NANO IN BIO 2026

Nanosciences for Life & Materials Sciences

5th Edition: From May 30 to June 6, 2026

Le Gosier, Guadeloupe (French Caribbean)

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Program

&

Book of Abstracts

Welcome

It is a great pleasure to welcome you to the 5th edition of NanoInBio, held from May 30 to June 6, 2026, at the Créole Beach Hotel & Spa in Le Gosier, Guadeloupe.

This year marks a special milestone: 10 years since NanoInBio was first launched in 2016. What began as a bold initiative to bridge nanoscience and biology has grown into a truly international gathering of researchers spanning physics, chemistry, biology, medical and materials sciences.

This edition combines a two-day Spring School (May 30-31) followed by the International Conference (June 1-6), bringing together over 120 researchers, engineers, clinicians and industry professionals. As usual, participants are encouraged to stay on-site and share not only scientific sessions, but also meals and leisure time — because the best collaborations often happen outside the lecture hall.

We wish you an inspiring week of science, discovery, and warm Caribbean hospitality.

The NanoInBio Committee

NANO IN BIO 2026
Nanosciences for Life & Materials Sciences

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Program

Spring School NanoInBio 2026

Saturday, May 30 - Sunday, May 31

Ruibing Wang, University of Macau, Macau
Tomaso Zambelli, ETH Zürich, Switzerland
Bianxiao Cui, Stanford University, United States
Menglin Chen, Aarhus University, Denmark
Frédéric Kanoufi, ITODYS, Paris, France
Michelle Peckham, University of Leeds, United Kingdom
Tom Willhammar, Stockholm University, Sweden
Ricardo Garcia, ICN2, Barcelona, Spain

Conference NanoInBio 2026

Monday, June 1 – Saturday, June 6

Invited Speakers

Dennis Discher, University of Pennsylvania, United States
Paul Ashby, Berkeley, United States
Georg Fantner, EPFL, Lausanne, Switzerland
Ruibing Wang, University of Macau, Macau
Malgorzata Lekka, Institute of Nuclear Physics, Krakow, Poland
Ricardo Garcia, CSIC, Madrid, Spain
Bianxiao Cui, Stanford University, United States
Simon Scheuring, Weill Cornell Medicine, New-York, United States
Michelle Peckham, University of Leeds, United Kingdom
Tomaso Zambelli, ETH Zürich, Switzerland
Elodie Boisselier, Laval University, Québec, Canada
Menglin Chen, Aarhus University, Denmark
Joerg Lahann, University of Michigan, United States
Adeline Goulet, LISM, Marseille, France
Birgit Plochberger, Univ of Applied Sciences Upper Austria, Austria
Cécile Breyton, IBS, Grenoble, France
Daniel Ruiz Molina, ICN2, Barcelona, Spain
Bjorn Tonger Stokke, NTNU, Trondheim, Norway
Tom Willhammar, Stockholm University, Sweden
Philippe Leclère, University of Mons, Belgium
Frédéric Kanoufi, ITODYS, Paris, France

General Public Conference

Saturday, June 6

Open to all residents of Guadeloupe, this free conference will address two major current topics:

- **Iron oxide based nanoparticles in lastest cancer treatments advances**
- **Influence of environment on the onset and cancer progression**

Presented by Guadeloupean researchers :
Bernard Bhakkan-Mambir, CHUG, Pointe-à-Pitre, Guadeloupe
Christine Barul, INSERM, Pointe-à-Pitre, Guadeloupe
Philippe Belmont, Université Paris Cité, Paris

Presented by internationally renowned French researcher:
Sylvie Bégin, University of Strasbourg, Strasbourg

Free admission, no reservation required.

	May 30 – Spring School
1.00 pm – 2.00 pm	**Welcome & Registration**
2.00 pm – 2.10 pm	**Opening of the Spring School – Kislon Voitchovsky (Durham University)**
	Spring School session 1: Basics of Electrochemical measurements at the nanoscale
2.10 pm – 3.30 pm	**Frédéric Kanoufi** (CNRS Paris) Some of the key topics covered include: • General introduction to electrochemical processes • Nanoscale vs macroscale electrochemistry: imaging electrochemistry and practical examples • Experimental approaches: recent instrumental approaches to image local electrochemistry: nanopipettes (SECCM), microelectrodes (SECM), combinations with other microscopies
3.30 pm – 4.00 pm	**Coffee Break (30 min)**
4.00 pm – 5.30 pm	Continued, spring school session 1

	May 31 – Spring School
	Spring School session 2: Structure and thermodynamics of soft interfaces
8.30 am – 10.00 am	**Ruibing Wang** (University of Macau) & **Tomaso Zambelli** (ETH Zurich) Some of the key topics covered include: • Molecular self-assembly to create complex biomaterials • Principles of molecular recognition • Responsive biomaterials • Mechanical deformation of cells • Drug delivery
10.00 am – 10.15 am	**Coffee Break (15 min)**
	Spring School session 3: The functional mechanics of soft and biological interfaces
10.15 am – 11.45 am	**Bianxiao Cui** (Stanford University) & **Menglin Chen** (Aarhus University) Some of the key topics covered include: • The interface between material mechanics and biology: how materials of different bulk stiffness, roughness, and flexibility affect their integrations with cells and tissues • Fabrication of 3D nanobiointerfaces: electrowriting, hydrogel technology, extrusion-based and light-based bioprinting, for biomedical applications such as neuromodulation, tissue engineering, and disease modeling
	Spring School session 4: Microscopy techniques
11.45 am – 12.30 pm	**Michelle Peckham** (University of Leeds) – Optical microscopy and super-resolution in biological systems
12.30 pm – 2.00 pm	**Lunch**
2.00 pm – 2.45 pm	**Tom Willhammar** (Stokholm University) – Electron Microscopy
2.45 pm – 3.30 pm	**Ricardo Garcia** (CSIC Madrid) – Atomic Force Microscopy
3.30 pm – 4.00 pm	**Coffee Break (30 min)**

	June 1
8.00 am – 8.30 am	**Welcome & Registration**
	Conference Session I **Bio- and nanomaterials from labs to medical applications**
8.30 am – 8.50 am	**Introduction – Grégory Francius**
8.50 am – 9.20 am	**Dennis Discher**, University of Pennsylvania, Philadelphia, USA **(Invited speaker)**
9.20 am – 9.40 am	**Philippe Lavalle**, Université de Strasbourg, France
9.40 am – 10.00 am	**Erika Porcel**, Université Paris Saclay, France
10.00 am – 10.30 am	**Coffee Break (30 min)**
10.30 am – 11.00 am	**Tom Willhammar**, Stockholm University, Stockholm, Sweden **(Invited Speaker)**
11.00 am – 11.20 am	**Laura Bonnecaze**, Université de Bordeaux, CBMN, France
11.20 am – 11.40 am	**Adel Traboulsi**, Université de Lorraine-CNRS, Nancy, France
11.40 am – 12.00 pm	**Angelika Mielcarek**, Adam Mickiewicz University, Poznan, Poland
12.30 pm – 2.00 pm	**Conference Lunch**
	Conference Session II **The bio & non-bio interface**
2.00 pm – 2.30 pm	**Paul Ashby**, Molecular Foundry, Berkeley, USA **(Invited speaker)**
2.30 pm – 2.50 pm	**Jérôme Dejeu**, Institut FEMTO-ST, Besançon, France
2.50 pm – 3.10 pm	**Amal Alamri**, Durham University, Durham, UK
3.10 pm – 3.40 pm	**Coffee Break (30 min)**
3.40 pm – 4.10 pm	**Georg Fantner**, EPFL, Lausanne, Switzerland **(Invited Speaker)**
4.10 pm – 4.30 pm	**Meike Koenig**, Karlsruhe Institute of Technology, Karlsruhe, Germany
4.30 pm – 5.00 pm	**Ruibing Wang**, University of Macau, Taipa, Macau **(Invited Speaker)**
5.00 pm – 6.30 pm	**Poster Session I – Networking Time**

	June 2
	Conference Session III **Bio- and nanotechnology for health & environment**
8.30 am – 9.00 am	**Malgorzata Lekka**, Institute of Nuclear Physics, Krakow, Poland **(Invited Speaker)**
9.00 am – 9.20 am	**Georg Papastavrou**, University of Bayreuth, Germany
9.20 am – 9.40 am	**Lasse Hyldgaard Klausen**, Aarhus University, Denmark
9.40 am – 10.10 am	**Ricardo Garcia**, CSIC, Madrid, Spain **(Invited Speaker)**
10.10 am – 10.40 am	**Coffee Break (30 min)**
10.40 am – 11.10 am	**Bianxiao Cui**, Stanford University, Stanford, USA **(Invited Speaker)**
11.10 am – 11.30 am	**Valendy Thesnor**, Université des Antilles, Pointe à Pitre, Guadeloupe, France
11.30 am – 12.00 pm	**Ariane Boudier**, Université de Lorraine, Nancy, France
12.30 pm – 2.00 pm	**Conference Lunch**
	Conference Session IV **Instrumentation for materials & life sciences**
2.00 pm – 2.30 pm	**Simon Scheuring**, Weill Cornell Medicine, New York, USA **(Invited Speaker)**
2.30 pm – 2.50 pm	**Etienne Dague**, LAAS-CNRS, Université de Toulouse, Toulouse, France
2.50 pm – 3.10 pm	**Luca Franco**, Instituto de Ciencia de Materiales de Madrid, Madrid, Spain
3.10 pm – 3.40 pm	**Michelle Peckham**, Univ of Leeds, UK **(Invited Speaker)**
3.40 pm – 4.10 pm	**Coffee Break (30 min)**
4.10 pm – 4.40 pm	**Tomaso Zambelli**, ETH Zürich, Switzerland **(Invited Speaker)**
4.40 pm – 5.00 pm	**Jialin Shi**, Ecole Polytechnique Férérale de Lausanne, Switzerland
5.00 pm – 5.20 pm	**Prabhu Prasad Swain**, Ecole Polytechnique Férérale de Lausanne, Switzerland
5.20 pm – 5.50 pm	**Alexander Dulebo**, Bruker BioAFM, Berlin, Germany

	June 3
	Social Event
7.00 am – 5.30 pm	**Special Cruise to Petite Terre Islands** Lagoon and Barrier Reef discovery  Snorkeling and barbecue on the beach

	June 4
	Conference Session V **Bio- & Nanomaterials from labs to medical applications**
8.30 am – 9.00 am	**Elodie Boisselier**, Laval University, Québec, Canada **(Invited Speaker)**
9.00 am – 9.20 am	**Jaroslaw Jacak**, University of Applied Sciences Upper Austria, Linz, Austria
9.20 am – 9.40 am	**Sylvie Begin-Colin**, University of Strasbourg, Strasbourg, France
9.40 am – 10.10 am	**Menglin Chen**, Aarhus University, Denmark **(Invited Speaker)**
10.10 am – 10.40 am	**Coffee Break (30 min)**
10.40 am – 11.10 am	**Joerg Lahann**, University of Michigan, USA **(Invited Speaker)**
11.10 am – 11.30 am	**Fabienne Quilès**, Université de Lorraine-CNRS, Villers-lès-Nancy, France
11.30 am – 11.50 am	**Laure Brice**, Université de Lorraine, Nancy, France
11.50 am – 12.10 pm	**Zhaoli Gao**, The Chinese University of Hong Kong, Hong Kong, China
12.30 pm – 2.00 pm	**Conference Lunch**
	Conference Session VI **Bio- & Nanotechnology for health & environment**
2.00 pm – 2.30 pm	**Adeline Goulet**, LISM, Marseille, France **(Invited speaker)**
2.30 pm – 2.50 pm	**Serena Danti**, University of Pisa, Pisa, Italy
2.50 pm – 3.10 pm	**Waking-Balaguer Mainviel**, Université des Antilles, Pointe à Pitre, Guadeloupe, France
3.10 pm – 3.30 pm	**Hana Jungová**, Chalmers University of Technology, Göterborg, Sweden
3.30 pm – 4.30 pm	**Coffee Break – Poster Session II**
4.30 pm – 5.00 pm	**Birgit Plochberger**, Univ of Applied Sciences Upper Austria **(Invited Speaker)**
5.00 pm – 5.20 pm	**Judith Zubia-Aranburu**, Aarhus University, Aarhus, Denmark
5.20 pm – 5.40 pm	**Vadim Frolov**, University of Basque Country, Leioa, Spain
Gala Diner	
7.30 pm	**Caribbean Music & Dance Show** Traditional music and dances with the famous Guadeloupe Carnival atmosphere by Double Face
Conference & Group photos	

	June 5
	Conference Session VII **The bio & non-bio interface**
9.00 am – 9.30 am	**Cécile Breyton**, Institut de Biologie Structurale, Grenoble, France **(Invited Speaker)**
9.30 am – 9.50 am	**Axel Gansmüller**, CRM2, Université de Lorraine, Nancy, France
9.50 am – 10.10 am	**Hannah Wunderlich**, Technical University of Munich, Munich, Germany
10.10 am – 10.40 am	**Coffee Break (30 min)**
10.40 am – 11.10 am	**Daniel Ruiz Molina**, ICN2, Barcelona, Spain **(Invited Speaker)**
11.10 am – 11.30 am	**Beatrice Geiger**, Niels Bohr Institute, University of Copenhagen, Denmark
11.30 am – 11.50 am	**Patryk Pyrcz**, Institute of Physical Chemistry Polish Academy of Sciences, Poland
12.30 pm – 2.00 pm	**Conference Lunch**
	Conference Session VIII **Instrumentation for materials & life sciences**
2.00 pm – 2.30 pm	**Bjorn Tonger Stokke**, NTNU, Trondheim, Norway **(Invited Speaker)**
2.30 pm – 2.50 pm	**Sreelatha Greeshma Pradeep**, University of Leeds, Leeds, UK
2.50 pm – 3.10 pm	**Hüsnü Aslan**, Danish National Metrology Institute, Hoersholm, Denmark
3.10 pm – 3.40 pm	**Coffee Break (30 min)**
3.40 pm – 4.00 pm	**Georg Gramse**, Johannes Kepler University, Linz, Austria
4.00 pm – 4.20 pm	**Tine Kalac**, Stockholm University, Stockholm, Sweden
4.20 pm – 4.50 pm	**Marco Portulapi**, Nanosurf AG, Liestal, Switzerland

	June 6
	Conference Session IX **Special NanoInBio session**
9.00 am – 9.30 am	**Philippe Leclère**, University of Mons, Belgium **(Invited Speaker)**
9.30 am – 9.50 am	**Leila Nouville**, Université des Antilles, Pointe à Pitre, Guadeloupe, France
9.50 am – 10.10 am	**Kamila Lępicka**, Institute of Physical Chemistry Polish Academy of Sciences, Poland
10.10 am – 10.30 am	**Hermann Dzoujo Tamaguelon**, Université des Antilles, Pointe à Pitre, Guadeloupe, France
10.30 am – 11.00 am	**Coffee Break (30 min)**
11.00 am – 11.30 am	**Frédéric Kanoufi**, ITODYS, Paris, France **(Invited Speaker)**
11.30 am – 11.50 am	**Pavel Bashkirov**, RISBM, Moscow, Russian Federation
11.50 am – 12.20 pm	**Peter Gorelkin**, ICAPPIC Ltd., London, UK
12.20 pm – 12.30 pm	**Closing Ceremony**

June 6	
Major Public Conference (in French) **Santé et environnement: quelles solutions apportées par les sciences ?**	
4.30 pm – 6.30 pm	**Keynotes Lecturers : Sylvie Bégin (CNRS, Université de Strasbourg)** **Bernard Bhakkan-Mambir (CHU Guadeloupe)** **Christine Barul (INSERM, Guadeloupe)** **Philippe Belmont (Université Paris Cité, Paris)** **Moderators : Lucie Largitte (Université des Antilles)** **Grégory Francius (INSERM CNRS, Strasbourg)** **Topic 1 : Iron oxide based nanoparticles in lastest cancer treatments advances** **Topic 2 : Influence of the environment on the onset and cancer progression**

Oral Presentations

	June 1
8.00 am – 8.30 am	**Welcome & Registration**
	Conference Session I **Bio- and nanomaterials from labs to medical applications**
8.30 am – 8.50 am	**Introduction – Grégory Francius**
8.50 am – 9.20 am	**Dennis Discher**, University of Pennsylvania, Philadelphia, USA **(Invited speaker)**
9.20 am – 9.40 am	**Philippe Lavalle**, Université de Strasbourg, France
9.40 am – 10.00 am	**Erika Porcel**, Université Paris Saclay, France
10.00 am – 10.30 am	**Coffee Break (30 min)**
10.30 am – 11.00 am	**Tom Willhammar**, Stockholm University, Stockholm, Sweden **(Invited Speaker)**
11.00 am – 11.20 am	**Laura Bonnecaze**, Université de Bordeaux, CBMN, France
11.20 am – 11.40 am	**Adel Traboulsi**, Université de Lorraine-CNRS, Nancy, France
11.40 am – 12.00 pm	**Sandra Vranic**, University of Manchester, UK
12.30 pm – 2.00 pm	**Conference Lunch**
	Conference Session II **The bio & non-bio interface**
2.00 pm – 2.30 pm	**Paul Ashby**, Molecular Foundry, Berkeley, USA **(Invited speaker)**
2.30 pm – 2.50 pm	**Jérôme Dejeu**, Institut FEMTO-ST, Besançon, France
2.50 pm – 3.10 pm	**Amal Alamri**, Durham University, Durham, UK
3.10 pm – 3.40 pm	**Coffee Break (30 min)**
3.40 pm – 4.10 pm	**Georg Fantner**, EPFL, Lausanne, Switzerland **(Invited Speaker)**
4.10 pm – 4.30 pm	**Meike Koenig**, Karlsruhe Institute of Technology, Karlsruhe, Germany
4.30 pm – 5.00 pm	**Ruibing Wang**, University of Macau, Taipa, Macau **(Invited Speaker)**
5.00 pm – 6.30 pm	**Poster Session I – Networking Time**

Tissue, Matrix, & Cell interfaces probed at different scales – unifying trends

D. Discher,[1]

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Tissues consist of cells and extracellular matrix, which together give rise to collective physical properties that have the potential to influence cell fates and functions. Our past studies had shown various types of cells including stem cells adhere to the surrounding matrix, use cell forces to probe the microscale stiffness or softness, and transduce the signal through the force-generating cytoskeleton and into the nucleus [1-3]. Proteomic methods revealed a close correlation between tissue-dependent levels of fibrous collagens of the extracellular matrix and particular nuclear structure filaments. We observe similar trends for cancer mutations [Anlas, in revision]. Mechanical measurements down to the nano/meso scale have further suggested tissue stiffness scales with collagen protein densities. We have now extended such observations to in situ studies of fibers in live tissue using the interface-sensitive imaging method of Second Harmonic Generation (SHG). Combining SHG with relevant perturbations of fresh tissues including human heart slices allows for real-time monitoring of collagen fibers outside the cell connecting to the cytoskeleton and nucleus within [4].

While tissue is mostly water and protein, lipid is especially abundant in some tissues, especially in fat tissues but even in some cancers. Careful morphological analyses at subcellular scales shows lipid droplets (which are filled with fat) remain spherical as they interact with other organelles inside cells. This suggests lipid droplets are surprisingly rigid – which we measure as a high effective interfacial tension. Lipid droplets indent and deform the nucleus and cytoskeleton in tissues and cell cultures. This can lead to nuclear rupture and DNA damage as well as immune dysfunction. [5; 6]

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[1] A.J. Engler, S. Sen, H.L. Sweeney, D.E. Discher, Cell. 126 (2006).
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[3] S. Cho, M. Vashisth, A. Abbas, S. Majkut, K. Vogel, Y. Xia, I.L. Ivanovska, J. Irianto, M. Tewari, K. Zhu, E.D. Tichy, F. Mourkioti, H.Y. Tang, R.A. Greenberg, B.L. Prosser, D.E. Discher, Dev Cell 49 (2019).
[4] K. Saini et al, in revision.
[5] I.L. Ivanovska, M.P. Tobin, T. Bai, L.J. Dooling, D.E. Discher, J Cell Biol. 222 (2023).
[6] M.P. Tobin, I.L. Ivanovska, S.H. Phan, T. Bai, J. Deans, G.P.F. Nader, D.E. Discher, Mol Biol Cell. 37 (2026)

Fully biosourced self-assembled hydrogel with simultaneous antiviral, antibacterial and antifungal activities

P. Lavalle[1,2] Hadda Zebiri[1], Lorène Tallet[1], Marine Oudot[3], Viola Mazzoleni[1], Claire Medemblik[1], Eric Mathieu[1], Skander Hathroubi[2], Vincent Ball[1], Benoit Frisch[1], Catherine Schuster[3], Nihal Engin Vrana[2]

[1]*Inserm UMR_S 1121, CNRS EMR 7003, Université de Strasbourg, Biomaterials and Bioengineering, Strasbourg, France*

[2]*SPARTHA Medical, NextMed Campus, Strasbourg, France*

[3]*Inserm UMR_S 1110 Institute for Translational Medicine and Liver Diseases, Institut de virologie, Strasbourg, France*

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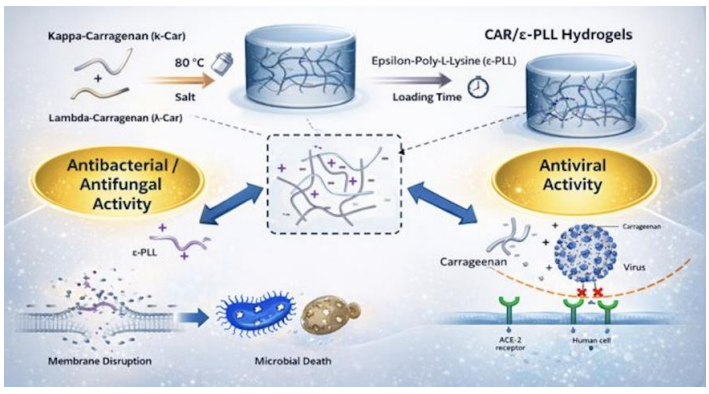
Infectious diseases caused by pathogenic viruses, bacteria, and fungi remain a major global health challenge. Conventional treatment methods are indispensable but often suffer from limited efficacy, safety concerns, and poor adaptability. We report the development of innovative fully biosourced multifunctional hydrogels based on self-assembly of three natural biopolymers that display simultaneous antiviral, antibacterial and antifungal properties, with rapid and long-lasting biocidal efficacy. Due to the intrinsically contradictory requirements of antiviral and antibacterial mechanisms, development of such a multifunctional biopolymer-based biocidal system is particularly challenging, and screening of more than 30 compositions was therefore required.

Hydrogels were designed with marine sulfated polysaccharides, a mixture of lambda- and kappa-carrageenan (CAR). These polysaccharides act as reservoirs for the natural polycationic polypeptide ε-poly-L-lysine (ε-PLL)[1,2]. Carrageenans provide hydrogels with antiviral properties, whereas ε-PLL ensure their antibacterial and antifungal activity, while simultaneously improving the stability and the mechanical properties of the hydrogels. Slow release of ε-PLL over several days enables rapid and durable biocidal activity against Gram-positive and Gram-negative bacteria. In addition, CAR/ε-PLL hydrogels demonstrate high antiviral efficacy against SARS-CoV-2 and hepatitis C virus (HCV). These CAR/ε-PLL hydrogels, relying exclusively on the self-assembly of two marine polysaccharides and one natural polypeptide, are a powerful, sustainable, and multifunctional platform to prevent infectious diseases by offering fast and long-lasting broad-spectrum biocidal activity.



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[2] L. Kocgozlu L., A. Mutschler, L. Tallet, C. Calligaro, H. Knopf-Marques, E. Lebaudy, E. Mathieu, M. Rabineau, V. Gribova, B. Senger, N. E. Vrana, P. Lavalle P., Mater. Today Bio., (2024), 28, 101168

Nanoparticles combined with innovative radiation therapies for the treatment of tumors

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[2] *Gustave Roussy, U1030, Villejuif, France*
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The challenge of radiotherapy is to increase radiation damage on tumor whilst preserving healthy tissue. Particle therapy offers an alternative method whose ballistic properties improve tumor targeting. This work aims to enhance particle therapy's performance in sterilizing radioresistant tumors and reducing side effects on healthy tissues by adding Platinum Nanoparticles (PtNPs) that amplify ionizing radiation effects [1].
To evaluate the effectiveness of combining nanoparticles, experiments are being conducted on 3D cell models. This tumor-like model, called "spheroid," mimics the geometric (3D) and environmental (nutrient and oxygen gradients) conditions of a tumor.
Spheroids obtained using human cell lines from different cancers: Hela (cervical), BxPC3 (pancreatic), and U-87 (glioma), were used in this study. The internalization and localization of metallic PtNPs in the cytoplasm of the spheroid cells were observed using confocal and light sheet microscopies (figure below).
Irradiations were performed using FLASHtherapy and particle therapy. Carbon ion beam (290 MeV/uma) was used at the Heavy Ion Medical Accelerator (HIMAC) in Chiba, Japan, a world leader in particle therapy and a long-term collaborator. Ultra High Dose Rate electrons (10 MeV) was used at Gustave Roussy in Villejuif, France. For both radiations, radio-enhancements effects of PtNPs between 20 and 30 % were observed at 2 Gy. A 27% radio-enhancement effect of PtNPs was also observed with a 6MV photon irradiation (reference beam in radiotherapy) of the spheroids. Auto-amplified electronic cascades within the nanoparticles, which increase energy deposition near the metal core and promote biomolecules damage, explain the damage induced by PtNPs [2].
These experiments, combining PtNPs with ions, are being conducted for the first time on spheroids.

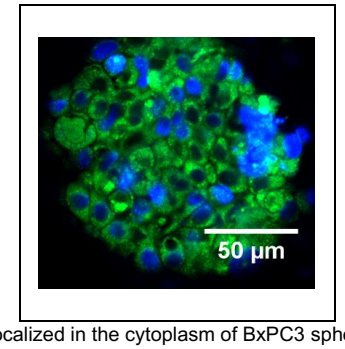

Figure 1: PtNPs (in green) localized in the cytoplasm of BxPC3 spheroid cells (cell nuclei in blue)

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[1] S. Lacombe, E. Porcel, Cancer Nanotechnology. 2017, 8(1), first page.
[3] E. Porcel, S. Liehn, Nanotechnology. 2010, 21(8), first page.

Scanning Electron Diffraction Unravels the Nanostructures of Polysaccharide Fibrils

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s

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[2] *Department of Biomaterial Sciences, Graduate School of Agricultural and Life Sciences University of Tokyo, Tokyo, Japan*
3 Paul Scherrer Institute(PSI), Villigen,, Switzerland
[4] *Institute of Materials, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland*
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Cellulose is the most abundant biopolymer. Nature links glucan units to form polysaccharide chains which are organized in an intricate network of hydrogen bonds into crystalline cellulose fibers. These fibers are assembled into hierarchical structures that constitute the secondary cell wall of plants, forming the basis for their mechanical properties. The macroscopic attributes of these materials are determined by chemical interactions and mesoscopic organization spanning from the atomic scale to the macroscopic level. Understanding these nano fibrils as well as their assemblies is vital for grasping the properties of biological materials and for exploring ways to incorporate these naturally occurring components into hybrid materials.

The strong interaction between an electron probe and matter enables the acquisition of scattering from sub-nanometer-sized volumes. Electron diffraction has proven to be an invaluable tool for the structural examination of a diverse range of nanomaterials. Scanning electron diffraction (SED) offers detailed maps that reveal the crystalline nanostructure, shedding light on the arrangement of polysaccharide chains in individual nano fibers and their hierarchical assemblies.

Cellulose nano fibers (CNFs) can be extracted from various origins and stand out as a promising, sustainable building block with remarkable mechanical properties. Using SED data, the crystalline nanostructure within individual CNFs can be analyzed, offering insights into how the crystalline ordering persists, even in twisted sections of the fibers, despite the strain these twists introduce.[1] Furthermore, SED data can be employed to investigate the hierarchical organization within plant cell walls and hybrid materials based on wood cells.[2] SED reveals insights at the nanocale of the organization of cellulose fibrils in wood cell walls, where the transition between layers can be studied. In the cell walls of out husks the SED technique has been able to reveal a layers ultra structure, where cellulose is organized with opposing chiral hierarchies.[3]

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N-terminal capping tunes fibrillation and cytotoxicity of *Staphylococcus aureus* PSMα3

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The virulence of *Staphylococcus aureus*, a multi-drug resistant pathogen, is tightly linked to the expression of phenol-soluble modulins (PSMs), notably PSMα3, the most cytotoxic member of PSMs which self-assembles into unique cross-α amyloid-like fibrils[1]. Here, we investigate how N-terminal capping influences PSMα3's aggregation behavior and cytotoxic potential under near-physiological conditions.

Using Thioflavin T (ThT) fluorescence spectroscopy, NMR, infrared spectroscopy and TEM, we compared formylated (f-) and acetylated (ac-) PSMα3 forms. The more hydrophobic ac-PSMα3 exhibits reduced ThT binding and preserves a greater proportion of soluble species, with fibrils observed at late aggregation stages that morphologically differ from f-PSMα3. Importantly, this functionally correlates with significantly reduced cytotoxicity towards HEK293 cells, in a serum deprived medium, both in a time- and concentration-dependent manner. Using Laurdan fluorescence and Atomic Force Microscopy, we also demonstrated that only the intermediate species led to membrane fluidification, a disruptive mechanism that was further validated *in vitro* using model membranes of controlled lipid compositions[2]. Such *in vitro* studies finally revealed that membrane properties - particularly fluidity and lipid segregation - are key determinants for PSMα3 activity[3]. Overall, our results demonstrate that the N-terminal capping critically modulate PSMα3 aggregation and cytotoxicity *via* membrane permeation[4], thus offering new insights into *S. aureus* pathogenicity.

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Designing Protein-Functionalized Metasurfaces with Tunable Spatial Order to Control Thickness, Wettability and Adhesion Force

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Hyperuniform disordered metasurfaces provide advanced control over light-matter interactions in nanophotonics, yet their potential as a structural design framework for biofunctional interfaces remains largely unexplored. In our work, we investigate how hyperuniform spatial organization in protein-functionalized metasurfaces modulates protein layer thickness[1], surface wettability[2], and adhesion forces[3].

In this work, we propose to present the design of metasurfaces spanning a continuum of spatial order, generated through a centroidal Voronoi tessellation (CVT) simulation using Lloyd's algorithm. Precisely it starts from Poisson and Poisson-disk point distributions and evolving toward weak, moderate, and strong hyperuniform patterns, as well as periodic lattices. The resulting structures are fabricated by electron beam lithography followed by controlled protein functionalization.

The use of atomic force microscopy and force spectroscopy allowed the full characterization of protein layer thickness, wettability, and adhesion force across these architectures. By combining the various results, we could demonstrate that the nanoscale spatial order provides a powerful lever to regulate protein adsorption and interfacial properties, without altering surface chemistry. These finding extend hyperuniformity metasurface design beyond optics and establish a new strategy for engineering tunable biointerfaces for biosensing and biomedical applications.

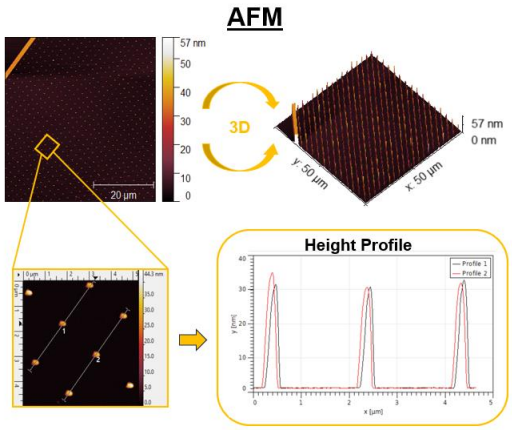

Figure 1: AFM Surface Topography and Height Profile Analysis

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Surface-Modified Metal-Organic Framework Nanoparticles for Enhanced Stability in Biological Media

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Metal-Organic Frameworks (MOFs) are increasingly recognized for their versatility in applications such as separation, catalysis, energy storage, and sensing, owing to their high porosity, large surface area, and structural stability[1]. In biomedicine, biocompatible nanoMOFs are promising, particularly for drug delivery and imaging, owing to their capacity for high drug loading, controlled release, and non-toxicity. Zeolitic Imidazolate Frameworks (ZIFs), particularly ZIF-8 nanoparticles (NPs), are a well-studied class of MOFs. Another biocompatible MOF example is MIL-100. However, nanoMOFs face challenges under physiological conditions; they tend to aggregate and exhibit poor colloidal stability, and ZIF-8 NPs are especially sensitive to pH changes. At pH 5-6, Zn^{2+} ions and imidazolates dissociate, leading to structural breakdown of the MOF. To address these issues and improve stability and drug delivery efficiency, surface modification of nanoMOFs is essential.

Metal-Organic Frameworks (nanoMOFs) nanoparticles are highly valuable for drug delivery due to their distinctive qualities, including (a) high drug encapsulation, (b) controlled release, (c) improved targeting of disease cells and tissues, (d) low toxicity from gradual degradation and lack of accumulation in the body, (e) simple surface modification for enhanced *in vivo* stability, and (f) easy customization of size, shape, and surface properties. Among these, Zeolitic Imidazolate Framework-8 (ZIF-8) nanoparticles stand out for drug delivery and cancer therapy due to their pH-sensitive degradation. To effectively target tumors, nanoparticles must circulate in the bloodstream for prolonged periods without accumulating in the liver or spleen; thus, efficient surface modification is necessary.

In this study, various methods were used to synthesize ZIF-8, yielding nanoparticles (NPs) with different sizes and shapes. Lipid coatings were then applied to improve colloidal stability and prevent degradation under physiological conditions. MOF@lipid NPs combine the advantages of porous particles and liposomes[2]. Coating nanoMOFs with lipids aims to enhance stability and control drug release. Additionally, MOF@lipid nanoparticles have shown greater stability than liposomes, which contain an aqueous core instead of a porous MOF core [2]. We successfully coated DOPC lipids onto ZIF-8 NPs with different morphologies. We also examined how this coating affects their stability in physiological environments. Furthermore, we tested drug encapsulation and release, including doxorubicin and paclitaxel.

Acknowledgments
The authors thank the National Science Centre of Poland for financial support through the Opus grant (project number 2019/33/B/ST5/01495) and the Initiative of Excellence-Research University program for funding via the grant “50x50: fifty grants for 50 young scientists” (number 140/04/POB3/0031).

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Nanoscale insights into functional materials from Bacterial Elastomers to EUV resist patterning

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I will present our use of advanced scanned probe techniques to investigate in-situ the nanoscale properties of soft functional materials. We assembled a bacterial elastomer, an Engineered Living Material, built by crosslinking the S-layer of the fresh water bacterium, C. Crescentus. The bacterial elastomer is regenerable and responsive to external stimuli. We also create all liquid structures with persistent shape called structured liquids. We show how the dense packing of nanoparticles at the liquid-liquid interface leads to jamming which solidifies the interface allowing for the formation of far-from-equilibrium liquid shapes. Lastly, I will present our efforts to investigate the dissolution process for high performance EUV resist materials and characterize the factors that influence resist patterning performance.

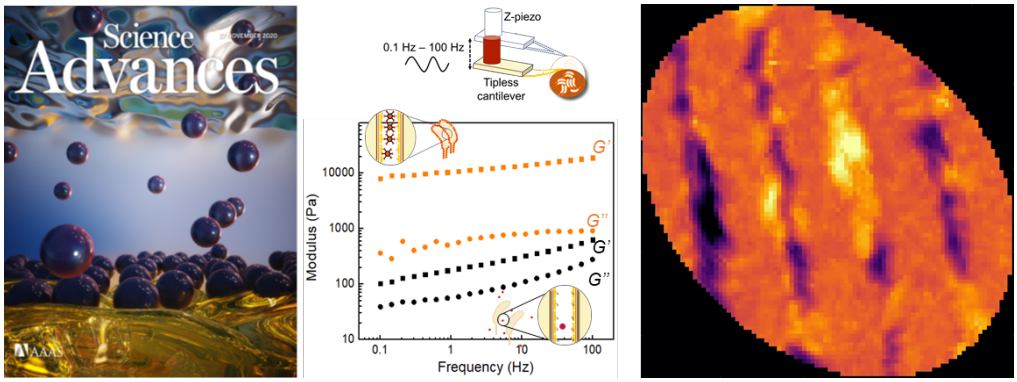

Figure 1: Cover cartoon depicting the adsorption of nanoparticles to the oil-water interface to make structured liquids. AFM based rheology of bacterial elastomer showing significant increase in storage modulus with crosslinking. Frame from the movie of resist dissolution showing swelling before clearing of the pattern.

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A label-free characterization of extracellular vesicles on a unique multiplexed biochip by a multimodal & multiscale analytical platform

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Recent advances in the clinical extracellular vesicles (EVs) field highlight their potential as biomarkers for various pathologies, in addition to their therapeutic applications. However, due to their high complexity in size, composition, and cell origin, the characterization of EVs subpopulations from complex media remains challenging. To achieve this goal, we established a nanobioanalytical platform (NBA) which allowed original investigations of various type of EVs based on a combination of multiplexed biosensing methods based on Surface Plasmon Resonance with metrological and morphomechanical analyses by Atomic Force Microscopy [1-2]. At present, the NBA platform investigates EVs in medical fields as cancer research, wound healing, toxicology ...
For the last 3 years, we have been working on implementing this platform with additional analytical modules and performances, in order to improve the discriminative characterization of coexisting components presents in a complex biological sample. For that, our particular strategy is especially to rethink & optimize the substrate at the core of this analytical platform, to make it compatible with the different techniques [3]. The phenotype of the different EVs subsets is obtained by Surface Plasmon Resonance Imaging, followed by Raman spectroscopy that gives a deeper & broader molecular signatures and Atomic Force Microscopy to address metrology of the EVs, size distribution and the morpho mechanical information of the different subsets. By combining machine learning algorithm, we accurately identified whether the spectra came from the treated cells derived EVs or the control ones [4]. The nanomechanical mapping highlighted noticeable difference in the Young's modulus between different EV subpopulations, some of which containing mitochondria [5]. Lastly, we increased the throughput and speed of the EVs subets analysis through nanospotting of numerous ligands on the biochip. These new multiplexed chips will be used for multi-scale detection of the main active compounds (cytokines and extracellular vesicles) in different secretomes from M1 and M2 macrophages which have demonstrated anti-fibrogenic and pro-fibrogenic properties, respectively. The EVs and molecules identified could lead to the development of an innovative drug (or drug product).

Acknowledgement

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Mechanical Characterisation of Lipid Membranes on Nano-Curved Surfaces Using AFM Imaging and Force Spectroscopy

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Biological membranes are inherently dynamic highly curved systems, with their mechanical properties tightly linked to cellular processes such as endocytosis and signal transduction [1]. Little is however known about how their high-curvature (less than 100 nm curvature) influences membrane stability, deformation, and force response. Practically, investigating these effects remains experimentally challenging. One approach is to simplify the problem using supported lipid bilayers (SLBs). Model SLBs on highly curved surfaces can provide insights into these processes in situ and with high resolution owing to the control of membrane composition and increased spatial stability.
In this study, we investigate the mechanical properties of dioleoylphosphatidylcholine (DOPC) SLBs supported on nanostructured silicon substrates with tuneable high curvature, fabricated using 50 nm silica nanoparticles. Within the first part of the study, we show a precise reproducible and cost-effective protocol to create hydrophilic substrates with precisely controlled curvatures and using standard laboratory equipment. SLBs are then deposited onto these high-curvature substrates (Figure 1). In the second part of the project, we use atomic force microscopy (AFM) and force spectroscopy to study the impact of curvature on bilayer mechanics.
Our observations reveal consistent and reproducible force curves on flat regions, indicative of relatively uniform membrane behaviour. In contrast, measurements on curved regions exhibit significant variability in breakthrough forces and mechanical response. Notably, repeated force cycles on curved areas reveal tube-pulling events during tip retraction, with tube lengths varying across cycles. These results illustrate how curvature alters the mechanical stability of the bilayer and highlight the substrate's contribution to membrane mechanics [2]. Understanding these curvature-dependent effects is critical for applications in drug delivery systems and cellular processes like endocytosis.

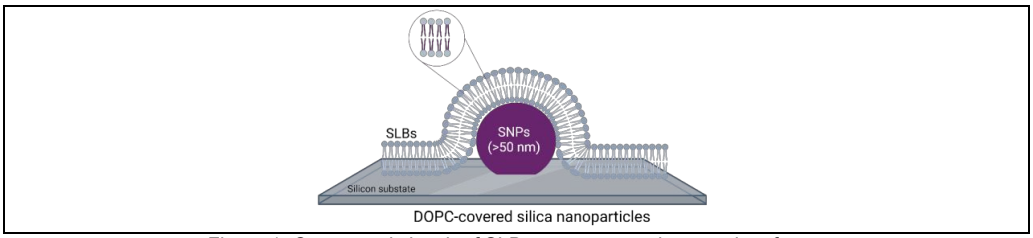

Figure 1: Conceptual sketch of SLBs on a nanoscale curved surface.

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Multiscale tracing of peptide and protein fibrils from atomic stacking to surface-constrained spirals.

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Understanding how molecular-scale interactions give rise to large-scale structure in amyloid fibrils remains a central challenge in biophysics and materials science. Here, we present a multiscale investigation of peptide self-assembly that bridges atomic stacking interactions to supramolecular curvature and chirality. Using a model 19-residue peptide (KG19), we combine time-resolved atomic force microscopy (AFM), cryo-electron microscopy (cryo-EM), molecular dynamics simulations, and targeted mutagenesis to directly trace fibrillization pathways across length scales.

We show that surface-confined assembly produces spiral “squeelix” structures, while solution conditions yield hierarchically organized twisted fibrils. Cryo-EM reveals a ‘double-J’ protofilament architecture, whose interlayer interactions—particularly electrostatic coupling mediated by aspartic acid residues—introduce small angular displacements that accumulate into macroscopic curvature. Time-resolved AFM captures dynamic growth processes, including directional propagation and curvature switching, providing direct evidence of structure formation in real time.

Importantly, we demonstrate that chirality governs both growth direction and fibril handedness: switching from L- to D-amino acids reverses spiral trajectories and twist orientation, while heterochiral mixtures disrupt curvature propagation. Together, these results establish a general physical mechanism linking sequence-encoded interactions, chirality, and interfacial constraints to emergent fibril morphology.

This work provides a unified framework for understanding amyloid polymorphism and offers design principles for controlling curvature and chirality in peptide-based nanomaterials.

Vapor-borne Functional and Nanostructured Polymer Coatings

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For many years, coatings from unsubstituted, as well as halogenated poly(p-xylylene) (PPX) fabricated via Chemical Vapor Deposition (CVD) polymerization have already been widely applied, for instance in the semiconductor industry and in biomedical areas. [1,2] The main advantages of this coating technique are that the polymer film is applied from the gas phase in a vacuum setup without the use of any solvent, catalyzer or liquid phase leading to defect-free coatings without impurities. Since the polymerization only happens on the cooled substrate, PPX can be coated uniformly and conformally even on structured surfaces. Using a great variety of otherwise functionalized [2.2] paracyclophane-derivatives as a precursor material, we are able to produce diverse homopolymer, copolymer or copolymer gradient coatings for the subsequent immobilization of active moieties, such as proteins or nanoparticles. [4,5]

Recent developments include the synthesis of responsive or degradable polymer coatings and the formation of nanostructured polymer films:
By polymerization of an amine-functionalized precursor, stimuli-responsive coatings can be prepared which exhibit pH-induced swelling- and de-swelling in aqueous environments. [6,7] Co-polymerization of a cylic ketene acetal leads to insertion of ester linkages in the polymer main chain, which render the coating degradable properties under physiological conditions. [8] Bottom-up nanostructured PPX can be fabricated via templated deposition into liquid crystal films or via material selective deposition [9,10]. Current research focuses on the further advancement and application of these novel coating systems.

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Engineered Living Microalgae for Targeted Therapies

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We present a new paradigm of engineered living microalgae as dynamic, multifunctional platforms for targeted therapy, addressing complex diseases through a shared supramolecular strategy. The core approach leverages supramolecular host-guest chemistry—primarily β-cyclodextrin/adamantane interactions—to non-invasively attach modular therapeutic payloads onto motile microalgae. This creates bio-hybrid systems that harness the algae's inherent biocompatibility, autonomous motility, and biosynthetic functions. This platform is engineered to overcome critical therapeutic barriers, including navigating harsh physiological environments, achieving precise site-specific targeting, and remodeling hostile disease microenvironments.

For targeted cancer therapy, the paradigm manifests in two distinct yet complementary forms. In one application, phototactic *Chlamydomonas reinhardtii* algae are conjugated with liposomes carrying a prodrug for photodynamic therapy (PDT).[1] The algae's natural light-seeking behavior drives tumor accumulation, while its concurrent photosynthesis generates oxygen to directly alleviate tumor hypoxia, a major limitation of traditional PDT, leading to significantly enhanced therapeutic efficacy and complete tumor regression in models. In a synergistic strategy for sonodynamic immunotherapy (SDT),[2,3] *Chlorella* algae are first cloaked with a macrophage cell membrane. This biomimetic coating endows the algae with the macrophage's inflammatory homing ability for improved tumor targeting. The membrane-coated algae are then functionalized with liposomes co-loaded with a sonosensitizer and an autophagy inhibitor. Within tumors, the algae perpetually oxygenate the microenvironment via photosynthesis to potentiate hypoxia-limited SDT, while the co-delivered inhibitor blocks a key cellular survival pathway, resulting in robust immunogenic cell death and the establishment of anti-tumor immune memory.

The same engineering philosophy is applied to inflammatory diseases.[4] For inflammatory bowel disease (IBD), *Haematococcus pluvialis* algae are pre-conditioned under stress to thicken their cell walls and biosynthesize the potent antioxidant astaxanthin. These robust, astaxanthin-producing algae are then conjugated with polydopamine-coated probiotic bacteria. The resulting biohybrid robots survive the acidic gastric environment, adhere to inflamed intestinal sites via polydopamine, and exert a dual therapeutic action: the algae-derived astaxanthin scavenges pathological reactive oxygen species, while the delivered probiotics restore gut microbiome homeostasis, collectively alleviating colitis.

In summary, this body of work establishes a versatile and powerful framework where living microalgae are engineered as intelligent, multi-role therapeutic agents. By seamlessly integrating autonomous propulsion, microenvironment modulation, and modular drug delivery into a single living entity, these systems enable precise, multimodal, and highly effective treatment strategies for both cancer and inflammatory diseases, marking a significant advance in targeted biological therapeutics.

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	June 2
	Conference Session III **Bio- and nanotechnology for health & environment**
8.30 am – 9.00 am	**Malgorzata Lekka**, Institute of Nuclear Physics, Krakow, Poland **(Invited Speaker)**
9.00 am – 9.20 am	**Georg Papastavrou**, University of Bayreuth, Germany
9.20 am – 9.40 am	**Lasse Hyldgaard Klausen**, Aarhus University, Denmark
9.40 am – 10.10 am	**Ricardo Garcia**, CSIC, Madrid, Spain **(Invited Speaker)**
10.10 am – 10.40 am	**Coffee Break (30 min)**
10.40 am – 11.10 am	**Bianxiao Cui**, Stanford University, Stanford, USA **(Invited Speaker)**
11.10 am – 11.30 am	**Valendy Thesnor**, Université des Antilles, Pointe à Pitre, Guadeloupe, France
11.30 am – 12.00 pm	**Ariane Boudier**, Université de Lorraine, Nancy, France
12.30 pm – 2.00 pm	**Conference Lunch**
	Conference Session IV **Instrumentation for materials & life sciences**
2.00 pm – 2.30 pm	**Simon Scheuring**, Weill Cornell Medicine, New York, USA **(Invited Speaker)**
2.30 pm – 2.50 pm	**Etienne Dague**, LAAS-CNRS, Université de Toulouse, Toulouse, France
2.50 pm – 3.10 pm	**Luca Franco**, Instituto de Ciencia de Materiales de Madrid, Madrid, Spain
3.10 pm – 3.40 pm	**Michelle Peckham**, Univ of Leeds, UK **(Invited Speaker)**
3.40 pm – 4.10 pm	**Coffee Break (30 min)**
4.10 pm – 4.40 pm	**Tomaso Zambelli**, ETH Zürich, Switzerland **(Invited Speaker)**
4.40 pm – 5.00 pm	**Jialin Shi**, Ecole Polytechnique Férérale de Lausanne, Switzerland
5.00 pm – 5.20 pm	**Prabhu Prasad Swain**, Ecole Polytechnique Férérale de Lausanne, Switzerland
5.20 pm – 5.50 pm	**Alexander Dulebo**, Bruker BioAFM, Berlin, Germany

Exploring cancer through the cell nanomechanorheology

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Atomic force microscopy (AFM) has been widely used to explore the mechano-rheological properties of bladder cancer cells using both two-dimensional (2D) and three-dimensional (3D) models [1-5]. In 2D systems, AFM measurements of cell elasticity, adhesion, and rheology have revealed clear differences between malignant and non-malignant urothelial cells, showing that bladder cancer cells become significantly more deformable even in early tumor stages despite the bladder's highly variable mechanical environment, which ranges from a few to several hundred kPa. These changes are closely linked to cytoskeletal remodeling, shifts in actin polymerization, variations in glycocalyx composition, and altered surface receptor expression. The use of brush models, combined with high-throughput microfluidic experiments, has helped connect the behavior of flowing cancer cells to the structure of the pericellular glycocalyx layer. AFM-based force spectroscopy has enabled analysis of single-molecule interactions, including integrin- and syndecan-mediated adhesion to extracellular matrix (ECM) components such as vitronectin. In 3D models, AFM has been used to study bladder cancer spheroids embedded in collagen–hyaluronic acid (Col-HA) hydrogels that simulate the ECM's rheological properties. These studies showed that the microenvironment mechanics strongly influence cancer cell migration and revealed links between mechanical phenotypes and metabolic activity, establishing mechano-metabolism as a key regulator of cancer cell adaptation across different tumor grades.

Collectively, these findings indicate that bladder cancer progression is governed by coordinated changes in cell morphology, cytoskeletal organization, glycocalyx structure, and cell–ECM interactions, leading to distinct deformability and variability in single-molecule adhesion behavior. The integration of mechanobiology and mechano-metabolism through AFM-based approaches provides a comprehensive framework for understanding tumor invasion and adaptation, and identifies mechanobiological markers with strong potential for early diagnosis and targeted therapeutic strategies.

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Nanoindentation of Microgels by AFM – From the Double Contact Model to High-Throughput Techniques

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Nanoindentation of soft materials, like cells or microgel particles, represents by now a standard technique to determine the Young's modulus. The fundamental concept goes back more to Hertz and has been adapted accordingly for AFM. However, the roles of substrate, indenter geometry, and adhesion bring additional complexity in the nanoindentation process and the following data analysis. In particular for soft hydrogel particles and cells, the deformation due to an incompressible substrate must be considered. [1] In a recent study, we verified this simplified double contact model for several indenter geometries (cf. Figure 1a) and two different types of microgel particles, which have been synthesized by microfluidics. [2] In combination with total internal reflection fluorescence measurements, we could demonstrate that previously observed deviations for different indenter geometries result from the adhesion between the particle and the substrate. In this case the adhesion plays the role of a 'pre-stress' on the particle. These results can be extended to the indentation by AFM of living cells and show which indenter geometry provides the most reliable quantitative results.

The elastic moduli of microgel particles show a large variation, even when they are synthesized by microfluidics. [2, 3] Hence, the development of techniques that allow determining Young's moduli for a statistically relevant number of microgels is important. In this respect, fluidic force microscopy (FluidFM)[4] provides, in combination with the double contact model, a new approach: The particles are aspirated at the aperture of the FluidFM cantilever, and the substrate takes the role of the indenter. [5] Thereby a significantly large number of particles can be probed in the same time interval. Moreover, this approach allowed us to confirm the role of adhesion on the apparent elastic modulus as determined from the force vs. indentation curves.

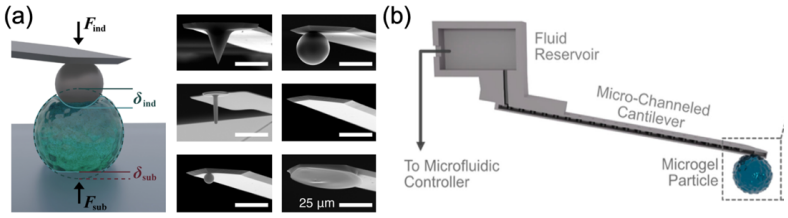

Figure 1: (a) Different indentation geometries utilized in the nanoindentation of microgel particles by AFM (from [2]. (b) Principle of nanoindentation by fluidic force microscopy (from [5]).

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Maskless photolithography fabrication of 3D microstructures for improved cell interface

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Three-dimensional (3D) structures with complex geometric features at the micro and nanoscale are powerful tools for biomedical engineering and single-cell analysis. However, the application of structures at length scales similar to cellular components is normally limited to simple geometries due to the difficulty in fabricating three-dimensionally curved structures. Here, we present a maskless photolithography workflow that overcomes this limitation, enabling rapid and high-throughput fabrication of biocompatible 3D nano-topographies with controlled curvature. Using a digital micromirror device projection system, we digitally modulate dose and axial focus based on simulated out-of-focus point-spread functions to achieve sub-micrometer lateral resolution and fabricate convex as well as concave micropillars. Compared with mask-based lithography and multiphoton lithography, this approach presents a convenient high-throughput way of fabricating complex substrates, with possible application in fundamental studies of cell-surface interactions as well as for engineering interfaces for directing cell and/or tissue function.

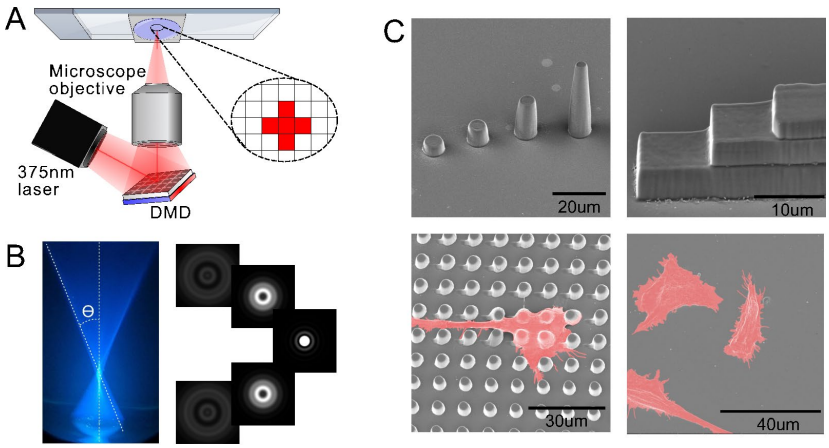

Figure 1: Maskless photolithography fabrication of micropatterned substrates. A) Schematic representation of experimental setup. **B)** Simulated optical point spread function at different z-planes. **C)** Scanning electron micrograph of different 3D structures and their interaction with cells.

Nanomechanics and Nanorheology of Proteins and Cells

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The mechanical properties of cells and proteins are of paramount relevance in mechanobiology. The atomic force microscopy (AFM) has become the most common technique to measure the elastic and viscoelastic properties cells and proteins at the nanoscale.

Here, we report some recent progress on the characterization of the mechanical properties of cells and proteins by AFM methods. First, we report a method to determine with quantitative accuracy the viscoelastic properties of living cells and their relevance in mechanobiology [1-4]. Second, we report an application of high-speed bimodal AFM to study the assembly, disassembly and reassembly of collagen nanostructures. on a mica surface [5-6]. Those processes are imaged with high spatiotemporal resolutions (1 nm and 0.1 μs (pixel)). Third, we show how 3D-AFM provides angstrom-scale resolution images of the formation of water layers on collagen nanofibers [7].

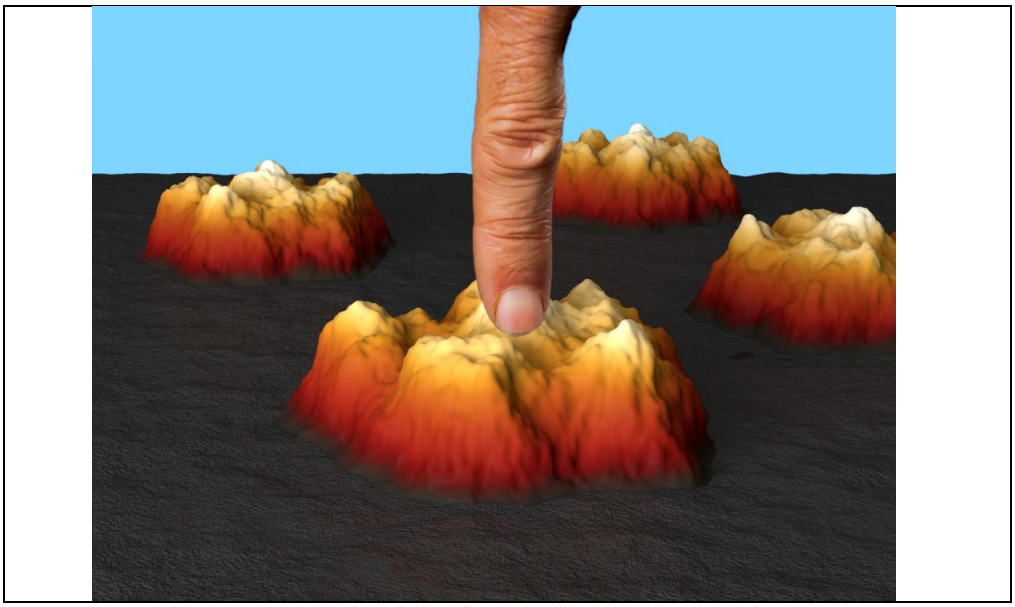

Figure 1: One figure if needed (Arial, centred, 9 pts)

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Membrane Curvature-Induced Cell Adhesion and Drug Development

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The extracellular matrix (ECM) is a fibrous scaffold composed of proteins like collagen, fibronectin, and elastin. When cells interact with these ECM fibers, their cylindrical geometry can induce local curvature in the cell membrane. We discovered that such membrane curvature gives rise to a previously unrecognized class of integrin-mediated cell adhesion – **curved adhesion**. Curved adhesions bear lower mechanical forces than focal adhesions and exhibit distinct molecular compositions. Curved adhesions are especially prevalent in soft, 3D fibrous environments and form independently of the strong mechanical forces typically associated with focal adhesions. Interestingly, unlike focal adhesions, curved adhesions resist disruption by high affinity av integrin inhibitors. As a result, curved adhesions continue to support cancer cell invasion into 3D ECM in the presence of these inhibitors. These findings reveal a limitation of current integrin-targeting strategies and also highlight new opportunities for future therapeutic development.

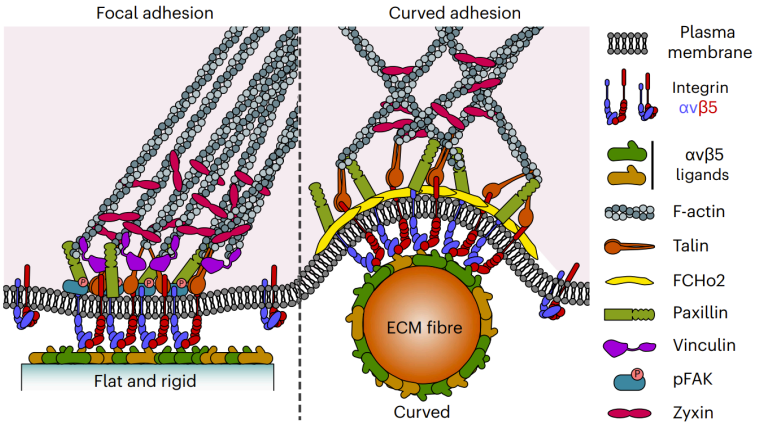

Figure 1: Schematic comparison of focal adhesion and curved adhesion architectures

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Chemical degradation strategies and identification of chlordecone metabolites

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Chlordecone (CLD, $C_{10}Cl_{10}O$), a persistent organochlorine pesticide used from 1972 to 1993 [1] in the French West Indies (Guadeloupe and Martinique) against the banana weevil Cosmopolites sordidus, durably contaminates soils, waters, and the food chain. Hydrophobic and bioaccumulative, it persists for decades to half a millennium in soils, causing elevated incidences of prostate cancer and neurological, hepatic, endocrine, and reproductive disorders [2]. Its prolonged use after the U.S. ban (1976) exacerbates the environmental and health crisis [3], There is an urgent need to develop reliable remediation process for contaminated soils. Such research requires the availability of well-characterized standard compounds corresponding to metabolites potentially formed during remediation processes. Consequently, it is essential to set-up controlled degradation pathways enabling the targeted production of these metabolites. The objective is to destabilize the CLD structure to generate less toxic or non-toxic secondary metabolites and identifying the resulting degradation products.

Materials and methods
Three novel chemical degradation strategies for CLD aimed at opening its perchlorinated bis-homocubane cage were tested: (1) chemical reduction under inert atmosphere (vitamin B12/ Zinc zero), (2) photodegradation (LED 450 nm/UV-C), and (3) redox electrosynthesis (±10 V), with or without reduced vitamin B12.

Results
Eleven reactions, analyzed by LC-MS (Orbitrap), identified 45 metabolites grouped into three families: Family A (intact cage): Hydrochlordecones (MonoHydrochlordecone, DiHydrochlordecone, TriHydrochlordecone). Family B: Polychloroindenes (PentaPolychloroindene, TetraPolychloroindene). Family C: Carboxylated polychloroindenes (Carboxylated Tetrachloroindene to Carboxylated Monochloroindene, loss of 6-9 Cl). Yields varied widely: near-null in photodegradation (>99 % intact CLD); 6-91% in chemical reduction (optimum: 57% Carboxylated Trichloroindene); low in electrosynthesis alone (maximum 22%); but up to 99% with reduced vitamin B12. Six reactions generated 21 cage-opened compounds, confirmed by standards (pentachloro-1H-indene, indene-3-carboxylic acid).

Conclusion
These results confirm cage destabilization of CLD via reductive pathways. Electrosynthesis, rapid and catalyzed by vitamin B12, emerges as the superior CLD degradation method with 99%. The most performant results will involve isolating the metabolites and fully elucidating their structures (chlorinated positions of the isomers).

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Nanoclusters of zero-valent iron to treat anaemia and other iron deficits

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Iron is a trace element essential to homeostasis, brought by food (meat, containing heme iron, and vegetables, containing non-heme iron). The recommended daily intake of this metal is 16 mg/day for women and 11 mg/day for men. It is known that 30% of the world's population is iron deficient and in Europe, *ca* 30 million of women are concerned. This is mainly due to chronic bleeding and diet (vegan) [1]. Iron supplementation can be given *per os*. However, due to its poor bioavailability (10 to 20%), the iron dosage is very high (3 to 120 mg/day) and patients usually experiment digestive side effects. As a consequence, 50% of patients abandon their treatment.

In this context, we developed iron nanoclusters (FeNC) [2], which are ultra-small nanoparticles of less than 1 nm, and are able to cross the physiological barriers This property should improve the bioavailability of the metal and then allow to treat efficiently iron deficiencies. We extensively characterized these particles and we tested them in *in vitro* and *in vivo* models. The nanocluster size was confirmed by dynamic light scattering with hydrodynamic diameters of 0.7 +/- 0.1 nm and by the innate fluorescence of the metallic core of FeNC (excitation at 382 and emission at 445 nm). The yield of iron incorporation in NC was 95,4 ± 13,1% and the redox state of iron was metallic, *i.e.* zero-valent, as investigated by transmission electron microscopy (TEM) equipped by energy dispersive X-ray spectroscopy (EDS) and electron diffraction. In iron-depleted hepatocyte cell line (HLF, treated with deferoxamine), the treatment by FeNC decreased the level of the mRNA expression of transferrin receptor (*Tfr1*) to control level, as analyzed by Reverse Transcription quantitative Polymerase Chain Reaction (RT-qPCR). As expected, the result was the same than controls (without deferoxamine or with iron sulfate). FeNC were then tested on another hepatocyte line, HepG2. At non cytotoxic concentrations, the quantification of ferritin in HepG2 increased from day 3 till day 10 after treatment. These results confirmed the capacity of FeNC to deliver their metal in the cell at a physiological level that downregulates *Tfr1*. Iron from FeNC is further stocked in ferritin which is the reservoir form of the organism, proving that iron from FeNC follows its physiological trafficking.

The capacity of FeNC to restore the pool of iron in a whole organism will be investigated in an *in vivo* murine model of iron deficiency (C57BL6 with an iron-free diet). After oral treatment, biochemical parameters such as blood count, hemoglobin, transferrin, ferritin and non-transferrin-bound iron (NTBI) will be monitored to prove the superiority of FeNC *vs* a traditional treatment by iron sulfate. These experiments are ongoing. Unlike *in vitro* models, *in vivo* experiments will bring the proof of the superiority of FeNC to iron sulfate, showcasing improved bioavailability, therapeutic efficacy at reduced dosages and the elimination of gastrointestinal toxicity.

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[2]. WO2024/100213, A. Boudier, I. Clarot, F. Feillet Iron-based nanoclusters, methods for obtaining same and uses thereof for combatting iron deficiencies.

Do it yourself (DIY) : Seesaw HS-AFM cantilevers with sharp tips

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High-speed atomic force microscopy (HS-AFM) movies have contributed significantly to our understanding of biomolecular dynamics. However, the resolution of HS-AFM images critically depends on the quality of the cantilever and the tip. Here, we detail in-lab approaches for the fabrication of HS-AFM seesaw cantilevers with a rigid reflective board oscillating over torsional hinges separating the laser-reflective and mechanical functions. Finite element analysis and experiment verified the seesaw mechanism. The board can be optimized for laser-reflection and the shortened distance between tip and hinges enhances the angular sensitivity, while seesaw cantilever stiffness is tunable via the hinge dimensions. [1] The seesaw cantilevers are completed with focused electron beam induced deposition (FEBID) tips fabricated using a commercial benchtop SEM. We describe an optimized workflow for FEBID tip fabrication and show high-resolution long-term stability HS-AFM movie acquisition using lab-made FEBID tips. We anticipate that the seesaw cantilevers and the benchtop SEM made FEBID tips may be useful for a wide range of AFM practitioners [2]. These approaches facilitate the reproducible acquisition of high-resolution AFM data in all fields of AFM application.

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Machine learning classification of normal and malignant cells based on viscoelastic properties probed by dynamic mechanical analysis

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Cell mechanics, particularly elasticity and viscoelasticity, are recognized as key biomarkers for distinguishing between normal and malignant cells. While atomic force microscopy (AFM) is a powerful tool for probing these properties, its low throughput has historically limited its application in generating large datasets for machine learning (ML) classification. To address this challenge, we employed dynamic mechanical analysis (DMA) to extract high-density viscoelastic descriptors from normal (RWPE-1) and grade IV cancerous (PC3-GFP) prostate cells. By probing cells at frequencies ranging from 1 to 200 Hz, we generated 304 features per cell, including storage modulus (*G'*), loss modulus (*G''*), and loss tangent (η), as well as the viscoelastic transition frequency (*fT*).

Our study[1] demonstrates that the combination of DMA and ML enables robust classification of cell types, even with limited sample sizes. Using a fuzzy logic-based LAMDA algorithm trained on 19 selected features, we achieved a classification accuracy of 79% with a training set of just 40 cells per line. Notably, the inclusion of additional features improved model performance, suggesting that fewer training samples may suffice when rich datasets are available. We also optimized the classification threshold to prioritize sensitivity, reducing false negatives in cancer detection.

The results highlight the potential of viscoelastic analysis combined with ML for mechanome-based diagnostics, offering a promising framework for applications in cancer and stem cell research. This approach is particularly valuable in scenarios where sample availability is limited, as the richness of DMA-derived features compensates for smaller cohort sizes. Future work will focus on refining training protocols, integrating new features, and exploring deep learning techniques to further enhance classification performance.

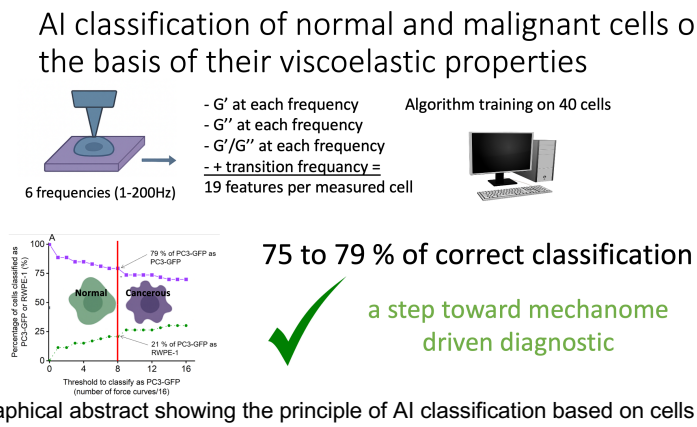

Figure 1: graphical abstract showing the principle of AI classification based on cells viscoelastic properties

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In-Situ Nanorheology Exposes the Role of Heavy Water in Collagen Fibrillogenesis

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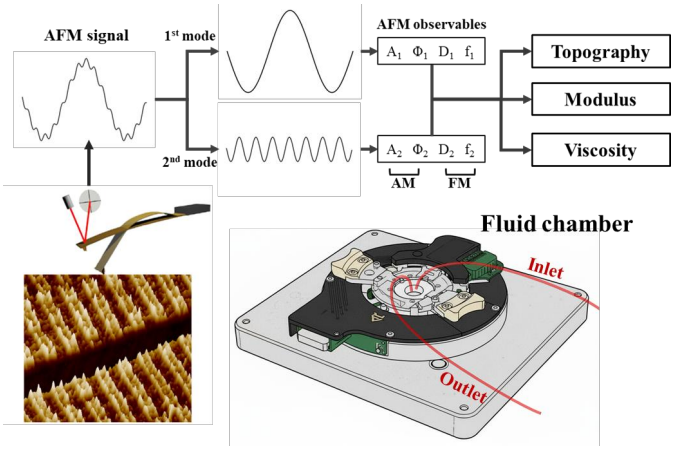
Collagen fibrillogenesis, the assembly of tropocollagen into structural nanofibrils of the extracellular matrix, is a process extremely sensitive to hydration and the solvation environment. Although heavy water (D_2O) is commonly used in structural studies in NMR, its specific impact on collagen assembly remains poorly explored. We developed an in-situ AFM nanorheology platform that integrates microfluidic H_2O/D_2O exchange with bimodal AFM to study the the fibrillogenesis of type I collagen on mica. This approach allowed simultaneous characterization of nanofibril morphology, effective Young's modulus (E_{eff}), and viscoelastic dissipation. D_2O induces a reorganization of the nanomechanical properties and assembly dynamics of collagen nanoribbons. The nanoribbons exhibited an 80% increase modulus along with an increase of the viscous properties. Those changes reflected polymer relaxations, transient intermolecular constraints, and confined hydration layer effects. Critically, the rapid perfusion of D_2O rich in collagen accelerated nucleation, producing thinner and more disordered fibrillar networks compared to conditions in H_2O. The preferential water-water binding of D_2O dehydrated the tropocollagens, creating a "poor solvent" environment that amplified the chemical potential difference ($\Delta\mu$) between the monomeric and fibrillar states. This process lowered the nucleation barriers (ΔG^*), favoring rapid but a less ordered assembly. These results established isotopic substitution as a powerful probe of hydration-controlled fibrillogenesis, revealing the links among molecular solvation, assembly kinetics, and emerging mechanical properties with implications for biomaterials engineering and fibrillopathies. Finally, our results revealed that isotopic substitution with D_2O modified the physical properties of proteins. This is particularly relevant for hydration-sensitive processes such as collagen fibrillogenesis.



Super-resolution of the cytoskeleton: Using iPALM to determine protein organisation in cardiac muscle Z-discs

Michelle Peckham,[1,3] Oliver Umney[2]*, Alistair P. Curd[2]*, Heather L. Martin[1], Tarek Lewis[1,3], Anna Tang[1,3], Harikrushnan Balasubramanian[4], Satya Khuon[4], Jesse Aaron[4]

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The organisation of the cytoskeleton in cells is complex and difficult to understand using standard fluorescence microscopy methods. We have developed single molecule localisation fluorescence microscopy approaches such as dSTORM, PALM and DNA PAINT to resolve the fine details of the organisation of the cytoskeleton. We have exploited novel small non-antibody binding proteins (Adhirons (previously called Affimers) to specifically label targets (1, 2). These binders are about 12 kDa, and 3-4 nm in size; small enough to penetrate dense regions of the cytoskeleton. They can be directly dye labelled or functionalised with DNA strands using a unique cysteine, which places dye labels close to the target of interest with minimal linkage errors. We have additionally developed software (PERPL: Pattern Extraction from Relative Positions of Localisations) to analyse the organisation within structures and identify patterns of organisation (3, 4), as well as automated methods for segmenting and analysing single molecule data (5, 6).

As part of this research effort, we have used these approaches to investigate protein organisation within the Z-discs of muscle sarcomeres. Sarcomeres are the basic repeating unit of striated (skeletal and cardiac) muscle. They are joined together by crosslinked actin filaments found at the boundaries of muscle sarcomeres, termed Z-discs. Z-discs play a key role in cardiac signalling and disease, however, the arrangement and function of many of the proteins present in the Z-disc remain to be understood. They are narrow (~ 120nm wide) and contain over 50 different proteins. The only protein that has been unequivocally identified, and which we have some idea of its organisation within the Z-disc is α-Actinin-2, which crosslinks actin filaments within the Z-disc. The organisation of other proteins is uncertain.

Here, we isolated specific Adhirons to 3 key Z-disc proteins, ZASP, α-Actinin-2 and the Z1Z2 epitope of titin. We used Alexa-647 labelled Adhirons to label these proteins in cardiac myofibrils and used interferometric photoactivated localization microscopy (iPALM) to obtain the 3D position of these proteins to a high precision (<10nm in x,y,z). We then used PERPL, to analyse patterns in the relative positions of the proteins and reveal their underlying organisation. This analysis revealed that ZASP and α-Actinin-2 have a similar repeating organisation, but the pattern for Z1Z2 is somewhat different and that it shows the highest level of organisation of all three proteins. These findings provide us with new insight into the organisation of proteins within the Z-disc, and demonstrate the power of this technique to reveal underlying patterns of protein organisation.

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Patch-clamp with Pyramidal and Cylindrical FluidFM Probes

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Patch clamp [1], a technology based on glass capillaries, is the gold standard for electrophysiology experiments, in particular for the recording of voltage-gated ion channels.
FluidFM is a force-controlled pipette, relying on AFM cantilevers with an embedded microchannel [2, 3], which make it a versatile tool from single-cell biology to metal microprinting.
By inserting an electrode in the FluidFM fluidic circuit together with a reference electrode in the physiological solution of the petri dish (~150 mM NaCl), we were able to simultaneously measure the ionic current and the cantilever deflection (force) [4].
The FluidFM setup with the electrodes can be directly utilized as patch clamp setup [5].
We are currently pursuing two strategies corresponding to the two kinds of tips at our disposal, pyramidal and cylindrical ones [6].

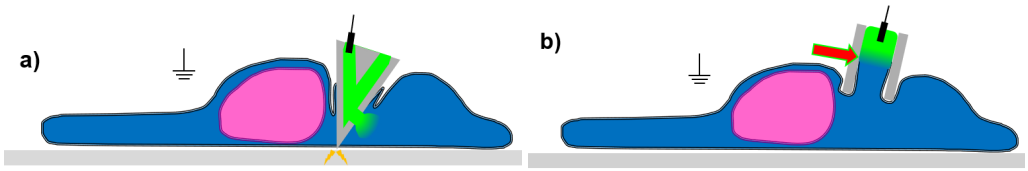

Figure 1: Our patch-clamp strategies with FluidFM probes: a) insertion of pyramidal and sharpened cylindrical probes, b) whole-cell mode with cylindrical probes.

According to the first one, we are inserting a pyramidal probe into a cell, upon puncturing the cell membrane, and measure the transmembrane potential in current-clamp mode. However, pyramidal tips are not guaranteeing the formation of a stable tight seal between the cell membrane and the tip walls (“gigaseal”). Therefore, according to the second strategy, we are employing cylindrical probes (supposed to mimic the apex of a glass capillary) to be approached onto the cell membrane with force-control, followed by application of an underpressure to suck in the cell membrane “patch”.
Results with hiPSC cardiomyocytes will be reported.

In the last minutes, I am describing our first experiments with the high-speed SICM assembled according to the instrument by Prof. Fantner (EPFL, Switzerland) [7].

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An Integrated Physical Model for Quantitative Nanomechanics in Scanning Ion Conductance Microscopy

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Scanning Ion Conductance Microscopy (SICM) has emerged as a powerful technique for non-contact nanomechanical measurements of living cells. However, most existing SICM-based mechanical analyses estimate mechanical properties from the slope between two current setpoints of the current-distant (I–Z) curve [1][2]. This approach is largely empirical, highly sensitive to measurement noise, and implicitly assumes a constant pressure acting on the sample. In reality, the pressure generated in the confined gap between the nanopipette and the sample arises from fluid flow and varies strongly with the pipette–sample distance, a mechanism that has not been explicitly incorporated into existing SICM mechanical models. Here we introduce an integrated physical framework for SICM quantitative nanomechanics that couples the established current–distance relationship with classical deformation mechanics and a new hydrodynamic model describing how fluid exiting the nanopipette generates pressure in the pipette–sample gap. The model captures the distance-dependent evolution of flow-induced pressure and its coupling to sample deformation and ionic current. Within this framework, complete I–Z curves can be analyzed using physics-based forward modeling, enabling robust extraction of mechanical parameters from the full signal rather than from discrete setpoints. The formulation is independent of the specific origin of the flow and therefore provides a general framework for SICM-based quantitative nanomechanics. In this work, the required flow is provided by intrinsic electroosmotic flow, allowing quantitative mechanical measurements without externally applied pressure. Applied to living cells, the method produces high-resolution maps of Young's modulus and deformation that can be directly correlated with SICM topography. Compared with slope-based approaches, this model-based analysis enables more robust, physically interpretable, and quantitatively reliable nanomechanical measurements.

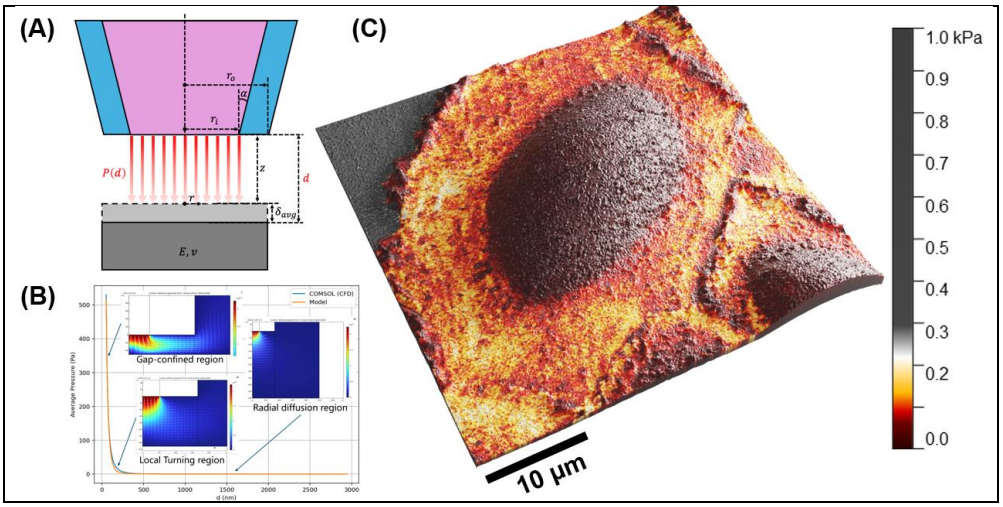

Figure 1: (a) Schematic of the integrated physical model for SICM nanomechanics. (b) Flow-induced pressure in the confined nanopipette–sample gap: simulation and model results. (c) Overlay of a living-cell mechanical property map and topography.

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CLEAM: Correlative light, electron and atomic force microscopy for ultrastructural tissue imaging

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Understanding tissue architecture requires simultaneous access to molecular specificity, ultrastructural context, and nanoscale contrast. However, no single imaging modality can provide all three with sufficient resolution and contextual integrity. Fluorescence microscopy (FM) helps study molecular identity and nanoscale localization of proteins within complex tissue environments, albeit at a poor resolution. Back-scattered electron imaging inside a scanning electron microscope (SEM) provides ultrastructural context, however, lacks specificity and has poor contrast. Atomic force microscopy (AFM) has been extensively used to study proteins and molecules in-vitro, at nanometric resolution, however, is limited to surfaces. Here, I present **CLEAM** (Correlative Light, Electron and Atomic force Microscopy), a correlative workflow that integrates the three microscopy modalities to image Tokuyasu[1] cryo-sections for multimodal and volumetric tissue imaging.

Tokuyasu cryo-sectioning is known to preserve antigenicity in tissues while maintaining its ultrastructural integrity[2]. This enables high-specificity labeling for fluorescence imaging prior to light fixation for SEM imaging and force-based topographic mapping. After FM imaging on these cryo-sections, we use an AFM mounted inside an SEM chamber[3] to perform backscattered electron imaging and use SEM's large field of view to navigate the AFM cantilever over the sample. While the SEM provides correlative ultrastructural context, the AFM maps quantitative topographical information of the sections based on the degree of fixation, at nanometric resolution. Importantly, sectioning with cryo-ultramicrotomy, we overcome the intrinsic surface limitation of AFM and enable correlative FM-AFM-SEM three-dimensional reconstruction of tissue architecture.

We use this correlative workflow to study mitochondrial organization in outer plexiform layer of Zebrafish larvae retina tissue (Fig. 1). Through accurate registration across the three modalities and serial Tokuyasu cryo-sections, CLEAM generates aligned datasets that integrate protein localization, ultrastructure, and topographical contrast within the same volumetric framework. Thus, CLEAM establishes a scalable platform for correlative nanoscale analysis of biological tissues, with broad applicability in structural cell biology and pathology.

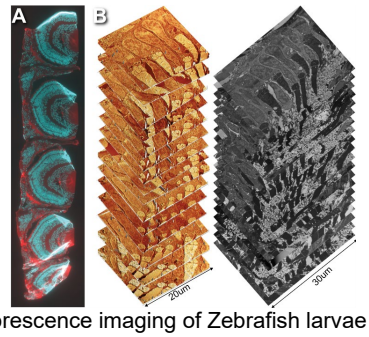

Figure 1: CLEAM (a) Epifluorescence imaging of Zebrafish larvae retina tissue of nucleus and mitochondria (b) AFM (in yellow) and SEM (in gray) imaging of 15 serial Tokuyasu cryo-sections

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Large-Area AFM Mapping for Mechanical Studies in Cells, Spheroids and Organoids

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Atomic force microscopy (AFM) is a powerful technique for nanoscale mechanical property mapping, enabling high-resolution characterization of stiffness, adhesion and viscoelasticity. This capability is essential for understanding material behaviour in complex structures such as living cells, tissues and biomaterials, thereby advancing studies of cell behaviour, disease progression and drug treatment responses. However, challenges such as sample roughness and the limited lateral scanning range of conventional systems often hinder large-scale mechanical mapping, particularly for complex and heterogeneous specimens including biopolymers, cell spheroids/organoids and tissues.

We have developed a new nanomechanical mapping tool that overcomes these limitations by coordinating the AFM head motors with the XYZ piezo movement in a fully automated manner. Together with a newly designed large-range, high-accuracy stage, these innovations enable continuous, high-resolution mapping over extensive areas without user intervention, significantly enhancing the precision, throughput and reliability of AFM measurements. We successfully validated this system through comprehensive analyses of hydrogels with different stiffnesses (1 kPa and 50 kPa), mapping centimetre-scale areas and generating detailed mechanical property distributions. Additionally, we demonstrated the applicability of the new feature for analysing 2D cell populations cultured on hydrogels and high-grade serous ovarian cancer spheroids exceeding 100 µm in height. Furthermore, we assessed extremely soft (<1 kPa) iPSC-derived organoids, demonstrating that - even in the presence of substantial surface roughness - the mechanical properties of such samples can be effectively characterized.

Together, the new nanomechanical mapping tool and large-range high-accuracy stage represent a significant advancement in AFM capabilities, enabling precise and efficient large-scale mechanical mapping. This development opens new opportunities for studying a wide range of materials, from complex biopolymers to soft biological tissues, and expands the scope and impact of automated AFM in biomedical and biomaterial research.

	June 4
	Conference Session V **Bio- & Nanomaterials from labs to medical applications**
8.30 am – 9.00 am	**Elodie Boisselier**, Laval University, Québec, Canada **(Invited Speaker)**
9.00 am – 9.20 am	**Jaroslaw Jacak**, University of Applied Sciences Upper Austria, Linz, Austria
9.20 am – 9.40 am	**Sylvie Begin-Colin**, University of Strasbourg, Strasbourg, France
9.40 am – 10.10 am	**Menglin Chen**, Aarhus University, Denmark **(Invited Speaker)**
10.10 am – 10.40 am	**Coffee Break (30 min)**
10.40 am – 11.10 am	**Joerg Lahann**, University of Michigan, USA **(Invited Speaker)**
11.10 am – 11.30 am	**Fabienne Quilès**, Université de Lorraine-CNRS, Villers-lès-Nancy, France
11.30 am – 11.50 am	**Laure Brice**, Université de Lorraine, Nancy, France
11.50 am – 12.10 pm	**Zhaoli Gao**, The Chinese University of Hong Kong, Hong Kong, China
12.30 pm – 2.00 pm	**Conference Lunch**
	Conference Session VI **Bio- & Nanotechnology for health & environment**
2.00 pm – 2.30 pm	**Adeline Goulet**, LISM, Marseille, France **(Invited speaker)**
2.30 pm – 2.50 pm	**Serena Danti**, University of Pisa, Pisa, Italy
2.50 pm – 3.10 pm	**Waking-Balaguer Mainviel**, Université des Antilles, Pointe à Pitre, Guadeloupe, France
3.10 pm – 3.30 pm	**Hana Jungová**, Chalmers University of Technology, Göterborg, Sweden
03.30 pm – 4.30 pm	**Coffee Break – Poster Session II**
4.30 pm – 5.00 pm	**Birgit Plochberger**, Univ of Applied Sciences Upper Austria **(Invited Speaker)**
5.00 pm – 5.20 pm	**Judith Zubia-Aranburu**, Aarhus University, Aarhus, Denmark
5.20 pm – 5.40 pm	**Vadim Frolov**, University of Basque Country, Leioa, Spain
Gala Diner	
7.30 pm	**Caribbean Music & Dance Show** Traditional music and dances with the famous Guadeloupe Carnival atmosphere by Double Face
Conference & Group photos	

Innovative Nanomedicine Approaches to Improve Ocular Drug Efficacy

Elodie Boisselier

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Globally, at least 2.2 billion people have some form of vision impairment or blindness, making eye conditions one of the most prevalent health issues worldwide. Four major diseases account for the majority of vision loss cases: age-related macular degeneration (AMD), glaucoma, diabetic retinopathy, and cataracts. The etiology of many ocular diseases remains poorly understood or incompletely characterized. There is therefore a critical need to advance our understanding of the molecular and cellular mechanisms underlying these conditions in order to improve patient care.

Approximately 90% of ophthalmic medications are administered as topical eye drops. However, even under optimal conditions, less than 0.02% of the active compound reaches intraocular tissues. The limited ocular bioavailability of conventional formulations thus represents a major barrier to therapeutic efficacy.

Our research group is developing innovative drug delivery systems based on gold nanoparticles (AuNPs) to enhance the therapeutic performance of ophthalmic drugs. By engineering the surface chemistry and functionalization of AuNPs, we aim to optimize drug loading, controlled release, and tissue-specific interactions within ocular compartments.

In parallel, we investigate the function of selected ocular proteins, particularly members of the S100 and annexin families, through membrane interaction studies to elucidate their roles in physiological and pathological processes of the eye. A better understanding of these molecular mechanisms may reveal novel therapeutic targets that can be exploited using nanoparticle-based delivery strategies.

The methodologies employed in this research integrate chemistry, molecular biology, biochemistry, and biophysics to establish a comprehensive framework for translational ophthalmic nanomedicine.

Overall, our work seeks to generate fundamental insights into ocular mechanisms while developing innovative diagnostic and therapeutic tools based on gold nanoparticle technology for the treatment of vision-threatening diseases.

Hybrid Multiphoton Lithography Scaffolds for Nanoscale Mechanobiological Assessment in Microscale Bone Models

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We developed a hybrid 3D scaffold platform fabricated via MultiPhoton Lithography (MPL) that integrates synthetic polymers (BisSR/CEA) with methacrylated collagen I (Coll-MA) [1]. This approach enables geometry-dependent confinement of single cells or clusters, allowing control over cell–cell contact within precisely defined microenvironments. Our hybrid scaffolds are the first biodegradable MPL-printed constructs with locally tunable stiffness and spatially programmed biodegradation, supporting dynamic microenvironment remodeling [2,3]. Structures with features down to 240 nm and stiffness ranging from tens of kPa to tens of MPa were achieved. Bioactivity was confirmed using 3D Single-Molecule Localization Microscopy (SMLM), visualizing the nanoscale organization and dynamics of vinculin. Vinculin localization was independent of scaffold stiffness and composition, while collagen I and osteocalcin expression were significantly increased in cells confined within hybrid scaffolds. These results indicate that scaffold geometry and biochemical cues, rather than stiffness alone, dictate early osteogenic differentiation. The combination of tunable micro/nanoarchitecture with super-resolution imaging provides a versatile platform for studying mechanobiology and for developing advanced Organ-on-a-Chip systems, including bone-on-a-chip models.

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Engineering of surfactant coated iron oxide nanostructures to improve phosphate removal in peritoneal dialysis treatment

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Chronic kidney disease (CKD) induces the loss of blood purification functions by the kidneys in patients. Among toxic elements, phosphates are a special species whose chronically excessive concentration in the blood can lead to life-threatening complications, notably cardiovascular problems. Peritoneal dialysis (PD) is one of two dialysis modalities for treating patients with CKD and offers advantages such as a preservation of vascular access and renal residual function, less drugs administration, a higher suitability for treating children and infants, a low cost by comparison with the more conventional dialysis mode: hemodialysis.
However, its phosphate removal efficiency needs to be improved to upgrade this dialysis technique. In these works, we have studied the addition of iron oxide nanoparticles (IONPs) into dialysate to enhance phosphate removal from blood and even to reduce the PD duration.
Surfactant-coated IONPs have been designed to balance between a (bio)compatibility with the PD process (which requires IONPs which do not cross the peritoneal barrier) and a high efficiency of phosphate capture (lowest amount of introduced IONPs). Surfactant coated iron oxide nanostructures were synthesized through polyol solvothermal and coprecipitation approaches following strong specifications related to the PD process.
Phosphate removal experiments in water and dialysate solutions have been performed in batch mode but also in two laboratory-scale dialysis set-ups. The removal efficiency was found strongly dependent on the surfactant coating and synthesis method. All these experiments have allowed us selecting the most suitable surfactant coated IONPs for our application. They have been then tested in a specifically designed device mimicking as close as the PD process. Cellular and in vivo studies have also confirmed the suitability of our surfactant-coated IONPs.
These experiments have confirmed the suitability of this strategy to enhance and speed up phosphate removal efficiency. These results strongly demonstrated the potential of adding stable, biocompatible IONPs in dialysate to enhance phosphate transport in PD process.

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Embracing Remote Fields in Biofabrication for Neuromodulation

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Alongside the widely studied pathways of biochemical regulation by chemokines, cytokines and growth factors, one often overlooked but significant influence over the behavior of biological systems is bioelectricity. Voltage gradients among all somatic cells (not just excitable nerve and muscle) control cell behavior, and the ionic coupling of cells into networks via electrochemical synapses allows them to implement tissue-level patterning decisions. Neuromodulation is therefore a potential target for many new therapies for a range of diseases and biological functions. Biomodulation facilitated by external remote fields, such as those generated by magnetic, optical, and acoustic stimuli, has emerged as an intriguing avenue for tissue biofabrication, owing to their precision and non-invasive characteristics. The active modulation of 3D tissue structures through cellular signaling transductions, encompassing thermo-, mechano-, and electro-transduction, has proven highly effective in inducing spatiotemporally controlled, functional tissue maturation. Our current research focuses on advancing biofabrication with remote field stimulation to explore multi-dimensional nano-biointerfaces that synergise the structural induction and the bioelectrical/biochemical signaling to affect cellular behaviours, for biomedical applications in neuromodulation and tissue engineering.

Biography

Dr Menglin Chen completed her PhD in Chemistry from Aarhus University, Denmark, and is currently an Associate Professor in the Department of Biological and Chemical Engineering at Aarhus University. She leads the research group of Nanofiber Technology and Cellular Engineering (NTCE), focusing on the development of functional nanofibrous biomaterials that mimic the extracellular matrix for biomedical engineering applications. Supported from Independent Research Fund Denmark, Lundbeck foundation, Novo Nordisk Foundation, Innovation Fund Denmark and EU Horizon Europe, she has published over 100 peer-reviewed publications in esteemed journals such as Biomaterials, Advanced Science, ACS NANO etc. Dr. Chen has received Semper Ardens Award from the Carlsberg Foundation.

Protein-Centered Design of Biomaterials

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Proteins offer a versatile biomolecular platform for constructing functional biomaterials. This presentation will explore engineering strategies to create protein nanoparticles (PNPs) with tailored properties, drawing inspiration from natural proteins and employing advanced synthetic techniques. Scalable manufacturing of PNPs via electrohydrodynamic jetting allows for precise control of critical particle characteristics such as size, stability, and drug loading capacity. Applications of PNPs in brain tumor therapy will be discussed. Additionally, protein-based scaffolds, specifically engineered extracellular matrix (EECM), leverage human proteins like fibronectin to support cell growth and expansion, relevant to cancer vaccine construction and tissue engineering. The design of PNPs and protein-based scaffolds extends beyond the properties of the protein itself, encompassing surface modification with targeting ligands, controlled release strategies, and the creation of 3D microenvironments.

Ulvan-based hydrogels as sustainable biomaterials for tuneable antibacterial performance

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Bacterial infections remain a major concern in wound care and implantable medical devices, especially with the rise of antibiotic resistance. Among natural polysaccharides, marine-derived ulvan remains underexplored despite its structural similarity to glycosaminoglycans and inherent bioactive properties, which offers promises for antiadhesive and antimicrobial properties. Here, we report ulvan-based surface coatings as hydrogels synthesized using EDC/s-NHS, 1,4-butanediol diglycidyl ether or divinyl sulfone as crosslinkers, designed to prevent bacterial adhesion and growth. A comprehensive physicochemical characterization by FTIR, XPS, and AFM analyses was performed. It showed the successful hydrogel formation with different characteristics. Performances were evaluated against Gram-negative and Gram-positive bacteria. Both hydrogels significantly reduced bacterial colonization on all ulvan coatings by up to 90% compared to glass used as a control. Fluorescence imaging revealed sparse bacterial adhesion and signs of membrane disruption, suggesting antiadhesive and antibacterial effects. The membrane-disrupting activity was observed without antimicrobial agent loading. Comparable efficacy between formulations confirms ulvan's intrinsic antimicrobial potential, independent from crosslinking chemistry.
These coatings offer short-term protection against microbial colonization, particularly effective during the critical early adhesion phase, and provide a chemically tuneable platform for anti-infective surfaces in applications such as catheters, wound dressings, or food-contact materials. This work lays the groundwork for designing glycosylated interfaces in biomedical and environmental applications where early-stage biofilm prevention is critical.

Copper nanoclusters stabilized by histidine as new antimicrobial agents

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Copper, a physiological metal, plays a crucial role for organism homeostasis. However at doses higher than physiological levels, copper exhibits antimicrobial properties, preventing or inhibiting infections caused by Gram-positive or Gram-negative bacteria or fungi and exhibits anti-infectious properties (1). Copper has been studied mainly in a nanoparticle form to inhibit microorganism growth but toxicity issues were identified (2).

A promising alternative is proposed here, with the design of copper nanoclusters stabilized by histidine (CuNCHis) (size between 0.7 to 2 nm), which offer an intermediate structure between molecules and nanoparticles, and exhibit unique properties thanks to well defined chemical compositions and high degree of purities (3) [patent WO 2022/238656]. They show fluorescent properties, (380 nm and 440 nm for excitation and emission wavelengths, respectively). In this work, we studied the antimicrobial activity of CuNCHis against Gram-negative (*Escherichia coli* and *Pseudomonas aeruginosa*), Gram-positive (*Staphylococcus aureus*) bacteria and on a yeast (*Candida albicans*). A strong antibacterial activity on all the bacterial strains was observed, at concentrations as low as 9-18 µg/mL and 18-35 µg/mL copper equivalent for Gram-positive and Gram-negative bacteria, respectively. No antifungal activity was obtained over the range of concentrations tested (0.3-35 µg/mL copper equivalent). The structure of the nanocluster was studied by DFT, including the metal core and the adsorption of ligands on the metal core. Possible antimicrobial modes of action were explored: DFT calculations showed that the NCs would have a strong oxidizing potential ($E°_{vs\ ESH}$ = + 0.83 V) and an ability to stick to the membranes of *Pseudomonas aeruginosa* and *Staphylococcus aureus*. The study of the interactions between NCs and the membrane of Candida albicans is in progress. Further work will focus on testing the activity on other strains as well as resistant ones and elucidating their mechanism of action. It will also be interesting to modify CuNCHis to obtain an additive antifungal activity and to verify that their use does not generate toxicity and resistance.

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Rapid miRNA Detection Enhanced by Exponential Hybridization Chain Reaction in Graphene Field-Effect Transistors

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Scalable electronic devices that can detect target biomarkers from clinical samples hold great promise for point-of-care nucleic acid testing, but still cannot achieve the detection of target molecules at an attomolar range within a short timeframe (<1 hour). To tackle this daunting challenge, we integrate graphene field-effect transistors (GFETs) with exponential target recycling and hybridization chain reaction (TRHCR) to detect oligonucleotides (using miRNA as a model disease biomarker), achieving a detection limit of 100 aM and reducing the sensing time by 30-fold, from 15 hours to 30 minutes. In contrast to traditional linear TRHCR, our exponential TRHCR enables the target miRNA to initiate an autocatalytic system with exponential kinetics, significantly accelerating the reaction speed. The resulting reaction products, long-necked double-stranded polymers with a negative charge, are effectively detected by the GFET through chemical gating, leading to a shift in the Dirac voltage. Therefore, by monitoring the magnitude of this voltage shift, the target miRNA is quantified with high sensitivity. Consequently, our approach successfully detects 22-mer miRNA at concentrations as low as 100 aM in human serum samples, achieving the desired short timeframe of 30 minutes, which is congruent with point-of-care testing, and demonstrates superior specificity against single-base mismatched interfering oligonucleotides.

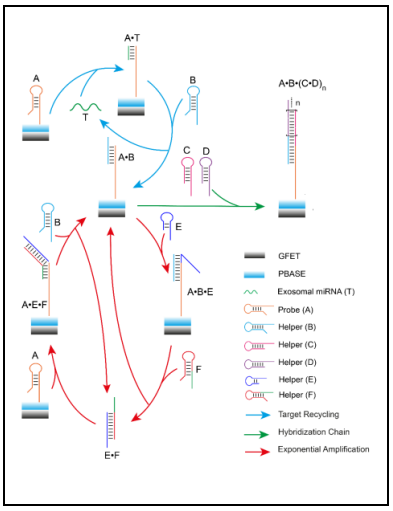

Figure 1: Schematic illustration of the target triggered self-assembly Exp-TRHCR amplification for miRNA detection on GFET.

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Seeing the invisible: How structural biology reveals the molecular basis of phage-bacteria interactions

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Bacteriophages (phages), viruses that infect bacteria, are highly sophisticated natural nanomachines. Their ability to recognize and kill a specific bacterium makes them promising biotechnological tools in the context of rising antibiotic resistance. Infection is initiated by interactions between the phage adhesion device, a multiprotein complex located at the tip of the tail, and receptors on the bacterial surface. Understanding the molecular basis of these interactions is therefore essential for deciphering phage-host specificity, enabling better control of phage infections and the rational development of phage-based therapeutic applications.

Here, I will present the impact of structural biology, including computational approaches such as AlphaFold-based structure prediction and experimental methods such as cryo-electron microscopy, in the study of phage-host interactions. Drawing on our recent work on phages infecting the lactic acid bacterium *Oenococcus oeni* and mycobacteria such as the human pathogen *Mycobacterium abscessus*, I will discuss the remarkable modularity and structural diversity of phage adhesion devices. These findings illustrate how phages have evolved molecular adaptations to recognize their host surfaces and how such studies can guide the rational engineering of these nanomachines.

Piezoelectric nanomaterial-based devices for cochlear implants

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Sensorineural hearing loss, primarily caused by damage to sensory hair cells in the cochlea, affects millions worldwide and leads to profound developmental, cognitive, and psychosocial consequences. Current cochlear implants (CIs) provide partial restoration of hearing through electronic multichannel stimulation; however, their limited spatial resolution (maximum 22 electrodes), mechanical mismatch with soft tissues, and reliance on complex external electronics constrain performance.

To overcome these intrinsic limitations, we propose a nano-engineered, biomaterial-based strategy for next-generation cochlear interfaces based on piezoelectric nanofibers capable of self-powered mechano-electrical transduction. Moving beyond bulk piezoelectric membranes, whose sensitivity remains insufficient, we adopt a bottom-up nanotechnological approach in which electromechanical functionality is engineered directly at the fiber level [1].

Ultrafine Janus fibers, made of 2 polymers with different chemistry and piezoelectric properties, were fabricated via an optimized eccentric bifluid electrospinning process, generating a side-by-side asymmetric architecture that functions as an intrinsic unimorph without passive interlayers. This nanoscale structural asymmetry enabled enhanced electromechanical coupling while preserving mechanical compliance and acoustic impedance compatible with the cochlear microenvironment. The produced fibers were surface-functionalized using different methods, such as gas plasma and polydopamine coating to improve adhesion with the basilar membrane of the cochlea. Morphological characterization confirmed continuous, well-defined bifacial fibers with controlled diameter distributions, forming aligned nanofibrous meshes suitable for integration with neural tissues. Multiscale piezoelectric characterization demonstrated the impact of nano-architecture on functional performance. At the nanoscale, contact-electrostatic force microscopy piezoresponse mapping (CE-FM-PFM) confirmed spatially resolved functional asymmetry, directly correlating nanoscale structural design with unimorph electromechanical behavior. A biodegradable hydrogel microcarrier was developed to insert these fibers in 3D printed artificial cochleae while releasing neuro/otoprotective and anti-inflammatory drugs.

This nano-enabled strategy advances the concept of piezoelectric CIs from bulk devices toward implantable, nanostructured interfaces capable of intimate integration with peripheral nerve endings. By enabling potentially hundreds of microscale stimulation sites and intrinsic feedback at micrometer resolution, Janus piezoelectric nanofibers represent a transformative platform for biomimetic auditory sensors and soft, self-powered neuroprosthetic devices.

Acknowledgements

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Magnetic sargassum biochars as catalysts for degrading emerging pollutants and pesticides via Fenton-Like reactions

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Currently, new classes of contaminants are appearing with increasing frequency, called “emerging contaminants” are known for their harmful effects on the ecosystem and human health, even at very low concentrations. These pollutants include: per-and polyfluoroalkyl substances (PFAS), polychlorinated biphenyls (PCBs), pesticides, pharmaceutical products such as antibiotics [1]. Finding effective techniques to treat these pollutants is extremely essential. Several mechanisms, such as adsorption, sequestration, and degradation, can be used to eliminate pollutants from water or soils [2].
This study aims to produce magnetic catalysts based on sargassum algae biochar with an important specific surface 959 m^2/g and iron oxide with different iron contents of 10%, 25%, 40%, and 50%, using a co-precipitation method.The physico-chemical properties of the materials were determined by various techniques, including pH at zero point charge (pHpzc), infrared spectroscopy (FT-IR), Raman Spectroscopy, Scanning Electron Microscopy, specific surface area using the BET method, and thermogravimetric analysis (TGA). These composites were used to remove caffeine (20 mg/L) from an aqueous solution using a Fenton-like process. The 25% iron catalysts removed 92 % of caffeine after 180 minutes of reaction where the catalyst dosage was 0.2 g. L^{-1}, H_2O_2 concentration 5 mmol. L^{-1}, pH 3 and the temperature was 298 K. The effects of hydrogen peroxide from 5 to 20 mmol. L^{-1}, pH from 3 to 5.8 and catalyst dosage from 0.2 to 0.3 g. L^{-1} were studied.

The key advantage of using these composites lies in their ability to be reused in the same Fenton process, as they remain stable over three degradation cycles. Regeneration efficiencies of 91.3%, 88.1% and 81%, were obtained. The results obtained from this oxidation process, including the catalytic performance of the materials, pave the way for further studies such as the degradation of chlordecone, a recalcitrant pesticide found in the water and soil of Guadeloupe.

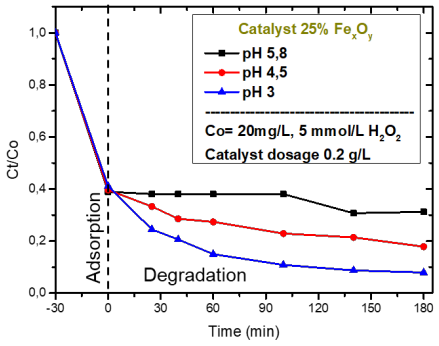

Figure 1: pH effect on the degradation of caffeine

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Light-Driven Gold Nanomotors for Mapping Subcellular Nanomotion in Living Cells

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Nanoscale mechanical fluctuations are an intrinsic feature of living cells and have emerged as sensitive indicators of cellular viability and disease. These motions span a wide range of scales, from nanometer-sized protein displacements to coordinated oscillations across entire cell populations. Despite their importance, capturing these transient events with sufficient spatial and temporal resolution remains a major experimental challenge.

We recently introduced light-driven plasmonic nanomotors as nanoscale motion detectors of living cells [1]. In this approach, gold nanorods are optically trapped and set into rotation by circularly polarized near-infrared light. Positioned just above the cell surface, they function as freely spinning probes. Their kilohertz rotation frequency is highly sensitive to axial position: when the membrane moves, the nanomotor responds immediately, converting tiny vertical displacements into measurable frequency shifts. In this way, cellular nanomotion is directly translated into an optical readout.

The platform achieves ~10 nm axial precision at second timescales with sub-diffraction lateral localization (~300 × 300 nm). The optical forces involved are well below typical cytoskeletal forces, and the method requires no fluorescent labels or intracellular probes. Applying this technique to living human endothelial cells, we mapped nanomotion patterns across different subcellular regions and observed pronounced mechanical heterogeneity. The nucleus displays large, slowly varying fluctuations consistent with long-range correlated dynamics. In contrast, the perinuclear region exhibits faster and more dynamic motion, likely reflecting cytoskeletal remodeling and intracellular trafficking, while the cell periphery remains comparatively stable. Frequency-domain analysis reveals scale-invariant 1/f behavior with a characteristic transition near ~0.3 Hz, suggesting a common mechanical crossover within the cell. We also resolve transient oscillatory bursts in the 10–20 Hz range, capturing rapid events that are often inaccessible to conventional techniques.

By using photon angular momentum to sense cellular mechanics, this work connects nanophotonics with mechanobiology. Light-driven nanomotors offer a minimally invasive way to map dynamic mechanical signatures in living cells, opening new possibilities for single-cell mechanophenotyping, disease studies, and advanced nano–bio interfaces.

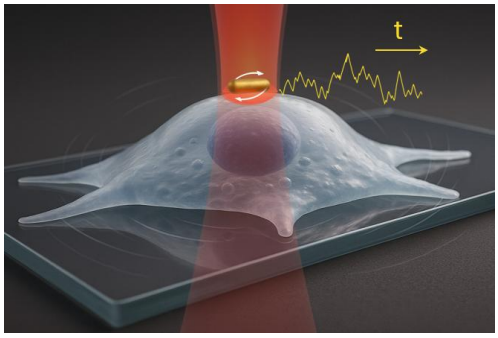

Figure 1: Illustration of the nanomotor-based method. A gold nanorod, trapped and rotated by circularly polarized light, serves as a freely spinning nanosensor that converts nanoscale cellular movements into measurable frequency changes.

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TTYH2-Mediated Lipid Transfer via Apolipoprotein Interactions

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TTYH2, an isoform of the conserved Tweety family, is a eukaryotic transmembrane protein implicated in lipid transfer across cellular membranes. Recently, TTYH2 was identified as an interaction partner of apolipoprotein E (ApoE) [1], the principal apolipoprotein regulating lipid homeostasis in the brain. In vivo lipid transport depends on the assembly of lipids into apolipoprotein-containing complexes; however, the mechanisms that link intracellular membranes to apolipoproteins remain poorly understood. Our recent work indicates that TTYH2 acts as a catalyst for lipid transfer between intracellular membranes, such as endosomes, and apolipoproteins or lipoprotein particles. This interaction is modulated by the apolipoprotein isoform, the lipidation state of the apolipoprotein, and the local lipid composition of the membrane.

To define the molecular basis of TTYH2–apolipoprotein interactions, we applied an integrated biochemical and biophysical framework across well-defined lipid particle and membrane environments. Quantitative analysis of TTYH2 interactions with ApoE isoforms revealed distinct binding affinities, kinetic rate constants, and epitope specificities, as determined by cryo-electron microscopy, single-molecule force spectroscopy, mass spectrometry, and surface plasmon resonance. Functional implications for lipid transfer were assessed using complementary fluorescence-based assays. Direct visualization of lipid exchange between lipoprotein particles and TTYH2 was achieved using a combined atomic force and fluorescence microscopy platform, while super-resolution microscopy resolved their subcellular colocalization.

Our data reveal specific interactions of TTYH2 with both lipidated and delipidated ApoE and show that binding is markedly enhanced under mildly acidic conditions, consistent with an endosomal interaction pathway. Comparative analysis of variable peptides derived from the ApoE C-terminus uncovered sequence-dependent determinants of TTYH2 binding, providing initial mechanistic insight into epitope recognition. Beyond ApoE, we identify apolipoprotein A1 (ApoA1), which shares structural features in its C-terminal region, as an additional TTYH2 interaction partner. Together, these findings establish TTYH2 as a lipid transfer–competent interaction hub for multiple apolipoproteins and uncover sequence- and environment-dependent principles governing binding. This work provides a mechanistic framework for understanding how intracellular membranes interface with apolipoproteins and lays the foundation for future studies addressing the physiological and pathological roles of TTYH2-mediated lipid transport in vivo.

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Regulation of T-cell mechanics via MgAl-LDH-mediated local pH and ionic strength modulation

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The tumour microenvironment (TME) suppresses cytotoxic T-cell activity in solid tumours [1]. Although immune checkpoint inhibitors and cytokine-based therapies can transiently reactivate $CD8^+$ T cells, their efficacy is often limited by unresolved TME features such as extracellular acidosis and Mg^{2+} deficiency [2, 3]. Acidic pH and low Mg^{2+} impair T-cell function and metabolism, motivating strategies to convert tumours into immunologically "hot" environments that promote effective immune responses [4].

Among emerging approaches, MgAl-layered double hydroxide (LDH) is a promising immunomodulatory nanomaterial due to its ability to neutralise excess lactic acid while simultaneously releasing Mg^{2+} [5, 6]. Building on our previous findings that acidic conditions alter the mechanical properties of T cells, this study investigates how local pH modulation by MgAl-LDH nanoparticles can regulate T-cell mechanics.

LDH nanoparticles were synthesised and characterised using dynamic light scattering, transmission electron microscopy, and atomic force microscopy (AFM). T-cell responses were assessed using AFM microrheology [7], traction force microscopy, and advanced optical microscopy to quantify single-cell mechanical and morphological features under physiological and acidic conditions, with and without LDH nanoparticles. These analyses were complemented by flow cytometry to characterise cell populations.

Overall, this work provides new insights into the pH-responsive behaviour of MgAl-LDH nanoparticles and demonstrates how their local pH modulation influences T-cell mechanical properties, highlighting a potential biophysical mechanism by which nanomaterials may enhance anti-tumour immune responses.

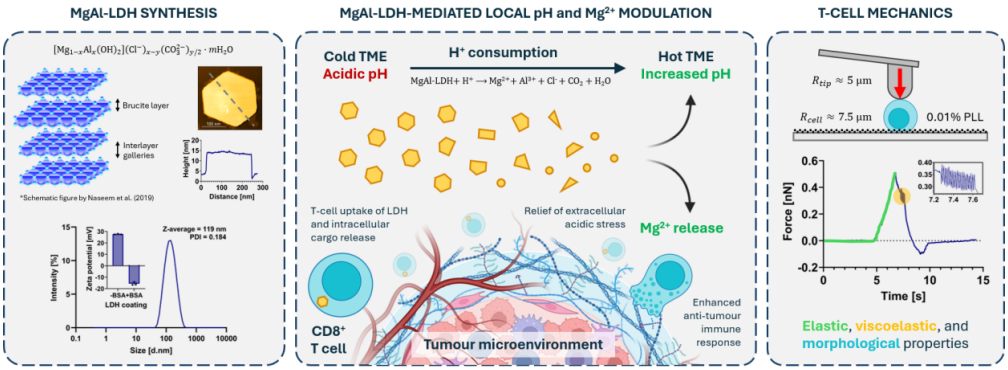

Figure 1: Overview of MgAl-LDH synthesis, local pH and Mg^{2+} modulation, and T-cell mechanics.

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Single Molecule Characterization of Elastic Interactomics in Biomimetic Membrane Nanotubes

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Elastic forces govern various aspects of biomolecular interactions, from allosteric regulation and catalysis to oligomerization and condensation. Quantifying elastic interactomics for individual proteins in their natural milieu, crucial for understanding basic mechanics of molecular interactions, remains extremely challenging. In the cell, most of the protein interactomes are confined to a membrane, transiently or permanently. Protein interactions with the soft-elastic lipid bilayer, the membrane core, cause membrane deformations. Here we show that single molecule deformation footprints can be used to identify individual molecules and characterize their elastic interactomes in the membrane. We used soft-elastic membrane nanotubes (seNT), drawn from a biomimetic membrane reservoir, as a nanopore-like electronic sensors detecting membrane deformations as changes of the ionic current through the seNT lumen. The tunability of seNT geometry and surface properties enables single molecule detection of diverse membrane analytes, from small transmembrane molecules to large peripheral membrane proteins, such as GTPase Dynamin 1. Real time assessment of their elastic interactomes enabled seNT to resolve as small structural modification, such as addition of a flexible side-chain, as real time conformational dynamics of a single Dynamin1 molecular machine. This capacity to both single molecule detection and analysis of corresponding elastic interactions makes seNT a unique tool for functional proteomics. This work was partially supported by the Spanish Ministry of Science and Innovation, grant PID2024-159156NB-I00

	June 5
	Conference Session VII **The bio & non-bio interface**
9.00 am – 9.30 am	**Cécile Breyton**, Institut de Biologie Structurale, Grenoble, France **(Invited Speaker)**
9.30 am – 9.50 am	**Axel Gansmüller**, CRM2, Université de Lorraine, Nancy, France
9.50 am – 10.10 am	**Hannah Wunderlich**, Technical University of Munich, Munich, Germany
10.10 am – 10.40 am	**Coffee Break (30 min)**
10.40 am – 11.10 am	**Daniel Ruiz Molina**, ICN2, Barcelona, Spain **(Invited Speaker)**
11.10 am – 11.30 am	**Beatrice Geiger**, Niels Bohr Institute, University of Copenhagen, Denmark
11.30 am – 11.50 am	**Patryk Pyrcz**, Institute of Physical Chemistry Polish Academy of Sciences, Poland
12.30 pm – 2.00 pm	**Conference Lunch**
	Conference Session VIII **Instrumentation for materials & life sciences**
2.00 pm – 2.30 pm	**Bjorn Tonger Stokke**, NTNU, Trondheim, Norway **(Invited Speaker)**
2.30 pm – 2.50 pm	**Sreelatha Greeshma Pradeep**, University of Leeds, Leeds, UK
2.50 pm – 3.10 pm	**Hüsnü Aslan**, Danish National Metrology Institute, Hoersholm, Denmark
3.10 pm – 3.40 pm	**Coffee Break (30 min)**
3.40 pm – 4.00 pm	**Georg Gramse**, Johannes Kepler University, Linz, Austria
4.00 pm – 4.20 pm	**Tine Kalac**, Stockholm University, Stockholm, Sweden
4.20 pm – 4.50 pm	**Marco Portulapi**, Nanosurf AG, Liestal, Switzerland

Structural basis of bacterial infection by siphophages studied by cryo-EM and cryo-ET

Alessio d'Acapito, Romain Linares, Séraphine Degroux, Rubén Perez-Bucio, Alice Decombe, Guy Schoehn and Cécile Breyton

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The vast majority of bacteriophages (phages) - bacterial viruses - present a tail that allows host recognition, cell wall perforation and safe channelling of the viral DNA from the capsid to the cytoplasm of the infected bacterium. The viral DNA then takes over the host cell to produce hundreds of new virions. The majority of tailed phages bears a long flexible tail (siphophages) at the distal end of which a tip complex, often called baseplate, harbours one or more Receptor Binding Protein·s (RBPs). Interaction between the RBPs and the host surface triggers cell wall perforation and DNA ejection, but little is known on these mechanisms for siphophages [1]. We determined the atomic structure of siphophage T5 tip, by electron cryo-microscopy, before and after interaction with its E. coli receptor FhuA reconstituted into nanodisc [2,3]. It brings out the dramatic conformational changes underwent by T5 tip upon infection, allowing us to propose a mechanism of host recognition and activation of viral entry for siphophages, including the cascade of events that commits T5 to cell wall perforation and DNA ejection. Analysis of the structure of the tip of other phages identified conserved structural elements pointing to a general mechanism of infection for Gram negative-infecting siphophages [4]. We also use electron cryo-tomography to investigate the structure of the channel that perforates the whole cell envelop and have a more integrated view of bacterial infection by phages.

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In-situ PhotoNMR and Its Applications in Photochemistry for Light-Activated Chemotherapy

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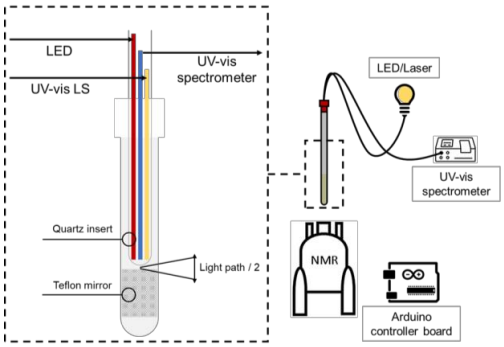
The development of drug delivery approaches is crucial for efficient spatial and temporal treatment of tumors or local control of vasodilation. Among these approaches, light-activated prodrugs have gained significant attention, as they enable the release of active molecules specifically at the desired site. In this context, **photoactivated chemotherapy (PACT)** and **photodynamic therapy (PDT)** have emerged as promising strategies over the past decades. Ideal candidates for both PACT and PDT must remain stable and non-toxic in the dark while being activated by light to generate cytotoxic species capable of suppressing cancer cells.

However, studying such photo-triggered reactions is often limited by **UV-vis spectroscopy**, which only confirms reactant transformation and product formation without providing detailed structural insights. To fully understand the cytotoxic effects of these prodrugs, it is essential to characterize all reaction products, side products, and transient species. The scarcity of such characterizations stems from methodological challenges, including the complexity of reaction mixtures containing transient and potentially paramagnetic species.

To address these limitations, we developed an **in-situ photo-NMR approach**, where optical fiber bundles enable sample illumination inside the NMR spectrometer. This setup leverages NMR's high chemical resolution to monitor photoreaction kinetics for all reactants, photoproducts, and transient species. Additionally, our system allows simultaneous UV-vis absorbance measurements within the NMR magnet, enabling the correlation of molecular structure with optical properties and the determination of pure photoproduct absorbance spectra for optimized photoreaction conditions.



To demonstrate the potential of our methodology, we present two practical examples. The first involves the **trans-[Ru(NOPy$_4$F)]Cl$_2$ ruthenium complex**, which undergoes nitrosyl release and multiple ligand exchanges under extended illumination, yielding **trans-[Ru(Py$_4$Cl$_2$)]** as the most stable product. Interestingly, this product exists in both **diamagnetic (Ru^{2+})** and **paramagnetic (Ru^{3+})** forms depending on light exposure. Using **solution NMR spectroscopy combined with in-situ light irradiation**, we accurately tracked thermo-, photo-, and redox processes within the system.

The second example focuses on **benzylidene-thiazolidine-2,4-dione (BTZD)**, a glitazone derivative exhibiting **P-type photochromism** and undergoing **Z → E photoisomerization** upon 310 nm irradiation[1]. Similar to other photoswitches with cis-trans isomerism, the absorbance spectra of (E)- and (Z)-BTZD overlap, hindering quantitative isomerization analysis and preventing the acquisition of pure photoproduct spectra. By employing our **in-situ UV-vis/NMR setup**, we characterized the **photostationary states (PSS)** and obtained photoisomerization kinetic profiles from simultaneously measured NMR and absorbance spectra. Comparing these results with conventional ex-situ measurements, we demonstrate that in-situ data enables the determination of the **pure (E)-BTZD absorbance spectrum** and facilitates irradiation wavelength optimization.

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Advances in Surface Functionalization of Magnetoelectric Nanoparticles for Bioelectronic Applications in Nervous Tissue

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Neural implants have significantly improved the treatment of motor disorders, Parkinson's disease, and sensory hearing loss but remain invasive, bulky, and technically complex. To address these limitations, we are developing injectable, wireless nanoelectrodes based on magnetoelectric nanoparticles (MENPs), which convert magnetic carrier signals into electric neuromodulatory signals, and thus enable non-invasive stimulation of neurons without genetic modification (1). This positions MENPs as a promising platform in neuromodulatory bioelectronics and as a potential neurostimulator.
The physicochemical properties of MENPs are strongly influenced by the chemical composition and stability of their surface coatings, which are crucial for colloidal stability, biocompatibility, and targeted biological interaction. Effective coatings prevent aggregation, minimize immune responses, and improve nanoparticle–tissue interactions (2-7). In this work, MENPs were functionalized with different polymers: non-covalent coatings with oleic acid–polyethylene glycol (OA-PEG) and polylactide–PEG (PLA-PEG) via hydrophobic interactions, and covalent coatings with methoxy-PEG (mPEG), poly(acrylic acid-co-2-acrylamido-2-methyl-1-propanesulfonic acid) (P(AA/AMPS)), polyethyleneimine (PEI), and poly(3,4-ethylenedioxythiophene) tetramethacrylate (PEDOT-TMA). Successful functionalization was verified by Fourier transform infrared spectroscopy (FTIR), thermogravimetry (TGA), and characteristic shifts in the zeta potential corresponding to the respective polymer charges. Dynamic light scattering (DLS) showed an increase in hydrodynamic diameter by 35–137% compared to uncoated MENPs, depending on the polymer coating, consistent with different polymer–water interactions. In addition, confocal microscopy confirmed reduced aggregation of MENPs in an aqueous environment. Absorption measurements revealed an extended sedimentation time by an average factor of 2 over 30 minutes, confirming improved colloidal stability. To quantify coating amount and assess long-term stability, loss on ignition (LOI) was performed at 800 °C under oxygen, allowing calculation of the organic polymer fraction from the mass loss. These analyses showed that the coatings remain stable for at least three months at 4 °C, and observations suggest that stability is maintained over longer periods of up to approximately one year. In vitro experiments with a neuronal cell line derived from human induced pluripotent stem cells (hiPSCs) confirmed the biocompatibility of all polymer coatings, with no evidence of cytotoxicity and cell viabilities >97% at MENP doses up to 500µg.
These results demonstrate that surface modification of MENPs with polymeric coatings significantly enhance their colloidal stability and biological compatibility, and thereby support the development of safe, precise, and minimally invasive bioelectronic applications in the central nervous system.

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Bioinspired polyphenol-based functional biointerfaces

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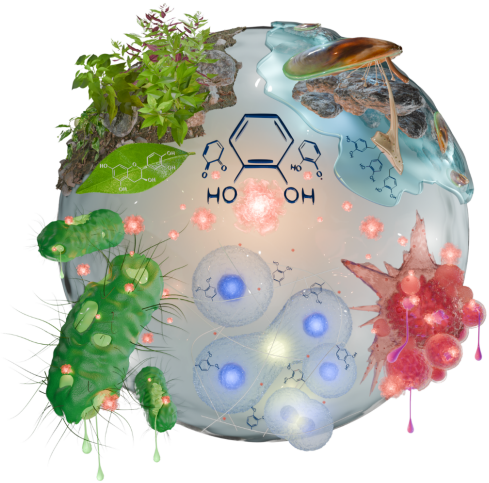
Polyphenol-based interfaces have been subject to intense research, aimed at mimicking natural protein-segregation adhesive properties of mussels and barnacles. To achieve these objectives, our group has been very active on different synthetic approaches, ranging from the polymerization of catechols in the presence of amines (ammonia or bisamines) to the oxidative condensation of readily available pyrocatechol and thiol-capped functional moieties. So far, we have developed functional coatings and thin-films with a broad range of architectures, functionalities and characteristics relevant in biomedicine, among them:

- Nanoparticle-coatings for diagnosis and therapy.
- Fiber-coatings to modulate hydrophilicty, biocompatibility and antimicrobial properties.
- Thin films for the regeneration of human cells/tissues.

In this talk I will give a brief overview of these research topics using representative examples..



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Bimodal Mechanical Response of Necks in Stomatocytic Membranes: Implications for the Nuclear Envelope

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Membranes with complex shapes containing many necks commonly occur in both synthetic and organelle membranes. For example, the membranes of the nuclear envelope or open autophagosomes can be visualised as spherical double membranes with the inner and outer membrane connected by neck-like structures. Hence, they are effectively stomatocytes characterised by a high topological genus, making them part of a largely unexplored shape family with a higher degree of polymorphism and new emerging properties that are absent from simple spherical membranes. The nuclear envelope (NE) is a prime example for a high-genus stomatocyte, containing multiple necks. These necks are often occupied by specific biomolecular complexes, like the nuclear pore complex in the NE, which divide the space into three distinct compartments. Understanding how the size of these necks responds to pressure gradients is fundamental to uncover the influence of mechanical stimuli on traffic control through the necks, for example in nuclear mechanosensing.
Therefore, we have employed multiscale computer simulations (Dynamically Triangulated Surface simulations [1], coarse-grained Molecular Dynamics simulations) and theoretical analysis to investigate how the membrane neck size responds to pressure or tension variations. This reveals a two-phase behavior: surprisingly, necks first constrict as the pressure gradient increases, while above a threshold, they dilate. This response stems from the pure membrane's mechanics and depends on the magnitude of the pressure gradient or tension, the initial neck diameter and the membrane bending rigidity. We also establish a simple equation that links the threshold tension, the neck diameter and the bending rigidity, offering a useful tool to quickly assess different scenarios. Furthermore, when protein complexes occupy a neck they partially counteract both constriction and dilation, stabilising the neck size while preserving the same two-phase response. These findings uncover a promising, previously overlooked membrane property with significant implications for cell organelle function, as well as for biomimetic system design.

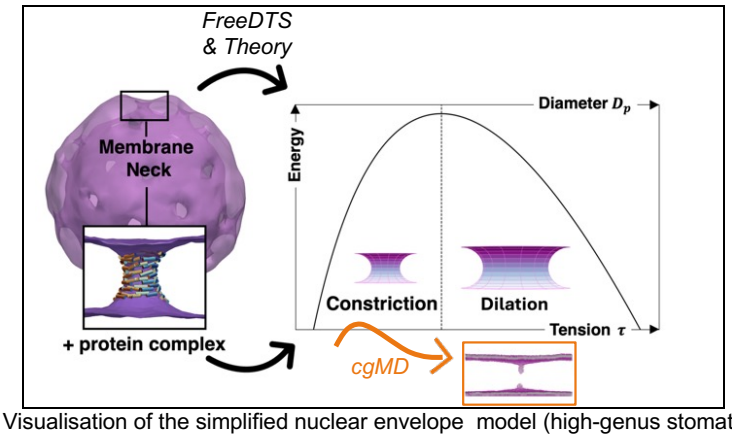

Figure 1: Visualisation of the simplified nuclear envelope model (high-genus stomatocyte), the membrane neck response and methods employed in this work. Adapted from [1].

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Influence of the electropolymerization conditions on the electrochemical and spectroelectrochemical behavior of ambipolar polymers

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Donor-acceptor-donor (D-A-D) conjugated polymers have attracted significant attention as electrode materials for energy-storage devices due to their tunable electronic structure, ambipolar redox activity, and ability to reversibly store charge through both *p*- and *n*-doping processes. These features make D-A-D polymers particularly promising for supercapacitor applications, where fast charge-discharge rates and long-term stability are required. In this study, we investigate ambipolar polymer deposited by electropolymerization under potentiostatic (PS) and potentiodynamic (PD) conditions of the NDI(DTP)$_2$ monomer [1], in which naphthalene diimide (NDI) functions as the acceptor core and two dithienopyrrole (DTP) units serve as electron donors as well as electropolymerizing sites.

The polymers were electropolarized using both potentiostatic and potentiodynamic methods to elucidate the effect of the polarization strategy on material properties. [2] A comparative analysis was carried out using electrochemical and spectroelectrochemical to elucidate the formation and evolution of diagnostic optical signatures associated with charge carriers, including radical cations, dications, radical anions, and dianions, which are directly responsible for electrical conductivity in ambipolar polymers. (Fig. 1) Particular attention was paid to potential-dependent shifts in the absorption spectra, enabling correlation of specific redox states with changes in the electronic structure and charge delocalization. Resonance Raman spectroscopy was implemented by tuning the excitation wavelength to the electronic transitions of *p*- and *n*-doped species, providing direct insight into the molecular structure of ambipolar polymers with respect to the polymerization method. Electrochemical studies, including galvanostatic charge–discharge measurements of poly[NDI-(DTP)$_2$] films, indicate that poly[NDI-(DTP)$_2$] deposited under potentiostatic conditions exhibits lower asymmetry between charge and discharge times compared to poly[NDI-(DTP)$_2$] obtained under potentiodynamic conditions.

Overall, our results demonstrate that the electropolymerization method critically influences the stabilization of ambipolar charge carriers and the resulting electrochemical performance of poly[NDI-(DTP)$_2$] electrodes.

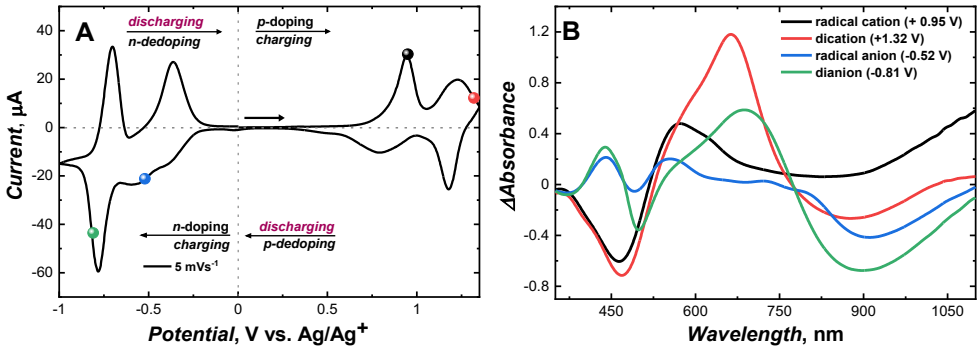

Fig. 1. Spectroelectrochemical UV-Vis-NIR response recorded *in situ* for potentiostatically deposited poly[NDI-(DTP)$_2$] | ITO during ambipolar charge transport in the negative and positive potential ranges at a potential scan rate of 5 mV s^{-1}.

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From genes to gels: Microfluidic high-throughput characterization at the picolitre scale

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The developments of microfluidics throughout the past decades have led to profound advances in miniaturization, reaction control, characterization and production pipelines of various biological samples of biological relevance. In this presentation, two examples of custom-designed workflows including fabrication of microfluidic devices adapted to need of the actual high-throughput characterization will be illustrated. The first example is directed towards determination of the nucleotide sequence needed for transcription initiation in bacteria. Thus, a microdroplet-based workflow supporting cell-free transcription in picolitre water-in-oil-in-water (W/O/W) double emulsion which subsequently allowed sorting in a conventional flow cytometer, was established. The overall workflow involved design and exploitation of two custom developed microfluidic devices where the first was used to encapsulate DNA templates down to single chain inclusion in each emulsion droplet (~ 2 pL), followed by off-chip incubation using isothermal rolling circle amplification (RCA) to increase the copy number to enhance detectability in the final fluorescence intensity based sorting in a flow cytometer (FACS). The emulsion with the increased nucleotide copy-number was reinjected in a custom designed device supporting serial operation of the sample comprising (i) controlled spacing of emulsion droplets, (ii) injection of in vitro transcription reagents to each droplet in a picoinjection step and (iii) downstream double emulsification. The chip fabrication included establishing electrodes for the electric field needed for the picoinjection, and establishing different wettability preferences in specific regions as needed for the workflow. Proof-of-concept experiments showing T7-polymerase transcription of DNA templates with a Mango III aptamer in W/O/W emulsion were successfully binned on a commercial benchtop FACS where the abundance in the bins were found to reflect the concentration of the DNA template encapsulated in the initial emulsification step.

The second example is the high throughput characterization of viscoelastic relaxation of microgel beads using a custom designed microfluidic device supporting serial squeezing and relaxation of the injected beads. Monodisperse cohorts of Ø 45 μm Ca-alginate gel beads and core-shell structures prepared from such samples using polyelectrolyte layer coating and dissolution of the core, were used. A computer vision algorithm based on YOLO11 was implemented to extract geometric relaxation after squeezing of the beads from the recorded high-speed movies. The observed tumbling of beads in the relaxation regions of the microfluidic device precluded characterization of relaxation of individual beads. Ensemble average shape relaxation was characterized by an increased relaxation time with increasing alginate concentration for the Ca-alginate gel beads, and the core-shell particles relaxed more slowly than the beads. This example shows that high throughput viscoelastic characterization can be realized in a scalable manner, exploiting image- based tracking of shape recovery of constricted microgels in custom designed microfluidic devices.

Video rate super-resolution instant structured illumination microscopy for live cell imaging

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The development of super-resolution microscopy has enabled the study of cellular structures, functions, and dynamics at spatial scales smaller than the Abbe diffraction limit. Various techniques, including confocal microscopy, Stimulated Emission Depletion (STED), Structured Illumination Microscopy (SIM), and Single Molecule Localization Microscopy (SMLM), have been developed to achieve higher spatial resolution. Ongoing research aims to further improve both spatial and temporal resolution, particularly for live-cell imaging.

Instant Structured Illumination Microscopy (iSIM) [1, 2] is a high-speed SIM technique that reduces computational delay compared with traditional SIM. This is achieved through a purely optical implementation that does not rely on extensive computational reconstruction. In iSIM, the super-resolved image is generated by incorporating microlens arrays, pinholes, and a galvanometric scanning mirror into the optical path.

The aim of this project is to develop a high-speed iSIM system and extend it for simultaneous multi-colour, uniform, and video-rate super-resolved imaging of living cells. By generating multiple foci that are scanned across the sample, the system can achieve an improved imaging resolution of approximately 145 nm laterally and 320 nm axially, with image acquisition speeds exceeding 100 frames per second.

To further enhance image quality while reducing photobleaching, a deep-learning approach called DeAbe [3], will be applied to iSIM data. This method trains a residual channel attention network using synthetically aberrated images and corresponding ground-truth data, and then applies the trained model to images acquired with low laser power, which typically have a low signal-to-noise ratio (SNR). The iSIM system has been rebuilt, and training on the DeAbe deep-learning approach has been initiated. The developed iSIM platform will be used to image and characterize biological samples that can benefit from high-speed super-resolution imaging.

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Optical and Tactile Correlative Imaging Methods for Nanometrology

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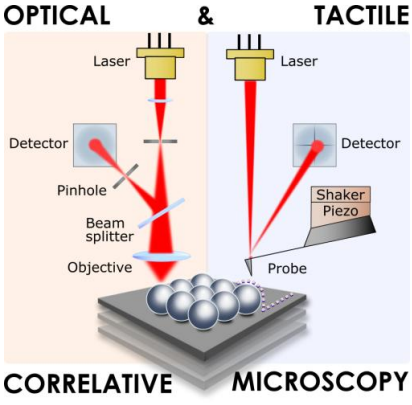
Accurate, traceable quantification of the size and morphology of microscopic objects is a fundamental requirement across numerous domains, including fundamental research, environmental monitoring, pharmaceutical manufacturing, contamination control in cleanroom environments, and the characterization of complex biological and soft-matter systems. In these, contexts, dimensional metrology must accommodate a broad class of specimens, ranging from rigid particulate standards to compliant structures such as cells, vesicles, and other mesoscale biological assemblies while maintaining well-defined measurement uncertainty and traceability to primary standards of length.[1]

Atomic Force Microscopy (AFM) is particularly well suited for the dimensional measurement of micro- and nanoscale objects and has therefore become a primary tool for traceable particle size determination. However, the practical application of AFM for large-scale dimensional analysis is constrained by several intrinsic limitations, including restricted scan areas, limited measurement throughput, soft sample deformation and increasing challenges in reliably characterizing objects with vertical dimensions exceeding approximately 10 µm.[2]

Optical methods such as confocal microscopy, by contrast, provide rapid, non-contact imaging over substantially larger fields of view. However, diffraction-limited resolution and sample-dependent optical contrast typically restrict their use in dimensional metrology, particularly for translucent or weakly scattering specimens.

Here, we present a correlative optical-tactile metrology approach that bridges these limitations by transferring calibration from AFM to confocal microscopy using the same set of certified particle standards. Using this strategy, we demonstrate that optical microscopy can achieve dimensional accuracy comparable to AFM for objects with nominal diameters of 1 µm and larger. Furthermore, the method enables traceable measurements for particles far beyond the practical range of AFM, including diameters around 20 µm and above, thereby extending reliable dimensional metrology to biological and soft-matter systems without compromising measurement uncertainty or traceability.



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Dielectrophoretic Nano-Coax Tweezers with GHz readout for single particle detection

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Optical microscopy and Coulter- type methods can detect and count micro- and nanoscale objects like bacteria, but they are typically limited to µm size objects and by the information they provide. More difficult even is the label-free identification or characterization of such objects, highlighting the need for integrated approaches that overcome these constraints.
We report on a method that enables simultaneous dielectrophoretic manipulation and electro-mechanical characterization of micro- or nanoscale particles like bacteria or virus[1].
The method is based on our newly developed nanoscale coaxial probes, that allow us to merge resonant microwave detection and dielectrophoresis at the micro- and nanoscale . The probes are precisely impedance-matched enabling ultra-high sensitivity ($<10^{-18}$S Farad) [2], and at the same time creating a very local and inhomogeneous electric field around the end of the probe that can attract and repel particles. The advantages and (some disadvantages) of these "coaxial Tweezers" will be discussed[1].

We show a number of example applications of this recently patented method for particle sensing/identification, which include polymer particles, bacteria and GUV[1,3].

Finally, the steps towards the transfer of this concept to lab-on-the-chip devices will be discussed[4].

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3 Maxwell Sparey, et al. in preparation
4 Maxwell Sparey, et al. in preparation

Revealing the Nanoscale Architecture of Biomaterials with Scanning Electron Diffraction

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Hierarchically structured biomaterials, like bone and wood, have distinct structural features at different length scales, endowing them with many remarkable physical properties. However, many aspects about their nanoscale architecture remain difficult to study, mostly due to inherent resolution limits of conventional structural characterization methods. Overcoming these limits is essential to understanding and repairing biomaterials, as well as to guide the design of new bioinspired materials systems. Scanning electron diffraction (SED) is an emerging characterization technique that enables nanoscale mapping of crystallographic information in textured materials. By resolving features such as phase distribution and crystalline orientation, SED provides direct insight into structural parameters that govern bulk mechanical behaviour. Recent advances in electron microscopy instrumentation and data analysis have extended the applicability of SED to weakly scattering and beam-sensitive materials, including biomaterials, enabling quantitative nanoscale structural mapping. We will present our recent work in leveraging these advancements to perform three-dimensional orientation mapping of fibres in biomaterials, including oat husk, wood, and bone. With 3D-SED, we were able to resolve sub-micron-sized structural features previously unreported by literature [3]. Furthermore, we applied tailored data analysis strategies to significantly reduce errors associated with electron beam damage, enabling more reliable quantitative surveys. Together, these advances establish 3D-SED as a powerful method for probing the nanoscale structural organization of hierarchical biomaterials and for revealing new insight into their structure–function relationships.

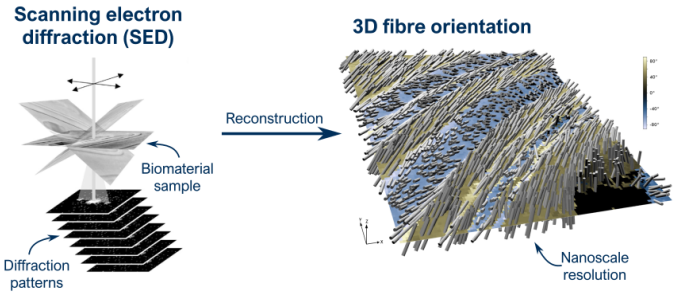

Figure 1: Fibre orientation mapping with 3D-SED.

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Automated AFM framework applied to polymer nanomechanical characterization at different temperatures.

Portalupi Marco[1], Andany Santiago[1], Gunstheimer Hans[1], Corte-León Héctor[1], Adams Jonathan[1]

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Automated experiments, that allow increasing parallelizing and reproducibility, are a primordial need of the machine learning and AI era [1]. But unlike other techniques [1], Atomic Force Microscopy (AFM) still largely relied on human-on-the-loop to operate. However, with the release of commercial systems such as the DriveAFM from Nanosurf, it is now possible to fully script the AFM operation [2,3].

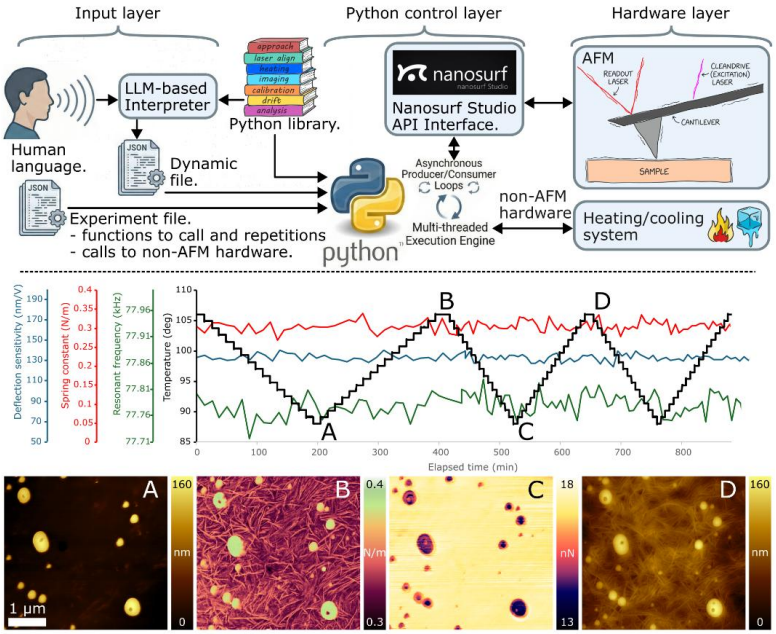

Figure 1 : Top: Automated AFM framework architecture. Bottom: Polymer characterization cycles.

Here we present an automated AFM framework (Figure 1 top) centred around a Python library containing functions for AFM operations (e.g. probe calibration or surface approach). The framework operates through three primary stages: Input, where experiments are initiated via either experiment files or human commands (with an LLM as interpreter); Control Logic, where the core Python engine utilizes asynchronous producer-consumer loops to manage task execution; and hardware layer, where the API calls generate hardware actions.

In the example presented here (Figure 1 bottom), the automated AFM framework operates using an experiment configuration file that ramps the temperature of a polymer sample, and after a settling time, initiates the data capture process. The data capture consist in several steps: laser alignment and probe contactless-calibration; WaveMode [4] setup and surface approach; acquisition of a nanomechanical map; retract from surface and estimation of drift correction needed (using image autocorrelation).

In conclusion, the framework presented here allows parallelizing experiments, reproducing data acquisition conditions, and enables long periods of data acquisition without human-in-the-loop supervision.

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	June 6
	Conference Session IX **Special NanoInBio session**
9.00 am – 9.30 am	**Philippe Leclère**, University of Mons, Belgium **(Invited Speaker)**
9.30 am – 9.50 am	**Leila Nouville**, Université des Antilles, Pointe à Pitre, Guadeloupe, France
9.50 am – 10.10 am	**Kamila Lępicka**, Institute of Physical Chemistry Polish Academy of Sciences, Poland
10.10 am – 10.30 am	**Hermann Dzoujo Tamaguelon**, Université des Antilles, Pointe à Pitre, Guadeloupe, France
10.30 am – 11.00 am	**Coffee Break (30 min)**
11.00 am – 11.30 am	**Frédéric Kanoufi**, ITODYS, Paris, France **(Invited Speaker)**
11.30 am – 11.50 am	**Pavel Bashkirov**, RISBM, Moscow, Russian Federation
11.50 am – 12.20 pm	**Peter Gorelkin**, ICAPPIC Ltd., London, UK
12.20 pm – 12.30 pm	**Closing Ceremony**

Towards Correlative Analysis of Mechanical and Chemical Properties of Soft Materials: When AI Meets Materials !

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Over the past few decades, functional polymeric materials have progressively replaced traditional materials in a wide range of applications, from aerospace engineering to cosmetics. Mapping mechanical and chemical properties at the nanoscale provides critical insight into the fundamental local processes governing the structure–property relationships of these materials.

In this work, we focus on recent advances in Scanning Probe Microscopy (SPM) and spectroscopy techniques for the characterization of surfaces and interfaces in soft polymeric materials. In particular, we highlight the capabilities of state-of-the-art SPM-based methods—such as PeakForce Tapping and nano Dynamic Mechanical Analysis—to quantitatively map multiple physical and mechanical properties with sub-nanometer lateral resolution and high repeatability. Special attention is devoted to nanomechanical parameters, including adhesion, deformation, indentation, elastic modulus, storage modulus, and loss modulus. When combined with infrared or Raman spectroscopies, these techniques enable the chemical detection and identification of distinct domains and (inter)phases within materials at the nanoscale (Figure 1).

In this context, machine learning (ML) has emerged as a powerful tool for materials design and discovery across a broad range of applications, including biomaterials. Here, we present a novel mechano-spectroscopic SPM approach that overcomes key limitations of conventional spectroscopic methods by integrating high-resolution SPM imaging with ML-based classification. We briefly discuss computational strategies and deep-learning algorithms for data validation, clustering, and analysis, in which multidimensional observables are partitioned into classes based on intrinsic similarities.

This integrated approach is expected to provide the scientific community with deeper insight into the parameters governing material behavior, thereby supporting both fundamental research and the optimization of materials for industrial applications.

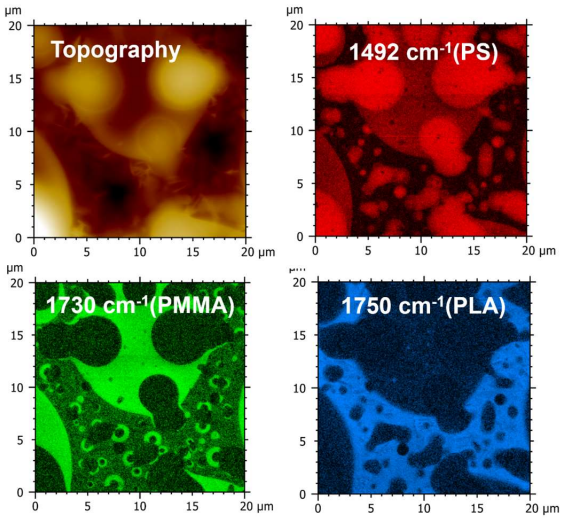

Figure 1: Topographic and chemical images of a PS-PMMA-PLA polymer blend.

Cassava-based catalyst for advanced oxidation of emerging pollutants in wastewaters

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Micropollutants, including pesticides such as chlordecone, pharmaceutical residues (such as antibiotics) or endocranial disruptors, represent a pressing challenge in the Caribbean, also in territories like Guadeloupe where wastewater treatment plants (WWTPs) are often outdated or undersized. Despite being present at trace levels, these compounds exhibit persistent ecotoxicological effects, threatening aquatic ecosystems and public health. The enforcement of the 2024 EU Urban Wastewater Directive, which also applies to overseas territories such as Guadeloupe, intensifies the urgency to develop advanced, cost-effective, and locally adaptable solutions for wastewater treatment.

In this study, cassava processing residues (peels, stems, leaves) were valorized as catalysts support for advanced oxidation processes (AOP) targeting the degradation of organic micropollutants. The solid fraction was transformed into biochars (via pyrolysis treatment at 600°C during 1 hour) for heterogeneous Fenton-like catalysis, while the liquid phase was explored as a precursor for carbon quantum dots (via hydrothermal treatment at 180°C during 12h) with potential photocatalytic properties. As such, several methodologies were employed. Solid biochars were magnetized through co-precipitation of Fe^{2+}/Fe^{3+} salts, yielding Fe_3O_4-impregnated composites with enhanced recovery potential.[1] [2] These materials demonstrated promising performance in the catalytic degradation of model micropollutants under simulated wastewater conditions. For instance, magnetized biochars synthesized from cassava branches, leaves, and peels achieved over 80% tetracycline degradation within 120 minutes, underlining the effectiveness of this approach for antibiotics removal. Ongoing work aims to shorten both degradation time and removal efficiency by varying the testing conditions (ie. pH, catalyst dosage and H_2O_2 concentration). In parallel, material characterization using SEM-EDX, FTIR, RAMAN spectroscopy and thermogravimetric analysis (TGA) revealed a homogenous dispersion of catalyst within the carbonaceous matrices, along with the identification of iron phases.

To further enhance catalytic performance, biochars were engineered by extracting bioactive compounds prior to carbonization, aiming to improve both surface functionality and reactivity. For instance, microwave-assisted extraction successfully recovered biomolecules such as 14-Taraxen-3α-ol, Trigonelline or Valine. Future work will focus on converting the resulting residues into biochar for use in the Fenton-like system.
This approach showcases how traditional crops, often linked to pollution concerns, can become a key enablers of circular innovations for water treatment in tropical regions.

Keywords: Biochar, cassava, micropolluant, fenton-like, wastewater, dregradation

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Ambipolar polymer finite-space probing of voltage-driven counterion-insertion-coupled charge transport for wide-voltage energy storage

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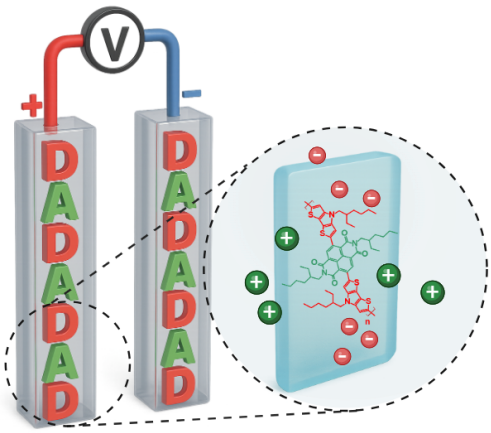
Wide-voltage faradaic storage in ambipolar polymer electrode materials derives from *p*- and *n*-type doping and dedoping triggered by their electrooxidation and electroreduction. However, the role of ambipolar polymer layer-confined molecular packing of donor and acceptor units in controlling dynamics of reversible electrochemical doping and, thereby, energy storage performance remains poorly understood. Another problem arises from mutual donor-acceptor interactions within the ambipolar layer architecture, where specific spatial arrangements can perturb electronic coupling and ion-access pathways, thereby altering charge transport.

In that regard, we dissected the fabrication conditions of the ambipolar poly[NDI-$(DTP)_2$] electrode material to achieve a balanced interaction between its alternatingly conjugated dithienopyrrole donor and naphthalene diimide acceptor units. Electrochemical measurements and atomic force microscopy imaging revealed that potentiostatic electrodeposition imposes a privileged molecular arrangement in the studied ambipolar polymer.

Finite-space probing of the potentiostatically arranged poly[NDI-$(DTP)_2$] layer resolved the ambipolar charge transport dynamics and showed well-balanced donor and acceptor charge storage contributions despite differing *p*- and *n*-doping and dedoping rates.

This understanding guided the assembly of a poly[NDI-$(DTP)_2$]-based supercapacitor operating at 2.0 V, delivering an energy density of 12.2 μWh cm^{-2} at a power density of 389 μW cm^{-2}. Our insights provided a general framework for probing reversible solid-solution counterion insertion to redox-active ambipolar polymer electrodes for high-voltage energy storage applications [1]. Thus, highlighting the role of thin-layer ambipolar supercapacitors in technologies where the volume of energy storage materials matters, such as military field electronics, pacemakers, and sensors.



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Synthesis of alkali-activated geopolymers from pozzolan and geothermal silica (Guadeloupe, French West Indies) for the adsorption-degradation of emerging contaminant and pesticides in aqueous phase.

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Abstract

Growing concerns about pesticides such as chlordecone and emerging contaminants such as antibiotics linked to their persistence and proliferation of antimicrobial resistance in aquatic and terrestrial ecosystems have led to the development of sustainable materials to mitigate their impact on the environment. This study highlights the benefits of converting waste such as pozzolan from Loum in Cameroon, sargassum from Sainte Anne (Bouillante) and geothermal silica produced by the Bouillante geothermal station in Guadeloupe, respectively, into sustainable geoadsorbents for circular economies. Geopolymerization technology was used to obtain the geoadsorbents, and the influence of alkali-modified geothermal silica on the surface characteristics of geopolymers and geopolymer-sargassum biochar composites during this process was evaluated using standard physicochemical analyses (FRX, XRD, FTIR, SEM/EDX and BET). Fenton-like adsorption-degradation experiments on tetracycline (TC) were conducted under non-dynamic conditions. The porosity of geopolymers increases with their activator binder content, unlike composites. Functionalization of the geopolymer with biochar resulted in a TC removal rate of 71% compared to the pristine geopolymer (65%) over 72 hours. The simultaneous adsorption-degradation process revealed a TC removal rate of 100% after 24 hours on the different geomaterials. The adsorption-Fenton kinetics are multimechanical. The results of this work have demonstrated the value of using geothermal silica as a low-cost, environmentally friendly material in the preparation of geopolymers that are effective in removing antibiotics, and paved the way for the use of these geoadsorbents in the removal of pesticides such as chlordecone.

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Operando Optical and Electrochemical Probing of Soft Objects and Active Interfaces

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Understanding physicochemical processes at the nanoscale requires approaches able to probe matter under operation, at the level of individual objects or localized nanodomains. At these scales, interfaces are often dynamic, heterogeneous, and coupled to transport, wetting, or mechanical effects, so that the macroscopic response cannot be viewed simply as the sum of independent elementary contributions. Accessing these local processes is therefore essential both to establish the relevant physical description of nanoscale electrochemical systems and to build more realistic models of their collective behavior.

In this presentation, I will discuss how the combination of localized electrochemistry and operando optical imaging provides such an access for soft and weakly confined systems. Particular attention will be given to situations where electrochemical activity is coupled to interfacial transformations, such as ionic polarization in soft charged objects, gas formation at reactive interfaces, or liquid redistribution in confined wetting films. In these systems, optical signals do not merely provide visualization, but reveal the dynamics of active interfaces themselves: their displacement, growth, deformation, or local reorganization under electrical actuation. This makes it possible to detect and quantify processes that remain difficult to access from electrical signals alone.

More broadly, this approach highlights how single-entity and spatially resolved measurements can renew our understanding of nano(electro)chemical reactivity in complex media, where confinement, softness, and multiphase interfaces strongly shape local behavior. By identifying the elementary mechanisms operating at these scales, such studies help bridge the gap between model nanosystems and the emergent response of macroscopic materials and devices.

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Geometric Membrane Composites as Stress- Responsive Nanomaterials

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Cellular membranes balance extreme deformability with fragile tensile strength, enabling local remodeling (fusion, fission and poration) while preserving global barrier integrity. Replicating this balance is a central challenge for biomedical nanomaterials, from lipid drug carriers to membrane-coated devices used in electroporation, which must tolerate combined mechanical and electrical stresses without catastrophic failure. Here we decode this principle using a minimal geometric membrane composite: a cylindrical lipid nanotube (NT) connected to two flat bilayer reservoirs (FR). Using real-time electrical readouts under controlled tension, protein-induced packing stress and constant electric fields, we show that composite geometry concentrates the effective driving force for defect nucleation into the curved NT, establishing it as a stress-sensor node that localizes barrier breach away from the reservoirs. Direct measurements further show that the curved element remains linearly elastic down to nanometre-scale radii until defect-mediated failure, supporting a continuum, quantitative description up to the instability threshold. In multicomponent membranes, curvature–composition coupling (CCC) provides a diffusion-limited adaptive response that dynamically tunes the effective mechanical behavior. Depending on constraints (fixed geometry versus fixed tension), CCC can relieve stress or amplify bending, biasing the composite toward distinct outcomes and enabling composition-programmed switching between resealable poration and leakage-free scission events. These results establish design principles for adaptive lipid nanomaterials that localize and control failure, informing safer electroporation protocols, more robust drug-delivery vesicles, and programmable synthetic compartments. This work was supported by Russian Science Foundation (grant # 22-15-00265-П).

Scanning Ion Conductance Microscopy for Materials & Life Sciences

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Scanning Ion Conductance Microscopy (SICM) probes, employing micro- or nanopipettes, are ideally suited for performing nanoscale assays on cell surfaces. These probes facilitate a range of applications including patch-clamp recording from individual surface structures, iontophoretic delivery of reagents, and pressure micro-application to probe mechanical properties or deliver agents. The SICM methodology enables high-resolution imaging of uneven and convoluted cell surfaces by ensuring the pipette approaches from above, thereby avoiding surface dragging and potential damage.

In this study, we combined SICM imaging with fluorescence microscopy and nanomechanical mapping to observe changes in the mechanical properties of single cancer cells in response to various chemotherapeutic drugs targeting different components of the cytoskeleton [1,2]. We demonstrated that SICM probes can function as local biosensors measuring extracellular pH (pHe) [4], reactive oxygen species (ROS) [2], and various metabolites and electrochemically active compounds in living cells, organoids, and animal tumor models [6-7].

By integrating pHe data with mechanical properties and ROS levels, we could phenotype the heterogeneity of individual cells more precisely. Additionally, SICM probes were utilized for nanoinjection [3] or for nanobiopsy, enabling single-cell omics analysis of pre-characterized cells. This multifunctional approach positions SICM as a unique tool for detailed phenotyping of individual cell heterogeneity and for verifying gene expression profiles of different subpopulations at the single-cell level, offering significant applications in cancer research.

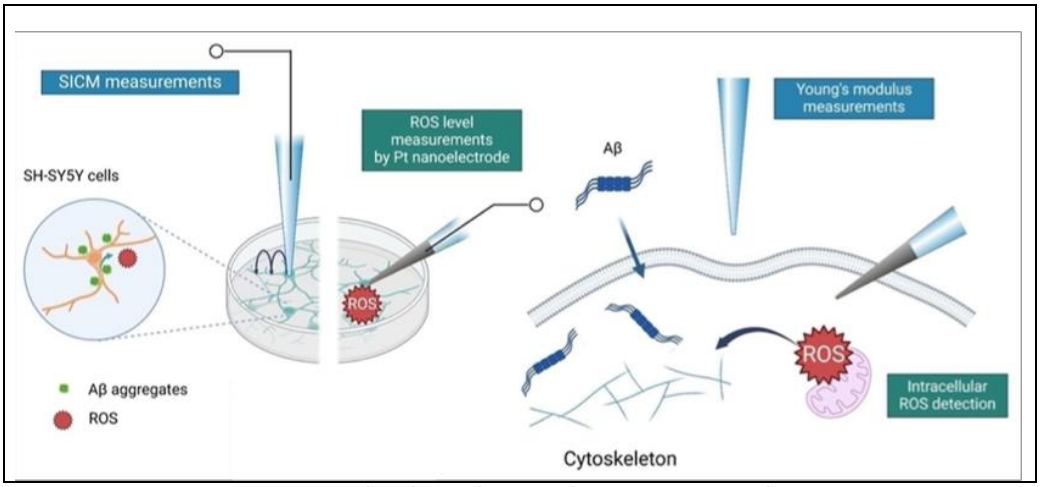

Figure 1: One figure if needed (Arial, centred, 9 pts)

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Posters

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Quantitative Surface Charge Mapping of Soft Matter by Scanning Ion Conductance Microscopy

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Surface charge is a fundamental property governing interfacial phenomena in both biological and synthetic soft matter systems, influencing cell–cell interactions, ion transport, colloidal stability, and material environment interfaces. However, resolving surface charge heterogeneity under near-physiological conditions remains challenging, as conventional techniques such as zeta potential measurements provide only ensemble-averaged information and lack spatial resolution.

Here, we employ Scanning Ion Conductance Microscopy (SICM), previously used to quantitatively map surface charge density on lipid bilayers [1], to probe the electric double layer (EDL) at soft matter interfaces, including fixed mammalian cells (T cells, 3T3 fibroblasts, and HEK293T cells) and layered double hydroxide (LDH) nanostructures. SICM utilizes an electrolyte-filled nanopipette whose ionic current is sensitive to both pipette–sample separation and local surface charge [2]. By systematically analysing distance-dependent ionic current variations in SICM approach curves, we resolve spatial differences in surface charge across distinct sample types without physical contact or mechanical perturbation.

To enable quantitative interpretation, we combine experimental measurements with finite element method (FEM) simulations based on the coupled Poisson–Nernst–Planck (PNP) equations, which describe ionic transport and electrostatic screening near charged interfaces. These simulations establish a direct link between experimentally measured current–distance curves and effective surface charge density. In addition, pH-dependent modulation of the EDL and surface ionization is investigated computationally, providing insight into how environmental conditions influence charge-sensitive SICM signals.

A custom data processing and analysis tool was developed to streamline approach curve extraction and charge-sensitive analysis from SICM measurements. Together, this integrated experimental computational framework provides a practical route toward nanoscale, spatially resolved surface charge mapping of soft matter, extending the capabilities of SICM for quantitative electrostatic characterization of biological and synthetic interfaces.

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‘Smart’ Scanning Electrochemical Cell Microscopy and the Targeted Imaging of Electrodeposited Conductive Polymer Dots

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In a standard scanning electrochemical cell microscopy (SECCM) experiment, a micro- or nanopipette is filled with an electrolyte, which causes a meniscus to hang at its end. With the insert of a quasi-reference counter electrode, the pipette can function as a size-controlled electrochemical cell when brought into contact with a surface. This probe (for which 2-channel and 4-channel variants are also available) is attached to a piezoelectric positioning system, which allows its control in the three spatial axes (*x*, *y* and *z*), enabling the investigation of the sample at a spatially-defined array of points.

The control of the components comprising an experimental SECCM setup can be enabled through an FPGA-based architecture, recently described by McKelvey *et al*. [1]. Experiments can be further aided through the incorporation of optical microscopy, such as an inverted microscope in interference reflection microscopy (IRM) configuration [2], allowing the synchronous opto-electrochemical monitoring of the meniscus. This enables researchers to direct the probe to areas of electrochemical interest, optimizing the SECCM experimental protocol and minimizing redundant information.

Previous studies have presented solutions to enable targeting of the SECCM to locations of interest on a sample surface using setups with integrated optical microscopes; for instance, by performing landings on known positions as relative points of reference with this technique [3]. To advance this methodology, herein, we present a new software protocol using Python and LabVIEW which allows SECCM users to directly select the exact features to be interrogated in a SECCM-IRM setup. This selection can also be automated *via* a machine learning (ML) algorithm after performing sample-specific training. In this approach, a single calibration step allows the subsequent translation of any observable pixel point (within the calibration boundaries) to a position understood by the piezoelectric positioning system, thus allowing the targeted interrogation of any number of features through their manual selection.

This protocol has been tested for the electrodeposition and subsequent targeted imaging using SECCM of polyaniline, a conductive biopolymer. Herein, polyaniline is deposited on an Au substrate using potentials ranging from 0.5 to 1 V, and the differences in the electrochemical response of each polymer dot are then evaluated through targeted SECCM. In a general case, however, this protocol can be applied to any (semi)conductive and (semi)transparent substrate, paving the way to a new ‘smart’ SECCM imaging system that allows experiment automation and the production of more relevant electrochemical datasets, minimizing redundant information.

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Supramolecular polymorphism of induced chiral amyloids of insulin and lysozyme determined by AFM.

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Formation of amyloid structures from various proteins are a prevalent signature associated with neurodegenerative diseases as well as functional forms in other cases. Recently, isoforms with distinct vibrational circular dichroism (VCD) signatures either being left-, flat- or right-handed chirality's have been reported [1]. In the present study, these three VCD isoforms of insulin and lysozyme were prepared, quality controlled by VCD, and characterized by AFM to assess possible structural polymorphism discernible at the supramolecular level reflecting the VCD chirality. The isoforms were prepared by inducing amyloid formation at various pH conditions in the aqueous solutions [2]. Samples were prepared for characterization by AFM using covalent anchoring to mica exploiting a silanization strategy with carboxyl terminated silanes followed by conjugation to relevant functional group of the amyloid similar to that reported [3, 4]. The subsequently vacuum dried samples were characterized by tapping mode AFM at ambient conditions. AFM topographs of VCD right-handed insulin fibrils grown at pH 1.6 reveal fibrillar morphologies heterogeneous in lengths, with extensive lateral aggregation and possible indications of twisted morphologies in their supramolecular state. The left-handed insulin (grown at pH 2.5) was observed with less tendency to form large aggregates than the right-handed counterpart. The right-handed lysozyme amyloids (grown at pH 2) observed with fibrils of nearly uniform thickness was in particularly different from the right-handed insulin by showing nearly no tendency to aggregate beyond the uniform fibril state. The left-handed and flat type of the lysozyme showed additional variations in the AFM topographs compared to the right-handed counterpart. The largest differences in ultrastructures of the various chiral amyloids of insulin and lysozyme studied here is the differences in the supramolecular polymorph of aggregation in the right-handed insulin and lysozyme (Fig. 1). Background results of CD characterization and assays using fluorescence chiral amyloid ligands will also be presented in the poster presentation. The lack of a clear chiral structure discernable by AFM corresponding to the VCD chiral signatures indicate that the latter is embedded in internal structures of the protein assemblies.

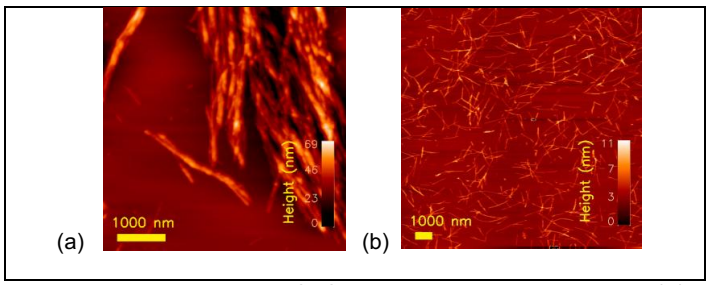

Figure 1: Tapping mode AFM topographs of VCD right-handed insulin amyloids (A) and VCD right-handed lysozyme amyloids.

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Effects of extra- and intracellular mechanical stimuli on cellular growth and development

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Wound healing and tissue regeneration remain central challenges in regenerative medicine, where increasing evidence[1] highlights the interplay between mechanical cues and biochemical, electrophysiological, and genetic pathways in directing cell fate. A deeper understanding of how mechanical signals regulate cellular mechanosensing and function is essential for elucidating complex tissue behavior.

Among the diverse mechanical stimuli encountered by cells, extracellular matrix (ECM) curvature represents a critical yet underexplored factor. Variations in substrate curvature and geometry can modulate the activation of mechanosensitive proteins, thereby influencing cytoskeletal organization, cell morphology, and functional responses.

To investigate curvature-mediated mechanotransduction, we employed Melt Electrowriting (MEW), a high-precision electrospinning technique, to fabricate biomaterial scaffolds capable of delivering multiscale mechanical stimulation to PC12 neural cells and 3T3 fibroblasts. MEW enables the reproducible production of microscale fibers in defined architectures, offering a cost-effective and versatile platform for generating complex, extrusion-based scaffold geometries with controlled curvature features.

In addition to extracellular mechanical inputs, we examine intracellular mechanical perturbations arising from protein crystallization. Specifically, the serine/threonine kinase PAK4 has been shown to assemble into rigid, needle-like crystalline structures within the cytoplasm[2]. We aim to determine how such intracellular rigid inclusions interact with externally imposed substrate curvature to influence cellular behavior.

Using advanced real-time microscopy, we seek to characterize how combined extracellular and intracellular mechanical stimuli modulate mechanosensing pathways, migration dynamics, and cell function. These findings are expected to provide new insights into curvature-driven mechanobiology, with implications for pathological understanding and the development of future therapeutic strategies in regenerative medicine.

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Molecular dynamics study of organochlorine pesticide interactions with phospholipid membranes

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Organochlorine pesticides such as β-hexachlorocyclohexane (β-HCH) and chlordecone (CLD) are of particular concern in the French West Indies, where their extensive past use has led to long-term soil, water, and food chain contamination [1,2].In this contribution, molecular dynamics simulations are applied to investigate molecular interactions at biological membranes. Understanding their partitioning behavior between aqueous phases and lipid membranes is therefore essential for elucidating early molecular events involved in biological exposure [3].

MD simulations are performed to examine the interaction of these pesticides and its metabolites with model phospholipid bilayer membranes (POPC, DOPC, DPPC). The local hydration environment is quantified by monitoring the number of surrounding water molecules within a 3 Å cutoff distance from each pesticide as a function of time. This descriptor is used as an indicator of molecular positioning, allowing the distinction between aqueous, interfacial, and membrane-associated states. Trajectory analyses further provide information on molecular stability and orientation at the membrane interface.

MD simulations show that chlordecone and several of its metabolites progressively insert into the lipid phase, whereas indene-3-carboxylic acid enters the membrane but remains predominantly localized at the water–lipid interface. The carboxylic acid group preferentially interacts with the polar phosphate headgroups of the phospholipids, while the hydrophobic indene core exhibits favorable interactions with the lipid acyl chains.

Overall, this work highlights the relevance of molecular dynamics as a powerful tool to investigate early-stage interactions at biological interfaces, contributing to a better molecular-level understanding of pesticide exposure processes.

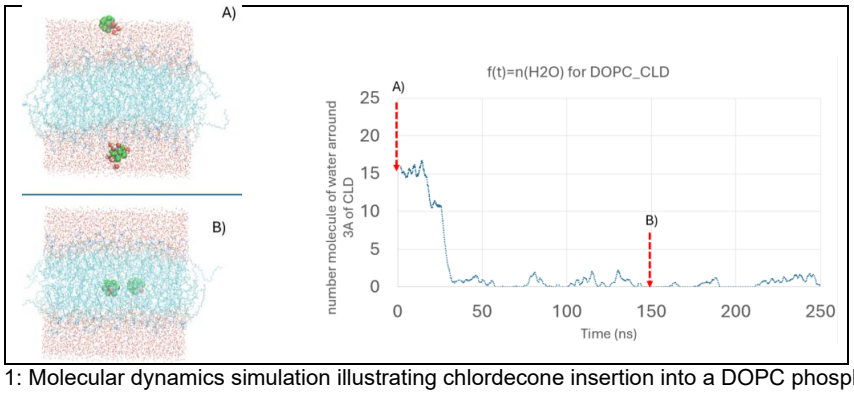

Figure 1: Molecular dynamics simulation illustrating chlordecone insertion into a DOPC phospholipid bilayer membrane at (a) 0 ns and (b) 150 ns.

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Deep Learning Assisted Investigation Of Drug-Protein Interactions Using Drying Droplet Pattern

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Deep learning provides a powerful tool for studying the interactions between biomaterials by analysing their drying droplet patterns. Traditional available techniques, such as circular dichroism (CD) spectroscopy, Fluorescence spectroscopy, and mass spectrometry, are costly and time-consuming, causing a limitation in their capacity to do high-throughput interaction screening. Previous research has successfully utilized deep learning models to classify biomaterial interactions with high accuracy, including histone-DNA complexes[1], protein-immunoglobulin[2], protein-protein[3], protein-surface[4], and amyloid beta mutants[5]. This research aims to utilize the convolutional neural networks (CNNs) to predict the drug-protein binding affinity. In this study, Human Serum Albumin (HSA) was used as a drug carrier along with various drugs. Drug-protein carrier mixtures were pipetted onto hydrophobic glass surfaces, followed by imaging their drying droplet patterns using polarized light microscopy. These images were used to train the CNN models to classify the binding affinity, as validated by complementary techniques such as CD. The trained model was tested on new unseen drugs to predict their binding affinity to HSA, followed by verification of the prediction with experimental data. This method shows great potential to serve as a high-throughput screening method for optimal drug-protein combinations.

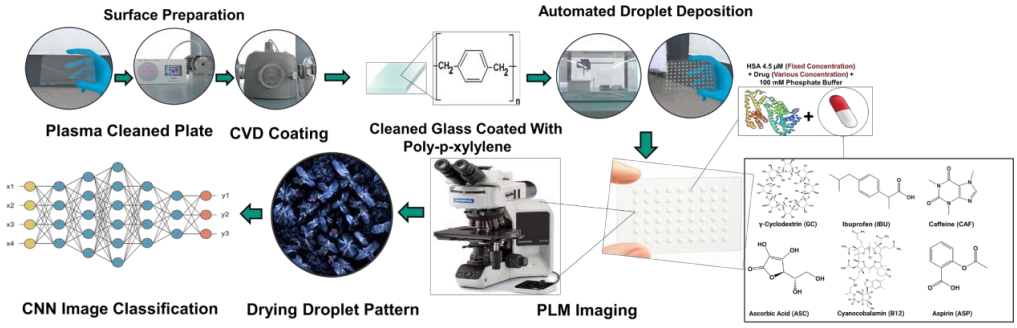

Figure 1: Overview of our workflow to study drug–albumin interactions using drying droplet patterns. Drug–HSA mixtures are first prepared and deposited as small droplets under controlled temperature and humidity conditions. After drying, the resulting patterns are imaged using optical microscopy, relevant features are extracted, and deep-learning analysis is applied to classify the patterns and gain insights into drug–albumin interactions.

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Interpretation of Scanning Ion Conductance Microscopy Measurements through Finite Element Modelling

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Scanning Ion Conductance Microscopy (SICM) is a Scanning Probe Microscopy (SPM) technique that enables nanoscale measurements at solid-liquid interfaces by combining non-contact topographical imaging with simultaneous detection of ionic current [1,2]. In SICM, the measured current is affected by several coupled factors, including probe-surface distance, pipette geometry, local conductivity, solution viscosity and surface charge, which complicate the interpretation of the signal and the extraction of the sample surface charge density [3,4]. For this reason, capturing the full complexity of the experimental conditions becomes essential when developing a reliable model. Consequently, finite element modelling (FEM) has been widely used in pipette-based studies to simulate ion transport and electric potential, enabling the interpretation of experimental results.

In this work, we present a FEM model created in COMSOL Multiphysics that describes how ions and electric fields behave within the narrow space between the pipette tip and the sample surface, to extract its surface charge density. It is based on the coupled Poisson-Nernst-Planck equations, which link ion motion and electrostatics. The model allows simulations to be performed under conditions consistent with SICM measurement protocols and the exploration of the underlying processes governing SICM measurements. By varying geometric, electrostatic and electrolytic parameters, the model helps to identify their individual contributions to the observed current and how it is affected by changes in surface charge. The simulations also provide access to spatial distributions of electric potential and ion concentration that cannot be directly measured experimentally.

Overall, the developed FEM model helps to better understand and interpret the complex response measured in SICM experiments, and supports a more systematic analysis of experimental data.

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Unveiling the Localized Tensile Mechanical Properties of Collagen Hydrogels via FluidFM

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Soft collagenous tissues exhibit high heterogeneity at the cellular length scale, where local deformation mechanisms critically influence tissue properties and resident cell behaviour. While Atomic Force Microscopy (AFM) indentation is a standard tool for micromechanical characterization, it primarily probes compressive responses and may fail to activate the collagen fiber network [1]. Previous studies have shown that AFM indentation cannot distinguish between collagen hydrogels (control) with approximately 14-fold increased collagen concentrations (compressed) [1]. To address this limitation, we developed a Fluid Force Microscopy (FluidFM)-based microtraction assay that targets tensile fiber activation at the microscale [2]. As illustrated in Fig. a, a hollow cantilever applies localized negative pressure to form a suction contact, enabling controlled pulling on the hydrogel surface. The characteristic force-displacement retraction curve (Fig. b) allows extraction of key metrics such as the minimum force (peak force before detachment). Our results demonstrate that while AFM indentation lacks the sensitivity to distinguish collagen concentrations [1], using microtraction method can differentiate collagen concentrations (Fig. c). Spatial mapping (Fig. d, e) reveals that the microtraction response reproduces the inherent mechanical heterogeneity of the hydrogels captured at 10 µm intervals. This approach may provide insights into how the collagen fiber network responds to local forces. Furthermore, by employing this FluidFM-based microtraction method, we can characterize the response of collagen hydrogels under varying testing conditions such as different retraction speeds and negative pressures.

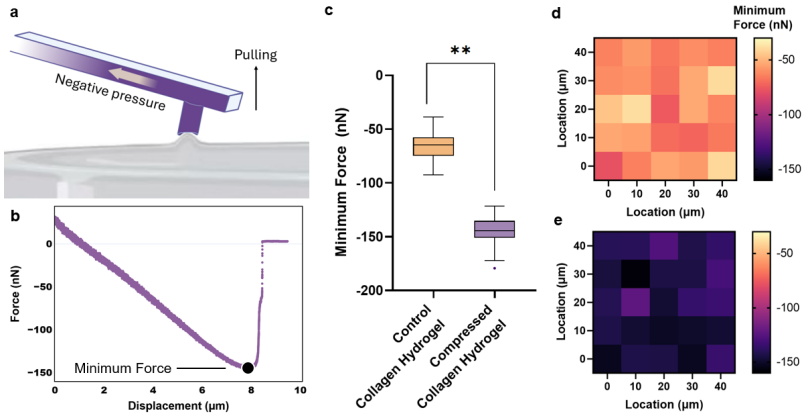

Figure 1: (a) Schematic illustration of the FluidFM-based microtraction assay. (b) Representative force-displacement retraction curve. (c) Boxplot showing comparison of Minimum Force between control and compressed groups. (n=40, per group from 3 independent batches). Spatial heatmaps of Minimum Force distribution with10 µm intervals, for (d) control and (e) compressed collagen hydrogels. Statistical significance was determined using a paired t-test on the median values of three independent batches (N=3, ** indicates P = 0.0069)

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Advanced signal modulation schemes in microwave scanning probe microscopy for materials and biological systems

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Nanoscale characterization of electrical and dielectric properties is essential for understanding functional materials and biological systems. Microwave-frequency scanning probe techniques, such as scanning microwave microscopy (SMM) and microwave scanning tunneling microscopy (STM), have emerged as powerful tools for this purpose [1], [2]. However, these measurements remain limited by weak local signals and dominant background contributions, making the reliable isolation of local responses a central experimental challenge.

Here, we introduce signal modulation as a measurement strategy to extend conventional static detection schemes. Controlled modulation of excitation and detection signals encodes local tip–sample interactions into dynamic response signals, enabling the separation of genuine local contributions from parasitic microwave backgrounds.

Beyond improving measurement robustness, modulation provides access to distinct physical observables, electronic response, and microwave impedance variations through tailored detection channels. This approach introduces additional contrast mechanisms and enables alternative feedback strategies, allowing measurements in regimes where conventional detection becomes unreliable.

We present recent experimental implementations and discuss how modulation-based detection expands the operational parameter space of microwave scanning probe techniques. These results establish signal modulation as a versatile route toward more informative nanoscale electrical characterization across materials science and bio-related applications.

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Probing Free-Standing Graphene by Bipolar Electrochemistry

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Abstract

Nanoscale confinement of electrolytes exhibits significant deviations from bulk behavior due to altered ion transport, modified solvent structure, and changes in charge transfer mechanisms. Understanding these effects is essential for advancing applications in nanofluidics and energy storage. In this respect our long-term objective is to probe the effect of nanoscale electrolyte confinement on electrochemical processes. Two-dimensional (2D) material-based electrochemical systems is such a nanoconfined situation. However, experimentally decoupling intrinsic electrode properties from confinement-induced phenomena remains a major challenge. Here, we establish a well-defined experimental framework to isolate and quantify electrochemical processes at individual graphene flakes but free-standing, i.e. not electrically contacted to an electrode. We then propose to investigate the electrochemical behavior of graphene using closed-cell bipolar electrochemistry, providing a robust baseline for confined studies.

The experimental platform consists of a free-standing graphene or multilayer graphite membrane suspended onto a micrometer-sized aperture in a silicon nitride (SiN) support, separating two electrolyte compartments. Under an externally applied electric field, the graphene layer acts as a wireless bipolar electrode, enabling spatially separated oxidation and reduction reactions at opposite sides of the same 2D sheet. which further allows for direct optical monitoring of reaction sites.

The bipolar response is first compared to a model bipolar system made of gold ultramicroelectrodes (UME), reproducing the key geometrical and transport features of the graphene device. Electrochemical measurements using ferrocenemethanol and hexaammineruthenium(III/II) redox couples in aqueous KCl electrolytes, supported by numerical simulations, show excellent agreement between graphene and UME voltammetric responses.

Furthermore, the SiN configuration allows for direct monitoring of reaction sites on graphene. Optical microscopy reveals distinct anodic and cathodic regions on the graphene surface.

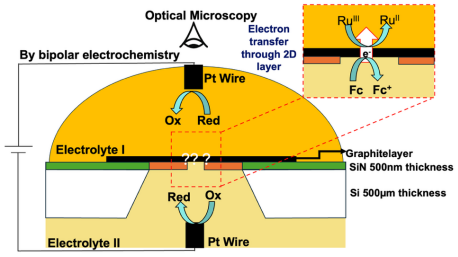

Figure 1. Bipolar electrochemistry through graphene. Graphene-based bipolar device with optical visualization of spatially separated redox reactions.

These results establish graphene as a reliable bipolar electrode platform and provide a solid experimental baseline for investigating electrochemical phenomena in confined electrolyte systems.

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Tunable Organ-Specific Drug Delivery via Peptoid-Functionalized Nanogels

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The development of organ-specific drug delivery systems remains a major objective in nanomedicine, as most systemically administered nanocarriers exhibit limited tissue selectivity and accumulate predominantly in clearance organs such as the liver and spleen. While peptide-based targeting ligands have been widely explored, their clinical translation is often limited by proteolytic instability, conformational flexibility, immunogenicity, and batch-to-batch variability. To overcome these challenges, we developed a peptoid-functionalized gelatin-based nanogel system that combines the programmable precision of sequence-defined peptoids with the unique properties of hydrated nanogels. These properties include high cargo loading capacity, tunable release profiles, enhanced biocompatibility, and a flexible, porous architecture that facilitates tissue penetration.[1]

The biodegradable nanogels are composed of photo-crosslinked polymer networks [2] forming highly hydrated, nanoscale hydrogel particles. This architecture provides high cargo loading capacity, tunable release profiles, reduced nonspecific adsorption, and enhanced biocompatibility compared to rigid nanoparticles.[1] The soft, porous structure also facilitates improved tissue penetration and adaptable mechanical properties that influence vascular interactions. Surface functionalization with structurally defined peptoid tetramers endowed the nanogels with proteolytic stability, precise sequence control, and versatile synthetic tunability. Systematic variation of peptoid side-chain composition enabled investigation of structure-biodistribution relationships, allowing tissue selectivity to be programmed through minimal sequence modifications.[3]
Comprehensive physicochemical characterization demonstrated that the nanogels possess a uniform particle size of approximately 100 ± 20 nm, as determined by dynamic light scattering (DLS) and scanning electron microscopy (SEM). The nanogels maintained high colloidal stability over 7 days at 37 °C under physiologically relevant conditions and achieved a drug loading efficiency (DLE) of around 50 %, features that support targeted drug delivery and enhanced biodistribution performance. In vitro investigations further demonstrated a previously unreported organelle-specific localization of these nanogels within mitochondria, highlighting the potential for subcellular precision in drug delivery. Our *in vivo* biodistribution studies in zebrafish embryos revealed sequence-dependent organ accumulation patterns of the peptoid-functionalized nanogels compared to non-functionalized controls and conventional targeting approaches, with selected nanogel constructs achieving remarkable enrichment in defined target organs while minimizing off-target deposition in clearance tissues.[4]

Together, these findings establish peptoid-functionalized nanogels as a versatile and programmable platform for organ-specific drug delivery. By integrating the structural advantages of soft nanogels with the stability and synthetic precision of peptoids, this system provides a robust alternative to conventional peptide-based ligands and establishes rational design principles for next-generation precision nanotherapeutics.

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Elucidating the Antimicrobial Properties of Layered Double Hydroxide Films

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Layered double hydroxides (LDH) have gained significant attention as promising materials for antimicrobial applications [1]. These two-dimensional hydrotalcite-like materials, with the general formula $[M^{2+}_{1-x}\ M^{3+}_{x}\ (OH)_2]_{x}^{+}\ [(A^{n-})_{x/n}.\ y\ H_2O]_{x}^{-}$, consist of charge-balancing anions intercalated between positively charged, brucite-like layers composed of octahedrally coordinated divalent (M^{2+}) and trivalent (M^{3+}) cations. By altering the composition of the octahedrally centred M^{2+} and M^{3+} cations, the LDH material may generate Reactive Oxygen Species [2] under light activation. The intrinsic antibacterial nature of certain substituted divalent cation (i.e., Zn^{2+}, Cu^{2+}) [3], when combined with light activation, may lead to an amplified microbicidal effect. Developing these LDH in the form of coatings is useful for antimicrobial assays. The growth of LDH as coatings [4] favours morphological control and easy retention after use. To harness these advantages, we have optimised the *in-situ* synthesis of different LDH films on aluminium-based substrates. Using hydrothermal routes and different precipitants (ammonia or urea), we have obtained LDH films with two different divalent cations (M^{2+} = Cu^{2+} or Zn^{2+}). The as-synthesized films were characterized primarily by XRD and vibrational spectroscopies (Infrared and Raman) to confirm the LDH phase and determine the intercalated anions. The film morphology was analysed by SEM. DRS was used to determine the optical properties. The elementary composition was determined by XPS and EDX. Finally, these films were evaluated for their photoactive assisted antimicrobial activity by classical microbiological methods involving Colony Forming Units counting, diffusion method and epifluorescence microscopy.

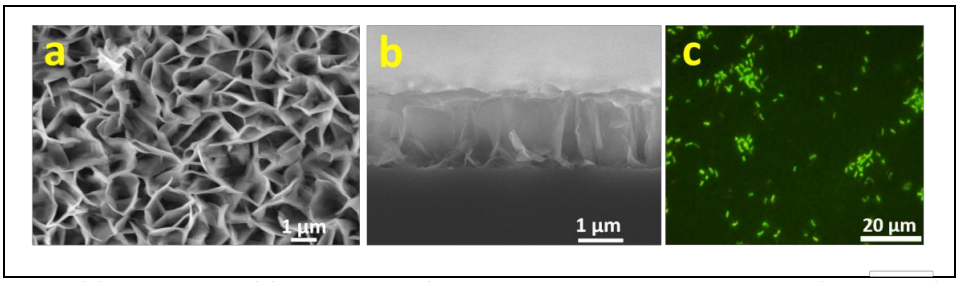

Figure 1: (a) Top-view and (b) cross-section Scanning Electron Microscopy images of ZnAl LDH film. (c) Epifluorescence image of *E. coli* on LDH surface after BacLight™ staining.

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Efficacy of Anaerobic Biodegradation of Chlordecone-Contaminated Mangrove Sediments Under Mesophilic and Thermophilic Conditions

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Abstract

Chlordecone, a persistent organochlorine pesticide, continues to impact ecosystems and human health long after its widespread use and subsequent ban in 1993 in the French West-Indies[1]. Despite the ban, the chemical's environmental persistence, particularly in the soils and sediments of the French Caribbean, underscores the challenges in addressing its legacy [2]. This study aims to evaluate the chlordecone-degrading potential of anaerobic bacterial consortia isolated from mangrove and freshwater sediments in biostimulated microcosm experiments under modulated mesophilic (30 °C) and thermophilic (55 °C) conditions. The microcosm setup replicates natural environmental conditions in a controlled laboratory environment, with artificial groundwater formulated to mimic saline mangrove and freshwater ecosystems. Temperatures were carefully modulated at mesophilic (30 °C) and thermophilic (55 °C) conditions under anoxic conditions [3]. Bacterial community composition and chlordecone degradation will be assessed using metabarcoding and LC-MS, respectively. Samples will be collected at 0, 1, 3, 5, and 8 months. Successful extractions have been completed for LC-MS (0, 1 months) and microbial DNA (0, 1, 3 months). The expected outcome is the identification of consortia bacterial communities shift, including iron-reducers, methanogens, and sulfur-reducers, along with the degradation of chlordecone at the Hydrochlordecones and indene stages as previously described [4], [5].

Key words: Anaerobic Biodegradation: Bacterial Consortia: Chlordecone: Mangrove Sediment: Persistent Organic Pollutant.

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Self-regenerating phage-loaded hydrogels: a synergistic prophylactic approach against staphylococcal skin infections

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The increasing number of therapeutic failures due to antibiotic resistance is of global concern. In this context, new alternative treatments such as the therapeutic use of bacterial viruses, also called bacteriophages or phages, are being considered. However, significant gaps remain in understanding the practical aspects of phage-based therapy. Our project aims to propose a prophylactic approach focused on human and animal skin infections caused by *Staphylococcus aureus,* using hydrogels – safe and biocompatible materials that are already used as wound dressings. Our developed formulation of multilayered hydrogels combines long, charged polymers. These hydrogels are designed to trap bacteriophages and release them in response to the presence of bacteria, thereby offering a synergistic mechanism of action that combines a physical and chemical barrier, with intrinsic antimicrobial activity complemented by targeted bacteriolysis (Figure 1).

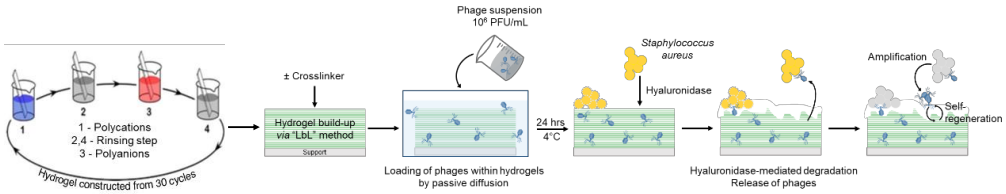

Figure 1: Phage-loaded hydrogel system: bacteria-triggered phage release, and self-regeneration.

In the present work, we characterized 14 phages from different families, assessing their hydrophobicity, size, morphology and surface charge. Despite the viruses being phylogenetically close to each other, these properties varied substantially, influencing the interaction of the phages with the hydrogel matrix and their loading efficiency. Co-incubating individual phages with preformed hydrogels resulted in concentrations ranging from 10^6 to 10^8 plaque-forming units (PFU)/mL of hydrogel, representing an up to 500-fold enrichment compared to the initial suspensions. This suggests that phage uptake depends exponentially on their size.

Chemical cross-linking was employed to modulate hydrogel stiffness; at optimal crosslinker concentration, the physical and chemical properties of hydrogels enhanced phage entrapment by up to 100-fold relative to non-crosslinked hydrogels.

Bactericidal activity was evaluated using two complementary methods: measuring bacterial adhesion to the hydrogel surface and determining the clearance of planktonic populations. First results indicate that crosslinked hydrogels without phages reduced bacterial adhesion by over 90% compared with glass controls (a ~2-log reduction), suggesting combined anti-adhesive and contact-killing effects. Incorporating phages further increased bacterial clearance, achieving a reduction of over 99% of planktonic cells, corresponding to 7-log depletion (release killing effect). Interestingly, phages released by lysed bacteria appeared to be re-sequestered within the hydrogel matrix, creating a self-regenerating reservoir that sustains high local concentrations of phages for an extended period of time. These results demonstrate that we managed to develop phage-loaded hydrogels combining intrinsic antimicrobial activity with self-regenerating phages, offering a robust system for the prophylaxis and therapy of *S. aureus* skin infections. Ongoing work aims to decipher triggered phage release, assess durability and cytotoxicity of the loaded hydrogels, and validate their *ex vivo* and *in vivo* efficacy.

Synthesis of alkali-activated geopolymers from pozzolan and geothermal silica (Guadeloupe, French West Indies) for the adsorption-degradation of emerging contaminant and pesticides in aqueous phase.

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Abstract

Growing concerns about pesticides such as chlordecone and emerging contaminants such as antibiotics linked to their persistence and proliferation of antimicrobial resistance in aquatic and terrestrial ecosystems have led to the development of sustainable materials to mitigate their impact on the environment. This study highlights the benefits of converting waste such as pozzolan from Loum in Cameroon, sargassum from Sainte Anne (Bouillante) and geothermal silica produced by the Bouillante geothermal station in Guadeloupe, respectively, into sustainable geoadsorbents for circular economies. Geopolymerization technology was used to obtain the geoadsorbents, and the influence of alkali-modified geothermal silica on the surface characteristics of geopolymers and geopolymer-sargassum biochar composites during this process was evaluated using standard physicochemical analyses (FRX, XRD, FTIR, SEM/EDX and BET). Fenton-like adsorption-degradation experiments on tetracycline (TC) were conducted under non-dynamic conditions. The porosity of geopolymers increases with their activator binder content, unlike composites. Functionalization of the geopolymer with biochar resulted in a TC removal rate of 71% compared to the pristine geopolymer (65%) over 72 hours. The simultaneous adsorption-degradation process revealed a TC removal rate of 100% after 24 hours on the different geomaterials. The adsorption-Fenton kinetics are multimechanical. The results of this work have demonstrated the value of using geothermal silica as a low-cost, environmentally friendly material in the preparation of geopolymers that are effective in removing antibiotics, and paved the way for the use of these geoadsorbents in the removal of pesticides such as chlordecone.

References

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May 30th	May 31st	June 1st	June 2nd	June 3rd	June 4th	June 5th	June 6th
Spring School		**International Conference**					
	Spring School	**8.30am – 12.30pm** Session I : Bio- and nanomaterials from labs to medical applications	**8.30am – 12.30pm** Session III : Bio- and nanotechnology for health & environment	**Social Event 7.00am – 5.30pm** Special Cruise to Petite Terre Islands	**8.30am – 12.30pm** Session V: Bio- and nanomaterials from labs to medical applications	**9.00am – 12.30pm** Session VII: The bio & non-bio interface	**9.00am – 12.30pm** Session IX : Special NanoInBio session
Lunch					Lunch		
Spring School	**Spring School**	**2pm – 5.00pm** Session II : The bio & non-bio interface	**2pm – 5.50pm** Session IV : Instrumentation for materials & life sciences		**2pm – 5.30pm** Session VI: Bio- and nanotechnology for health & environment	**2pm – 5.20pm** Session VIII: Instrumentation for materials & life sciences	
		5.00pm – 6.30pm Poster session 1			**5.30pm – 6.30pm** Poster session 2		**4.30pm – 6.30pm** Major Public Conference (in French)
					7.30 pm Gala dinner		