HL 22: Biocompatible Organic Semiconductors

Time: Wednesday 9:30–11:00 Location: POT/0006

HL 22.1 Wed 9:30 POT/0006

Stable n-Type OECTs with BBL: Unlocking Complementary Circuits — •Clemens Rössler[1,2], Laura Teurle[1,2], Hans Kleemann[1,2], and Karl Leo[1,2] — [1]Dresden Integrated Center for Applied Physics and Photonic Materials — [2]TU Dresden

Organic mixed ionic-electronic conductors (OMIECs) have emerged as a key materials platform for next-generation bioelectronics, energy-efficient signal processing, and neuromorphic computing. Among the most versatile OMIEC devices is the organic electrochemical transistor (OECT), whose ability to couple ionic and electronic transport enables low-voltage operation and is particularly advantageous for solid-state electrolyte systems that enable densely integrated circuitry. While p-type materials such as PEDOT:PSS have driven much of the field's progress, the lack of stable and high-performance n-type counterparts remains a critical bottleneck - limiting the realization of complementary circuits, low-power logic, and more complex bioelectronic architectures. In this talk, I present recent progress on n-type OECTs based on the ladder polymer poly(benzimidazobenzophenanthroline) (BBL). I will discuss how we have developed and optimized n-type OECTs that exhibit remarkable stability and a unique electrochemical conditioning behaviour. Spectroscopic, AFM, and transfer curve analyses show that BBL combines excellent optical and morphological stability with a high mobility capacitance product, indicating efficient ion penetration and intrinsically high electronic mobility.

HL 22.2 Wed 9:45 POT/0006

A Nonlinear Organic Infrasound Sensor — •Maarten Mittmann[1], Carsten Habenicht[1], Andreas Hofacker[1], Richard Kantelberg[1], Stefan Jacob[2], Hans Kleemann[1], and Karl Leo[1] — [1]Dresden Integrated Center for Applied Physics and Photonic Materials (IAPP) and Institute for Applied Physics, Dresden University of Technology, 01062 Dresden, Germany — [2]National Metrology Institute (PTB), 38116 Braunschweig, Germany

Most works on speech recognition using reservoir computing focus on the nonlinear transformation of the data, which is fed electronically from a conventional sensor to the device. However, this approach necessitates two separate devices, consuming power and possibly requiring additional signal processing steps. In this work, we demonstrate that an efficient interface between acoustic stimulation and nonlinear, electronic output can be established using a free-standing viscoelastic film containing a poly(3,4-ethylenedioxythiophene) hexafluorophosphate (PEDOT:PF_6) fiber organic electrochemical transistor (OECT). Upon application of a constant drain-source and gate-source voltage, the system shows a time-dependent, nonlinear modulation of the drain current when excited acoustically. This nonlinearity opens possibilities of combining the existing system with a reservoir computing approach to perform complex tasks like infrasound source discrimination and anomaly detection. The devices show great sensitivity within the order of magnitude of $10^2\, mV\, Pa^{-1}$ in the infrasound frequency regime thanks to the amplification via the gate electrode.

HL 22.3 Wed 10:00 POT/0006

Is Printed Electronics a Sustainable Technology? A Framework to Efficiently Implement an Early-Stage Life-Cycle-Analysis — •Laura Teuerle, Tommy Meier, Klara Hänisch, Finn Jaekel, Yeohoon Yoon, Andreas Wendel, and Hans Kleemann — Dresden Integrated Center for Applied Physics and Photonic Materials, TU Dresden, Germany

The rise of microelectronic system has been the major driving focus of the global economy for the last couple of decades. As we are now transitioning to the era of the internet-of-things, with an increasing number of small autonomous electronic circuits, e.g, for sensing, we need to urgently consider the environmental impact of this development due to the unsustainable use of natural resources. Thus, to ensure the environmental sustainability of the development, future electronics must prioritize both performance and environmental impact, explaining the interest in flexible and printed electronics. However, the sustainability claims often connected to the field of flexible and printed electronics must be substantiated using analytic methods, providing the motivation for quantitative Life-Cycle Assessment (LCA). Here we demonstrate our approach to implement an LCA for an early-state research topic such as Organic Electrochemical Transistors (OECTs). Using hands-on examples, we will show how to set up an inventory database (the core of the LCA) using a process-of-record (PoR). By making LCA a standard tool in printed electronics, the community can move beyond sustainability claims to measurable environmental impact, driving truly responsible innovation in electronics.

HL 22.4 Wed 10:15 POT/0006

Obtaining In-Vivo Data for AI Applications Using Implantable Biocompatible Materials — •Finn Jaekel[1], Richard Kantelberg[1], Hans Kleemann[1], Daniel Freund[2], Julia Henne[2], Dennis Wahl[2], Eberhard Grambow[3], Sebastian Hinz[2], Clemens Schafmayer[2], Jochen Hampe[4], and Karl Leo[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, Dresden, Germany — [2]Klinik und Poliklinik für Allgemeine Chirurgie, Thorax, Gefäß- und Transplantationschirurgie, Universitätsmedizin Rostock, Rostock, Germany — [3]Klinik für Herz-, Thorax- und Gefäßchirurgie (HTG), Universitätsmedizin Göttingen, Göttingen, Germany — [4]Universitätsklinikum Carl Gustav Carus Dresden, Dresden, Germany

Artificial intelligence can be of great use in biomedical applications, especially when implemented in implantable hardware solutions. However, robust, biomedical AI applications crucially depend on real, high-quality, physiological training and input datasets, which are scarce in practice. In this presentation, we provide a prototypical use-case scenario by demonstrating in-vivo impedance measurements in a porcine small-intestinal anastomosis using printed, fully biocompatible organic sensors. Ischemia was induced locally, and manual evaluation shows a characteristic signature in the recorded impedance spectra, confirming that the system captures physiologically relevant data. This positions the technology in a realistic sensor to AI analysis pipeline, where automated detection of ischemia can be used to create an early warning system of anastomotic failure.

HL 22.5 Wed 10:30 POT/0006

Towards Fully Biodegradable and Sustainable Organic Electrochemical Transistors Printed on Leaf-Derived Substrates — •Bilge Kahraman, Rakesh R. Nair, Hans Kleemann, and Karl Leo — Dresden Integrated Center for Applied Physics and Photonic Materials, Technische Universität Dresden, 01187 Dresden, Germany.

The rapid proliferation of disposable electronics has exacerbated electronic waste and its associated environmental burden. Here, we demonstrate fully screen-printed organic electrochemical transistors (OECTs) fabricated on robust biodegradable leaf-derived substrates using non-toxic carbon and PEDOT:PSS-based inks. Magnolia grandiflora leaves were skeletonized to function as sequestering matrices for hydroxypropylcellulose (HPC) based resin, which was subsequently crosslinked to create robust flexible, compostable substrates. Life-cycle assessment (LCA) reveals that the combination of leaf-skeleton-based substrates and carbon gate electrodes for electronic device fabrication reduces CO_2-equivalent emissions by up to four orders of magnitude compared to conventional glass substrates and gold electrodes (19,400 times lower for substrates; 680 times lower for electrodes). The printed OECTs exhibit steady-state performance comparable to devices made on glass using commercial PEDOT:PSS formulations, with on/off ratios $> 10^4$ and transconductance values exceeding 1 mS. This work presents a viable path toward truly green bioelectronic devices that can be manufactured for disposability and safely returned to the environment after use.

HL 22.6 Wed 10:45 POT/0006

Flexible Organic Photodiodes Based on Advanced Encapsulation Strategies — •rabiul islam[1,2], siddhartha saggar[1,2], jakob wolansky[3], darius pohl[4], markus löffler[4], bernd rellinghaus[4], johannes benduhn[3], and caroline murawski[1,2] — [1]Institute of Solid-State Electronics, Technische Universität Dresden, Dresden, Germany — [2]Kurt Schwabe Institute for Sensor Technologies, Waldheim, Germany — [3]Dresden Integrated Center for Applied Physics and Photonic Materials, Technische Universität Dresden, Dresden, Germany — [4]Dresden Center for Nanoanalysis (DCN), Technische Universität Dresden, Dresden, Germany

Organic photodiodes (OPDs) are promising for biomedical applications due to their flexibility, spectral tunability, and biocompatibility, yet their moisture sensitivity demands robust encapsulation for long-term operation. Conventional flexible substrates offer limited device protection in humid conditions; to overcome this, we employed a parylene-C/ALD-deposited Al2O3/ZrO2 hybrid substrate, providing flexibility and strong barrier properties. We fabricated flexible OPDs with an ultrathin (7 nm) silver electrode on a hybrid substrate, which remained stable after 10,000 bending cycles and demonstrated high mechanical robustness. Using PM6:PC71BM as the active layer, the OPDs achieved responsivity of 0.26 A/W at -0.1 V under 639 nm illumination, retained 86% of their initial performance after 12 days in deionized water, and remained functional after one hour of machine washing, showing that parylene/nanolaminate-based ultra-flexible OPDs enable long-term operation in aqueous environments.