Biomedical Sensors and Detectors

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Programme

09:30 Registration

10:00 Welcome and Introduction

Session 1: Micro/nanoscale sensors for in-cell / lab bench
Chair: Michelle Peckham

10:15 (Invited) Mapping microscopic viscosity and temperature using molecular rotors
Marina Kuimova, Imperial College London, UK

10:45 Micro- and Nanolasers for Sensing and Bioimaging
Soraya Caixeiro, University of Bath, UK

11:00 Single molecule biosensing with rationally designed DNA origami
Paolo Actis, University of Leeds, UK

11:15 Coffee Break

Session 2: Recent biomedical detector innovations in imaging which go beyond X-rays
Chair: Michael Tanner

11:40 (Invited) Recent biomedical detector innovations in imaging which go beyond X-rays
Dan Watts, University of York, UK

12:10 Inline holographic microscopy via fibre imaging bundles
Michael Hughes, University of Kent, UK

12:25 Reactive Inkjet Printing: A Pathway to Biomedical Sensing Devices
David Alexander Gregory, The University of Sheffield, UK

12:40 Flash Posters / Lunch

Session 3: Testing of new therapeutics using organoids on a chip
Chair: Ioanna Mela

14:00 (Invited) Organ-on-Chip: Next Generation In vitro Platforms for Drug Assessment
Sally Peyman, Heriot-Watt University

14:30 Laser-microfabricated 3D Multi-Electrode Array for in vitro Electrophysiology of Cerebral Organoids
Massimo Mariello, University of Oxford, UK

14:45 3D Printed Bioelectronic Model of the Intestinal Tissue Architecture
Maria Lopez Cavestany, University of Cambridge, UK

15:00 Tea Break

Session 4: Developments in personalised biomedical diagnostics such as optical sensing And wearable technology
Chair: Mark Leake

15:25 (Invited) Personalised biomedical diagnostics: where we are and what the future holds?
Hemant Pandit, University of Leeds, UK

15:55 Ex vivo detection of anal sphincter defects using a sensorised surgical glove
Carmen Salvadores Fernandez, University College London, UK

16:10 Nanopipette Biomedical Sensors: Multifunctional SICM Probes for Single-Cell Phenotyping and In Vivo Sensing
Petr Gorelkin, ICAPPIC, UK

16:25 Panel Discussion

16:50 Posters and Drinks

18:00 End

Posters

P1: Characterising Charge Retention of 3D Printed Conductive Hydrogel Scaffolds
Arya Sunkara, University of Cambridge, UK

P2: Clinical translation of a time-resolved single-photon imaging system for safe placement of feeding tubes
Michael Tanner, Heriot-Watt University, UK

P3: Time-resolved single photon counting Raman spectroscopy with SPAD arrays
Michael Tanner, Heriot-Watt University, UK

P4: Diffusiophoresis-Enabled Microfluidic Detection of Protein-Coated Colloids for Diagnostic Applications
Christina Puijk, University College London, UK

P5: Diffusiophoretic Accumulation of Gold Nanoparticles in Paper Based Membranes as a Step Towards Enhancing Sensitivity of Lateral Flow Assay Devices
Henry Peterson, University College London, UK

P6: Functional Patterning of Intracellular Environment
Innes Bakkali, University of St Andrews, UK

P7: Modelling Changing Crypt and Villi Structures Down the Intestinal Tract Using 3D Printed Conductive Hydrogels
Zakariya Ahmed, University of Cambridge, UK

P8: Design Evolution of Pillar[5]arene-Based Nanopores: From Dynamic Control to High Sensitivity Sensing
Kharina Fenton, Kings College London, UK

P9: Time-Resolved Detection of Singlet Oxygen for Monitoring Benzoporphyrin Uptake and Photodynamic Therapy in Mice
Vikas Vikas, University of Glasgow, UK

Invited: Mapping microscopic viscosity and temperature using molecular rotors

Marina Kuimova
Imperial College London, UK

Viscosity is one of the main factors which influence diffusion in condensed media. In a cell viscosity can play a role in several diffusion mediated processes, such as drug delivery, signalling and mass transport. Previously, alterations in viscosity in cells and organs have been linked to malfunction; however, mapping viscosity on a single-cell scale remains a challenge.

We have imaged viscosity and crowding inside artificial model systems and in live cells using fluorescent probes, called molecular rotors.[1] In molecular rotors the speed of rotation about a sterically hindered bond is viscosity-dependent, which strongly affects fluorescence lifetime or spectra of rotors, allowing fluorescence imaging. This approach enabled us to measure both the microscopic viscosity and macromolecular conformation, in response to cancer treatment, inflammation, and in the presence of unusual DNA topologies, G-quadruplexes (G4s),[1-6] and to monitor their temporal changes in real time. The talk will cover our recent developments of this technique, such as genetic and passive targeting of rotors and applications to monitoring dynamic processes.

[1] M. Paez-Perez, M. K. Kuimova, Angew. Chem. Int. Ed. 2024, 63, e20231123
[2] J. Robinson et al, Angew. Chem. Int. Ed. 2025, e202424931
[3] P. A. Summers, B. W. Lewis, et al Nat. Commun. 2021, 12, 162
[4] J. Robinson et al, J. Amer. Chem. Soc., 2024, 146, 1, 1009
[5] T. Bradford et al, Anal. Chem. 2024, 96, 20223–20229.
[6] S. Allerton et al, ACS Appl Mater Interfaces, 2025, 17(7), 10499-10508

Micro- and Nanolasers for Sensing and Bioimaging

Dr Soraya Caixeiro
University of Bath, UK

Micro- and nanoscale lasers hold great promise in the field of biophotonics due to their distinct optical properties, such as a sharp emission spectrum, high brightness, narrow linewidth, and sensitivity to changes in the local refractive index. These features make them attractive alternatives to traditional fluorescent markers, enabling highly precise chemical measurements via minute shifts in their resonant modes. When integrated into living cells, these laser particles can facilitate real-time monitoring of dynamic biological processes, including the contraction of individual myofibrils in heart cells.

Additionally, advancements in spectral detection and optical systems have empowered these lasers to create a wide array of intracellular barcodes, allowing for precise tracking of cellular activity over extended periods, often spanning multiple days. This capability offers

new avenues for understanding cell migration and tissue dynamics with unprecedented resolution. Despite their diminutive size, micro- and nanolasers are poised to revolutionize biological sensing and imaging, pushing the boundaries of what is possible in the study of complex biological systems and enhancing our understanding of the intricate processes underlying life.

Single molecule biosensing with rationally designed DNA origami

Chalmers Chau[1], Gayathri Mohanan[1], Dylan Charnock[1], Christoph Wälti[1], and **Paolo Actis**[1]
[1]University of Leeds, UK

Nanopore systems have emerged as a leading electrical platform for the analysis of biomolecular complexes with single-molecule resolution. Nanopore platforms are now commercially available for the sequencing of nucleic acids, but the technology has also great potential for biophysical characterization of a range of biomolecules and biochemical reactions. Here, I will present the development of nanopore platforms coupled with polymer electrolytes to comprise ultra-sensitive single molecule detection platforms. I will present experimental and multiphysics modelling data to describe the mechanism of signal enhancement of a nanopores in presence of a polymer electrolyte. I will then discuss a biosensing based on DNA origami disassembly driven by toehold mediated strand displacement (TMSD). Symmetrical DNA origami dimers are separated into monomers via TMSD using miRNAs as invading strands. We visualized the real-time dynamics of dimer separation at high resolution using high-speed atomic force microscopy (HS-AFM), providing direct insight into the kinetics of the TMSD process. The entropically driven disassembly process can be followed using single molecule nanopore sensing leading to a quantitative readout of the ratio of dimers to monomers. This direct read-out method enabled the multiplexed detection of miRNAs.

(Invited) Recent biomedical detector innovations in imaging which go beyond X-rays

Dan Watts
University of York, UK

The quantum entanglement of photonic systems in the optical or near optical regime (electron volt energy scale) underpins recent advances in quantum information, computing, encryption and imaging. However for the mega electron volt scale (gamma energies) our knowledge of entanglement and decoherence is relatively poor. The significant recent progress in this field will be presented along with an outlook for next generation entangled PET and SPECT medical imaging.

Inline holographic microscopy via fibre imaging bundles

Michael Hughes
University of Kent, UK

Holographic microscopy is a promising tool for rapid and point-of-care biomedical diagnosis. Phase information provides enhanced contrast of weakling scattering objects, while quantitative phase recovery can allow for thickness and dry mass measurements of unstained samples. The ‘inline’ approach to holographic microscopy has particular advantages: devices can be lensless, meaning they do not require mechanical focusing, allowing them to be compact and low-cost.

Some recent research into performing holographic microscopy through fibre imaging bundles will be presented. This offers a new approach to collecting images in confined spaces which may be suitable, for example, for plug-in imaging for microfluidic chips. In fibre bundle holography, the sample is illuminated from one side with light from a small-core multimode fibre, while a sub-millimetre fibre bundle on the opposite side collects a hologram and relays it to a camera. Following removal of the bundle core pattern, the hologram is numerically propagated to recover images of objects, such as cells, at multiple depths within the sample volume [1]. Sequential illumination of the sample from slightly different angles, using multiple fibres, allows for enhanced resolution and estimation of the axial position of objects, supporting fast computational autofocusing. Open-source libraries are provided for all of the numerical processing, demonstrating real-time performance on consumer-grade hardware.

[1] Michael R. Hughes and Callum McCall, "Improved resolution in fiber bundle inline holographic microscopy using multiple illumination sources," Biomed. Opt. Express 15, 1500-1514 (2024)

Reactive Inkjet Printing: A Pathway to Biomedical Sensing Devices

David Alexander Gregory, Patrick Smith, Jonathan Foster, and Stephen Ebbens
The University of Sheffield, UK

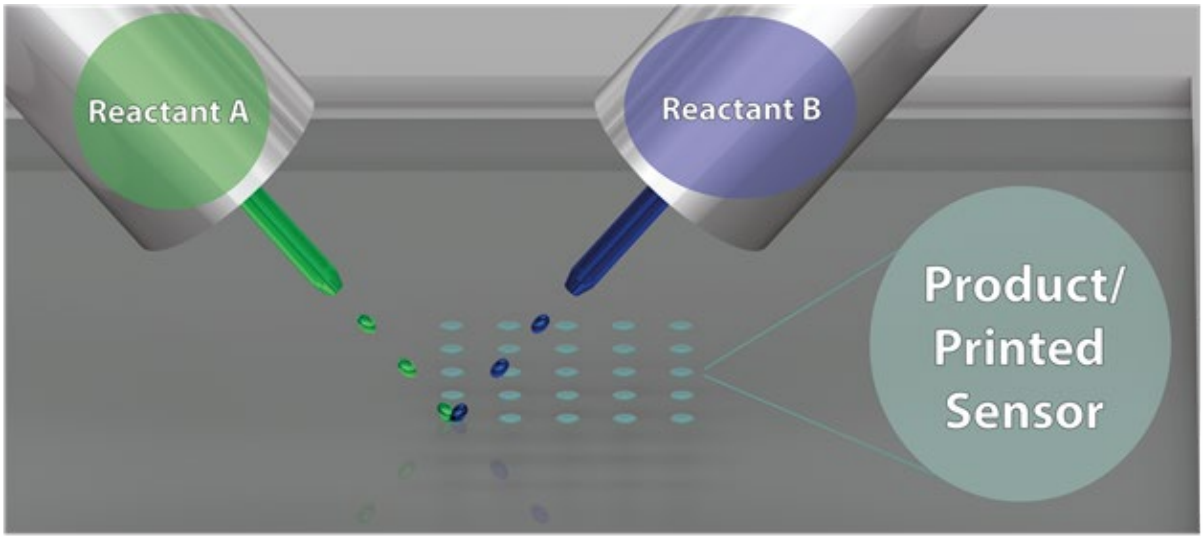
Reactive Inkjet Printing (RIJ) is emerging as a powerful platform for the digital fabrication of functional materials and devices. Unlike conventional inkjet printing, RIJ exploits localised chemical reactions at the point of deposition, enabling the in-situ synthesis and spatial patterning of active sensing materials with high precision (See Figure). This capability offers unique opportunities for biomedical applications where sensitivity, selectivity, and miniaturisation are paramount.

I will present recent advances from my group’s work demonstrating the versatility of RIJ for biomedical sensing. A key example is the fabrication of multivariate metal-organic framework (MOF) gradients via RIJ, which enables tuneable analyte interactions and has potential to be applied to the development of responsive sensing.

Extending this approach, I will discuss results on a circulating tumour cell detection device, where RIJ has been harnessed to pattern functional interfaces tailored for selective cell capture and analysis.

Finally, I will highlight the use of RIJ-printed silk micro-stirrers for contamination detection, illustrating how printed micro-actuators can be integrated into liquid-phase sensing environments.

Together, these studies underline the potential of RIJ as a flexible, low-waste, and scalable method for engineering next-generation biomedical sensing devices. The ability to digitally design and print multifunctional components ranging from chemical receptors to microfluidic actuators, points towards a future where portable, bespoke, and highly sensitive diagnostic tools can be produced on demand.



(Invited) Organ-on-Chip: Next Generation In vitro Platforms for Drug Assessment

Sally Peyman
Heriot-Watt University, UK

Over 90% of new drug candidates fail in clinical trials, often due to unforeseen toxicity or insufficient efficacy in humans. This high failure rate is largely attributed to inadequate preclinical disease models. Traditional 2D cell cultures, though widely used, lack the structural and functional complexity of living tissues. Animal models, while useful, differ significantly from humans in genetic, metabolic, and immunological aspects, limiting their predictive value. These limitations hinder the accurate assessment of drug safety and effectiveness, resulting in costly setbacks for drug development.

To address these challenges, researchers have increasingly adopted 3D cell culture systems,

which offer improved tissue architecture and cellular interactions. However, these models still fall short of replicating key physiological conditions found in vivo, such as fluid dynamics, mechanical forces, and shear stress. These factors are essential for mimicking the natural environment of human tissues and understanding how drugs behave within them.

Organ-on-chip technology presents a promising advancement in in vitro disease modelling. These microfluidic platforms incorporate fluid flow into 3D cell cultures, simulating the dynamic conditions of human tissues. This enables more accurate modelling of cell behaviour and drug interactions within diseased tissues.

In this work, I present several organ-on-chip approaches designed to enhance therapeutic assessment, including spheroids-on-chip, pancreatic cancer-on-chip, and human vasculature-on-chip models. These systems have been used to evaluate both existing drugs and novel therapeutics, offering improved predictive potential and insights into drug delivery mechanisms.

[1] Bourn, 2023, Lab on a Chip, 23 (6), 1674-1693
[2] Kpeglo, 2022, Matrix Biology Plus, 14, 100109
[3] Kpeglo, 2024, Lab on a Chip, 24 (4), 854-868

Laser-microfabricated 3D Multi-Electrode Array for in vitro Electrophysiology of Cerebral Organoids

Massimo Mariello
University of Oxford, UK

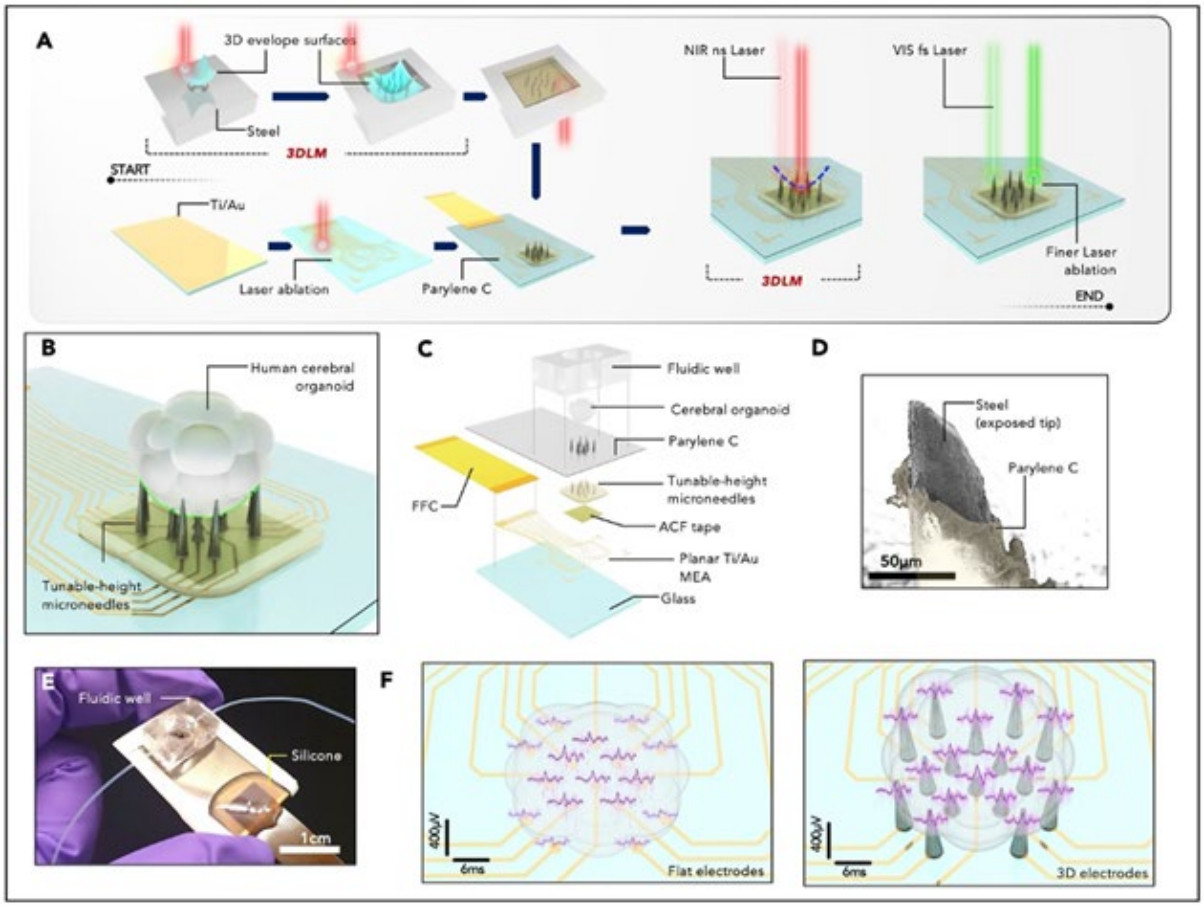
Neural organoids are valuable in-vitro models for studying brain development and disease, with spontaneous electrophysiological activity offering insights into functional maturation. However, conventional planar MEAs poorly capture the 3D neural dynamics of organoids, and existing 3D-compatible designs—buckled, rolled, kirigami, and stretchable—often require complex fabrication and manipulation that can affect cell viability and reproducibility.

We present a cleanroom-free 3D laser micromachining (3DLM) approach for fabricating tunable-height 3D MEAs using stainless-steel microneedle (MN) electrodes (Fig.1A). A single laser-ablation process defines MN height (300 µm–2.8 mm), tip diameter (15–25 µm), and conical shape, enabling optimal contact with organoids while preserving architecture (Fig.1B). The MNs are detached, bonded to planar glass/Ti/Au MEAs with anisotropic conductive film, and insulated with 5 µm parylene-C (Fig.1C). Tip de-insulation is performed via a two-step laser process: ns-pulsed removal of parylene followed by fs-pulsed polishing for precise (<50 µm) exposure (Fig.1D).

Electrochemical tests showed lower impedance (~4–6 kΩ at 1 kHz) and higher charge storage capacity (1.4 nC/µm²) compared to planar MEAs (0.2 nC/µm²). Integration within a PDMS well enabled stable culturing and medium exchange (Fig.1E). Using year-old cerebral

organoids, 3D MEAs recorded spontaneous local field potentials (~200 µV, ~1.5 ms) after 10 min stabilization at 37 °C. Immunofluorescence confirmed neuronal and glial viability around electrodes.

Compared to 2D MEAs, the tunable 3D configuration improved spatial coverage and signal fidelity by accessing deeper networks along the curved organoid surface, offering a scalable platform for neurodevelopmental research and drug screening (Fig.1F).

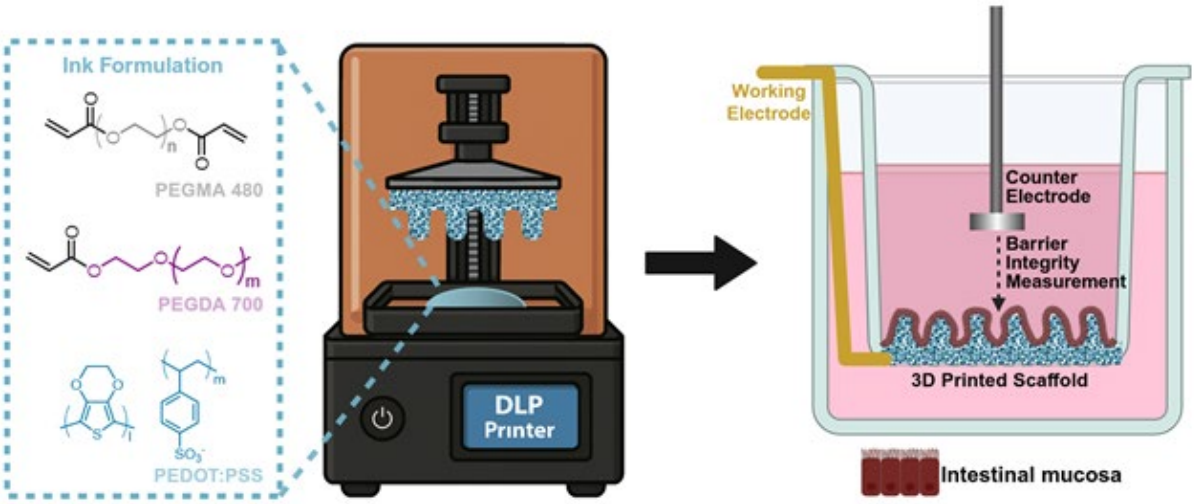


3D Printed Bioelectronic Model of the Intestinal Tissue Architecture

Maria Lopez Cavestany[1], Antonio Dominguez-Alfaro[2], Gorane Sansiñena Emazabel[1], Arya Sunkara[1], Zak Ahmed[1], Jordan Hill[3], Ricky Wildman[3], George Malliaras[1], and Roisin Owens[1]
[1]University of Cambridge, UK [2]Instituto de Microelectrónica de Sevilla, Spain, [3]University of Nottingham, UK

The architecture of intestinal tissue is crucial for gut health, with the characteristic villi structures supporting diverse epithelial cell types that absorb nutrients, and the crypts hosting stem cells that continuously renew the tissue [1]. In modeling this environment in vitro, the use of organic electronic platforms allows for real-time, non-invasive probing of intestinal barrier function in longitudinal experiments [2]. The goal is to engineer a low-

stiffness, conducting polymer scaffold with the microscale architecture of the extracellular matrix and the larger crypt and villi structures, to act as a bioelectronic gut-on-a-chip model with greater biological complexity. The ink formulations include 50% (v/v) PEDOT:PSS in DI water and 50% of an acrylate mix comprised of 99% (v/v) PEGA and 1% (v/v) PEGDA [3]. The printed scaffolds were then integrated into an electronic transmembrane platform to compare the conductivity of each of the 3D printed scaffold formulations via electrical impedance spectroscopy and cyclic voltammetry [4]. These were confirmed to be biocompatible and to support the growth of fibroblasts filling the structures. Overall, this bioelectronic gut-on-a-chip model provides a scaffold that mimics the 3D structure and mechanical properties of intestinal tissue, enabling cell growth and EIS measurements as a platform to study gut health and disease.



[1] Rudolph et al. ACS Biomater Sci Eng, 2022.
[2] Pitsalidis et al. Chem Rev, 2022.
[3] Lopez-Larrea et al. ACS Appl Polym Mater, 2022.
[4] Pitsalidis et al. Sci Adv, 2022.

(Invited) Personalised biomedical diagnostics: where we are and what the future holds?

Hemant Pandit[1]
[1]University of Leeds, UK

NHS 10-year plan stresses the importance of moving the healthcare from analog to digital, from hospital to the community and from treatment to prevention. This shift in focus is partly in response to reduce the waiting lists and in part to encourage a personalised approach to manage individual patients rather than "one size fits all" philosophy. Use of wearable sensors, implantable devices and associated technology have the potential to shift the NHS focus from disease management to disease prevention, early diagnosis, remote

delivery of patient care and reduction in the need for face-to-face consultations. Indeed the associated advantages can be huge both in terms of health economics as well as efficiency.

There have been many advances over the past 10 years due to miniaturisation of electronic gadgets, technology convergence and trans-disciplinary approach to tackling healthcare issues. Indeed there is a huge market pull and some of the previous inventions have proven there worth but have also raised some key questions such as digital literacy, equity of healthcare, data sharing ethics and so on. Engagement with patients and public leading to co-development of a personalised device, checking their accuracy in a representative population and keeping the patient at the centre of any such interventions is crucial to ensure timely and meaningful progression of these exciting opportunities.

My key note speech will cover the above points and walk the attendees through a handful of examples and provide an overview of the challenges and opportunities in this quickly expanding field of health technology.

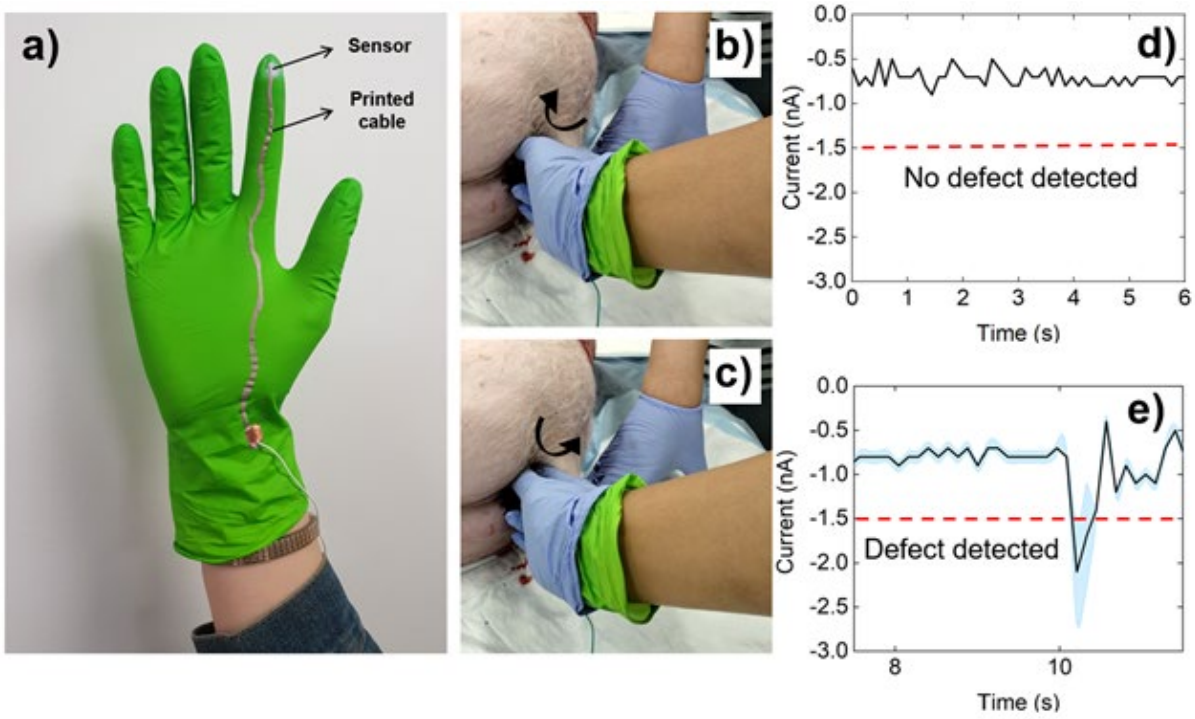
Ex vivo detection of anal sphincter defects using a sensorised surgical glove

Carmen Salvadores Fernandez[1], Shireen Jaufuraully Jaufuraully[3], Dimitrios Siassakos[4], and Manish Tiwari[2]
[1]Hawkes Institute, University College London, UK, [2]Nanoengineered Systems Laboratory, University College London, UK, [3]Elizabeth Garrett Anderson Institute for Women's Health, University College London, UK, [4]NIHR Biomedical Research Centre at University College London, UK

Sensorised gloves with embedded force sensors are useful to map contact and force for a wide range of applications. Following the need for surgical devices, we introduce our novel sprayable nanocomposite-based triboelectric force sensor which can be sprayed directly onto printed electrodes on surgical gloves. Our triboelectric coating-based sensors allow us to sense tactile forces during normal contact and to detect stiffness changes from rubbing signals, unlike previous works which relied on tapping signals. Relying on rubbing motion may be more suitable for surgical and interventional applications where there is a lack of space and maneuverability. Tactile force sensing and stiffness change detection is also feasible with a second surgical glove on top, and the thinness achieved ensures that haptic perception is not impaired.

As a clinical case study, we exploited these sensorised gloves for vaginal and rectal examination to aid diagnosis and assessment of maternal anal sphincter injuries after vaginal birth. Up to 12% of women sustain such injuries, which can have long-lasting effects including faecal incontinence, recurrent urinary tract infection, and fistula formation. Swift diagnosis and repair is key, yet up to 40% are missed on initial assessment. Our aim was to establish whether a sensorised surgical glove could accurately detect injury in pig anal sphincters.

The calibrated sensors achieved a 20 N force range and a 0.1 N sensitivity, enabling accurate and repeatable detection of sphincter defects. We demonstrate a strategy to exploit flexible force sensors to detect injury ex vivo, anticipating improved diagnostic accuracy and outcomes.



Nanopipette Biomedical Sensors: Multifunctional SICM Probes for Single-Cell Phenotyping and In Vivo Sensing

Petr Gorelkin[1], and Yuri Korchev[2]
[1]ICAPPIC, UK, [2]Imperial College London, UK

Scanning ion-conductance microscopy (SICM) uses a micro-/nanopipette to approach living samples from above without lateral contact, enabling non-perturbative imaging of convoluted cell surfaces at nanometre resolution. We combine hopping-mode SICM with fluorescence readouts and intrinsic nanomechanical mapping to run nanoscale assays directly on the membrane, revealing drug-induced remodeling of cytoskeletal mechanics in single cancer cells. Beyond imaging, we repurpose the nanopipette as a local biosensor: (i) label-free, high-resolution mapping of extracellular pH microgradients around living cells, (ii) electrochemical quantification of intracellular reactive oxygen species, and (iii) minimally invasive detection of clinically relevant therapeutics and metal ions in complex models — from tumor spheroids/organoids to live tumors. Most recently, we demonstrated a gold-modified nanopipette for in vitro/in vivo Cu^{2+} sensing with a 0.1–10 µM linear range, providing a route to track metal-based drugs and dysregulated copper homeostasis in cancer. Complementing these capabilities, nanobiopsy with multi-barrel SICM probes enables longitudinal, minimally invasive sampling for single-cell omics from pre-characterized cells, linking phenotype to gene expression over time. By co-registering topography, stiffness, pHe, ROS, and drug/ion readouts with subcellular precision,

nanopipette sensors provide a unified platform for multifunctional phenotyping and microenvironment analytics at single-cell resolution. A recent field review co-authored by Gorelkin highlights how nanopipettes bridge single-molecule/nanopore sensing with electrochemical and optical modalities, paving the way for portable diagnostics. Collectively, these advances position SICM-enabled nanopipettes as versatile biomedical sensors for mechanobiology, pharmacology, and precision oncology, with a clear path from cultured cells to organoids and in vivo applications.

Posters

P1: Characterising Charge Retention of 3D Printed Conductive Hydrogel Scaffolds

Arya Sunkara, Maira Lopez Cavestany, and Róisín Owens
University of Cambridge, UK

PEDOT: PSS is an organic electrically conductive polymer. Recent applications have seen the use of this polymer in 3D organ-on-a-chip technologies where its conductive properties allow for real-time monitoring of cellular growth and barrier integrity. Through digital light printing, we 3D print hydrogels with architectures that mimic human tissue as a cell scaffold. The scaffolds are composed of an aqueous fraction of PEDOT: PSS and DBSA composites in DI water, the concentrations of which were varied during the experiment, and organic fractions of acrylates in equal volumes. The aqueous fraction provides the conductive properties while the acrylates form the hydrogel, creating a need for optimisation between increasing conductivity and low stiffness. Calculating charge retention of the scaffolds is a critical consideration in determining the ideal ink formulations. Cyclic voltammetry (CV) measurements were conducted, where the scaffolds were swept with voltages ranging from -0.5 V to 0.5 V in both a forward and reverse scan, plotting the resultant current. Mathematically, the CV loop area gives us the total charge exchanged in the process. Larger loop areas suggest a higher amount of charge transfer and, therefore, greater charge exchange capacity. Using MATLAB, the area between these curves was calculated and compared across all ink formulations to ascertain trends across different concentrations of PEDOT: PSS and DBSA. Ultimately, the results are critical for improvements in scaffold design that may enhance the reliability of these scaffolds for in vitro studies.

P2: Clinical translation of a time-resolved single-photon imaging system for safe placement of feeding tubes

András Kufcsák[1], Thomas Craven[2], Bea Selby[2], Paul Fineran[2], Joanne Mair[2], Kieran Burgess[2], Katie Hamilton[2], Kev Dhaliwal[2], Robert Thomson[1,2], and Michael Tanner[1,2]
[1]Institute of Photonics and Quantum Sciences, School of Engineering and Physical Sciences, Heriot-Watt University, UK [2]Translational Healthcare Technologies, Institute for Regeneration and Repair, University of Edinburgh, UK

Nasogastric tubes (NGTs) are common to provide nutritional support for patients who cannot take nutrition orally. The placement of NGTs – through the nose down into the stomach - is a routine medical procedure, yet the consequences of misplacement are dire, e.g. food entering the lungs, leading to death and/or disability from pulmonary complications. The current practice for NGT localisation relies on X-rays. This introduces delays to initiation of feeding (associated with worse patient outcomes), increases burden on healthcare system resources, and exposes patients and staff to ionising radiation.

We have developed a clinical prototype system with off-the-shelf componentry (Figure 1), capable of determining the location of an NGT inside the patient's body using near-infrared light. This device utilises an imaging implementation of time-correlated single-photon counting (TCSPC): early photons with a near direct path from a point source of light placed inside an NGT are detected by a time-resolved single-photon sensitive camera positioned outside of the patient [1].

To date, we have validated device functionality, specifically differentiation between stomach and non-stomach NGT placements, in porcine and human cadaver models. We shall shortly be commencing a first in- human clinical study at Edinburgh's Royal Infirmary. Our goal is to develop a compact bedside system with immediate feedback for dynamic tracking of the tube location for tactile optically guided NGT placements.

[1] E. P. McShane, et al., "High resolution TCSPC imaging of diffuse light with a one-dimensional SPAD array scanning system," Opt. Express 30, 27926-27937 (2022)

P3: Time-resolved single photon counting Raman spectroscopy with SPAD arrays

Caitlin Tye[1], Katjana Ehrlich[1], András Kufcsák[1], Calum Ross[1], Andrew Green[1], Robert Henderson[2], and Michael Tanner[1]
[1]Institute of Photonics and Quantum Sciences, Heriot-Watt University, Edinburgh, UK
[2]Institute for Micro and Nano Systems, University of Edinburgh, UK

Raman spectroscopy is a technique used to identify cancerous tissue and other diseases by analysing its chemical composition. A major limitation is that Raman signals from biological samples are weak and often masked by background noise such as fluorescence. Furthermore, accessing the tissue often requires the use of fibre optic probes, which also introduces background noise into the measurement. To overcome this challenge the time-domain can be used to separate these signals as they occur on different time-scales.

Here, we separate Raman scattering and background noise by using a time resolved 512-pixel single photon avalanche diode (SPAD) line sensor array with 512-pixels operating in time-correlated single photon counting modality configured as a spectrometer. In this setup, the SPAD array measures the backscattered light from the sample and the optical fibre as a function of time and wavelength. The arrival time of the photons are used to separate the sample Raman and the background fluorescence/Raman signals. The integrated timing electronics of the SPAD array allow for rapid and multiplexed single photon counting therefore increasing possible count rate, and decreasing measurement time for practical application (30 s in this work). We demonstrate results from organic samples with a miniature (<0.25 mm) probe.

[1] Caitlin S. Tye, András Kufcsák, Calum A. Ross, Katjana Ehrlich, Robert K. Henderson, and Michael G. Tanner, "Time-resolved Raman spectroscopy using a CMOS SPAD array to

remove fluorescent and fibre Raman backgrounds," Biomed. Opt. Express 16, 2824-2834 (2025)

P4: Diffusiophoresis-Enabled Microfluidic Detection of Protein-Coated Colloids for Diagnostic Applications

Christina Puijk[1], Adnan Chakra[2], Goran Vladisavljevic[3], and Guido Bolognesi[1]
[1]Department of Chemistry, University College London, UK , United Kingdom, [2]Department of Chemistry, Imperial College London, UK [3]Department of Chemical Engineering, Loughborough University, UK

The ability to control nanoparticle motion within confined geometries is central to point-of-care diagnostics, where efficient pre-concentration, sorting, and analysis of bioparticles is crucial for processing of the small sample volumes commonly obtained from point-of-care testing. We adopt a previously reported physical mechanism [1] that enables the pre-concentration, sorting, and characterisation of colloidal particles in straight flat microchannels, and extended it for the manipulation of protein-modified polystyrene nanoparticles. Using a 3-inlet double junction microfluidic device, as shown in Figure 1, a steady-state salt concentration gradient was generated perpendicular to the flow. Through diffusiophoretic and diffusioosmotic effects, particles dispersed in the electrolyte solution accumulate into two symmetric regions at the channel edges and centre. The location of accumulation is highly sensitive to the presence, or absence, of a protein corona on the particle surface, highlighting the influence of biologically relevant surface modification on particle mobility. Furthermore, modification of the microchannel surface yielded distinctly different particle dynamics compared to unmodified channels. This tuneable particle manipulation strategy offers a passive method for controlling nanoparticle trajectories in complex fluids. By leveraging particle–solute interactions and the influence of a protein corona on the observed dynamics, this approach provides a platform for point-of-care diagnostics, with applications in bioparticle sensing, sorting, preconcentration, and analysis.

[1] Chakra et al., ACS Nano 17 14644-14657 (2023)

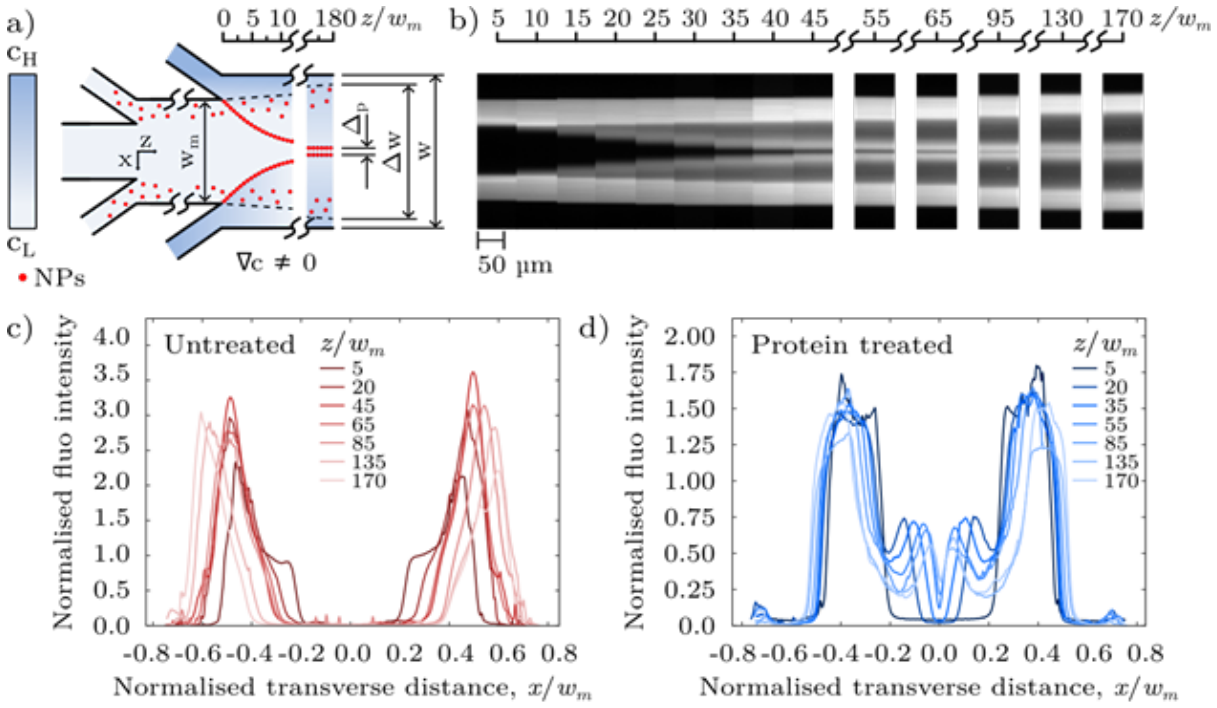


Figure 1 - (a) Experimental setup for the manipulation of modified polystyrene particles using solute concentration gradients. Schematic shows dynamics of particles under a salt concentration gradient, $\nabla c \neq 0$, in a double junction microfluidic device. (b) Images show epi-fluorescence micro-graphs taken at nominal distances from the junction. (c, d) Plots show differences in particle behaviour in protein treated (d) and untreated (c) particles.

P5: Diffusiophoretic Accumulation of Gold Nanoparticles in Paper Based Membranes as a Step Towards Enhancing Sensitivity of Lateral Flow Assay Devices

Henry Peterson[1], Amina Farooq[1], Goran T. Vladisavljevi[2], and Guido Bolognesi[1]
[1]University College London, UK [2]Loughborough University, UK

We report a novel physical passive method for the accumulation of gold nanoparticles (AuNPs) within paper based porous membranes1. A Y-junction paper-based device, as shown in Figure 1a, was used to generate a LiCl salt concentration gradient by merging a low salt concentration cL stream, containing AuNPs, with a high salt concentration cH stream.

The salt contrast drives the diffusiophoretic migrations of AuNPs and their accumulation at the interface between the two streams, as depicted in Figure 1a. To the best of our knowledge, this is the first time that diffusiophoresis of conductive nanoparticles, like AuNPs, has been observed experimentally. Through careful selection of electrolyte conditions and particle surface functionalisation, it is possible to accumulate particles up to 15 times their initial concentration under ionic strengths similar to those in physiological conditions. The intensity of the accumulation peak increases with time (Figure 1b) and it correlates positively with the particle electrophoretic mobility, the ionic strength of the solution, and the relative salt concentration gradient.

Finally, we have designed a proof-of-concept lateral flow test device that exploits the solute-driven accumulation of AuNPs to enhance the device's sensitivity. Unlike other particle manipulation strategies for paper-based microfluidic devices, our approach enables the accumulation of labelling particles in lateral flow assay devices without requiring any power supply or auxiliary equipment, nor compromising the device's portability, simplicity, and ease of fabrication and use.

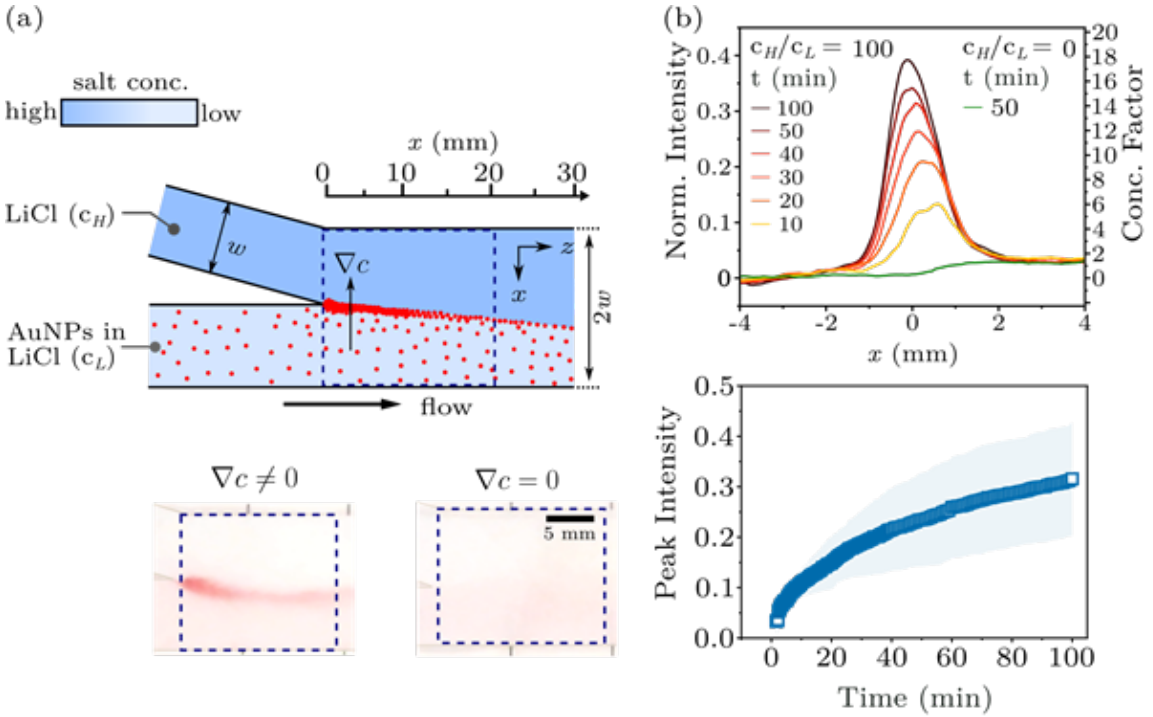


Figure 1: (a) Schematic of the Y-junction paper based device showcasing the accumulation of AuNPs. (b) Time-evolution of the normalised pixel intensity profiles along the transverse (x) direction (top) and peak intensity (bottom).

P6: Functional Patterning of Intracellular Environment

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Cells sense and respond to a variety of environmental cues, including mechanical signals transmitted through the plasma membrane [1]. This process, known as mechanotransduction, is fundamental for regulating cellular function and sensory pathways. Engineered nano- and microstructured surface arrays can be employed to introduce controlled mechanical perturbations at the cell membrane [2], and when combined with tailored surface chemistries, they enable selective biomolecule recruitment.
Here, we present a photolithographically fabricated micropatterned array, functionalized with a specific chemical scaffold to direct the targeted recruitment of transmembrane proteins in HEK-293 cells. We also designed custom 3D-printed microfluidic devices that incorporate the functionalized micropatterned arrays, enabling controlled shear stress to

perturb the cellular environment. This platform offers a tool for investigating the intricate mechanisms of cellular mechanotransduction, potentially advancing our understanding of how cells interpret and respond to mechanical cues.

For functionalization, we employed biotin–streptavidin binding for protein recruitment on gold surfaces, with Biotin/OH PEGs to minimize nonspecific adsorption. This strategy enables highly selective membrane receptor binding via O6-benzylguanine (BG)/SNAP-tag® chemistry [3], with alternative approaches using biotinylated antibodies. Each step of the functionalization process was validated using fluorescence anisotropy measurements and confocal microscopy. We are currently working on selective membrane receptor recruitment by studying HEK cells expressing fluorescently tagged transmembrane receptors with an N-terminal SNAP-tag on gold micro arrays.

[1] Sansen, T. et al. ACS Appl Mater Interfaces 2020. DOI: https://pubs.acs.org/doi/full/10.1021/acsami.0c05432
[2] Gandor et al. Angew Chem Int Ed Engl 2013 DOI: 10.1002/anie.201209127
[3] Keppler et al. Nature biotechnology (2003) DOI: https://doi.org/10.1038/nbt765

P7: Modelling Changing Crypt and Villi Structures Down the Intestinal Tract Using 3D Printed Conductive Hydrogels

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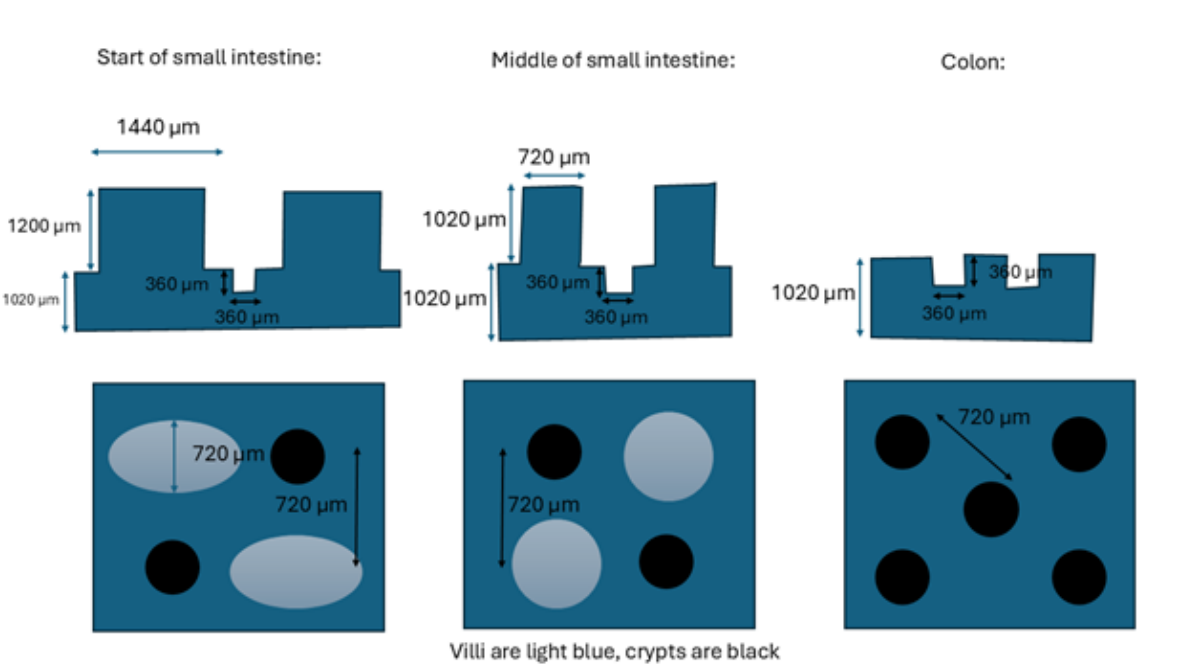
Throughout the intestinal tract, the arrangement of villi and crypts varies, as the intake of minerals and nutrients at each stage of digestion changes [1]. More specifically, the villi start off larger at the oral side of the small intestine and gradually decrease in size further along. By the time the colon is reached, only crypts are present. Three different parts of the tract were modelled and designed using Autodesk Inventor. This included the start of the small intestine, with an alternating pattern of 720x1440x1200 µm (width x length x height) villi and crypts with a diameter and depth of 360 µm. For the middle of the small intestine, a similar pattern was employed, except the villi in this case were cylindrical with a diameter of 720 µm and a height of 1020 µm. Lastly, the colon structure consisted of a hexagonal structure of crypts with the same diameter and depth as previous [2]. For all models, the spacing between adjacent villi and crypts was 720 µm. A pore structure (with cube pores of side length 180 µm) runs along each model; this mimics the extracellular matrix. These models will be 3D printed so that bench top models of the intestinal epithelium can be made. This can be done by by using telomerase-immortalised fibroblasts (TIFs) and Caco-2 cells [3].

[1] Hatoko et al. Nature, 2022. [2] Romanazzi et al. AIM Sciences, 2022. [3] Pitsalidis et al. Sci Adv, 2022.



P8: Design Evolution of Pillar[5]arene-Based Nanopores: From Dynamic Control to High Sensitivity Sensing

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Artificial nanopores offer significant potential for drug delivery, biosensors and synthetic biology applications by enabling controlled molecular transport across lipid membranes. Previous efforts have primarily focused on designing water-soluble macrocyclic ion channels for therapeutic applications, requiring spontaneous membrane insertion and aqueous compatibility. In contrast, nanopore sensing requires different design criteria where stable, low-noise scaffolds with irreversible membrane insertion under physiological conditions are essential. The challenge lies in engineering robust, programmable channels that can simultaneously achieve controlled molecular delivery and high sensitivity sensing, opening new possibilities for advancing precision medicine and biotechnology applications.

Here, we developed pillar[5]arene-based macrocyclic scaffolds through design iterations guided by molecular dynamics simulations, advanced experimental synthesis and characterisation techniques to target these major limitations. Our strategy progressed from membrane spanning optimisation through alkyl chain length variation, stability enhancement through anchoring strategies, and incorporation of photoswitchable units for dynamic control. This evolution from basic membrane insertion to sophisticated stability optimisation has resulted in functional systems capable of guest binding and translocation at a single-molecule level, characterised through single channel recordings in droplet interface bilayers.

P9: Time-Resolved Detection of Singlet Oxygen for Monitoring Benzoporphyrin Uptake and Photodynamic Therapy in Mice

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Photodynamic therapy (PDT) relies on photosensitizer excitation to produce singlet oxygen, the primary cytotoxic agent responsible for tumor destruction. However, direct monitoring of produce singlet oxygen in vivo is challenging due to its short lifetime and weak near-infrared luminescence at ~1270 nm. Conventional techniques for measuring produce singlet oxygen are limited by sensitivity, complexity, or poor temporal resolution, creating barriers to accurate PDT dosimetry.

Here, we report the development of a compact time-resolved singlet oxygen luminescence detection (TSOLD) device, optimized for in vivo applications. The system integrates a pulsed 690 nm fiber-coupled laser, a bifurcated fiber bundle for simultaneous excitation and collection, a series of optical filters for background suppression, and a high-sensitivity InGaAs single-photon avalanche diode (SPAD) detector coupled to time-correlated single-photon counting electronics. This portable configuration enables highly sensitive, real-time detection of produce singlet oxygen signals in mice bearing RIF tumors following benzoporphyrin derivative (BPD) administration.

Our results demonstrate clear produce singlet oxygen luminescence peaks within 180 minutes post-BPD injection, correlating with photosensitizer uptake in tumor tissue. Signal specificity was validated using BPD-free controls and oxygen quenching experiments. Furthermore, pre- and post-PDT measurements revealed a measurable reduction in produce singlet oxygen counts, reflecting BPD photobleaching and therapeutic action. This study validates the TSOLD system as a reliable and practical platform for real-time monitoring of produce singlet oxygen in vivo. Its portability, sensitivity, and time-resolved capability highlight its potential to guide personalized PDT protocols, optimize dosimetry, and improve therapeutic outcomes.

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