ALD Applications
Room Auditorium - Session AA1-TuM2
ALD for Medical Applications

Moderators: Mato Knez, CIC nanoGUNE, Angel Yanguas-Gil, Argonne National Lab

10:45am **AA1-TuM2-1 Plasma-assisted ALD of IrO_2 for Neuroelectronic Applications**, ***Valerio Di Palma***, *A. Pianalto,* University of Milano Bicocca, Department of Materials Science, Italy*; M. Perego, G. Tallarida,* CNR-IMM, Unit of Agrate Brianza, Italy*; M. Fanciulli,* University of Milano Bicocca, Department of Materials Science. CNR-IMM, Unit of Agrate Brianza, Italy

Investigation *in-vitro* of neural networks is fundamental for the development of strategies to study neurological diseases such as Alzheimer's. Large arrays of microelectrodes (MEAs), planar or micro/nanostructured, are commonly used to stimulate neurons and record their response to external stimuli. MEAs materials are selected to perform charge transfer towards the cells medium efficiently and in a reversible way. IrO_2 has attracted attention in the field because of its pseudo-capacitive behavior, along with its stability and non-toxicity. In parallel atomic layer deposition (ALD) is confirmed as an efficient tool for the conformal functionalization of micro/nanostructured MEAs, with a good control of the thickness and of the physical properties of the film. In this work we report on the ALD growth of IrO_2 thin films and their physical/chemical characterization. The functional properties relevant for neuroelectronic applications, have been addressed with electrochemical measurements. We propose a new plasma-assisted ALD process, using (EtCp)Ir(CHD) as precursor and a mix of Ar/O_2 plasma as reactant. The process exhibits a linear growth, with a growth per cycle of about 0.3 Å at 150°C. *In-situ* spectroscopic ellipsometry shows the typical step-like behavior, *i.e.* the thickness increases during precursor absorption and then it decreases, because of the ligands removal, during the O_2 plasma step.

XRD analysis exhibits the characteristic peaks reported in the literature for the rutile phase of IrO_2. Furthermore, XPS confirms the presence of Ir in the oxidation state of +4, characterized by the chemical shift of the Ir $4f_{7/2}$ component to 61.7 ± 0.1 eV. AFM characterization shows that ALD prepared IrO_2 is smooth and conformal to the substrate. On smooth Al_2O_3 substrates, IrO_2 RMS roughness is 0.7 ± 0.3 nm for a 24 nm thick layer. The chemical characterization via TOF-SIMS indicates that carbon content in the film is below the detection limit, indicating the good quality of the ALD prepared IrO_2.

Electrochemical characterization of the IrO_2/electrolyte interface was performed by impedance spectroscopy (EIS), cyclic voltammetry (CV) and voltage transient (VT) measurements, using a phosphate buffer solution (PBS) as electrolyte. The EIS results indicate that the interaction IrO_2/PBS is purely capacitive, with no faradaic contribution involved in the charge transfer mechanism. In addition, CV measurements confirm that the faradaic contribution is negligible within the range from -0.8 to +0.8 V vs. Ag/AgCl. The charge injection capacity for ALD prepared IrO_2 thin films determined by VT measurements is 1.40 mC, in line with the literature.

11:00am **AA1-TuM2-2 Hydrophilic Surface Modification of Microfluidic Channel by Room Temperature PEALD SiO_2**, ***Chien-Wei Chen***, Taiwan Instrument Research Institute, NARLabs, Taiwan*; Y. Yu, B. Li,* National Yang Ming Chiao Tung University, Taiwan

Microfluidic devices are often used in biomedical applications for fluidic sample testing and analysis, where multiple tests need to be performed with a small amount of retrieval, and the surface wetness of the flow channel affects the operability and flow rate during sample injection, making it difficult to successfully complete the process with limited retrieval conditions. PMMA is one of the commonly used substrate materials for microfluidic devices, but its surface is relatively hydrophobic (water contact angle >60°), which may be unfavorable when performing aqueous sample analysis.

The most common way to increase hydrophilicity is O_2 plasma treatment, but the short duration and limited increase in hydrophilicity are the biggest inconveniences in use. There are other hydrophilic coating methods such as sol-gel, PVD and CVD, but some of the above process may have the limitation that the process temperature is too high for plastic substrates. On the other hand, these methods require the inner side of the channel to be coated with a hydrophilic layer before it can be assembled into a microfluidic device, which not only increases the complexity of the process, but also may reduce the reliability of the device. For the above reasons, we use room temperature PEALD SiO_2 process to modify the microfluidic surface. ALD SiO_2 thin film not only has better and longer hydrophilic properties than O_2 plasma treatment (Figure 1), but also takes advantage of the fact that ALD can be used to deposit a uniform cover film on non-planar or high aspect ratio structures, and can directly deposit SiO_2 hydrophilic film on the internal surface of the assembled microfluidic channel. The possibility of contamination of the microfluidic surface during assembly is reduced. Finally, we also designed a simple microfluidic device to verify its autonomous absorption of aqueous solution (Figure 2), which can be used to inject fluidic samples without additional pump system and has high potential for Point-of-care testing.

11:15am **AA1-TuM2-3 Atomic Layer Deposition (Ald) on 5-Aminosalicylic Acid for Delayed and Targeted Drug Release Treatment of Inflammatory Bowel Disease**, ***Jaynlynn Sosa***, University of Central Florida*; P. Banerjee,* University of Central Florida

The incidence of chronic diseases continues to increase worldwide. Exploring new treatment alternatives for chronically ill patients has therefore been an active field of research. To improve patient compliance and reduce harsh side effects, delayed drug release systems have been developed. However, the techniques currently used to coat pharmaceuticals still face limitations in specific site targeting, loading efficiency, and pH tunability when administered orally. To overcome these challenges, we demonstrate the potential of using atomic layer deposition (ALD) as a technique to coat 5-Aminosalicylic acid (5-ASA)—a pharmaceutical drug to treat inflammatory bowel disease—to control the release of 5-ASA throughout the gastrointestinal tract.

5-ASA drug release was investigated by coating 7 mm pellets with 300, 150, and 75 cycles of ALD Al_2O_3. All pellets were made using a hydraulic pellet press and were then coated using an ALD Fiji Veeco® system at a deposition temperature of 120°C to avoid the decomposition of the organic material. To understand the dissolution rate of the coated pellets, we performed kinetic studies using a UV-1800 Shimadzu spectrometer by monitoring the 5-ASA UV signal at 298 nm. Each pellet was analysed for extended periods of time (< 20,000 seconds) in acidic media with various pH's to track dissolution rates. Successful coating on the 5-ASA powders was further characterized by high resolution transmission electron microscopy (TEM) and energy dispersive x-ray spectroscopy (EDX).

Through our investigation, we show ALD's potential in coating 5-ASA as a proof-of concept to achieve delayed and controlled drug release that is tunable based on the ALD coating thickness/chemistry. Our research seeks to promote further research and interdisciplinary collaboration between ALD and pharmaceutical researchers to discover new pathways for personalized treatment for patients who suffer from chronic illnesses.

11:30am **AA1-TuM2-4 Atomic Layer Deposition Enables Dimensionless, Biocompatible Encasings for Medical Implants Pro-Longing Their Lifetime**, ***Juhani Taskinen***, *R. Ritasalo, M. Pudas, T. Blomberg, M. Matvejeff,* Picosun Oy, Finland **INVITED**

All kinds of medical devices – various types of implants and wearables - must withstand the corrosive environment of salts, temperature variations, electrical stress, and pollutants, inside and outside the human body, for prolonged periods of time. Hermetic sealing of the device to protect it from the outside environment when used in contact with the human body, (and further to protect the body from the device) is a key step to enable a longer service lifetime, better patient safety, and lower number of replacement surgeries.

To make a robust protective sealing for the medical device, the film properties must fulfill many criteria. First and foremost, the film material needs to be non-toxic for human cells, i.e., biocompatible. Secondly, the film needs to function as an extremely good diffusion barrier against the ions and molecules present in body fluids, while also blocking any leaks (ion or molecular) from the device into the body. In addition, the adhesion of the film to the device surface needs to be high enough that delamination of the film will not occur.

Since Intel introduced ALD HfO2-based high-k into their mass production line in mid-2000's[1], ALD has been a gold standard coating method in various electronics industries, and it is now doing the same in the medical field. A key benefit of an ALD coating is that it is one of the very few ways to make a barrier that leaves no surface of the device "visible" to the surroundings, making the device "invisible" to human body fluids and the immune system. Without an immune response, ALD coated device lasts longer than devices that are coated through other methods. At the same time the ALD coatings are virtually dimensionless, e.g., enabling

miniaturization of all MEMS devices and improving surface activity on orthopedic implants.

The advantages of ALD over other deposition techniques makes it a powerful method for applications where sensitive substrate materials combined with extreme demands on coating quality and temperature / chemical resistance are needed, such as those often seen in the medical applications.

We will present applications and use cases of ALD in the medical field.

Keywords:

Electronics, encasing, biocompatible, medical devices, electronic implants, implants, immunology

Ref. [1] K. Mistry et al., Electron Devices Meeting 2007, IEDM 2007, IEEE International (2007), pp. 247-250.

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