ALD Applications
Room 116-118 - Session AA2-WeM
Flexible Application
Moderator: Jin-Seong Park, Hanyang University

10:45am **AA2-WeM-12 A Condense Polymer-inorganic Hybrid Nanolayer with Extremely Low Gas Transmission Rate Behavior and Ultra-flexible Nature***, **Myung Mo Sung**,* Hanyang University, Republic of Korea

Hermetic sealing is an important technology to isolate and protect air-sensitive materials, and a key issue to develop foldable and stretchable electronic devices. We reported an ultrahigh gas-proof polymer hybrid nanolayer, prepared by filling the free volume of the polymer with Al O by using gas-phase atomic layer infiltration. The free-volume-free polymer-inorganic hybrid shows extremely low gas transmission rate behavior, which is below the detection limit of the Ca corrosion test (< 10 g m day). Furthermore, due to the ultra-thin complete hybrid of polymer-inorganic materials, the polymer hybrid nanolayer has ultra-flexible nature, which is useful as hermetic sealing for stretchable and foldable electronic devices.

11:00am **AA2-WeM-13 SiN-Al_2O_3 Nano-laminates Fabricated with Combination of CVD-ALD Method for Encapsulation of Highly Stable Flexible OLED Electronics***, **Huizhi Yang**, Y Li, Y Liu, K Cao,* Huazhong University of Science and Technology, China*; H Hsu, J Huang,* Wuhan China Star Optoelectronics Technology Co., Ltd (CSOT), China*; R Chen,* Huazhong University of Science and Technology, China

The expansion demand for wearable and flexible electronics based on organic light emitting diode (OLED) displays have attracted great attention. Flexible OLED displays, however, widely utilize materials that are sensitive to oxygen and water which causes performance degradation or failure during usage. It is imperative to develop reliable and efficient thin film encapsulation methods to improve the stability and meet the requirements of miniaturization, flexibility and low cost.

This work focuses on the design and fabrication of nano-laminates SiN-Al_2O_3 encapsulation films for high stable flexible OLED electronics with the combination of plasma enhanced chemical vapor deposition (PECVD) and spatial separated atomic layer deposition (S-ALD) methods. SiN layer is deposited on OLED devices with ~1 um thickness via PECVD, after which ~20 nm Al_2O_3 is deposited on the SiN layer with S-ALD. The service life of encapsulated devices is tested under heat/humid environment. The failure time of nano-laminates SiN-Al_2O_3 encapsulated device is enhanced ~10 times compared with SiN or Al_2O_3 coating alone. The coating layers configurations play an important role in determining the encapsulation ability. It is found that the SiN layer fabricated by PECVD contains large amount of pinholes and defects. After very thin layer of Al_2O_3 deposited, most of defects are passivated and the water-oxygen resistance ability is enhanced significantly.

11:15am **AA2-WeM-14 Thermoelectric Device Based on ALD/MLD-grown ZnO and ZnO:benzene Thin Films on Flexible and Textile Substrates***, **Giovanni Marin**, M Karppinen,* Aalto University, Finland

We have fabricated simple flexible thermoelectric devices on different substrates, such as plastics, flexible glass and different textiles, using ALD-grown ZnO and ALD/MLD-grown coatings as the active thermoelectric materials. In the hybrid ZnO:benzene superlattice thin films monomolecular benzene layers are inserted in between ZnO blocks of varying thicknesses to block the thermal conductivity.[1], [2]

The thermoelectric performance of the devices with the different ZnO and ZnO:benzene layer structures were tested with an applied (cross plane) temperature varying between 30 and 100°C at the bottom side of the substrate. The voltage generated by the device with the varying temperature was measured for both open-circuit and with a load of 1.4 Ω. The hybrid ZnO:benzene devices exhibited enhanced performances compared to those based on plane ZnO.

The final goal of our work is in wearable devices fabricated on textile. Such devices would enable energy harvesting from human body heat to power small sensors (constant medical monitoring) without the need of changing batteries. The current results based on simple model device architectures have provided us useful knowledge and guidelines towards this final goal.

11:30am **AA2-WeM-15 Transparent Graphene Heater Improved by Defect Healing of Metal Atomic Layer Deposition***, **Hyun Gu Kim**, W Kwon, T Im, M Khan,* Incheon National University, Republic of Korea*; H Choi,* Yonsei University, Republic of Korea*; W Kim,* Chonbuk National University, Republic of Korea*; J Chung,* Soongsil University, Republic of Korea*; H Lee,* Incheon National University, Republic of Korea

Graphene has been widely applied for various applications, such as flexible display, energy device, and transparent electrode due to its superior properties over bulk materials in transparency, flexibility, and electrical conductivity. Until now, many methods to synthesize graphene have been reported, such as physical exfoliation, epitaxy, chemical vapor deposition (CVD), and chemical reduction of graphene oxide (GO). Since the chemical reduction of GO has a high rate of obtaining graphene as a single layer, it can be used in a wide variety of applications through the formation of a complex with other materials as well as high compatibility with mass production. In many cases, however, the reduced GO (RGO) is not completely reduced and many defects are left, so there is a disadvantage that reliability such as electrical properties is deteriorated. When the GO is reduced to RGO, the functional groups of the graphene surface remain or are not restored to the original structure of the graphene. In order to avoid such problem, researches for improving the conductivity by healing defects of RGO have been reported in recent years. In this study, a selective metal deposition process by atomic layer deposition (ALD) was applied on the surface of RGO to study the defect healing of RGO. Since the ALD process involves deposition only through a surface reaction, it is able to perform selective deposition at defective sites that have a relatively high energy. The surface coverage of Pt deposited on RGO was analyzed by using various analytical methods, including field emission electron microscopy (FE-SEM), X-ray photoelectron spectroscopy (XPS), and THz spectroscopy. In order to confirm the defect healing effect, the thermal characteristics of the heater were prepared by using a transparent graphene heater before and after healing the defect. In addition, the self-healing of damaged self-healing polymers was studied suing the thermal properties of the heater.

11:45am **AA2-WeM-16 Surface Modification Studies and Stabilization of Perovskite Quantum Dots with Atomic Layer Deposition***, **Binze Zhou**, Q Xiang, K Cao, R Chen,* Huazhong University of Science and Technology, China

Perovskite quantum dots (QDs) have received extensive attention for potential display applications, due to their excel lent prop erties for high photoluminescence, tunable wavelength, and narrow emission wavelength [1]. However, perovskite QDs are very sensitive to air, and hot/humid atmosphere which tend to failure in practical applications.[2,3] In this work, atomic layer deposition (ALD) is applied to modify and encapsulate the surface of perovskite QDs with thin layers of oxides to enhance the stability during usage. To study the surface interaction mechanisms of ALD precursors with the ligands of perovskite QDs, in-situ characterizations such as quartz crystal microbalance (QCM), infrared spectrometer (IR) are applied to monitor the ALD process. It is found that process parameters, such as deposition temperature, precursors and pulse time are critical to its surface modification behavior. Higher temperatures resulted in etching or replacing the surface ligands of perovskite QDs by ALD precursors. At room temperature, the perovskite QDs films can be stabilized effectively with just few cycles of oxide passivation, and the light emitting diode's performance has also enhanced.

[1] Yuan, M. Quan, L. N. Comin, R. Walters, G. Sabatini, R. Voznyy, O. Hoogland, S. Zhao, Y. Beauregard, E. M. Kanjanaboos, P. Lu, Z. Kim, D. H. Sargent, E. H., *Nat Nanotechnol,* 2016**,***11*, 872.

[2] Shi, Z. Li, Y. Zhang, Y. Chen, Y. Li, X. Wu, D. Xu, T. Shan, C. Du, G., *Nano Lett,* 2017**,***17*, 313.

[3] Wang, H. C. Bao, Z. Tsai, H. Y. Tang, A. C. Liu, R. S., *Small,* 2018, *14,*1.

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