ALD Applications
Room Hall 3E - Session AA3-WeA

Display Applications
Moderator: Marianna Kemell, University of Helsinki

4:00pm **AA3-WeA-11 Atomic Layer Deposition for Stable On-Chip Quantum Dot LEDs: Hybrid Quantum Dot Pockets***, **Robin Petit**, R. Özdemir, H. Van Avermaet, J. Kuhs, A. Werbrouck, J. Dendooven, Z. Hens, P. Smet, C. Detavernier,* Ghent University, Belgium

The latest advancements in displays include micro-LEDs with chip sizes < 100 µm that are used as subpixels. To avoid color filters and bulky layers with separate color converter devices, the color converter is preferably deposited on-chip.

Their narrow emission spectrum and size-tunability make quantum dots (QDs) attractive as color converters in displays. The best alternative to Cd-based QDs are InP-based QDs, owing to their ability to emit the full spectrum of colors, their structural integrity and low toxicity[1]. However, non-radiative pathways from defect-related traps or interactions with the environment (H_2O, O_2) can be detrimental to the luminescence efficiency.

State-of-the-art hybrid barriers are explored to safeguard the QD luminescence. Metal oxides grown by atomic layer deposition (ALD) have shown potential when paired with organic layers, such as those deposited by molecular layer deposition[2]. The defect-free nature and conformality of the coatings is unique to ALD, making it an ideal technique for barrier applications.

This study investigates ALD for stable on-chip QD LEDs as follows: **(a) Understanding the optical response** of core/multi-shell InP/ZnSe/Zn(Se,S)/ZnS QDs to precursors (TMA, TDMAT, DEZ), reactants (H_2O, O_3), plasmas (Ar, H_2, O_2) and full ALD processes (Al_2O_3, TiO_2, ZnO) using a home-built in situ photoluminescence setup[3]. Results show that the QDs are highly susceptible to degradation during the ALD process (Fig. 1). **(b) Characterizing ALD growth** (Al_2O_3) **on polymer substrates** (Kraton) by spectroscopic ellipsometry and Fourier transform infrared spectroscopy. Island growth is identified as the dominant growth mode and is linked to the copolymeric structure of Kraton (Fig. 2). It is observed the stability of the QDs during ALD is vastly improved by polymer embedding. **(c) Fabrication of pick-and-place, hybrid QD pockets** using a digital light processing setup as a demonstrator for on-chip QD LEDs (Fig. 3)[4]. By combining the on-chip design of the QD pockets and seamless encapsulation of the QDs by a polymer (thiol:ene) with the barrier performance of ALD coatings, this work aims to contribute to the development of stable QD LEDs for displays. **(d) Examining the long-term stability** of (ALD coated) pristine QDs, polymer-embedded QDs, and QD pockets through accelerated aging tests using a humidity chamber. The hybrid QD pockets show superior stability demonstrating their potential for QD LEDs.

[1]ACS Nano 2022, 16, 6, 9701–9712.

[2]Nanoscale Res. Lett. 2015, 10, 130.

[3]ACS Appl. Mater. Interfaces 2019, 11, 29, 26277–26287.

[4]ACS Appl. Mater. Interfaces 2023, 15, 7, 9629–9637.

4:15pm **AA3-WeA-12 A Comparative Study on Cation distribution effects in Heterogeneous channel IGZO TFTs via Atomic Layer Deposition Supercycle Design***, **Hye-Jin Oh**, H. Kim,* Hanyang University, Korea*; C. Park,* Hanyang University, Republic of Korea*; J. Park,* Hanyang University, Korea

Oxide semiconductors (OSs), known for their high mobility, large-area uniformity, low temperature processability, low off current, are garnering interest in display applications.[1] To apply in various fields, it is essential to enhance the electrical properties of OS thin-film transistors (TFTs). Atomic layer deposition (ALD) a-IGZO has been reported to exhibit improved electrical properties due to increased packing density compared to the conventional sputtering method.[2] Sputtering uses a target mixed with each element to form a homogeneous thin film, but supercycle-based ALD forms a relatively heterogeneous thin film. In this regard, it is crucial to consider the cation distribution resulting from the ALD supercycle configuration in multicomponent OSs.

In this study, we aimed to compare surface and bulk compositions based on cation distributions by reversing the supercycle sequence of the indium (In), gallium (Ga), zinc (Zn) elements in IGZO: **A (In (14) -Ga (3) -In (14) -Zn (4))**, **A'(Zn (4) -In (14) -Ga (3) -In (14))**. As a result, the surface composition (XPS) of channels A and A' was significantly higher for the element located in the last order of the supercycle sequence (A: Zn-rich surface, A': In-rich surface). However, the XRF analysis indicated a similar bulk composition for A and A', and notable distinctions in physical properties were not evident. Despite considerable differences in surface composition between A and A', the TFT electrical properties did not show substantial variation, but there was a significant distinction in reliability. The outcomes suggest that the bulk composition has a more pronounced influence on the electrical properties of the TFTs, and the composition ratio at the surface acting as the back channel has a significant impact on stability. The A' TFT, with an In-rich surface, experiences a hump phenomenon caused by the formation of a parasitic channel on the back channel, leading to performance degradation. Our research proposes that the cation distribution in ALD-based multicomponent heterogeneous channel TFTs can affect the electrical properties and reliability results, depending on the device structure.

References

1. Mativenga, Mallory, Sungjin An, and Jin Jang. Bulk accumulation a-IGZO TFT for high current and turn-on voltage uniformity. *IEEE electron device letters* 34.12 (2013): 1533-1535.

2. Cho, Min Hoe, et al. Comparative study on performance of IGZO transistors with sputtered and atomic layer deposited channel layer. *IEEE Transactions on Electron Devices* 66.4 (2019): 1783-1788.

4:30pm **AA3-WeA-13 Characteristics of PEALD IGZO Films Using Tetrahydrofuran-Adducted In & Ga Precursors***, S. Lee, S. Jeon, S. Lee, Y. Kwone, Y. Im, T. Byun, **Sungchul Kim**,* DNF Co. Ltd., Republic of Korea

As the down-scaling of semiconductor materials, silicon compatible emerging materials have extensively researched for next generation display and 3D structured devices. In particular, oxide semiconductors are considered a promising candidate for backplane applications in display. Among them, indium-gallium-zinc oxide (IGZO) using plasma enhanced atomic layer deposition (PEALD) has excellent properties, like high mobility, low leakage current, high transparency and low temperature processability. However, conventional precursors for IGZO still have some problems to solve such as low deposition rate, low thermal stability and high price.

In this study, we developed indium precursor (Trimethylindium Tetrahydrofuran, DIP-4) and gallium precursor (Trimethylgallium Tetrahydrofuran, DGP-2) to overcome the shortcomings of the conventional In & Ga precursors. ALD characteristics of the films deposited using the newly developed the precursors were confirmed through the source feeding time saturation and linearity. Furthermore, the incubation time of In, Ga and Zn oxide films according to the different bottom layer was respectively verified and calculated using the developed DIP-4, DGP-2 and commercially used DEZn. In order form a multilayer IGZO thin film, application of the incubation factors at IGZO process were experimentally demonstrated. Thickness of the IGZO films can be easily controlled through modulation of the incubation factors. The physical and chemical properties of the films were analyzed by X-ray diffraction, X-ray reflectrometer, X-ray photoelectron spectroscopy, transmission electron microscope.

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