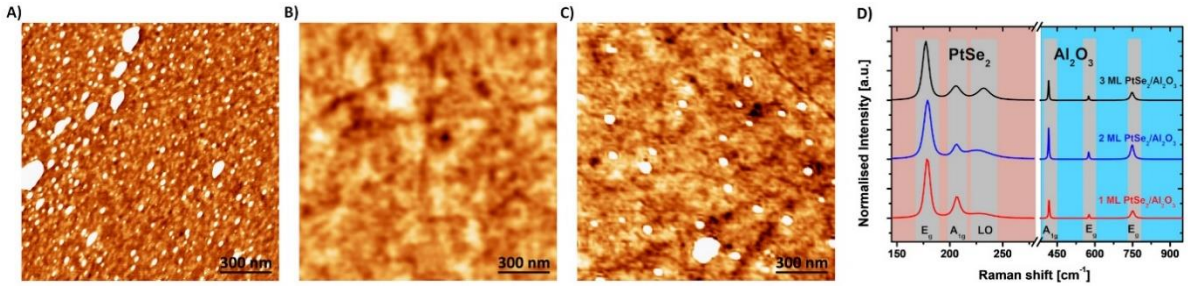

Figure 5. Representative AFM images (area of 1.5 × 1.5 μm^2) of the samples that present the morphology of the continuous $PtSe_2$ layers with thicknesses: A) 1ML $PtSe_2$, B) 2ML $PtSe_2$, and C) 3ML $PtSe_2$. The *z* range in all images is 1.75 nm. D) Raman spectra of the samples collected before plasma processing. The intensities are normalized to the maximum value in the individual spectra. The Raman modes corresponding to the $PtSe_2$ layer and the Al_2O_3 substrate are signed [3].

Acknowledgements:
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[2] S. Joseph, J. Mohan, S. Lakshmy, T. Simil, B. Chakraborty, T. Sabu, N. Kalarikkal, Materials Chemistry and Physics, 2023, **297,** 127332.
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Notes:

Electrostatic gating of the Van der Waals heterostructures

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Electrostatic gating is extremely ubiquitous in all electronic devices. It is known that electrostatic field might dope or deploy electronic bands. When the positive bias voltage is applied, the conduction bands could be "pulled down" below the Fermi level and consequently probed by angle-resolved photoelectron spectroscopy (ARPES).

In 2019 the group of prof. N.P. Wilson showed, for the first time, the electronic structure "above the Fermi level" of the single, double and three-layer WSe_2 (and other similar MX_2 semiconductors) measured by microprobe ARPES [1]. This experiment opened a new research area with the ability to directly monitor electronic states in an operating micro device. The micro device could be made using dry transfer procedure [2] as a heterostack of Van der Waals materials as it was proposed by Geim and Grigorieva [3]. The gating effect is achieved by applying the bias voltage to the few micrometers sized graphite flake covered by insolating, about 5-nm thick, hexagonal boron nitride. On such a stack graphene or any other two-dimensional Van der Waals material could be deposited.

Despite the easy concept, making such a device that not only works but is suitable for micro ARPES measurements is challenging. First, the device is made in ambient conditions but for APRES measurements it must be atomically clean. Moreover, it is necessary to provide electrical contact to the back gate and ground voltage to the surface material. In this presentation I will show a complete preparation procedure of a Van der Waals heterostructure where the stack is deposited on an insulating silicon oxide substrate with premade electric contacts. The contacts pads were made of palladium and the 25 micrometers gap between them was achieved using a hand-made mask and UHV deposition. This kept the surface clean and makes it possible to prepare such a device without lithography.

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[2] P.J. Zomer, et al., Appl. Phys. Lett. 2014, **105**, 013101.
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Notes:

Epitaxial MoO_3 monolayer – manipulation and electrical properties study by atomic force microscopy

Aleksandra Nadolska[1,*], Dorota A. Kowalczyk[1], Iaroslav Lutsyk[1], Michał Piskorski[1], Paweł Krukowski[1], Paweł Dąbrowski[1], Maxime Le Ster[1], Witold Kozłowski[1], Rafał Dunal[1], Przemysław Przybysz[1], Wojciech Ryś[1], Klaudia Toczek[1], Paweł J. Kowalczyk[1], Maciej Rogala[1]

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Atomic force microscopy is widely used for nanoscale investigation of topography and electrical, magnetic, mechanical properties of novel materials. This method is particularly important for study of two-dimensional (2D) materials, especially when their thickness is less than 1 nm and imaging is beyond the limits of other standard research techniques. One of the representatives of this group of materials is α-MoO_3, which can be applicable in electronics, optoelectronics, data storage devices and catalysis.

We report nanoscale investigation and manipulation of MoO_3 monolayer, deposited by molecular beam epitaxy in ultra high vacuum conditions. We show sliding of the MoO_3 islands on the highly oriented pyrolytic graphite (HOPG) surface, forced by slight mechanical stress of AFM tip. Additionally, we present conductivity map and point electrical stimulation of molybdenum trioxide monolayer preformed using scanning spreading resistance mode. We show an example of how a material can be changed and shaped at the nanometer scale.

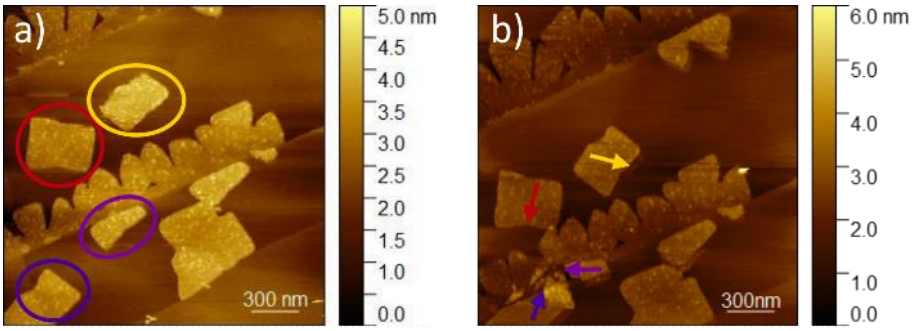

Figure 6. Semi-contact AFM images of MoO_3 on HOPG: (a) topography with mobile MoO_3 islands marked using ovals; (b) topography with next locations of islands, where arrows represent the sliding direction of each island.

Acknowledgments

This work was supported by the National Science Centre, Poland, under the Grant 2020/38/E/ST3/00293.

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Notes:

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Firma LABSOFT jest wieloletnim, uznanym dostawcą urządzeń badawczych, aparatury pomiarowej i technologicznej renomowanych producentów. Oferowane przez nas urządzenia znajdują zastosowanie w ogólnie pojętej nanotechnologii, inżynierii materiałowej, naukach fizycznych, chemicznych, biologicznych i medycznych. Posiadamy bazę ponad 700 zainstalowanych przyrządów badawczych, w tym o bardzo wysokim poziomie złożoności, oraz szereg referencji ze zrealizowanych dostaw świadczących o naszych kompetencjach i doświadczeniu.

Labsoft to zespół ponad 30 osób, w tym 14 inżynierów serwisowych rozlokowanych na terenie całego kraju. Śledzimy uważnie dynamicznie rozwijający się rynek urządzeń badawczych, stale podnosimy swoje kwalifikacje, wprowadzamy i proponujemy nowe rozwiązania. Wysokie kompetencje naszych inżynierów sprawiają, że pomagamy partnerom w serwisie aparatury także poza granicami Polski. Jako doświadczona firma, doskonale zdajemy sobie sprawę ze złożoności współczesnej aparatury badawczej, z jej niesamowitego potencjału badawczego, ale również z wyzwań stawianych operatorom oraz osobom interpretującym uzyskane wyniki. Dlatego naszym celem jest wdrożenie koncepcji pełnego wsparcia klienta – od doradztwa przy wyborze urządzeń, poprzez przygotowanie pomieszczeń, instalację i uruchomienie aparatury, przeszkolenie użytkowników, utrzymanie jej w ruchu, aż do udzielenia wsparcia aplikacyjnego dla użytkowników.

Notes:

Probing the local chemical structure of artificial lipid membranes with Tip-enhanced Raman spectroscopy

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A plethora of biologically significant phenomena involving lipid membranes, such as extracellular and intracellular transport or cell-cell and cell-extracellular matrix (ECM) communication, occur at the nanoscale. These processes are driven by the local heterogeneity of a lipid membrane leaflet. Despite the best scientific efforts, the properties of lipid raft assemblies are still poorly understood. It is expected that characterization of lipid domains heterogeneity, as well as local structural rearrangements at the nanoscale, should greatly enhance current understanding of the raft functionality and dynamics in human physiology and pathogenesis of diseases. [1]
The combination of scanning probe microscopy (SPM, including atomic force microscopy (AFM) and scanning tunneling microscopy (STM)) and vibrational spectroscopy called tip-enhanced Raman spectroscopy (TERS), will be introduced as an efficient tool in studies of model lipid membranes. TERS combines the nanometric spatial resolution of SPM and the chemical selectivity of the Raman spectroscopy, providing information on the chemical structure of nano-volume samples. Additionally, TERS does not require any kind of chemical labeling. [1]
In the presentation, several important aspects of TERS nanospectroscopic investigations into lipid layers will be presented:

i) TER hyperspectral mapping of monolayers containing dipalmitoylphosphatidylcholine (DPPC), 1,2-dipalmitoyl-*sn*-glycero-3-phosphoethanolamine (DPPE), cardiolipin (CL), and their mixtures for comprehensive characterization of artificial membranes, revealing local molecular distribution, orientation, phase separation, and formation of domains,
ii) a comparison of AFM-TERS and STM-TERS in imaging of the model lipid membranes,
iii) an application density-functional theory (DFT) and molecular dynamics and multivariate data analysis for an appropriate interpretation of the obtained spectral data,
iv) correlation between the local chemical structure and nanomechanical properties of the investigated monolayers,
v) pioneering implementation of STM-TERS in liquid - a protective role of solvent [2].

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[2] E. Lipiec, J. Kaderli, J. Kobierski, R. Riek, K. Skirlińska-Nosek, K. Sofińska, M. Szymoński, Renato Zenobi, *Angewandte Chemie International Edition*, 2021, 133 4595-4600

Notes:

Therapeutic strategies against melanoma skin cancer metastasis by targeting exosomes, cells, and tissues with the use of label-free methods

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Metastasis is the main cause of cancer mortality for many types of cancer. Once melanoma enters the metastatic stage, it causes the highest mortality rate among skin malignancies due to the lack of effective therapy for its metastasis. Numerous studies have shown that during oncogenic transformation, there are rapid changes in the biosynthesis of glycans, which results in the appearance of marker glycans on the cell surface, the tumor-associated carbohydrate antigens (TACA) [1]. The clinical relevance of TACAs is currently the subject of intense research, as they are not only a characteristic feature of tumors and contribute to tumor development and progression but may also be a source of new biomarkers that could be used in screening and, in addition, as prognostic and prediction factors, and as new potential targets for cancer therapy.

This study aims to evaluate interactions between these specific glycans, present on the surface of the primary tumor and metastasis of melanoma cells at various stages of cancer progression, with appropriate lectins, using biophysical methods. Combining atomic force microscopy with other label-free methods, such as quartz crystal microbalance or surface plasmon resonance, leads to the determination of several critical physicochemical parameters, allowing the monitoring of biological systems at the interface [2]. Our results showed that lectin binding to glycans on cells allows distinguishing melanoma cells with a higher metastatic potential from those with a lower metastatic potential. The developed procedure was verified with exosomes isolated from melanoma cells and tissue sections from paraffin blocks containing fragments of melanocytic lesions (primary tumor and metastasis to the lymph node).

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Notes:

Nanomechanical Changes in Erythrocytes of Diabetic Patients Before and After Dapagliflozin Therapy

Patrycja Twardawa[1,2,*], Bartłomiej Matejko[3], Agata Kubisiak[1,2], Joanna Hajduk[1,2], Katarzyna Cyranka[3,4], Tomasz Klupa[3,4], Marta Targosz-Korecka[1]

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Untreated diabetes can lead to numerous comorbidities, particularly cardiovascular diseases. Prolonged hyperglycemia affects cells related to the cardiovascular system, including erythrocytes [1]. Increased erythrocyte stiffness heightens the risk of severe vascular complications, contributing also to endothelial dysfunction [2]. Recently, SGLT-2 inhibitors (flozins) have emerged as a new class of diabetes medications that lower glycemia by inhibiting glucose reabsorption in renal tubules [3]. Studies have indicated their positive impact on the vascular system in diabetic patients. The hypothesis of the presented study was that one month of flozin treatment would improve erythrocyte nanomechanical parameters in 30 patients aged 18-50 with type I diabetes and no related complications. The samples consisted of whole blood diluted in HBSS buffer and fixed in a 1% glutaraldehyde solution on a microscope slide coated with poly-L-lysine. Measurements were conducted using the nanoindentation method with an AFM probe, and photos of the samples were taken using both an optical and confocal microscope (with actin staining). AFM measurements were carried out in contact mode using the force mapping method (CM-FM). The elasticity modulus for each force-distance curve attributed to the erythrocyte area was obtained from Hertz-Sneddon model fits. Student's t-tests were performed for cells before and after therapy, and comparisons were also made considering various factors such as sex, age, and duration of diabetes. Significant stiffness reduction was observed in the entire population and in both genders after therapy. Longer diabetes duration and older age correlated with a more substantial reduction in elasticity modulus. This supports the cardioprotective potential of SGLT2 inhibitors and suggests their use in type I diabetes patients, regardless of body weight or glycemia normalization.

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[2] D. K. Kaul, A. Koshkaryev, G. Artmann, G. Barshtein, S. Yedgar, *Additive effect of red blood cell rigidity and adherence to endothelial cells in inducing vascular resistance, Am J Physiol Heart Circ Physiol*, 2008, **295**, H1788–H1793.
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Notes:

Nanospectroscopy for Revealing Secrets of Protein Aggregation in Alzheimer's Disease

Kamila Sofińska[1,*], Sara Seweryn[1,2], Katarzyna Skirlińska-Nosek[1,2], Jakub Barbasz[3], Piotr Batys[3], Adrian Cernescu[4], Dhiman Ghosh[5], Roland Riek[5], Natalia Wilkosz[1,#], Marek Szymoński[1], and Ewelina Lipiec[1]

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Alzheimer's disease (AD) is the major cause of dementia, which currently is one of the most serious health and social problems worldwide. The presence of intraneuronal tau neurofibrillary tangles (NFTs) and extra-neuronal amyloid-β (Aβ) plaques in the brain is the histopathological hallmark of AD.
In the presentation, the research at the nanoscale into the chemical structure and conformation of tau protein aggregates at the growth phases of the aggregation process will be reported. Tau neurofibrillary tangles (NFTs) appear in neurons at the late stage of the disease. It suggests that inhibiting tau aggregation at the early stages of the tau aggregation process could prevent neurodegenerative symptoms characteristic for the late stages of AD. However, while the structure of tau monomers or fibrils is thoroughly investigated, still little is known about the structure of tau aggregates occurring in the course of aggregation. Thus, we incorporated tip-enhanced Raman spectroscopy (TERS) to acquire spectra of protofibrils and young fibrils at the early aggregation stage to reveal their structure and to gain insights into TER signature related to structural transitions resulting from the ongoing aggregation. We applied multivariate data analysis to treat the data acquired from protofibrils and young fibrils to reveal structural differences between tau aggregates in time.
Moreover, the application of infrared nanospectroscopy in studies on the influence of the small molecule drug, bexarotene, on the secondary structure of individual amyloid-β aggregates will be presented [1]. Specifically, the anti-aggregation effect of bexarotene on the structure of amyloid-β fibrils were studied with nanoFTIR and sSNOM imaging. The collected data were treated with multivariate data analysis to reveal spectral markers of bexarotene impact on the structure of aggregates.

[1] K. Sofińska, et al., Nanoscale, 2023, 15, 14606.

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W ofercie posiadamy m.in.:

- uniwersalny mikroskop badawczy NX10 o szerokim zakresie zastosowań. System wyposażony jest w niezależne skanery XY oraz Z oferujące wysoką dokładność obrazowania. Ponadto układ niezależnych skanerów osi X i Y umożliwia idealnie liniowy i ortogonalny przesuw próbki pod sondą, eliminując geometryczne zniekształcenia obrazowania. Mikroskop AFM zapewnia dokładny pomiar topografii przy użyciu niskoszumowego detektora położenia oraz szybkiego servo w osi Z. Tryb True Non-ContactTM, umożliwia obrazowanie wysokiej rozdzielczości i niskie zużycie sond pomiarowych.

- mikroskop FX40 to innowacyjny system do badania próbek o małych i średnich rozmiarach, umożliwiający automatyczną wymianę i strojenie sond oraz strojenie układu detekcyjnego. Dzięki obecności dodatkowego układu optycznego wyposażonego w skaner QR, sondy pomiarowe można przygotowywać do pracy w sposób bezpieczny. Intuicyjny i wygodny nawigator pozwala na szybkie wybranie miejsca na próbce oraz rozpoczęcie procesu obrazowania za pomocą zaledwie kilku kliknięć. Dzięki funkcji StepScan możliwe jest obrazowanie zamocowanych próbek jedna po drugiej bez przerywania pracy.

- LiteScope™ firmy NenoVision, moduł mikroskopu sił atomowych AFM do instalacji w mikroskopie SEM służący do wykonywania wysokorozdzielczych obrazów łączonych SEM+AFM 3D. Urządzenie zbiera informacje zarówno z mikroskopu AFM, jak i SEM, jednocześnie tworząc wspólny obraz próbki z nanometryczną dokładnością – CPEM (Correlative Probe and Electron Microscopy) w czasie rzeczywistym.

[1] https://technolutions.pl/
[2] https://www.parksystems.com/
[3] https://www.nenovision.com/

Notes:

Saturday, 2.12.2023		
09:00 - 09:30	Advances in charge and spin characterization on the atomic scale using scanning probe microscopy	**Pavel Jelinek**
09:30 - 09:50	On-Surface Synthesis of Higher Acenes and Their Analogues	**Szymon Godlewski**
9:50 - 10:10	Synthesis of antimonene/silicene heterostructure by epitaxial growth and self-ordering induced by temperature	**Mariusz Gołębiowski**
10:10 - 10:30	Functional Nanopattering of 2D-TMDs via Large Scale and Thermal Scanning Probe Lithography	**Francesco Buatier de Mongeot**
10.30 - 10.50	Characterization of metallic and oxidized 2D-Bi layers epitaxially grown on HOPG/hBN/mica	**Klaudia Toczek**
10:50 - 11:20	**COFFEE BREAK**	
11:20 - 11:50	New class of massless fermions	**Ryszard Zdyb**
11:50 - 12:20	Identifying nanostructures at surfaces using STM/STS	**Mikołaj Lewandowski**
12:20 - 12:40	Novel cantilever MEMS technologies for scanning probe microscopy nanometrology	**Bartosz Pruchnik**
12:40 - 13:00	Identification of electrical properties of third/fourth generation solar cells in nano-, micro- and macroscale.	**Marcin Palewicz**
13.00 - 13.20	Single Filament Bio-Mechanical Study of Type 3 Secretion System Reveals High Elastic Aspect Ratio	**Ronen Berkovich**
13:30 - 14:30	**LUNCH**	
15:00 - 15:30	Infrared scattering-SNOM for chemical mapping of soft matter	**Szczepan Zapotoczny**
15:30 - 15:50	2D-supramolecular organization of liquid crystal bi- and ter-phenyl-based nonsymmetric dimers	**Robert Nowakowski**
15:50 - 16:10	Highly Hydrophobic Self-Assembled Monolayers on Technologically Relevant Aluminum Surface	**Daria Cegiełka**
16:10 - 16:30	Modification of MoS2/Au Interface By Force Spectroscopy At Nanoscale For Resistive Switching Applications	**Rafał Dunal**
16:30 - 16:50	Dynamically altered conductance in organic thin film memristive devices	**Jakub Rysz**
16:50 - 17:20	**COFFEE BREAK**	

17:20 - 17:50	Magnetization switching of ferromagnetic thin film without applying a magnetic or electric field induced solely by adsorption of chiral molecules	**Lech Baczewski**
17:50 - 18:10	Using polymer processing techniques to obtain domains with Single Ion Magnets	**Anna Majcher-Fitas**
18:10 - 18:30	Iron-based magnetic materials for application in recording devices – DFT studies of thin films	**Joanna Marciniak**
18:30 - 18:50	Means of Control over Poly(4-vinylpyridine)-CoBr2 Complexes Functional Thin Films Formation in Static and Dynamic Conditions	**Julia Chudzik**
18.50 - 19.10	Magnetic tuning of nanomechanical spectroscopy in a freestanding graphene quantum dot	**Marcin Kisiel**

20:00 - 22:00	**CONFERENCE DINNER**

Sunday, 3.12.2023	
From 9:00	**TRANSPORT TO KRAKOW (AFTER BREAKFAST)**

Advances in Charge and Spin Characterization on the Atomic Scale Using Scanning Probe Microscopy

Pavel Jelinek[1*]

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This talk will discuss recent progress in high-resolution SPM imaging with functionalized probes and future directions. The unprecedented chemical resolution of individual molecules acquired functionalized tips [1,2] created much excitement among researchers from many fields, including material science, physics, and chemistry. We will discuss the possibility of detecting spin states of molecular structures on surfaces using a nickelocene probe [3,4]. In next, we will demonstrate that Kelvin probe force microscopy with functionalized probe allows us to image the anisotropic charge distribution of the atomic charge, such as sigma-hole [5] or pi-hole [6]. Finally, we outline the future possibilities of using the SPM with functionalized tips for imaging biomolecules.

[1] R. Temirov et al, New J. Phys. 10, 053012 (2008); L. Gross et al, Science 325, 1110 (2009); Ch. Chiang et al, Science 344, 885 (2014); P. Jelinek J. Phys. Cond. Matt 29, 166001 (2017).
[2] P. Hapala et al, Phys. Rev. B 90, 085421 (2014); P. Hapala et al, Phys. Rev. Lett. 113, 226101 (2016); B. de la Torre et al Phys. Rev. Lett. 119, 166001 (2017).
[3] Ormaza et al, Nano Lett. 2017, 17, 3, 1877–1882, (2016); Verlhac et al., Science 366, 623–627 (2019).
[4] Ch. Wackerlin et al, ACS Nano 22, 16402 (2022).
[5] B. Mallada et al., Science 374, 863 (2021).
[6] B. Mallada et al., Nature Communication 14, 4954 (2023).

Notes:

On-Surface Synthesis of Higher Acenes and Their Analogues

Rafał Zuzak,[1] Irena Izydorczyk,[1] Mariusz Krawiec,[2] Antonio M. Echavarren,[3] Szymon Godlewski[1,*]

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[3] Institute of Chemical Research of Catalonia (ICIQ), Barcelona Institute of Science and Technology, Avenida Països Catalans 16, 43007 Tarragona, Spain

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In recent years we observe renewed interest in the development of electronics based on electron transport through single molecules. Among different families of organic species, acenes and nanographenes hold the special position. In particular a lot of effort is undertaken to achieve efficient synthetic strategies to generate such well-defined sections of graphene or graphene-like modules with diverse topological modifications. However, the reactivity/instability of numerous molecules as well as the insolubility of large polycyclic aromatic hydrocarbons limits the applications of conventional chemistry methods. An attractive alternative to the solution chemistry is based on its combination with the on-surface synthesis approach.

Herein we present the on-surface generation of higher acenes [1-2] and their analogues [3] as well as the detailed study of their electronic structure on the Au(111) surface. Our method is based on the two-step dehydrogenation and thermally induced sequential cyclodehydrogenation of a stable and easily handled molecular precursors.

High-resolution non-contact atomic force microscopy (NC-AFM) imaging was applied for the detailed visualization of the internal structure of the intermediates, as well as the target molecules with diverse topologies. Details on the electronic structure were revealed using high resolution dI/dV mapping.

The research was supported by the National Science Center, Poland (2017/26/E/ST3/00855).

[1] R. Zuzak, et al., *ACS Nano* 2017, **11**, 9321−9329.
[2] R. Zuzak, et al., *Angew. Chem. Int. Ed.* 2018, **57**, 10500 –10505.
[3] I. Izydorczyk, et al., *Chem. Commun.* 2022, **58**, 4063 – 4066.

Notes:

Synthesis of antimonene/silicene heterostructure by epitaxial growth and self-ordering induced by temperature

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Two-dimensional structures have been of growing interest for several years because of their unique properties that can develop the world of electronics, optoelectronics and spintronics. In the present work, two of them have been synthesized in the form of heterostructure - antimonene and silicene. The former is distinguished from other 2D materials by its high stability in air and water, excellent thermoelectric and topological properties. The second can provide compatibility with current silicon-based technology.

In the present experiment, a SPLEEM microscope operating under ultra-high vacuum ($p < 3 \cdot 10^{-10}$ mbar) was used. The development of antimonene and silicene layers and their changes as a function of temperature were studied with the LEED technique.

An antimonene layer with a lattice constant of 4.23 Å was synthesized on a Si(111) substrate with a (6x6)Au surface reconstruction. The blue arrow in Fig. 1a indicates one the diffraction spots of antimonene. The structure was then heated up to about 500°C. At temperature of about 250°C diffraction spots originating from the low buckled phase of silicene appear (the green arrow in Fig. 1b) as evidenced by a lattice constant of 4.09 Å. Further annealing results in the desorption of antimony and the appearance of the planar phase of silicene with a lattice constant of 4.40 Å (the red arrow in Fig. 1c).

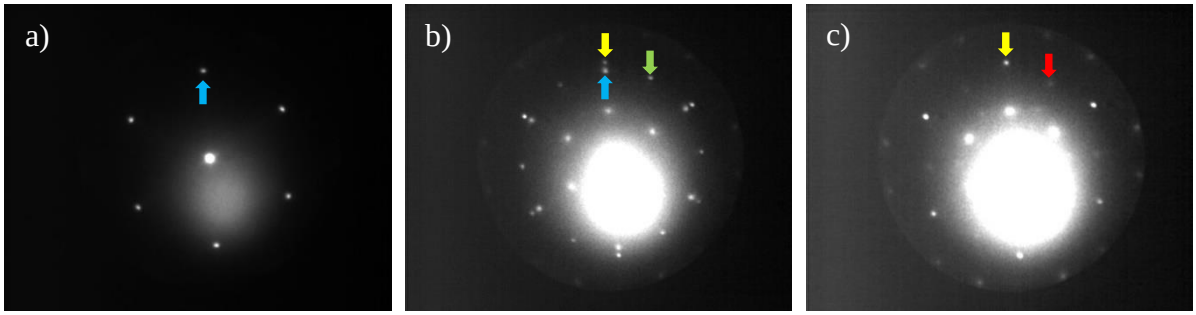

Figure 7. LEED images (E = 24.5 eV) of beta antimonene on top of Si(111)-(6x6)Au at: a) room temperature; b) 265 °C; c) 305 °C. The arrows denote diffraction spots corresponding to: antimonene - blue, Si(111) - yellow, low buckled silicene - green, planar silicene - red.

Acknowledgments: The research was carried out as part of the research project of the National Science Center No. 2020/37/B/ST5/03540.

Notes:

Functional Nanopattering of 2D-TMDs via Large Scale and Thermal Scanning Probe Lithography

Giorgio Zambito, Giulio Ferrando, Matteo Gardella, Matteo Barelli, Maria Caterina Giordano, and Francesco Buatier de Mongeot *

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Two dimensional (2D) materials like transition metal dichalcogenides (TMD) have emerged as promising platforms for creating new generation, atomically thin devices in various fields, from nanoelectronics and nanophotonics, to quantum technologies and energy conversion [1–3].
Manufacturing of devices based on such materials is generally a slow and inefficient process which requires manipulation of mechanically exfoliated micrometric flakes. The re-shaping of 2D materials is attractive, since it opens interesting possibilities for engineering optoelectronic and photonic responses, as well as it enables the fabrication of devices with optimized geometries. Nanopatterning of exfoliated flakes is generally obtained by subtractive chemical etching methods [4] which, although effective for creating single demonstrative configurations, are not suitable for fabricating scalable devices for real-life applications.
In one approach we demonstrate large area nanopatterning of the 2D-TMDc layers (like MoS2 or WS2) via self-organised and interference lithography approaches which make possible real-world energy conversion applications [2-3]. In a second approach we obtain direct fabrication of few-layer MoS2 nano-architectures with arbitrary geometries combining i) a custom-developed sputtering growth for creating few-layers MoS2 extended films and ii) a high-resolution lithography technique which makes use of a nanoscopic (∼10nm) hot silicon probe (thermal Scanning Probe Lithography – t-SPL, NanoFrazor) [5].
The electrical transport properties of these MoS2 nano-paths are investigated via Kelvin Probe Force Microscopy (KPFM) and conductive - AFM (ResiScope c-AFM), demonstrating the possibility to employ these 2D semiconducting nanocircuits as building blocks of integrated electronics devices.
We finally show some preliminary results on alternative application of t-SPL on 2D materials, such as direct localized annealing of MoS2 few-layer films or on-demand strain engineering of 2D materials by 3D grayscale lithography.

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[2] C. Martella, et al., Adv. Mater. 2018, 30, 1705615.
[3] M. Bhatnagar, et al., Nanoscale 2020, 12, 24385.
[4] M. G. Stanford, et al., Npj 2D Mater. Appl. 2018, 2, DOI 10.1038/s41699-018-0065-3.
[5] M.C. Giordano, et al. Adv. Mater. Interfaces 2023, 10, 2201408.

Notes:

Characterization of metallic and oxidized 2D-Bi layers epitaxially grown on HOPG/hBN/mica

Klaudia Toczek[1*], Maciej Rogala[1], Paweł Krukowski[1], Michał Piskorski[1], Maxime Le Ster[1], Iaroslav Lutsyk[1], Witold Kozłowski[1], Paweł Dąbrowski[1], Rafał Dunal[1], Aleksandra Nadolska[1], Przemysław Przybysz[1], Wojciech Ryś[1], Paweł J. Kowalczyk[1]

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Two-dimensional materials are of growing interest due to their unique chemical, physical, electronic, and optical properties. [1] Among them are those less understood from 15th group of the periodic table. This group includes bismuth, which can exist as 2D materials. It is a semi metal with minimal radioactivity. 2D Bismuth exists in two crystallographic structures – α-Bi (110) with a rectangular elemental cell and β-Bi (111) with a hexagonal elemental cell [2]. Bismuth is chemically low in activity but exhibits unusual electronic properties. These properties are of interest due to spin-orbital effects and surface and edge states [2]. It was in bismuth that many quantum phenomena such as magnetoresistance, quantum size effects and, more recently, topologically protected edge states were first detected [2,3]. It is extremely important to understand the growth and degradation pathways of this new material.

In this work, we will present the properties and morphology of bismuth nanostructures growing epitaxially on a conductive substrate - highly oriented pyrolytic graphite (HOPG) - as well as on insulating materials such as mica and hexagonal boron nitride (hBN), on which 2D bismuth islands can be observed to grow.

The growth of bismuth thin films was done in ultra-high vacuum, X-ray photoelectron spectroscopy to analyze the chemical composition of metallic and oxidized surfaces. Raman spectroscopy (in an inert atmosphere) was also used to identify the oxidized phase on the sample surface, and the surface topography of the oxidized layers was also studied in the atmosphere using atomic force microscopy.

The above research is supported by the National Science Center under the project no. 2019/35/B/ST5/03956. Research is also supported by the University of Lodz as part of the UniLodz IDUB- "Doctoral Research Grants" - 2022 edition, as part of project no. B2310009000186.07.

[1] A. Hayat et al. *Energy Storage Materials*, 2023, **59**, 10278
[2] P. J. Kowalczyk et al. *Surface Science*, 2011, **605**, 659.
[3] S. Pinilla et al. *Nature Reviews Materials*, 2022, **7**, 717.

Notes:

New class of massless fermions

R. Zdyb

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Graphene is the most known member of a broad family of two-dimensional (2D) materials which possesses linear band dispersion. Other 2Ds like Xenes, transition metal dichalcogenides and others also host Dirac fermions. The electronic bands usually have a form of cones, however, other similarly shaped bands including tilted cones, multi cones, hourglass fermions have been found in various systems revealing 2D or quasi 2D properties.

In 2017 Damljanović *et al.* [1] found a new class of massless fermions. According to the authors' theoretical calculations a full classification of linearly dispersed bands in two-dimensional materials allows to distinguish two different forms: well-known Dirac fermions together with their diverse types and a new class called fortune teller-like (FT) states. The new states reveal very unique electronic structure – it consists of a set of planes (pyramid-like and fortune teller-like) instead of the cones. The planes join each other and form very sharp edges in the *k*-space. Those two features, pyramidal and/or fortune teller-like energy dispersion bands/planes and very sharp edges, are among the most characteristic for the FT states and distinguish them from the Dirac-type massless fermions.

In this report we demonstrate experimental results confirming existence of a pure form of the fortune-teller states found in a quasi 2D layer [2]. We also demonstrate a new version of the fortune-teller fermions discovered in a wired form of antimonene [3].

This research was in part funded by the National Science Centre (Poland) under Grant No 2020/37/B/ST5/03540.

[1] V. Damljanović, I. Popov, R. Gajić, *Nanoscale*, 2017, **9**, 19337.
[2] M. Kopciuszynski, M. Krawiec, L. Żurawek, R. Zdyb, *Nanoscale Horiz.*, 2020, **5**, 679.
[3] A. Stępniak-Dybala, T. Jaroch, M. Krawiec, P. Dróżdż, M. Gołębiowski, R. Zdyb, *Nano Letters*, accepted.

Notes:

Identifying nanostructures at surfaces using STM/STS

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Scanning tunneling microscopy (STM) is a powerful tool that allows atomic-scale imaging of nanostructures at surfaces. The invention of STM also paved the way for the development of a family of local spectroscopic techniques denoted as scanning tunneling spectroscopy (STS). STS studies are usually based on the local measurement of the intensity of the tunneling current as a function of the applied bias voltage or the tip-sample distance. The method utilizes the precise tip positioning mechanism of STM, allowing recording spectroscopic curves with atomic precision. The STS dI/dV and dI/dz spectra provide information on the electronic properties of the studied objects, including the density of electronic states (DOS) close to the Fermi level (dI/dV with open feedback loop) and the work function (dI/dV with closed feedback or dI/dz with open feedback loop). This information often allows identifying surface species observed on STM images.

During the lecture, examples of the use of STM and STS for the studies of various iron oxide and iron nitride nanostructures grown on metal single-crystal surfaces will be presented. These will include ultrathin iron oxides islands on Ag(111) [1] and Ru(0001) [2], as well as iron nitride islands on Cu(001) [3]. In particular, it will be shown how our STM and STS results – combined with the data obtained by our collaborators using density functional theory (DFT) calculations – led to the development of new structural models.

The author would like to thank the Foundation for Polish Science (Polish "Fundacja na rzecz Nauki Polskiej") for financial support through the First TEAM/2016-2/14 (POIR.04.04.00-00-28CE/16-00) project "Multifunctional ultrathin Fe(x)O(y), Fe(x)S(y) and Fe(x)N(y) films with unique electronic, catalytic and magnetic properties" co-financed by the European Union under the European Regional Development Fund.

[1] M. Lewandowski et al., *Nanomaterials*, 2018, **8**, 828.

[2] N. Michalak et al., M. Lewandowski, *Adv. Mater. Interfaces*, 2022, **9**, 2200222.

[3] P. Wojciechowski et al., M. Lewandowski, *Vacuum*, 2023, DOI: 10.1016/j.vacuum.2023.112716.

Notes:

Novel cantilever MEMS technologies for scanning probe microscopy nanometrology

Bartosz Pruchnik[1,*], Dominik Badura[1], Ewelina Gacka[1], Damian Pucicki[1], Andrzej Sikora[1], Tomasz Piasecki[1], Bartosz Świadkowski[1], Tomasz Dąbrowa[2], Ivo Rangełow[3], Tito Busani[4], Andrew Yacoot[5], Andrzej Sierakowski[6], Paweł Janus[6], Teodor Gotszalk[1]

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Scanning probe microscopy (SPM) reaches absolute limits of achievable resolutions. Therefore, versatility and multimodality stand as a prime direction of development in SPM area. Novel microelectromechanical (MEMS) cantilever solutions aspire to improve methodology as a more agile measurement sensor [1]. Simultaneously, due to the advanced circuity inherited by MEMS cantilevers, they may be utilized as tools for nanomachining and nanoengineering [2]. Active cantilevers are gateway to the traceable measurements with SPM thanks to metrologically consistent calibration methods.

In the presentation we will show methods for calibration and application of MEMS active piezocantilevers in conductive atomic force microscope (C-AFM). Methods for tip functionalization and tool-efector tip engineering will be presented, as well as nanoengineering of MEMS cantilever properties.

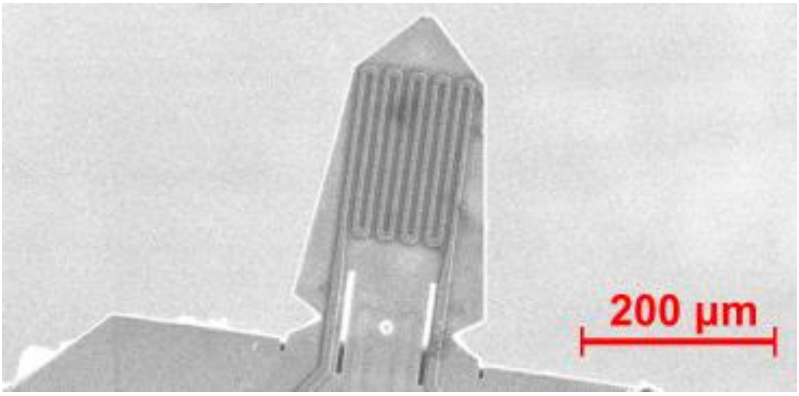

Figure 8. Novel Ω-cantilever from nano analytik GmbH – exemplary case of MEMS for SPM solution.

[1] I. Stricklin, T. Gotszalk, M. Behzadirad, E. Manske, T. Kissinger, I.W. Rangelow, T.L. Busani, *J. Vac. Sci. Technol. B*, 2023, 41, 042601
[2] S.A. Yianni, M.Hofmann, A.K. Schenk, C.Reuter, I.W. Rangelow, C.I. Pakes, *Appl. Phys. Lett.* 2022, 120, 093503

Notes:

Identification of electrical properties of third/fourth generation solar cells in nano-, micro- and macroscale.

Marcin Palewicz[1,*], Tomasz Piasecki[1], Andrzej Sikora[1], Ewelina Gacka[1], Teodor Gotszalk[1], Bożena Jarząbek[2], Paweł Nitschke[2], Paweł Gnida[2], Marek Lipiński[3], Sylwester Sahayaraj[3], Zbigniew Starowicz[3]

[1] Department of Nanometrology, Faculty of Electronics, Photonics and Microsystem, Wroclaw University of Science and Technology, Janiszewskiego 11/17, Wroclaw, 50-372, Poland
[2] Centre of Polymer and Carbon Materials, Polish Academy of Sciences, 34 M. Curie-Skłodowska Str, Zabrze, 41-819, Poland
[3] Institute of Metallurgy and Materials Science, Polish Academy of Sciences, 25 Reymonta St, Krakow, 30-059, Poland

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In order to identify the electrical parameters of multilayer photovoltaic devices in nano- , micro- and macro-scale, advanced modes of atomic force microscopy (AFM) and impedance spectroscopy (IS) techniques should be used. In articles [1, 2] IS method has been implemented to evaluate the electrical properties of third generation devices such as bulk heterojunctions organic solar cells (BHJ OSC) and estimation of relaxation times. Moreover, in papers [2, 3], authors used Kelvin Probe Force Microscopy (KPFM) to measure surface potential and calculate the surface photovoltage in dark and light. On the figure 1., the surface potential on top of perovskite solar half-cell is shown. I addition, a unique experimental approach was implemented [1-3] while investigating the response of tested objects in the dark and under the illumination with various wavelengths.

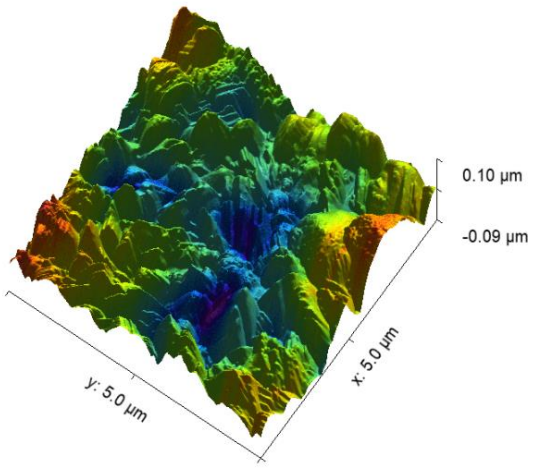

Figure 1. 3D representation of surface potential added on the top of topography of PVK.

[1] B. Jarząbek, P. Nitschke, M. Godzierz, M. Palewicz, T. Piasecki and T. P. Gotszalk, *Polymers*, 2022, **14**, 858.
[2] M. Palewicz, A. Sikora, T. Piasecki, E. Gacka, P. Nitschke, P. Gnida, B. Jarząbek and T. Gotszalk, *Energies*, 2023, **16**, 4741.
[3] S. Sahayaraj, Z. Starowicz, M. Ziółek, R. Socha, Ł. Major, A. Góral, K. Gawlińska-Nęcek, M. Palewicz, A. Sikora, T. Piasecki, T. Gotszalk and M. Lipiński, *Materials*, 2023, **16**, 5352.

Notes:

Single Filament Bio-Mechanical Study of Type 3 Secretion System Reveals High Elastic Aspect Ratio

Moran Elias-Mordechai[1], Nofar David[2], Sonia Oren[2], Jürgen Jopp[3], Boris Fichtman[4], Amnon Harel[4], Neta Sal-Man[2], and Ronen Berkovich[1,3,*]

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[3] The Ilse Katz Institute for Nanoscale Science and Technology, Ben-Gurion University of the Negev, Beer Sheva 8410501, Israel

[4] Azrieli Faculty of Medicine, Bar-Ilan University, Safed, Israel

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Type III secretion systems (T3SSs) are syringe-like protein complexes used by some of the most harmful bacterial pathogens to infect host cells. While the T3SS filament, a long hollow conduit that bridges between bacteria and host cells, has been characterized structurally, very little is known about its physical properties. These filaments should endure shear and normal stresses imposed by the viscous mucosal flow during infection within the intestinal tract. We used atomic force microscopy (AFM) to probe the longitudinal and radial mechanical response of individual T3SS filaments by pulling on filaments extending directly from bacterial surfaces and later pressing into filaments that were detached from the bacteria. The measured longitudinal elastic moduli were higher by about two orders of magnitude than the radial elastic moduli. These proportions are commensurate with the role of the T3SS filament, which requires horizontal flexibility while maintaining its structural integrity to withstand intense stresses during infection.

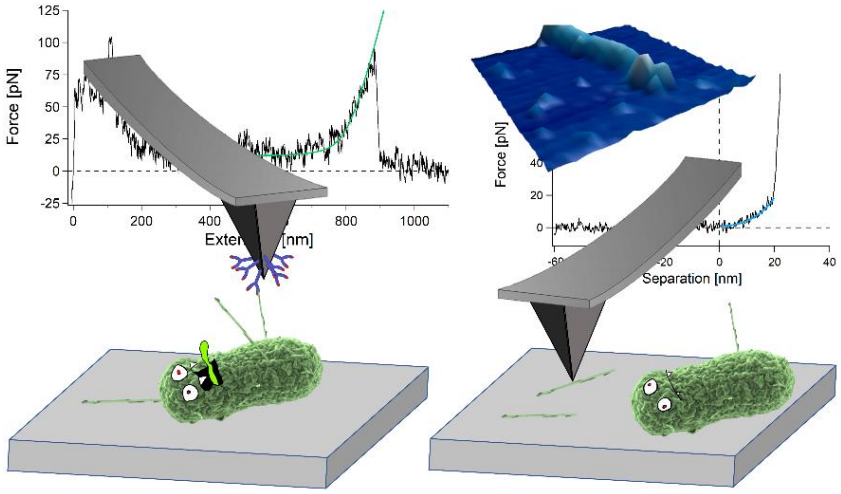

Figure 9. The mechanical response of individual T3SS filaments was measured by pulling on filaments extending out from bacterial surfaces and by pressing into detached filaments.

Notes:

Infrared scattering-SNOM for chemical mapping of soft matter

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Scattering Scanning Near-Field Optical Microscopy (s-SNOM) operating in the infrared (IR) range has brought real chemical sensitivity to scanning probe microscopy, enabling chemical mapping of surfaces with unprecedented XY resolution (below 20 nm) as compared to far-field infrared microscopy. In particularly, this method may be useful in imaging of soft matter samples (e.g., polymers, biological samples) while working in semicontact mode that is not destructive for such materials. Both absorption maps at selected wavenumber characteristic of a given chemical groups as well as IR absorption spectra at various locations can be captured and analyzed for the unambiguous chemical assignment of various surface features.

Fundamentals of s-SNOM technique will be presented together with examples of its application for imaging of soft matter focusing on nanoheterogenous samples. As examples phospholipid bilayers [1], mixed polymer brushes (Figure 1) [2], and erythrocytes will be presented among other systems.

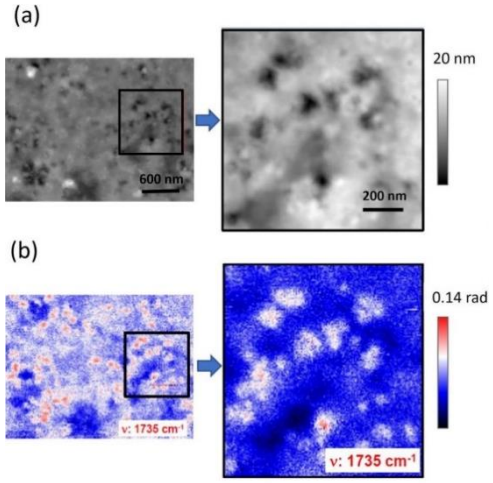

Figure 10. (a) AFM topography images and (b) the corresponding IR absorption maps captured for mixed polymer brushes at 1735 cm^{-1} that is absorbed only by one component of the brushes.

[1] A. Cernescu, M. Szuwarzyński, U. Kwolek, P. Wydro, M. Kepczynski, S. Zapotoczny, M. Nowakowska, L. Quaroni. *Anal. Chem.* 2017, **90**, 10179-10186.

[2] K. Wolski, J. Smenda, A. Grobelny, P. Dąbczyński, M. Marzec, A. Cernescu, M. Wytrwal, A. Bernasik, J. Rysz, S. Zapotoczny. *J. Colloid Interface Sci.* 2023, **634**, 2009-2020.

Notes:

2D-supramolecular organization of liquid crystal bi- and ter-phenyl-based nonsymmetric dimers

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Liquid crystal dimers are molecules consisting of two rigid mesogenic moieties interconnected by a flexible linker usually, but not always, an alkylene- or oligoether-type. Currently, these compounds are of great interest due to their unique supramolecular properties, e.g. strong parity effect (different arrangements of dimers containing an even and an odd number of repeating units in the linker), or the ability of these non-chiral molecules to form a fascinating and complex chiral twist bend nematic phase. All these properties are interesting from the point of view of basic research, and also in terms of potential applications in modern technologies.

Previously, we used tunneling microscopy to study 2D self-assembly of symmetric cyanobiphenyl dimers on the HOPG surface [1]. Studies performed on a series of homologues with different linker lengths enabled visualization at molecular resolution and analysis of their ordering, including the parity effect and the formation of a chiral structure. In the current presentation, we will present new results on the self-assembly of nonsymmetrical dimers in which both mesogenic units are chemically different. It should be emphasized that symmetric dimers typically tend to form smectic phases with a characteristic monolayer structure, in which the thickness of each particular layer corresponds to the length of the dimer. The main advantage of nonsymmetric dimers is the possibility of exploiting the specific interactions of various mesogenic units adjacently located in the molecular layer. As a consequence, these molecules can form smectic phases exhibiting much more complex distribution of intermolecular interactions and varying degrees of intercalation [2]. An important and difficult issue is the optimization of the mesogenic units by revealing the correlation between their structure and the ability to form complex liquid crystal phases with the desired properties. The presented examples concern nonsymmetric dimers of two families characterized by the following mesogenic units: i) cyanobiphenyl connected to pyrenyliminophenoxy, ii) cyanoterphenyl connected to benzylideneaniline. The compounds were synthesized in the group of professor Corrie C.T. Imrie (University of Aberdeen, UK).

This work has been supported by the National Science Centre (Poland) under OPUS23 Grant No. 2022/45/B/ST5/02120

[1] K. Krzyżewska et al. *Nanoscale* 2018, **10**, 16201
[2] C.T. Imrie et al. *Crystals* 2022, **12**, 1245

Notes:

Highly Hydrophobic Self-Assembled Monolayers on Technologically Relevant Aluminum Surface

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Aluminum, naturally covered by an oxide layer, is an affordable material with a wide range of technological applications. Its potential might be further enhanced by the functionalization with self-assembled monolayers (SAMs). In fact, carboxylic acids SAMs are customarily applied on aluminum to create superhydrophobic coatings, or to modify the gate dielectric morphology for the fabrication of high-mobility organic transistors. However, even though the performance of the final device is closely related to the quality and structure of the monolayer,[1,2] no systematical analysis of the impact of the preparation conditions on the quality of the carboxylate SAMs on aluminum oxide has been conducted so far. In the current work,[3] we analyze the influence of the three crucial factors (i.e., type of solvent, immersion time, and incubation temperature) on the quality of the heptadecanoic acid monolayer prepared by the standard immersion procedure. Several complementary techniques (IRRAS, XPS, NEXAFS spectroscopy, and water contact angle) are combined to demonstrate a critical role of solvent choice in terms of monolayer order, orientation, thickness, and wettability. Subsequently, employing optimized preparation strategy, we investigate the possibility of creating highly hydrophobic coatings on the surface of aluminum films prepared in different evaporation procedures. By corelating AFM measurements with contact angle goniometry, we demonstrate that increased roughness of our substates leads to creation of SAMs that show higher contact angle than reported before for this class of molecules on unstructured aluminum surface.[4] As a result, we propose a simple method to create highly hydrophobic coatings that may be easily applied to many substrates.

[1] Lee et al., J Am Chem Soc., 2008, 130, 10556-10564
[2] Lang et al., Appl Surf Sci., 2016, 365, 364-375
[3] Cegiełka et al., Appl. Surf. Sci., 2023, 636, 157798
[4] Liakos et al., Surf. Interface Anal., 2004 36, 347-354

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Notes:

Modification of MoS_2/Au Interface By Force Spectroscopy At Nanoscale For Resistive Switching Applications

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Resistive switching effect is the ability of the material to reversibly change its conductivity after the electrical stimulation. One of the main desirable applications of this is the technology of non-volatile computer memory, where distinguishable conductivity states represent logical states of the memory cell. The promising group for this application are 2D materials which are now intensively studied due to their atomically thin structure, outstanding mechanical properties, or electronic structure covering a wide range of properties from insulators to conductors or even superconductors. One of the most widely investigated 2D materials for resistive switching applications is MoS_2 due to the moderate band gap, high environmental stability, and ease of exfoliation and fabrication.

Charge transport from an electrode to 2D layers during resistive switching and the efficiency of devices made with 2D materials or their heterostructures relies highly on the quality of the material/substrate interface. In our work we focused on investigating MoS_2 and Au interaction at the interface by nanoscale force spectroscopy. We fabricated our samples with a standard tape exfoliation procedure on Au (111). We observed that applying a certain force with nanoprobe resulted in the modification of MoS_2/Au interface which is visible as the deformation of the layer. We explain the observed phenomena as correlated to a strong MoS_2/Au interaction. We show that a change in the morphology leads to a change in the electronic structure of the layer. With the use of KPFM we observed work function changes in the layer before and after morphology modification. We did not observe

a similar effect for the reference samples on SiO_2. Our research is an important step for better understanding the nature of MoS_2 and gold interaction in resistive switching devices.

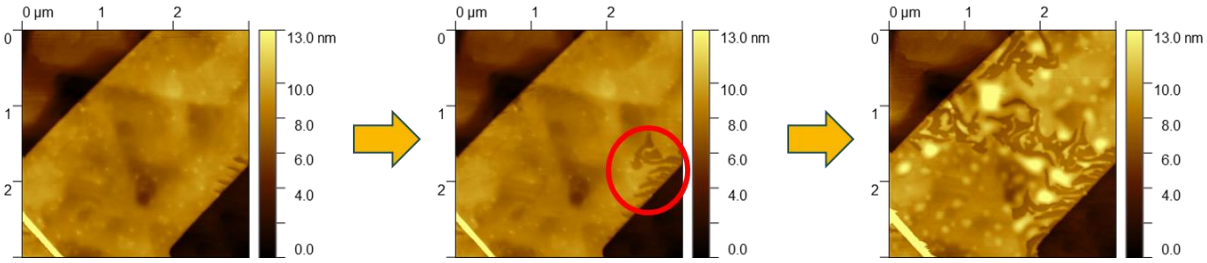

Figure 11. Changes in the morphology of the MoS_2 layer after mechanical stimulation with nanoscale force spectroscopy.

This work was supported by National Science Center, Poland, under the Grant 2020/38/E/ST3/00293.

Notes:

Dynamically altered conductance in organic thin film memristive devices

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A memristive device is a two-terminal passive element in which the resistance evolves with time under applied stimuli. Memristive circuits that mimic biological neurons and synapses could offer high-speed operation and low power consumption, enabling energy- and area-efficient, brain-inspired computing. Since the first demonstration, the memristive effect has been reported for many different systems, but only a few of those reports have been related to devices based on organic materials. Recently, we have demonstrated a memristive effect in simple planar devices with architecture similar to that of an organic field-effect transistor, in which the gate electrode was exchanged by an insulating layer doped with mobile ions. The conductance of the channel induced in the organic semiconducting layer changes dynamically with applied voltage, manifesting itself in a pinched hysteresis loop in the current-voltage characteristics - the trait of memristive behavior. Results of in situ secondary ion mass spectrometry and temperature-dependent I-V measurements prove that the ion displacement induced by the applied electric field is responsible for the changes of the conductance. The change of the ion mobility offers a unique possibility of fine-tuning the relaxation time in the system.

Notes:

Magnetization switching of ferromagnetic thin film without applying a magnetic or electric field induced solely by adsorption of chiral molecules

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Enantioselectivity is ubiquitous in nature and many of the molecules in plants and living organisms have their properties depending on the type of enantiomer. Accordingly, chromatography-based enantioseparation requires the chiral substrate to be adjusted so as to interact optimally with a specific enantiomer. Indeed, enantioseparation is an extremely important process in the pharmaceutical and chemical industries. However, despite intensive efforts, obtaining enantiomerically pure synthetic materials remains a challenge, as the cost of separation is relatively high and an extensive effort is required. We have demonstrated [1] a new effect of magnetization switching of ferromagnetic thin film without applying a magnetic or electric field but being induced solely by adsorption of chiral molecules. In this case, about 10^{13} electrons per cm2 are sufficient to induce magnetization reversal. The direction of the magnetization depends on the handedness of the adsorbed chiral molecules Here magnetization switching of FM thin layers is induced solely by adsorption of chiral molecules (magnetism induced by a proximity of adsorbed chiral molecules - MIPAC). The local magnetization switching is achieved by adsorbing the chiral molecules as a self-assembled monolayer (SAM) on a gold-coated FM layer with perpendicular magnetic anisotropy. The direction of the magnetization depends on the handedness of the adsorbed chiral molecules. Owing to spin-selective electron transfer, the FM layer underneath the SAM molecules becomes spin polarized, and hence magnetization direction is determined. Rrecent studies have suggested that charge redistribution in chiral molecules manifests an enantiospecific preference in electron spin orientation. Therefore it is possible that the induced spin polarization may affect enantio-recognition through exchange interactions. We have shown experimentally [2] that the interaction of chiral molecules with a perpendicularly magnetized substrate is enantiospecific. Thus, one enantiomer adsorbs preferentially when the magnetic dipole is pointing up, whereas the other adsorbs faster for the opposite alignment of the magnetization. The interaction is not controlled by the magnetic field per se, but rather by the electron spin orientations, and opens prospects for a distinct approach to enantiomeric separations. The enantioselective interaction of chiral molecules and a magnetic substrate with perpendicular anisotropy provides a potentially generic chromatographic method for enantioseparation, which does not require a specific and costly separating column. As the observed effect depends on the electrical polarization of the system (that is accompanied by spin polarization) and because this polarization depends on the global structure of the chiral molecule, this new method may also allow the separation of chiral molecules from a mixture of molecules, either chiral or achiral.

[1] O. Ben Dor, S. Yochelis, A. Radko, K. Vankayala, E. Capua, A. Capua, S.-H. Yang, L. T. Baczewski, S. S. P. Parkin, R. Naaman, Y. Paltiel, Nature Commun. 8, (2017), 14567

[2] K. Banerjee-Ghosh, O. Ben Dor, S. S. P. Parkin, S. Sarkar, L. Kronik, L. T. Baczewski, R. Naaman, Y. Paltiel et.al Science, Vol. 360, Issue 6395, (2018), 1331

Notes:

Using polymer processing techniques to obtain domains with Single Ion Magnets

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Using a new approach to combine polymer science and molecular magnetism, we obtained a new material that combines merits of both these groups: Co(II)-based Single Ion Magnets exhibiting field-induced slow magnetic relaxations embedded in a polymer matrix (poly(4-vinylpyridine), P4VP), cross linking it. We also obtained a thin film of this material, preserving its qualities.[1] Taking this approach one step further, we used phase separation of polymer mixes to obtain domains that selectively adsorb $CoBr_2$, yielding functional domains that can be controlled by simple mass ratio of the polymers used in the mix. P4VP with polystyrene (PS), mixed in a common solution in various mass ratios were spun-cast onto silica substrates, self-organizing into phase-separated films with domains in sizes depending on the mass ratio. These films were then immersed in a solution of $CoBr_2$ in a solvent orthogonal for both polymers. While the P4VP domains, as shown previously, adsorbed the metal salt forming the aforementioned material, PS domains remained unaltered. All the films were characterized by Atomic Force Microscopy and Secondary Ion Mass Spectroscopy, confirming that we indeed obtained functional magnetic domains. Studies of the influence of magnetic field on domains topography will also be presented.

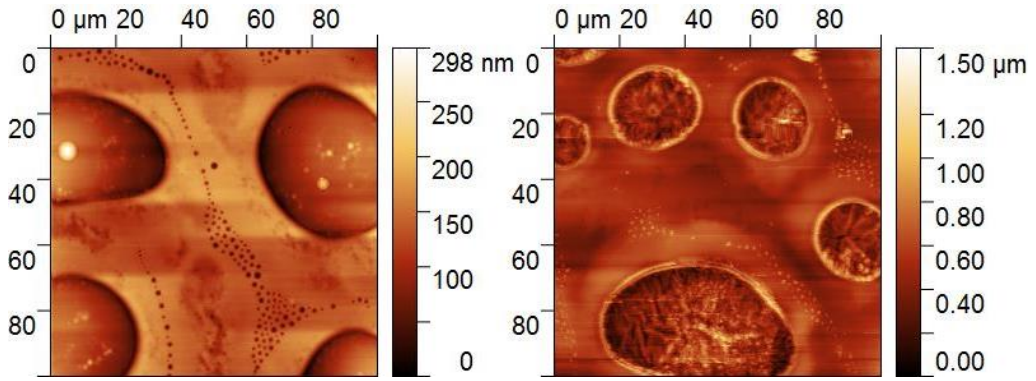

Figure 12. Atomic Force Microscopy topography images of P4VP domains in PS thin films before (left) and after selective adsorption of $CoBr_2$ (right).

[1] A. Majcher et. al., *Chem. Sci*., 2018, **9**, 7277.

Notes:

Iron-based magnetic materials for application in recording devices – DFT studies of thin films

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Technological development, including recording media, currently focuses mainly on the miniaturization of circuits and increasing their efficiency and speed of operation. It is required to have a reading and writing method and appropriate materials that meet the requirements for their use while maintaining the smallest possible size. Hence, there is a great interest in materials such as nanotubes, nanoparticles, or ultrathin films with thicknesses ranging from single atomic monolayers. However, their size causes a radical change in properties. One way to study them is to perform calculations using density functional theory (DFT).

Using DFT implemented in the full-potential local-orbital (FPLO 18.00) code, we carried out a series of research on the structural and magnetic properties of various iron-based systems, starting from the FePt $L1_0$ bulk system [1] through studies of ultrathin FePt $L1_0$ layers [2], FeNi $L1_0$ layers, to $Fe_{0.7}Co_{0.3}$ and $Fe_{0.7}Co_{0.3}$-X alloy layers (where X = B, C or N) [3]. To simulate disorder in FeCo systems, virtual crystal approximation was used. In $L1_0$ systems, this research allowed for examining the influence of layer thickness on magnetic properties such as the values of magnetic moments, magnetization direction, and magnetocrystalline anisotropy energy (MAE). Layers with a 9-monolayer thickness of FeCo and FeCo-X allowed us to look at the effect of doping on the fundamental structural, electronic and magnetic properties.

We acknowledge the financial support of the National Science Centre Poland under DEC-2018/30/E/ST3/00267.

[1] J. Marciniak, W. Marciniak, M. Werwiński, *Journal of Magnetism and Magnetic Materials,* 2022, **556**, 169347.

[2] J. Marciniak, M. Werwiński, *arXiv,* 2023, arXiv:2303.15877.

[3] J. Marciniak, M. Werwiński, J. N. Rychły-Gruszecka, (2023), doi.org/10.2139/ssrn.4535400.

Notes:

Means of Control over Poly(4-vinylpyridine)-$CoBr_2$ Complexes Functional Thin Films Formation in Static and Dynamic Conditions

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The presented work focuses on the kinetics of formation of *d*-block metal complexes in the top layer of polymer films. The studied material (poly(4-vinylpyridine)-$CoBr_2$) has already proven its interdisciplinary value: it successfully combines the advantages of polymers and Single Ion Magnets that exhibit magnetic relaxations[1] and has also found applications in organic field-effect transistor-like geometries, leading to an extraordinary conduction increase by four orders of magnitude.[2]

Our newest research focuses on the ways to control the concentration of the said complexes within the thin film (studied by Secondary Ion Mass Spectrometry), as well as elucidating the interplay between $CoBr_2$ adsorption and topography changes (top layer stiffening-induced surface wrinkles emergence studied by Atomic Force Microscopy). This was done in two ways: both static (dependence on the concentration of the cobalt) and dynamic (dependence on the time of immersion).

The kinetics of salt adsorption is characterised by a double breakthrough process that can be described by the Yoon-Nelson model[3], the first of which coincides with the appearance of the wrinkles.

The time of both breakthroughs occurrence for different submerging velocities has been studied, described and explained for both processes in dynamic studies. Static studies showed that the adsorption depends on changing topology of the surface, which in turn affects adsorption. To describe the process, modified Freundlich-Langmuir isotherm was fitted separately in region without and with wrinkles.[4] Before wrinkles appearance, the *n* parameter was equal to 1,00(47), quantitatively proving behaviour in accordance with Langmuir's assumptions. For concentrations that result in wrinkled topology *n* was 1,88(68), which proves that the adsorption model approaches Freundlich isotherm.[5]

We believe that this research will prove immensely useful in tuning the metal ion concentrations within device prototypes, possibly both in plastic electronics and in functional magnetic films.

[1] A.M. Majcher et.al., *Chem. Sci*., 2018, **9**, 7277, [2] P. Dąbczyński et.al., *Appl. Mater*. Today, 2020, **21**, 100880, [3] Y.H. Yoon and J.H. Nelson, *Am. Ind. Hyg. Assoc*. J., 1984, **45**, 509–516, [4] S. Azizian et.al., *Chem. Phys*., 2018, **513**, 99–104, [5] M. Ghaedi. Adsorption: Fundamental Processes and Applications. Elsevier, 2021, 7-8, 461-462.

Notes:

Magnetic tuning of nanomechanical spectroscopy in a freestanding graphene quantum dot

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Quantum spectroscopy of freestanding graphene [1] in magnetic field, ordinarily pursued by electronic conductance, is realized non-invasively. The nanomechanical dissipation of a pendulum-AFM oscillating hundreds of nm above a graphene nanodrum suspended above a hole-patterned substrate at variable tip voltages cause electronic transitions to occur inside a portion of graphene, that acts as an effective quantum dot [2]. Transitions give rise to tip frequency jumps and simultaneous dissipation peaks whose spectrum identify levels with their characteristic diamagnetic shifts, from B=0 to 1.2 T. Comparison of this evolution with calculated B-dependent spectra reveals an effective dot size around 80 nm, typical of a large static membrane deformation defect, independently revealed by so-called dissipation Coulomb rings. Interestingly, neither the larger nanodrum diameter of order 6 um, nor the local graphene wrinkling on a 2 nm scale play a major role. Calculations confirm the inability of wrinkles to act as quantum dot boundaries, in agreement with Klein tunneling.

[1] A. K. Geim and K. S. Novoselov, *Nature Materials* 6, 2007, 183.

[2] D. Halbertal D, J. Cuppens, M. Ben Shalom, et al. Nanoscale thermal imaging of dissipation in quantum systems. *Nature* 539(7629) 2016, 407-410.

Notes:

POSTER PRESENTATIONS

(Odd numbers – Thursday
Even numbers – Friday)

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P1

Concept of multiprobe nanoscopic robot station

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Technologies of correlated near-field interaction microscopy combined with nanorobotic technologies open up remarkably flexible possibilities not only for observing structures at the micro and nanoscale, but also for their metrology, manipulation and modification. Using various types of probes, it is possible to carry out measurements of thermal and mechanical properties of structures as well as their electrical properties. Such structures can exist, among others, in the form of nanoelectronic systems as well as microbiological objects.

The concept of a nanorobotic station equipped with a set of effectors in the form of measuring probes and tools, including piezoresistive cantilevers, will be presented. The system will make it possible to perform operations with a resolution of up to single nanometers, and to make observations in a field of hundreds of micrometers. The developed technology will allow measurement and fabrication of micro and nanostructures by correlated electron microscopy and near-field interaction methods at elevated temperatures (≥ 77K).

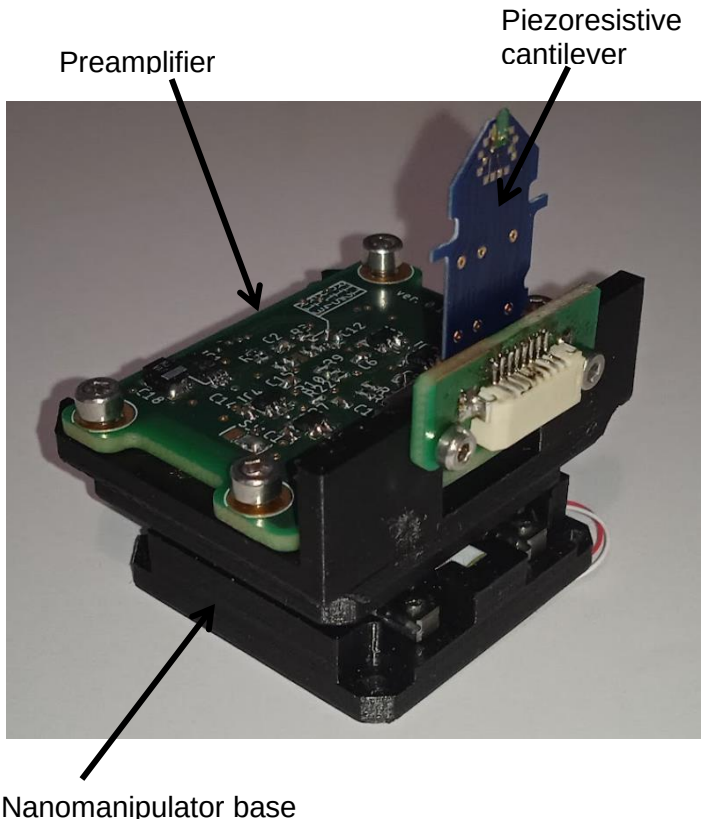

Figure 1. Example of single stage nanomanipulator with stick-slip piezoelectric actuator and piezoresistive cantilever as an end effector

P2

Microscopic studies on rutile TiO_2(011) surface exposed to ethanol vapor

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The (011) face of rutile TiO_2 upon exposure to ethanol vapor was studied by scanning tunnelling microscopy (STM) and thermally-programmed desorption (TPD). The lab-build Liquid Injection System (LIS) [1] was used to deliver ethanol onto the sample in vacuum condition. The sample preparation as well as STM measurements were taken at room temperature (RT). Microscopic studies on prepared surface revealed the commensurate superstructure made of ethanol molecules. Heating Rate Variable analysis (HRV) [2] allowed to estimate the activation energy for ethanol desorption $E_d = 0.66 \pm 0.06$ eV.

[1] Pat. PL 243789: Method of applying liquid to an object in a vacuum system and a vacuum system for applying liquid to an object. L.Bodek, B.Such, 2023.

[2] Flash desorption activation energies: DCOOH decomposition and CO desorption from Ni (110). J.L. Falconer, R.J. Madix, Surf. Sci. 1975, **48**, 393.

P3

Scanning Tunnelling Microscope DIY

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This is a basic version of a scanning tunneling microscope that can be built under home conditions. The project is characterized by relatively low costs of components needed for its implementation and a wide range of possibilities for further improvement and expansion.

The constructed device allowed to obtain an image of the atomic structure of the HOPG (Highly oriented pyrolytic graphite) sample in room conditions.

Figure 13. The Scanning Tunneling Microscope configuration. The STM scan head with vibration isolation system with background electronics. The acquired image of the HOPG atomic structure in the left corner [1].

[1] References text: https://github.com/ComplexityGarage/Scanning-Tunnelling-Microscope-DIY/

P. Chmolewski

P4

Innovative Metalworking System Based on Advanced Big Data Analysis

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The presented results of the project encompass the effects of various cutting methods (laser, plasma, and CNC cutting) on the quality of the resulting edges, specifically focusing on nano and micrometer-scale roughness. The research involved typical steel grades commonly used in the industry, including carbon and stainless steel. The objective was to correlate roughness measurements taken at the nanometer scale with optical images.

The primary challenge of the project was to conduct measurements on actual cutting surfaces formed during equipment operation in industrial conditions. Statistical methods were employed to process the extensive dataset, comprising thousands of measured edges. The analysis of both AFM (Atomic Force Microscopy) and data obtained from optical microscopy and the laser profilometer was performed in the automatic manner. Thanks to the correlations established, methods for optimizing the cutting process and achieving results in line with industry standards were developed using artificial intelligence.

This project had a practical, applied nature and relied on data from AFM, laser profilometry, and optical microscopy. Notably, the results from this project have been successfully implemented in the operations of Biga Stal Piotr Bicz Spólka Jawna, a company in which we take a special pride.

Acknowledgments

The project received co-financing from European funds under the program 'Innovative Metalworking System Based on Advanced Big Data Analysis,' with funding provided under project number RPMP.01.02.01-12-0190/18-00 by the Intermediate Body Małopolskie Centrum Przedsiębiorczości, totaling EU PLN 1,534,621.71.

P5

Fabry-Perot optical fiber interferometer for scanning probe microscopy applications

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The purpose of the presented work is to design an optical fiber Fabry-Perot interferometer for scanning probe microscopy (SPM) investigations. Its compact architecture, especially fiber structure, makes the proposed instrumentation suitable for the metrology of the micromechanical cantilevers - Fig.1. The designed systems record interferometric fringes, thus the cantilever deflection can be calibrated basing on the known wavelength of the applied laser (in our case single mode semiconductor 1.3 μm laser diode) - Fig. 2. The designed system should exhibit resolution of 10 pm with the selectivity of 10 Hz, in the bandwidth of up to 2 MHz). The fiber architecture makes it also possible to direct at the measured microstructure laser beams of two wavelengths, thus investigations of the optomechanical phenomena including the so, called photonic cooling will be possible.

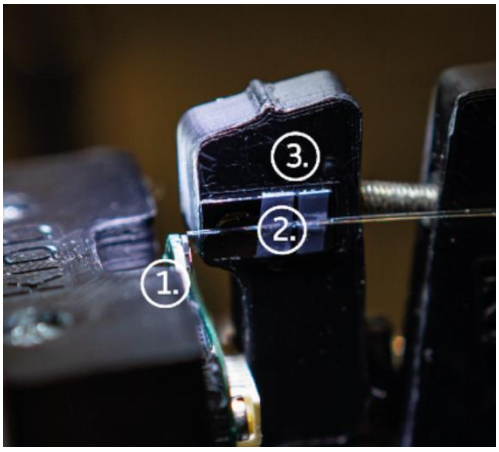

Fig. 1. Optical fiber and a cantilever in the interferometer socket (where: 1 – cantilever, 2 – optical fiber, 3 – optical fiber holder) [1]

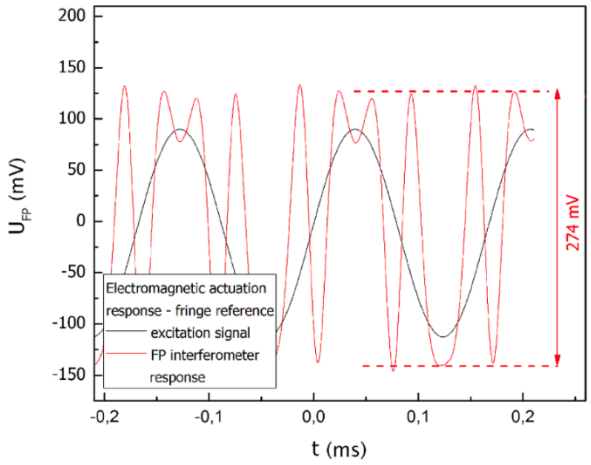

Fig. 2. Fabry Perot response-interferometric fringes recorded when the structure was moved at the distance larger than λ/4 (where λ is the laser wavelength) [1]

[1] K. Orłowska, B. Świadkowski, A. Sierakowski, T. Gotszalk, Meas. Sci. Technol., 2022, 33, 027001

P6

Atomic-Scale Friction on MoS_2 Layers Strained by Substrate Roughness and Vacancy Defects

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Atomic force microscopy (AFM) is a very suitable tool to investigate the friction behavior of solid surfaces on the nanometer scale. After pioneer applications of this technique to bulk crystal surfaces, significant research is in progress on two-dimensional (2D) materials aimed to be used as solid lubricants and/or protective coatings. In this contribution we present AFM-based nanofriction measurements on MoS_2 layers grown on amorphous SiO_2 by carbon vapor deposition (CVD). The goal is to understand the influence of the rough MoS_2/SiO_2 interface under different loading conditions, and the role of point defects such as crystal vacancies as pinning sites in the sliding motion. Numeric simulations aimed to support the experimental results are in progress.

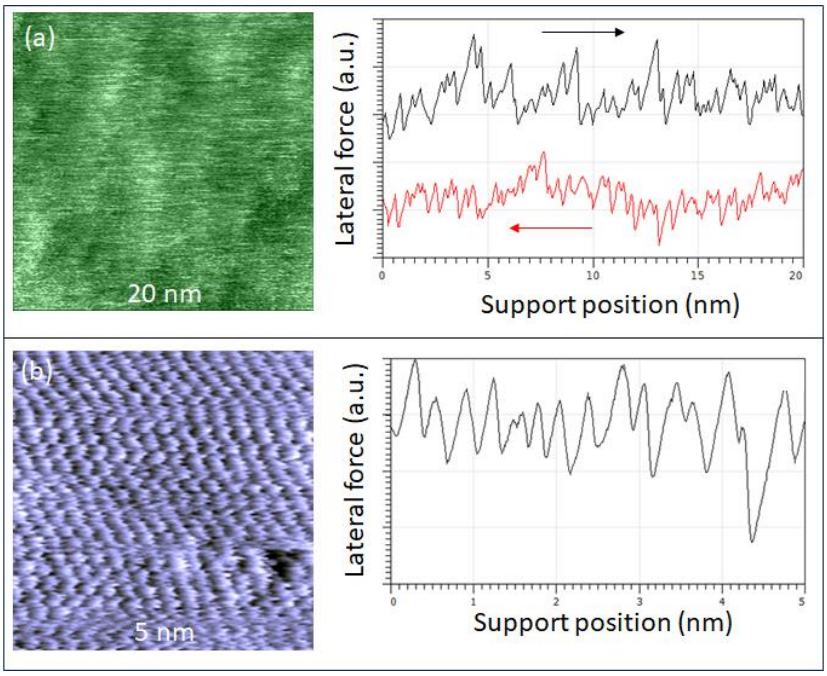

Figure 14. Atomic-scale stick-slip on a rough MoS_2 surface (a) under high loading conditions and (b) across a monatomic vacancy.

P7

Architecture and control of the “scanning probe” type atomic force microscope system

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Atomic force microscopy (AFM) enables high resolution investigations of the sample surface. This is usually achieved when a small sample is placed on a piezoelectrical XYZ scanner. In order, to image a surface of the much larger structures this architecture must be modified, which means that the probe is integrated with a XYZ scanner, and the large sample is stationary (Fig. 1a). In our design, the position of the XYZ scanner and the probe is adjusted by a set of 3 DC mikes (Fig. 1b). The angular position of the head must be known and controlled in order to enable sample scanning in the full range of the XYZ actuator. The mutual position is measured by a set of MEMS inclinometers with resolution of 0.004 degrees in XY axis of the head and the sample platform. The smallest step of the coarse approach done by three DC mikes is 200 nm and is smaller than the range of the Z piezoactuator. In this work we will present the system architecture and its operation including properties of the developed software.

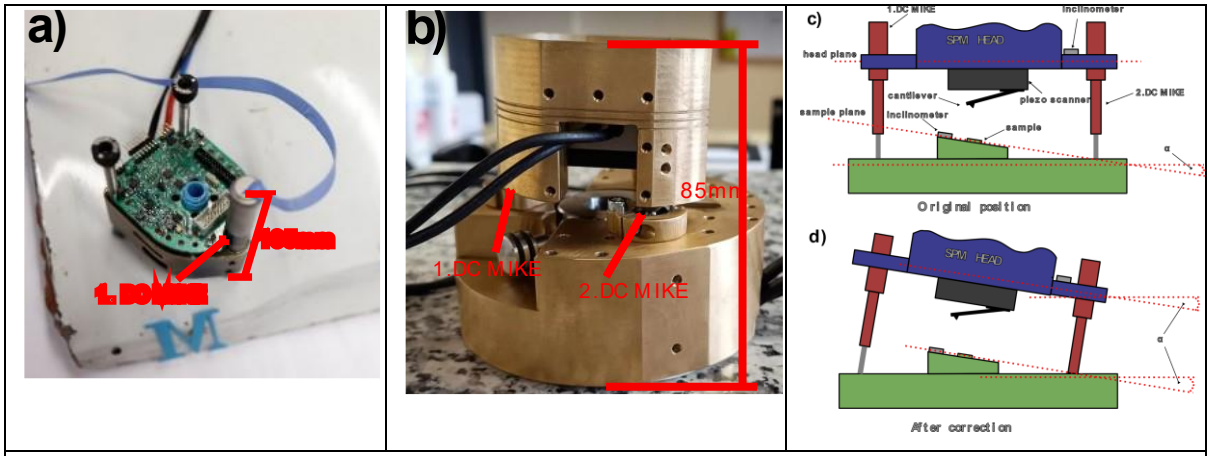

Fig. 1. Scanning probe stage measuring the car hood surface a) Architecture of the scanning probe AFM head b) Schematic diagram of working principle before adjustment c), Schematic diagram after adjustment d).

P8

High Resolution Optical Beam Deflection Measurement Heads for Scanning Probe Microscopy Investigations

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In scanning probe microscopy (SPM) high resolution detectors of micro- and nanostructure deflections are used. In this work we present a family of optical beam deflection (OBD) instruments for surface and cantilever type micro-electromechanical systems (MEMS) investigations. The design is compact ensuring low drifts and resistance to disturbance. The OBD head integrates a precisely controlled laser source, m an optics directing laser beam on the cantilever and a four segmented photodiode. In order to ensure the highest signal to noise ratio (SNR) a basic photodetector detection electronics is mounted on the head [1]. The developed devices detect the thermomechanical cantilever vibrations proving the instrument resolution. We present solutions making it possible to integrate with the OBD setup an electronics for the conductive atomic force microscopy (C-AFM), scanning thermal microscopy (SThM) and Kelvin probe force microscopy (KPFM)-fig. 1.

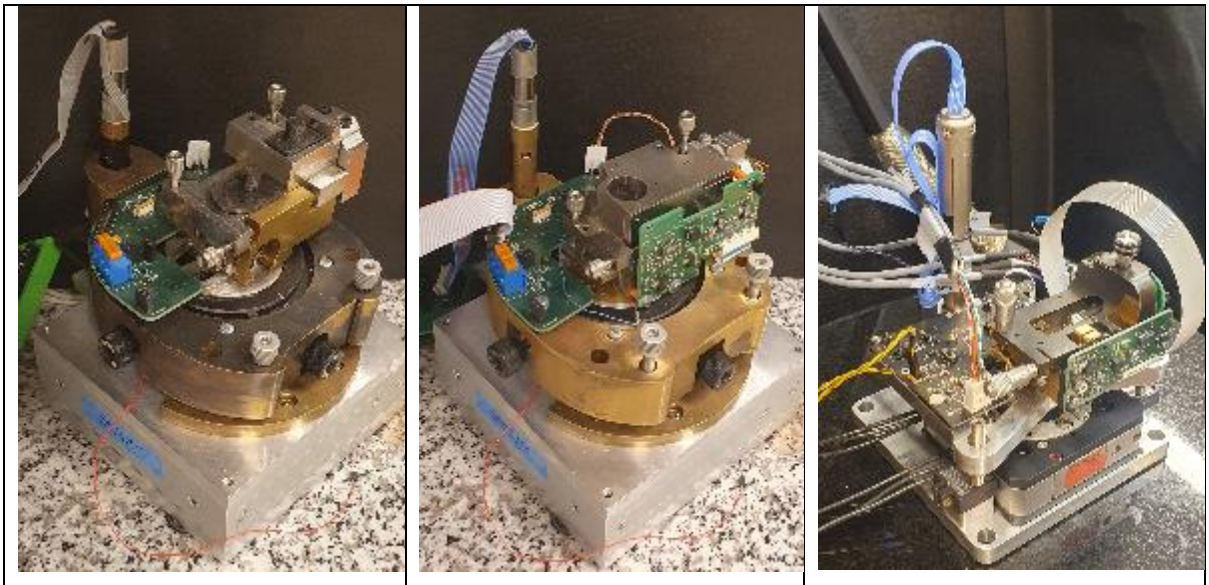

Figure 15. a) Bismarck OBD Head (C-AFM) b) Orzeł OBD Head (SThM) c) Luxtorpeda OBD Head (AFM/KPFM)

[1] D. Kopiec, W. Majstrzyk, B. Pruchnik, E. Gacka, D. Badura, A. Sierakowski, P. Janus, T. Gotszalk. Metrol. Meas. Syst., Vol. 28 (2021) No. 4, pp. 627–642

P9

Novel MEMS solutions for scanning probe microscopy technologies

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Recent developments in MEMS technology have led to the creation of highly miniaturized, integrated, high-performance structures for application in nanometrology. Such advancements are particularly evident in scanning probe microscopy derived measurement techniques. In this paper, we present several developments of nanoprobes and calibration samples for application in nanometrology and SPM techniques manufactured using combination of various MEMS processes.

Combination of several MEMS technologies (thin layer, CMOS, DRIE) allows to design and manufacture integrated ultrathin (200nm) cantilevers (Fig.1a). For standard silicon AFM nanoprobes such a doped polysilicon readout circuitry is used to provide high isolation (over 1 GΩ) between the tip and Wheatstone bridge, necessary for electrical measurements (Fig.1b).

SOI wafers processing allows to manufacture thin silicon cantilevers with highly controlled thickness distribution and complex shapes (Fig. 1c). Chemical mechanical polishing (CMP - planarization) and noble metal processing are used for development of various calibration structures with reduced topography contrast (Fig. 1d).

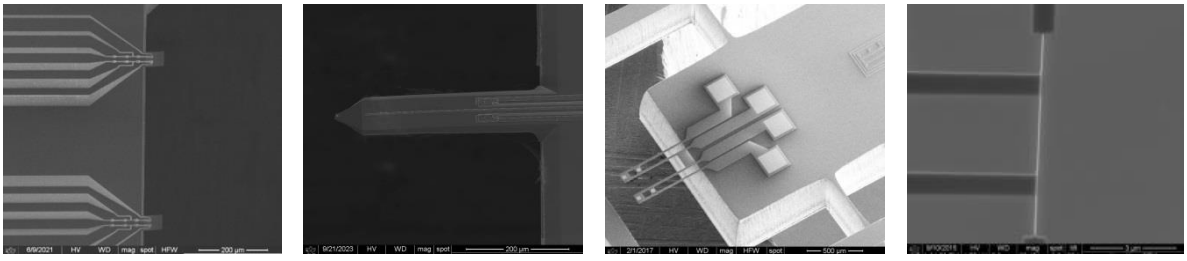

Figure 16. a) dielectric cantilever with readout, b) integrated AFM cantilever with isolated tip, c) SOI based cantilevers, d) topography-less Pt sample.

[1] P. Janus, at al. Active calibration reference of minimized height for characterization of scanning thermal microscopy systems, Ultramicroscopy, Volume 221, February 2021, 113188

[2] K. Orłowska, at al. A method of magnetic field measurement in a scanning electron microscope using a microcantilever magnetometer, Metrol. Meas. Syst., Vol. 27 (2020) No. 1, pp. 141–149. DOI: 10.24425/mms.2020.131710

P10

ArmScanner-Novel software for signal acquisition and control of a scanning probe microscope

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Scanning probe microscopy (SPM) is commonly used in materials characterisation [1]. This is not only related to surface morphology, but also its electrical, mechanical and thermal properties. Most of SPM experiments can be easily performed on commercial solutions, including microscopes, application modules or software. By further modification of available equipment or even development of new one [2], most challenging investigations can be performed [3,4]. In the case of Department of Nanometrology introduction of advanced SPM modes is done by custom-built ARMScope controller supported by ARMScanner software [2].

In this work recent advances of ARMScanner software will be presented. This includes its actual architecture and capabilities. ARMScanner capabilities includes raster, sinusoidal or SEM scanning, control of various digital / analogue PID controllers, 14 – 18 bit ADC / DAC acquisition cards and customized measurement devices. Utility of each ARMScanner feature will be summed-up by presentation of practical results.

Acknowledgments

This work was supported by the Joint Research Project within the European Metrology Research Programme EMPIR - 20IND08 MetExSPM Traceability of localised functional properties of nanostructures with high speed scanning probe microscopy.

[1] Recent Advances in Ultrathin Two-Dimensional Nanomaterials, C. Tan, et al., Chem. Rev. 2017, 117, 9, 6225–6331.

[2] ARMScope – the versatile platform for scanning probe microscopy systems, B. Świadkowski, et al., Metrology and Measurement Systems, 2020, vol. 27, No 1, 119-130.

[3] Fabrication of self-actuated piezoresistive thermal probes, M. Hofer, et al., Microelectronic Engineering, Volume 145, 1 September 2015, Pages 32-37.

[4] Microscale surface potential gradient disturbances observed in bilayer graphene, K. Gajewski, et al., Applied Surface Science, Volume 510, 30 April 2020, 145504.

P11

Novel scanning probe technologies for dentistry

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Prosthodontics overdenture treatment brings relieve and comfort to many patients with residual dentition. One type of overdenture is telescopic dentures. They are held in place by the frictional force created between the telescopic crowns; alas to fulfil, it must provide durable and stable technical solutions, mimicking natural dentition. Testing of biocompatible materials in repeatable conditions is complicated matter, therefore size reduction of test objects is favourable. It is possible to perform material tests (eg. wear of adhesion measurements) without loss of measurement trueness [1]. Especially wear measurements are free of scale effects while performed at micro- and nanoscales [2].

We present testing platform incorporating atomic force microscope (AFM) in scanning-tip configuration with active piezoresistive cantilever. System, working both in contact and non-contact modes, enables modifying the surface and imaging without apparent modification. To assure broad contact force area, cantilever was equipped with Degulor M gold alloy (prosthetic material) solid microball in the role of microindenter. Tests of FGP surface wear were done including surface modification and imaging with the same sensor-tool, giving quantitative values of wear process.

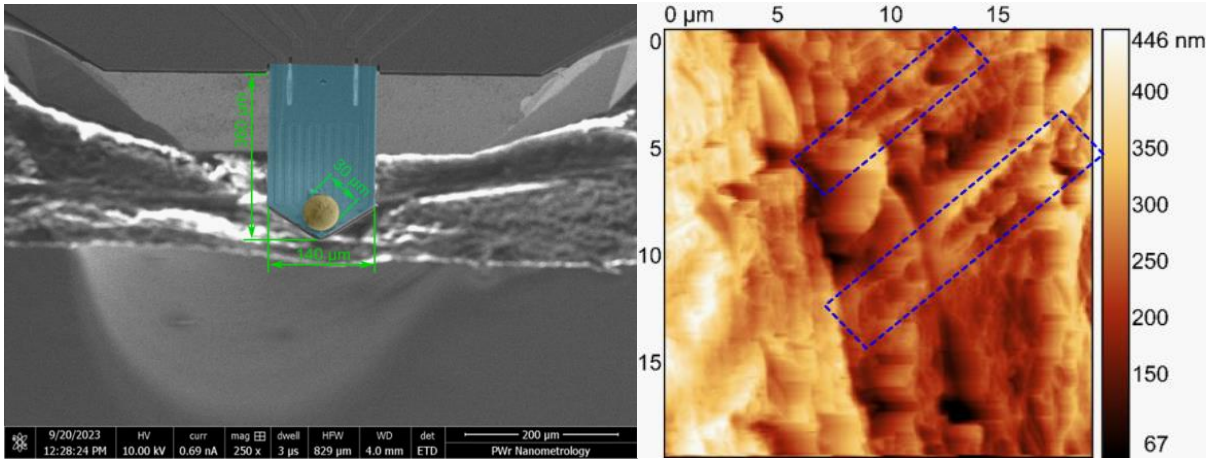

Figure 17. nano analytic GmbH active piezocantilever with solid gold ball as a tip (Left); FGP surface modified with wear from the gold (right) .

[1] T. Dąbrowa, A. Wcisło, W. Majstrzyk, P. Niedziałkowski, T. Ossowski, W. Więckiewicz, T. Gotszalk, *journal of the mechanical behavior of biomedical materials*, 121 (2021), 104648

[2] T. Dąbrowa, D. Badura, B. Pruchnik, E. Gacka, W. Kopczyński, M. Mikulewicz, T. Gotszalk, E. Kijak, *Materials* 16 (2023), 1991

P12

3D-Printed Scanning Probe Microscope

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The investigation of material properties requires the use of specialized tools. Scanning Probe Microscopy (SPM) offers a wide range of measurement modes for material characterization. It can be used to investigate not only mechanical properties, but also electrical, thermal and optical properties. The most common SPM systems consist of a micro-cantilever deflection detector (Atomic Force Microscopy, AFM) or a tunneling current detector (Scanning Tunneling Microscopy, STM).

In most commercial systems, customization is severely limited or even impossible. This disadvantage has led many research groups to create their own designs, such as the ARMScope [1, 2], which allow unusual solutions specialized for specific applications [3]. The modular construction of the presented design allows easy modifications, even in specific cases, using 3D printed mechanics. This latter technique opens up a wide spectrum of fast modifications and reproduction of all kinds of parts in a short time. 3D printing also allows the reproduction of a low-cost plastic scanning probe microscope (PlaSPM).

In this paper we present a fully 3D printed SPM based on Digilent's popular AnalogDiscovery2 signal acquisition unit and a custom DIY controller based on common analogue components. A wide range of modifications were made, including the scanner movement, the approach arm and even the case. Using Digilent's SDK and Python it was possible to implement a flexible application [4] to handle different types of scans, such as: sampling, semi-continuous, continuous. To verify reliability of implemented approach while maintaining relatively low complexity of the system, development of STM was performed.

[1] B. Świadkowski, T. Piasecki, M. Rudek, M. Świątkowski, K. Gajewski, W. Majstrzyk, M. Babij, A. Dzierka, T. Gotszalk, *Metrology and Measurement Systems*, 2020, **27(1)**, 119–130.

[2] H.-S. Liao, I. Akhtar, C. Werner, R. Slipets, et al., *HardwareX*, 2022. **12**, e00341.

[3] P. Biczysko, A. Dzierka, G. Jóźwiak, M. Rudek, T. Gotszalk, P. Janus, P. Grabiec, I.W. Rangelow, *Ultramicroscopy*, 2018, **184**, 199–208.

[4] https://github.com/maciej-rudek/XY_Surface_Scanner

P13

Structural and electronic properties of $F_{16}CuPc$ thin films on Ag (100) surfaces.

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[2]Johannes Kepler University, Institute of Experimental Physics, Linz, Austria
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Thin layers of metal phthalocyanines have potential applications in molecular electronics devices. Therefore, this work focuses on the structural and electronic properties of thin films composed of fully fluorinated phthalocyanine $F_{16}CuPc$ adsorbed on the Ag (100) surfaces.

The structural properties were monitored using Low Energy Electron Diffraction (LEED) during the deposition at room temperature for coverages between 0 and 2.5 monolayer (ML). During the initial deposition, the diffuse LEED pattern shows features characteristic of the presence of a 2D molecular gas phase. For coverages above 0.8 ML, sharp diffraction spots appear, revealing the formation of an ordered, condensed phase. The intensity of diffraction spots increases until it reaches a maximum associated with completion of the ordered $F_{16}CuPc$ monolayer. The analysis of the LEED patterns suggests the coexistence of two mirror domains on the surface even before closing the first monolayer. It was confirmed in a separate experiment, in which the Ag (100) covered by monolayer of $F_{16}CuPc$ was imaged in dark field mode of the Low Energy Electron Microscope (LEEM). Further deposition of $F_{16}CuPc$ leads to a weakening of the diffraction reflexes and re-appearance of the features characteristic for presence of the 2D molecular gas on the surface. Likely, the condensed structure of the second monolayer also has a precursor in form of a 2D molecular gas phase.

The electronic properties of molecular film were monitored using the Anderson method [1], in which the changes in the work function of Ag (100) as a function of the coverage of $F_{16}CuPc$ molecules were examined. Based on the values obtained in the Anderson method, changes in the normalized mean photoelectron yield were estimated using Fowler Du-Bridge theory [2 - 3]. The calculations assume that the system is illuminated by a mercury lamp with a main energy peak of 4.9 eV and that the photoelectrons therefore originate mainly from the substrate and not from the organic layer. For comparison the experiment was performed using Photoemission Electron Microscopy (PEEM).

The authors gratefully acknowledge the financial support from the program „Excellence Initiative - Research University" for years 2020 - 2026 for University of Wrocław.

[1] A. Sabik, F. Gołek, G. Antczak, Rev. Sci. Instr. **86**, 056111 (2015).
[2] L. A. DuBridge, Phys Rev. **39**, 108-118 (1932); L.A. DuBridge, Phys. Rev. **43**, 727-741(1933); R. H. Fowler Phys. Rev. **38**, 45-56 (1931); E. Bauer, Surface Microscopy with Low Energy Electrons, Springer 2014.
[3] Wagner et al, ACS Appl. Mater. Interfaces **14** 23983−23989 (2022).

P14

Electromagnetic cantilever arrays in molecular interactions metrology

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The usual approach for functional definition in high technology is "more, better, faster". It is supported by continuous miniaturization. This led to the creation of field of micro- and soon after nanoelectromechanical systems (MEMS and NEMS). One example of such MEMS/NEMS device is one side clamped silicon microcantilever, which now is versatile sensor with a wide field of applications in physical, chemical and biological sensing. Due to small dimensions, low mass cantilever offer very high sensitivity. Thus, it allowed for their application in molecular interaction forces measurements with possibility of sensing force of a single molecules.

In our experiments we use the electromagnetically actuated cantilever arrays - **Figure 18** fabricated in Institute of Electron Technology in Warsaw. They are entirely made from Boron-Doped Silicon (BDS) from SOI wafers. The heavy doping allows for current passing and Lorentz force actuation (1). In this technology the external magnetic field (B) interacts with the current (I) flowing through conductive loop producing the Lorentz force:

$$\vec{F} = L_L(\vec{I} \times \vec{B}) \quad (1)$$

We use applied Lorentz force to precisely control interactions between cantilever contact region (tip /sphere) and sample surface. In case of proposed experiment, the tips/spheres are covered with functional layers. These functional layers will only bond to the small range of complementary materials on the sample surface and can be used in selective force spectroscopy experiments.

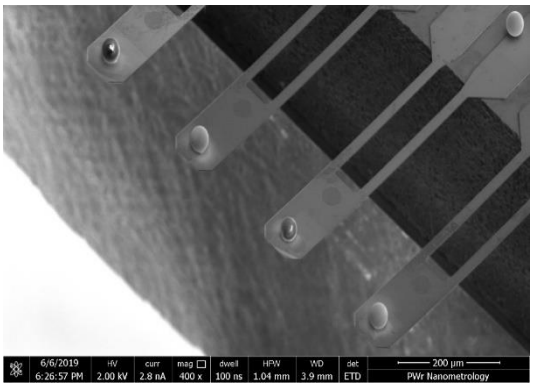

Figure 18. SEM image of the electromagnetically actuated cantilever array with attached spherical tips. These tips are covered with various functional layers.

P15

Investigation of liposomes nanostructure as biological membrane models using AFM

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Rapid development of liposome technology and their employment as a model membrane required a rational characterization approach. It is crucial to evaluate key parameters that significantly impact the effectiveness of liposomes in various type of research. These include characteristics such as size, morphology, polydispersity index, number of lamellae, charge, bilayer fluidity, lipid composition, encapsulation efficiency, liposome-drug interaction and chemical stability [1]. Diverse physical methods have been employed to assess these attributes: dynamic light scattering (DLS), nuclear magnetic resonance (NMR) and the electron paramagnetic resonance (EPR) as well as atomic fore microscopy (AFM) [2].

The aim of our investigation utilize the AFM microscopic approaches to characterise the structure of artificial cell membrane models differing in lipid composition. We have extensively tested liposome membranes represent the model of erythrocyte membrane (ghosts), model of bilayer mimicking the cancer cell membrane and model membrane consist of:

- saturated and unsaturated fatty acids with different temperature of main phase transition
- cationic and anionic lipids,
- different head group chemistry (e.g., phosphatidylcholine, phosphatidylethanolamine),
- different content of cholesterol

Based on the force measurements, our research has shown that liposome membrane models are significantly different in surface mechanical and chemical properties.

[1] B. Ruozi, G. Tosi, E. Leo, and M. A. Vandelli, "Application of atomic force microscopy to characterize liposomes as drug and gene carriers," *Talanta*, vol. 73, no. 1, pp. 12–22, 2007, doi: 10.1016/j.talanta.2007.03.031.

[2] A. L. Robson *et al.*, "Advantages and limitations of current imaging techniques for characterizing liposome morphology," *Front. Pharmacol.*, vol. 9, no. FEB, pp. 1–8, 2018, doi: 10.3389/fphar.2018.00080.

P16

The AFM investigation of light exposure caused morphological changes of selected photoresists

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The investigation aimed at the photoresist roughness change determination as a reliable estimator of the exposition rate in the processing verification in semiconductor industry will be presented. By employing atomic force microscopy as the 3D high resolution surface imaging tool, we tested twelve popular photoresists in terms of the morphological properties changes, while the following radiation doses were applied. Basing on high precision, and repetitive sample positioning, it was possible to perform the tests with high degree of confidence and observe the roughness change dynamics. Various profiles of roughness changes were observed, showing the need for individual study of each material. Moreover, it was possible to select the photoresists which due to poor homogeneity and small roughness changes are not suitable to such a verification.

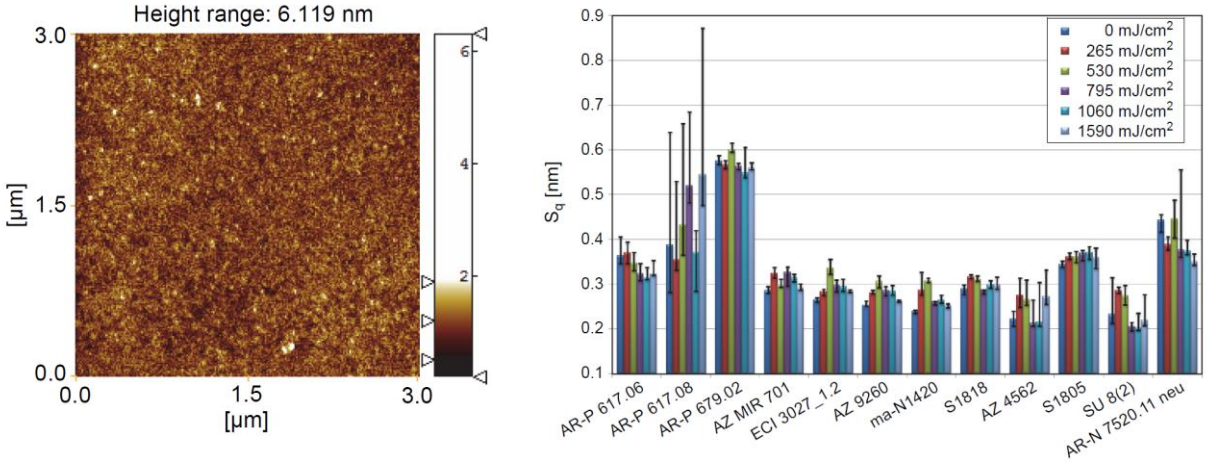

Figure 19. Example of the map of scanned photoresists topography (left), the set of roughness parameters determined for various samples and light exposition doses (right).

[1] A. Sikora, P. Janus, A. Sierakowski, *Optica Applicata*, 2019, XLIX, 1.

[2] A. Sikora, *Nanoscience and Nanometrology*, 2017, **3**, 6.

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P17

Analysis of individual chromosomes upon anticancer drug treatment

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Chromosomes are intranuclear structures composed of tightly packed histone proteins and DNA. They main function is to ensure that DNA is accurately copied to daughter cells during cell division. Nucleic acids are susceptible to various types of damage under physiological conditions. All organisms have advanced systems to detect and repair DNA damage. However, if unrepaired or repaired incorrectly, they can lead to mutations and chromosomal aberrations or even cell death [1].

In this study, we investigated chromosomes isolated from human cervical cancer cells (HeLa) under treatment of bleomycin. This anticancer drug leads to single- and double-strand breaks of DNA double helix [2]. To examine occurring changes, we used two complementary techniques. Atomic force microscopy enabled observation of morphological changes while Raman microspectroscopy allowed detection of chemical alterations. All measurements were performed on chromosome I - the biggest chromosome which contains 8% of whole genetic information. We used convolutional neural network (CNN) to extract spectra from chromosome I, which were further analyzed with principal component analysis (PCA). Such a complex approach revealed several molecular changes in individual chromosomes, including: enhanced synthesis of proteins, alterations in methylation of DNA and conformational changes of DNA upon bleomycin treatment.

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P18

Educational scanning tunneling microscope for nanodiagnostics teaching

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Recent progress in science and technology requires enabling more advanced classes for students, as their knowledge and experience should allow them to be effective employees during their professional career. Therefore, a variety of training setups and devices is continuously developed in order to follow the increasing needs.

As Department of Nanometrology at Wrocław University of Science and Technology is responsible for providing the classes in the field of nanodiagnostics, a set of specifically designed setups was developed in order to allow students to perform training procedures, and enable understanding the principles of the measurements at nanoscale. One of the abovementioned solutions is scanning tunneling microscope, which was designed basing on the hardware and software platform developed at Department of Nanometrology. It allows to measure a selected group of surfaces in ambient conditions, and to verify the impact of the settings on the outcome of the experiment. Acquired data can be used in various ways, allowing to determine lattice constants of highly ordered materials, but also known materials can be utilized as nanoscale length standards in order to calibrate X-Y scanning system.

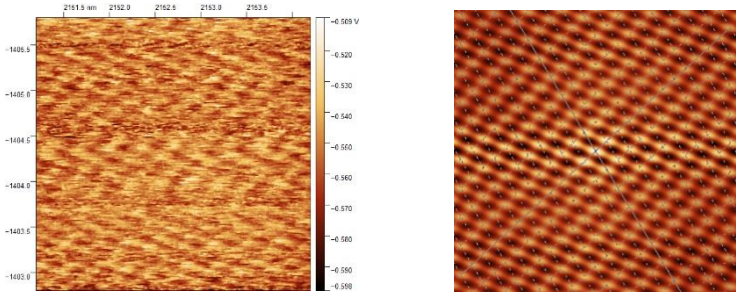

Figure 20. Example of HOPG image acquired with educational STM (left), lattice constant is determined using Gwyddion software (right).

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P19

Impact of self-assembled monolayers on tribological and antimicrobial properties of Ti-DLC coatings.

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The widespread miniaturization of electronic devices, the introduction of new biochemical analysis techniques, the development of medicine, modern and information technology require materials and systems with a micro- or nanometer dimension [1]. For this reason, materials that have gained increasing interest in recent years are titanium-doped diamond-like coatings (Ti-DLC). However, the high friction coefficient and low wear resistance of this material caused its use in the production of medical implants to be limited [2]. One of the ways to improve tribological and physicochemical properties of Ti-DLC on micro- and nanometer scales is to create on their surfaces one- or two-component self-assembled monolayers (SAM's). In this work, we present the tribological and antimicrobial properties of the obtained one- and two-component perfluoroalkylsilane layers with different chain length, such as 1H,1H,2H,2H-perfluorodecyltrichlorosilane (FDTS) and 3,3,3-trifluoropropyltrichlorosilane (FPTS) on diamond-like coatings doped with titanium (Ti-DLC). Analysis and characterization of the obtained films were carried out using infrared spectroscopy (FT-IR), contact angle, surface energy, atomic force microscopy (AFM), and a microtribometer. The antimicrobial properties were characterized by measuring the amount of live strains of *Staphylococcus aureus* (ATCC 6538) and *Escherichia coli* (ATCC 25992) bacteria present on the modified coatings after 24 h of incubation.

This work was supported by the University of Lodz, within Research Grant No. B2211102000109.07

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P20

Investigations of thermal properties of GaN/AlGaN multilayer nanostructure using novel transformer bridge circuitry

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The scanning thermal microscopy (SThM) allows measurement of temperature fields with nanometer spatial resolution. In most cases, the Wheatstone bridge is utilized to detect the changes in the output SThM signal. In the Department of Nanometrology, an approach with transformer bridge RTD (Resistance Temperature Detector) output signal readout has been proposed, giving opportunity to measure wide scope of specimens, under disparate environmental conditions. In this work we present measurement of semiconductor nitride-based multilayer structures thermal properties by means of SThM. The samples intended for research have been grown on 430 µm thick, (0001)-oriented sapphire using metalorganic vapor phase epitaxy (MOVPE). A 1.6 µm thick undoped GaN buffer layer was grown, followed by the growth of periodical multilayers consisting of GaN/AlGaN sequences. After the growth, the samples have been cleaved, placed in an epoxy resin and polished in order to prepare the edge of the samples to SThM investigation.

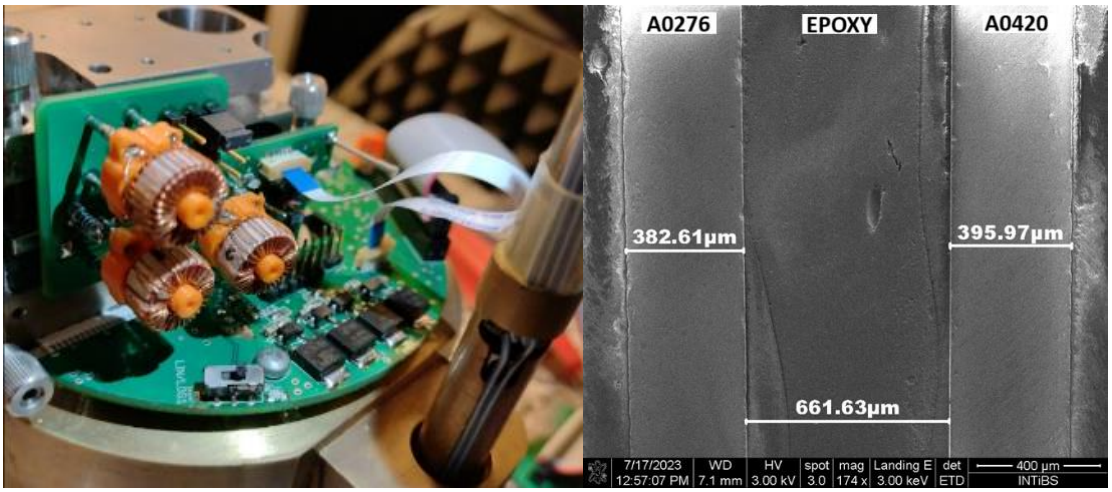

Figure 1. Transformer bridge setup used in Nanometrology Department for SThM (left) and test structure consisting of two semiconductor structures in epoxy resin matrix (right).

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P21

Preparation of TERS probes for nanospectroscopic investigations of lipid monolayers in liquid

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Tip-enhanced Raman spectroscopy (TERS) is a nanoscopic analytical tool delivering information on the local chemical structure of molecular systems. Due to its high sensitivity and label-free sample preparation, this technique is considered to be a promising approach for studying biological processes at the level of single biomolecules. [1]

TERS combines a nanoscale spatial resolution of the scanning probe microscopy (SPM) and the chemical sensitivity of Raman spectroscopy [1,2]. Collecting an optical signal with a nanoscopic resolution is possible due to the phenomenon of plasmonic enhancement which occurs at the end of the metallic SPM probe (typically gold or silver). Thus, the proper preparation of plasmonic probes is necessary to perform TERS measurements.

In this study, we propose a protocol for STM-TERS probe preparation by electrochemical etching with DC-pulsed voltage. Tips prepared with this procedure were applied for studies of lipid monolayers and allowed us to obtain information about organization of molecules at the nanoscale [3]. Moreover, additional procedure of the probe insulation allowed us to perform TERS experiments on lipid monolayers in the aqueous environment. According to our best knowledge, this is the first-ever nanospectroscopic investigation of the artificial lipid membranes in liquids.

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P22

Metrological SPM controller-ARMScope-II

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ARMScope is a versatile platform for SPM microscope controlling. It have been developped in the Department of Nanometrology, Wrocław University of Science and Technology. It is based on open and modular architecture which allows to improve certain aspects of the controller and to be able to access all signals that may be necessary in uncommon operating modes [1]. Recently the system was enhanced by implementation of the ADC module based on 18-bit ADC and new scanning field controller KOMPAS with the scan field generation, rotation and scaling done mostly in digital domain in FPGA device.

Another advantage of the ARMScope is the fact that it was precisely characterized. For example, the bit resolution of ADC does not provide sufficient data about the actual acquisition as it is limited by the noise and distortions of accompanying circuitry. The ADC was designed to maximise the resolution. 17.2 ENOB was achieved which may be increased up to 20.6 bits by oversampling (Figure 1a).

Another module which was improved and characterised is the scan field generator KOMPAS. It was designed to minimize the noise and improve the thermal and time stability and to include scan field generation, scaling, rotation and translation of the scan area in the digital domain. 18-bit DACs, decade attenuator and low-noise analogue circuitry was designed, implemented and tested. Obtained noise figures of 4,52 µVrms is close to the design calculations (Figure 1b) and thermal stability of generated voltages presented drifts smaller than 20 ppm of the full scale voltage which is less than 1 pixel of typical 256x256 scan performed at scan field zoomed down to 1% of full scanner range.

(a) (b)

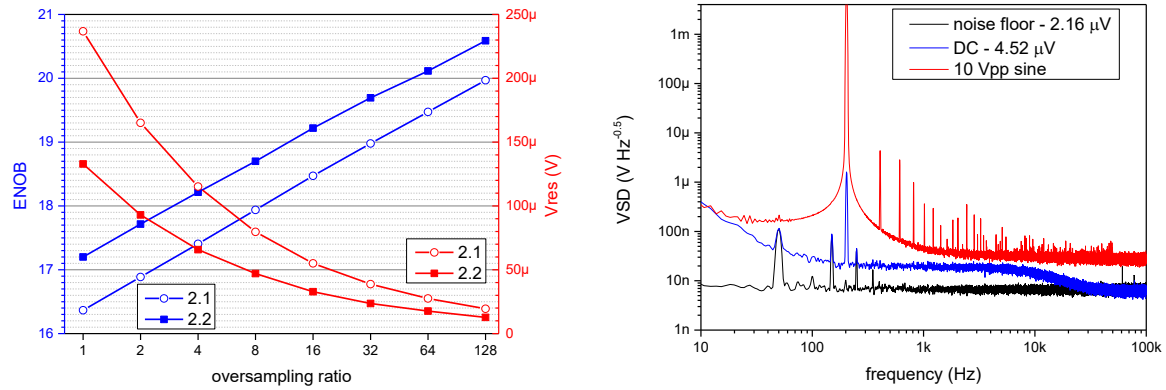

Figure 1. Exemplary results of the ARMScope-II SPM controller: (a) – effective number of bits of the ADC module for 2.1 and 2.2 version of the hardware for various oversampling ratios and (b) – noise characteristics of the KOMPAS module outputting constant DC voltage on one and full scale sine wave on second channels; calculated are the integrated RMS of the voltage noise.

Implementation of the scan field generator in FPGA device allows for future inclusion of non-raster scanning schemes like spiral or Lissajous curves scanning modes.

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P23

2D-supramolecular organization on HOPG of alkylthienyl-disubstituted benzothiadiazole donor-acceptor-donor (DAD) organic semiconductors - effect of alkyl group regioisomerism

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Donor-acceptor-donor molecular semiconductors are of great scientific interest, among others due to their potentially wide applications in organic electronics (OFET, OLED, electrochromic devices). Apart from the chemical structure, one of the major factors influencing the electronic properties of these semiconductors, for example charge carrier mobility, is their supramolecular arrangement in monolayers and thin-films [1]. In this communication, we present preliminary results of scanning tunneling microscopy (STM) studies of self-organization in a set of D-A-D molecules consisting of benzothiadiazole central acceptor unit connected to two regiochemically different alkylthienyl substituent. The investigations of the self-assembly of molecules within a monolayer obtained by the drop casting on the surface of highly oriented pyrolytic graphite (HOPG) were carried out at room temperature in ambient conditions. Three types of self-organization patterns were identified, namely: single row organization with and without intermolecular shift, and double row organization.
The observed differences were discussed in terms of the effect of the position (4- / 5-) and the length (-hexyl / -octyl) of *n*-alkyl substituents in the thienyl ring, which act as interlocking groups that increase molecular order and packing density in the layer.

This work has been supported by the National Science Centre (Poland) under OPUS23 Grant No. 2022/45/B/ST5/02120

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P24

The Role of Sphingomyelin in the Incorporation of an Oligomer with Potential Anticancer Activity into a Model Membrane

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It is well known that the individual components and organization of the biomembrane are crucial in targeting the molecule to a specific cell. In this study, special attention was paid to sphingomyelin, one of the main lipids of mammalian membranes. In this respect, the effect of a lithocholic acid-functionalized oligomer (OLithocholicAA-X) on a model membrane composed of cholesterol (Chol) and sphingomyelin (SM) mixed in different proportions was investigated using Langmuir monolayers [1]. OLithocholicAA-X can serve as a drug delivery system, and additionally it may show anti-cancer activity due to the presence of lithocholic acid in its skeleton [2,3]. The surface topography of the studied monolayers was investigated by atomic force microscopy (AFM). The obtained results showed that the amount of SM determines the bioavailability of the oligomer, causing fragmentation of its lattice. However, on the basis of thermodynamic calculations, it was also observed that ongoing fragmentation is not a thermodynamically favourable process because it leads to excessive film fluidization. Furthermore, it was shown that the investigated oligomer has affinity for a system that mimics lipid raft (SM:Chol 2:1).

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P25

The Influence of Phospholipid Degree of Unsaturation on Molecular Interactions and Heterogeneity in the Inner Mitochondrial Membrane Model

Anna Chachaj-Brekiesz[1,*], Ewelina Lipiec[2], Natalia Świętoniowska[1], Aleksandra Seń[1], Sara Włodarska[1], Anita Wnętrzak[1], Patrycja Dynarowicz-Łątka[1]

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Cell membrane-targeted pharmaceuticals are used in the treatment of many diseases such as bacterial, fungal, or viral infections, and cancer. Since these molecules demonstrate preferential affinity for the membrane, its fragment, or even a particular component, it is therefore necessary to assess the risk of the side effects and investigate their impact on the other key cell elements. In this context, the inner leaflet of the mitochondrial membrane (IMM) is particularly important because maintaining the impermeability of this membrane (except for specific transporters) is crucial for mitochondria functioning as the cellular energy generator [1]. Due to the complexity and variability of natural systems, the *in vivo* investigation of the chosen aspects often leads to questionable conclusions. In contrast, artificial models offer the possibility to study a particular issue in a controlled laboratory environment.

The aim of this study was to obtain the biomimetic model of the inner mitochondrial membrane for cellular membrane-targeted pharmaceuticals investigation. Among other methods of membrane modeling, the Langmuir monolayer technique was selected because it offers the possibility of (*i*) examining the thermodynamics of interactions within a film as well as (*ii*) applying microscopical techniques to investigate heterogeneity (Brewster angle microscopy and atomic force microscopy after film transfer onto solid support) [2]. Generally, the content of particular lipid classes in mammalian IMM is known, as it is composed of phosphatidylcholines (PCs), phosphatidylethanolamines (PEs), and cardiolipin (CL) [3]. As the latter lipid is characteristic for IMM, its content and unsaturation degree were investigated thoroughly, whereas the unsaturation degree of PCs and PEs remains unclear [4]. Therefore, in this study we examined and compared three systems differing in the unsaturation degree of phospholipid apolar chains (DOPC/DOPE/CL, POPC/POPE/CL, and DPPC/DPPE/CL). The systems were fully characterized in terms of mutual lipid miscibility, film mechanical properties, and phase separation.

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P26

Exploring Plasmonic Properties of AFM Tips and 2D Nanohole Arrays: Insights from Finite Difference Simulations

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In the Tip-Enhanced Raman Spectroscopy (TERS) technique, the enhancement of the electromagnetic field at the tip of the AFM probe allows for an extremely high spectroscopic sensitivity, enabling the identification and characterization of even individual molecules on a sample surface. The effect of the enhancement is observed in nanometric volumes between the tip and the sample, called plasmonic gaps. Beyond the plasmonic background, additional amplification occurs. A nonresonant lightning rod effect, observed on a subnanometric scale, produces an additional enhancement of the electric field. This effect was confirmed in quantum atomistic computations and observed in classical simulations [1]. Furthermore, this phenomenon can also be observed in the 2D nanomaterial matrices on which the substances of interest are deposited, extending the applicability of TERS to such nanostructures [2].

This study delves into the near-field enhancement properties of AFM tips and 2D nanohole arrays when exposed to a laser beam. Employing finite difference calculations, we examined the electric field distribution around the AFM tip and nanohole arrays across varying wavelengths, geometry, and metals. Utilizing the insights from our previous research [3], the goal was to identify the optimal parameters leading to the maximum field enhancement effect. Our findings not only deepen the understanding of near-field enhancements in AFM tips and nanohole arrays, but also open avenues for their applications in cutting-edge medical diagnostics employing nanotechnology.

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P27

Mechanical investigations and Kelvin probe force microscopy of ultrathin membranes of MoSSe alloy

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2D semiconductors, in particular transition metal dichalcogenides (TMDs), and their alloys are intensively studied due to their wide range of applications. Using mechanical exfoliation [1] and the dry transfer method [2], we created single atomic layers of these materials. Investigating membranes based on MoSSe crystals with different percentages of sulfur and selenium, we examined the impact of flake-substrate interactions on their electrical and mechanical properties. We performed our experiments on gold-coated SiO_2/Si substrates with etched cavities for membrane fabrication. From measured contact potential difference (CPD) using AFM with the Kelvin probe, we calculated the work function (WF) of the layers. MoS_2 exhibited a WF of 4.85 eV for supported material and 4.83 eV for suspended layers, while a single MoSSe layer showed an increased WF on the membrane (5.34 eV) compared to the supported material (5.32 eV). Additionally, we studied the elastic deformation of freely suspended MoSSe layers using AFM [3].

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P28

ATR-FTIR analysis of blood serum uncovers spectral markers associated with pancreatic cancer

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Cancer diagnoses are on the rise globally, with pancreatic cancer (PC) standing out as one of the most aggressive and deadliest [1]. Timely detection of PC is of paramount importance for patients, given its frequent advanced stage at diagnosis, leading to a significantly worsened prognosis [2]. Consequently, the development of early PC detection methodologies is of immense significance.

Vibrational spectroscopy, specifically Attenuated Total Reflection Fourier Transform Infrared Spectroscopy (ATR-FTIR), has been proposed as a solution to the problem of late PC diagnosis [3-4]. The primary objective of the presented research was to assess the potential of ATR-FTIR in distinguishing patients with malignancy compared to benign (non-neoplastic) controls from blood serum. Furthermore, distinguishing PC from other cancer types, such as gastric and colorectal cancers was evaluated. Advanced chemometric tools were employed to achieve the study's goals and investigate the spectral markers of each cancer type.

Data analysis revealed that all cancer types showed increased β-sheet protein conformation compared to controls, while controls had more α-helix/unstructured coil-rich proteins. PC samples featured more antiparallel β-sheet-rich proteins. Control samples had higher DNA in the A conformation, and PC samples exhibited a distinctive collagen bond at 1036 cm^{-1}. Figure 1 presents principal component analysis (PCA) findings of blood serum spectra of non-neoplastic controls and PC group. Spectra separate along PC-2, with controls on the negative side and cancer on the positive side.

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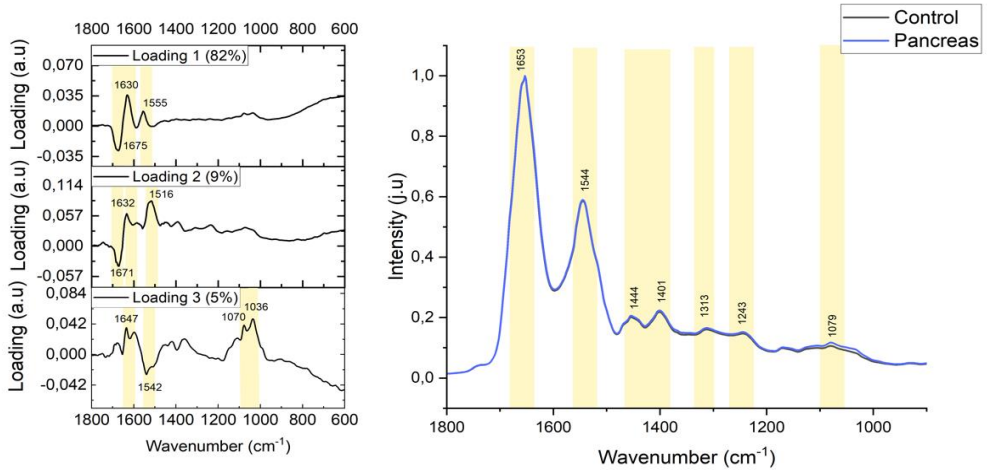

Figure 1. Results of PCA and ATR-FTIR spectra of blood serum obtained from PC patients compared to the non-neoplastic control group.

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P29

EMPIR MetSPMexp technologies-solutions and challenges

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In the last decade, one of the fastest growing scientific fields has been nanotechnology[1]. It enables the design, production and modification of structures with special properties that often differ significantly from their macroscopic counterparts. Wanting to conduct research on structures with at least one dimension smaller than 100nm, it is necessary to have appropriate tools. Such a tool should be able to image the structure on the nanometer [2] scale and be able to modify it if necessary (Nanoscratching). The standard scanning speed of the examined structure (material or instrument) is usually 1 to 2 lines per second, which at resolutions of 512x512 lines gives a time of several minutes. In so-called high-speed microscopy, this speed should be increased to a minimum of 15 lines/sec with the same or better resolution. This will be possible if a micro-electro-mechanical system - MEMS - is used for surface scanning, which, due to its miniaturization, features high resonant frequencies (>300kHz), integrated blade deflection detector circuits and static and resonant tip deflection actuators. In addition, the MEMS system will enable electrical and thermal properties of the surface to be investigated.The innovation of the research undertaken is the proprietary design of the microscope controller to enable control of the active piezoresistive lever and to conduct data acquisition at a speed of at least 2MS/s and resolutions of at least 18 bits.

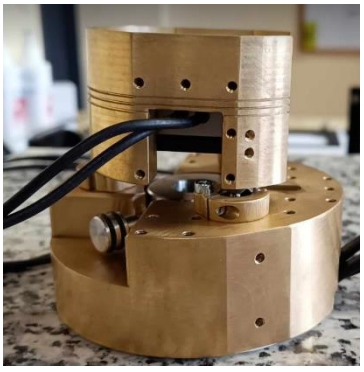

Figure 21. Microscope head

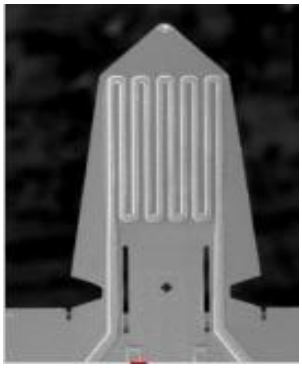

Figure 2. New design of piezoresistive active cantilever

[1, 2] - J. E. Sader, J. A. Sanelli, B. D. Adamson, J. P. Monty, X. Wei, S. A. Crawford, J. R. Friend, I. Marusic, P. Mulvaney, E. J. Bieske, „Spring constant calibration of atomic force microscope cantilevers of arbitrary shape", Review of Scientific Instruments, 83 (10), s. 103705, oct 2012, ISSN 0034-6748, doi: 10.1063/1.4757398

P30

Atomic force microscopy investigations of beta-amyloid controlled fibrillization

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The amyloid deposition in the form of fibrous aggregates of amyloid beta (Aβ) peptide is a relevant anomaly in Alzheimer's disease. The fibrilization of Aβ peptides *in vitro* can be affected by interaction with cystatins, naturally occurring inhibitors of protease activity [1]. Ovocystatin impairs fibrilization of Aβ by inhibiting the aggregation and breaking down long structures of Aβ formed during incubation [2]. Phenomenon is observable with atomic force microscopy (AFM), which follow the preparation of samples with specific compositions.

The samples have been prepared by incubating 50 μM of Aβ with or without 22 μM CWC at 37°C for 72 h. Every 24 h an aliquot (3 μl) of sample was dispersed onto V-1 grade mica discs and examined using AFM system [3] with a resolution of 0.1 nm developed at Department of Nanometrology.

AFM images of Aβ (fig. 1) show branched structures with the height of 90-110 nm, accompanied by globular forms; in case of Aβ in the presence of CWC there were only small spheroidal structures of height up to 40 nm present. Result therefore confirms antifibrillization properties of ovocystatine.

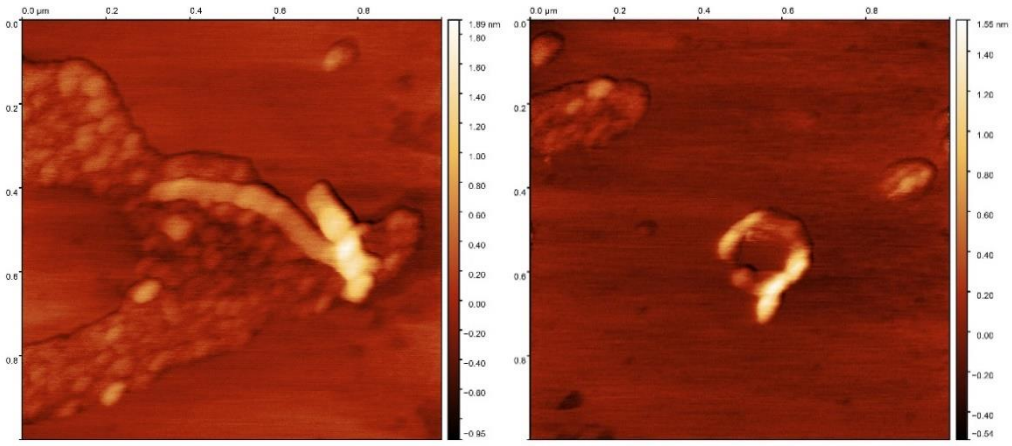

Figure 1. Single nanofibriles of Aβ during formation over aggregates.

[1] T.J. Perlenfein, J.D. Mehlhoff, M.M. Murphy, *J. Biol. Chem*., 2017, 292, 11485

[2] B. Stańczykiewicz, T.M. Goszczyński, P. Migdał, M. Piksa, K. Pawlik, J. Gburek, K. Gołąb, B. Konopska, A. Zabłocka, *Int. J. Mol. Sci*., 2023, 24, 5433.

[3] D. Kopiec, W. Majstrzyk, B. Pruchnik, E. Gacka, D. Badura, A. Sierakowski, P. Janus, T. Gotszalk, *Metrol. Meas. Syst.*, 2021, 28, 4

P31

Ferroelectric and incipient-ferroelectric perovskite oxides: a glimpse into the structure of the as-cleaved surfaces

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In recent years, perovskites have gained tremendous attention as materials for next-generation optoelectronic and photocatalytic devices due to their unique electronic and optical properties [1]. It is increasingly obvious that to understand the origin of their efficiency, not only bulk but also the very surface must be investigated. Since the surface constitutes the boundary between the crystal and the environment and chemical reactions take place on it, they can be additionally catalyzed by surface traits such as various reconstructions adopted, heterogeneous atoms deposited, or the presence of additional surface charges. All of these factors affect the reaction potentials, which can be altered by exploiting the ferroelectricity of some perovskites, which can help i.e. in the charge separation, towards applications in photo-, piezo-, and pyro-catalysis [2].

The purpose of this poster is to direct attention to the surface behavior of ferroelectric and incipient ferroelectric perovskite oxides and their stability under ambient conditions. Three materials were studied: $BaTiO_3$ (BTO), $KTaO_3$ (KTO), $KNbO_3$ (KNO), with the main focus on nonconductive undoped single crystals. The main research method was Atomic Force Microscopy (AFM) in contact and non-contact modes, supported by the SEM (Scanning Electron Microscopy) investigations. AFM studies were carried out under ambient conditions, whereas samples were prepared by cleaving along the main crystallographic axes of the crystal. To demonstrate the ferroelectricity of BTO and KNO a polarizing voltage of above 1 kV was applied beforehand to make ordered domains. SEM images clearly show the macroscopic pattern of ferroelectric domains and AFM results provide more information on their topography. Interestingly, ferroelectric domains significantly influence the friction signal, without the apparent structural changes on the surface. Overall ferroelectric domain structure suggests the coexistence of 90° and 180° domain walls on a scale of single micrometers [3]. Periodic modulation of optoelectronic and structural properties suggests that ferroelectric perovskite surfaces are suitable for the potential employment for real-life applications.

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P32

Nanoscopic SPM investigations of FEBID and FIBID halo effect

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The scanning electron microscope (SEM) with a focused ion beam (FIB) is a versatile tool with a resolution of single nanometers. Its functions include imaging, milling, deposition, ion implantation, and analyzing the chemical composition of samples. Focused electron beam induced deposition (FEBID) and focused ion beam induced deposition (FIBID) are methods for fabrication of two- or three-dimensional nano- and microobjects on any surface. The deposition of the material is performed in the vicinity of the focused beam scanning area, and the shape of the deposited object is defined by the scanning motion of the beam. The variety of available FEBID and FIBID precursors makes it possible to deposit materials with different compositions and properties. However, in the FEBID and FIBID process, an unwanted effect occurs, the so-called halo effect, in which a thin metallic layer is deposited around the created object on the surface of the sample.

In this work, we would like to present a study of the properties of a platinum-carbon composite deposited by three methods: electron beam, gallium ion beam, and electron beam with post-processing implantation of the material with gallium ions. Depending on the deposition method, the conductive properties of the composite were modified. Characterization was performed by conductive atomic force microscopy (CAFM). The area of occurrence of the halo effect also visible on SEM images was determined. Then, the work function of the studied material was investigated using Kelvin probe force microscope (KPFM).

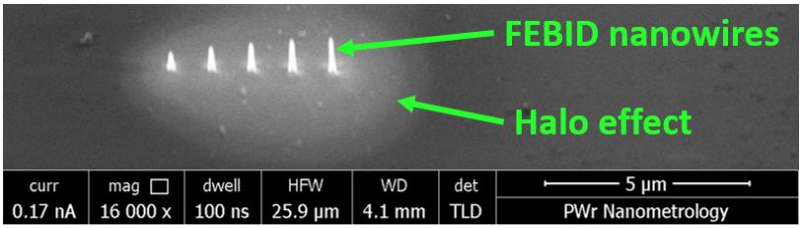

Figure 1. SEM image of the halo effect around deposited using electron beam nanowires

Acknowledgements: This work was supported by the National Science Centre, Poland PRELUDIUM-21 grant ["Nanometrology of field emission phenomena from electron beam deposited nanowires operating as nano- and picodeflection sensors – FEmet", grant number 2022/45/N/ST7/03049]; and the National Science Centre, Poland OPUS grant ["Nanometrology of Nottingham cooling effect using operational microelectromechanical systems", grant numbers 2020/37/B/ST7/03792].

P33

Entirely FIB-made GaN/AlGaN round-HEMT

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Performance optimization of AlGaN/GaN high electron mobility transistors (HEMTs) on sapphire or silicon substrates is still in progress. Firstly, the Round-HEMT topology, which is simple in processing and allows fast feedback between structure growth and device properties, is mostly used for epistructures quality evaluation. However, fabrication of such simple transistor structure requires several microelectronic processes like etching, source, drain and gate contacts evaporation/sputtering and thermal formation of source and gate contacts. Before the epistructure can be utilized to produce transistors, standard scanning electron microscopy (SEM) is mostly used for final surface morphology evaluation. Taking an advantage of dual beam SEM-focused ion beam (SEM-FIB) system we proposed an entirely FIB-made GaN/AlGaN round-HEMT fabrication for technology verification. However, the presented approach allows to integrate the separated transistor in one integrated circuit due to possibility of definition of electrical interconnections, etching, metal-rich semiconductor contact formation as well as isolated gate formation. The gallium beam parameters has been controlled in order to gently etching, ion implantation and electrical interconnection formation (Fig. 1a). Source-drain electrical connection via 2-dimension electron gas (2DEG) has been achieved as well as the conductivity modulation has been observed due to charging the area between two FIB-made contacts area (Fig. 1b). On the basis of that results the entirely FIB-made GaN/AlGaN round-HEMT is fabricated.

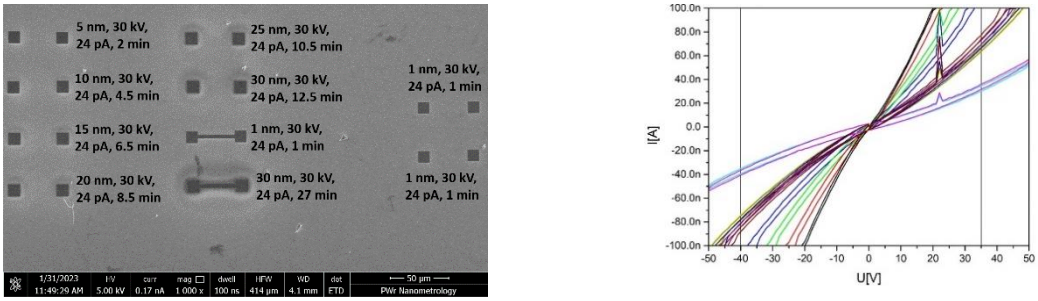

Figure 1. SEM image of FIB-made contacts and interconnections with fabrication parameters a); I-V characteristics modulation after electron beam exposure of the contacts pair etched 10 nm deep with 30 kV of Ga beam acceleration voltage.

Acknowledgements: This work was supported by the project: "High-performance AlGaN/GaN-HEMT transistors made with the hybrid MBE-MOVPE technology", number of agreement: 2/Ł-PORT/CŁ/2021, funded by The Łukasiewicz Centre.

P34

Defect free GaN whisker probes for scanning probe microscopy

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To meet the measurement requirements of scanning probe microscopy, the development of probes is necessary. Accordingly, probes ending with a tip from various materials, including GaN, are being prototyped [1]. GaN is a material of the III-V group, which is currently being extensively studied for its interesting electrical and optoelectrical properties. In this work, we present a novel type of cantilever's tips based on defect free GaN microrods for standard and conductive atomic force microscopy (AFM). GaN microrods were grown using the molecular beam epitaxy and arsenic-induced vapor-liquid-solid method (Fig. 1a). Such growth mode ensure fabrication of GaN microrods which are free of typical threading defects present in epitaxial GaN layers and structures. A scanning electron microscopy with manipulators system was used to transfer a single microrod (Fig. 1b). A focused ion beam milling was employed to form the GaN microrod into a tip shape (Fig. 1c). The usability of the new tips was verified. Conductive and mechanical AFM measurements did not reveal significant tip wear.

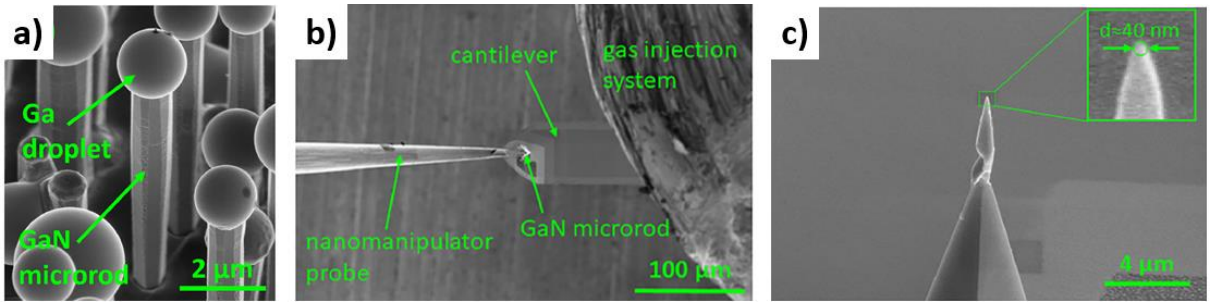

Figure 1. SEM image of: a) GaN microrods on the original substrate, b) GaN tip prototyping process, c) GaN tip.

Acknowledgements: This work was supported by the National Science Centre, Poland PRELUDIUM-21 grant ["Nanometrology of field emission phenomena from electron beam deposited nanowires operating as nano- and picodeflection sensors – FEmet", grant number 2022/45/N/ST7/03049]; and the National Science Centre, Poland OPUS grant ["Nanometrology of Nottingham cooling effect using operational microelectromechanical systems", grant numbers 2020/37/B/ST7/03792], and supported from the project: "High-performance AlGaN/GaN-HEMT transistors made with the hybrid MBE-MOVPE technology", number of agreement: 2/Ł-PORT/CŁ/2021, funded by The Łukasiewicz Centre.

[1] E. Gacka et al., *Ultramicroscopy*, 2023, **248**, 113713

P35

Conductive atomic force microscopy based surface nanometrology

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Electrical surface metrology of materials plays crucial role in modern science [1]. It can be done using conductive atomic force microscopy (C-AFM) or scanning spreading resistance microscopy (SSRM) modes.

Most of C-AFM and SSRM devices are in the form of application modules – one per single measurement mode. Each of them need to be precisely characterized for their long-term stability before surface metrology.

This work presents various solutions for C-AFM and SSRM application modules developed at the Department of Nanotechnology at WrUST. We are focused on three specific constructions:

1. Precise current integrator [2]
2. Multiple feedback transimpedance amplifier (MFTIA)
3. Logarithmic transimpedance amplifier

Precise current integrator is an alternative for transimpedance amplifiers based on resistance feedback loop in C-AFM. MFTIA integrates C-AFM with four linear feedbacks and SSRM mode in one module. It limits exchange of measurement mode just to single click. what speed-up measurements, and decrease the risk of tip/sample damage during operation. Logarithmic transimpedance amplifier with temperature compensation enables measurements C-AFM measurements up to 9-decades in single scan. Each solution will be briefly described, including its characterisation and their practical utilisation.

Acknowledgments

This work was supported by the Joint Research Project within the European Metrology Research Programme EMPIR - 20IND08 MetExSPM Traceability of localised functional properties of nanostructures with high speed scanning probe microscopy.

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[2] Design and evaluation of precise current integrator for scanning probe microscopy, K. Raczkowski, et al., 2017 *Meas. Sci. Technol.* 28 034013

P36

Conductive super sharp tip scanning probe microscopy technologies

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This poster presents the author's architecture of a current-voltage converter with logarithmic characteristics. This enables dynamic current measurements in the 1fA - 1 mA range during surface scanning in the author's atomic force microscope. In addition, the circuit is fully thermally compensated which allows measurements of any weakly conductive materials. The chip is equipped with a 16-bit digital-to-analog converter for convenient polarization of the structure from the computer program. The images taken with simultaneous topography data acquisition are presented. A piece of doped diamond, which is characterized by good electrical conductivity, was deposited on the active piezoresistive cantilever[1].

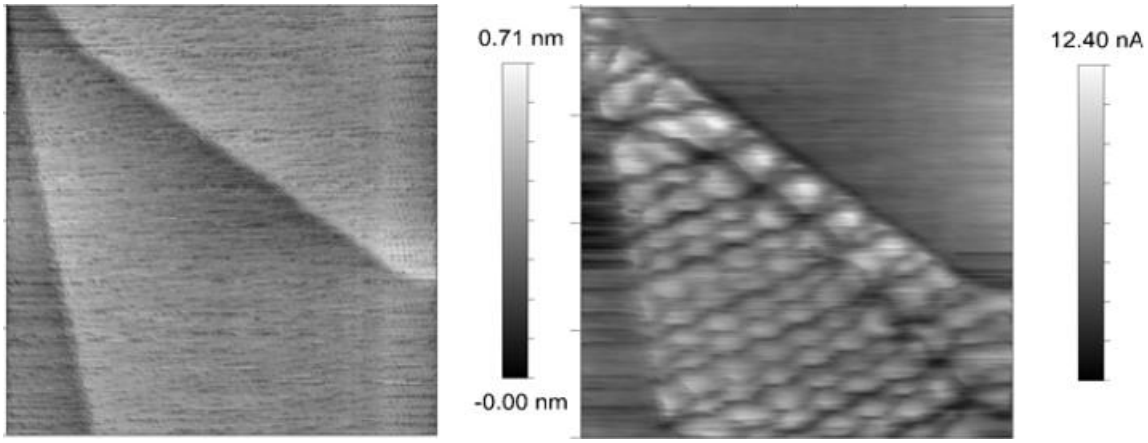

Figure 22. On the left is Topography and on the right is the current photo

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P37

Precise sample tilt reduction system for advanced AFM modes and the multi-angle scanning procedures

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The quality of the surface imaging using atomic force microscopy is limited by a number of factors, including the shape of the scanning tip. In addition, to the impact of the tip's cone angle (known also as aspect ratio) and radius of the apex, the sample tilt may be a significant source of the imaging artifacts. Moreover, within variety of advanced AFM techniques, one can point out a number of methods that can suffer from the non-orthogonality of the probe against the sample.

Therefore the physical correction of the sample's surface alignment in respect to the scanning plane and scanning tip's axis of movement is essential. In particular, the techniques basing on the lateral and orthogonal forces reveal particular sensitivity to such phenomenon. In case of lateral force microscopy, the sample tilt introduces topography-related component, which despite further processing, may compromise the outcome.

A home-made, user-friendly solution of sample tilt correction system will be presented. It can be easily utilized in the microscopes using probe-scanning solution. It will be shown, that the precision and stability of the solution allows to perform time consuming experiments with high level of confidence.

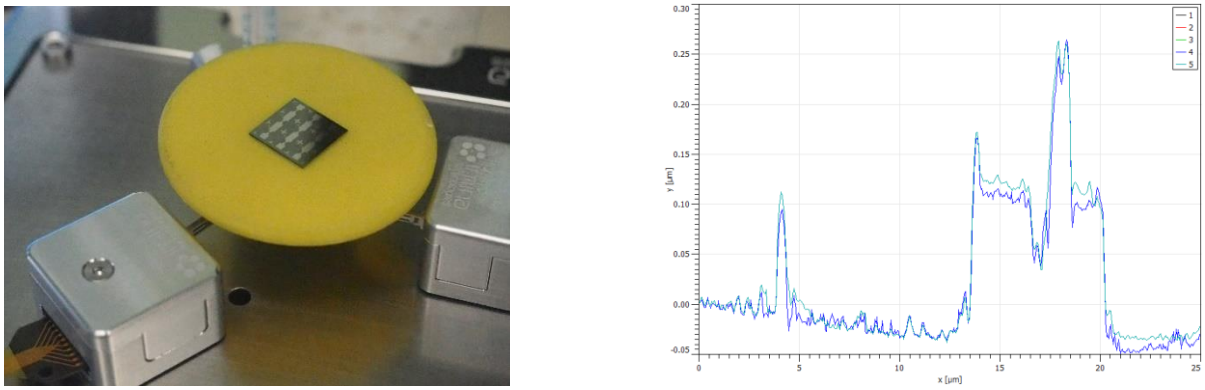

Figure 23. The view of the active support elements and the sample holder (left), the maximal deviation of the profiles acquired in 20 hours' time window, showing the stability of developed system.

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P38

Information theory based quantitative assessment of AFM images

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Assessing the image quality produced by atomic force microscopy (AFM) is an ongoing and challenging task. In our study, we applied the maximum information channel capacity (ICC)-based method [1] to measure the AFM image quality proposed in [2]. Within this method, the power spectrum and noise estimates are critical input information for the image quality evaluation. For example, the classical Welch method for spectral estimation uses an average of several windowed periodograms. In our work, we discuss an alternative technique based on the wavelet transform [3] that can be applied to solve this challenging problem, specifically in the case of noisy, uncertain AFM measurements. Finally, the enhanced ICC approach is verified using noisy measurement AFM data to assess quality images.

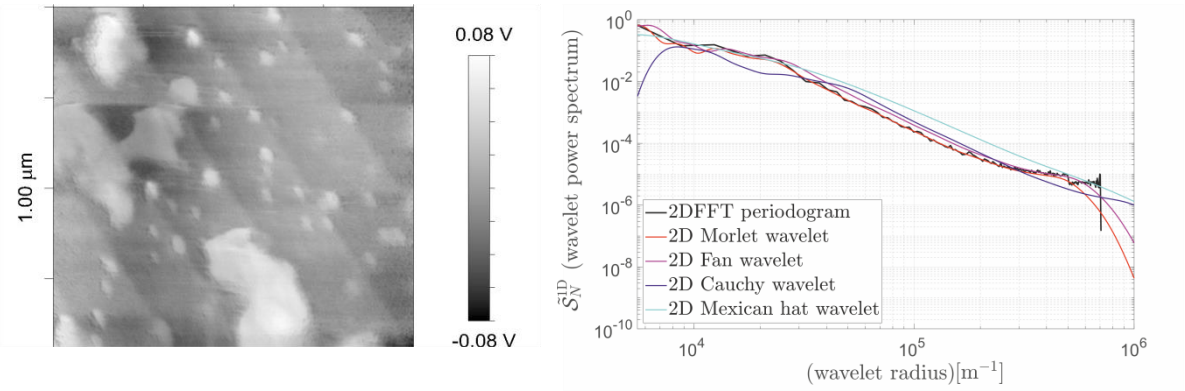

Figure 24. AFM image of reference sample: (a) result of the AFM measurement, (b) Wavelet spectrum compared to standard 2DFFT periodogram.

Correspondingly, since the ICC metric measure might be sensitive to signal-to-noise ratio due to the measurement uncertainties and image resolution, we propose to use the taper wavelet-based method to estimate the power spectra with insists on robust power noise estimation. The example of the wavelet spectrum for the reference sample has been shown in Fig. 1. Based on this information, the reliability of the biased ICC metric can be improved.

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P39

Effect of the Si Stepped Surface Anisotropy on Si-Au Structures

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Silicene, a two-dimensional (2D) allotrope of silicon [1], has recently emerged as a fascinating material in the realm of nanotechnology and materials science. With a structure resembling graphene, silicene exhibits unique electronic, mechanical, and thermal properties that set it apart from its three-dimensional silicon counterpart [2].
Synthesis of silicene, while challenging, has seen remarkable progress. It can be grown on various substrates, such as Ag, ZnB_2, and a few other [3], through techniques including molecular beam epitaxy and, and on Au(111) thin films grown on a Si(111) substrate in the process of surface segregation [4].

The distinction between silicene and graphene lies in their structural configuration; unlike graphene, silicene does not naturally exist as a free, single layer. However, the introduction of a metallic substrate has an impact on the electronic properties of silicene. On the other hand, this substrate serves as method to functionalize silicene [5]. Robust interactions between silicene and the substrate can give rise to the emergence of novel energy bands, consequently leading to the development of unique and exotic characteristics within silicene heterostructures that are not available separately for their individual constituents.

The findings presented in this study concern measurements conducted on Si structures grown on one-dimensional ordered substrates. These substrates consist of stepped silicon surfaces coated with Au layers. Utilizing a scanning tunneling microscope (STM), our investigations reveal that the attempt to synthesize silicene on vicinal surfaces often leads to a significant alteration of the substrate structure. As a consequence, the originally well-ordered, one-dimensional nature of the surface is disrupted, giving rise to the formation of wide and irregular terraces. Nevertheless, even on these modified structures, we still observed the presence of flat silicene alongside structures characteristic of the Si-Au interface.

The work has been supported by the National Science Centre (Poland) under Grant No. 2018/29/B/ST5/01572.

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P40

Haptic SPM Technologies

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Magnification and resolution are the two most critical parameters of the microscope. Nowadays, both are limited by physical laws and not by technology and engineering. Modern electronic devices become smaller and smaller, achieving (sub)nanometric sizes. Low-dimensional structures (2-D, nanowires, quantum dots, etc.) are considered to be the materials of the future. On the one hand, when using optical and electron optics, as the magnification increases, the more complicated and restrictive the system becomes. On the other hand, there are Scanning Probe Microscopy (SPM) systems enabling atomic resolution in ambient conditions. Regardless of the microscope type used, the biggest challenge is finding the tiny samples instead of measuring them.

By taking advantage of the sense of touch of humans, there is a possibility of overcoming these difficulties by incorporating a human into the scanning process in a 'Human in the loop' system. When using dedicated haptic device, an operator sets the position of the SPM probe and receives a haptic feedback of the measured tip-sample interactions. The author developed a multi–modal haptic manipulator and integrated it with a self–designed microscope controller. Any type of measurement signal can be used as a force-feedback input, e.g. topography, friction, temperature, or current. The system is metrological and calibrated with the use of a laser vibrometer.

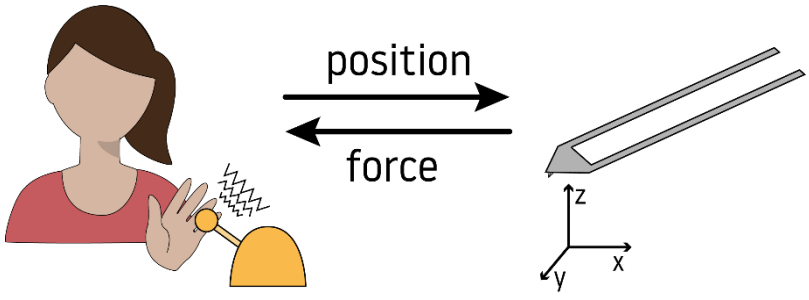

Figure 25. The proposed 'Human in the loop' system uses a dedicated haptic device to translate human hand movement to AFM stage movement and provides force feedback proportional to the tip-sample interactions.

P41

Neurofilament light chain level influencing changes in stiffness of the optic nerve as a potential biomarker in experimental autoimmune encephalomyelitis, an animal model of multiple sclerosis

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Multiple sclerosis (MS) is a debilitating disease of the central nervous system characterized by multi-focal inflammation, demyelination and neuronal damage. The mouse model of MS, experimental autoimmune encephalomyelitis (EAE) which mimics its clinical, immunological and histopathological features is commonly used for the investigation of neuroprotective agents with potential use against MS [1].

MS and its animal model, EAE) are often accompanied by optic neuritis associated with neurofilament disruption. In this study, the stiffness of the optic nerve was investigated by atomic force microscopy (AFM) in mice with induced EAE in the successive phases of the disease: onset, peak and chronic. AFM results were compared with the intensity of the main pathological processes in the optic nerve: inflammation, demyelination and axonal loss, assessed by quantitative histology. Optic nerve tissue and serum levels of neurofilament light chain protein (NEFL) were also examined by immunostaining and ELISA, respectively [2].

The stiffness of the optic nerve in EAE mice was lower than that in control and naïve animals. It increased in the onset and peak phases and sharply decreased in the chronic phase. Serum NEFL level showed similar dynamics, while tissue NEFL level decreased in the onset and peak phases, indicating a leak of NEFL from the optic nerve to body fluids. Inflammation and demyelination gradually increased to reach the maximum in the peak phase of EAE, and inflammation slightly declined in the chronic phase, while demyelination did not. The axonal loss also gradually increased and had the highest level in the chronic phase. Among these processes, demyelination and especially axonal loss most effectively decrease the stiffness of the optic nerve [2]. NEFL level in serum can be regarded as an early indicator of EAE, as it rapidly grows in the onset phase of the disease.

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P42

LaterCal – a software for easy wedge calibration method for Lateral Force Microscopy

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Lateral force microscopy (LFM) is a powerful AFM imaging mode, which can give valuable nanomechanical data on wide range of samples [1]. Its great advantage is that it can be performed together with a normal contact mode scan, without any specialized probes or additional equipment. However, LFM use is limited by the fact, that AFM probe calibration for torsional deformation is much more challenging than calibration of vertical bending. Even though many methods for lateral probe callibration were developed, none is as user friendly and reliable as thermal tune method employed in force spectroscopy [2]. Among these, the wedge calibration approach has an advantage of using a standard, off the shelf silicon grating with defined angles [3,4]. However, the method requires solving a polynomial equation and selection of correct solution, which can be often time consuming and challenging for AFM users without STEM background.

Here we propose LaterCal, standardized software designed for an easy and straightforward application of wedge lateral calibration. Based on values of adhesion, loading force and values from friction loop of lateral scans of standard TGF11 grating the software produces a probe calibration factor. We hope that LaterCal will contribute for wider application of LFM, particularly in life science applications.

This research was funded by the NCU INTER DISCIPLINAS EXCELLENTIA competition, research project "LATTE - LaTeralTEchniqueBio-AFM Team"

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P43

Titanium dioxide nanoparticles for applications in photovoltaic cells

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The mesoporous titanium dioxide layer is an important component of photoelectrochemical devices such as dye sensitized solar cells. Titanium dioxide in the form of a nanoparticles coating can act as a photosensitive material in the visible light range after adsorption of specially selected organic dyes, which must meet a number of requirements. The dye molecules have to create durable bond on the surface of nanoparticles, not to react with the liquid electrolyte penetrating the pores in TiO_2 and show appropriate alignment of the HOMO and LUMO energy levels in relation to the conduction band of semiconductor as well as the redox potential of the electrolyte. Organic dyes serve as sensitizers of titanium dioxide which is known for absorption in the UV range of light. The TiO_2 nanoparticles are deposited in form of a paste using a doctor blade method and sintered at a temperature of 450˚C to obtain contact between them and required conductivity. Important features of TiO_2 influencing the dye adsorption process are their crystalline structure, size of nanoparticles, thickness of the layer and the pore size. The work presents the results of research aimed at proper preparation of the photoactive TiO_2 anode coating and measurements of the I-V characteristics of the assembled photovoltaic cells.

P44

Nanomechanical and Adhesive Properties of Mesenchymal-Sword of Damocles (MSOD) Cells Studied by AFM Methods

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Mesenchymal Stromal Cells are multipotent cells that can differentiate in vitro or in vivo into a variety of cell types (e.g. adipocytes, chondrocytes, osteoblasts) and they are the crucial element of the bone marrow niche. They interact with hematopoietic and leukemic cells within the bone marrow niche. Therefore, characterization of hematopoietic and leukemic cells adhesion with MSCs may indicate potential targets to regulate hematopoiesis and eradicate leukemic cells.

In this work we used the MSOD (Mesenchymal Sword Of Damocles) cell line, which is a standardized, immortalized cell line, where some cells maintain the properties of primary bone marrow-derived human mesenchymal stromal cells (hMSCs).

Here we used the AFM nanoindentation method in the force spectroscopy mode applied for single cells to characterize the nanomechanical and adhesive properties of MSOD cells. The AFM measurements were supplemented by fluorescence imaging of cytoskeleton proteins and specific ligands. In addition to quantitative and qualitative analysis of the elastic modulus of MSOD cells, we performed measurements of the interaction of U937 leukemic cells with MSOD. In this experiment, the leukemia U937 cells have been attached to the fibronectin-functionalized tipless AFM cantilever. The measured force-distance curves provided the information about total detachment force and its work in the studied system. The interaction between bone marrow stromal cells and tumor cells constitutes one of the important issues in the considerations about tumor progression and metastasis process.

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P45

Plant-Derived Chalcones as Anti-Fibrotic Agents: Focus on Licochalcone A

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Recent *in vitro* and *in vivo* studies have proven antioxidant, anti-inflammatory, and antifibrotic properties of licorice (*Glycyrrhiza*) species root extract. Licochalcone A is one of many flavonoids responsible for the mentioned effects. As such, Licochalcone A has garnered attention from the scientific community, especially among researchers identifying potential pharmacological agents for managing inflammatory conditions and fibrotic pathologies.

Given the antifibrotic characteristics demonstrated by other flavonoids derived from licorice root extract, we suspected that Licochalcone A may inhibit the TGF-β-induced fibroblast-to-myofibroblast transition (FMT), a key process in subepithelial fibrosis associated with diseases like asthma. To verify this hypothesis, we conducted experiments involving bronchial fibroblasts obtained from asthmatic patients. Initial assessments involved viability and proliferation assays to establish non-cytotoxic and non-cytostatic concentrations of licochalcone A. Immunofluorescent staining results indicated that non-cytotoxic concentrations of Licochalcone A had an inhibitory effect on TGF-β1-induced fibroblast-to-myofibroblast transition, resulting in a reduction in the percentage of myofibroblasts formed under the influence of TGF-β1 when combined with this compound. Further analysis using Western Blot and in-cell Elisa techniques confirmed that Licochalcone A attenuated the expression levels of markers associated with fibrosis, including α-SMA, fibronectin, and collagen I. To elucidate the underlying molecular mechanisms responsible for these effects, the impact of Licochalcone A on the activity of TGF-β signaling pathways was assessed. Immunofluorescence staining revealed that Licochalcone A effectively inhibited the nuclear translocation of phosphorylated Smad2 and Smad3 proteins, integral components of the profibrotic TGF-β1 pathway.

In conclusion, our findings suggest that Licochalcone A is a promising candidate for preventive therapy against fibrotic processes, such as subepithelial fibrosis in asthma. However, further research is needed to confirm these preliminary observations.

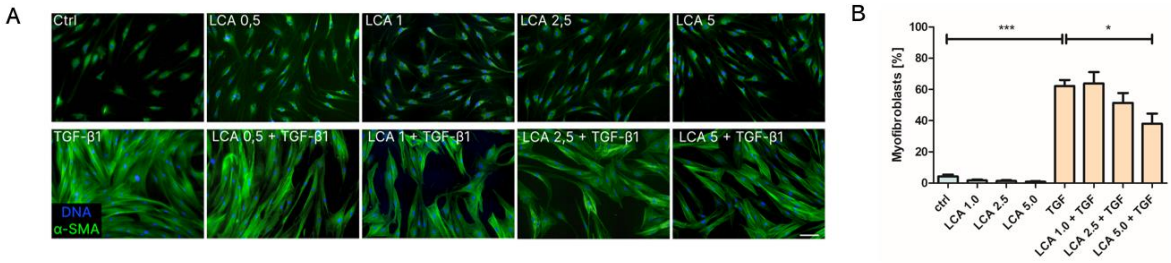

Figure 1. Inhibiting effect of LCA on FMT process in HBF populations. (A) Human bronchial fibroblasts fixed with 3.7% formaldehyde were stained by immunofluorescence using a primary antibody against α-SMA. (B) The percentage of myofibroblasts was calculated by counting the number of α-SMA positive cells and presented as mean ± SEM. Statistical significance analysis was performed using the Kruskal-Wallis test, *p <0.05, **p <0.01, ***p <0.001. Bar = 100 μm.

P46

Adaptation of *Escherichia coli* to sub-inhibitory concentrations of ampicillin

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According to the World Health Organization (WHO), bacterial resistance to antibiotics is one of the major threats to public health [1]. The widespread and often inappropriate use of antibacterial substances in medicine and agriculture results in a situation when bacteria are frequently exposed to non-lethal concentrations of drugs, an important factor in the evolution of antibiotic resistance [2]. Bacteria developed multiple strategies for antibiotic resistance. Recent studies suggest that cell morphological alterations in response to antibiotic, such as change in size and surface-to-volume ratio, may play an important role in resistance [3].

The main objective of the project was to determine whether long-term exposure of bacteria to sub-inhibitory concentrations of ampicillin would affect the cell morphology, surface properties and induce antibiotic tolerance.

LFM (Lateral Force Microscopy) measurements were performed with a Bioscope II AFM equipped with a NanoScope V controller (Veeco) and using an SNL-10 C silicon nitride cantilever with a normal spring constant 0,22 N/m. The lateral force calibration was performed using improved wedge method [4] using the TGF11 calibration grating (Micromash), with lateral PSD sensitivity 250 nN/V.

Repeated exposure to increasing sub-inhibitory concentrations of ampicillin resulted in a significant increase in *E. coli* tolerance to the antibiotic. Adaptation leds to changes in bacterial cell size, morphology and surface properties, particularly surface frictional forces.

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P47

Development of a surface-mapping Raman spectrometer for the analysis of sensitive compounds in an inert gas atmosphere of a glovebox.

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Raman spectroscopy is an experimental method commonly used in surface physics, chemistry and nanotechnology. It exploits the Raman effect, in which photons undergo inelastic scattering when interacting with a substance. However, a significant limitation of most commercial Raman spectrometers is that they are limited to measurements in air. This is problematic for many sensitive materials, as exposure to atmospheric conditions can alter their surface physicochemical properties and even cause the transformation of one chemical compound into another. In surface physics, these changes can play a key role in the analysis and characterisation of a material's structural and chemical attributes.

Solid rhenium heptoxide (Re_2O_7), a member of the Transition-metal oxides (TMOs) group, is an example of such a chemical. Due to its strong hygroscopicity, Re_2O_7 readily converts to perrhenic acid ($HReO_4$) when exposed to moisture. This sensitivity makes it an exemplary object for Raman spectroscopic studies under controlled conditions.

We present our innovative mapping Raman spectrometer, designed for characterisation in an argon-filled glovebox. This design enables the study of reactive compounds and materials in well-controlled environments, increasing accuracy in surface physics and material interaction studies.

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P48

Comparison of AFM and microfluidics in the analysis of biomechanical properties of cells treated with drugs affecting the cytoskeleton.

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The biomechanical properties of cells are, on the one hand, crucial for the proper functioning of the cells themselves and their interactions with the environment. On the other hand, with the development of many diseases, such as cancer, the biomechanical properties of cells may change. Furthermore, changes in the cell cytoskeleton caused by, among others, the action of drugs may lead to changes in the biomechanical properties of cells. Therefore, developing methods of analyzing the biomechanical properties of cells are essential approach to be integrated in biological and medical research.
In this work, we compare two methods for analyzing the biomechanical properties of cells. Although determination of cell mechanical properties by Atomic Force Microscopy is still considered to be the gold standard, its limitation in high throughput mechanoprofiling of larger cell populations has stimulated development of additional tools. Thus, a microfluidics-based approach is here selected as the second technique It is based on passing a cell suspension through narrow channels where cells are squeezed, then their size and flow time are analyzed.
In our studies, we treated melanoma cells with drugs that act on the cytoskeleton and then analyzed their biomechanical properties using both methods. In this work, we would like to present the differences between both methods and the possibilities of their application.

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P49

Pyramidal Growth of Transition Metal Oxide Films

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In our previous study, we have demonstrated the modification of work function of graphene by depositing a thin layer of rhenium oxide (Re_2O_7) [1,2] and molybdenum oxide (MoO_3) [3]. This process is usually accomplished by thermal evaporation of the oxide thin film under ultra-high vacuum conditions. However, our research shows that it is also possible to produce 2D crystalline materials using a hot plate in air. Then obtained layers can be transferred to the chosen substrate using a polymer: poly(methyl methacrylate) (PMMA) via a wet transfer process. Interesting in our study we observed pyramid-like structures as well.

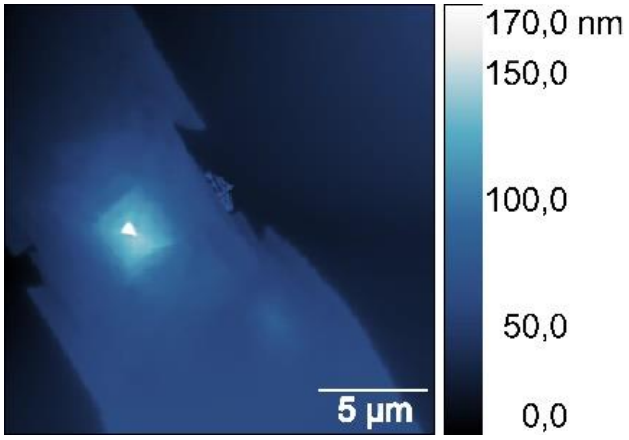

Figure 1. AFM image of layers formed by annealing mica over rhenium foil on a hot plate at 450° C for 3 h.

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P50

A new *in vitro* cellular model for pharmacological studies on liver sinusoidal endothelial cells refenestration

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Liver disease accounts for two million deaths annually and is responsible for 4% of all deaths [1]. One of the risk factors of liver disease is drug-induced liver injury. Several models of liver pathology have been established so far, allowing to test of liver pathology *in vivo* [2]. Over the years, the role of liver sinusoidal endothelial cells (LSECs) in maintaining a healthy liver has been highlighted. LSECs have transcellular pores, called fenestrations, that are indicators of the healthy phenotype of the liver. These nanostructures – 50-350 nm in diameter – participate in the passive, size-regulated bidirectional transport between the vascular system and the liver parenchyma. Loss of fenestrations (defenestration) in LSECs causes impaired transport to the liver and is considered as the "*canary in a coal mine*" for liver pathology. To investigate the direct effects of new drugs on LSEC porosity efficiently, a model of *in vitro* LSECs' defenestration is needed.

Atomic force microscopy (AFM) remains the exclusive tool allowing for drug response monitoring in living LSECs for up to 6 hours [3]. Fenestration number, diameter, lifespan, migration range, and deformability can be quantified. Moreover, Young's modulus distribution over the whole cell and its changes over time can be calculated [4]. Being a label-free method, AFM can be used to evaluate drugs' effects on LSEC fenestration in living cells.

Here, the results of *in vitro* profiling of LSECs fenestration on a single cell level in the genetic model of mice with deletion of Mcpip1 in myeloid leukocytes [5] are presented. Briefly, single-cell morphology and its nanomechanical properties are tracked over time. Then, a drug is injected into the culture medium and the cell response to the drug is further observed. It allows for monitoring morphological features and cytoskeleton remodeling, including their effects on alterations in Young's modulus distribution. The main aim was to induce pharmacological refenestration of defenestrated LSECs isolated from 3- and 6-month-old Mcpip1 knock-out mice. AFM data were supplemented with results with scanning electron microscopy (SEM) and quantitative fluorescence microscopy of fixed LSECs. We conclude that mice with deletion of Mcpip1 in myeloid leukocytes display defenestrated LSECs, that could be partially reversed by pharmacological tools, and could be used as a model of LSEC defenestration. The model will allow researchers to better understand the progression of LSECs' damage, the mechanisms of defenestration, and finally, to develop novel strategies for refenestration in liver pathology.

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P51

Nanoscale Dry Kinetic Friction of Diamond-Graphene pair: Computational Studies

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Tribology, the branch of science dedicated to studying surfaces moving relative to each other, plays a crucial role in improving the efficiency and ensuring greater reliability of mechanical components. A thorough understanding of the interactions between two surfaces in contact allows for significant reductions in energy and material losses, as well as surface damage. It is estimated that on a global scale, friction-related losses account for approximately 23% of all energy produced [1]. With the continuous drive to increase the efficiency of mechanical devices and their miniaturization, this field of science is more important than ever.

The most widely used tool for conducting friction research at the nanoscale is the atomic force microscope (AFM). However, this tool has limitations in scanning speed and applied forces. As a result, computational methods like molecular dynamics (MD) and steered molecular dynamics (SMD) complement physical experiments by simulating friction with precise control over sliding velocity and applied force.

Our work focuses on describing dry friction mechanisms influenced by materials (such as graphene, transition metal dichalcogenides, alkylsilane layers), as well as environmental conditions. Notably, the friction-reducing properties of graphene are context-dependent, requiring consideration of factors such as sliding velocity and loading force. The complexity of friction, evident in experiments, necessitates further investigations. Special attention is given to studying the relationship between friction force, sliding velocity, and loading force [2]. We studied friction phenomena in simulations across a range of cantilever tip sliding speeds, including values not achievable with an AFM microscope, and for different cantilever loading forces on the sample.

Acknowledgements

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P52

Application of AFM Microscopy and Spectroscopic Methods For Examination of Human Hair

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Human hair is a biomaterial that attracts great interest for many scientists. Chemically, it is primarily composed of proteins, particularly keratin. Keratin is a fibrillar protein mainly composed of sulfur-containing amino acids, namely cysteine and methionine [1].

The paper presents the results of microscopic and spectroscopic research on human hair, before and after dyeing. The objective of this research was to determine the physical characteristics and chemical composition of both forms of hair. Surface studies were carried out using AFM microscopy, while the chemical analysis employed FTIR spectroscopy and X-ray photoelectron spectroscopy.

Figure 1 presents the results of the microgeometry testing of the hair surface using AFM microscopy before and after dyeing.

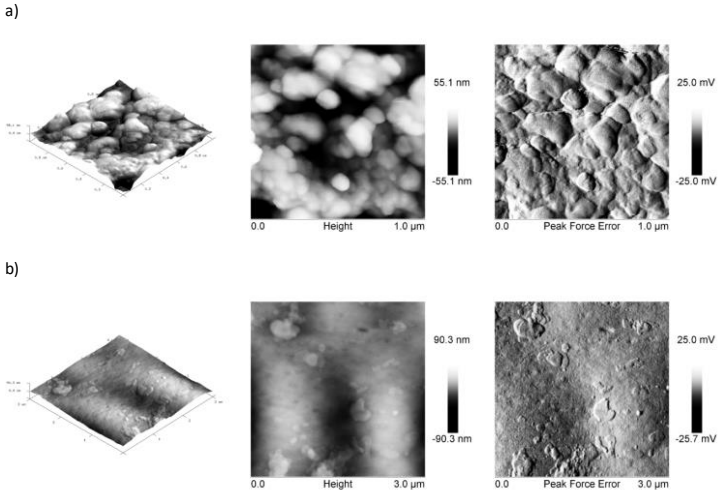

Figure 26. Surface microgeometry maps generated using AFM microscopy for the hair: a) before, and b) after dyeing.

The microgeometry studies carried out using atomic force microscopy (AFM) exhibited significant differences in the microscopic image of the hair surface before and after dyeing. Spectroscopic studies proved that the hair before dyeing has a larger sulfur content on its surface compared to the dyed hair.

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P53

Thermoresponsive smart copolymer coatings for biomedical applications studied with surface-sensitive methods

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Fabrication of thermoresponsive coatings for regenerative medicine based on polymers that can be easily functionalized is one of the most essential obstacles in modern biomaterials science. This study utilized atom transfer radical polymerization to produce two novel smart copolymer brush coatings. Their chemical compositions were verified using time of flight - secondary ion mass spectrometry and X-ray photoelectron spectroscopy. Their thermoresponsiveness was examined through water contact angle measurements at different temperatures, revealing a transition driven by lower or upper critical solution temperature, or a vanishing transition. Furthermore, it was demonstrated that the transition temperature of the coatings could be adjusted by modifying their composition. The topography and roughness of the coatings were characterized using atomic force microscopy.

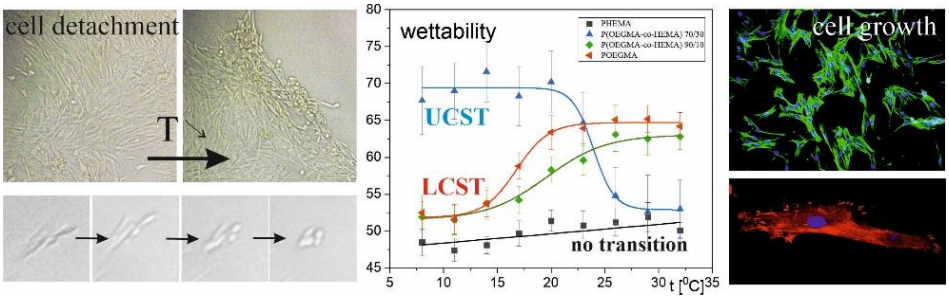

Fig. 1. Properties of the novel smart copolymer brush coatings for regenerative medicine.

To assess the biocompatibility of the coatings, dermal fibroblast cultures were employed, and the results indicated that none of the coatings exhibited cytotoxicity. Then, the formation of adhesive focal sites in the early adhesion stages was visualized by vinculin staining. However, the shape and arrangement of the cells were significantly influenced by the chemical structure of the coating. Additionally, the viability of the cells was correlated with the wettability and roughness of the coatings, which determined the initial adhesion of the cells. Lastly, the temperature-induced changes in the properties of the fabricated copolymer coatings effectively controlled cell morphology, adhesion, and spontaneous detachment in a non-invasive, enzyme-free manner that was confirmed using optical microscopy [1].

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P54

Thermal evolution of silicene on metallic ultrathin film – STM study

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Since the discovery of graphene, much focus has been oriented towards study of two-dimensional materials, such as group IV 2D-Xenes or transition metal dichalcogenides. These materials exhibit variety of unique properties and phenomena, such as quantum spin Hall effect or significant susceptibility of physical properties to chemical functionalization. Among such materials silicene – two-dimensional allotrope of silicon – is of particular interest, especially owing to its compatibility with existing silicon technology.

A multitude of possible substrates has been reported as suitable for silicene growth [1]. Among them of special interest is Si(111), as one of the most widely utilized substrates in electronics. It is possible to synthesize silicene on top of ultrathin metal films on Si(111), with lead [2] and gold [3] being already reported candidates. In case of ultrathin gold layers, several silicene phases has been observed [4]. Unfortunately, synthesis is highly sensitive to process temperature, with multiple phases appearing in small temperature window and high probability of obtaining multilayered structure.

Results of preliminary studies on structure of different Si phases, including silicene, obtained under different synthesis temperatures will be presented. Structures were examined using scanning tunneling microscope (STM) and reflection high-energy electron diffraction (RHEED). Results reveal the real-space arrangements of consecutive Si and silicene phases and establish a basis for future, application-oriented studies.

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We acknowledge financial support from the National Science Centre of Poland through the OPUS project no. 2022/45/B/ST5/01018.

P55

Detectors of SPM cantilever deflection based on field emission phenomenon

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The most common deflection detection methods for micro-electromechanical systems (MEMS), like microcantilevers used in scanning probe microscopy, include optical methods based on optical beam deflection systems, piezoresistive or capacitive methods. This issue is still being pursued in order to develop a method with the highest possible deflection sensitivity. For this reason, attention is focused on exploiting the field emission phenomenon – the tunnelling of electrons through a potential barrier that occurs when the applied threshold voltage between electrodes is exceeded.

This work presents a method for microcantilever deflection detection based on field emission phenomenon – fig. 1a. As a result of cantilever deflection, the distance between the emitter tips (electrodes) was changed, resulting in a variation of the threshold voltage and field emission current. Nanotip field emitters were integrated into the microcantilevers using a focused electron and ion beam induced deposition (FEBID/FIBID) (fig. 1b). This one-step process allowed for the simplification of their fabrication technology. The effect of distance between electrodes and emitter shape on the emission enhancement factor was analysed. Preliminary usability tests of the sensor have been performed.

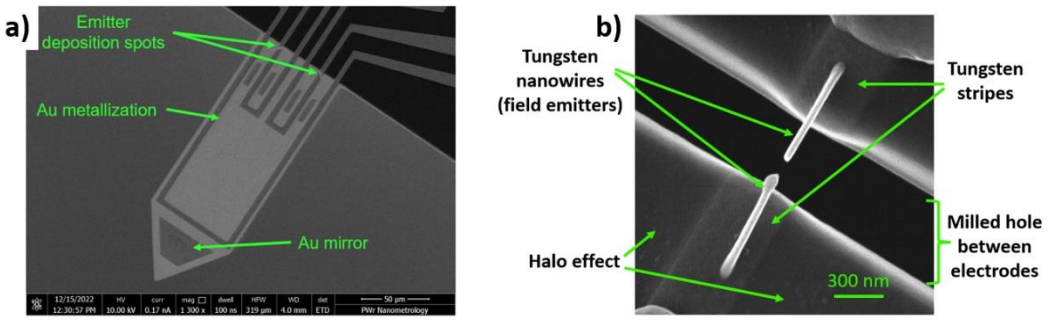

Figure 1. SEM image of: a) microcantilever and b) integrated with microcantilever FEBID/FIBID field emitters used as deflection detectors.

Acknowledgements: This work was supported by the National Science Centre, Poland PRELUDIUM-21 grant ["Nanometrology of field emission phenomena from electron beam deposited nanowires operating as nano- and picodeflection sensors – FEmet", grant number 2022/45/N/ST7/03049]; and a short term scientific mission funded by the COST Action CA19140 (http://www.fit4nano.eu/).

P56

Oxidation process in 1T-TaS_2/graphene heterostructure

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One of the most important demands of the current world is the search for new materials that can be used in the electronic industry. Because silicone transistors are now approaching the scaling limit to further scale down the device, application for this purpose of the 2D materials and their heterostructures is most promising. Currently, several different transistor construction methods based on 2D materials are taken into account, including bottom-gate or top-gate devices or even those without oxide layers. Each of them has some advantages and drawbacks. Bottom-gate and top-gate systems include oxide layers both based on the lithography technology, whose resolution is limited and requires high dielectric constant (k) oxides to scale down the device. The advantage is that the technology of this process is well known for years therefore application in the semiconducting industry can be more straightforward. Similarly, as in the case of transistors new generation prototypical resistive RAM (ReRAM) or even non-volatile memory-based hardware neural networks to realize brain-like computing based on non-von Neumann architectures have been implemented using 2D materials and their heterostructures as active layer.

Here, we present experimental results of the spontaneous oxidation process of 1T-TaS_2 and propose a nanolithography technique using a scanning tunneling microscope to control the number of the 1T-TaS_2 layers. This allows for studying properties of single- up to few-layer thick 1T-TaS_2 in the hybrid structure with graphene. Moreover, spontaneous oxidation leads to the creation of the three-component hybrid van der Waals heterostructure including high k-dielectric tantalum oxide, 1T-TaS_2 with large electron-electron interactions leading to CDW formation, and graphene working as a conductive layer. This system allows to study of the insulator-semiconductor-conductor junction which can be important from the point of view of next-generation electronic device construction.

This work was financially supported by National Science Centre, Poland under projects 2019/32/T/ST3/00487, 2018/31/B/ST3/02450, 2018/30/E/ST5/00667, 2020/37/B/ST5/03929.

P57

Shear force impact on bladder cancer spheroids deformation and cell migration in 3D collagen-hyaluronic scaffolds

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Rheological properties of the local cancer microenvironment have been shown to significantly influence cancer cell migration and invasion [1]. To fully understand the metastasis process, it is crucial to evaluate the dynamic interactions of cells with the mechanics of the surrounding extracellular matrix (ECM). In this study, collagen-hyaluronic acid (Col-HA) hydrogels have been used to resemble natural ECM properties, where embedded 3D spheroids mimicked complex physiological properties of living tissues, such as cell-cell and cell-scaffold interactions [2]. Spheroids were formed from non-malignant cancer cells of the ureter (HCV29) and human bladder cancer (transitional cell carcinoma, T24 cells). The study aims to analyze the viscoelastic properties of Col-HA hydrogels and their effect on cell migration from the spheroid surface. The designed hydrogels with different mechanical properties showed shear storage modulus (G') of 24.2 ± 9.7 Pa and 0.8 ± 0.3 kPa, and loss modulus (G'') of 6.6 ± 2.0 Pa and 0.1 ± 0.05 kPa, respectively. The samples were deformed by applying a shear strain γ = 1% and frequency f = 0.1 ÷ 10 Hz, mimicking physiological mechanical forces. Spheroid deformation and migration of single cells within the hydrogel structure were recorded using a light microscope. The migration of cells was significantly larger for T24 cells, which are highly invasive compared to HCV29 cells. The results showed that cell escape from the spheroid surface to the 3D Col-HA matrix depends on hydrogel mechanics and cell phenotype. Obtained results might help understand the relation between physicochemical and biological properties in the cell-ECM interfaces.

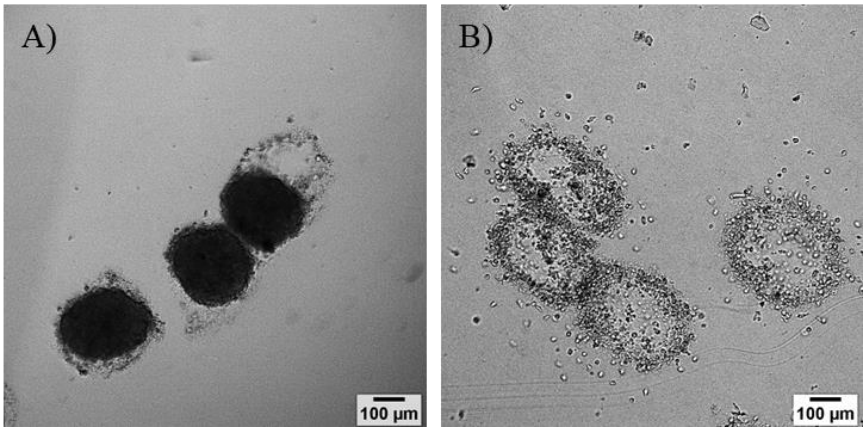

Figure 27. Cancer cells migration from spheroids surface into Col-HA hydrogel environment under applied shear forces: A) non-malignant cancer cells of the ureter (HCV29 cells) and B) transitional cell carcinoma (T24 cells).

Acknowledgments

This study was financed by the National Science Centre (Poland), project no. UMO-2021/41/B/ST5/03032 (NCN, OPUS-21).

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P58

The Influence of Different Concentrations of β-Hydroxy β-Methylbutyric Acid on Biosynthesis of the Collagen Type I

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Collagen type I is a major structural protein in the extracellular matrix of various tissues and organs. Its biosynthesis is a complex process leading to the creation of fibrils. β-Hydroxy β-methylbutyric acid (HMB) is a metabolite of the branched-chain amino acid leucine, which has been reported to stimulate collagen synthesis. However, the mechanism of HMB-induced collagen synthesis is not well understood. This study investigated the effect of different concentrations of HMB on the molecular structure and morphology of collagen type I using FTIR spectroscopy and atomic force microscopy. Collagen fibres were prepared according to the protocol presented in [1] with (experimental groups) or without (control) the addition of HMB in three concentrations: 3 mg/mL, 30 mg/mL and 300 mg/mL.

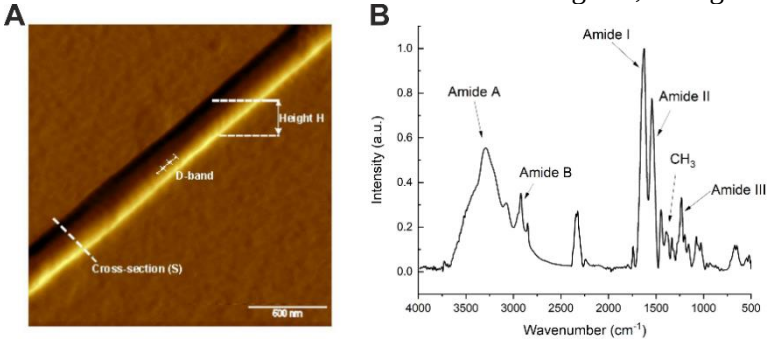

Figure 28. Collagen type I AFM image with height H, D-band and cross-section S (A) and its FTIR spectra with prominent bands (B).

AFM scans were done on dry samples. For each scan (Figure 1A), the parameters describing the fibre morphology were measured. FTIR spectra were recorded in the 4000-500 cm^{-1} range (Figure 1B) at a resolution of 4 cm^{-1}. A single spectrum was obtained as an averaged signal from 40 measurements. After the acquisition, the spectra were corrected and normalised. The ratio of the surface areas of Amide II to Amide I and the area under the band corresponding to Amide III were determined to quantify the changes occurring in the collagen structure. In addition, second derivatives were calculated in the ranges related to the Amide I and Amide III bands to determine the changes occurring in the secondary structure of the examined collagen.

Our results showed that HMB treatment at the lower concentration increased collagen type I biosynthesis and improved the quality of collagen fibrils, while in contrast, the highest concentrations of HMB disturbed collagen polymerisation, leading to various changes. Specifically, a decrease in the intensity of the amide I band and alterations in the amide III spectra were observed, suggesting disruptions in the secondary structure. AFM images also revealed a significant disorder in collagen organisation in higher HMB concentrations. In conclusion, our results indicate that optimal concentrations of HMB are necessary for enhancing collagen type I biosynthesis and improving collagen fibril quality.

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P59

A novel method of mechanical measurement of single nanowires on specialized substrates using the AFM method

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In this work, we report the repeatable mechanical measurements of single nanowires (NWs) [1]. We have shown that it is possible to locate NW on specific substrates with the support of nanomanipulation methods and focused electron beam-induced deposition (FEBID) (Fig. 1) and evaluate their properties like Young's modulus or tensile strength using AFM. Setup allows for thermal treatment of samples in situ, such case has also been investigated. The research is crucial for identifying the links between synthesis, structure, and property that, in turn, lead to the optimization of harvesting devices, biological systems, sensors, and many others.

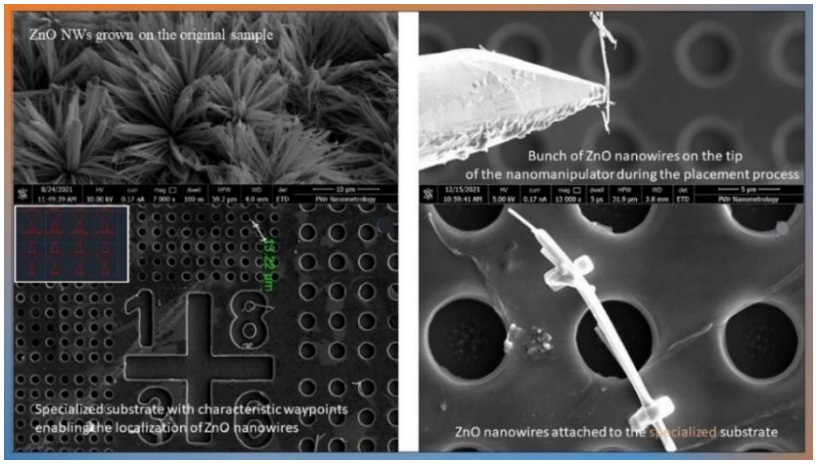

Figure 29. The process of transferring and mounting nanowires onto a substrate. Visible transport of the nanowire with manipulator and FEBID deposited mounting pads.

Acknowledgments
The following research has been conducted with financing from the project 19ENG05 – NanoWires funded from the EMPIR programme (European Union's Horizon 2020).

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P60

Doped Magnetite Nanoparticles – its Properties Related to the Composition.

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The synthesis of magnetite nanoparticles is gaining increasing interest due to their importance in technological and medical applications. Among the various magnetic nanoparticles Fe_3O_4 or γ- Fe_2O_3 are the most intensively studied [1]. Ferrite nanoparticles possess by the ability to change bath their morphology and properties by doping with other metal ions. This allows to create multifunctional materials. To optimize the properties of nanoparticles it is necessary to meet certain requirements that will it to the expanding scope of their applications [2]. Many scientists are trying to develop the controlled synthesis procedures to create magnetite nanoparticles of a specific size and narrow size distribution. Moreover, it is important to optimize the synthesis that does not require the use of toxic reagents and extremely high temperatures to minimalizing the ecological impact [3]. By standard to characterize the morphology and composition of nanoparticles, the following methods are used: transmission electron microscopy, atomic force microscopy, energy dispersive X-ray scanning electron microscopy, X-ray diffraction, etc.

This work presents the synthesis procedure and physicochemical characteristics of modified - doped ferrite nanoparticles. The aim of the work was to check the influence of synthesis conditions and dopant concentration on the physicochemical properties of nanoparticles. Nanoparticles were obtained by two chemical methods: co-precipitation of iron(II, III) chlorides in an alkaline solution and thermal decomposition of iron(III) acetylacetonate in a high-boiling solvent and in the presence of appropriate surfactants [4]. The obtained nanoparticles were characterized using: transmission electron microscopy, X-ray diffraction, energy-dispersive X-ray, infrared spectroscopy and porosimetry.

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P61

Epigenetic Alterations in Individual Chromosomes Upon Oxidative Damage

Karolina Juzba, Michał Sarna, Michał Czaja, Dawid Lupa, Kamila Sofińska, Marta Urbańska, Sara Seweryn, Ewelina Lipiec*

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Integrity of chromatin structure is essential for every process occurring in the cell nucleus. It also influences every aspect of cell function. Unfortunately, chromatin is continually endangered by various damaging factors, including oxidative stress. DNA, its genetic information, and methylation patterns are transmitted in a highly condensed form of chromatin called chromosomes to daughter cells upon a process known as cell division. Currently, the detection of oxidative damage is largely prohibited due to methodological limitations.

In this project, we examined chromosomes collected from two cancer lines – HeLa and MDA-T68. Hydroxyl radicals generated in Fenton's reaction were applied as the DNA damage-inducing factor. These radicals induce a conversion of the 5-methylcytosine to 5-hydroxymethylcytosine by oxidation.

We use two approaches to examine the influence of DNA damage on the structure and methylation patterns of chromosomes. The first one, a superresolution confocal microscopy, enabled the localization of dyed by using immunocytochemistry 5-hydroxymethylcytosine and 5-methylocytosine. The second approach uses atomic force microscopy to facilitate the changes in chromosomes morphology.

Achieved data demonstrates a correlation between the spatial localization of oxidative damage and morphological changes in chromosomal DNA.

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P62

Metallic nanoparticles produced by “green chemistry” and their antimicrobial potential

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The principles of green chemistry can be applied to nanotechnology to produce selected types of nanoparticles using natural reducing agents [1]. The addition of appropriately prepared plant extracts to selected metal precursors or metal oxides causes the growth of nanoparticles with a functional biocoating, which makes them more environmentally friendly. Numerous alkaloids, proteins and polyphenols present in plant extracts can both reduce and stabilize nanoparticles [2]. Biosynthesized nanoparticles can be obtained by mixing a salt precursor with a plant extract in an appropriate amount and appropriately selected synthesis conditions, e.g. pH, temperature, mixing time. TEM imaging enables confirmation of successful nanoparticle growth in this experiment. The size of the obtained nanostructures depends on the pH of the plant extract used and the type of matrix. Qualitative analysis of the diffractograms allows us to confirm that metallic nanoparticles were formed as a result of the reaction.

Atomic force microscopy can be used to interpret how nanoparticles interact with living organisms [3]. The growth and division of, for example, a wax rod can be monitored using atomic force microscopy (AFM). Studies using AFM imaging clearly showed that metallic nanoparticles caused damage to bacterial cells by changing their cell morphology.

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P63

Activity of the Nanotechnology Students' Association at the Jagiellonian University

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Nanotechnology Students' Association presents its activities and plans for the future. We are a dynamically operating and growing community of nanotechnology students who actively participate in various workshops, seminars, and scientific conferences. Our priority is to popularize knowledge about nanotechnology among students, including those outside our university. We have created a nationwide network of students' associations related to nanotechnology, aiming to support each other and share experiences. As part of our activities, we carry out a research project in the field of nanotechnology under the supervision of the Association's mentor. This initiative allows KNN members to participate in advanced research with specialized equipment.

Figure 30. *Board members with the mentor, prof. dr hab. Franciszek Krok*

P64

Setup for correlative electromechanical investigations of nanowires with scanning probe microscopy

Bartosz Pruchnik[1,*], Janusz Fidelus[2], Ewelina Gacka[1], Krzysztof Kwoka[1], Julia Pruchnik[1], Adrianna Piejko[1], Łukasz Usydus[3], Leszek Zaraska[4], Grzegorz Sulka[4], Tomasz Piasecki[1], Teodor Gotszalk[1]

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Measurement of mechanoelectric properties of nanowires (NW) require setup easily accessible for a mechanical probe and electrical connections [1]. We propose development of the novel device suited for scanning probe microscopy – SPM (specifically – atomic force microscopy – AFM) of nanowire simultaneously being measured electrically in four point setup by auxiliary equipment. Nanowire is delivered into the region of interest (RoI) with nanomanipulation methods, without modification of its chemical composition.

We present results of four-point resistance measurement with preliminary multimodal SPM tests performed on two prepared structures with ZnO NWs bound in the RoI mechanically and electrically.

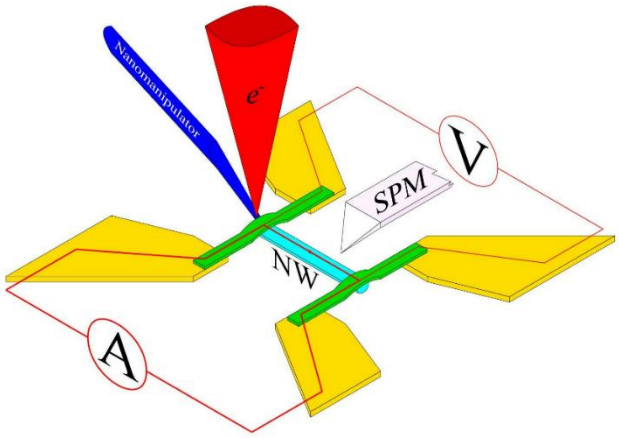

Figure 31. Schematic of the designed device device.

Acknowledgments
The following research has been conducted with financing from the project 19ENG05 – NanoWires funded from the EMPIR programme (European Union's Horizon 2020).

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- **Memsstar** - etching and deposition in semiconductor processes, MEMS and related technologies
- **TPT Wire Bonder** - Wire Bonding
- **Suss MicroTec** – photolithography, wafer bonding, photoresist deposition/etching and InkJet Printing
- **Grupa ECM** – vacuum furnaces, induction furnaces, CVD deposition reactors, photovoltaic furnaces

Research equipment:

- **Cameca** - secondary ion mass spectroscopes SIMS, APT (Atom Probe Tomography)
- **Hitachi** - electron microscopes SEM, TEM, STEM, FIB, Dual Beam, Triple Beam, AFM atomic force microscopes, sample preparation devices (flat milling, cross-section)
- **Thermo Fisher Scientific** - EDS, WDS, EBSD, XPS (ESCA) systems
- **Horiba Scientific** - Raman spectrometers, emission spectrometers: ICP-OES, GD-OES, GD-MS, monochromators, diffraction grids, spectroscopic ellipsometers, VUV spectrometers
- **Bruker-microCT** – computed microtomographs for research in the field of Material Science and Life Science (in-vivo and ex-vivo)
- **Neaspec** - nano-FTIR, neaSNOM systems
- **Setaram** - thermal analyzers: DTA, DSC, TG, TMA
- **C-therm** - thermal conductivity measurements
- **Solartron Analytical / PAR** - potentiostats/galvanostat
- **Newport Spectra-Physics** - photonics, optics and optomechanics, laser systems
- **Tribotechnic** – devices for tribological tests

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Firma LABSOFT jest wieloletnim, uznanym dostawcą urządzeń badawczych, aparatury pomiarowej i technologicznej renomowanych producentów. Oferowane przez nas urządzenia znajdują zastosowanie w ogólnie pojętej nanotechnologii, inżynierii materiałowej, naukach fizycznych, chemicznych, biologicznych i medycznych. Posiadamy bazę ponad 700 zainstalowanych przyrządów badawczych, w tym o bardzo wysokim poziomie złożoności, oraz szereg referencji ze zrealizowanych dostaw świadczących o naszych kompetencjach i doświadczeniu.

Labsoft to zespół ponad 30 osób, w tym 14 inżynierów serwisowych rozlokowanych na terenie całego kraju. Śledzimy uważnie dynamicznie rozwijający się rynek urządzeń badawczych, stale podnosimy swoje kwalifikacje, wprowadzamy i proponujemy nowe rozwiązania. Wysokie kompetencje naszych inżynierów sprawiają, że pomagamy partnerom w serwisie aparatury także poza granicami Polski. Jako doświadczona firma, doskonale zdajemy sobie sprawę ze złożoności współczesnej aparatury badawczej, z jej niesamowitego potencjału badawczego, ale również z wyzwań stawianych operatorom oraz osobom interpretującym uzyskane wyniki. Dlatego naszym celem jest wdrożenie koncepcji pełnego wsparcia klienta – od doradztwa przy wyborze urządzeń, poprzez przygotowanie pomieszczeń, instalację i uruchomienie aparatury, przeszkolenie użytkowników, utrzymanie jej w ruchu, aż do udzielenia wsparcia aplikacyjnego dla użytkowników.

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MEASLINE company specializes in designing and manufacturing of research and measuring devices for laboratory and industrial applications. We also serve as a distributor of advanced equipment in Poland.

Our offer includes advanced measuring systems, such as Multi-Platform UHV System (MPS), a single instrument enabling multiple technique surface analysis and correlative nanofabrication. This unique tool consists of ultra-high vacuum systems produced by MEASLINE and an atomic force microscope with the piezoresistive cantilever, developed by the Nanoanalytik company. A wide scope of available analytic techniques such as: Atomic Force Microscopy (AFM), Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy (XPS) and additional equipment like: an ion source for depth profiling, load-lock enabling transferring samples from/to the glove box under a protective atmosphere and separate preparation chamber (ex. for vacuum coating), makes this system ideal for wide range of research applications. One example can be future development of electronic devices based on single- or few dopant-QDs. The Field-Emission Scanning Probe Lithography (FE-SPL) may be used for the fabrication of single electron transistors (SETs), which make possible the control of quantum transport through a zero-dimensional island, source, drain, and gate electrodes. Fast switching between electron-field emission from the tip and non-contact AFM imaging greatly facilitates the analysis of the deposits. A further important advantage is that the placement of the deposits can be determined with very high positioning accuracy using the AFM for navigation and fabrication of the Electron beam-induced deposition (EBID) features.

Our goal is to help scientists in realisation of their brilliant research ides providing high quality devices fitted exactly to individual needs. MEASLINE delivers custom systems for thin layer deposition using the Physical Vapor Deposition (PVD) techniques starting from compact tools for thermal evaporation or magnetron sputtering to complex, multichamber systems equipped with multiple sources. We design and manufacture cryostats enabling to work in the temperatures range of 4 to 500 K and adapted to work with external devices like superconductive magnet, optical microscope, ect. and other diverse systems dedicated to specialized research, such as vacuum chamber reactors, reactors for spectroscopic research in IR, tools for laser ablation or systems for investigations of high-temperature behaviour of molten metals in contact with refractory materials etc. We also provide equipment for thin layer thickness measurements and optical analysis of surfaces.

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NanoAndMore GmbHwas founded 2002 with the objective to supply the scanning probesmicroscopes (SPM, aka. atomic force microscope, AFM) community in the best possible waywith a wide range of consumer goods from SPM probes, calibration standards, and more.
As an independent company our mission is to enable our customers to choose from a broadvariety of products, brands and manufactures the SPM probe suitable for their needs. Since 1991 we have experience in this market, nobody else has more insight into in the world of SPM probes.
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Currently we offer brands as: **BioForce NanoScience**, **BudgetSensors**, **KelvinNanotechnology**, **µmasch**, **Nanosensors**, **NanoTools**, **NanoWorld**, **SiMetrics**, **SmartTip**, **sQUBE**, and **Team NanoTec**. We will continue to extend our product scope.
Please feel free to visit our online catalogue, and do not hesitate to contact us via email, phone, or directlyat the booth of the exhibition!

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- **nanoscore** is the exclusive European distributor for **UNISOKU**, the renowned Japanese manufacturer of Low Temperature UHV SPM Systems.
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More than 10days between LHe refills,
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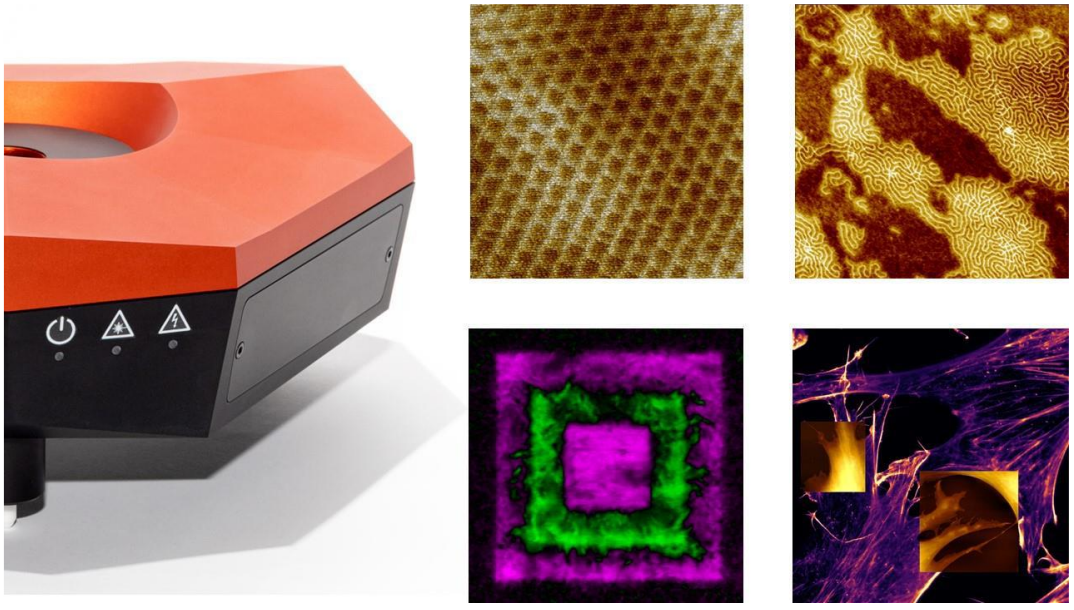
PIK Instruments is an innovative company that offers products from more than 25 manufacturers of laboratory equipment. We specialize in electron microscopy, preparation of biological and engineering samples, and atomic force microscopy. Our strengths also include metallography, digital microscopy and solutions dedicated to in-situ techniques. PIK Instruments' product portfolio also includes vacuum devices and advanced systems for imaging and preparation in medicine.

Our team is made up of a highly qualified group of passionate experts, who will professionally advise on any issue - not only the selection of suitable microscopes, but also in the field of preparation, or appropriate consumables for the laboratory.

Referring to the theme of the seminar, we would like to present the DriveAFM microscope, which represents the culmination of the continuous technical development of the Swiss company Nanosurf A.G., which since 1997 has been pushing the boundaries of what is possible in the study of interactions at close range. More information about the DriveAFM microscope can be obtained at our booth or during the presentation of the company PIK Instruments, to which we cordially invite you.



SPECS-GROUP

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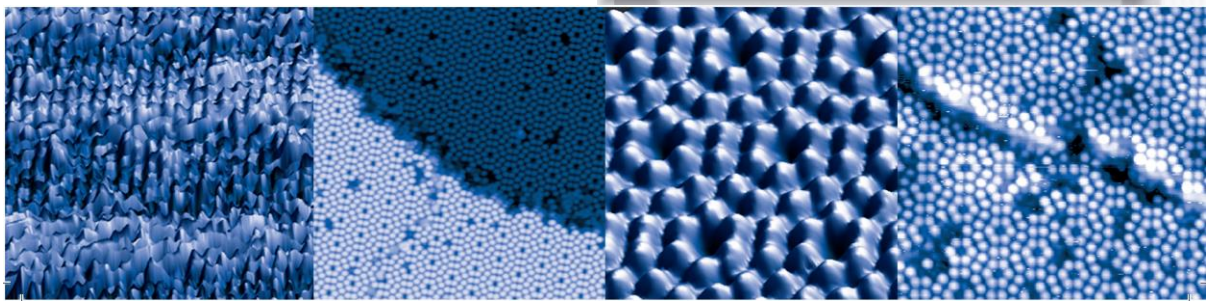
SPECS Surface Nano Analysis GmbH - A Story of Constant Innovation

SPECS has more than 150 employees at its headquarters in Berlin and its subsidiaries in the USA, China and Switzerland. The company also has sales offices and international sales channels in more than sixteen countries. A team of scientists and engineers are involved in developing and producing scientific instruments for surface analysis, material science and nanotechnology. By constant innovation new techniques, components or system concepts are launched every year since more than 30 years, revolutionizing the field of surface analysis.

Contact SPECS Surface Nano Analysis GmbH (www.specs-group.com) for further information.



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Scienta Omicron is a leading innovator in surface science and nanotechnology. At our technology centres in **Uppsala**, Sweden and **Taunusstein**, Germany we develop and produce high-tech instruments that are sold and serviced from our four regional hubs in **USA**, **China**, **Japan** and Germany to support top researchers globally.

We provide top capabilities in **electron spectroscopy**, **scanning probe microscopy** and **thin film deposition**, all in ultra-high vacuum (UHV). Focusing on the race for new unique materials and solutions, in areas like – smarter batteries, next generation electronics, quantum technologies, solar energy, intelligent sensors and advanced materials, Scienta Omicron drives surface science research towards the future.

Technolutions

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Firma Technolutions zajmuje się dostarczaniem innowacyjnej i zaawansowanej aparatury laboratoryjnej, badawczej, naukowej oraz przemysłowej. W portfolio Firmy znaleźć można między innymi mikroskopy sił atomowych firmy Park Systems.

W ofercie posiadamy m.in.:

- uniwersalny mikroskop badawczy NX10 o szerokim zakresie zastosowań. System wyposażony jest w niezależne skanery XY oraz Z oferujące wysoką dokładność obrazowania. Ponadto układ niezależnych skanerów osi X i Y umożliwia idealnie liniowy i ortogonalny przesuw próbki pod sondą, eliminując geometryczne zniekształcenia obrazowania. Mikroskop AFM zapewnia dokładny pomiar topografii przy użyciu niskoszumowego detektora położenia oraz szybkiego servo w osi Z. Tryb True Non-ContactTM, umożliwia obrazowanie wysokiej rozdzielczości i niskie zużycie sond pomiarowych.

- mikroskop FX40 to innowacyjny system do badania próbek o małych i średnich rozmiarach, umożliwiający automatyczną wymianę i strojenie sond oraz strojenie układu detekcyjnego. Dzięki obecności dodatkowego układu optycznego wyposażonego w skaner QR, sondy pomiarowe można przygotowywać do pracy w sposób bezpieczny. Intuicyjny i wygodny nawigator pozwala na szybkie wybranie miejsca na próbce oraz rozpoczęcie procesu obrazowania za pomocą zaledwie kilku kliknięć. Dzięki funkcji StepScan możliwe jest obrazowanie zamocowanych próbek jedna po drugiej bez przerywania pracy.

- LiteScope™ firmy NenoVision, moduł mikroskopu sił atomowych AFM do instalacji w mikroskopie SEM służący do wykonywania wysokorozdzielczych obrazów łączonych SEM+AFM 3D. Urządzenie zbiera informacje zarówno z mikroskopu AFM, jak i SEM, jednocześnie tworząc wspólny obraz próbki z nanometryczną dokładnością – CPEM (Correlative Probe and Electron Microscopy) w czasie rzeczywistym.

[1] https://technolutions.pl/
[2] https://www.parksystems.com/
[3] https://www.nenovision.com/