Thin Films
Room 206 B W - Session TF1-WeM
VSHOP III - Initiated Chemical Vapor Deposition

Moderators: Stefan Schröder, Kiel University, Germany, **Rong Yang**, Cornell University

8:00am **TF1-WeM-1 Vapor-Phase Deposited Functional Polymer Films for Electronics and Biomedical Device Applications***, **Sung Gap Im,*** Korea Advanced Institute of Science and Technology (KAIST), Republic of Korea **INVITED**

The initiated chemical vapor deposition (iCVD) process enables the deposition of diverse functional polymer films in the vapor phase. As a solvent-free technique conducted at ambient temperature, iCVD allows for easy application onto delicate substrates without causing damage. The functionality of polymeric coatings can be tailored by selecting different monomers, offering extensive possibilities for device applications. iCVD coatings serve as fundamental components in various fields, including flexible electronics, membranes, tissue scaffolds, stimuli-responsive drug delivery systems, and biosensors. This presentation will explore the advantageous properties of iCVD polymer films and their broad applications, such as gate dielectric layers for electronic applications and tissue engineering.

8:30am **TF1-WeM-3 Surface Initiated Layer Deposition: A New Chemical Vapor Deposition Process That Challenges the Limits of Polymeric Coating Conformality***, **Benny Chen,*** GVD Corporation

Coatings play a critical role throughout the semiconductor industry, where they are used for applications such as environmental protection, imparting electrical properties, modifying surface properties, and facilitating device fabrication. As demand for higher performing electronics increases, the ability to incorporate smaller features arranged in evermore complex geometries becomes critical. The miniaturization of devices heavily relies upon conformal coating processes to control feature sizes at the smallest scale. At the extreme range of conformality, atomic layer deposition provides a method for depositing a range of inorganic materials. However, limitations in chemical compatibility bar it from depositing organic polymer coatings. Polymeric materials are of interest for numerous reasons such as, low dielectric properties, desirable mechanical properties, and contrasting etching rates. GVD Corporation has recently developed a new process called surface initiated layer deposition (SILD) which enables the controlled deposition of a wide range of highly conformal polymer chemistries. The process operates by introducing a mixture of gases into a pressure-controlled vacuum chamber where the substrate to be coated is heated to a temperature between 100-350 °C. Upon encountering the heated substrate, a subset of precursors reacts to form radical species which subsequently combine with other precursors to synthesize a polymer film. Development work was conducted to explore the versatility of the process and confirmed its ability to deposit a range of chemistries. The conformality of SILD was evaluated by depositing coatings onto silicon microtrenches (57 µm deep and 4.5 µm wide) with an aspect ratio of 13:1 and measuring the film thickness along the depth of the trench wall. A comparison of the conformality between SILD and a filament-activated CVD process revealed that SILD was able to achieve a step coverage of ~75 % compared to only 13 % by the filament-activated process. The thickness profiles along the trench walls were extrapolated to demonstrate the relative feasibility of each process as a function of aspect ratio. Additional research was also conducted to evaluate the impact of typical deposition parameters on process kinetics and various coating properties.

8:45am **TF1-WeM-4 Recent Advances in the Understanding of Spontaneous Orientation Polarization in Polymer Thin Films Deposited by Initiated Chemical Vapor Deposition (iCVD)***, **Stefan Schröder**, Torge Hartig, Thomas Strunskus, Tayebeh Ameri, Franz Faupel,* Kiel University, Germany

A recent study demonstrated the formation of a spontaneous orientation polarization effect in polymer thin films deposited via initiated chemical vapor deposition (iCVD). It enables the integration of permanent, high-precision electric fields into electronic devices. However, the understanding of the exact mechanism and dependence on the reaction kinetics is still at an early stage. This work reports on new insights on the polarization process based on theoretical and experimental results. The enhanced understanding enables improved control over the resulting surface potential of the polymer films and discovery of new monomers based on electric dipole moment calculations. Furthermore, a few examples of potential applications will be given.

9:00am **TF1-WeM-5 Surface Roughness Control in Vapor-Deposited Nanocoatings for Bio-Adhesion Mitigation***, **Jessie Yu Mao**, Chengqian Huang, Mengfan Zhu,* Oklahoma State University **INVITED**

Superhydrophobic surfaces offer effective resistance against the adhesion of biomolecules like bacteria and proteins. This property holds promise for their application in medical devices, aiming to mitigate complications such as infections and thrombosis. Hierarchical roughness plays a pivotal role in enhancing superhydrophobicity by providing multiple scales of surface features, which collectively contribute to increased water repellency and reduced adhesion of biomolecules. Traditional fabrication of topographical roughness requires specific substrates or solvent-based processing, which could raise concerns regarding biotoxicity. We constructed topographical roughness using an initiated chemical vapor deposition (iCVD) method that is applicable independent of substrate material and geometry. We studied how the processing parameters affect the formed surface topography and the bio-adhesion properties. In addition, surfaces with hierarchical roughness were created by varying the vapor deposition parameters *in situ*. The hierarchically roughened surface demonstrated superhydrophobicity, with more than 80% reduction in the adhered bacteria and a 98.8% decrease in the surface fibrin clotting, as compared with the homogeneously rough surface. This iCVD technique presents a novel avenue for attaining superhydrophobicity on medical devices to reduce device-related adverse events.

9:30am **TF1-WeM-7 Precision Synthesis of Polymeric Materials Using initiated Chemical Vapor Deposition (iCVD) for Cyber Manufacturing***, **Rong Yang,*** Cornell University

initiated Chemical Vapor Deposition (iCVD) is emerging as a powerful technique for the precision synthesis of polymeric materials. New advances in iCVD-based precision polymerization span the synthesis of shaped particles, strategies to suppress side reactions, and achieving emergent properties, all of which are enabled by engineering non-covalent interactions. This talk highlights one example in which engineering monomer absorption into liquid templates enables the integration of artificial intelligence (AI) for the precision manufacturing of polymeric particles with programmable size, shape, and chemistry. We engineer non-covalent interactions between monomers and mesogens to control monomer partition into a liquid crystal (LC) film, thereby enabling LC-templated continuous polymerization. By tuning the relative strengths of non-covalent cohesive force versus elastic force afforded by the LC template, we guide the synthesis pathway along a variety of trajectories that lead to tailored polymer morphology. In addition, the LC templates are self-reporting, which both guide and optically report on the evolution of the morphology of polymeric particles during continuous polymerization. We perform real-time analysis of the optical outputs using AI, enabling on-the-fly feedback and selection of synthesis conditions to achieve targeted polymer morphology. This capability, combined with the automated and scalable CVD technology, points to a new paradigm of cyber manufacturing for polymeric materials.

9:45am **TF1-WeM-8 PFAS-free initiators for iCVD***, **Torge Hartig**, Hannes Nehls, Tim Pogoda, Joschka Paulsen, Julia Piehl, Thomas Strunskus, Franz Faupel,* Kiel University, Germany*; Tayebeh Ameri,* Kiel University, Germany, Iran (Islamic Republic of)*; Stefan Schröder,* Kiel University, Germany

Initiated Chemical Vapor Deposition (iCVD) is an all-dry method for the solvent-free deposition of ultra-thin conformal polymer coatings. In recent years a large library of more than 100 monomers in iCVD has been established representing an extraordinary toolbox while research on initiators has played a smaller role. TBPO (di-tert butyl peroxide) as the standard initiator in iCVD works generally well in all processes. While the deposition rates of TBPO are no problem in academia, faster rates are often required in industrial application. Hence, a focus on new initiators could open the doors to new process kinetics. Previously fluorocarbon initiators have been used for increased deposition rates. With the recent development of possible PFAS bans and fluorocarbon impact on reactor usage, new high-rate initiators are required for the iCVD process. Within this study the impact of the chemical structure of peroxides, including hydroperoxides, is explored, leading to drastically faster deposition rates.

Author Index

Bold page numbers indicate presenter