## Fundamentals and Technology of Multifunctional Materials and Devices
## Room Grand Hall - Session CP-ThP

## Fundamentals and Technology of Multifunctional Materials and Devices (Symposium C) Poster Session

**CP-ThP-1 Comparison of $SiC_xN_y$ Barriers using Different Precursors Deposited on Porous Low-Dielectric-constant SiCOH Dielectric Films**, *Y Cheng, Y Lin,* ***Chih-Yen Lee,*** National Chi-Nan University, Taiwan

In this study, two different $SiC_xN_y$ films using different deposition precursors were deposited onto the porous SiOCH low-*k* films. Their impacts on the electrical characteristics and reliability of a $SiCOH/SiC_xN_y$ dielectric stack were compared. A lower plasma damage on the SiOCH low-*k* film was made as $SiC_xN_y$ film was deposited onto the SiOCH low-*k* film using single-source precursor compared to that using the conventional multi-source precursors. This results in a lower capacitance of $SiCOH/SiC_xN_y$ dielectric stack. Moreover, better TDDB reliability and comparable Cu barrier performance were detected. As a result, the $SiC_xN_y$ layer deposited using a single precursor is a promising method to serve as a capping barrier for porous low-*k* dielectrics.

**CP-ThP-2 Stretchable Ultrasonic Transducer Arrays for Three-Dimensional Imaging on Complex Surfaces**, ***Hongjie Hu***, *X Zhu, C Wang, L Zhang, S Xu,* University of California, San Diego, USA

Ultrasonic imaging has been implemented as a powerful tool for noninvasive subsurface inspections of both structural and biological media. Current ultrasound probes are rigid and bulky and cannot readily image through nonplanar three-dimensional (3D) surfaces. However, imaging through these complicated surfaces is vital because stress concentrations at geometrical discontinuities render these surfaces highly prone to defects. This study reports a stretchable ultrasound probe that can conform to and detect nonplanar complex surfaces. The probe consists of a 10 × 10 array of piezoelectric transducers that exploit an "island-bridge" layout with multilayer electrodes, encapsulated by thin and compliant silicone elastomers. The stretchable probe shows excellent electromechanical coupling, minimal cross-talk, and more than 50% stretchability. Its performance is demonstrated by reconstructing defects in 3D space with high spatial resolution through flat, concave, and convex surfaces. The results hold great implications for applications of ultrasound that require imaging through complex surfaces.

**CP-ThP-6 Fabrication and Characterization of Ni-coated Ag Nanowire Electrodes with Bubble-like Random Meshes**, ***Jong-Seol Park***, *R Yoo, T Park, J Park,* Hanyang University, Republic of Korea

Recently, as the applications of flexible electronic devices have been expanded, transparent electrode materials are required to be flexible and stretchable in addition to having excellent electrical and optical properties. Examples of such materials include carbon nanotubes, metal meshes, metal nanowires, and graphene. Among them, metal nanowires along with metal meshes, are evaluated to be advantageous in terms of commercialization because they have a low electrical sheet resistance and a high visible light transmittance. In particular, compared to other materials, metal nanowires are the most advantageous in terms of flexibility and have the advantage of being able to fabricate electrodes using simple and relatively inexpensive solution-based methods. However, metal nanowires have a relatively high reflectance, high haze, and high contact resistance between their wires. They also have oxidation problems when exposed to the atmosphere. As an example of inhibiting the oxidation of metal nanowires, studies have been introduced to coat the nanowires with oxidation resistant materials. Also, in the case of the widely adopted grid-type electrode, there is another disadvantage in that it is difficult to secure high visibility due to the diffraction of light or the moiré phenomenon due to a regularly repeated lattice structure. To solve this problem, studies on the fabrication of random-type electrodes using the irregular patterns of crack, leaf, spider web, and bubble have been reported.

In this study, embedded-type nickel (Ni)-coated silver nanowire (AgNW) transparent electrodes with random-mesh patterns were fabricated via solution processes. The major manufacturing processes of the Ni-coated AgNW random mesh electrodes are summarized as follows. The AgNW bubble solution was prepared by mixing a surfactant with the AgNW solution and agitating it. The surface modification of polyethylene terephthalate (PET) substrate was performed using corona plasma. Using a spin-coating method, the AgNW bubble solution was deposited on the PET substrate with various surface energies. Then, the bubble solution was evaporated through the baking process to form a bubble-like random pattern. This was transferred to polydimethylsiloxane (PDMS) and coated with Ni by electroplating. The line width and line-to-line spacing of the fabricated electrodes were estimated according to the number of corona treatments and baking temperature on the PET substrate. For the electrodes fabricated, we have measured and characterized their morphology, transmittance and reflectance at visible light region, electrical sheet resistance, flexibility, stretchability, and oxidation-stability.

**CP-ThP-13 Study of Stress-electrical Properties of ITO Film Deposited on Stretchable Substrate**, ***Pierre-Olivier Renault***, Université de Poitiers, France*; C Grossias, P Goudeau, P Godard, F Paumier, S Hurand,* University of Poitiers, France*; D Thiaudière,* SOLEIL Synchrotron, France*; P Guerin,* University of Poitiers, France

Indium Tin Oxide (ITO) is one of the most widely used material with the unusual property of being transparent and conductor. The fabrication and characterization of these materials, called transparent conductive oxides (TCO), is a very active field of research motivated by their potential applications in optical and optoelectronic devices. ITO is almost always used as a thin film in a more or less complex stacking deposited on substrates. The mechano-electro-optical properties of transparent conductive oxide thin films deposited onto substrates depend on many elaboration parameters as well as their piezoresistive response.

In the present work, 400 nm thick ITO films have been prepared by ion beam sputtering controlling the oxygen partial pressure. Each thin film has been deposited on a polyimide stretchable substrate. The deformations are applied thanks to a biaxial tensile tester in situ during x-ray diffraction measurements at the french synchrotron SOLEIL. Thus, x-ray stress or x-ray strain (measured by x-ray diffraction technique), true strain (measured by digital image correlation technique) and electrical resistivity (Van der Pauw method) measurements are performed during in situ biaxial straining. The first results obtained on x-ray stress- true strain – electrical conductivity relation are reported. A negative gauge factor is observed for all thin films. The influence of oxygen residual pressure does not seem to have a large effect on gauge factor contrary to the mechanical behavior.

**CP-ThP-18 Dual Box Model based *In situ* Ellipsometry Growth Characterization: Oxygen Plasma Enhanced Atomic Layer Deposition of Metal Oxide Ultra-thin Films**, *U Kilic,* University of Nebraska-Lincoln, USA*; A Mock,* Linköping University, Sweden*; D Sekora, N Ianno,* ***Eva Schubert***, *M Schubert,* University of Nebraska Lincoln, USA

Atomic Layer Deposition (ALD) of conformal ultra-thin films has been shown to have potential for applications in microelectronics, photovoltaics, photoluminescence and fuel cells [1]. The integration of spectroscopic ellipsometry (SE), an optical, contactless, and non-invasive technique, into the ALD instrumentation has been a powerful and widely-used process monitoring method[2] which paves the way to unravel the surface roughness and thickness evolution during the ALD process.

In this study, we successfully optimized the oxygen plasma enhanced ALD recipes for two different metal-oxides: $WO_3$ and $TiO_2$, in which employs $(tBuN)_2(Me_2N)_2W$ and $Ti(OC_3H_7)_4$ organometallic precursors, respectively. Multi-sample analysis method is employed in order to obtain both thickness and optical constants from SE data analysis[3]. Thus, three films are deposited by using 75, 100, and 150 ALD cycles under the same conditions and *ex-situ* SE data is collected in the spectral range from 0.7-6.5~eV.

The as-grown $WO_3$ and $TiO_2$ dielectric functions are determined along with the respective film thicknesses. With this information, the *in-situ* SE data is retroactively analyzed to attain inherent layer-by-layer deposition parameters. We employed the dual-box model in order to obtain sub-angstrom scale in-cycle resolution time evolution of thin film thickness and effective surface roughness layer thickness parameters during the growth process. Our model analysis permits determination of growth rate and identification of cyclic surface modifications during exposure to individual cycle steps. Further implementation of this method allows for precise control and real-time optimization of deposition parameters ultimately providing us with the ability to develop ALD recipes *in-situ*.

**References:**

[1]: George, Steven M., Chemical reviews 110.1 (2009): 111-131.

[2]: Leick, N., et al. Journal of Physics D: Applied Physics 49.11 (2016): 115504.

[3]: Kilic, U., et al., Journal of Applied Physics*:1805.04171* (2018).

**CP-ThP-19 Controlled Release of Encapsulated Agents Deposited on Plasma Electrolytic Oxidation (PEO) Coatings for Corrosion Resistance and Biomedical Applications***, Y Guo, B Mingo, A Matthews,* ***Aleksey Yerokhin****,* The University of Manchester, UK

A number of surface treatment methods has been developed in order to increase the protective and functional properties of magnesium alloys. Plasma Electrolytic Oxidation (PEO) is an environmentally friendly treatment resulting in ceramic coatings with high hardness, excellent adhesion to the substrate and good wear and corrosion resistance. However, the passive corrosion protection provided by PEO coatings can be undermined if the coating is worn off or damaged.

Therefore, the aim of this work is to investigate a possibility functionalisation of PEO coating surfaces in order to achieve: i) sustained release of corrosion inhibitors encapsulated by halloysite nanotubes (HNT) for non – biological applications of magnesium alloys, in order to achieve self-healing effect; and ii) sustained release of encapsulated drugs for biological applications of degradable magnesium alloys, in order to develop the next generation of 'smart' biomedical implants materials.

Halloysite nanotubes (HNT) represent a type of bio-compatible naturally occurring clay with the walls consisting of two layered aluminosilicates. The hollow tubular structure of HNT allows different agents to be loaded by vacuum-induced capillarity. The release of the agents can be triggered by e.g. changes in the pH of environment, on mechanical impact or simply by osmotic pressure. The corrosion inhibitors in this study (vanadate, molybdate and 8-hydroxyquinoline) consist both negatively charged particles and electrically neutral molecules. For biological applications, the drugs are mostly electrically neutral molecules, and in this study is penicillin.

The main challenge of this work is ensure the adequateness of the deposited agents. The incorporation of encapsulated agents onto PEO coatings can be achieved by two approaches: hybrid and sequential. The hybrid approach is to incorporate the particles as the same time as the coating synthesis whereas the sequential approach is by post-treatment. In this work, post-treatment will be discussed. There are two post-treatment methods: electrophoretic deposition (EPD) and immersion. Both of the post-treatment methods require aqueous suspension of loaded HNT. So, the release kinetics of the loaded agents is of great importance since there are possibility of release during the deposition process. Ultraviolet-visible (UV-VIS) spectroscopy is employed for the release kinetics.

Successfully encapsulated and deposited corrosion inhibitors significantly improves the corrosion resistance of magnesium alloys. And for drugs, observation of zone of inhibition (ZOI) on Gram-positive bacteria Staphylococcus Aureus indicates the success of drug loading.

**CP-ThP-21 Influence of Substrate Temperature on the Growth of Molybdenum Trioxide Thin Films***, Madhuri Venkat Kalapala,* VFSTR University, India

Molybdenum oxide is one of the most important inorganic materials which exhibit several phases such as $MoO_3$, $MoO_2$, $Mo_4O_{11}$, $Mo_5O_{14}$, etc,. Out of this molybdenum trioxide ($MoO_3$) can crystallize in various phases such as Orthorhombic, Monoclinic etc., which lead it to the useful for potential applications in chemical, electrical and electrochemical industry. In the present work $MoO_3$ thin films were prepared by pulsed laser deposition techniques at various substrate temperatures from room temperature to 400$^0$c. The films were deposited on to glass and FTO quoted substrates at a base pressure of $10^{-5}$mbar. The crystal structure morphology and elemental analysis were recorded by XRD, SEM, EDS and AFM. The substrate temperature strongly influences the structure and surface topography. The films prepared at base pressures are found to be oxygen deficient and after annealing the films were found to be transparent. The presence of oxygen atmosphere at the time of deposition makes the films to show better properties.

**CP-ThP-22 Evaluation of the Influence of Pre-carburisation on the In-situ Performance of Chromized 304 Stainless Steel Bipolar Plate***, Atinuke Oladoye,* University of Lagos, Nigeria*; J Carton, J Stokes,* Dublin City University, Ireland*; A Olabi,* University of the West of Scotland, UK

This paper reports preliminary attempts at improving the in-situ performance of chromised 304 stainless steel (304SS) bipolar plates via the introduction of a pre-carburisation step prior to chromising. 304 stainless steel bipolar plates with parallel flow field design were pre-carburised at 900$^o$C for 3 hours and subsequently chromised at 1040$^o$C for 3 hours. The surface modified plates were tested in a 5cm$^2$ active area single proton exchange membrane fuel cell at room temperature for performance and durability. Results obtained was compared to that of non-carburised chromised 304SS bipolar plate tested under identical conditions. It was found that the single fuel cell with pre-carburised chromised bipolar plates attained a peak power density of 18.20 mW/cm$^2$, which was a double-fold increase in that of the single fuel cell with non carburised chromised 304SS bipolar plates. The ten-hour durability test, however, indicated the need for further research efforts to enhance the stability of the pre-carburised-chromised stainless steel bipolar plates.

**CP-ThP-23 Piezo- and Thermo-resistive Thin Films Integrated into a Polymer Injection Mold to Control Dynamically the Pressure and Temperature of the Injection Process***, Filipe Vaz, A Ferreira, M Barbosa,* University of Minho, Portugal*; J Larangeira,* Moldit, Portugal

The present work reports on the development of metallic piezoresistive thin films, aiming to investigate an innovative solution to control dynamically the temperature of the injection molding process of polymeric parts using technologies of thin films. The general idea was to analyse the signal response of the $Ti_{1-x}Cu_x$ and ZnO/Ag based transducers exploring the possibility to use this thin film system in force, deformation and temperature sensor devices. $Ti_{1-x}Cu_x$ and ZnO/Ag thin films were produced by the Glancing Angle Deposition technique (GLAD).

The results reveal that the zigzag microstructure has an evident influence on the overall response of the films as well as the influence of the Cu or Ag doping level. The values of temperature coefficient of resistance reach 8 .73×10$^{-3}$ ºC$^{-1}$ for pure copper films and 4.38 ×10$^{-3}$ ºC$^{-1}$ for films with an intermedium composition. The values of the gauge factor show that a longer distance between Ag particles, which varies from 0.1 to 10 nm, leads to enhanced GF, which ranges from 8 ± 1 to 120 ± 3, respectively.

In order to demonstrated the sensing capabilities of the system, a proof-of-concept experiment was carried out by integrated the thin films of $Ti_{1-x}Cu_x$ and ZnO/Ag with the best response in an injection steel mold and connected to a data acquisition system based on a homemade dedicated read circuit hardware and LabVIEW software, connected to a radio-frequency access point, plugged to a universal serial bus (USB) port. The most challenging part in this work is to quantify the results obtained from this experiment which has not been done in literature yet.

**CP-ThP-25 Investigation of $Sb_2Se_3$ Ultra-thin Hole-transporting Material for Perovskite/ $Sb_2Se_3$ Heterojunction Solar Cells***, Gwomei Wu,* Chang Gung University, Chang Gung Memorial Hospital, Taiwan

$Sb_2Se_3$ thin film photovoltaic has a low energy band gap for effective and wide solar-spectrum utilization. This report presents a new solar cell architecture with ultra-thin $Sb_2Se_3$ hole-transporting material (HTM) layer (<300 nm) in between bi-layer Mo metal-electrode layer and $CH_3NH_3PbI_3$ ($MAPbI_3$) perovskite active absorber layer. The solar cell nano-structures were prepared as Mo/ $Sb_2Se_3$/perovskite/ ZnS/Ag multi-layers on FTO ( fluorine-doped tin oxide ) glass substrates. The hole-transporting layer, active absorber layer, electron-transporting buffer layer, and top metal-electrode contact layer, were made of $Sb_2Se_3$, perovskite, zinc-sulfide, and silver, respectively. The ultra-thin $Sb_2Se_3$ HTM layers were annealed at temperature of 400, 500, and 600℃. The nano-crystal grain size, revealed by scanning electron microscopy, was enhanced with the increaing annealing temperature. T he advantages of using $Sb_2Se_3$ HTM on perovskite photovoltaics included better device performance, reduced HTM film thickness, and diminished HTM film cost. The $Sb_2Se_3$ HTM has acted to maintain perovskite absorber layer's optical-current and stability. The device photo power-conversion efficiency can reached about 14.4%, and the related photo-electronic characteristics will be summarized and further discussed. This work was supported in part by the Ministry of Science and Technology under research grants MOST105-2221-E182-059-MY3/BMRP246 and CGMH CMRPD3G0062.

Keywords: $Sb_2Se_3$, Hole-transporting material, perovskite, $MoSe_2$, ZnS,

**CP-ThP-27 Fabrication of a Thermoelectric Generator Device by Suspension Plasma Spray Technique***, Fabian Ambriz-Vargas, C Moreau,* Concordia University, Canada

About seventy percent of the world energy production is lost in the form of heat dissipation which is one of the most significant contributions in the global warming. Thermoelectric generators are one of the most viable devices to recover waste heat (generated by the vehicles, factories, houses etc.) and convert it into electricity. With the rising cost of fuel and increasing demand for clean energy, solid-state thermoelectric devices are good candidates to reduce fuel consumption and $CO_2$ emissions. Although, they are reliable energy converters, there are several issues that have

limited their implementation into the market. These issues include toxicity of the thermoelectric materials (coatings-based lead and tellurium) and the limited ability to mass-manufacture thermoelectric materials. Recent theoretical predictions have demonstrated that titanium dioxide ($TiO_2$) can overcome the above issues, since they are non-toxic, relatively abundant and present excellent thermoelectric properties. However, formation of high quality $TiO_2$ phase is not feasible. Among the different emerging synthesis process, suspension plasma spray technique is a good candidate to synthesize $TiO_2$ coatings since it presents several advantages such as control over the chemical stoichiometry, industry-scalable and low-cost process. Then, this work presents the evaluation of the thermoelectric properties of $TiO_2$ coatings produced by suspension plasma spray technique. This research strategy involves the study of the effect of the synthesis technique parameters on the microstructural, structural and thermoelectric properties of $TiO_2$.

**CP-ThP-31 Morphology Controlled of Silver/Silver Oxide Nanoparticles-MnO2 Nanocomposites for Supercapacitor Application**, *F Sari,* ***Kuang-Cheng Lin****, J Ruan, J Huang, J Ting,* National Cheng Kung University, Taiwan

Ag nanoparticles (NPs)-$MnO_2$ having various morphology have been synthesized through a facile method. It was found that by controlling the amount of Ag NPs, temperature, and time of reaction lead to the formation of urchin-like structure with $Ag_2O$ NPs on the tips of □-$MnO_2$ nanowires, while the addition of surfactant agent poly(vinylpyrrolidone) (PVP) leads to the formation of nanoflower-like structure with Ag NPs distribute well on the δ-$MnO_2$ nanosheets surface. Moreover, the formation of the Ag sub-oxides such as $Ag_2O$ and $Ag_2O_2$ were also investigated. Varied dimension and different morphology resulting the different of specific surface area. Supercapacitors having the obtained Ag/Ag sub-oxides –$MnO_2$ nanocomposite as the electrodes were evaluated. We demonstrated the synergistic effect of high specific surface area with the Ag/$Ag_2O$ NPs, which provide more active sites and effectively reduce the resistance. As a result, the obtained nanocomposite with optimum specific surface area of 250.9 $m^2g^{-1}$ and low Rct of 84 ohm showing high Csp of 226 F $g^{-1}$ at 5 mV $s^{-1}$ which is three times compare to pure □-$MnO_2$. The nanocomposites also show no degradation after 1000 cycles, indicating excellent electrochemical stability.
Keywords: $MnO_2$, Ag nanoparticles, $Ag_2O$, supercapacitor

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