Surface Engineering of Biomaterials, Medical Devices and Regenerative Materials
Room Palm 1-2 - Session MD2-WeM

Surface Response to Biological Environments, Biointerphases, and Regenerative Biomaterials

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9:20am **MD2-WeM-5 Green Fabrication of Conductive Carbon Thin Film Patterns for Biosensors**, ***Ying-Chih Liao [liaoy@ntu.edu.tw]***, National Taiwan University, Taiwan **INVITED**

The demand for sustainable and cost-effective materials in biosensing is growing, especially for real-time and portable health monitoring. However, conventional electrode fabrication methods often require multiple processing steps and use non-renewable materials. This reliance raises environmental concerns and limits scalability. In this study, a green approach is developed to directly transform biodegradable bacterial cellulose (BC) into conductive carbon thin films using CO_2 laser-induced carbonization under ambient conditions for biosensor fabrication. Bacterial cellulose (BC) a biopolymer generated by specific bacteria, features a highly porous, nanoscale fibrous structure along with notable mechanical strength and biocompatibility. These properties make it a highly versatile material for biomedical applications. The laser-induced carbonization process leverages these unique structural features of BC, converting it into a conductive carbon matrix suitable for electrochemical applications. This one-step technique involves the precise application of a CO_2 laser, which locally heats the BC, breaking down organic components and rearranging carbon atoms to create conductive graphitic structures.

This approach integrates essential elements into the BC matrix, enhancing conductivity and sensor functionality without requiring complex post-treatments. The laser-induced carbonized BC electrode offers promising detection capabilities for glucose and lactate, enabling concurrent sensing in phosphate buffer solution (PBS) and demonstrating selectivity, reproducibility, and stability, verified through differential pulse voltammetry (DPV). This streamlined laser carbonization method facilitates electrode fabrication and yields electrodes capable of application in real sweat sample analysis.These characteristics highlight BC-based electrodes as highly promising candidates for portable, cost-effective on-site biosensors for monitoring key biomarkers in sweat, underscoring the potential of laser-induced carbonization in advancing sustainable, high-performance materials for health monitoring technologies.

11:00am **MD2-WeM-10 Functionalized Graphene for Sensor Applications**, ***Chi-Hsien Huang [chhuang@mail.mcut.edu.tw]***, Ming Chi University of Technology, Taiwan **INVITED**

Graphene (G), a one-atom-thick, two-dimensional material, exhibits great potential as a biosensor transducer due to its high sensitivity to foreign atoms or molecules. However, its inertness limits its application, making functionalized graphene is very crucial for biosensor applications. In this presentation, I will talk about an atomic layered composite of graphene oxide/graphene (GO/G) by functionalizing chemical vapor deposition (CVD)-grown bilayer graphene (BLG) using our developed low damage plasma treatment (LDPT). This process selectively oxidized only the top layer of BLG, leaving the bottom layer intact. The GO top layer provides active sites for stable covalent bonding with biorecognition elements, while the G bottom layer acts as a sensitive transducer. With this GO/G composite, we constructed a solution-gated field effect transistor (SGFET)-based biosensors for miRNA-21, a cancer biomarker and p-tau 217, a Alzheimer's disease biomarker. In addition, laser induced graphene attracts a lot of attention because the preparation is low-cost, easy pattern fast and environment friendly. However, the electrochemical performance of standalone LIG is limited. To address this, the study enhances LIG by synthesizing nickel-iron Prussian blue analogues through co-precipitation and calcination, forming porous NiFe-Oxide, which is subsequently deposited onto the LIG surface via a facile physical deposition method. The porous NiFe-Oxide@LIG electrode material demonstrates excellent electrochemical sensing capabilities due to its high conductivity, improved surface area, enhanced active sites, and superior electrocatalytic performance for detecting the antioxidant propyl gallate (PG).

Keywords: graphene, LIG, sensor, biomarker

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11:40am **MD2-WeM-12 Surface Functionalization of Indium Tin Oxide via (3-Aminopropyl) Triethoxysilane and Glutaraldehyde for Enhanced Sensitivity in Glucose Detection**, ***Kai-Jhih Gan [jameswsalebron@gmail.com]***, *Jialong Xiang,* Fuzhou University, China*; Kuei-Shu Chang-Liao, Bo-Syun Syu,* National Tsing Hua University, Taiwan*; Dun-Bao Ruan,* Fuzhou University, China

In this study, (3-aminopropyl)triethoxysilane and glutaraldehyde were employed to functionalize the surface of indium tin oxide (ITO) thin films, followed by a comprehensive analysis of their material structure and properties. The structural characteristics of the ITO thin films before and after surface modification were investigated using atomic force microscopy and x-ray diffraction. The chemical composition of both the surface-modified layer and the ITO thin films was confirmed via x-ray photoelectron spectroscopy. Additionally, the structure of the ITO-based glucose biosensor fabricated with the modified films was characterized using transmission electron microscopy and energy-dispersive spectroscopy. The results reveal that surface modification of the ITO thin films not only optimized their surface properties but also enhanced the effective contact area, thereby improving the sensor performance. ITO sensing patch exhibited a broad linear response range for glucose detection, from 10 fM to 10^{10} fM, under optimized conditions.

12:00pm **MD2-WeM-13 Magnetron-Sputtered Ti-Based Thin Films: A Versatile Platform for Biopotential Sensing and Neurorehabilitation**, ***Claudia Lopes [claudialopes@fisica.uminho.pt]***, CF-UM-UP, University of Minho, Portugal*; Patrique Fiedler,* Technische Universität Ilmenau, Germany*; Jean-Francois Pierson,* Institut Jean Lamour - Université de Lorraine, France*; Brigitte Vigolo,* Institut Jean Lamour - Université de Lorraine (F), France*; Nelson Azevedo,* Nellson Azevedo & Terapias Globais, Portugal*; Michael Cullinan,* Department of Mechanical Engineering, The University of Texas at Austin, USA*; Armando Ferreira, Filipe Vaz,* CF-UM-UP, University of Minho, Portugal

Four distinct Ti-based thin film systems, doped with different metals (Au, Ag, Cu, Al), have been prepared by magnetron sputtering, allowing precise control over their chemical composition and microstructure. The strategic incorporation of these metals induces significant variations in phase composition, grain morphology, crystallographic orientation, and surface topography, which directly impact the electrical conductivity, mechanical flexibility, and electrochemical stability. These tunable properties are crucial for optimising their performance in biomedical applications, particularly as functional interfaces for biopotential sensing.

All the systems exhibit three distinct regimes based on their chemical composition. At low metal contents, Ti-based films establish α-Ti(metal) metastable solid solutions. For intermediate metal/Ti ratios (0.2 - 1.0), the precipitation of intermetallic phases leads to high structural disorder, giving rise to different microstructures depending on the metal type. At higher ratios (> 1.0), the systems display contrasting morphologies, from well-defined domains to amorphous structures. The mechanical properties vary accordingly: Ti-Au and Ti-Cu films demonstrate superior toughness ($H/E \approx 0.1$) and high elastic recovery, whereas Ti-Ag and Ti-Al, characterised by columnar and brittle intermetallic structures, exhibit lower plastic deformation resistance ($H/E < 0.04$). Electrical resistivity is also metal-dependent, with Ti-Au and Ti-Cu films maintaining nearly constant resistivity (~180 μΩ·cm) due to their Thin Film Metallic Glasses-like morphology, while Ag- and Al-rich films exhibit resistivity variations (130–270 μΩ·cm) linked to their crystalline structures.

These Ti-based systems have been implemented as advanced dry biopotential electrodes, namely on the integration of novel neuro-rehabilitation systems combining electroencephalography (EEG), electrocardiography (ECG), electromyography (EMG), and functional electrical stimulation (FES). Ti-Au and Ti-Cu electrodes demonstrated superior electromechanical performance and in vivo signal acquisition, outperforming conventional Ag/AgCl electrodes. Their dense, disordered

structures contribute to enhanced durability, while Ti-Cu electrodes exhibited prolonged reusability, maintaining high-fidelity signal recording for at least 24 hours. The integration of these biocompatible, flexible thin films onto polymeric substrates ensures mechanical adaptability and stable skin-electrode interaction, reinforcing their potential in bioelectronic and neurorehabilitation systems.

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