New Horizons in Coatings and Thin Films
Room Town & Country C - Session F3-TuA

2D Materials: Synthesis, Characterization, and Applications

Moderators: Prof. Ying-Hao Chu, National Tsing Hua University, Taiwan , **Prof. Chih-Yen Chen**, National Sun Yat-sen University, Taiwan , **Dr. Yi-Cheng Chen**, National Tsing Hua University, Taiwan

1:40pm **F3-TuA-1 Tellurene Electronics and Sensors*, Wenzhuo Wu,*** Purdue University, USA **INVITED**

Emerging technologies such as distributed computing and the internet of things (IoT) necessitate the implementation of high-speed, energy-efficient devices. Various technological paths are being actively pursued to synthesize and integrate high-performance channel materials for these applications. Specifically, 2D semiconductors have been intensely explored as promising channel materials for related ultra-scaled technologies. However, there has been a lack of synthetic strategies for the scalable, substrate-agnostic production of large-area, high-quality 2D crystals with a low thermal budget for back-end-of-line (BEOL) compatible applications. In this talk, I will discuss our recent progress in the scalable nanomanufacturing of tellurene, an emerging 2D multifunctional material pioneered by my group, for high-performance nanoelectronics and optoelectronics applications. Our results show that the air-stable tellurene exhibits a plethora of intriguing properties appealing for applications in electronics, optoelectronics, energy, sensors, and quantum devices.

2:20pm **F3-TuA-3 Phase/Structure-Engineered Two-Dimensional Layered Materials for Innovative Nanoelectronics*, Yu-Lun Chueh,*** National Tsing Hua University, Taiwan **INVITED**

Novel condensed matter systems can be understood as new compositions of elements or old materials in new forms. According to the definition, various new condensed matter systems have been developed or are under development in recent years. 2D layered materials, including graphene and transition metal dichalcogenides (TMDs) allow the scaling down to atomically thin thicknesses and possess unique physical properties under dimensionality confinement. The chemical vapor deposition (CVD) process is the most popular approach for all kinds of 2D materials due to its high yield and quality. Nevertheless, the need for high temperature and the relatively long process time within each cycle hinders commercial development in terms of production cost. However, the transfer procedure has become one of the major limitations of the overall performance. In my talk,an inductively coupled plasma (ICP) was used to synthesize Transition Metal Dichalcogenides (TMDs) through a plasma-assisted selenization process of metal oxide (MO_x) at a low temperature. Compared to other CVD processes, ICP facilitates the decomposition of the precursors at lower temperatures.We create the phase/structure-engineered-1T/2H 3D-hierarchical 2D materials derived from the MOx 3D-hierarchical nanostructures through a low-temperature plasma-assisted selenization process with controlled shapes grown by a glancing angle deposition system (GLAD). The applications, including (1) water splitting, (2) gas sensors, (3) batteries, and (4) resistive change memory, will be reported.

3:00pm **F3-TuA-5 Tellurene-Based Wearable Biosensor for Real-Time Longitudinal Monitoring of Neurotransmitters in Human Sweat*, Ruifang Zhang,*** *W. Wu,* Purdue University, USA

Metabolic biomarkers provide direct indicators of physical and mental health status. However, the state-of-the-art tools for monitoring metabolites in body fluids are expensive, time-consuming, and often require invasive procedures to collect the samples. Non-invasive wearable sensors for monitoring metabolites in sweat, the most accessible human secretion, are promising alternatives to costly diagnostic tools. Moreover, existing wearable sensors have limited sensitivity, selectivity, and lifetime for measuring disease-specific metabolic markers (e.g., neurotransmitters) from human sweat. Wearable sweat sensors that can monitor the dynamics of neurotransmitters directly from human sweat have yet to be developed. Here, the applicant reports a wearable biosensor based on tellurene that can enable, for the first time, the selective and sensitive longitudinal quantification of dopamine (DA) and norepinephrine (NE) concentrations in real human sweat. The applicant also evaluated and validated the concentrations of neurotransmitters in human sweat using high-performance liquid chromatography/mass spectrometry (HPLC/MS) for the first time. This research could create unprecedented diagnostic tools for improving the experience and outcomes of patient care. The development of non-invasive wearable sensors capable of longitudinal measurement of disease-specific metabolic markers from sweat will positively impact erroneous or delayed diagnoses, enable affordable and ubiquitous diagnostic tools, and foster data-driven precise mobile health monitoring with translational applications in patient care and beyond.

4:00pm **F3-TuA-8 A Two-Dimensional $Ti_3C_2T_x$ MXene/Mesochannel Ionic Diode Membrane for High-Performance Osmotic Energy Harvesting*, Wen-Hsin Hung,*** National Taiwan University of Science and Technology, Taiwan*; C. Chu,* Feng Chia University, Taiwan*; L. Yeh,* National Taiwan University of Science and Technology, Taiwan

Osmotic energy has attracted explosive attention in recent year because of its advantages of clean and sustainable. Osmotic energy can be harvested via the reverse electrodialysis technique and it can convert chemical potential stored in an ionic concentration gradient into an electrical energy by using an ion-selective membrane. The osmotic power generation, however, is still restrained due to the inherently limited ion flux in such a small nanochannel. Here, we report a subnano-on-meso architecture (named as MXene@MC), realized by deposition of an ultrathin layer of two-dimensional $Ti_3C_2T_x$ MXene on a single conical PET mesochannel (MC) (Fig. 1). The introduction of the asymmetries in pore geometry gives the MXene@MC outstanding ion current rectification property, which can amplify ionic current at a degree of up to 25.6 times (Fig. 2). We therefore probe the application of the subnano-on-meso ionic diode device in osmotic energy harvesting. The results show that a single MXene@MC can achieve a record osmotic power as high as 343 pW at a 1000-fold KCl gradient, exceeding all the state-of-the-art single-pore devices (Fig. 3).We expect that this study can provide an emerging platform towards high-performance osmotic energy generator.

4:20pm **F3-TuA-9 Discussion on the Growth Parameters and Oxygen Evolution Reaction Performance of Copper Sulfide*, Li-Wen Lin,*** *C. Chen,* Department of Materials and Optoelectronic Science, National Sun Yat-Sen University, Taiwan

With the advancement of science and technology, energy demand is increasing day by day. People began to look for alternative energy sources in order to solve the problem of insufficient energy. Hydrogen fuel cells have become one of the most notable research projects because of their environmentally friendly and renewable characteristics. One of the cleanest ways to generate hydrogen is through electrochemical water splitting, which can be divided into two parts: Hydrogen evolution reaction (HER) at cathode and oxygen evolution reaction (OER) at anode. Among them, OER is known to be more complicated and thus became the biggest hinder to water splitting.

In this work, Cu_2S microplates were successfully synthesized with non-toxic chemicals via a one-step solvothermal method. The as-prepared samples were then applied as working electrodes for OER electrochemical measurements. The results turned out that the as-prepared Cu_2S/CF electrodes have excellent OER performances with a low overpotential of 269.2 mV (at a current density of 10 mA cm^{-2}) and a Tafel slope of 102.1 mV dec^{-1}. These outstanding results indicated that Cu_2S microplates could be developed as excellent OER electrocatalysts.

4:40pm **F3-TuA-10 Cation and Anion Co-Doped Iron Oxide Toward Efficient Hydrogen Peroxide Formation and Electro-Fenton Degradation of Organic Pollutant*, Yemima Purba,*** *J. Ting,* National Cheng Kung University (NCKU) Tainan, Taiwan

Nowadays, electrochemical advanced oxidation processes, Fenton process, have attracted a lot of attention as compared to conventional degradation. Regarding the Fenton catalyst, iron oxide has been known as an efficient catalyst and demonstrated in degradation of organic pollutants. The metal doping into iron oxides has been shown to enhance the degradation rate due to rich redox reactions. However, there are only a few studies on the anion doping. It is known that anion doping is able to enhance the electrical conductivity of the oxide. In this study, novel cation and anion co-doped iron oxide has been firstly demonstrated for electron-Fenton catalyst. The synergistic effect of cation and anion doping is favorable to improve the selectivity of hydrogen peroxide, which thus can be utilized for electro-Fenton degradation of organic pollutants. The electro-Fenton degradation performance has been evaluated through degradation of tetracycline at different conditions. At the optimized condition, the obtained material generates hydrogen peroxide and tetracycline degradation efficiency of 98% within 2-h. This novel oxide catalyst can be regarded as a promising catalyst for wastewater treatment.

5:00pm **F3-TuA-11 Molten Salt Synthesis of Highly Dispersible Hexagonal Boron Nitride Nanosheets for Ultrafiltration***, **Neon Vicente III Rosell,*** National Cheng Kung University (NCKU), Taiwan, Philippines*; K. Chang,* National Cheng Kung University (NCKU), Taiwan

Hexagonal boron nitride (hBN) is a key material analogue for graphene. It is best known for its use by industry as a chemically-inert, refractory material for use in harsh environments. Conversely, it is this same robustness that make it difficult for researchers to synthesize hBN in the lab without the use of exotic setups and reagents. Molten salt synthesis affords researchers a facile method to synthesize quantitative amounts of hBN for research. In this research, hBN was synthesized in a LiCl-KCl molten salt eutectic at 900°C under nitrogen atmosphere. Boric acid and melamine were used as the boron and nitrogen source respectively. Recovery of bulk hBN from the cooled melt was done with washing with deionized water and centrifugation. The resulting powders were then subjected to materials characterizations such as XRD, FT-IR, Raman, and TEM-EELS that confirm the synthesis of hBN powders. The resulting powders has been shown to have high dispersibilty in water when subjected to exfoliation techniques such as ultrasonication. This hBN dispersion was then used as basis for an ultrafiltration membrane that demonstrates excellent separation efficiency for organic dyes (i.e. Rhodamine B, Methylene Blue, Methyl Orange). Regeneration of this ultrafiltration membrane has been demonstrated through the use of advanced oxidation processes where either exposure to hydrogen peroxide solutions, or decoration of P25 titania nanoparticles was used under xenon lamp illumination.

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