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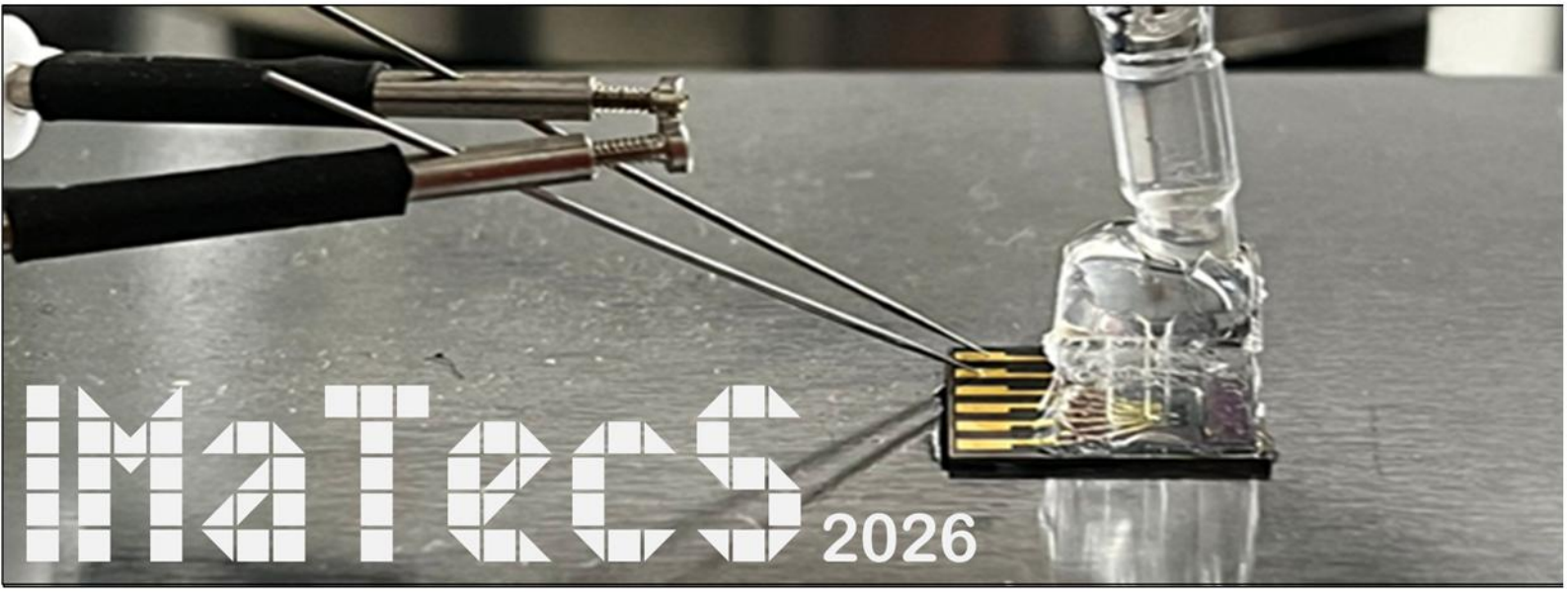

Innovative Materials and Techniques for advanced Sensing

Pozzuoli, 16 Gennaio 2026

Finanziato dall'Unione europea NextGenerationEU

Ministero dell'Università e della Ricerca

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ImaTecS 2026

In the modern world, advanced sensing systems are rapidly becoming ubiquitous, paving the way for the development of a wide range of smart technologies. These include robotics, telecommunications, environmental monitoring platforms, medical devices, and biotechnologies, all of which rely on the ability to detect, process, and respond to complex signals with high precision. Basic driving forces behind this technological transformation are undoubtedly represented by the integration in these systems of novel materials, whose properties can be tailored for targeted applications, and by the implementation of new sensing strategies able to enhance the final performances.

In this scenario, ImaTecS workshop is designed to bring together members of the local and national scientific communities presently committed to investigating innovative materials and techniques for the achievement of high-performance sensing platforms.

A special emphasis will be dedicated to selected classes of materials, including organic semiconductors, hybrid organic-inorganic perovskites, carbon-based and low dimensional nanomaterials, whose properties at the micro- and nanoscale can be engineered to improve detection sensitivity and response stability. Contributions will also address progress in new device architectures and optical/electronic techniques to be mainly applied in the fields of biosensing, photo-sensing and ionizing radiation detection.

Sessions will be aimed at encouraging discussion about emerging trends in this area and stimulating the formulation of new collaborative ideas that could evolve into future projects. The program will conclude with a dedicated round table, involving both scientists and representatives from the industrial sector, with the goal to further strength the dialogue between academic research and practical innovation.

TOPICS

Biosensors	Nanomaterials for sensing	Photosensors and detectors
Electrolyte gated organic transistors	Carbon based materials	Flexible organic devices
Nanoplasmonics	Organic and hybrids	NIR phototransistors
Nanobiosensors	2D materials	Weareble devices

ImaTecS 2026

Members of the Scientific and Organizing Committee:

Mario Barra (CNR-SPIN),
Fabio Chiarella (CNR-SPIN),
Patrizia Minutolo (CNR-STEMS),
Ettore Sarnelli (CNR-SPIN),
Antonio Vettoliere (CNR-ISASI),
Secretariat: Valentina Formicola (CNR-ISASI)
Website: Francesco M. Taurino (CNR-SPIN)

Contacts

imatecs@spin.cnr.it
https://imatecs.spin.cnr.it/

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PROGRAM

08:30	**Registration**	
09:15	Welcome address	
09:25 - 11:10	**Session I**	Chair: *Mario Barra*
09:25	Stefano Toffanin	Smart-integrated System based on Organic Optoelectronic Components for Optical Biosensing
09:50	Lucia Petti	From nanomaterials to biosensors: the smartsenso approach to diagnostics and food safety
10:10	Valentina Preziosi	Integrating microfluidics and biosensing techniques to detect biomarkers in biological fluids
10:30	Roberto Di Capua	Synthesis and characterization of bio-inspired molecules starting from 5,6-dihydroxyindole (DHI) for implantable and stretchable bioelectronics
10:50	Ettore Sarnelli	High-performance flexible organic phototransistors
11:10	*Coffee break/Poster session*	
11:45 – 13:30	**Session II**	Chair: *Patrizia Minutolo*
11:45	Carlo Altucci	Innovative Nanomaterials for sensing and biomedical applications at the NANO-PHOR-UNINA group
12:10	Silvia Romano	Bound States in the Continuum in Nanophotonic Metasurfaces for Next-Generation Biomedical Sensors and Advanced Light–Matter Interaction Control
12:30	Vincenzo Guarino	Biofunctional interfaces via electro fluid dynamics: from diagnosis to treatment
12:50	Gino Giusi	Low Frequency Noise in DNTT/Cytop Organic Thin Film Transistors
13:10	Fabio Chiarella	2D Organic-Inorganic Halide Perovskites for Hybrid Heterostructures: single crystals, thin films and exfoliated flakes
13:30	*Lunch/Poster session*	
14:35 – 16:20	**Session III**	Chair: *Antonio Vettoliere*
14:35	Massimo Cuscunà	2D and 3D Nanostructured Sensing Platforms: Enabling Ultrasensitive Diagnostics for Personalized Medicine
15:00	Simonetta Grilli	Highly sensitive detection of protein biomarkers by using an innovative pyro-electrohydrodynamic jet
15:20	Pierluigi Casolaro	Probing radiation effects on solid-state devices through impedance spectroscopy
15:40	Davide D'Ambrosio	Whispering-Gallery Mode Raman sensing and nanoparticle detection
16:00	Luca Basta	Flame synthesis of carbon nanoparticle thin films for innovative sensors

16:20	*Coffee break/Poster session*	
16:50 – 18:00	**Session IV**	Chair: *Ettore Sarnelli*
	Round Table: from science to industries	
18:00	Remarks and Greetings	

POSTER SESSION

High-responsivity and fast response DNTT-based phototransistor
A. Caldarelli, A. Vettoliere, F. Chiarella, L. Basta, P. Minutolo, M. Campajola, V. Izzo, G. Giusi, A. Aloisio, E. Sarnelli.

Xerosydryle and electro-optical transport properties
R. Germano, F. Ciccarelli, A. Calabrese, G. Malandra

Innovative Flexible Bottom-Up SERS Materials for Ultra-Sensitive Detection of Toxins and Pathogens in Biomedical and Food Matrices
A. D'Avino, A. Milano, V. Marchesano, B. Guilcapi, D. Sagnelli, M. Rippa, L. Petti

Flame synthesized nanostructured C-TiO2 films for sensing and electronic device applications
A. Khalique, G. De Falco, P. Minutolo, M. Commodo, A. D'Anna

High-Sensitivity SERS Profiling of Shiga Toxins: Bridging Fundamental Validation and Real-World Clinical Application
A. Milano, A. D'Avino, V. Marchesano, D. Sagnelli, M. Rippa, B. Guilcapi, L. Zhou, M. Brigotti, S. Morabito, L. Petti

Design and characterization of N-type isoindigo semiconductors for organic electronics and sensing
F. Mocerino, M. Barra, F. Borbone, A. Carella, R. Centore, F. Chiarella, A. Landi, A. Peluso

An Autonomous Multi-Agent Framework for Deep Learning Architecture Discovery and Optimization in SERS-based Pathogen Detection
D. Sagnelli, B. Guilcapi, A. D'Avino, A. Milano, V. Marchesano, M. Rippa, L. Petti

Femtosecond laser nanotexturing for high performance and reusable silicon SERS platforms
M Valadan, X. Zhao, Y. He, J. JJ Nivas, A. Purushothaman, C. Altucci, K.Lin, Y. Lun, S. Amoruso, X. Wang

Hybrid nanocomposites: effect of different synthesis route on electrical memristive behaviour
A. Zotti, S. Aprano, A. Rafiq, S. Zuppolini, M. Zarrelli, M. G. Maglione, P. Tassini, A. Cassinese, A. Borriello

IMaTecS 2026

Session I 09:25 - 11:10

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09:50	Lucia Petti	From nanomaterials to biosensors: the smartsenso approach to diagnostics and food safety
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10:50	Ettore Sarnelli	High-performance flexible organic phototransistors

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Smart-integrated System based on Organic Optoelectronic Components for Optical Biosensing

Stefano Toffanin
Institute for the Study of Nanostructered Materials (ISMN), Italian National Research Council (CNR), Italy
Via Gobetti, 101 40129 Bologna
stefano.toffanin@cnr.it

The continuous growth of the global population has been remarking the need of early detection systems to prevent the spread of epidemics as well as to improve the standards of living. The emerging demand of sensing technologies has prompted researchers and industrial companies to develop devices able to monitor medical, food, water, and environmental safety/quality indicators in an efficient, simple, and reliable way. While high sensitivity and selectivity must be guaranteed, compactness, user-friendliness and low-cost are key characteristics to enable the use of the sensing technology for point-of-care diagnostics without the need for trained personnel.
In this scenario, organic optoelectronic components might enable the definition of new miniaturized detection schemes to boost the advent of compact optical sensors for on-site analysis, given their inherent capability of smart monolithic integration in nm-thick multi-stack devices on almost any surface[1].
Here, we report the integration of organic light-sources and -detectors (such as light-emitting diodes and transistors, and organic photodiodes) into ultra-compact systems for plasmonic- and fluorescence-based detection without the implementation of bulky optical components. Suitable nanostructured bidimensional plasmonic photonic components are implemented for enabling and improving the sensing capabilities[2]. The components and the layout of integration were suitably designed to make the elements work cooperatively in a reflection-mode configuration. In particular, the organic photodiode was vertically stacked onto the organic light-emitting transistor thus providing electrical switching, light-emission and light-sensing in a single organic multilayer architecture[3]. We demonstrated remarkably low sensor size as low (0.1 cm^3), while providing (i) a quantitative and linear response that reaches a limit of detection of 10^{-4} refractive index units for surface-plasmon resonance[4] and (ii) significant increase of the signal-to-noise ratio allows for halving the detection limit to 9.2 μM for a fluorescent-dye detection[5].
Finally, we will report our latest results on the use of a semi-automatic prototype of the integrated optical biosensor as a screening test for the detection of albenzole pesticide and sulfonamide antibiotic in spiked and raw milk samples.

References

[1] M. Prosa et al. *Nanomaterials* **2020**, *10*, 480.
[2] E. Benvenuti et al. *Org. El.* **2024**, *128*, 107023.
[3] M. Prosa et al. *Adv. Funct. Mater*. **2021**, *31*, 2104927.
[4] M. Bolognesi et al. *Adv. Mater.* **2023**, 2208719.
[5] E. Benvenuti et al. *J. Mater. Chem. C* **2024**,*12*, 4243.

FROM NANOMATERIALS TO BIOSENSORS: THE SMARTSENSO APPROACH TO DIAGNOSTICS AND FOOD SAFETY

A. Milano[1], A. D'Avino[1], V. Marchesano[1], M. Rippa[1], B. Guilcapi[1], D. Sagnelli[1], G. Ardissino, M. Brigotti[2,1], S. Morabito[3,1], L. Petti[1]

[1]Institute of Applied Sciences and Intelligent Systems of CNR, 80072 Pozzuoli, Italy

[2]Dipartimento di Medicina Specialistica, Diagnostica e Sperimentale, Sede di Patologia Generale, Università di Bologna, 40126 Bologna, Italy;

[3]Laboratorio Nazionale di Riferimento per E. coli, Dipartimento di Sicurezza Alimentare, Nutrizione e Sanità Pubblica Veterinaria, Istituto Superiore di Sanita, 00161 Rome, Italy

Lucia.petti@isasi.cnr.it

Shiga toxin-producing *Escherichia coli* (STEC) are among the most dangerous foodborne pathogens, responsible for severe diseases such as hemorrhagic colitis and hemolytic uremic syndrome (HUS). Rapid, sensitive, and accurate identification of different Shiga toxin variants (Stx1, Stx2, and Stx2 cleaved) is crucial for effective clinical diagnostics and outbreak control [1, 2]. In this study, we present a **dual-platform SERS strategy** that combines two innovative and efficient sensing architectures: (1) **flexible SERS substrates** based on Kapton films coated with gold nanoparticles, and (2) **nanoengineered plasmonic metasurfaces** fabricated via electron beam lithography on gold-coated glass. Both platforms enable **label-free, real-time detection** of Shiga toxins with high sensitivity and molecular specificity. The flexible sensors offer a **low-cost, portable**, and conformable solution suitable for point-of-care applications, achieving **enhancement factor of 5.41 × 10^6** and an impressive **limit of detection (LOD) as low as 15 pM**. In parallel, the nanostructured metasurfaces, characterized by highly reproducible periodic architectures, yielded LODs of **7 pM for Stx1a,** and **2 pM for Stx2a**, confirming their capability for ultra-sensitive detection. To overcome the challenges posed by the high structural similarity between toxin subtypes, we applied **Principal Component Analysis (PCA)** to the acquired SERS spectra, enabling robust spectral discrimination and classification of the three toxin variants. PCA revealed distinct clustering patterns for each variant, confirming the capability of both sensor platforms to differentiate even subtle biochemical differences.

Together, these results illustrate the **SmartSenso vision**: leveraging tailored nanostructures—from flexible colloidal assemblies to lithographically defined metasurfaces—coupled with intelligent data analysis to deliver robust, low-cost, and high-performance biosensing solutions. This **integrated approach** supports real-time pathogen monitoring across clinical, environmental, and food supply domains, paving the way for scalable diagnostic technologies capable of addressing emerging public-health challenges.

Acknowledgements**:** *The authors gratefully acknowledge the support for this work from European Union - NextGenerationEU Call PRIN2022 Development of a plasmonic nanobiosensor for the rapid diagnosis of Shiga toxin producing E. coli human infections at the point of care - SENSOSTEC (CUP B53D23019990006).*

References

[1] M. Rippa, A. Milano, V. Marchesano, D. Sagnelli, B. Guilcapi, A. D'Avino, G. Palermo, G. Strangi, L. Consagra, M. Brigotti, R. Tozzoli, J. Zyss, L. Petti, *Nanophotonics* **2025**, *14*, 4005-4018.

[2] A. Milano, A. D'Avino, V. Marchesano, D. Sagnelli, M. Rippa, B. Guilcapi, L. Zhou, E. Varrone, G. Rossi, M. Brigotti, G. Ardissino, S. Morabito, L. Petti, *ACS Appl. Mater. Interfaces* **2025**, *17, 46, 63237–63252*.

[3] A. D'Avino, A. Milano, V. Marchesano, B. Guilcapi, D. Sagnelli, M. Rippa, L. Zhou, G. Rossi, L. Consagra, M. Brigotti, S. Morabito, L. Petti, *Biosensors and Bioelectronics: X* **2025**, *27,* 100696.

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Integrating microfluidics and biosensing techniques to detect biomarkers in biological fluids

M. Barra[1], G. Tomaiuolo[2,3], J. Babic[4,5], A. Ballesio[4,5] S. L. Marasso[4,5], M. Cocuzza[4,5], V. Preziosi[2]

1 CNR-SPIN, c/o Dip. di Fisica "Ettore Pancini", Università di Napoli Federico II, 80125 Napoli, Italy

2 Dip. di Ingegneria Chimica, dei Materiali e della Produzione Industriale, Università di Napoli Federico II, 80125 Napoli, Italy

3 CEINGE, Biotecnologie Avanzate, Via Gaetano Salvatore 486, I-80145 Naples, Italy

4 PiQuET LAB- Piemonte Quantum Enabling Technology -

Str. delle Cacce, 91, Politecnico di Torino, I-10129 Torino, Italy

5 IMEM-CNR, Parco Area delle Scienze 37/A, 43124 Parma, Italy

valentina.preziosi@unina.it

The use of microfluidic and biosensing technologies has recently opened avenues for the creation of compact and effective diagnostic instruments. This study deals with an innovative integrated lab-on-a-chip apparatus coupled with organic electrochemical transistors (OECTs) for the precise analysis of specific biomarkers in biological fluids, including human blood and seminal fluid. In recent years, OECTshave gained significant attention due to their capability to enable ionic-electronic transduction at low voltages (< 1V), as versatile platforms for biosensing applications[1-4]. These devices are made of three electrodes—source, drain, and gate—alongside an active layer of conducting polymer. The polymer channel links the source and drain contacts and is electrically connected to the gate electrode through an electrolyte. By applying a voltage to the gate, ions migrate from the electrolyte into the polymer channel, effectively modulating in a reversible way the electronic current between the drain and source electrodes. In this work, in particular, we show how OECTs based on PEDOT:PSS channels, coupled with microfluidics and driven by antibody-functionalized gates electrodes can be employed for the detection of cardiac biomarkers. The results shed light on both the potential of utilizing such lab-on-a-chip platform in biosensing applications, providing invaluable insights for future advancement in the field of bioelectronics.

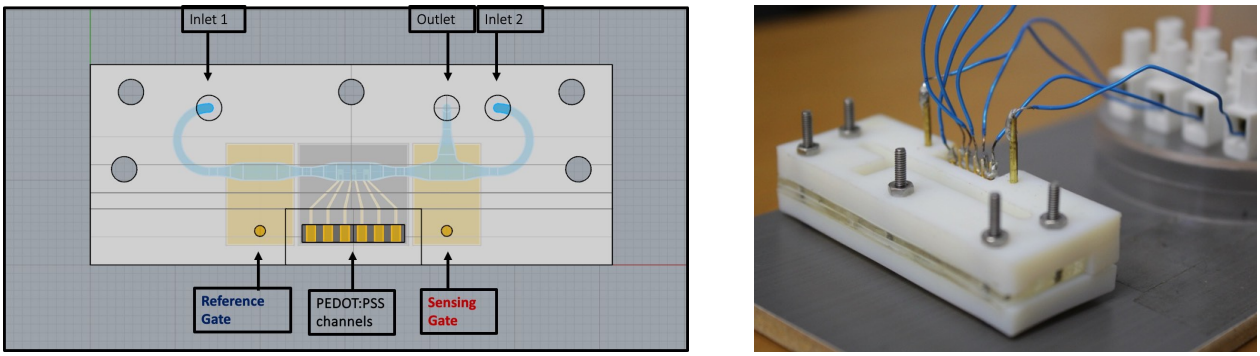

***Figure 1**: Sketch and image of the lab-on-chip platform combining microfluidics and highly sensitive OECTs.*

References

1. V. Preziosi, et al., *Journal of Materials Chemistry B*, **10**, 87-95 (2022).
2. V. Preziosi, et al., *Biosensors*, **13**, 448 (2023).
3. M. Barra, et al, *Biosensors*, **13**, 739 (2023).
4. J. Rivnay et al., *Nature Reviews Materials*, **3**, 17086 (2018).

SYNTHESIS AND CHARACTERIZATION OF BIO-INSPIRED MOLECULES STARTING FROM 5,6-DIHYDROXYINDOLE (DHI) FOR IMPLANTABLE AND STRETCHABLE BIOELECTRONICS

Jalal Ahmad[1], Domenica Capasso[1,2], Emanuele Carrella[1], Roberto Di Capua[1,2,3,4], Alfonso Iadonisi[5], Alessandro Pezzella[1,2,6,7]

[1]*Dipartimento di Fisica "E. Pancini", Università degli Studi di Napoli "Federico II", Via Cinthia, 80126 Napoli (Italy)*

[2]*Bioelectronics Task Force at University of Naples Federico II, 80126 Napoli (Italy)*

[3]*Institute of Sciences and Technologies for Sustainable Energy and Mobility (STEMS), CNR, Via Marconi, 80126 Napoli (Italy)*

[4]*Institute for Superconductors, Innovative Materials and Devices (SPIN), CNR, Piazzale Tecchio 80, 80125 Napoli (Italy)*

[5]*Dipartimento di Scienze Chimiche, Università degli Studi di Napoli "Federico II", Via Cinthia, 80126 Napoli (Italy)*

[6]*Institute for Polymers Composites and Biomaterials (IPCB), CNR, Via Campi Flegrei 34, IT, Naples, 80078 Pozzuoli (Italy)*

[7]*National Interuniversity Consortium of Materials Science and Technology (INSTM), Piazza S. Marco 4, 50121 Firenze (Italy)*

roberto.dicapua@unina.it

Organic semiconductors have gained significant attention for bioelectronics due to their biocompatibility, flexibility, and ability to efficiently conduct both ionic and electronic charges. Compared to conventional conducting polymers and carbon-based compounds, bio-inspired materials ensure higher biocompatibility and functionalization possibility. Achieving suitable level of electrical conductivity, reproducible behaviour and stable operation (also in physiological environments), in view of the realization of biosensing devices, remains however a challenge for thin films based on bio-inspired molecules.

Recent work demonstrated that selenium oxidative action and its possible incorporation into 5,6-dihydroxyindole (DHI) enhances conductivity and electrochemical stability, making it a promising candidate for OECT (Organic Electro-Chemical Transistor) based applications. In our experiments, selenium tetrachloride ($SeCl_4$) was reacted with DHI under controlled conditions, and the resulting materials exhibited improved charge transport properties. Nuclear Magnetic Resonance (NMR) measurements provided insights about the synthesized molecules. The thin films fabricated from Se-DHI were characterized using UV-Visible spectroscopy, dc electrical transport measurements, impedance spectroscopy, revealing significant enhancements in electronic behaviour and providing information about the fundamental mechanisms involved in the electrical transport.

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High-performance flexible organic phototransistors

Antonio Caldarelli[1], Antonio Vettoliere[2], Fabio Chiarella[3], Luca Basta[4], Patrizia Minutolo[5], Marcello Campajola[6], Vincezo Izzo[6], Gino Giusi[7], Alberto Aloisio[6,8,9], Ettore Sarnelli[6,9]

[1]*CNR-SPIN Napoli, c/o Dipartimento di Fisica "Ettore Pancini," Via Cinthia, 21, 80126 Napoli, Italy*
[2]*CNR_ISASI – Comprensorio Olivetti, Via Campo Flegrei 34, 80078 Pozzuoli (NA) - Italy*
[3]*CNR-SPIN Napoli, c/o Dipartimento di Fisica "Ettore Pancini," P.le Tecchio 80, 80125 Napoli, Italy*
[4]*Dipartimento di Fisica "Ettore Pancini," P.le Tecchio 80, 80125 Napoli, Italy*
[5]*CNR-STEMS, P.le Tecchio 80, 80125 Napoli, Italy*
[6]*INFN Napoli, c/o Dipartimento di Fisica "Ettore Pancini," Via Cinthia, 21, 80126 Naples, Italy*
[7]*Dipartimento di Ingegneria, Università di Messina, Contrada di Dio, 98158 Sant'Agata, Messina, Italy*
[8]*Dipartimento di Fisica "Ettore Pancini," Via Cinthia, 21, 80126 Napoli, Italy*
[9]*CNR_SPIN – Comprensorio Olivetti, Via Campo Flegrei 34, 80078 Pozzuoli (NA) - Italy*
ettore.sarnelli@cnr.it

Today, the growing market and social demands drive research toward new functional materials and the development of efficient and miniaturized devices in many sectors. Preventive medicine, medical diagnostics, and telecommunications are particularly relevant for advanced societies. Indeed, flexible, light-responsive devices represent an important step forward in next-generation healthcare and communication technologies. Their flexibility allows integration into wearable systems for continuous, comfortable monitoring of vital signs, even in non-hospital environments. Light sensitivity adds optical sensing and data transmission via visible light communication (VLC), that offers high bandwidth and immunity to electromagnetic interference. Combining these features can lead to multifunctional platforms for real-time diagnostics, personalized medicine, and smart connectivity. To this goal, we have developed a process for making thin film organic phototransistors (OPTS) on flexible substrates, using DNTT (dinaphtho-thieno-thiophene) as semiconductive active layer and Al_2O_3 as dielectric. We have optimized the fabrication of bottom gate-top contact OPTs, which have yielded excellent electrical mobility, up to 5 $cm^2/V \cdot s$, which is about the double with respect similar organic transistors using DNTT and Al_2O_3[1]. Most likely, this is a result due to clean interface between the organic and the dielectric layers, obtained by using plasma treatments and Self-Assembled Monolayer (SAM). As a consequence, light response parameters, such as optical sensitivity and responsivity, significantly improved with respect our previous samples[2]. Indeed, our OPTs respond to power density values as low as 39 nW/cm^2, providing photosensitivity up to 120, and responsivity up to 250 W/A. For their use in optical communications, we tested the OPTs up to 150 kHz, using LED diodes to irradiate them. We plan to investigate their response at even higher frequencies, using laser diodes. Finally, some of us (MC, AA, ES) investigated the employment of OPTs, coupled to organic scintillators, as dosimeters of 5 Mev proton beams, value close to the effective ones hitting the organs in medical treatments[3]. Preliminary tests have demonstrated a direct response of Al_2O_3-based OPTs to ionizing particle beams, without the use of scintillators. In the future, efforts are expected to focus on this direction too.

***Acknowledgements*:**
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References
[1] M. Geiger, *Scientific Reports* **11**, 6382, pages 1-13
[2] A. Vettoliere et al., *IEEE Journal of Electron Devices Society* **2025**, 13, pages 317-325
[3] S. Calvi et al., *NPJ Flexible Electronics* **2023**, 5, pages 1-11

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Session II 11:45 – 13:30

11:45	**Carlo Altucci**	**Innovative Nanomaterials for sensing and biomedical applications at the NANO-PHOR-UNINA group**
12:10	Silvia Romano	Bound States in the Continuum in Nanophotonic Metasurfaces for Next-Generation Biomedical Sensors and Advanced Light–Matter Interaction Control
12:30	Vincenzo Guarino	Biofunctional interfaces via electro fluid dynamics: from diagnosis to treatment
12:50	Gino Giusi	Low Frequency Noise in DNTT/Cytop Organic Thin Film Transistors
13:10	Fabio Chiarella	2D Organic-Inorganic Halide Perovskites for Hybrid Heterostructures: single crystals, thin films and exfoliated flakes

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INNOVATIVE NANOMATERIALS FOR SENSING AND BIOMEDICAL APPLICATIONS AT THE NANO-PHOR-UNINA GROUP

Carlo Altucci[1,2,3]
[1]*Dipartimento di Scienze Biomediche Avanzate, Università degli Studi di Napoli Federico II, Napoli, Italia*
[2]*CNR-ISASI Pozzuoli (NA), Italia*
[3]*Istituto Nazionale di Fisica Nucleare, sezione di Napoli, Napoli, Italia*

carlo.altucci@na.infn.it

Various applications of innovative nanomaterials aimed at sensing and biomedical sciences are reviewed, taking place at the Nano-Phor group[1]. In particular, a portable and innovative immunosensor is presented, capable to detect antigens of various types such as pesticides like parathion and mytoxins like patulin[2,3]. The device is based on a proper immuno-functionalization process of a Quartz Crystal Microbalance[4], by means of the so-called Photonic Immobilization Technique[5]. Sensitivity and Specificity of the realized sensor are very good and comparable to what obtained by the use of large, off-line monitoring facilities such as LC-MS laboratories. The device detects antigens in real time either in water-based environment and, more recently in gas phase in its refined version, that has been patented for polyciclic aromatic hydrocarbons monitoring, emitted in combustion[6].
Large scale production in liquid phase of nanomaterials of several types is also presented, based on the Liquid Phase Exfoliation method. It is possible this way to produce biocompatible water-based solutions of nanoparticle, nanoflakes and quantum dots, meant for wide-spread applications with specific focus to biomedical sciences, such as (*i*) photo-thermal effect possibly employed for tumor single cell mapping[7], (*ii*) Magnetic Resonance Imaging with fabrication and test of novel biodegradable contrast agents based on innovative magnetic nanomaterials and nanocomplexes[8] and (*iii*) the study of functionalization dependent biodegradability od 2D antimonene by peroxidases in human cells.

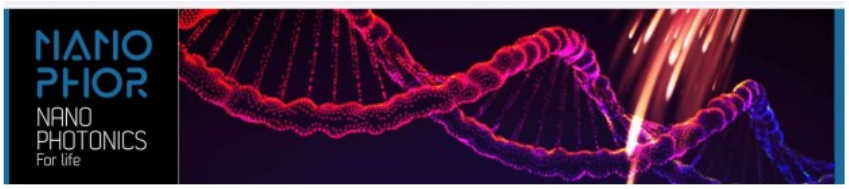

Figure 1*: Nano-Phor Unina Group at https://nano-phor.unina.it/*

References

[1] see the web site https://nano-phor.unina.it/.
[2] R. Funari et al. *Anal. Chem.* **2013**, *85*, 6392
[3] B. Della Ventura et al. *ACS Appl. Mat. & Int*. **2016**, *8*, 21762-21769
[4] B. Della Ventura et al. *PLOS One* **2017**, DOI:10.1371/journal.pone.0171754
[5] R. Funari et al. *Bionsensor & Bioelectronics* **2015**, *67*, 224-229
[6] *Metodo per la rivelazione e la misura di antigeni specifici* **2022**, N. 102021000002717
[7] G. Rusciano et al. *Front. Bioeng. Biotechnol* **2022**, *10*, 844011
[8] C. Feoli et al. *Biodegradable 2D Magnetic Nano-complexes in biomedical application for Dual T1 and T2-Weighted Magnetic Resonance Imaging: a novel approach*, to be submitted
[9] J. Kaur et al. *Nanoscale* **2025**, *17*, 11293-11304

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Bound States in the Continuum in Nanophotonic Metasurfaces for Next-Generation Biomedical Sensors and Advanced Light–Matter Interaction Control

Silvia Romano[1*], Bruno Miranda[1], Ankit Singh[1], Annalisa Lamberti[2], Scott Duhey[3], Adam Schwartzberg[3], Vito Mocella[1], Ivo Rendina[1], Gianluigi Zito[1]

[1]*Institute of Applied Sciences & Intelligent Systems, National Research Council, CNR-ISASI, Naples, Italy*
[2]*Department of Molecular Medicine and Medical Biotechnology, University of Naples Federico II, Naples, Italy*
[3]*Molecular Foundry, Lawrence Berkeley National Laboratory, Berkeley, California*
[*]*corresponding author: silvia.romano@cnr.it*

Photonic bound states in the continuum (BICs) constitute a unique class of electromagnetic modes that, despite existing within the continuum of radiation states, remain decoupled from external radiation [1, 2, 3]. Their non-radiative character results in ultrahigh radiative quality factors (Qr up to 10^6), enabling strong light confinement and extraordinary sensitivity to minute refractive index changes. These features make BICs particularly suitable for advanced biosensing, environmental monitoring, and bioanalytical applications, where precision and rapid detection are crucial. Our research group has demonstrated numerous applications of BICs, including biological and chemical sensing and imaging with the ability to detect molecules of ultralow weight [4, 5, 6, 7], as well as surface-enhanced fluorescence emission and Raman scattering [8] and directive giant upconversion via supercritical coupling [9]. Herein, we present our recent progress in developing integrated nanophotonic biosensors based on BIC-enabled metasurfaces. Large-area, transparent, all-dielectric metasurfaces are engineered and functionalized with biomolecular recognition elements such as aptamers, proteins and molecularly imprinted polymers (MIPs). This integration allows for highly specific detection of biomolecules at ultralow concentrations, down to the femtomolar regime [10, 11]. Our approach demonstrates that BIC-based metasurfaces offer a versatile platform for next-generation biosensing technologies. By combining ultrahigh sensitivity, microfluidic compatibility, and scalable fabrication, these devices hold strong potential for applications in healthcare diagnostics, personalized medicine, and high-throughput bioanalytics. Finally, we propose hybrid nanostructures that combine dielectric and plasmonic components. These architectures leverage the strong field enhancement of metals with the sharp spectral response of dielectrics, offering an effective route toward biosensors with simultaneously high sensitivity and high figures of merit (FOMs).

References

1. C. Hsu et al., *Nat. Rev. Mater.* **1,** (2016)
2. J. Lee et al., *Phys. Rev. Lett.* **109,** 67401 (2012)
3. V. Mocella and S. Romano, *Phys. Rev. B - Condens. Matter Mater. Phys.* **92,** 1–5 (2015)
4. S. Romano et al., Photon. Res. 6, 726 (2018)
5. G. Zito *et al.*, Nanophotonics-Berlin 10, 4279, (2021)
6. S. Romano et al., ACS Nano 14, 15417, (2020)
7. C Schiattarella et al., Biosensors and Bioelectronics: X 12, 100262 (2022)
8. S. Romano et al., *J. Phys. Chem.* **122,** 19738–19745 (2018)
9. C. Schiattarella et al., Nature (2024)
10. G. Zito et al., Advanced Science 11.41, 2401843 (2024)
11. B. Miranda et al., Biosensors and Bioelectronics, 117754 (2025)

BIOFUNCTIONAL INTERFACES VIA ELECTRO FLUID DYNAMICS: FROM DIAGNOSIS TO TREATMENT

Vincenzo Guarino

Institute of Polymers, Composites and Biomaterials (IPCB), National Research Council of Italy, Mostra d'Oltremare Pad. 20, Viale J.F. Kennedy 54, 80125 Naples, Italy;

Corresponding author: vincenzo.guarino@cnr.it, vguarino@unina.it

Electro-fluid dynamics (EFDs) are currently accredited as highly versatile and cost-effective processes to design green materials and/or biomaterials by the application of high-voltage electric fields, in the form of fibres and/or particles with tailored sizes and functionalities, from macro- to nano-metric scale [1,2].

Bio- active and degradable polymers can be variously processed to fabricate a large variety of cell-instructive platforms serving as scaffolds [3], templates [4] and in vivo-like symmetric [5] or asymmetric [6] interfaces to investigate biological interactions that regulate the physiological activity of cells, typically mediated by the microenvironment. Organic phases with electro-conductive [7]/piezoelectric properties [8] or inorganic nanoparticles with electric, magnetic or optical properties (e.g., iron NPs [9], MXenes[10], Nanodiamonds[11]) can be also embedded to design nanocomposite fibres for bio-functional applications (e.g., bioactuation[12], biosensing [13]). Moreover, biopolymers can be functionalized to design innovative drug loaded membranes [141], fibrogels [15], micro-[16] or nano-carriers[17], for therapeutic treatments via oral/intranasal routes and nanomedicine.

In this view, the large versatility of EFDs may also serve to define new strategies to modify "ad hoc" interface/surface properties, for a promising use in the fabrication of functionalized bio-textiles [18] and composite integrated devices [19].

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References:

[1] V. Guarino et al. *Nanomedicine* **2016**, 11(12):1515.
[2] Z. Renkler et al. *Polymers,* **2022**, 14 (19), 4249.
[3] C Vineis et al. *Int J Biol Macromol*, **2021**, 190, 375.
[4] P. Guida et al. *ACS Biomater. Sci. Eng*. **2020**, 6, 3649.
[5] I. Cruz-Maya et al. *Gels*, **2023**, 9 (11), 846.
[6] Z. Renkler et al. *Col & Surf B: Biointer*, **2025**, 256, 115023.
[7] E. Saracino et al. *RSC Adv,* **2021**, 11 (19), 11347.
[8] W. Serrano et al. *Materials,* **2023**, 16 (8), 3106.
[9] I. Cruz-Maya et al. *Polymers* **2025**, 17(13), 1877.
[10] Z. Renkler et al. *Macromol Mat & Eng*. **2025**, 310, 7, 2400433.
[11] V. Guarino et al. *ACS Appl Nano Mater*. **2020**, 3, 11, 10814.
[12] V. Iannotti, V. Guarino et al. *Sens & Act* A: Phys **2024**, 371, 115272
[13] R. Styles et al. *Adv Opt Mat* **2024***,* 12 (14), 2302940.
[14] I. Cruz-Maya et al. *Pharmaceutics* **2024**, 16 (7), 925.
[15] A. Salama et al. *Carbohyd Polym,* **2020***,* 229 115472.
[16] Cruz-Maya et al. *Pharmaceutics* **2024**, 16 (2), 193.
[17] S. Zuppolini et al. *Mater Sci & Eng C* **2020**, 108, 110385.
[18] F. De Falco et. al, *J Col & Inter Sci* **2019**, 541, 367.
[19] Z. Renkler et al. *Pharmaceutics*, **2024**, 16 (1), 134.

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Low Frequency Noise in DNTT/Cytop Organic Thin Film Transistors

G. Giusi
Engineering Department, University of Messina, I-98166 Messina, Italy
ggiusi@unime.it

Organic Thin Film Transistors (OTFTs) based on dinaphtho-[2,3-b:2′,3′-f]thieno[3,2-b]thiophene (DNTT) are attracting considerable interest due to their excellent DC stability under ambient conditions and relatively high mobilities [1]. High-performance DNTT OTFTs have demonstrated mobilities up to 8.3 cm²/V/s and on/off ratios exceeding 10^8 [2–4]. In this work, we investigate the low-frequency noise (LFN) characteristics of OTFTs designed for optoelectronic applications, featuring a staggered bottom-gate top-contact configuration, employing DNTT as the semiconductor layer and the fluoropolymer Cytop™ as the dielectric. LFN measurements were performed using a specially adapted high-sensitivity noise measurement setup [5]. Noise spectra (not shown) were acquired by biasing the devices in the linear regime (V_{DS} = −1 V) at increasing gate voltages, exhibiting a typical flicker-type (1/f) behavior. Figure 1(a) presents the square root of the normalized noise power spectral density (PSD) S_{ID}/I_D^2 at f=1 Hz, scaled by the geometrical factor $k_{NF}=kTq^2/(WLC_{ox}^2 f)$, as a function of the bias ($-g_m/I_D$), for Cytop-based and reference SiO_2 devices with different gate lengths (50 µm to 500 µm) and W = 1000 µm. The noise data are interpreted within the correlated mobility fluctuation (CMF) framework [6]. Figure 1(b) reports the corresponding extracted trap densities as a function of the effective mobility. The results reveal a clear correlation between lower mobility and higher trap density, and show that Cytop devices exhibit trap densities nearly two orders of magnitude lower (and higher mobility) compared to SiO_2 devices. Noise measurements on larger Opto-Electronic Transistors (OPTs) fabricated with similar technology are also presented - confirming a noise behavior consistent with that observed in smaller devices.

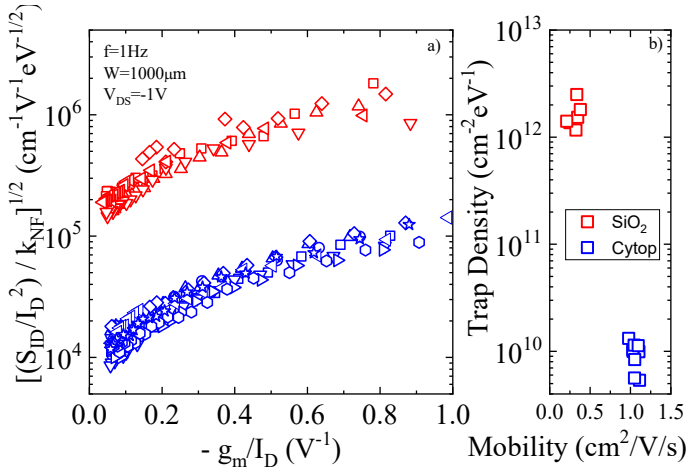

Figure 1: (a) Normalized noise power spectral density, S_{ID} being the drain current power spectral density (A²/Hz) measured at f = 1Hz and I_D the drain current, plotted as a function of the bias (with g_m being the transconductance) for several Cytop and SiO_2 devices with gate lengths ranging from 50 µm to 500 µm; (b) corresponding interfacial trap densities extracted for the individual devices as a function of the effective mobility, according to the correlated mobility fluctuation model [6].

References

[1] T. Yamamoto *et al.*, *J. Photopolym. Sci. Technol.*, 20, pp. 57–59, 2007.
[2] U. Zschieschang *et al.*, *Adv. Mater.*, 22, pp. 982–985, 2010.
[3] S. Haas *et al.*, *Appl. Phys. Lett.*, 95, 022111, 2009.
[4] J. Guo *et al.*, *Org. Electron.*, 93, 106170, 2021.
[5] G. Giusi *et al.*, Proc. *I2MTC*, pp. 2095–2100, May 2015.
[6] G. Ghibaudo *et al.*, *Phys. Status Solidi A*, 124(2), pp. 571–581, 1991.

2D Organic-Inorganic Halide Perovskites for hybrid heterostructures: single crystals, thin films and exfoliated flakes.

Fabio Chiarella
CNR-SPIN, c/o Dipartimento di Fisica "Ettore Pancini", P.le Tecchio, 80, Napoli I-80125, Italy)
fabio.chiarella@spin.cnr.it

Rapid progress on the fabrication of lead halide perovskite has led to high performance optoelectronic devices particularly in the field of solar cells technologies. Then these efforts have been extended to layered 2D halide perovskite structures motivated in part by their good environmental stability, but mainly by their interesting fundamental photophysics. The main uses of hybrid halide perovskites are in solar cells, but there is an increasing interest for their application in other optoelectronic devices alike phototransistors and photodetectors [1] and as potential partner layers to improve the photoresponsivity of monolayer transition metal dichalcogenides in heterostructure [2].
We report a study on the synthesis of the (C6H5C2H4NH3)2(CH3NH3)n-1PbnI3n+1 series (with n=1,2,3) of 2D halide perovskites (see figure 1), aimed at developing a platform that provides ultrathin exfoliation layers for the fabrication of heterostructures where the crystal synthesis method and their basic structural and optical characterization are presented highlighting the differences in the crystal processes.
Furthermore, we explore the synthesis of 2D halide perovskites ultra-thin flakes by using mechanical exfoliation method and few-layer-areas of n=1 member of the series, are identified using atomic force microscopy.
Finally, we present some results about the deposition of thin and ultra-thin films by spin coating technique to provide an alternative way to the exfoliation process.
All these activities are founded by the project "2DieHarD" PRIN 2022SPCM9R.

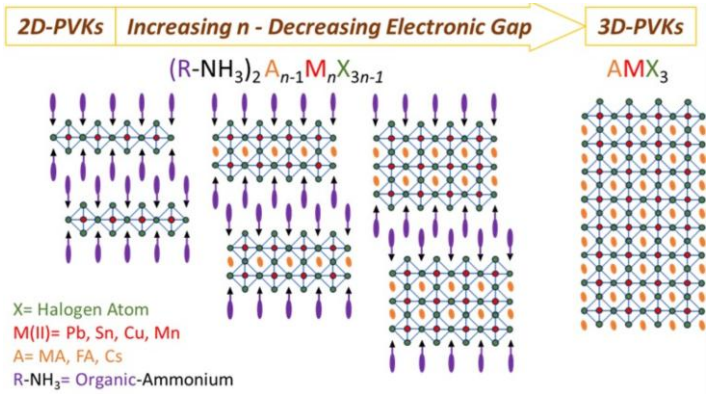

***Figure 1**: Sketch of the Ruddlesden- Popper series structure at increasing the n index from 1 to 3 in comparison with the 3D-perovskites*

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References

[1] Chao Xie, Chun-Ki Liu, Hok-Leung Loi, and Feng Yan Perovskite-Based Phototransistors and Hybrid Photodetectors Adv. Funct. Mater. 2020, 30, 1903907.
[2] Zhang, Z.; Wang, S.; Liu, X.; Chen, Y.; Su, C.; Tang, Z.; Li, Y.; Xing, G. Metal Halide Perovskite/2D Material Heterostructures: Syntheses and Applications. Small Methods 2021, 5, 2000937.

IMaTecS 2026

Session III 14:35 – 16:20

14:35	**Massimo Cuscunà**	**2D and 3D Nanostructured Sensing Platforms: Enabling Ultrasensitive Diagnostics for Personalized Medicine**
15:00	Simonetta Grilli	Highly sensitive detection of protein biomarkers by using an innovative pyro-electrohydrodynamic jet
15:20	Pierluigi Casolaro	Probing radiation effects on solid-state devices through impedance spectroscopy
15:40	Davide D'Ambrosio	Whispering-Gallery Mode Raman sensing and nanoparticle detection
16:00	Luca Basta	Flame synthesis of carbon nanoparticle thin films for innovative sensors

TITLE: 2D and 3D Nanostructured Sensing Platforms: Enabling Ultrasensitive Diagnostics for Personalized Medicine

Daniela Simeone[1§], Marco Esposito[1§], Gianluca Balestra[1], Elisabetta Pisanò[1], Elisabetta Primiceri[1], Adriana Passaseo[1], Vittorianna Tasco[1], David Maria Tobaldi[1], Alessandra Quarta[1], and Massimo Cuscunà[1]

§ Equal Contribution

CNR Nanotec - Institute of Nanotechnology

University Campus Ecotekne

Via per Monteroni, Lecce 73100, Italy

massimo.cuscuna@cnr.it

The field of medical science is rapidly advancing, giving rise to the 'Personalized Medicine' paradigm. This novel approach involves customizing therapies based on a patient's unique genetic profile, lifestyle, and environmental exposures. Essential to its success is the ability to continuously monitor and modulate treatment protocols, thereby maximizing patient benefit while concurrently minimizing adverse effects. To this end, highly sensitive diagnostic tools capable of detecting extremely low concentrations of circulating biomarkers are needed. Such tools promise to unlock new pathways for both the timely detection of diseases and the effective tracking of their progression. Our work specifically highlights the sophisticated sensing performance attainable through the integration of 2D[1] and 3D[2,3] nanostructures.

The 2D nanostructures are represented by plasmonic gold nanoparticles. The effects of the particles' size, shape, spatial organization, and surface coating on the analytical performance of the resulting sensors were investigated. We demonstrated a rapid method for ultrasensitive, label-free detection of therapeutic drugs (like doxorubicin, DOX) in biological fluids up to the nanomolar range, even in diluted (1:10) and undiluted blood serum samples from cancer patients receiving the drug.

The 3D structures are represented by a chiral geometry providing circular polarization-dependent optical response, allowing analysis in a complex environment without significant background interferences. The system was tested for detecting of TAR DNA-binding protein 43, clinically relevant for neurodegenerative diseases. Measurements were performed in spiked solution and in human serum with concentrations from 1 pM down to 10 fM, which is a range not accessible with common immunological assays, opening new perspectives for next-generation biomedical systems.

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References

[1] A. Quarta et al, *ACS Appl. Nano Mater.* **2024**, 7, 18724−18736.

[2] M. Manoccio et al, Nano Lett. **2021**, 21, 6179−6187.

[3] Saravanan Rajamani et al, *Adv. Mater. Technol.* **2023**, 2301250.

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HIGHLY SENSITIVE DETECTION OF PROTEIN BIOMARKERS BY USING AN INNOVATIVE PYRO-ELECTROHYDRODYNAMIC JET

Simonetta Grilli[1], Stefania Carbone[2,1], Concetta Di Natale[2,1], Sara Coppola[1], Veronica Vespini[1], Pietro Ferraro[1], Volodymyr Tkachenko[1]

[1] *Institute of Applied Sciences and Intelligent Systems (ISASI), National Research Council of Italy (CNR), Italy*
[2]*University of Naples "Federico II", Department of Chemical, Materials and Industrial Production Engineering, Italy*

simonetta.grilli@cnr.it

Abstract. It is well known that the detection of low abundant protein biomarkers in body fluids is highly desirable to ensure early diagnosis [1,2]. As an example, the Tau protein experiences a transition phase from a native disorder conformation into a preaggregation state, which leads to fibrillization processes. Here we show the possibility to detect model proteins such as Tau in urine samples at sub-picogram level, through the concentration effect of our pyro-electrohydrodynamic (p-jet) technique [3-5]. An immunofluorescence protocol is applied to concentrated p-jet spots able to reduce drastically the diffusion effects in the typical antibody-antigen reactions used in solid phase biosensing formats. A set of diluted samples were prepared, and the fluorescence signal was detected by a confocal scanner [6-8]. We achieved a linear response with a significant signal-to-noise ratio down to sub-picogram levels. In perspective, the technique could be integrated into a compact device to be used for monitoring the early stage associated to neurodegenerative syndromes.

***Acknowledgements*:**
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References

[1] *Talanta* 2021, 223, 121718
[2] *Expert Rev. Mol. Diagn.* 2020, 20, 421.
[3] *Adv. Eng. Mater.* 2022, 24, 2100756.
[4] *Nat. Nanotechnol.* 2010, 5, 429.
[5] *Nat. Comm.* 2014, 5, 5314.
[6] *Sensing and Bio-Sensing Research* 2022, 38, 100536.
[7] *Biosensors and Bioelectronics* 2024, 254, 116234.
[8] *Analytica Chimica Acta* 2024, 1329, 343178.

PROBING RADIATION EFFECTS ON SOLID-STATE DEVICES THROUGH IMPEDANCE SPECTROSCOPY

Pierluigi Casolaro[1]
[1] *Department of Physics "Ettore Pancini", Università degli Studi di Napoli Federico II, Complesso Univ. Monte S. Angelo, Napoli, I-80126, Italy*
[2] *INFN Sezione di Napoli, Complesso Univ. Monte S. Angelo, Napoli, I-80126, Italy*[3]
pierluigi.casolaro@unina.it

Understanding radiation effects on solid-state devices is essential for applications in harsh environments such as high-energy physics, space, and nuclear technologies. Conventional analyses of radiation-induced degradation typically rely on I–V characteristics, signal integrity, and noise measurements. We are exploring an alternative approach based on Impedance Spectroscopy (IS), a non-invasive technique from electrochemistry that is widely used to study solar cells, fuel cells, batteries, biosensors, and corrosion processes [1]. In IS, a small sinusoidal perturbation is applied to a device under test over a broad frequency range, superimposed on a constant bias level. The impedance response is represented with Nyquist plots, which display the imaginary part of the impedance vs. its real part. By fitting Nyquist plots with suitable models, one can extract key physical parameters and gain insight into the underlying charge-transfer mechanisms. IS modeling of the impedance of a Si pn diode in forward-bias allowed us to disentangle the contributions of diffusion and depletion capacitances in forward bias [2]. By studying radiation effects in BiCMOS integrated circuits with IS [3], we observed subtle degradation mechanisms not easily detectable through standard methods. More recently, we also used IS to investigate gamma-irradiation effects in commercial p-i-n photodiodes [4]. In this case, the IS modeling enabled us to distinguish the contributions of the n–i and i–p junctions, allowing a separate analysis of radiation-induced modifications at each interface. Nyquist plots of irradiated and nonirradiated devices (Fig. 1) showed measurable variations in the impedance spectra which can serve both as an alternative readout method and as a diagnostic tool for monitoring device degradation. Overall, this work highlights the potential of IS as a powerful technique for studying radiation effects in modern sensing technologies.

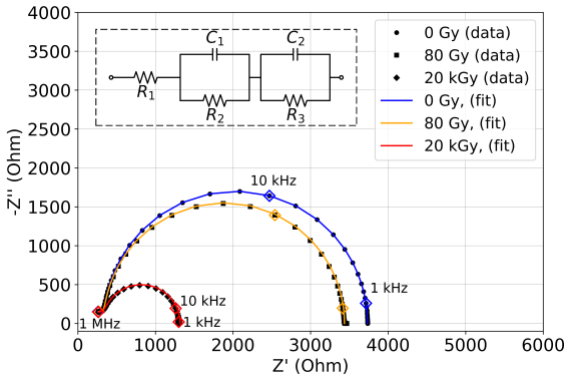

Fig. 1: Nyquist plots at 500 mV for the VEMD5510FX01 photodiode at 0 Gy, 80 Gy, and 20 kGy.

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References

[1] A. Lazanas and M. I. Prodromidis, *ACS measurement science au* **2023**, 3.3, 162-193
[2] P. Casolaro, et al. " *Journal of Applied Physics* **2024** 136.1
[2] P. Casolaro et al, *Radiation Physics and Chemistry* **2025** 113367
[3] P. Casolaro *et al.*, *2024 IEEE NSS MIC - RTSD*, Tampa, FL, USA, **2024**, pp. 1-1

Whispering-Gallery Mode Raman sensing and nanoparticle detection

Davide D'Ambrosio[1], Naveed Ahmed Chishti[1], Benedetta Catalano[2], Giulia Rusciano[2], Antonio Sasso[2] and Gianluca Gagliardi[1]

[1] *Consiglio Nazionale delle Ricerche, Istituto Nazionale di Ottica (INO), via Campi Flegrei, 34 Compr. A. Olivetti, I-80078 Pozzuoli, Italy*

[2] *Department of Physics "E. Pancini", University of Naples Federico II, 80126 Naples, Italy*

davide.dambrosio@ino.cnr.it

Whispering-Gallery Mode Resonators (WGMRs) have recently proven to be highly effective platforms for ultrasensitive biochemical sensing[1]. By exciting a WGM resonance, light is concentrated within a small optical volume, markedly boosting its interaction with surrounding analytes. In parallel, Surface-Enhanced Raman Spectroscopy (SERS) stands out as a technique that integrates the molecular specificity of Raman spectroscopy with the optical near-field amplification produced by localized surface plasmon resonances (LSPRs) on metallic nanostructures. The combination of these effects enables extremely sensitive and selective detection of a broad range of substances, including those within liquid media[2].

We report about an ultra-sensitive Raman probe, enhanced by wgm resonance-based pumping scheme. The developed device allows real-time, label-free detection of analytes in liquid samples, achieving high sensitivity while preserving the intrinsic benefits of Raman sensing.

Figure 1*: A dielectric sphere can withstand whispering gallery mode resonances while the surface can act as a nanoparticle detection sensor*

References

[1] F. Vollmer, S. Arnold, D. Keng, "Single virus detection from the reactive shift of a whispering-gallery mode", Proc. Natl. Acad. Sci. U.S.A. 105, 20701-20704, https://doi.org/10.1073/pnas.0808988106 (2008).

[2] J. Sun, W. Mao, C. Xia, W. Wang, Q. Cui, Z. Shi, G. Zhu, M. Wang, C. Xu, "Plasmon-Coupled GaN Microcavity for WGM Lasing and Label-Free SERS Sensing of Biofluids", Adv. Optical Mater, 12, 2301989 (2024), https://doi.org/10.1002/adom.202301989.

FLAME SYNTHESIS OF CARBON NANOPARTICLE THIN FILMS FOR INNOVATIVE SENSORS

Luca Basta[1,2], Anna Iannotta[1], Mario Commodo[3], Alberto Aloisio[2], Andrea D'Anna[1], Patrizia Minutolo[3]

[1]*Dipartimento di Ingegneria Chimica, dei Materiali e della Produzione Industriale, Università degli Studi di Napoli Federico II, P.le Tecchio 80, Napoli 80125, Italy*

[2]*Dipartimento di Fisica Ettore Pancini, Università degli Studi di Napoli Federico II, Complesso Universitario di Monte S. Angelo, Edificio 6, Via Cinthia, 21, Napoli 80126, Italy*

[3]*Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili, Consiglio Nazionale delle Ricerche, P.le Tecchio 80, Napoli 80125, Italy*

luca.basta@unina.it

Carbon nanoparticle (CNP) thin films are highly attractive for sensing applications due to their unique electrical, optical, and morphological properties. While conventional production methods, such as laser ablation or chemical oxidation, face significant limitations, flame synthesis addresses many of these challenges by enabling continuous, scalable deposition of uniform films with improved adhesion, along with controllable porosity, particle size, and composition[1]. Thermophoretic deposition of carbon nanoparticles from a fuel-rich hydrocarbon flame enables the formation of self-assembled, porous, and nanostructured films, making them promising candidates for practical applications such as sensors.

Furthermore, flame-based synthesis enables film deposition on diverse substrates with arbitrary designs, opening pathways to integrate sensors into commercial products.

This study examines CNP films for low-cost, lightweight, environmentally friendly sensors. Flame-synthesized CNPs are produced and characterized by Atomic Force Microscopy (AFM), Raman spectroscopy, and Current-Voltage measurements. Exploiting distinct nanoparticle formation regimes, CNPs of varying sizes and opto-electrical properties are obtained by adjusting the flame residence time. High resistivity films, which allow a low current flow and, therefore, both a negligible self-heating effect and a lower electrical power consumption, are produced with minimal particle deposition while maintaining percolative network continuity among semiconductive CNPs. Conversely, increased CNP loading enhances surface area and roughness, thereby amplifying the active surface exposed to temperature variations or atmospheric composition, ultimately improving sensitivity.

The electrical characteristics of these films exhibit high sensitivity to inter-grain distance and surrounding chemical environment, making them ideal for temperature and gas sensing[2-3].

The films exhibit temperature-dependent electrical resistance and rapid, highly sensitive responses to ethanol gas, underscoring their potential for portable sensors.

References

[1] S. Pokhrel, et al., *Energy & Fuels* **2020**, *34*, 13209−13224.
[2] P. Minutolo, et al., *Applied Sciences* **2022**, *12*, 7714.
[3] P. Darvehi, L. Basta, et al., *Particuology* **2024**, *91*, 202−210.

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Poster Session

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HIGH-RESPONSIVITY AND FAST RESPONSE DNTT-BASED PHOTOTRANSISTOR

Antonio Caldarelli[1], Antonio Vettoliere[2], Fabio Chiarella[3], Luca Basta[4], Patrizia Minutolo[5], Marcello Campajola[6], Vincezo Izzo[6], Gino Giusi[7], Alberto Aloisio[6,8,9], Ettore Sarnelli[9]
[1]*CNR-SPIN Napoli, c/o Dipartimento di Fisica "Ettore Pancini," Via Cinthia, 21, 80126 Napoli, Italy*
[2]*CNR-ISASI – Comprensorio Olivetti, Via Campo Flegrei 34, 80078 Pozzuoli (NA) - Italy*
[3]*CNR-SPIN Napoli, c/o Dipartimento di Fisica "Ettore Pancini," P.le Tecchio 80, 80125 Napoli, Italy*
[4]*Dipartimento di Fisica "Ettore Pancini," P.le Tecchio 80, 80125 Napoli, Italy*
[5]*CNR-STEMS, P.le Tecchio 80, 80125 Napoli, Italy*
[6]*INFN Napoli, c/o Dipartimento di Fisica "Ettore Pancini," Via Cinthia, 21, 80126 Naples, Italy*
[7]*Dipartimento di Ingegneria, Università di Messina, Contrada di Dio, 98158 Sant'Agata, Messina, Italy*
[8]*Dipartimento di Fisica "Ettore Pancini," Via Cinthia, 21, 80126 Napoli, Italy*
[9]*CNR-SPIN – Comprensorio Olivetti, Via Campo Flegrei 34, 80078 Pozzuoli (NA) - Italy*
antonio.caldarelli@cnr.it

Organic phototransistors (OPTs) are promising as flexible, low-cost devices for flexible displays, wearable electronics, biosensors, environmental monitoring and, also for developing new concept devices for visible light communication (VLC) systems. In this work, we report on a dinaphtho-thieno-thiophene (DNTT) based OPT optimized for detecting blue light. The device employs an Al/Al_2O_3/DNTT/Au layered structure fabricated at ≤ 100 °C on PEN (see fig.1) by shadow-mask patterning. Key performance metrics include a high field-effect mobility (≈ 4.2 $cm^2/V{\cdot}s$) and a low contact resistance (≈ 12 kΩ·cm), which together enable efficient charge transport. Under low-intensity illumination (≈ 10^{-8} W/cm^2) the phototransistor achieves an exceptional responsivity of ≈ 250 A/W, indicating significant photoconductive gain. Even at higher light levels (≈ 10^{-3} W/cm^2), it maintains a large photosensitivity up to ≈ 120. High-frequency tests demonstrate a fast temporal response is realized (rise time ≈ 6.6 µs). The device thus offers a rare combination of high sensitivity and fast response. These results represent a substantial advancement for organic optoelectronics. It is worth noting that the OPTs we have developed are fully compatible with next-generation VLC receivers and other applications requiring lightweight, high-performance photodetectors in the visible range.

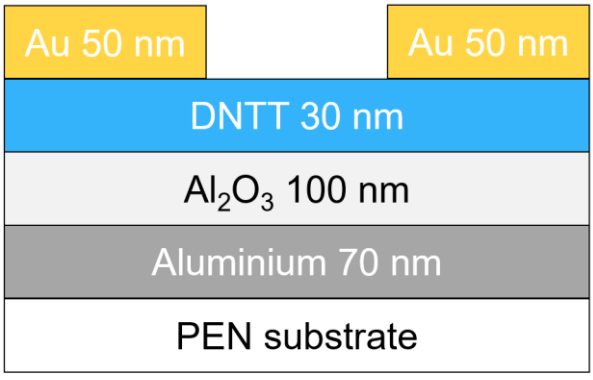


***Figure 1**: Schematic representation of the device*

***Acknowledgements*:**
This work was supported by PRIN PNRR OPTICS under Grant P20227A8K2

XEROSYDRYLE AND ELECTRO-OPTICAL TRANSPORT PROPERTIES

Roberto Germano[1], Fabrizio Ciccarelli[1], Alessia Calabrese[1], Gabriel Malandra[1]
[1] *OXHY SRL*
Via Coroglio, 57 - 80124 Napoli
germano@oxhy.it, ciccarelli@oxhy.it, calabrese@oxhy.it, malandra@oxhy.it

Xerosydryle acts in the development of innovative systems capable of exploiting the principle of the oxhydroelectric effect to convert environmental infrared radiation into electrical energy. Xerosydryle is a newly identified class of materials obtained from supramolecular aggregates of ultrapure water formed after repeated interaction cycles with hydrophilic substrates [1]. Once isolated, these aggregates appear as a stable solid at ambient conditions and display a nanometric filamentous morphology, suggesting unconventional electrical and electro-optical transport properties. Experimental evidence shows that Xerosydryle, when dispersed in water, can increase electrical conductivity by up to three orders of magnitude, an effect not attributable to ionic contamination. AFM and SEM analyses reveal continuous filaments composed of H_2O(+C) nanostructures, while the presence of UV fluorescence indicates weakly bound or delocalized electronic states, a phenomenon impossible in ordinary water [2]. The combination of coherent nanofilaments, potential electronic and protonic delocalization, and nonlinear responses to electric fields makes Xerosydryle a promising soft semiconductor-like material, enabling memristive-like conduction mechanisms, IR-sensitive behavior, and electro-optical modulation. Its structural anisotropy may also give rise to advanced optical responses such as circular dichroism, field-induced refractive index changes, nonlinear optical effects, and emergent magnetic properties associated with coherent proton currents. Overall, Xerosydryle represents a novel material platform of high significance for technologies based on the oxyhydroelectric effect, enabling the conversion of ambient infrared radiation into electrical energy without the use of conventional chemical components.

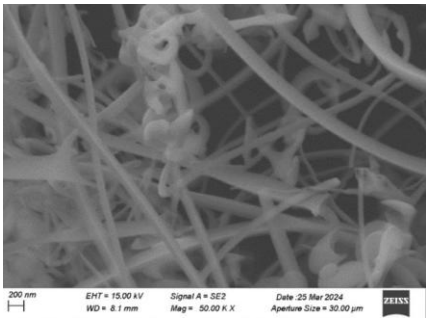


***Figure 1**: SEM image of Xerosydryle*

References

[1] V. Elia, E. Napoli, R. Germano, D. Naviglio, M. Ciaravolo, G. Dal Poggetto, D. Caputo, R. Oliva, TA Yinnon, New physicochemical properties of liquid water resulting from recurrent contact with hydrophilic polymers. Characteristics of the resulting supramolecular aggregates: the Xerosydryle, **2022**, *WATER*, Napoli, 72-85.

[2] V. Elia, E. Napoli, R. Germano, V. Roviello, R. Oliva, M. Niccoli, A. Amoresano, M. Toscanesi, M. Trifuoggi, A. Fabozzi, TA Yinnon, Water perturbed by Cellophane: Comparison of its physicochemical properties with those of water perturbed with cotton wool or Nafion, **2020**, Journal of Thermal Analysis and Calorimetry, Napoli, 2073-2088.

1st Workshop on Innovative Materials and Techniques for advanced Sensing (IMaTecS)

Innovative Flexible Bottom-Up SERS Materials for Ultra-Sensitive Detection of Toxins and Pathogens in Biomedical and Food Matrices

A. D'Avino[1,2], A. Milano[1], V. Marchesano[1], B. Guilcapi[1], D. Sagnelli[1], M. Rippa[1] and L. Petti[1]

[1] *Institute of Applied Sciences and Intelligent Systems "E. Caianiello" CNR, Pozzuoli, Italy*
[2] *Department of Engineering, University of Naples "Parthenope", Centro Direzionale Isola C4, 80143, Napoli, Italy*

amalia.davino@isasi.cnr.it; amalia.davino001@studenti.uniparthenope.it

Flexible SERS (Surface-Enhanced Raman Scattering) sensors fabricated through simple and cost-effective bottom-up approaches represent a powerful class of analytical platforms for rapid, ultrasensitive, and label-free detection of pathogens and toxins in both biomedical and food-safety contexts. In this work, we present two complementary flexible SERS architectures based on gold nanoparticle (AuNP) self-assembly, designed to operate reliably both in water and complex matrices such as human serum, faecal extracts and milk. The first platform consists of a Kapton-based flexible SERS tape coated with AuNPs, enabling highly reproducible enhancement and mechanical adaptability. As a case study, we demonstrate its applicability to the detection and differentiation of Shiga toxins (Stx1, Stx2, and cleaved Stx2), produced by Shiga toxin-producing Escherichia coli (STEC) and associated with severe clinical outcomes. The sensor exhibits an enhancement factor on the order of 10^6 and achieves an ultra-low limit of detection of 15 pM for Stx2 among the lowest reported for flexible SERS substrates while maintaining sensitivity within clinically relevant concentration ranges in human sera. Combined with Principal Component Analysis (PCA), the system enables robust toxin discrimination [1-2]. The second platform is a paper-based flexible SERS sensor produced by coating adhesive paper tape with self-assembled AuNPs. In aqueous media, it allows label-free discrimination of E. coli, Enterococcus, and Citrobacter through their unique SERS fingerprints and PCA. In milk, antibody functionalization enables selective E. coli detection at 25 CFU/mL, with enhancement factors around 10^7 [2]. Overall, these bottom-up flexible SERS sensors offer a versatile, low-cost, and highly sensitive solution for real-time diagnostics, environmental monitoring, and food contamination screening, highlighting their strong potential for widespread on-site applications.

Acknowledgements**:** *The authors gratefully acknowledge the support for this work from European Union - NextGenerationEU Call PRIN2022 Development of a plasmonic nanobiosensor for the rapid diagnosis of Shiga toxin producing E. coli human infections at the point of care - SENSOSTEC (CUP B53D23019990006).*

References

[1] D'Avino, A., et al. "Flexible Gold Nanoparticle SERS Tape for Rapid, Label-Free and Ultrasensitive Detection and Differentiation of Shiga Toxin Variants." Biosensors and Bioelectronics: X (2025): 100696.

[2] Milano, Alessia, et al. "Advancing Medical Diagnostics: Rapid, Label-Free Detection and Differentiation of Shiga Toxin Variants in Human Serum Using a Cost-Effective PCA-Assisted SERS Platform." ACS Applied Materials & Interfaces (2025).

[3] D'Avino, A., et al. "Innovative flexible gold nanoparticle SERS platform fabricated by a self-assembly and rapid approach." Smart Materials for Opto-Electronic Applications 2025. Vol. 13528. SPIE, 2025.

FLAME SYNTHESIZED NANOSTRUCTURED C-TIO₂ FILMS FOR SENSING AND ELECTRONIC DEVICE APPLICATIONS

A. Khalique [1,*], G. De Falco[2], P. Minutolo[2], M. Commodo[2], A. D'Anna[1]
[1] *Dipartimento di Ingegneria Chimica, dei Materiali e della Produzione Industriale, Università degli Studi di Napoli Federico II, Napoli, Italy*
[2] *Istituto di Scienze e Tecnologie per l'Energia e la Mobilità Sostenibili, Consiglio Nazionale delle Ricerche, Napoli,Italy*
abdul.khalique@unina.it

Titanium dioxide (TiO_2) remains a cornerstone semiconductor material in resistive switching technologies, with potential applications ranging from resistive random-access memory (ReRAM) and neuromorphic computing to biosensing, photo-sensing and photocatalysis [1]. Integrating resistive switching (RS) into TiO_2-based gas sensors creates a memory-enabled device that records and retains temporal changes in gas concentration. This is achieved by using the gas concentration to modulate the TiO_2's resistance, triggering the non-volatile memory state. Despite extensive research, the commercial and practical realization of TiO_2-based devices remains hindered by limited understanding of the underlying switching mechanisms and material-process-property interdependencies. In this study, we present a novel and scalable approach for the synthesis of nanostructured carbon-TiO_2 (C-TiO_2) composite thin films using a custom-designed aerosol flame reactor (AFR). This single-step, flame-assisted deposition process enables simultaneous nanoparticle formation and film growth under controlled conditions. Comprehensive characterization was performed to elucidate the structure, composition, and functional properties of the resulting nanocomposites. Raman spectroscopy confirmed carbon incorporation within the TiO_2 matrix, while UV–Vis revealed broadened visible-range absorption. AFM characterized surface morphology and roughness, and SMPS monitored in-situ particle size evolution in the flame. Electrical characterization via current-voltage (I-V) measurements revealed significantly enhanced conductivity and improved capacitive-coupled memristive behavior in the C-TiO_2 films compared to pristine TiO_2, attributed to the formation of additional conductive pathways facilitated by carbon incorporation [2]. These findings suggest that carbon compositing not only tailors the optoelectronic properties of TiO_2 but also stabilizes and enhances electrical performance [3]. To assess their potential for light-assisted sensing and advanced electronics, the coated samples were treated in dark storage and exposed to UV irradiation using both solar sources and controlled LEDs. The demonstrated synthesis method offers a promising route toward the development of high-performance, cost-effective, and scalable materials for a plethora of applications, spanning from photocatalysis to photodetectors and photosensors.

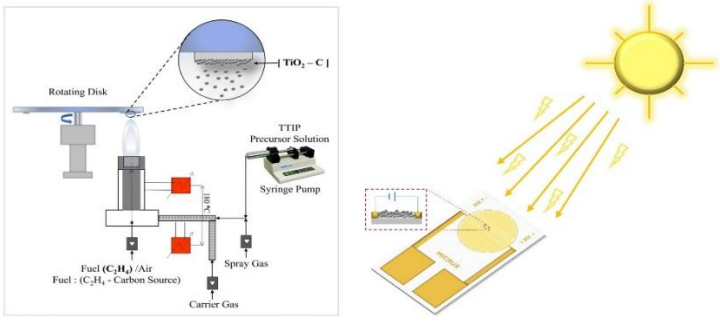


Figure 1*: (a) Flame Synthesis of C-TiO2 films (b)Solar Irradiation*

Acknowledgements**:** *This work was supported by Italian MUR through the PRIN PNRR 2022 project "Flamenco" P2022HKE88 (Next generation EU program - Missione 4 - Componente 2 - Investimento 1.1)*

References

[1] Illarionov et al., Frontiers in Chemistry 2020, 8, 556815.
[2] Kim et al., Scientific Reports 2020 10:1, 10(1), 18830
[3] Khalique et al., Materials Science in Semiconductor Processing, 2026202, 110125.

1st Workshop on Innovative Materials and Techniques for advanced Sensing (IMaTecS)

High-Sensitivity SERS Profiling of Shiga Toxins: Bridging Fundamental Validation and Real-World Clinical Application

Alessia Milano[1], Amalia D'Avino[1,2], Valentina Marchesano[1*], Domenico Sagnelli[1], Massimo Rippa[1], Bryan Guilcapi[1], Lu Zhou[3], Maurizio Brigotti[4,1*], Stefano Morabito[5,1] and Lucia Petti[1*]

[1] *Institute of Applied Sciences and Intelligent Systems "E. Caianiello" CNR, Pozzuoli, Italy*
[2]*Department of Engineering, University of Naples "Parthenope", Centro Direzionale Isola C4, 80143, Napoli, Italy*
[3] *Shandong First Medical University & Shandong Academy of Medical Sciences, Jinan, China*
[4]*Dipartimento di Scienze Mediche e Chirurgiche, Sede di Patologia Generale, Università di Bologna, Bologna, Italy*
[5]*Department of Food Safety, Nutrition and Veterinary Public Health, Istituto Superiore di Sanitá, Rome, Italy*
alessia.milano@isasi.cnr.it

Shiga toxin-producing Escherichia coli (STEC) infections remain a major threat to global health due to their rapid progression toward hemolytic uremic syndrome (HUS). This life-threatening condition demands early and accurate detection of circulating Shiga toxins (Stx). However, conventional diagnostic approaches struggle with sensitivity, time-to-result, and the intrinsic challenge that Stx rapidly clear from patient fluids during disease progression.

In our recent work, we introduced a highly sensitive, label-free SERS platform based on self-assembled gold nanoparticle monolayers on rigid silicon substrates, engineered for high electromagnetic enhancement and clinical robustness. This system enabled precise detection and discrimination of Stx1, Stx2a, and Stx2a cleaved variant directly in human serum, achieving an exceptionally low limit of detection (0.007 ng/mL) with remarkable reproducibility and specificity. By integrating PCA-assisted spectral analysis, we demonstrated that even subtle structural differences among toxin subtypes can be reliably resolved, overcoming one of the most critical limitations of current diagnostic tools. Preliminary validation on serum from HUS patients further confirmed the platform's ability to detect toxin signatures even at the extremely low concentrations typical of early disease stages. Work is in progress to translate our SERS sensing platform into a clinically usable diagnostic tool by implementing a dual-antibody sensor (anti-Stx1 and anti-Stx2) combined with supervised machine-learning classifiers. This system will categorize samples into clinically relevant groups and be validated against qPCR using early-stage serum and fecal samples.

The final goal is a rapid, portable, and interpretable diagnostic workflow that supports timely clinical decision-making. Together, this work represents a technological trajectory—from fundamental nanoplasmonic sensing to real-world clinical translation—aimed at reshaping early detection and management of STEC infections.

Acknowledgements**:** *The authors gratefully acknowledge the support for this work from European Union - NextGenerationEU Call PRIN2022 Development of a plasmonic nanobiosensor for the rapid diagnosis of Shiga toxin producing E. coli human infections at the point of care - SENSOSTEC (CUP B53D23019990006).*

References

[1] A. Milano, A. D'Avino, V. Marchesano, D. Sagnelli, M. Rippa, B. Guilcapi, L. Zhou, E. Varrone, G. Rossi, M. Brigotti, G. Ardissino, S. Morabito, L. Petti. Advancing Medical Diagnostics: Rapid, Label-Free Detection and Differentiation of Shiga Toxin Variants in Human Serum Using a Cost-Effective PCA-Assisted SERS Platform (2025). *ACS Applied Materials & Interfaces*, 17(46), 63237-63252. 10.1021/acsami.5c18171

1st Workshop on Innovative Materials and Techniques for advanced Sensing (IMaTecS)

DESIGN AND CHARACTERIZATION OF N-TYPE ISOINDIGO SEMICONDUCTORS FOR ORGANIC ELECTRONICS AND SENSING

Fabio Mocerino[1], Mario Barra[2], Fabio Borbone[1], Antonio Carella[1], Roberto Centore[1], Fabio Chiarella[2], Alessandro Landi[3] and Andrea Peluso[3]

[1]*Dipartimento di Scienze Chimiche, Università Degli Studi di Napoli Federico II, Complesso Universitario di Monte Sant'Angelo, via Cintia 21, 80126 Napoli, Italy; fabio.mocerino@unina.it; fabio.borbone@unina.it; roberto.centore@unina.it*

[2]*CNR—Institute for Superconductors, Innovative Materials and Devices, SPIN, Piazzale Tecchio 80, 80125 Napoli, Italy; mario.barra@spin.cnr.it; fabio.chiarella@spin.cnr.it*

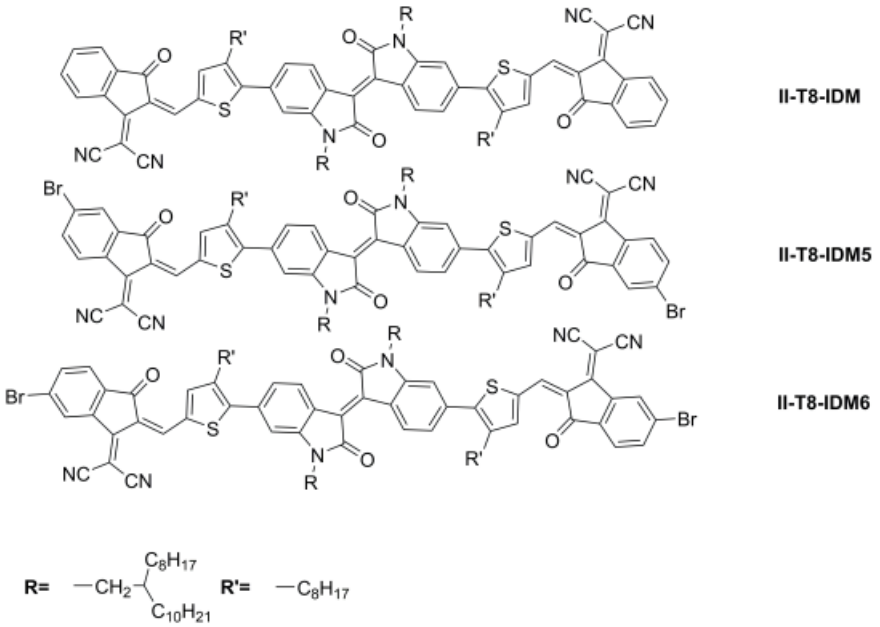
[3]*Dipartimento di Chimica e Biologia, Università di Salerno, Via Giovanni Paolo 132, 84084 Fisciano, Italy; alelandi1@unisa.it; apeluso@unisa.it*

fabio.mocerino@unina.it

We report the synthesis and characterization of three novel isoindigo (II)-based organic semiconductors designed within a donor–acceptor–donor architecture. The materials share a common structural motif consisting of an electron-acceptor isoindigo core symmetrically linked to two 3-octylthiophene donor units, end-capped with three different dicyanomethylene-indanone (IDM) derivatives, including two brominated analogues.

The effect of bromination and of the bromine substitution pattern on thermal, optical and electrochemical properties was systematically investigated, and complemented by DFT calculations to elucidate structure–property relationships. These molecular design variations allow fine modulation of electron affinity and frontier orbital energies, features that are essential for enabling responsive behavior in chemical and environmental sensing platforms based on organic electronics.

All three derivatives were integrated as active layers in organic field-effect transistors (OFETs), exhibiting unipolar n-type transport with electron mobilities in the 10^{-3}–10^{-4} cm^2 V^{-1} s^{-1} range. The combined tunability of their electronic properties and their reliable n-type behavior underline the potential of isoindigo-based systems as functional materials for sensing-oriented OFET architectures, where controlled charge transport and molecular recognition events can be exploited for (bio)chemical detection.



***Scheme 1**: Molecular structure of the synthesized **II**-based organic semiconductors*

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An Autonomous Multi-Agent Framework for Deep Learning Architecture Discovery and Optimization in SERS-based Pathogen Detection

Domenico Sagnelli[1], Bryan Guilcapi[2], Amalia D'Avino[3], Alessia Milano[4], Valentina Marchesano[5], Massimo Rippa[6], Lucia Petti[7]

[1]*Istituto delle Scienze Applicate e Sistemi Intelligenti , CNR Pozzuoli, via campi flegrei 34, Italia*

domenico.sagnelli@isasi.cnr.it

Surface-Enhanced Raman Spectroscopy (SERS) enables rapid and ultra-sensitive pathogen detection; however, the intrinsic variability of spectral signals and the requirement for complex data representations make the manual design of Convolutional Neural Networks (CNNs) a labor-intensive and often sub-optimal process. In this work, we present an Automated Machine Learning (AutoML) framework based on a Multi-Agent System driven by Large Language Models (LLMs), designed to operate autonomously on Consumer grade and High-Performance Computing (HPC) infrastructures.

Surpassing the limitations of traditional Neural Architecture Search (NAS), our system integrates a continuous cognitive cycle composed of specialized roles: an *Analyst* for data interpretation, a *Strategist* for architectural hypothesis formulation, and a *Decider* for computational resource allocation. The framework manages the entire model lifecycle, from the autonomous generation of Python code for custom architectures (e.g., 1D-CNNs for raw spectra, 2D-CNNs for transformed representations such as GAF or Spectrograms) to validation and automated runtime debugging. A distinguishing feature of the system is the utilization of long-term semantic memory and a "Strategic Graph," enabling agents to retain knowledge from past experiments, avoid local minima, and optimize convergence over time.

Experimental validation was conducted on two fronts: (1) a domain-specific benchmark using both data collected in out labs and public SERS[1] spectral databases for the classification of pathogenic bacteria, demonstrating superior performance compared to standard architectures; and (2) a generalization benchmark on the CIFAR-10 dataset, confirming that the agent's optimization capabilities are domain-agnostic and robust against overfitting specific to spectral data. Results indicate that our multi-agent approach drastically reduces human development time while producing robust, high-accuracy models for biomedical diagnostics.

References

[1] Ho CS, *Nature communication* **2019**, *10*, 4927

1st Workshop on Innovative Materials and Techniques for advanced Sensing (IMaTecS)

FEMTOSECOND LASER NANOTEXTURING FOR HIGH-PERFORMANCE AND REUSABLE SILICON SERS PLATFORMS

Mohammadhassan Valadan[1], Xiaona Zhao[2], Yuxuan He[2], Jijil JJ Nivas[3,6], Achu Purushothaman[3], Carlo Altucci[4,5], Kun Lin[7], Yinghao Lun[2], Salvatore Amoruso[1,2], Xuan Wang[2]

[1] *CNR- SPIN, c/o Dip.to di Fisica, Complesso Universitario di Monte S. Angelo, via Cintia, 80126 Napoli, Italy*
[2] *School of Remote Sensing and Information Engineering, Wuhan University, Wuhan 430072, China*
[3] *Dipartimento di Fisica Ettore Pancini, Università degli Studi di Napoli Federico II, Complesso Universitario di Monte S. Angelo, Via Cintia, I-80126 Napoli, Italy*
[4] *Dipartimento di Scienze Biomediche Avanzate, Università degli Studi di Napoli Federico II, via 12 Pansini 5, I-80131 Napoli, Italy*
[5] *CNR-ISASI, Via Campi Flegrei 34, Pozzuoli (NA), Italy*
[6] *FZU–Institute of Physics of the Czech Academy of Sciences,7 Na Slovance, 18200 Prague 8, Czech Republic*
[7] *Purification Equipmet Research Institute of China State Shipbuilding Corporation Limited, Handan 056027, China*

mohammadhassan.valadan@spin.cnr.it

Recent advances in ultrafast-laser micro/nanostructuring highlight how both the irradiation environment and focusing geometry critically influence energy coupling and surface morphology[1-3]. Complementary work on silicon demonstrated that ambient air enhances ablation efficiency through nanoparticle redeposition, whereas vacuum suppresses this mechanism, leading to much higher ablation thresholds[2]. Further investigations clarified that, in air, increasing repetition rate induces plume shielding and progressively suppresses material removal, while in vacuum the same effect remains negligible even at high frequencies[3]. Together, these results point to a broader principle: ambient-assisted surface texturing can intentionally leverage near-surface particle dynamics to create functional hierarchical architectures.

Building on these insights, we fabricated reusable SERS substrates by fs-laser writing of LIPSS on crystalline silicon, exploiting the multiscale roughness that naturally forms during ambient processing[4]. Compared to vacuum-fabricated samples, substrates produced in air exhibited almost an order-of-magnitude stronger Raman signal. This enhancement originates from a synergy of electromagnetic effects: subwavelength inter-ripple cavities, nanoscale roughness from laser-induced redeposition, and strong hybrid plasmonic coupling after Au-nanoparticle decoration. Finite-element simulations confirmed the formation of dense, vertically distributed hotspots, yielding enhancement factors above 10^{10} with excellent spatial uniformity.

These architectures translated into outstanding practical performance. The substrates enabled detection of microcystin-LR down to 10^{-7} µg/L and malachite green down to 10^{-12} M. Furthermore, it maintained ≈91% of their initial SERS activity after 20 regeneration cycles. The results show that simple ambient fs-laser processing can reliably produce scalable, ultrasensitive, and recyclable SERS platforms, offering a powerful route for rapid monitoring of environmental and food-safety contaminants.

References

[1] Hu M., et al., *Nanomaterials*, **2023**, 13,1005.
[2] Hu M., et al., *Applied Surface Science*, **2022**, 606, 154869.
[3] Allahyari E., et al., Amoruso S., *Optics and Laser Technology*, **2020**, 126, 106073.
[4] Zhao X., et. Al., *ACS Applied Materials & Interfaces*, **2025**, 17 (44), 61410-61425.

HYBRID NANOCOMPOSITES: EFFECT OF DIFFERENT SYNTHESIS ROUTE ON ELECTRICAL MEMRISTIVE BEHAVIOUR

Aldobenedetto Zotti[1], Salvatore Aprano[2], Asma Rafiq[3], Simona Zuppolini[1], Mauro Zarrelli[1], Maria Grazia Maglione[2], Paolo Tassini[2], Antonio Cassinese[3], Anna Borriello[1]

[1]*CNR-IPCB, Piazzale Enrico Fermi 1, Portici (NA), Italy*

[2]*ENEA, Piazzale Enrico Fermi 1, Portici (NA), Italy*

[3]*Università Federico II, Dipartimento di Fisica, p.le tecchio 80, Napoli (NA), Italy*

Aldobenedetto.zotti@cnr.it

This work reports preliminary results on development of electrical devices characterized by memristive-like behaviour, consisting of polyaniline (PANI) nanofibers decorated with gold nanoparticles (Au NPs), as conductive hybrid fillers, and atactic polystyrene (aPS), as an insulating matrix, for applications in non-volatiles memories and artificial neural networks. In this hybrid system, PANI nanofibers were selected due to their environmental stability, large surface area, ease of synthesis (e.g. via interfacial or seeding polymerization) and an electrical conductivity that can be finely tuned through reversible doping processes. Moreover, the Au choice is associated to the observation[1] that PANI/noble metal NPs composites exhibit memristor-like behaviour, fundamental requirement to reproduce the 0/1 states.

Two different synthetic strategies were adopted to synthesize the nanostructures[2]: (1) embedding of 1-dodecanthiol-capped Au nanoparticles in PANI nanofibers grown by biphasic synthesis; (2) direct reduction of auric salt precursors onto previously prepared PANI nanofibers through a rapid-mixing method. The PANI/Au weight ratios were determined by Thermogravimetric Analysis (TGA), while gold and PANI dimensions, as well as the morphology of the resulting nanocomposites, were examined via Transmission Electron Microscopy (TEM). Preliminary electrical tests on aPS-based devices reveal a non-linear current–voltage response, characteristic of memristive behaviour. Furthermore, the two synthetic approaches result in distinct device performances.

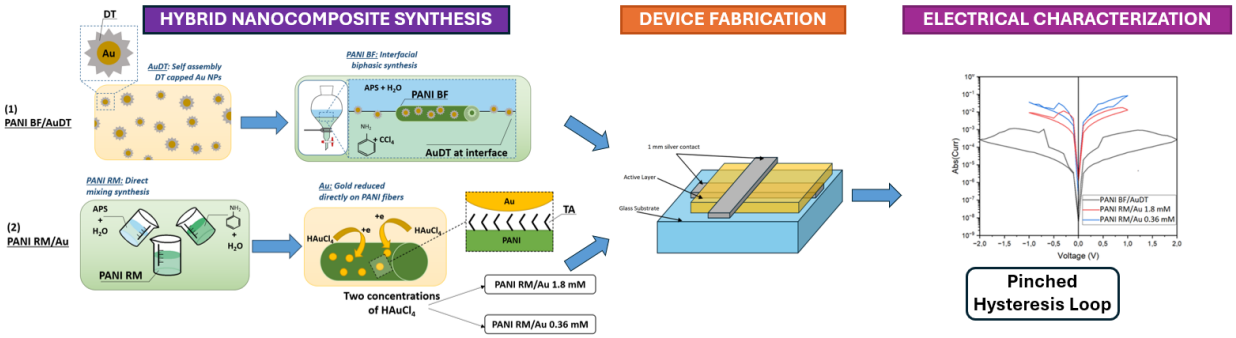

***Figure 1**: Schematic layout of the fabrication process with current–voltage characteristics of the produced devices.*

References

[1] J. Han, M. Wang, …, R. Guo, Prog. Polym. Sci. 70 (2017) 52–91.

[2] A. Zotti, S. Aprano, …, Mater. Adv. 6 (2025) 1788-1793

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"***Development of flexible low-voltage organic phototransistors for visible light communication" (OPTICS)***

"***Photophysics and optoelectronics with TMD/2D Perovskite heterostructures for efficient near-infrared detection" (2DieHarD)***

"***A lab-on-a-chip integrated with electrochemical transistors for cardiac biomarkers evaluation in human blood" (LIFEBLOOD)***

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