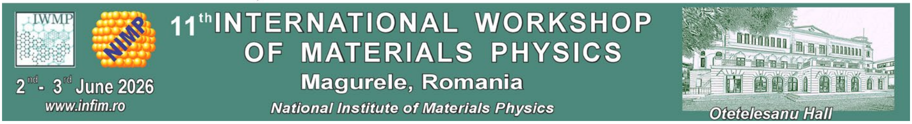
THE MISSION



The National Institute of Materials Physics (NIMP) proudly announces the organization of the 11th edition of the International Workshop of Materials Physics (IWMP).

The workshop will focus on emerging concepts and technologies in neuromorphic and brain-inspired systems, including (but not limited to) artificial synapses, artificial neuromorphic networks, sensory integration in neuromorphic architectures, brain-machine and brain-computer interfaces, and parallelism in brain-inspired computation. The workshop aims to bring together researchers and specialists from Physics, Chemistry, Materials Science, Neurosciences, Biology, Engineering fostering interdisciplinary dialogue at the interface between materials, devices and computation. The interest will be not only on materials/architectures for new hardware devices and interfaces but will also address fundamental questions such as: “Is it the human brain a computer?” or “Is it the human brain a sophisticated quantum device?”. Both theoreticians and experimentalists are invited to present some of their latest results and to share their perspectives on the current progress and future directions of neuromorphic brain-inspired devices and computation paradigms.

The 11th edition will be held as a two-day event, from 02–03 June 2026, and will feature invited contributions and poster sessions only. The goal is to attract leading researchers in the field and to stimulate new collaborations, with the ultimate goal of initiating joint publications, research projects, and personnel exchanges.

THE VENUE

The Oteteleșanu Hall in Măgurele has a storied past dating back to the 19th century (1843), when it was built by the influential Oteteleșanu family. Initially serving as their private residence, it underwent a significant transformation in 1894, becoming the esteemed "Ioan Oteteleșanu Institute for Girls" under the auspices of the Romanian Academy.

Across its existence, the Oteteleșanu Hall has stood witness to the dynamic evolution of Romanian history, from periods of subjugation at the cross-roads of three Empires to the victorious pursuit of independence and modernization. During its journey, the hall has endured three major wars, the vicissitudes of Communism, and the arduous path back to Democracy, navigating through cycles of transformation, neglect, and revitalization. Through it all, the Oteteleșanu Hall has remained a steadfast symbol of resilience amidst political turmoil and societal shifts.

Following a decade of careful restoration overseen by NIMP, Oteteleșanu Hall has been rejuvenated as the headquarters of the Culture and Physics Foundation in Măgurele, the International Centre for Advanced Training and Research in Physics (CIFRA), and the DRIFMAT cluster.

Today, it serves as a prestigious venue for international events like IWMP, embodying both its historical scope and contemporary relevance while upholding its unwavering, 130-years-old commitment to education and scientific advancement.

In the present day, the Oteteleșanu Hall stands as a testament to the cultural legacy of Măgurele, offering a captivating window into the past while remaining an integral part of the local community vibrant present.

THE HOST

NATIONAL INSTITUTE OF MATERIALS PHYSICS

Established in 1949, the Institute of Physics of the Romanian Academy was founded by Horia Hulubei, a distinguished scientist renowned for his ground-breaking contributions to various fields of physics, including X-ray, atomic physics, and nuclear physics. Horia Hulubei earned his PhD in Paris under the tutelage of Nobel Prize laureates Pierre Curie and Maria Skłodowska-Curie.

In 1956, the Institute underwent a division resulting in the formation of two separate entities: the Institute of Atomic Physics (IFA) in Măgurele & the Bucharest Institute of Physics (IFB), the latter led by the Acad. Prof. Eugen Bădărău. E. Bădărău, a prominent professor from Sankt Petersburg and Cernăuți Universities, played a pivotal role in advancing the Romanian school of physics, particularly in the study of electrical discharges in gases and plasma.

Relocating to Măgurele in 1974, the Institute experienced further transformation in 1977 with the amalgamation of laboratories from IFB and IFA, forming the Institute of Physics and Technology of Materials. In 1996 it was officially rebranded the National Institute of Materials Physics (NIMP) following a national accreditation process, subsequently re-accredited in 2008 and 2016.

Throughout its history, NIMP has been home to distinguished physicists such as Acad. Eugen Bădărău, Acad. Radu Grigorovici, Acad. Ioan Iovitz Popescu, Acad. Margareta Giurgea, Acad. Rodica Mănăilă, and Acad. Vladimir Țopa.

Over the past fifty years, NIMP has emerged as a leading research institution in Romania, investing over 35 million EUR in a new laboratory building equipped with state-of-the-art research facilities and the restoration of the historic Oteteleșanu Hall. Internationally, NIMP has played a significant role as one of the founders of the Central European Research Infrastructure (C-ERIC) and as an associated member of the Francophone University Agency (AUF). Additionally, it hosts a UNESCO category 2 centre – the Centre for Advanced Training and Research in Physics (CIFRA).

THE PROGRAM

of the 11th edition of the

International Workshop of Materials Physics

2nd of June, 2026

INVITED ORAL PRESENTATIONS

Hour	Name of the speaker and Title of the talk
08:50	**Lucian PINTILIE** National Institute of Materials Physics, Romania **Welcome address**
Session 1: Chair – Lucian PINTILIE	
09:00	**Dimitris PINOTSIS** City St George's, University of London, United Kingdom ***Brain implants, AI and biophysics***
09:30	**Beatrice RADU** University of Bucharest, Romania ***From brain physiology to intelligent interfaces: Lessons for neuromorphic technologies***
10:00	**Romain BRETT** Sorbonne University, INSERM, CNRS, France **Brains beyond computers** – *Online*
10:30	Coffee break
Session 2: Chair – Victor KUNCSER	
10:45	**Herbert JAEGER** Rijksuniversiteit Groningen, The Netherlands ***From materials to maths: The necessity and nature of a formal foundation for neuromorphic computing*** – *Online*
11:15	**George Alexandru NEMNEȘ** University of Bucharest, Romania ***Classical and quantum memristive devices for neuromorphic computing***
11:45	**Coriolan TIUȘAN** Babes-Bolyai University, Cluj-Napoca, Romania ***Skyrmionic qubits stabilized by Dzyaloshinskii-Moriya interaction as platforms for qubits and quantum gates***
12:15	**Liliana PREJBEANU** University Grenoble Alpes-INP, SPINTEC, France ***Phase dynamics of injection locked spin-torque nano-oscillators: From synchronization to Ising machines*** – *Online*
12:45	Lunch
Session 3: Chair – Andra Georgia BONI	
13:45	**Brahim DKHIL** CentraleSupélec, Universite Paris-Saclay, CNRS, France ***Multistate memories to neuromorphic computing with ferroelectric-related materials***
14:15	**Jean-Francois DAYEN** University of Strasbourg, France

	Van der Waals ferroelectric heterostructures for in-memory computing and emergent electronics
14:45	**Athanasios DIMOULAS** Institute of Nanoscience and Nanotechnology, National Center for Scientific Research DEMOKRITOS, Greece ***Ferroelectric materials for neuromorphic computing technologies***
15:15	**Coffee break**
Session 4: Chair – Andrei C. KUNCSER	
15:30	**Wolfgang SCHWINGER** Zeiss, Germany ***Introducing the new ZEISS Crossbeam 750 with Gemini 4 column and ZEISS EM Toolkit SW***
16:00	**Jose Luis 'Pepe' CONTRERAS-VIDAL** IUCRC BRAIN University of Houston, USA ***Brain, mind, body, art and the neural basis of creativity*** *– Online*
16:30	**Ghazi Sarwat SYED** IBM Zurich, Switzerland ***Intelligence through physical computing***
17:00	**Poster session & Coffee break**
18:00	**Departure for dinner**
19:00	**Dinner**

02nd of June, 2026

POSTER PRESENTATION SESSION

P1	***Nanoconjugated caffeic acid–gold nanoparticles for passive diffusion across a simplified blood–brain barrier model*** **Anca ALDEA[1,2], Sara NISTOR[1,3], Mihaela BEREGOI[1], Alexandru EVANGHELIDIS[1,2], Monica ENCULESCU[1,2], Liviu NEDELCU[1], Valentin MARALOIU[1], Cristina BUSUIOC[3], Bogdan DRAGNEA[2,4], Teodor Adrian ENACHE[1,2]** [1]National Institute of Materials Physics, Romania [2]CIFRA – Centre International de Formation et de Recherche Avancées en Physique, Romania [3]National University of Science and Technology Politehnica Bucharest, Romania [4]Department of Chemistry, Indiana University, USA
P2	***Sputtering of III-V wurtzite materials for active component in neuromorphic dedicated heterostructures*** **Liliana M. BĂLESCU[1], Luminița M. HRIB[1], George E. STAN[1], Roxana Elena PĂTRU[1], Lucia Nicoleta LEONAT[1], Dana g. POPESCU[1], Ion SPÎNU[1], Sara LAAFAR[1], Lucian PINTILIE[1]** [1]National Institute of Materials Physics, Romania
P3	***Ferroelectric multilayers exhibiting memristive and/or memcapacitive signatures for neuromorphic functions*** **Andra Georgia BONI[1], Polychronis TSIPAS[1,2], Cristina CHIRILĂ[1], Ion SPÎNU[1], Dana POPESCU[1], Cristian RADU[1], Sara LAAFAR[1], Lucian PINTILIE[1], Athanasios DIMOULAS[1,2]** [1]National Institute of Materials Physics, Romania [2]Institute of Nanoscience and Nanotechnology, National Center for Scientific Research DEMOKRITOS, Greece

P4	***Memristive spin-valves based on a DNA component*** **Nicușor IACOB[1], Cristina CHIRILĂ[1], Andrei KUNCSER[1], Marcela SOCOL[1], Anda Elena STANCIU[1], Lucian TRUPINĂ[1], Claudiu LOCOVEI[1,2], Gabriel SCHÎNTEIE[1], Aurelian C. GÂLCĂ[1], Victor KUNCSER[1], Bogdana BORCA[1]** [1]National Institute of Materials Physics, Romania [2]Faculty of Physics, University of Bucharest, Romania
P5	***Toward efficient probabilistic bits using 2D magnetic materials*** **Claudiu LOCOVEI, Andrei KUNCSER, Ioan Alexadru IVAN, Andrei ALEXANDRU-DINU, Nicușor IACOB, Anda Elena STANCIU, Aurelian C. GÂLCĂ, Victor KUNCSER, Bogdana BORCA** National Institute of Materials Physics, Romania
P6	***Substrate-temperature-controlled ferroelectricity in Zr-doped HfO_2 thin films for CMOS-compatible neuromorphic devices*** **Cristina F. CHIRILĂ[1], Andra Georgia BONI[1], Dana G. POPESCU[1], Cosmin ISTRATE[1], Luminița M. HRIB[1], Lucian PINTILIE[1], Athanasios DIMOULAS[1,2]** [1]National Institute of Materials Physics, Romania [2]Institute of Nanoscience and Nanotechnology, National Center for Scientific Research DEMOKRITOS, Greece
P7	***Targeted delivery of neuro-regenerative agents to minimize neuroinflammation*** **Daniel N. CRIȘAN[1], Luminița NASTAS[1,2], Iulia Corina CIOBOTARU[1], Daniela OPREA[1,3], Teodor Adrian ENACHE[1]** [1]National Institute of Materials Physics, Romania [2]Faculty of Medical Engineering, National University of Science and Technology Politehnica Bucharest, Romania [3]Faculty of Physics, University of Bucharest, Romania
P8	***Amyloid beta fibril-functionalized conductive biointerfaces for neuronal cell proliferation and neuromorphic applications*** **Mihaela BEREGOI[1], Sara NISTOR[2], Iulia Corina CIOBOTARU[1], Andrei NIȚESCU[1], Irina ZGURĂ[1], Mihaela Cristina BUNEA[1], Monica ENCULESCU[1], Liviu NEDELCU[1], Cristina BUSUIOC[2], Teodor Adrian ENACHE[1]** [1]National Institute of Materials Physics,, Romania [2]National University of Science and Technology Politehnica Bucharest, Romania
P9	***Engineering ferroelectric hysteresis for artificial synapses: The role of insulating interlayers in neuromorphic device design*** **Lucian Dragoș FILIP, Andra Georgia BONI, Cristina CHIRILĂ, Mihaela BOTEA, Marius HUȘANU** National Institute of Materials Physics, Romania
P10	***Electrospun polymeric nanofibers scaffold coupled with electrochemical transducers for long-term neuronal modeling and neurotransmitter analysis*** **Daniela OPREA[1,2], Mihaela ONCEA[2], Monica ENCULESCU[2], Teodor Adrian ENACHE[2]** [1]University of Bucharest, Romania [2]National Institute of Materials Physics, Romania
P11	***Interconnected resistive networks in nanostructured electroceramics: Premise for neuromorphic interfaces*** **Roxana Elena PĂTRU[1], C.A. STANCIU[2], Bogdan Ștefan VASILE[2], Nadejda HORCHIDAN[4], Liliana MITOŞERIU[4], Adelina Carmen IANCULESCU[2], Lucian PINTILIE[1], Ioana PINTILIE[1]** [1]National Institute for Materials Physics, Romania [2]Department of Science & Engineering of Oxide Materials and Nanomaterials, Faculty of Chemical Engineering and Biotechnologies, National University of Science and Technology Politehnica Bucharest, Romania [3]National Institute for Lasers, Plasma and Radiation Physics, Romania [4]Department of Exact & Natural Sciences, Alexandru Ioan Cuza University of Iași, Romania

P12	*Mechanisms of resistive switching in IGZO memristors* **Ion SPÎNU[1,2], Nicolae FILIPOIU[1], George Alexandru NEMNEȘ[2], Algirdas MEKYS[3], Cătălin NEGRILĂ[1], Cristina BEȘLEAGĂ[1], Lucian PINTILIE[1]** [1]National Institute of Materials Physics, Romania [2]Materials and Devices for Electronics and Optoelectronics Research Center, Faculty of Physics, University of Bucharest, Romania [3]Institute of Photonics and Nanotechnology, Vilnius University, Lithuania

03rd of June, 2026

INVITED ORAL PRESENTATIONS

Session 5: Chair – Cristina BEȘLEAGĂ STAN	
9:00	**Ilia VALOV** Institute of Electrochemistry and Energy Systems, Bulgaria ***From artificial neurons and synapses to standards for resistance and time – Rational design of memristive functionalities***
9:30	**Martin ZIEGLER** Technische Universität Ilmenau, Germany **Cognitive material systems for neuromorphic information processing**
10:00	**Liza HERRERA DIEZ** Centre for Nanoscience and Nanotechnology, CNRS-Université Paris Saclay, France ***Magneto-ionic synaptic devices***
10:30	**Mario LANZA** NUS, Singapore ***Neuromorphic computing with NSRAM cells*** *– Online*
11:00	**Coffee break**
Session 6: Chair – George E. STAN	
11:15	**Heidemarie KRÜGER** Leibniz-Institute for Photonics Technologies (IPHT), Germany ***Physical AI with analog memristors for Edge Computing*** *– Online*
11:45	**Erika COVI** Technical University of Munich, Germany ***Emerging memory for neuromorphic Edge Computing*** *– Online*
12:15	**Sabina SPIGA** Istituto per la Microelettronica e Microsistemi (IMM-CNR), Italy ***Oxide-based memristors for brain-inspired and unconventional information processing*** *– Online*
12:45	**Lunch**
Session 7: Chair – Victor C. DICULESCU	
13:30	**Andreas OFFENHAUSER** RWTH Aachen and FZ Julich, Germany ***Designing the neuro-electronic interface: From nanostructured to flexible electrodes***
14:00	**Yoeri VAN DE BURGT** Eindhoven University of Technology, the Netherlands ***Learning and adaptivity in organic neuromorphic systems***
14:30	**Ewelyna KURTIS** FinalSpark, Switzerland ***Living computers*** *– Online*

15:00	**Nikhil GARG** University of Groningen, the Netherlands ***Neuromorphic in-memory learning with analogue integrated circuits and nanoscale memristive devices***
15:30	**Coffee break**
Session 8: Chair – Lucian PINTILIE	
15:45	**Andrei PĂUN** Research Institute for Artificial Intelligence "Mihai Drăgănescu" of the Romanian Academy, Romania ***Unconventional computing using ANNs***
16:15	**Simas RACKAUSKAS** Kaunas University of Technology, Lithuania ***Self-assembled ZnO nano-tetrapod network for neuromorphic computing***
16:45	**Paschalis GKOUPIDENIS** Max Planck Institute for Polymer Research, Germany ***Organic neuromorphic electronics*** – *Online*
17:15	**Round Table**
18:00	**Departure for Dinner**
19:00	**Dinner**

Biographies and Abstracts

of

Invited Oral Presentations

BIOGRAPHY

Dimitrios PINOTSIS
City St George's, University of London, United Kingdom

Dr. Dimitris PINOTSIS is an Associate Professor at the Department of Psychology and Neuroscience at City, University of London and head of the computational neuroscience and psychiatry lab (www.pinotsislab.com). He is also the Editor-in-Chief of the Journal of Computational Neuroscience published by Springer Nature and a Research Affiliate at MIT's Miller Lab. Previously, he was a Senior Research Fellow at UCL's Welcome Trust Centre for Neuroimaging and a Senior Scientist at MIT. Dimitris holds a PhD and an MSc in Mathematics from the Department of Applied Mathematics and Theoretical Physics (DAMTP) of the University of Cambridge, UK. His research has been funded by the NIH, US Air Force Office of Scientific Research, UK Research Councils (EPSRC, ESRC, Innovate UK) and several UK charities. It spans diverse areas including machine learning, the analysis of big data in neuroimaging, theoretical neurobiology and nonlinear systems in mathematical physics. Dimitris has received over 10 Fellowships from Cambridge Isaac Newton Trust, Onassis Foundation, NATO, Bernstein Organization and others. He is also the recipient of several awards including an OCNS Award, a Smith-Rayleigh Prize of the University of Cambridge and a Poincare Institute Award.

INVITED ORAL PRESENTATION

Brain implants, AI and biophysics

Dimitris PINOTSIS
City St George's, University of London, London EC1V 0HB, United Kingdom
pinotsis@citystgeorges.ac.uk

I will discuss theoretical advances in brain implants for depression, focusing specifically on how understanding the interaction between neuronal spiking and the brain's electric fields can yield putative biomarkers [1]. I will argue that these insights are particularly relevant for the development of next-generation AI-guided brain implants [2], in which machine-learning models do not simply decode spikes but learn from higher-order electrical dynamics of neural tissue. These dynamics, implemented by Electric Fields (EFs), operate one level above neuronal spiking: while they emerge from spiking, they turn around and constrain spiking by providing more stable and efficient representations of neuronal information [3]. This reciprocal top-down influence, known as ephaptic coupling [4], can account for representational drift [5]—where individual neurons change over time but the electric field patterns remain similar when the same cues are represented—as well as for intertrial variability [6].
I will present analyses that quantify these effects and explain how electric fields could be harnessed to develop more efficient brain implants. I will suggest that AI systems designed for brain–machine interfaces could exploit this stability in electric fields rather than relying solely on single-neuron activity. Finally, I will discuss a broader hypothesis that extends these findings to other brain structures, known as "cytoelectric coupling." This hypothesis suggests that electrical activity arising from other components of the cytoskeleton—at multiple spatial scales, including microtubules and proteins—interacts with neuronal electric fields; the resulting aggregate fields then exert causal influence back onto the cytoskeleton at the molecular level, promoting stability and enhancing information-processing efficiency [7]. I will propose that future AI models for neural interfaces may need to incorporate this multi-scale electrical architecture, moving beyond neuron-centric approaches toward a more holistic, field-based view of brain computation

References:

[1] Pinotsis, D. A., Alagapan, S., Sarikhani, P., Nauvel, T., Rozell, C. J., & Mayberg, H. S. Ephaptic coupling and power fluctuations in depression, Cerebral Cortex (to appear)
[2] Alagapan, S., Choi, K. S., Heisig, S., Riva-Posse, P., Crowell, A., Tiruvadi, V., ... & Rozell, C. J. (2023). Cingulate dynamics track depression recovery with deep brain stimulation. Nature, 622(7981), 130–138.
[3] Pinotsis, D. A., & Miller, E. K. (2023). In vivo ephaptic coupling allows memory network formation, Cerebral Cortex, 33(17), 9877–9895.
[4] Anastassiou, C. A., Perin, R., Markram, H., & Koch, C. (2011). Ephaptic coupling of cortical neurons. Nature Neuroscience, 14(2), 217–223.
[5] Pinotsis, D. A., & Miller, E. K. (2022). Beyond dimension reduction: Stable electric fields emerge from and allow representational drift. NeuroImage, 253, 119058.
[6] Pinotsis, D. A., & Miller, E. K. (preprint). Ephaptic coupling can explain variability in neural activity, https://doi.org/10.64898/2025.12.21.695758
[7] Pinotsis, D. A., Fridman, G., & Miller, E. K. (2023). Cytoelectric coupling: Electric fields sculpt neural activity and "tune" the brain's infrastructure. Progress in Neurobiology, 226, 102465.

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BIOGRAPHY

Beatrice Mihaela RADU
University of Bucharest, Romania

Beatrice Mihaela RADU is a professor of biophysics and biomedical microscopy at the University of Bucharest, Faculty of Biology, where she has pursued her academic career since 2002. She is affiliated with the Department of Anatomy, Animal Physiology, and Biophysics and is actively involved in teaching and doctoral supervision in neuroscience.

Her research activity is centred on the study of blood–brain barrier structure and function, neurovascular coupling, and the development of physiologically relevant in vitro platforms, including blood–brain barrier–on-chip and organ-on-chip systems, with applications in drug testing and translational neuroscience. Current research interests include endothelial barrier regulation, neuroinflammation, brain–device interfaces, and the integration of cellular and microfluidic models with advanced sensing and analytical approaches. Her research group involves undergraduate, graduate, and doctoral researchers working at the interface between neurophysiology, biomedical engineering, and applied neurotechnologies.

INVITED ORAL PRESENTATION

From brain physiology to intelligent interfaces: Lessons for neuromorphic technologies

Beatrice Mihaela RADU[1,*], Cristina STAICU[1,2], Felix SIMA[2]
[1]*Department of Anatomy, Animal Physiology and Biophysics, Faculty of Biology, University of Bucharest, Bucharest, Romania*
[2]*Center for Advanced Laser Technologies, National Institute for Laser, Plasma and Radiation Physics, 077125 Măgurele, Romania*
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The development of neuromorphic technologies increasingly relies on emerging hardware platforms, including memristive devices, spiking sensors, and adaptive neural interfaces [1,2]. Despite substantial progress, current implementations face critical limitations related to device variability, endurance, scalability, and the insufficient integration of physiological constraints into hardware and interface design [1,3]. The intrinsic complexity of neurophysiological properties, including spike timing–dependent coding, synaptic and homeostatic plasticity, neuromodulatory control, and multiscale feedback across neuronal and neurovascular loops, poses significant challenges for their translation into implementable neuromorphic architectures [4]. In parallel, the growing use of organ-on-chip and blood–brain barrier–on-chip platforms for drug testing highlights the need for neuromorphic devices and interfaces capable of interacting with physiologically relevant, dynamically regulated biological systems, particularly with respect to selective transport, adaptive regulation, and interface stability [5]. Within this context, the blood–brain barrier provides a reference model for interface architectures in which selective permeability, transporter-mediated exchange, and bidirectional signalling are dynamically co-regulated to maintain system stability while enabling controlled pharmacological access. Translating these principles to neuromorphic device and interface design underscores the need for adaptive, resource-aware interface layers capable of controlled signal and molecular transduction, supported by advances in emerging memristive and brain-inspired device technologies [6]. Addressing these challenges requires integrated device–system co-design strategies that align materials engineering, interface architectures, and biologically informed models to enable robust neuromorphic technologies and physiologically relevant platforms for drug testing.

References:

[1] Indiveri, G., & Liu, S.-C. (2015). Memory and information processing in neuromorphic systems. Proceedings of the IEEE, 103(8), 1379–1397.
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[6] Wang, J., Zhu, Y., Zhu, L., Chen, C., & Wan, Q. (2022). Emerging memristive devices for brain-inspired computing and artificial perception. Frontiers in Nanotechnology, 4, 940825.

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BIOGRAPHY

Romain BRETT
Sorbonne University, INSERM, CNRS, France

Romain BRETTE is a theoretical neuroscientist at the Institute of Intelligent Systems and Robotics, Paris. He was previously faculty at the Departments of Computer Science and Cognitive Science of Ecole Normale Supérieure, Paris, then in the Vision Institute, Paris. He has authored over 80 articles on various topics in neuroscience, from cellular biophysics to systems neuroscience, psychophysics and philosophy of neuroscience. He was awarded the early career scientific prize from Fondation pour l'Audition for his work on auditory perception, and the Open Science Free Software Award for his development of the neural simulator Brian. His current work lies at the intersection of microbiology and neuroscience, on the integrative neuroscience of protists.

INVITED ORAL PRESENTATION

Brains beyond computers

Romain BRETTE
Sorbonne Université, CNRS, Institute of Intelligent Systems and Robotics (ISIR), 75005 Paris, France
romain.brette@inserm.fr

Mainstreams theories of the brain are rooted in engineering concepts, such as computation, code, control, information, reverse-engineering, optimization. Living organisms are machines and the brain is a computer. It is rather ironic that, in the process of expelling God and magic from mind studies, cognitive science has persistently insisted that the brain is a machine, i.e., an artifact made by someone for a purpose using knowledge and planning. But the machine view of life is so engrained in scientific culture that it seems very difficult for many scientists to imagine that living organisms could be something else than machines, or that brains could be something else than computers.

Starting from a discussion of our biological nature, I will show how many traditional concepts of brain and mind science, such as computation, information or prediction, are poorly suited to the study of biological cognition. As it turns out, living organisms are not actually engineered, and this makes considerable differences in the way neurons work, interact with each other, and are organized.

Reference:

[1] Brette, R. (2026). The Brain, In Theory. Princeton University Press.

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BIOGRAPHY

Herbert JAEGER
Rijksuniversiteit Groningen, The Netherlands

Herbert JAEGER studied mathematics and psychology in Freiburg (Germany), got his PhD Computer Science / AI in Bielefeld (Germany) and then did a postdoc fellowship at the (then) German National Research Institute for Mathematics and Computer Science (GMD) in Sankt Augustin (Germany), where he subsequently founded the research unit on modelling intelligent dynamical systems (MINDS); then from 2001 to 2019 he served as professor in the CS department of the private Jacobs University Bremen (Germany). Since 2019 he is Professor for Computing in Cognitive Materials at the University of Groningen. Current research focus: mathematical foundations for a theory of computing on the basis of non-digital physical substrates. Jaeger retired in June 2025 and now has much more time for his research.

INVITED ORAL PRESENTATION

From materials to maths: the necessity and nature of a formal foundation for neuromorphic computing

Herbert JAEGER
Rijksuniversiteit Groningen (RUG), Bernoulliborg, Nijenborgh 99747 AG Groningen, The Netherlands
h.jaeger@rug.nl

In this talk I want to alert materials scientists and device physicists to the painful absence of a unifying formal theory for neuromorphic computing (NC). Starting from rehearsing the conditions that make digital computing (DC) so immensely powerful, I outline in what ways NC is fundamentally different from DC, and which structural elements from the theory of DC must be recovered in new ways to help NC climb toward the usefulness levels of DC, ... and why this is not going to be mathematically easy.

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BIOGRAPHY

George Alexandru NEMNEȘ
University of Bucharest Romania

George Alexandru NEMNEȘ is a professor at the Department of Electricity, Solid State and Biophysics, Faculty of Physics, University of Bucharest (UB). He obtained the PhD degree in 2008 from Chemnitz University, Germany. His research focuses on material physics and optoelectronic devices, the physics of many-body systems and the application of machine learning techniques in condensed matter.

INVITED ORAL PRESENTATION

Classical and quantum memristive devices for neuromorphic computing

George Alexandru NEMNEȘ
Faculty of Physics, University of Bucharest, Măgurele, Romania
alexnemnes@yahoo.com

Neuromorphic computing (NC) is nowadays a highly active research field, changing the paradigm of classical computer architectures. NC allows for training models from examples, while it benefits in terms of processing speed and low power consumption from new compact designs that use in-memory computing.

Starting from the initial proposal of a memristor device introduced by Chua [1] and a practical implementation in TiO_2 devices by Strukov et al. [2], where the migrating oxygen vacancies have the essential role, several other mechanisms for resistance modulation have been proposed, like the formation of metallic filaments, phase change or involving spintronic or ferroelectric effects. More recently, hybrid perovskite materials have been proposed for the realization of memristive devices [3], owing to their peculiar capacitive and inductive behaviours in the context of ion migration [4]. In this context, we review the major concepts and some particular implementations.

However, the continuous downscaling of electronic devices has prompted a discussion about quantum implementations of memristive devices. We approach this subject from the perspective of coherent scattering in multi-terminal neuron-like devices [5]. For this kind of systems, we establish connections between the synaptic weights and the scattering matrix elements. A possible implementation of a non-linear activation function is discussed. Next, a few-electron neuromorphic system is investigated, focusing on charge commutation effects on different terminals under the action of applied potentials on external gates [6]. Here, we employ machine learning (ML) techniques in form of conditional generative-adversarial networks (cGANs) [7] to predict charge density maps and deconvolute tunnelling current maps given the scattering potentials. The ML-based image translation procedure enables an efficient design of such quantum neuromorphic devices. Further examples include the implementation of quantum sorters, as a mirrored neuron geometry, which enable a direct identification of quantum states [8]. In the end, we present future perspectives concerning memristor implementations using quantum many-body systems.

References:

[1] L.O. Chua, IEEE Trans. Circuit Theory 18 (1971) 507.
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BIOGRAPHY

Coriolan TIUȘAN
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Prof. PhD. Habil. Coriolan TIUȘAN has over 30-year experience in the field of Spintronics acquired within several high level international European laboratories: Inst. de Phys. et Chim. des Matériaux (IPCMS) Strasbourg-FR, Oxford Clarendon Lab. –UK, SIEMENS Res. Lab. Erlangen-DE and, since 2001, as a permanent researcher in the French CNRS at the Jean-Lamour Institute (IJL)–Nancy University. Since September 2021, C. Tiusan joined the Faculty of Physics, Department of Solid-State Physics and Advanced Technologies Babes-Bolyai-University, Cluj-Napoca, Romania as tenured University Professor and Senior Researcher from the National Centre of Scientific Research (CNRS), France. His current research projects are related to neuromorphic and quantum materials and spintronics. In these upstream R&D areas, C. Tiusan brings his broad scientific expertise in material science and nanotechnologies area from both experimental and modelling perspectives. They mainly concern the elaboration and characterization techniques of simple and complex small dimensional systems based on multilayered thin film heterostructures, micro and nano devices, using ultra-high vacuum techniques equipped with various in-situ characterization tools for analysing surfaces and interfaces, clean room techniques for micro- and nano-structuring, various magnetic, magneto-electric and micromagnetic characterization tools and near-field microscopy techniques. The experimental skills are assisted by a long-term experience in physical phenomena modelling involving both analytical and numerical DFT and micromagnetic tools. He authored more than 130 ISI papers, over 100 oral presentations in international conferences with over 20 invited talks and coordinated research activities at different levels: PhD, postdocs, and research teams within various research projects with national or European funding. He was awarded by the Romanian Academy Prize "Constantin Miculescu", the Bronze Medal of CNRS France and by the French national award for scientific excellence (PES). During the last two decades, C. Tiusan was leader of R&D projects of about 2M€ in France and Romania meant to develop various R&D capabilities for spintronic devices and sensor prototypes based on thin film, micro and nanoelectronic technologies.

INVITED ORAL PRESENTATION

Skyrmionic qubits stabilized by Dzyaloshinskii-Moriya interaction as platforms for qubits and quantum gates

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Quantum computation departs from the classical paradigm of deterministic, bit-based processing by exploiting inherently quantum phenomena such as superposition and entanglement. We propose a framework for qubit realization based on skyrmionic states stabilized by the Dzyaloshinskii–Moriya interaction (DMI) in two-dimensional spin lattices [1]. The model incorporates competing exchange interactions, perpendicular magnetic anisotropy, and Zeeman coupling, and is solved via exact diagonalization under periodic (PBC) and open boundary conditions (OBC). A quantum skyrmionic phase emerges under PBC within a parameter space defined by DMI strength, exchange, external field, and anisotropy, whereas OBC favor classical-like, topologically protected skyrmions. Quantum logic gates (Pauli X, Y, Z, and Hadamard) are implemented for both skyrmion types. Energy density and entanglement entropy analyses reveal that quantum skyrmions are susceptible to DMI-driven decoherence and reduced gate fidelity, while classical-like skyrmions retain enhanced stability. Exact simulations of qubit dynamics, including drive effects and Lindblad decoherence, demonstrate tunable anharmonic energy levels and coherent Bloch-sphere manipulation, positioning these skyrmionic states as promising candidates for qubit implementation. Overall, the Dzyaloshinskii–Moriya interaction plays a dual role, stabilizing skyrmionic qubits while simultaneously inducing decoherence during gate operations. Finally, we outline a forward-looking paradigm in which skyrmionic qubit architectures may be integrated with skyrmion-based neuromorphic architectures, enabling neuromorphic logic to augment and actively reinforce the stability of topological skyrmionic qubits.

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BIOGRAPHY

Liliana PREJBEANU
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Liliana PREJBEANU is Professor at Phelma Engineering School and Scientific Director at Grenoble– INP/UGA (France). She is expert in modelling of spintronic devices (memories, sensors, oscillators) and unconventional computing (Ising machine, neural networks).

INVITED ORAL PRESENTATION

Phase dynamics of injection locked spin-torque nano-oscillators: From synchronization to Ising machines

Mateo Ibarra GOMEZ[1], Arthur COURBERAND[1], Abderrazak HAKAM[1], Chloé CHOPIN[1], Philippe TALATCHIAN[1], Ursula EBELS[1] and Liliana D. BUDA-PREJBEANU[1,*]
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The phase dynamics of coupled and/or injection locked arrays of spin torque nano-oscillators (STNO) can be harnessed for novel hardware concepts within unconventional computing schemes [1] or for smart communication applications [2]. Here we address the case of an array of weakly coupled STNOs that are simultaneously injection locked to an RF signal whose frequency is close to two times the free running STNO frequency. This 2f - injection-locking leads to a phase binarization (π-peridiodic values of the oscillator phase) that can be exploited as a binary spin to implement an Ising machine (IM) for solving combinatorial optimization problems (COP) [3]. For this purpose, the problem is mapped on the Ising Hamiltonian $\mathcal{H}_{\rm Ising} = -\Sigma_{<i\,j>} J_{ij}\, \sigma_i\, \sigma_j - \Sigma_i\, h\sigma_j$ that describes a 2D array of binary-valued spins σ_i, σ_j and where the coupling constants J_{ij} encode a given problem. The inherent convergence towards the global energy minimum can then be used as an algorithm to determine the solution of the COP.

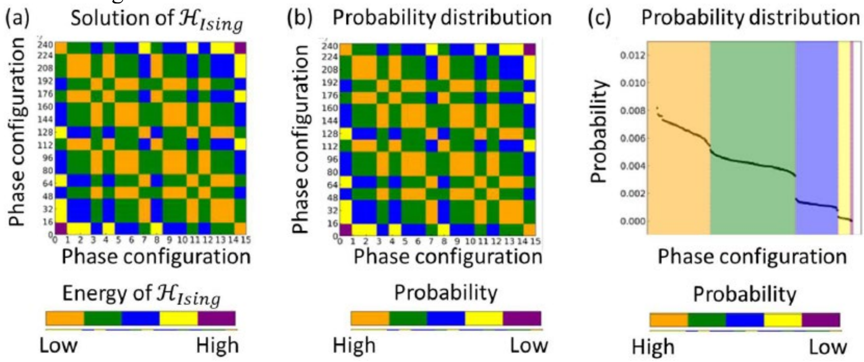

***Figure 1**: Comparison of the solution of (a) the Ising Hamiltonian $\mathcal{H}_{Ising}$ for N=8 spins, with 256 highly degenerate spin states, resulting in only 5 different energy levels indicated by the color code and (b) the probability distribution for N=8 coupled identical STNOs for V_{DC} = 1.5V, rf source frequency 9.618 GHz and a ratio of detuning to locking range δ/ΔΩ = 0.6. The total simulation time is 200 µs and the temperature T=50 K. The probabilities are grouped into five levels according to (c), where the states of highest to lowest probability are plotted.*

To explore the stochastic phase dynamics within an Ising system based on in-plane magnetized STNOs the the coupled Landau-Lifshitz-Gilbert-Slonczewski equations including thermal fluctuations have been solved numerically. Combing these numerical simulations with analytical models provided by the non-linear auto-oscillator theory [4] allows one to extract the instantaneous phase of single and N coupled STNOs (N ≥ 2). Due to thermal fluctuations, the phase of each STNO jumps stochastically between its two binary states and, therefore, phase state probabilities and phase correlations between different STNOs are extracted. For a single oscillator, both phase states are equiprobable in the isolated and coupled case. However, the probabilities of the 2^N collective phase states are unequal when the coupling between STNOs is activated. The probability distribution of the phase states of all coupled STNOs is analyzed as a function of the coupling parameters (strength, sign, type of coupling), frequency mismatch and operational point in order to determine the parameter range that provides the solution to an optimisation problem. Results will be illustrated for the MaxCut problem ($J_{ij}=K<0$) for which the energy levels of the corresponding Ising Hamiltonian $\mathscr{H}_{Ising}$ are determined for all possible phase state combinations (Fig. 1a). The phase states with lowest energy are expected to correspond to the phase states of highest probability (Fig.1b). We first present results for identical STNOs and then address the important question of non-identical STNOs to guide experimental implementations of an Ising machine.

This work was supported in part by the France 2030 government investment plan managed by the French National Research Agency under grant reference « PEPR SPIN – SPINTHEORY ANR-22-EXSP-0009 », by the French National Research Agency project SpinIM ANR-22-CE24-0004 and by the CEA project PTC-MINOS. M. Ibarra Gomez acknowledges financial support from the French Space Agency (CNES) and the European Union's Horizon 2020 research and innovation programme under grant agreement No 800945 — NUMERICS — H2020-MSCACOFUND-2017.

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BIOGRAPHY

Brahim DKHIL
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Prof. Brahim DKHIL obtained his PhD in Physics and Materials Science in 1999 from Ecole Centrale Paris and the University of Orsay, France, and joined the Structures, Properties and Modelling of Solids Laboratory at Centrale Supélec, Université Paris-Saclay to develop his research activity on ferroelectrics and related materials, with the aim of gaining a better understanding of the microscopic mechanisms at play in these systems through their structure-property relationships at multiple scales, and better exploiting their functionalities for electronic, computing, energy and environmental applications.

INVITED ORAL PRESENTATION

Multistate memories to neuromorphic computing with ferroelectric-related materials

Brahim DKHIL[1,*] et al.[2]
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The processing of cognitive and data intensive tasks, such as real-time image recognition, data classification or natural language processing, to name but a few, requires to go beyond the conventional von Neumann architecture and move toward neuromorphic computing by imitating the structure of the human brain and the way it operates. As a result, ferroelectrics have been considered to emulate artificial synapse behaviours by designing memristors based on the ability to tune the domain configurations using electric field pulses. Here, besides classical ferroelectrics, we also explore other ferroelectric-related materials such as antiferroelectrics and relaxor relaxor-based materials to achieve multiple state memories and synaptic functions. Instead of exploiting the domain arrangements, we rather use the possibility to switch the polarization and dielectric responses using close energy phases, e.g. by exploring the flat energy landscape in relaxors. We show that indeed electric field pulses induce phase transitions enabling to tune the polar and capacitance responses along multiple states and in a non-volatile manner. We also show it is possible to reproduce memcapacitor behaviour similar to that of biological synapses. Some fundamental learning rules including short-term and long-term memory or spike-timing-dependent-plasticity are successfully emulated.

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BIOGRAPHY

Jean-Francois DAYEN
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Jean-François DAYEN is Full Professor at the University of Strasbourg and group leader at the Institut de Physique et de Chimie des Matériaux de Strasbourg (IPCMS/CNRS/Unistra), where he has been based since 2008 within the Advanced Materials and Devices team. He also heads the Master's program in Quantum Technologies – European Program at the University of Strasbourg and has been recognized by the Institut Universitaire de France for the excellence of his research.

His research lies at the interface of nanomaterials, device physics and functional materials for next-generation electronics. Over nearly two decades, he has developed a coherent scientific program centred on low-dimensional and hybrid materials for electronic, spintronic, optoelectronic and neuromorphic applications. His work includes the study of ferroelectric materials for neuromorphic computing, magnetic materials for spintronic devices and memory technologies, quantum spinterfaces based on graphene proximized with magnetic materials, and hybrid heterostructures combining 2D materials with quantum dots for optoelectronic functionalities. More broadly, he has contributed to the field of 2D materials since 2006, from graphene electronics to van der Waals heterostructures and advanced hybrid device concepts.

He has extensive expertise in nanofabrication, nanomaterials and device engineering, together with a strong record in research leadership and project management. He has coordinated or co-coordinated several national and European projects. He also plays an active role in the French 2D materials community through national research networks (GDR 2D+ : https://gdr-2dplus.cnrs.fr/). He has co-authored more than 67 publications in leading international journals, including review articles and a book chapter, and is co-inventor of four patents in nanotechnology and sensor-related fields.

INVITED ORAL PRESENTATION

Van der Waals ferroelectric heterostructures for in-memory computing and emergent electronics

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2D ferroelectric materials are attracting fast growing interest for the implementation of complex more-then-Moore and beyon-Moore architectures that are challenging to design with standard thin film technology.[1] Here, I will present recent developments on the coupling of a 2D vdW electron gas with various ferroelectric gate controls. We will discuss how these systems allow for rethinking circuit topology and memory-logic interaction, opening up new research directions in the area of frugal computational enhancement and neuromorphic computing for AI.

I will first detail how by making use of the switchable polarization state of two splitted ferroelectric gates, the electrical potential landscape within a semiconductor channel can be permanently and reconfigurably modified.[2] While using the non-volatile ferroelectric states encoded in each gate, the ferroelectric logic circuits can function as six alternative logic gates, while CMOS circuit are limited to a single function. Such Re-FeFET circuits demonstrate high compactness, with an up to 80% reduction in transistor count compared to standard CMOS design.

Then, I will show the emulating of synaptic plasticity in vdW Ferroelectric Field Effect Transistor (FeFET) using unipolar or ambipolar 2D semiconductor.[3][4] Combined electronic transport and piezo force microscopy investigations allows to carefully investigate the fine tuning of multidomains polarization landscape of the vdW ferroelectric gate, and its transduction into the conduction of the 2D semiconductor channel down to 50 nm scale for emulating artificial synapse plasticity. This dynamic synaptic reconfigurability offers new possibilities for next-generation neuromorphic computational architectures.

Finally, I will present how light-structure interactions in vdW systems allow for implementing the non-volatile electrical and optical control of the ferroelectric polarization in ferroelectric/semiconductor heterostructures.[3][5][6] The wavelength-dependent study unveils ferroelectric polarization control and decouples the mechanisms driven by photogenerated carriers for each material and at the interfaces. Following, long-term potentiation/depression, and spike rate-dependent plasticity are shown using electrical AND optical controls, enabling optically-stimulated and optically-assisted synaptic devices implementation.

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BIOGRAPHY

Athanasios DIMOULAS
INN-Demokritos, Greece

Dr. Athanasios DIMOULAS received his PhD in Applied Physics in 1991 from the University of Crete and FORTH, Greece. He then obtained an EU-Human Capital & Mobility Fellow at the University of Groningen (The Netherlands) where he stayed until 1994, and a fellowship at CALTECH, which ended in 2006. He was also a research associate at the University of Maryland until 1999, a visiting researcher at IBM Zurich in 2006 and 2007, and between 2016 and 2018 he was appointed LANEF Chair of Excellence at CEA-INAC and the University of Grenoble Alpes, France. Dr. Athanasios DIMOULAS is currently Director of Research at NCSR-DEMOKRITOS, Athens, Greece. He is the founder and head of the Epitaxy and Surface Science Laboratory (ESSL) since 1999. He is also a member of the Greek government's advisory committee on Physical Sciences. He was also elected full professor of Experimental Condensed Matter Physics in the Department of Physics of the National Kapodistrian University of Athens. He has over 200 published papers, with more than 7,000 citations (H=45), and over 60 invited presentations at international conferences. He has been and is the director of several research projects, including an ERC Advanced Grant.

INVITED ORAL PRESENTATION

Ferroelectric materials for neuromorphic computing technologies

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An introduction on memristors with a brief historical survey will first be presented, emphasizing their relation to biological systems. A review on emerging non-volatile memory devices functioning as memristors will follow with a special focus on the ferroelectric memristors which offer a number of technology implementations (FRAM, FeFET, FTJ) to cover a wide spectrum of applications.

Hafnia based ferroelectrics (*e.g.*, $Hf_{0.5}Zr_{0.5}O_2$ (HZO)) are of particular interest due to compatibility with Si processing. The HZO FTJ two terminal devices stand-out for their simplicity, non-destructive read and low voltage/low power operation. Their performance and reliability are enhanced by using functional bottom electrodes made of oxide semiconductors such as STO. These oxides allow for epitaxial or textured growth of HZO with improved ferroelectric switching characteristics. Also, they contribute additively to the electroresistance with ionic effects enhancing the performance of the FTJs.

The HZO FTJ devices show various types of synaptic plasticity making them suitable as electronic synapses in artificial neural networks in hardware. They can be programmed by voltage pulses to a number of stable intermediate states which could be accessed by identical pulses or variable width pulses creating prospects for use in AI accelerators for analogue in-memory computing. Moreover, the HZO FTJ memristors exhibit spike timing dependent plasticity (STDP) featuring potentiation or depression of a synapse depending on the synchronization of pre-and post-neuron pulses. This property emulates synaptic dynamics of biological synapses and it can be used for unsupervised learning in spiking neural networks (SNN) for next generation neuromorphic computing. We will show that, using HZO FTJs, biological timescales of a few tens of milliseconds are accessible. Much faster STDP time responses are also obtained down to the (sub)microsecond range, albeit with an increased voltage (and power) consumption. Despite the time-to voltage trade-off it is shown that the energy consumption due to Joule heating is negligibly small because FTJs are voltage driven devices consuming only the energy necessary to charge the ferroelectric capacitors. As a result, the energy consumed per synaptic event is low, comparable to biological numbers of ~10 fJ. Therefore, HZO FTJ technology provides an excellent platform for energy efficient chips powered by AI.

Acknowledgments: Financial support is acknowledged from project ARSYF, and HE projects CONCEPT, ViTFOX and FIXIT.

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BIOGRAPHY

Wolfgang SCHWINGER
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Wolfgang SCHWINGER received his Master's degree in Physics in 2003 from the Johannes Kepler University in Linz, Austria, where he also completed a Master's degree in Physics and Mathematics for the Teaching Profession in the same year. Earlier, between 1998 and 1999, he studied Physics at Uppsala University in Sweden.
He began his professional career in the field of electron microscopy, serving as Account Manager for Electron Microscopy at FEI (now Thermo Scientific) from 2008 to 2015. In 2015, he joined the Kepler University Clinic in Linz as Leading Scientist for Computational Neuroscience, a position he held until 2016. Since 2012, he has also been a Lecturer in Microscopy at the University of Applied Sciences Upper Austria. Since 2016, Wolfgang Schwinger has been working at Carl Zeiss, where he holds the role of Regional Manager and Business Development Manager for Electron Microscopy (EM), Ion Microscopy (IM), and X-Ray Microscopy (XRM) across Austria and South-East Europe.

INVITED ORAL PRESENTATION

Introducing the new ZEISS Crossbeam 750 with Gemini 4 column and ZEISS EMToolkit SW

Wolfgang SCHWINGER[1,*], Manoj MATHEW[2]
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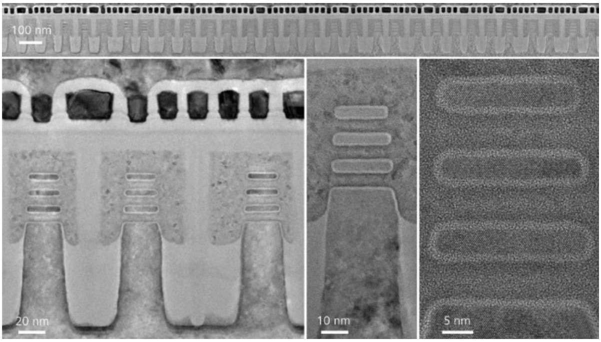
For any advanced FIB/SEM application like sub 50 nm TEM lamella or atom-probe tip preparation, for milling beam sensitive samples, 3D tomography or precise site-specific preparation, the ability to mill and watch the ongoing milling-process unfold live with the electron beam is key.
With the all-new Crossbeam 750 introducing the new ZEISS Gemini 4 electron column fast, distortion free live observation is finally at your hand. The new high-dynamic-range (HDR) FIB-mill & SEM capability maintains a clear, high-resolution SEM view at any FIB condition, from rapid milling with high FIB currents down to fine polishing at 0.5 keV. This real-time clarity, paired with the Gemini 4 electron optics, allows to fine-tune processes as they work—reducing rework, improving yield and delivering highly uniform lamellae on the first pass.



TEM image of 3nm GAA-FET SRAM prepared with Crossbeam 750

In the second part of this talk we will present ZEISS **EM toolkit**, a new and innovative software tool for easy automatization of imaging workflows on ZEISS electron microscopes by using the standard API interface. The user can built workflows using drag-and-drop building blocks, eliminating the need for time consuming coding (although parallel phyton scripting is available). Bulit in AI-based detection algorithms significantly enhance accuracy and repeatability compared to labour-intensive manual processes.
New auto-functions and customizable measurement capabilities ensure precise and reliable correlation between metrology data statistics and processing conditions. Logics and conditional loops allow for simple setup even of complex and demanding analytical workflows.

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BIOGRAPHY

Jose Luis 'Pepe' CONTRERAS-VIDAL
IUCRC BRAIN University of Houston, USA

Dr. Jose 'Pepe' L CONTRERAS-VIDAL is Hugh Roy and Lillie Cranz Cullen Distinguished Professor, director of the U.S. National Science Foundation Industry-University Cooperative Research Center for Building Reliable Advances and Innovations in Neurotechnology (IUCRC BRAIN) at the University of Houston, Director of the NSF-funded Movement, Music and Brain Health AccelNet international network and Co-PI of the NIH U24 Music Dementia Research Network, and an elected Fellow of the IEEE and AIMBE for his pioneering contributions to development of brain-machine interfaces for controlling wearable exoskeletons for rehabilitation, and for mapping art-evoked brain activity. His work at the nexus of art and science is opening new windows to study the neural basis of human creativity and the design of personalized arts prescriptions. His art-science team received the Chamber Music America's 2025 Interdisciplinary Collaboration of the Year for "Meeting of Minds", which was performed at the United Nations' 2024 AI for Good" Summit in Geneva, Switzerland. Dr. Contreras-Vidal is a former member of the National Advisory Board for Medical Rehabilitation Research (NABMRR) at the NIH. He is a Senior Member of the National Academy of Inventors. His career development in biomedical engineering was highlighted by the journal Science.

INVITED ORAL PRESENTATION

Brain, mind, body, art and the neural basis of creativity

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Non-invasive brain-computer interface (BCI) systems have shown the potential to extend neural control beyond clinical applications into broader human-computer interaction for communication and control of digital, physical and more recently, co-creative environments. Whereas early applications of Generative AI (GenAI) in art often treated the machine as a one-way executor of human ideas, the next frontier lies in interactive intelligence: BCI – GenAI systems that engage in the improvisational flow of human expression. Such systems detect internal states and respond dynamically to intent, emotion, attention or other states, thereby facilitating ongoing human–AI collaboration during artistic performance or creation. In this talk, I will provide an overview of our collaborative art-science performance studies integrating mobile brain-body imaging (MoBI), BCI approaches, hyperscanning, adaptive noise cancelling algorithms and GenAI to understand the creative brain during artistic performance in ecological settings. Time permitting, I will conclude with examples of new applications to investigate the impact of nature- and faith-based practices on brain health and wellbeing.

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BIOGRAPHY

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Dr. Ghazi Sarwat SYED is a Research Staff Member at IBM Research–Zurich, where he conducts research on processing-in-memory accelerators across both electronic and optical platforms. He holds a Ph.D. Materials Science from the University of Oxford, United Kingdom. Dr. Syed has authored 50 publications, delivered 20 invited talks/tutorials, and holds 35 international patents in the field. He has also contributed to the development of IBM's commercial inference infrastructure watsonx.ai for serving LLMs. Dr. Syed also has an active record of mentoring, including 3 PhD and 6 Master's dissertations. In 2023, he was recognized as a Forbes 30 Under 30 honouree. In the same year, he was also awarded the honorary title of IBM Master Inventor. Dr. Syed is also a recipient of the European Research Council (ERC) Starting Grant, Principal Investigator of the EU Pathfinder Open NEQIOS project, and Co-Principal Investigator and project manager of the HYBRAIN project. Dr. Syed is a passionate advocate for science communication and STEM education and is always eager to engage in discussions and initiatives supporting this cause.

INVITED ORAL PRESENTATION

Intelligence through physical computing

Ghazi Sarwat SYED
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We have entered an exciting era of technology in which we can converse with machines with remarkable fluency. Yet true machine intelligence is not defined solely by the accuracy of responses; it must also be achieved in a manner that is sustainable in both energy and physical space. Meeting this challenge is fundamentally a hardware problem.
In this talk, I will introduce the concept of physical computing as pursued in my research, where computation emerges directly from the intrinsic physics of materials, devices, and circuits, rather than from the abstract digital operations that dominate conventional computing. The talk is divided into three parts. The first part establishes the foundations for scalable physical computing through manufacturable materials and rigorous device engineering at the nanoscale. The second part focuses on circuits and architectures designed to achieve high compute density and efficiency. The final part presents real-world examples demonstrating the merits of physical computing across sensor and inference applications, charting a path toward more efficient and scalable intelligent systems.

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BIOGRAPHY

Ilia VALOV
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Ilia Valov is Professor in Electrochemistry at the Institute of Electrochemistry and Energy Systems, Bulgarian Academy of Sciences and Head of Group Nanoelectrochemistry at the Research Centre Juelich in Germany, teaching at the RWTH-Aachen University. He received his M.Sc. in materials' electrochemistry at the University of Chemical Technology and Metallurgy, Sofia, Bulgaria, and Ph.D. in physical chemistry of solids with summa cum laude at the University of Giessen, Germany. His research interests and activities are concentrated on electrochemical and, in general, physicochemical phenomena at the nano and sub-nanoscale, such as mass and charge transport, electric double layer, point defects, surfaces and interfaces with a focus on developing artificial neurons and synapses, memristive and neuromorphic devices, energy conversion and electro- catalysis. A special focus is set on the relation between materials chemistry, structure and properties, materials design and particular applications and functionalities.
Ilia VALOV has published over 160 research papers with over 14000 citations, h-factor 58 and also guest edited special issues for RSC, Wiley and Elsevier journals. He serves as editorial advisory board member of NPG Unconventional Computing, Advanced Electronic Materials (Wiley) and APL Machine Learning. Ilia is a member of the Scientific Advisory Board of Leibniz Institute for Surface Modifications (IOM), Leipzig, and is Erskine Fellow (New Zealand) for 2024.

INVITED ORAL PRESENTATION

From artificial neurons and synapses to standards for resistance and time – Rational design of memristive functionalities

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Tuning the electric characteristics of nanoscale devices by reversible insertion or removal of ions has proven to be a reliable and effective way to achieve spectacular functionalities. The process of ion incorporation can be considered as electrochemically driven doping, where the inserted species play the role of either donors or acceptors, and the resulting electron band structure and conductivity are a direct function of the chemical state and physicochemical properties of the mobile dopants' concentration. Ideal example for the nanoionic-enhanced devices are memristors, considered the next generation building units of the future, brain-inspired hardware, going beyond the von Neumann architecture. Memristive devices exhibit a broad spectrum of functionalities, being used for volatile and non-volatile memories, selectors, sensors, field-programmable gate arrays and for in-memory computing. Sharing same electrochemical fundamentals with their biological counterparts, they are especially appropriate to be used as artificial neurons and synapses for neuromorphic applications. However, challenges for this technology remain variability and still unresolved puzzle on precise tuning and control of the different functionalities. To overcome these problems, in-depth understanding of the fundamentals of material related properties and details on nanoscale processes is urgently required.

In this contribution, essential but mostly overlooked fundamental factors, that strongly influence memristive properties will be discussed, that are of key importance for establishing a materials-based, rational design roadmap. It will be showcased that the level of intrinsic impurities in both oxide and metal components determine the performance. Stack composition and even the thickness ratios of individual layers within the stack should be properly adjusted. The importance of the interplay between the Schottky and electrochemical redox barriers, and the resulting demand on rational interface engineering will be highlighted. New areas of application are identified, using memristors as standards for resistance and time in the light of the revised SI system of units. Finally, results from a newly developed, unique synchrotron-based technique for nm-resolved structural and chemical analysis will be shown, demonstrating the prospective for revealing new fundamental knowledge, further expanding the fields of application for memristive devices.

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BIOGRAPHY

Martin ZIEGLER
Technische Universität Ilmenau, Ilmenau, Germany

Martin ZIEGLER (Prof. Dr. rer. nat. habil.) is Professor and Head of the Chair of Energy Materials and Devices at the Institute of Materials Science, Kiel University, Germany. He received his Diploma in Physics (2006) and his doctorate in Experimental Physics (2009) from Kiel University, where his research focused on spin-polarized scanning tunnelling microscopy and spectroscopy. His academic training included physics studies at Technical University of Darmstadt, University of Bordeaux 1, and Kiel University. Following his doctoral studies, he worked as Research Assistant (2006–2010) and Postdoctoral Researcher (2010–2017) at Kiel University and qualified as Privatdozent in 2017. From 2018 to October 2024, he served as Head of the Chair of Micro- and Nanoelectronic Systems at Technical University of Ilmenau, where he also held leadership roles including Deputy Director of the Institute of Micro- and Nanoelectronics. Since October 2024, he has led the Chair of Energy Materials and Devices and is a member of the institute's directorial board at Kiel University.

His research focuses on memristive materials and devices, as well as neuromorphic electronics. He has led and coordinated several major research initiatives, including the DFG Research Unit FOR 2093 Memristive Devices for Neural Systems, the BMBF infrastructure project Ilmenau Research Laboratory for Neuromorphic Electronics, and the Carl Zeiss Foundation–funded research groups Memristive Materials for Neuromorphic Electronics (MemWerk) and Neuromorphic Acoustic Sensor Technology for High-Performance Hearing Aids of Tomorrow (NeuroSensEar). He also serves as Deputy Spokesperson of the Collaborative Research Centre 1461 Neurotronics.

INVITED ORAL PRESENTATION

Cognitive Material Systems for Neuromorphic Information Processing

Martin ZIEGLER
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Conventional computer architectures separate sensing, memory, and computation into predefined functional blocks, whereas biological systems realise information processing through embodiment, where function emerges from adaptive cellular dynamics and structural plasticity across scales. This motivates solid-state material systems in which sensing, learning, memory, energy conversion, and adaptive response are physically co-located, enabling emergent behaviour and intrinsic computation. Such cognitive material systems transform microscopic physical processes into functional macroscopic responses and can natively perform tasks such as pattern recognition or time-series prediction.

In this talk, I present neuromorphic approaches as a pathway toward embodied information processing (see Figure). I demonstrate how redox-based memristive devices and an adaptive acoustic MEMS sensor exploit their underlying device physics to tightly integrate sensing, memory, and computation, enabling continuous adaptation to changing environmental conditions. Together, these examples delineate a technological route toward cognitive, sustainable, and highly energy-efficient information technology.

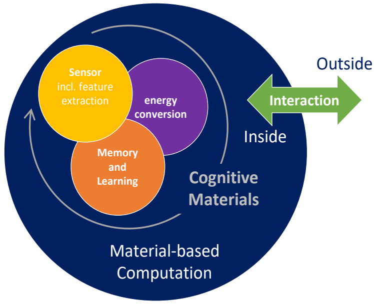

***Figure**:| Physical embodiment of information processing: Cognitive materials integrate sensing, energy converion, learning, memory and adaptive responses within solid-state ionic and electronic systems enabling material-based computing. The system continuously interacts with its environment, for adaptive information processing.*

Acknowledgements:
This work was partially funded by the Carl-Zeiss Foundation via the Projects MemWerk and NeuroSensEar and the German Research Foundation (DFG) through the Collaborative Research Centre CRC 1461 "Neurotronics – Bio-Inspired Information Pathway" and the SPP 2262 "Memristive Devices Toward Smart Technical Systems".

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BIOGRAPHY

Liza HERRERA DIEZ
Centre for Nanoscience and Nanotechnology CNRS- Université Paris Saclay, France

Liza HERRERA DIEZ is a CNRS research director at the Centre for Nanoscience and Nanotechnology in Palaiseau, France. She studied physical chemistry at the National University of Córdoba in Argentina and conducted her PhD work at the Max Planck Institute for Solid State Research in Germany while enrolled in the physics doctoral school at Ecole Polytechnique Fédérale de Lausanne.

She has an interdisciplinary background in physics and chemistry. Her research focuses on magneto-ionics, which combines the analogue functionality of ionics with the binary nature of magnetism to develop reconfigurable multistate spintronic nanodevices. She coordinated the MSCA Innovative Training Network MagnEFi on electric-field effects in magnetic materials and devices, and currently coordinates the EU Pathfinder project METASPIN, which explores magneto-ionic approaches to design multifunctional nanodevices for neuromorphic hardware.

INVITED ORAL PRESENTATION

Magneto-ionic synaptic devices

Liza HERRERA DIEZ
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The ability to manipulate magnetic properties through ionic motion in ferromagnetic/oxide structures in a non-volatile way, rather than through volatile, purely electronic means, presents exciting opportunities for the development of functionalities like reconfigurable multistate memories and the implementation of cumulative gate effects in spintronics devices. Magneto-ionics takes inspiration from memristor technologies and offers one of the most advanced approaches today for controlling magnetic properties using ionics. Integrating ionic and spintronic technologies offers new degrees of freedom to design neuromorphic hardware with novel magnetic functionalities, alongside the established ionic analogue behaviour.

I will present different strategies to develop multistate magneto-ionic memory devices using CoFe alloys. A variety of material combinations and device designs allows to explore the control of nucleation/propagation of a spin-reorientation transition under gate voltage and the exploration of an extended gate-induced oxidation-reduction spectrum to generate multiple stable, electrically detectable magneto-ionic states. I will also demonstrate that magneto-ionic nanodevices can not only function as basic synaptic elements, using their capacity to encode multiple analogue states, but also enable new bioinspired functionalities. We show that in magneto-ionic synaptic elements, synaptic depression can be tuned using a magnetic field, allowing to dynamically control the linearity of the synaptic weight update. This functionality is reminiscent of neuromodulation, observed in biological systems, and neural network simulations reveal that a magnetically induced enhancement in weight-update linearity improves learning accuracy across a wide range of learning rates.

These findings highlight the versatility and promise of magneto-ionic devices for developing multifunctional synaptic elements for neuromorphic hardware.

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BIOGRAPHY

Mario LANZA
NUS, Singapore

Dr. Mario LANZA is an Associate Professor of Materials Science and Engineering at the National University of Singapore, since August 2024. He got the PhD in Electronic Engineering in 2010 at the Autonomous University of Barcelona, where he won the extraordinary PhD prize. In 2010-2011 he was NSFC postdoctoral fellow at Peking University, and in 2012-2013 he was Marie Curie postdoctoral fellow at Stanford University. On September 2013 he joined Soochow University (in China), where he promoted until the rank of Full Professor. Between October 2020 and July 2024 he was full-time Associate Professor at the King Abdullah University of Science and Technology (in Saudi Arabia), where he became known for his work in the field of nano-electronics. He has published over 250 research articles in top journals like Nature (3), Science (2), and Nature Electronics (8), many of them becoming highly cited. He has been plenary, keynote, tutorial and invited speaker in over 150 conferences, and he and his students have received some of the most prestigious awards in the world (like the IEEE Fellow). He has been often consulted by leading semiconductor companies and publishers. He is an active member of the board governors of the IEEE – Electron Devices Society, and has been involved in the technical and management committee of top conferences in the field of electron devices, including IEDM, IRPS and IPFA. He speaks fluently five languages: English, Chinese, German, Spanish and Catalan.

INVITED ORAL PRESENTATION

Neuromorphic computing with NSRAM cells

Mario LANZA
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The semiconductor industry is experiencing an accelerated transformation to overcome the scaling limits of the transistor and to adapt to new requirements in terms of data storage and computation, especially driven by artificial intelligence applications and the internet of things. Within this process, new materials, devices, integration strategies, and system architectures are being developed and optimized. In this talk, I will present how silicon CMOS transistors operated on the verge of punch-through impact ionization can be used to emulate neural and synaptic behaviours while providing a massive area reduction compared to other solutions. I will also present a 2-transistors cell called Neuro-Synaptic Random Access Memory (NSRAM), which exhibits adjustable neural and synaptic response with a yield of 100% and an ultra-low device-to-device variability, and it represents a short-term solution for the implementation of efficient artificial neural networks.

More information can be found in our recent publication: S. Pazos et al. Nature 640, 69–76 (2025), https://doi.org/10.1038/s41586-025-08742-4.

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BIOGRAPHY

Heidemarie KRÜGER
Leibniz-Institute for Photonics Technologies (IPHT), Germany

Prof. Heidemarie SCHMIDT received her Diploma/PhD in experimental physics from University Leipzig in 1995/1999. Her research focuses on solid materials with novel optical and transport properties. She was Heisenberg fellow from the German Research Foundation (2012-2017) and was appointed as professor at the Friedrich-Schiller University Jena and as Head of Department "Quantum Detection" at Leibniz-IPHT e.V., Jena, in 2017. She has been the author of over 200 publications including original research papers and reviews and she has contributed to over 100 patents. Her team and she discovered a material for memristors which merge data processing and data storage in the same cell in 2011, and she set up a company to bring electronic products with their world-wide unique memristors to market in 2021. Prof. SCHMIDT wishes to pave the way for resource-saving neuromorphic computers to stop the exponential increase of power consumption and the annual tenfold increase of AI training computing time in von Neumann computers.

INVITED ORAL PRESENTATION – ONLINE PRESENTATION

Physical AI with analog memristors for Edge Computing

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The AI accelerators for edge sensing and edge computing currently available on the market are based on the classic von Neumann architecture, process digital data, consume more than 90% of their energy for data exchange between the processor and memory unit, and are not real-time capable. In comparison, AI accelerators with the memory unit located very close to the processor exhibit 30% reduced energy consumption and lower latency.

However, addressing the problem of the exponential global increase in data volumes and the associated computing power requirements, as well as the increasing complexity of AI training algorithms, necessitates further fundamental breakthroughs in AI accelerator hardware. For example, new AI accelerators utilize ReRAM memristor Xbars. Such memristors are reconfigurable, non-volatile memory cells that can be used, for instance, to simulate the function of weights in neural networks.

The analogue BFO memristor presented here [1-5] is one of the few memristors with continuous memory and time-separated read and write operations for data storage and processing in the same memristor cell [6]. It is discussed why BFO memristors are promising for low-power, low-latency AI accelerators, e.g., for autonomous driving, surveillance, and robotics.

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BIOGRAPHY

Erika COVI
Technical University of Munich, Germany

Prof. Dr. Erika COVI is an Assistant Professor at the Technical University of Munich (Germany), where she leads the Nanoelectronics Circuits and Systems (NCAS) Group. She received her Ph.D. in Microelectronics from the University of Pavia (Italy) in 2014. Following her doctoral studies, she was a researcher at the National Research Council (CNR) of Italy and Politecnico di Milano (Italy). She was later Senior Scientist at NaMLab gGmbH in Dresden, Germany, and Assistant Professor at the University of Groningen (the Netherlands).

Her research focuses on the intersection of emerging memory devices, circuit design, and brain-inspired computing, with an emphasis on design-technology co-optimization (DTCO). Her work explores how the intrinsic physical properties of novel memory technologies can be leveraged to develop energy-efficient computational systems by integrating emerging memory devices with CMOS circuits. She has been awarded with the ERC Starting Grant in 2021 and the ERC Proof of Concept in 2025.

Prof. Dr. COVI has co-authored approximately 50 publications in international journals and conferences, and she has served on the organizing committee of around 10 international conferences. She is a Senior Member of IEEE and serves on the Board of Governors of the IEEE Circuits and Systems Society.

INVITED ORAL PRESENTATION

Emerging memory for neuromorphic Edge Computing

Erika COVI
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The shift from cloud-based data classification toward edge computing has enabled real-time data processing closer to the source of data collection, cutting latency and improving overall efficiency. Yet this shift brings with it strict demands around power consumption, physical footprint, and computational performance. Meeting these demands calls for novel hardware approaches that can operate within such tight constraints.
Brain-inspired computing paradigms, particularly spiking neural networks (SNNs), offer a promising path toward low-latency, stateful, and energy-efficient processing. However, current implementations largely rely on digital or mixed-signal CMOS technologies, which fall short of the demanding memory, area, and power requirements typical of edge environments. Incorporating emerging memory technologies at the back-end-of-line (BEOL) of CMOS circuits, or within 3D array configurations, opens up exciting possibilities for advancing neuromorphic hardware.
Non-volatile memory devices, in particular, show strong potential for enabling energy-efficient, massively parallel computing due to their CMOS-compatible operating voltages and analogue behaviour. These characteristics make it more practical to implement efficient neural dynamics and synaptic plasticity in hardware, both of which are essential for brain-inspired emulation. Realizing this potential, however, means tackling a set of critical obstacles: fabrication compatibility, device variability, reliability, scalability, and system-level integration.
This presentation highlights the importance of design-technology co-optimization (DTCO) as a means of seamlessly combining emerging memory devices with CMOS circuits, laying a design foundation for next-generation memory systems built on BEOL and 3D integration. It will explore the challenges and opportunities that arise when co-designing devices, circuits, and architectures together, making the case for a holistic approach to enabling the full potential of neuromorphic computing at the edge.

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BIOGRAPHY

Sabina SPIGA
Istituto per la Microelettronica e Microsistemi (IMM-CNR), Italy

Sabina SPIGA is Research Director at the National Research Council of Italy (CNR), Institute for Microelectronics and Microsystems (IMM). She received her Degree in Physics from the University of Bologna in 1995 and earned a Ph.D. in Materials Science from the University of Milan in 2002.

Her research focuses on the development of memristive devices that exploit ionic and electronic phenomena at the nanoscale to emulate synaptic and neuronal function in hardware, enabling advances in neuromorphic and unconventional information processing.

S. SPIGA has served as Principal Investigator for CNR in several national and Horizon 2020/Horizon Europe projects, including MeM-Scales, Neuram3 and Neurotech, and is currently involved in the European IPCEI ME/CT initiative. She is presently the Editor-in-Chief of the Journal of Physics D: Applied Physics.

INVITED ORAL PRESENTATION

Oxide-based memristors for brain-inspired and unconventional information processing

Sabina SPIGA
CNR – IMM, Unit of Agrate Brianza, Italy
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Oxide-based memristors are emerging as key enabling technologies for neuromorphic hardware and unconventional computing paradigms. These devices have been proposed to emulate biological synaptic and neuronal behaviours directly in hardware, as well as to serve as computational units for in-memory processing and reservoir computing approaches [1]. In this talk, I will present an overview of our recent research on two-terminal oxide memristors exhibiting both volatile and non-volatile resistive switching driven by filamentary mechanisms [2–4], and I will discuss how these devices can be harnessed to implement brain-inspired computing primitives and unconventional information-processing schemes.

In the first part, I will introduce HfO_2-based analogue memristors and their application in a memristor-driven circuit inspired by the Murali–Lakshmanan–Chua (MLC) architecture. This circuit exploits the programmable and nonlinear characteristics of $Pt/HfO_2/TiN$ devices, enabling single-node reservoir computing for a broad range of nonlinear classification tasks and real-time signal-processing applications [5]. The second part will focus on our recent results on volatile electrochemical memristors based on an $Ag/SiO_x/Pt$ structure, and on how their functional properties can be tailored by introducing an ultrathin (1–2 nm) Al_2O_3 layer via atomic layer deposition at the SiO_x/Ag interface [6]. I will discuss how the interplay between switching times and relaxation dynamics governs device behaviour, and how the insertion of the Al_2O_3 layer enables engineering of distinct retention-time scales—an essential requirement for brain-inspired temporal information processing.

Finally, I will highlight our ongoing work on three-terminal ionic transistors, specifically electrochemical random-access memories (ECRAMs) based on $WO_3/HfO_2/WO_3$ stacks. These devices operate through gate-controlled ion migration that modulates the channel conductivity and represent a promising next generation of memristive technologies for neuromorphic architectures.

Acknowledgements: *This work has been partially funded by Ministero delle Imprese e del Made in Italy (MIMIT) under IPCEI Microelettronica 2, project MicroTech_for_Green;*

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BIOGRAPHY

Andreas OFFENHÄUSER
RWTH Aachen and FZ Julich, Germany

Andreas OFFENHÄUSSER studied physics and completed his dissertation at the University of Ulm in 1989. He then worked in the field of power transistors at Robert Bosch GmbH in Reutlingen, Germany, for two years. From 1992 to 1994, he conducted postdoctoral research at the RIKEN Frontier Research Program in Japan. Subsequently, he worked as a group leader at the Max Planck Institute for Polymer Research in Mainz, Germany. Since 2001, he has been a director at the Institute of Biological Information Processing — Bioelectronics at Forschungszentrum Jülich and a professor of experimental physics at RWTH Aachen University. His research focuses on bioelectronic hybrid systems, particularly neuroelectronic systems. He also contributes to neuronal signal processing in in vitro and in vivo model systems and biosensors based on aptamers. To develop new biological interfaces, he investigates nanostructures, microstructures, and organic surface modifications.

INVITED ORAL PRESENTATION

Designing the Neuro-Electronic Interface: From Nanostructured to Flexible Electrodes

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Neural electrodes are the core components of neuroelectronic devices, enabling the recording and stimulation of neural activity. Our research focuses on two primary areas: (1) the design and characterization of the neuron-electrode interface, and (2) the development of flexible neural interfaces for both in vivo and in vitro applications.

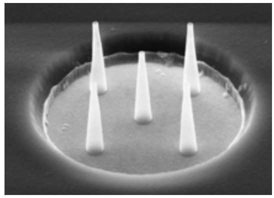

Fig. 1: *Nanostraw-Microelectrodes for improved recordings from neurons*

Microelectrode arrays (MEAs) are commonly used to bridge the interface between neurons and electronic systems. However, current MEAs face limitations in signal fidelity, precision of neural modulation, and long-term biocompatibility. To address these challenges, we are developing nanomaterial-based MEAs that offer enhanced physical and chemical properties, leading to improved cell-electrode coupling. Specifically, we have engineered a hybrid structure combining vertical nanostraws with nanocavities (Fig.1), enabling stable, non-invasive, and long-term recording at sub-threshold resolution.[1]

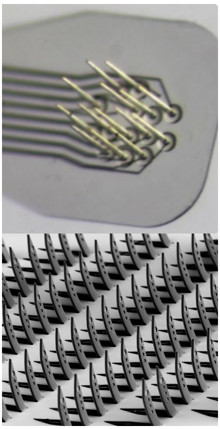

Fig. 2: *3D printed microelectrodes (top) and Kirigami-Microelectodes (bottom).*

Implantable neural prosthetic devices provide direct access to local neural circuits and are critical components of brain-computer interfaces. While current clinical-grade devices—typically based on silicon or noble metals—have driven significant advances, they often fail to sustain reliable neural communication over extended periods. Our goal is to create next-generation neurotechnologies that integrate seamlessly with biological tissue, supporting multimodal neural interrogation through electrical, optical, or chemical means. We are actively exploring novel device architectures (Fig.2), materials, and implantation strategies, alongside rigorous performance evaluation, with the ultimate aim of enabling both acute and chronic in vivo applications. Our approach combines thin-film technology and surface micromachining processes with additive manufacturing techniques, including two-photon lithography. These are integrated with self-aligned, template-assisted electrodeposition processes, kirigami-inspired designs with matched-die forming, novel bonding methods, and the stacking of two-dimensional neural probes with key-lock systems.

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BIOGRAPHY

Yoeri VAN DE BURGT
Eindhoven University of Technology, the Netherlands

Yoeri VAN DE BURGT is professor at Eindhoven University of Technology leading the neuromorphic engineering group. He obtained his PhD degree in 2014 in Eindhoven and worked as a postdoctoral fellow at the department of Materials Science and Engineering at Stanford University. He has been a visiting professor at the University of Cambridge in 2017 and Georgia Tech in 2022, and was awarded an ERC Starting Grant in 2018 and an ERC Consolidator Grant in 2023.

INVITED ORAL PRESENTATION

Learning and adaptivity in organic neuromorphic systems

Yoeri VAN DE BURGT
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The process of neural network training can be slow and energy-expensive due to the transfer of weight data between digital memory and processor chips. Neuromorphic systems can accelerate neural networks by performing multiply-accumulate operations in parallel using non-volatile analogue memory. However, the backpropagation training algorithm in multi-layer (deep) neural networks requires information - and thus storage - on the partial derivatives of the weight values, preventing easy implementation in hardware.

In this talk I will highlight a novel hardware implementation of the well-established backpropagation algorithm that progressively updates each layer using in situ stochastic gradient descent, thus avoiding this storage requirement. We experimentally demonstrate the in situ error calculation and the proposed progressive backpropagation method using a multi-layer hardware implemented neural network based on organic EC-RAM, and confirm identical learning characteristics and classification performance compared to conventional backpropagation in software. I demonstrate how we can use on-chip learning in trainable biosensors and smart autonomous robotics and highlight a manufacturing route towards large-scale integration of organic neuromorphic arrays that are necessary for advanced intelligent computing systems.

Next to that, organic electronic materials have the potential to operate at the interface with biology. This can pave the way for novel architectures with bio-inspired features, offering promising solutions for the manipulation and the processing of biological signals and potential applications ranging from brain-computer-interfaces to bioinformatics and neurotransmitter-mediated adaptive sensing. I will highlight our recent efforts for such hybrid biological memory devices and artificial neurons.

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BIOGRAPHY

Ewelyna KURTIS
FinalSpark, Switzerland

I specialize in turning advanced technologies into solutions companies can actually deploy. I work at the intersection of advanced research and real-world implementation. My focus is helping organizations understand, evaluate, and operationalize complex technologies — from early-stage innovation to scalable deployment. Areas I frequently work across: deep-tech commercialization, technical strategy, innovation evaluation, product vulnerability & risk analysis, implementation pathways. Background in neuroscience-driven technologies and multidisciplinary R&D environments, with hands-on involvement in commercialization, partnerships, and technical positioning. I regularly speak with engineers, innovation teams, and technical decision-makers exploring how emerging technologies can be applied in practice. Always open to exchanging technical perspectives.

INVITED ORAL PRESENTATION

Living computers

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FinalSpark Sarl Rue du Clos 12 – 1800 Vevey, Switzerland
ewelina.kurtys@finalspark.com

We are working on designing the first living processor. The goal is to use living neurons instead of transistors. I describe the whole process we use, starting from cells and ending with algorithms interacting with living brain organoids. I also present the various strategies which are tested in order to reach our next goal which is to master training of the brain organoids and put them in relation with training strategies already performed with artificial neural networks.
For this we designed a system that enables to perform easily in-vitro electrophysiological and neuromodulators experiments. The operations that can be performed include current stimulations, action potential readings, real-time visualization of electrical activity, real-time imaging of nervous tissue, real-time monitoring of environment, control of micro-fluidics, control of UV light for molecular uncaging and automatic generation of graphical representations of results. Moreover, all those operations are scripted in Python, which enables to automate experiments, perform exhaustive screenings or gradient-based optimization of any experimental parameters while keeping a detailed log of what was tested, and even give power to LLM agents to perform their own experiments.

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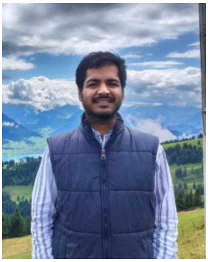
BIOGRAPHY

Nikhil GARG
University of Groningen, the Netherlands



Nikhil GARG received the B.Eng. degree in Electrical and Electronics Engineering and the M.Sc. degree in Biological Sciences from the Birla Institute of Technology and Science Pilani, India, in 2021. He completed his joint Ph.D. in 2024 between Universit´e de Lille (France) and Universite de Sherbrooke (Canada), conducting his research at the CNRS laboratories: Institute of Electronics, Microelectronics and Nanotechnology (IEMN) and the Interdisciplinary Institute for Technological Innovation (3IT). His doctoral work focused on neuromorphic systems based on nanoscale memristive devices, spanning learning algorithms, mixed-signal circuits, and system-level co-design. From 2025 to 2026, he was a postdoctoral researcher at ETH Zurich (Department of Information Technology and Electrical Engineering, D-ITET), working with the Integrated Systems Laboratory and the Neuromorphic Electronics with Oxides group on neuromorphic hardware using ferroelectric devices and emerging in-memory computing technologies. Since 2026, he has been a postdoctoral researcher with the Bio-Inspired Circuits and Systems (BICS) group at the Zernike Institute for Advanced Materials, University of Groningen, and is affiliated with the CogniGron Center for Cognitive Systems and Materials. His research focuses on neuromorphic computing, in-memory learning with emerging devices, and energy-efficient intelligent systems for edge and neurotechnology applications.

INVITED ORAL PRESENTATION

Neuromorphic in-memory learning with analog integrated circuits and nanoscale memristive devices

Nikhil GARG
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Building intelligent systems that can learn continuously under tight energy constraints remains a central challenge for edge computing. While modern AI relies heavily on offline training and digital acceleration, the brain suggests a different paradigm: local learning, analog computation, and tight coupling between memory and processing. This talk explores how these principles can be translated into practical neuromorphic hardware through joint advances in learning algorithms and mixed-signal circuits. I will first present voltage-dependent synaptic plasticity (VDSP) [1,2], a local and unsupervised learning rule designed for nanoscale memristive synapses. Instead of relying on precise spike timing, VDSP uses the neuron's internal state as the learning signal, enabling compact implementations of online learning without complex peripheral circuitry. This approach allows learning rules to be expressed directly in device physics and mapped across different memory technologies, including filamentary and ferroelectric synapses. The second part of the talk focuses on hardware realization through the UNICO neuromorphic chip [3], which integrates analog CMOS neurons with memristive synapses into self-learning neural building blocks. I will describe circuit strategies that enable ultra-low-power neurons to interact reliably with nanoscale memories while preserving local plasticity and configurability. The resulting systems demonstrate compact neural networks that can adapt in real time while operating within the constraints of edge hardware.

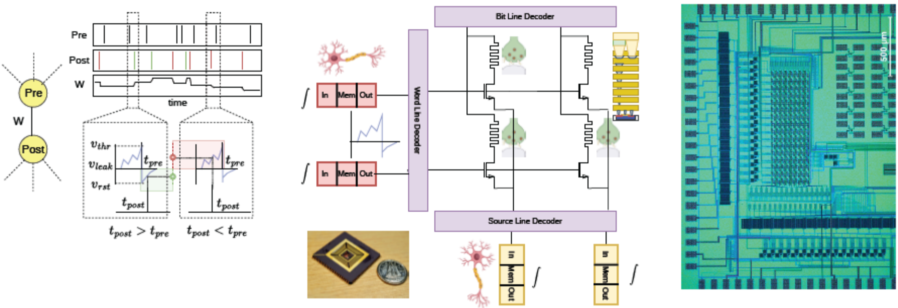

***Figure 1**: VDSP learning rule, architecture of CMOS-RRAM Neural Building Block (NBB), and optical micrograph of UNICO ASIC.*

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BIOGRAPHY

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Research Institute for Artificial Intelligence "Mihai Draganescu" of the Romanian Academy, Romania

Andrei PĂUN received his BSc in Mathematics with a major in Computer Science from University of Bucharest (Romania) and later he received a Master's followed by a PhD in Computer Science from University of Western Ontario (Canada) in 2003. His PhD supervisor was Dr. Sheng Yu, from whom he "inherited" the interest in Finite Automata and OOP modelling as well as the Biocomputing research field that was the main thrust of his PhD dissertation. Following the PhD Andrei was a postdoc at Technical University of Wien (Austria) and later at University of Rovira i Virgili (Spain). He then moved to the US as an assistant and later associate professor of Computer Science (tenured) at Louisiana Tech University (USA). He later returned to Europe having positions at University of Bucharest (Romania), National Institute of R&D for Biological Sciences (Romania) and recently he accepted a position of director of the Research Institute for Artificial Intelligence "Mihai Draganescu" of the Romanian Academy (ICIA). His main interests are Biocomputing, Bioinformatics, AI as well as finite automata and other related areas.

INVITED ORAL PRESENTATION

Unconventional computing using ANNs

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We present recent results from the area of Spiking Neuronal P Systems (SNP systems) which are a class of distributed parallel neural-like computation models inspired by the mechanism that biological neurons process information and communicate with each other by means of spikes.

In the past decade the neurons in particular and the brain in general have been investigated and better understood in part also due to the two major projects: Human Brain Project in Europe and BRAIN Initiative (US). We will present several results related to the SNP systems and their variations as computing devices, in many cases achieving Turing Universality even in restricted cases.

Recent research results and open questions will be also presented especially for the Spiking neural P systems with communication on request (SNQ P systems). We are able to construct small Turing universal SNQ P systems by using low numbers of neurons.

Several other research projects from ICIA will also be presented.

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BIOGRAPHY

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Simas RACKAUSKAS is a Chief Researcher in Kaunas University of Technology (KTU). He defended his PhD in Physics at Aalto University, Finland in 2011. He was a Marie Curie Fellow in University of Turin (Italy). He had fellowships in Swiss Federal Institute of Technology in Lausanne (EPFL, Switzerland), Technical University of Denmark (DTU) and University of Nagoya (Japan). His research interests are mainly focused on metal oxide nanowires and application in sensing, neuromorphic computing and multifunctional coatings. He is involved in commercialization of multifunctional anti-reflection coatings, founder of spin-off company "Zinotech". He is a coordinator of Horizon-MSCA-SE project on neuromorphic computing (TetraNET).

INVITED ORAL PRESENTATION

Self-assembled ZnO nano-tetrapod network for neuromorphic computing

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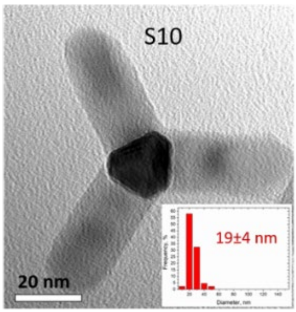
ZnO nanotetrapods are low-cost, low-toxicity semiconductor nanostructures that form highly porous, three-dimensional self-supported networks with large surface area and efficient charge transport. These properties make them promising candidates for hardware neuromorphic computing platforms. In this work, we demonstrate a simple and scalable low-temperature spray-coating method for fabricating ZnO nanotetrapod network devices without the need for complex lithography or high-vacuum processing. The approach enables controllable network thickness, morphology, and connectivity across a wide range of substrates, supporting flexible device design.

We systematically evaluate the neuromorphic behaviour of multiple devices under both electrical and UV optical pulsed stimulation, observing reproducible synaptic functionalities in purely electrical and optoelectronic modes. Statistical analysis confirms strong device-to-device repeatability, highlighting the robustness of the fabrication process. Furthermore, we correlate network packing and processing parameters with electrical and photoresponsive performance, identifying conditions suitable for reliable dual-mode operation. These results position self-assembled ZnO nanotetrapod networks as a versatile and scalable materials platform for future neuromorphic computing architectures.



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BIOGRAPHY

Paschalis GKOUPIDENIS
Max Planck Institute for Polymer Research, Germany

Dr. Paschalis GKOUPIDENIS is an Associate Professor at North Carolina State University and former Independent Group Leader at the Max Planck Institute for Polymer Research. He joined NC State as part of the Chancellor's Faculty Excellence Program, contributing to the university's strategic research leadership in advanced materials and carbon electronics. His research lies at the intersection of materials science, electronics, and neuroscience, focusing on organic devices and circuits for brain-inspired processing and neuromorphic bioelectronics. His work has played a leading role in advancing organic neuromorphic devices and circuits capable of adaptive learning behaviours and biorealistic communication with living tissue. Dr. Gkoupidenis has authored over 60 peer-reviewed publications, including several in Nature family journals. His research has received broad international recognition and has been featured in Scientific American, Yale Scientific, Max Planck Magazine, and TechXplore. He is the recipient of the 2025 Sherwin I. Seligsohn Innovation Award for his contributions in organic neuromorphic electronics.

INVITED ORAL PRESENTATION

Organic neuromorphic electronics

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Organic neuromorphic electronics harnesses ionic and electrochemical processes to emulate core features of synaptic adaptation and neural computation in a bio-realistic and highly efficient manner. In this talk, we will explore how organic and iontronic materials enable the design of neuromorphic devices and circuits that can sense, process, and respond in real time, forming the foundation for both intelligent systems and efficient neuromorphic biointerfaces.

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Abstracts

of

Poster Presentations

POSTER PRESENTATION ***P1***

Nanoconjugated caffeic acid–gold nanoparticles for passive diffusion across a simplified blood–brain barrier model

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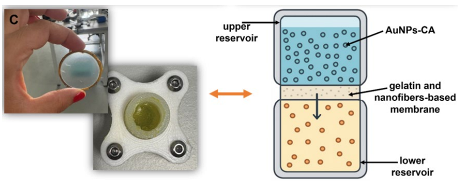
Oxidative stress is a major contributor to neurodegenerative disorders highlighting the need for antioxidant systems capable of crossing the blood–brain barrier (BBB) and preserving neuronal viability. In this study, caffeic acid (CA)-functionalized gold nanoparticles (AuNPs–CA) were developed as multifunctional nanoplatforms designed to combine antioxidant activity with enhanced passive diffusion through a simplified BBB model. Monodisperse gold nanoparticles with an average diameter of approximately 12 nm were synthesized using citrate/tannic acid reduction and subsequently functionalized with caffeic acid through PEG-mediated conjugation. SEM, TEM, and XRD analyses confirmed the spherical morphology, uniform size distribution, and preserved crystalline structure of the nanoparticles after functionalization. Electrochemical characterization performed by cyclic voltammetry demonstrated that caffeic acid retained its reversible catechol/o-quinone redox behaviour after conjugation. Standard addition methods combined with cyclic voltammetry and UV–Vis spectroscopy enabled quantitative determination of CA loading on the AuNP surface.
A simplified non-cellular BBB model based on electrospun PMMA fibre networks integrated with gelatin-crosslinked hydrogel layers was fabricated to evaluate passive diffusion, **Scheme 1**. Transport studies showed that AuNPs–CA exhibited significantly improved diffusion across the membrane compared to free caffeic acid after 24 h, suggesting that nanoparticle conjugation enhances permeability and transport efficiency. Furthermore, enzymatic release experiments demonstrated controlled liberation of caffeic acid under proteolytic conditions, supporting the potential for intracellular delivery.



***Scheme 1** Digital images of the membrane and cell vs. the schematic representation of the experimental set-up of simulated BBB.*

Biological investigations performed on SH-SY5Y neuroblastoma cells demonstrated high biocompatibility for both free CA and AuNPs–CA systems, with no significant cytotoxic effects observed within the investigated concentration range. Under oxidative stress induced by LPS and TNF-α, AuNPs–CA displayed enhanced radical-scavenging activity compared to free CA or bare AuNPs, significantly reducing intracellular reactive oxygen species accumulation. These findings demonstrate that AuNPs–CA function as dual-purpose neuroprotective nanoplatforms capable of combining antioxidant activity with improved passive transport across a BBB-mimicking structure. The developed systems represent promising candidates for future therapeutic strategies targeting oxidative stress-related neurodegenerative diseases.

POSTER PRESENTATION ***P2***

Sputtering of III-V wurtzite materials for active component in neuromorphic dedicated heterostructures

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Wurtzite III–V based wide band-gap semiconductors, particularly $Al_{1-x}Sc_xN$ (ASN) solid solutions, are nowadays among emerging candidates for ferroelectric component in an extensive range of application, including neuromorphic systems. Their high polarization, large coercive fields, CMOS compatibility, and fast switching speeds are attributes that position III-nitrides as a promising platform for next-generation ferroelectric devices [1−3]. Alongside with its performance arise fundamental questions regarding the interplay between nitride structure, morphology, chemistry and ferroelectricity. These correlations still impel novelty to the topic of nitride ferroelectrics.
A critical challenge in designing ASN based heterostructures for achieving its full potential lies in understanding and controlling how deposition conditions tailor film properties. In this context, magnetron sputtering stands out as a scalable and industry-compatible technique, offering a high degree of tunability with respect to growth parameters. Variables such as substrate temperature, gas working pressure and composition, RF power and target configuration directly influence film composition, crystallographic texture, defect density, and phase stability. These features govern the ferroelectric response, including polarization magnitude, coercive field, and switching dynamics.
In this work, $Al_{1-x}Sc_xN$ thin films were synthesized by reactive RF magnetron sputtering, with systematic variation of deposition parameters to establish process–structure–property relationships. The films were integrated into capacitor geometries with platinum electrodes to enable electrical characterization. The ferroelectric behaviour of the ASN heterostructures was analyzed in correlation with the wurtzite phase evolution, microstructure and composition, characteristics that were induced by the growth conditions.

Acknowledgments: This research was funded by PNRR - ARSYF project 760239/28.12.2023, funded by the Romanian Ministry of Research, Innovation and Digitization through the National Recovery and Resilience Plan.

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POSTER PRESENTATION ***P3***

Ferroelectric multilayers exhibiting memristive and/or memcapacitive signatures for neuromorphic functions

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Ferroelectric materials provide an internal state variable (polarization) that can be switched and tuned by an electric field, naturally enabling history-dependent responses such as hysteresis, nonlinearity, and multi-level state programmability. These features are directly relevant for neuromorphic hardware, where information processing benefits from analog-like tunability and adaptive dynamics. In this work we focus on $HfZrO_2$ (HZO), attractive for CMOS-compatibility and scalability, and $Pb(Zr,Ti)O_3$ (PZT), a benchmark ferroelectric with robust polarization and pronounced switching behaviour. By leveraging polarization dynamics and interface-mediated charge processes, ferroelectric stacks can implement device-level memory and nonlinear responses required for neuron- and synapse-inspired functions.
Translating ferroelectric functionality into computing infrastructures requires device concepts that can be integrated at high density with low programming energy and stable readout. Ferroelectric multilayers stacks allow deliberate interface engineering (electrodes, interlayers, barrier tuning) to control the competition between domain switching, charge trapping/de-trapping, and conduction pathways. Such stacks are compatible with crossbar-like arrays and near-memory/in-memory schemes, and they offer a pathway to combine non-volatile state retention with pulse-driven dynamics. Here we explore multilayer architectures based on HZO and PZT tailored to emphasize either resistive-memory-like behaviour or capacitive-memory-like behaviour, as a route to hardware primitives suitable for neuromorphic computing platforms.
While memristors encode memory through a history-dependent conductance (I–V hysteresis), memcapacitors encode memory through a history-dependent capacitance (C–V hysteresis and dielectric "memory"). Ferroelectric stacks can exhibit either one signature, or a mixed response. We report a comparative experimental study of different HZO- and PZT-based multilayer structures designed to display memristive and/or memcapacitive effects. The devices are characterized using DC and pulsed electrical protocols (voltage sweeps, pulse trains, and incremental programming), aiming at neuromorphic figures of merit such as gradual state modulation, pulse-controlled potentiation/depression, and short-/long-term plasticity-like behaviour. The results highlight how multilayer design can shift the response toward predominantly resistive or capacitive memory, and how these regimes can be exploited to implement neuromorphic functions in compact ferroelectric hardware elements.

POSTER PRESENTATION ***P4***

Memristive spin-valves based on a DNA component

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The memristive properties of multiferroic tunnel junctions are determined by the possibility to modulate the junction's electrical resistance by independently controlling the magnetization orientation of the ferromagnetic electrodes and the ferroelectric polarization of the tunnel barrier [1]. The coupling of these magneto-electric properties is important for electronic applications with low power consumption from nonvolative memory, to elements in logic circuits, sensing devices, biological synapses models in the emerging area of neuromorphic computing and artificial intelligence. Realizing these multifunctional electronic elements using organic materials and/or biomolecules is presenting various advantages related to their low cost, versatile synthesis, flexibility, lightweight and biocompatibility that are actually of major scientific and technological interest for applications in the fields of spintronics, molecular electronics, transient electronics, bioelectronics, and therapeutic techniques. Moreover, the lightweight elements in their composition have a small spin-orbit coupling and thus, favour a longer spin lifetime and spin transport length of the charge carriers than in standard inorganic materials.
Herein, we demonstrate the non-volatile memristive spintronic behaviour of multiferroic junctions [2] that can be manipulated with small external magnetic and electric fields. These memristors have two terminals and are composed of organic biomolecular ferroelectric films [3] of a DNA component, the guanine nucleobase, sandwiched between two different ferromagnetic electrodes that have an in-plane easy axes of magnetization and different coercive fields. At 100 K a difference of about 370% is achieved between the magnetoresistive hysteresis loops in the low-resistance and the high-resistance states (Figure). The guanine film ensures a very long spin transport length of up to 200 nm. The guanine films show typical ferroelectric polarization–electric-field hysteresis loops with large electrical polarization and pyroelectric signal at low temperatures of up to 200 K. Above this transition temperature, at which different properties are affected, the guanine films have a preponderant paraelectric phase containing residual or locally induced nanoscopic ferroelectric domains, as observed by piezoresponse force microscopy at room temperature.

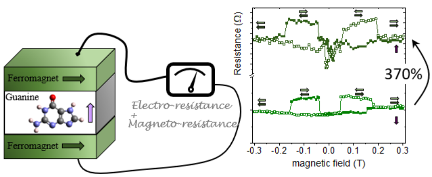

Figure*: Metal-organic memristive multiferroic junctions.*

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POSTER PRESENTATION ***P5***

Toward efficient probabilistic bits using 2D magnetic materials

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Statistics is used to study and solve problems in daily life, including scientific, industrial and social issues. Deterministic computers based on classical bits (0 or 1) are utilized to emulate the probabilistic characteristic to resolve these problems, but the efficiency is very low. These statistical problems can be more effectively addressed using a probabilistic computer. Moreover, the probabilistic bits (p-bits) are offering a physical, stochastic building block for brain-inspired architectures to process uncertainty, optimize and learn efficiently. P-bits are non-stable, fluctuating between 0 and 1, simulating the inherent randomness in neural systems, making them ideal for Boltzmann machines and Bayesian inference. Therefore, building a true probabilistic computer using p-bits as a basic component [1] will serve a pivotal role in solving statistical problems. The state-of-the-art p-bit is built on a stochastic magnetic tunnelling junction combined with transistors that facilitate the switching characteristic of the magnetic tunnelling junction [2]. The challenge is whether it is possible to build a truly simple p-bit with new materials without the help of these transistors.

Two-dimensional (2D) magnetic materials have emerged as a highly promising platform for next-generation spintronic and probabilistic computing devices because of their atomically thin nature, strong tunability and rich magnetic phenomena. Since the discovery of intrinsic ferromagnetism in monolayers [3], van der Waals magnets have attracted significant attention for enabling low-power, highly scalable magnetic devices with enhanced electrostatic control and reduced switching energy. Their reduced dimensionality allows efficient manipulation of magnetic anisotropy, exchange interactions and spin textures through gating, strain and interfacial engineering, offering unique advantages over conventional bulk ferromagnets for stochastic magnetic devices. In particular, the low energy barriers and tuneable thermal stability of nanoscale 2D magnets make them excellent candidates for implementing p-bits. Here we are presenting our mission on designing and control of the magnetic properties of different 2D materials, under external excitations such as magnetic field, gate voltage, electrical current and light excitation, to introduce magnetic fluctuations at room temperature, paving the way toward high-performance, simple p-bit devices. Based on international collaborations, our approach is to introduce additional degrees of freedom (such as dopant concentration, co-doping and thickness variation) to control the magnetic stability of ferromagnets, including V-doped WSe2 [4] and V-doped WS2 [5], antiferromagnets such as NiPS3 [6,7] and Fe-doped PdSe2 [8].

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POSTER PRESENTATION ***P6***

Substrate-temperature-controlled ferroelectricity in Zr-doped HfO_2 thin films for CMOS-compatible neuromorphic devices

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Zr-doped HfO_2 thin films have emerged as promising materials for next-generation ferroelectric memories, CMOS-compatible microelectronic devices, and neuromorphic computing architectures due to their scalability, robust nanoscale ferroelectricity, and tuneable dielectric properties. The incorporation of Zr into the HfO_2 lattice plays an important role in promoting the stabilization of the metastable orthorhombic ferroelectric phase, which is essential for non-volatile memory operation. However, the practical integration of $Hf_{1-x}Zr_xO_2$ thin films requires reliable control over crystallinity, phase formation, and ferroelectric stability through optimized deposition conditions. In this work, the influence of substrate temperature on the stabilization of ferroelectricity in Zr-doped HfO_2 thin films deposited by pulsed laser deposition on silicon and strontium titanate substrates is discussed. The results show that ferroelectricity can be achieved in films grown on silicon at a relatively low substrate temperature of 400 °C, without the need for post-deposition rapid thermal annealing. In contrast, films deposited on strontium titanate require a significantly higher substrate temperature of 800 °C to exhibit ferroelectric behaviour, but show enhanced ferroelectric performance, including higher remanent polarization and lower coercive fields. Structural and chemical analyses confirm the formation of the metastable orthorhombic ferroelectric phase, highlighting the critical role of substrate temperature, substrate nature, and Zr doping in phase stabilization. While strontium titanate promotes superior ferroelectric properties, the ability to obtain ferroelectric Zr-doped HfO_2 films directly on silicon at reduced processing temperatures represents an important step toward simplified fabrication and seamless integration with CMOS technology. These findings provide valuable insight into the processing–structure–property relationships of hafnia–zirconia ferroelectric thin films and support their potential use in energy-efficient non-volatile memories and neuromorphic devices, where stable and tuneable polarization states can be exploited for artificial synaptic functionalities.

POSTER PRESENTATION ***P7***

Targeted delivery of neuro-regenerative agents to minimize neuroinflammation

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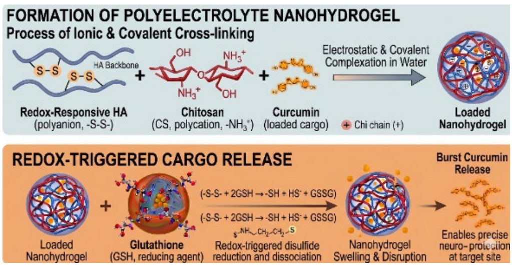
The integration of anti-inflammatory processes with neuromorphic devices is one of the most critical challenges in neuro-engineering today. The success of a neuromorphic interface depends entirely on the health of a the “bio-link” – the physical and chemical space where the synthetic device meets living neurons. Diferuloylmethane (Curcumin), the primary bioactive polyphenol in turmeric, exhibits strong anti-inflammatory properties1 by inhibiting the activation of NF-κB, a primary transcription factor that triggers pro-inflammatory responses in microglia and astrocytes. Curcumin is also a potent scavenger of Reactive Oxygen Species (ROS) protecting both the biological tissue and organic neuromorphic materials from oxidative degradation. Furthermore, it has been shown to promote axonal outgrowth by upregulating the expression of Brain-Derived Neurotrophic Factor and stimulating the TrkB signalling pathway. Hyaluronic acid (HA) and Chitosan (CS) polyelectrolyte nanohydrogels are ideal nanocarriers for targeted delivery of curcumin. Both components play key specific biological roles that complement curcumin’s properties. HA binds specifically to CD44 receptors2 with are upregulated on activated microglia and astrocytes during inflammation, and it is a primary component of the brain’s extracellular matrix, increasing its biocompatibility. Chitosan’s positive charge promotes interaction with the negatively charged neuronal membranes, enhancing the cellular uptake of curcumin. During early inflammation response, glutathione (GSH) synthesis, a potent antioxidant, is upregulated. By crosslinking HA chains with cystamine in the HA-CS system, we introduce a redox-responsive functional group that promotes the release of curcumin in a GSH concentration dependent manner.

Herein, we present the synthesis and characterization of HA modified with cystamine, formation of curcumin loaded nanohydrogels by self-assembly with CS and release studies with Sh-sy5y neuroblastoma cells.



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POSTER PRESENTATION ***P8***

Amyloid beta fibril-functionalized conductive biointerfaces for neuronal cell proliferation and neuromorphic applications

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Alzheimer's disease-associated amyloid beta (Aβ) peptides are widely recognized for their involvement in neurodegeneration; however, their highly ordered fibrillary architectures also exhibit remarkable physicochemical stability and self-assembly properties that may be exploited for advanced biointerfaces [1]. In this work, conductive rigid and flexible nanostructured scaffolds functionalized with Aβ40 fibrils were developed and investigated as potential platforms for neuronal cell interaction and neuromorphic engineering applications.

Two categories of conductive substrates were fabricated: rigid gold-coated glass slides and flexible electrospun poly(methyl methacrylate) (PMMA) fibre networks coated with gold by magnetron sputtering. The electrospun fibres exhibited uniform morphology and conductivity, while XRD analysis confirmed the crystalline Au coating. Surface functionalization was achieved through spontaneous adsorption of Aβ40 fibrils obtained from controlled peptide aggregation protocols. AFM and SEM analyses demonstrated homogeneous fibrillary coatings, with fibril morphology strongly dependent on incubation conditions. Contact angle measurements revealed that Aβ40 fibrils converted initially hydrophobic gold-coated substrates into hydrophilic surfaces favorable for cell adhesion, decreasing the contact angle from approximately 93–127° to 24–41° [2].

The biological performance of the scaffolds was evaluated using fibroblast L929 and neuroblastoma SH-SY5Y cell lines. MTS assays, fluorescence microscopy, and SEM imaging demonstrated high cell viability and enhanced cell adhesion on Aβ40-functionalized conductive surfaces compared to bare gold substrates. The Aβ40 fibrils promoted clustered yet non-toxic cellular growth, indicating that the fibrillary coatings create a biologically favourable microenvironment. Quantitative image analysis showed increased surface coverage for cells grown on Aβ40-modified scaffolds relative to unmodified conductive controls. Importantly, no evidence of membrane damage, apoptosis, or cytotoxicity was observed [2].

A major advantage of the amyloid-functionalized interfaces is their exceptional resistance to proteolytic degradation. Unlike collagen coatings, which were degraded after trypsin exposure, Aβ40 fibrils maintained their morphology and integrity, highlighting their suitability for long-term bioelectronic applications [2]. These findings demonstrate that Aβ40 fibrils can act as stable, conductive, and biocompatible nanostructured coatings capable of supporting neuronal cell proliferation while preserving structural integrity. The developed amyloid-functionalized conductive scaffolds represent promising candidates for neural interfaces, biosensors, and neuromorphic devices designed for long-term interaction with living tissues.

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POSTER PRESENTATION ***P9***

Engineering ferroelectric hysteresis for artificial synapses: The role of insulating interlayers in neuromorphic device design

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Ferroelectric heterostructures are attractive for neuromorphic hardware due to the non-volatile properties provided by polarization and electrically addressable internal state. In artificial synapses this state can encode conductance, threshold shift, retention bias, or history-dependent weight update. However, the same electrostatic boundary conditions that enable this tunability also make the device response strongly interface-dependent: incomplete screening, dielectric interlayers, trapped charge, and asymmetric electrodes can reshape the hysteresis loop and preferentially stabilize one polarization orientation.

Here we use charge-compensated first-principles slab calculations to analyse model $SrRuO_3/PZT/SrTiO_3/SrRuO_3$ Heterostructures. In uncompensated finite slabs, bound polarization charge generates a large depolarization field that artificially drives the ferroelectric layer toward a low-polarization state. We remove this artefact by introducing fractional interfacial compensation charges through virtual atoms and determine the required compensation from the condition that the depolarization field, extracted from the nano-smoothed planar-averaged Hartree potential, vanishes inside the ferroelectric layer. The resulting compensation charge is then used as a microscopic measure of the experimentally accessible coercive field.

The key result is obtained for an asymmetric $SrRuO_3/PZT/SrTiO_3/SrRuO_3$ stack. The experimental response in Fig.1(a–d) shows broadened switching, back-switching after poling, and a shifted capacitance-voltage characteristic. The charge-compensation calculation in Fig.1(e) reproduces the corresponding physical origin: the insulating interlayer makes the two polarization orientations electrostatically inequivalent. Depending on whether polarization points toward or away from the $SrTiO_3$, the

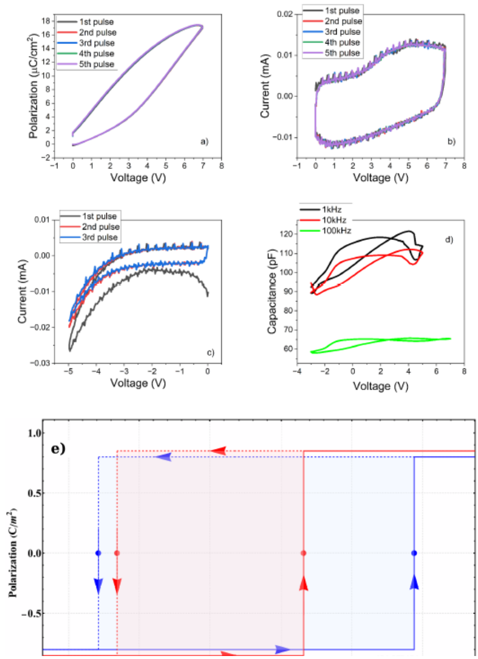

Figure 1: *Combined experimental and theoretical response. Panels* ***(a–d)****: measured P–V, I–V, and C–V characteristics of the PZT/$SrTiO_3$ heterostructure, showing asymmetric switching, back-switching, and capacitance contrast. Panel* ***(e)****: Calculated MFM/MFIM hysteresis from the charge-compensation method, showing that the $SrTiO_3$ interlayer shifts the loop and produces unequal switching fields.*

residual internal field distribution changes, especially inside the insulating layer, producing different effective switching fields and an imprint-like hysteresis shift.

This response is naturally interpreted as memcapacitive rather than only ferroelectric. The internal state is still rooted in remanent polarization and delayed charge compensation, but the practical readout variable is the small-signal capacitance measured below the switching threshold. In this regime the device behaves as a two-terminal ferroelectric memcapacitor: voltage pulses program a persistent internal electrostatic configuration, while the stored state is read non-destructively through capacitance, and optionally dielectric loss, without forcing polarization reversal or requiring a restore step.

The asymmetric $SrTiO3$ interlayer is therefore not a passive series dielectric. It acts as an electrostatic bottleneck that converts polarization history into multiple capacitance states. By tuning the interlayer thickness, dielectric response, and compensation dynamics, one can target separated and stable intermediate capacitance levels suitable for multi-bit storage or analogue synaptic weights. This capacitive route is complementary to memristive operation: it avoids relying on a DC conduction path as the state variable, reduces static-power constraints, and directly links neuromorphic plasticity to controllable interface electrostatics. For artificial synapses, this means that hysteresis asymmetry, imprint, gradual reversal, and capacitance-state retention can be treated as design parameters. Charge-compensated modelling provides the microscopic bridge between the computed internal-field landscape and the experimentally observed memcapacitive response, enabling ferroelectric-insulator stacks to be engineered as non-volatile, low-perturbation, multi-state capacitive synaptic elements rather than merely as imperfect ferroelectric capacitors.

POSTER PRESENTATION ***P10***

Electrospun polymeric nanofibers scaffold coupled with electrochemical transducers for long-term neuronal modeling and neurotransmitter analysis

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The understanding of how cells or neurons communicate with each other requires platforms that recreate key features of the native microenvironment while enabling sensitive and real-time detection of biochemical signals [1]. Here we developed a cellular scaffold based on electrospun polymeric nanofibers engineered to support neuronal cell models and to interface with electrochemical (bio)sensors for neurotransmitters monitoring.

The basic feature of the platform is the biofunctional modification of the electrospun fibres to increase biocompatibility and long-term stability. The nanofibers are tailored to promote robust neuronal adhesion and network formation by introducing cell-instructive surface chemistries. The approach relies on coating the fibres with poly-D-lysine (PDL) and or amyloid beta structures that enhance surface charge and hydrophilicity, providing strong anchoring points for cell membranes, thereby improving attachment and spreading. Both PDL and amyloid fibrils functionalization lead to a nanostructured, peptide-based fibrous scaffold with exceptional mechanical and chemical robustness and high resistance to proteolytic degradation, which is particularly useful in long-term experiments or in cultures where secreted enzymes can compromise conventional protein coatings [2]. Importantly, these coatings can be combined—PDL for rapid and uniform cell anchoring, and amyloid fibrils for long-term stability and topographical guidance—creating a hybrid interface that is both biologically supportive and structurally resilient.

The modified electrospun fibrous scaffold is engineered to integrate with adjacent electrochemical transducers, including planar electrodes and microelectrode arrays functionalized with selective biosensing layers targeting specific neurotransmitters. Its ultrathin, highly porous, and high-surface-area architecture facilitates efficient mass transport toward the sensing interface. This structural configuration enables rapid diffusion of released analytes and enhances electrochemical signal transduction [3]. Consequently, the recorded electrochemical readouts can be directly correlated with neurotransmitter release dynamics, supporting real-time monitoring of neuronal activity within bioinspired or neuromorphic platforms.

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POSTER PRESENTATION ***P11***

Interconnected resistive networks in nanostructured electroceramics: Premise for neuromorphic interfaces

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Developing neuromorphic hardware interfaces requires scalable materials with resistive networks capable of controlling charge flow and defect behaviour at the nanoscale [1,2]. In this context, perovskite oxides, particularly $BaTiO_3$-based systems, have recently emerged as leading candidates for artificial synapses because of their highly tuneable interfacial properties [3,4].
This research presents recent findings on the conductivity and dielectric relaxation of $Ba_{1-x}Sr_xTiO_3$ (BST) ceramics, focusing on the ferroelectric $Ba_{0.8}Sr_{0.2}TiO_3$ (BST8/2) and the paraelectric $Ba_{0.6}Sr_{0.4}TiO_3$ (BST6/4). These samples, prepared by sol-gel synthesis and consolidated via Spark Plasma Sintering (SPS), exhibit precisely controlled nanoscale grains (~74–77 nm) and densities of 98–99%. Results show that grain sizes below 100 nm reduce the macroscopic DC component and promote localised hopping conduction. The electrical properties reveal two key phenomena relevant to memristive applications, both of which are phase-dependent. In BST8/2, HR-TEM confirms a ~12 nm-thick low-permittivity interfacial layer (dead layer) at grain boundaries [5], forming a resistive network and creating a potential barrier that impedes charge transport. In BST6/4, dielectric dynamics are governed by the relationship between the defect network at interfaces and polar nanoregions (PNRs) within the cubic matrix [6]. Complex impedance spectroscopy and Havriliak-Negami (H-N) analysis reveal a fundamental energy decoupling: long-range charge transport, limited by oxygen-vacancy accumulation at interfaces (Maxwell-Wagner effect), involves barriers up to 0.62 eV, whereas local polarisation, driven by short-range jumps within PNRs, remains highly flexible below 0.16 eV.
Extreme nanostructuring redefines BST electroceramics as a system primarily governed by interfaces, leading to a fundamental separation of energy between interface-blocked transport (dead layer) and dynamic local polarisation (PNRs). This approach limits long-range charge flow while preserving local polar mobility, offering valuable physical insights into the control of resistive states. Such mechanisms are essential for designing future memristive devices that act as artificial synapses in neuromorphic computing.

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POSTER PRESENTATION ***P12***

Mechanisms of resistive switching in IGZO memristors

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Memristors are the novel and the fourth fundamental passive electronic component with potential applications in the future, particularly in fields such as neuromorphic computing, data filtering in electric circuits, and camera surveillance. Additionally, they present a promising solution for creating an ultrahigh density memory device that can be seamlessly integrated directly into the processor chip. Indium-Gallium-Zinc Oxide (IGZO) micro-memristors have been fabricated using UV photolithography and RF-magnetron sputtering techniques. Current-voltage, current-time, current-temperature characteristics, and Hall measurements were performed on the obtained devices.
The free carrier density and mobility were extracted from Hall effect measurements, being evaluated to ~$1x10^{20}$ cm^{-3} and ~7 cm^2/Vs. It was showed that both density and mobility of the free carriers are constant in the 80 – 450 K temperature domain which is characteristic to a degenerate semiconductor. It was observed that the resistance switching in IGZO devices begins at a writing threshold voltage between 1.5 and 2 V. Two mechanisms for the resistance change were proposed: a reversible mechanism related to the migration of oxygen vacancies, and an irreversible mechanism that occurs when the device temperature exceeds 340 K. The latter may be associated with the presence of metallic gallium in IGZO, as indicated by XPS measurements.
The above transport mechanisms are discussed and confronted with empirical results obtained on IGZO micro-memristors.

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