

Nanostructure Synthesis and Fabrication

Room Arteveldeforum & Pedro de Gante - Session NS-MoP

Nanostructures Synthesis and Fabrication Poster Session

NS-MoP-1 Atmospheric Pressure ALD to Increase Organic Solvent Resistance of PDMS, Albert Santoso, A. Damen, S. Khedoe, V. van Steijn, R. van Ommen, Delft University of Technology, Netherlands

In the field of microfluidics, PDMS (polydimethylsiloxane) is one among the most used polymers since it is cheap and allows easy device fabrication. On top of its high transparency, PDMS is also known to be amiable with cells and harsh inorganic solvents, making it good candidates for fluidic researches. However, there is one big downside of PDMS, which is its incompatibility with organic solvents. As a result, swelling of the polymer, and subsequently microchannel collapse, render the use of PDMS microfluidics in oil-water system such as emulsion and liquid-liquid extraction. Furthermore, current researches in increasing the so-called organic solvent "barrier resistance" are limited to finding alternative materials, which ignores the whole benefit of PDMS bulk properties. Therefore, there is a need to increase PDMS' barrier resistance without changing the bulk property. We investigate surface modification using atomic layer deposition (ALD) as an approach to improve the barrier properties of PDMS. Metal oxide such as 'bio-friendly' titanium oxide can be deposited with atomic level precision, leading to formation of barrier layer without compromising other properties of PDMS. This study focuses on the use of atmospheric pressure atomic layer deposition (APALD) on flat thin film PDMS. Compared with the conventional vacuum ALD, the convective transport allows gaseous ALD reactant to flow in high aspect ratio microfluidic channel, which is a big potential in in-situ deposition. The result shows that PDMS film coated with APALD layer has an equilibrium mass swelling ratio of 1.06 after exposure with cyclohexane. This is a large improvement than the non-coated PDMS (1.25) and the ones coated with vacuum ALD (1.22). Further investigation using scanning electron microscopy shows that uniform coating is important to reduce the organic solvent intake. Furthermore, the formation of mixed layer due to ALD reactant infiltration in the PDMS during APALD contributes in the formation of robust and crack-free surfaces, as shown by x-ray photoelectron spectroscopy depth profiling. As an addition, little to no changes are observed in the transparency and mechanical property of PDMS. This study opens up potential of in-situ coating of PDMS microfluidic, that can be used in the field of bio-radio-assays, emulsion, and extraction with organic solvent.

NS-MoP-2 The Fabrication of Heterojunctions by Atomic Layer Deposition for Gas Sensing Application, Muhammad Hamid Raza, N. Pinna, Humboldt-Universität zu Berlin, Germany

Material and methods for detecting a wide range of harmful species are becoming increasingly necessary as automation and industrial growth increase. Chemoresistive gas sensors using semiconducting metal oxides (SMOX) are fundamental for developing efficient gas sensors. The sensitivity and selectivity of these nanostructured SMOX can be boosted by combining them with other SMOX. Yet control over the thickness of the shell layer is crucial; particularly, a thin shell layer modulates the space charge layer at the interface, thereby influencing effectively the charge conduction channel. The engineering of heterojunctions with well-defined core and shell layers is required to better understand the sensing response of heterostructured nanomaterials. A comprehensive understanding of the role of semiconductor heterojunctions and the sensing response of core-shell heterostructures is achieved by synthesizing a series of well-defined and well-controlled heterostructures with varying core and shell layers. NiO- and SnO₂-based hierarchical coaxial core-shell heterostructures are therefore proposed to achieve this objective. The designed heterostructures exhibit sensing responses related to the NiO or SnO₂-shell layers, or in some cases to the heterojunctions between nSMOX (SnO₂) and pSMOX (NiO). A comparison of the sensing response in order to understand the transduction mechanism across the interfaces in ALD grown heterojunctions will be presented.

NS-MoP-4 Combining Initiated Chemical Vapor Deposition and Plasma-Enhanced Atomic Layer Deposition: A Study of Initial Growth and Interface Formation, Lisanne Demelius, K. Unger, A. Coclite, Graz University of Technology, Austria

In recent years, atomic layer deposition (ALD) on polymer substrates has attracted increasing interest due to potential applications in organic electronics and photovoltaics, as well as for the surface functionalization of packaging and biomaterials. However, the inherent porous structure of polymeric substrates often leads to non-ideal ALD processes that result in precursor diffusion and subsurface growth of the deposited material. The use of plasma-enhanced ALD (PE-ALD) is known to enhance nucleation due to the surface-activating effect of plasma and can be expected to significantly reduce subsurface diffusion, enabling the surface-limited deposition of thin conformal coatings. However, plasma can also have detrimental effects on polymeric substrates causing polymer degradation or etching.

In our work, we have investigated the initial growth of piezoelectric ZnO during PE-ALD on different polymer thin films deposited by initiated chemical vapor deposition (iCVD). iCVD is a prominent method to deposit highly uniform thin films of a wide range of (functional) polymers while fully retaining their rich chemistry. ZnO growth was monitored via in-situ spectroscopic ellipsometry (SE) and the resulting thin films were further characterized in terms of crystallinity, interface and surface morphology and elemental composition. To gain a better understanding of how the chemical structure of the polymer influences ZnO thin film formation, polymers exhibiting varying degrees of reactivity with the ALD precursor were studied. Furthermore, the influence of plasma power on growth behavior was investigated.

Our results show that film formation on the iCVD polymers is a consequence of two competing processes: ZnO PE-ALD growth and plasma etching of the polymer substrate. During the initial ALD cycles, polymer etching dominates, resulting in an overall decrease in thickness. At a certain point, ZnO growth takes over and the regime of normal ALD growth behaviour is entered. The strength of etching is proportional to the applied plasma power and depends strongly on the type of polymer. Despite the initial etching, the resulting thin films exhibit sharp interfaces and a quality, in terms of surface roughness, crystallinity and ZnO density, comparable to those of ZnO deposited on silicon.

This study sheds light on the mechanisms governing initial growth during PE-ALD of ZnO on different polymers and illustrates the potential of the combined use of iCVD and PE-ALD as means to achieve highly uniform and smooth multilayer structures that could be applied in a wide range of functional devices including sensing or actuation.

NS-MoP-11 Synthesis of Novel Composite Thin Film Systems With Outstanding Mechanical Properties, L. Pethö, Empa, Swiss Federal Laboratories for Materials Science and Technology, Thun, Switzerland; C. Guerra, Swiss Cluster, Switzerland; T. Xie, T. Edwards, J. Michler, X. Maeder, Ivo Utke, Empa, Swiss Federal Laboratories for Materials Science and Technology, Thun, Switzerland

Nanoscale multilayered thin films consisting of alternating sublayers of dissimilar materials have attracted extensive attention in recent years due to their electrical, thermal and mechanical properties as compared to their single component counterparts and prove to be very promising for engineering applications. The advantage in mechanical properties are mainly attributed to the dense interfaces and interfacial structure among the different materials that form the multilayers.

We have built a hybrid thin film deposition system by combining physical vapor deposition (PVD) and atomic layer deposition (ALD) into a single machine without breaking vacuum. Multilayer composite systems were synthesized that consist of ALD Al₂O₃ sublayers between pure PVD Al structural layers. By using this system, we obtain precise control of the thickness of each ultrathin alumina layer, well below the native surface oxide thickness of pure aluminum.

We show that the ALD alumina sublayers effectively interrupted the grain growth of the ~250 nm thick Al sublayers by enabling precise grain surface control. Native surface oxide formation on the PVD deposited pure Al sublayers was circumvented by keeping the substrate in high vacuum between processing steps.

The pure Al layers are constituted of equiaxed grains with no epitaxial or texture relationship among the neighboring layers. The Al grain boundaries are parallel to the film growth direction and extend the height of each Al sublayer to form a brick-and-mortar type microstructure.

Monday Afternoon, June 27, 2022

We have furthermore seen that these multilayer coatings have high yield strength compared to bulk pure aluminum. This is explained by the amorphous alumina layers acting as a dislocation sink, absorbing defects. The high tensile strength and good ductile properties of alumina are shown to restrain the deformation of Al layers and reinforce the structure.

Author Index

Bold page numbers indicate presenter

— C —

Coclite, A.: NS-MoP-4, **1**

— D —

Damen, A.: NS-MoP-1, **1**

Demelius, L.: NS-MoP-4, **1**

— E —

Edwards, T.: NS-MoP-11, **1**

— G —

Guerra, C.: NS-MoP-11, **1**

— K —

Khedoe, S.: NS-MoP-1, **1**

— M —

Maeder, X.: NS-MoP-11, **1**

Michler, J.: NS-MoP-11, **1**

— P —

Pethö, L.: NS-MoP-11, **1**

Pinna, N.: NS-MoP-2, **1**

— R —

Raza, M.: NS-MoP-2, **1**

— S —

Santoso, A.: NS-MoP-1, **1**

— U —

Unger, K.: NS-MoP-4, **1**

Utke, I.: NS-MoP-11, **1**

— V —

van Ommen, R.: NS-MoP-1, **1**

van Steijn, V.: NS-MoP-1, **1**

— X —

Xie, T.: NS-MoP-11, **1**