Thin Films Division
Room 316 - Session TF1+PS-FrM
Plasma, PVD and HIPIMS Processes for Emerging and Advanced Materials

Moderators: Joe Becker, Kurt J. Lesker Company, **Christophe Vallee**, SUNY College of Nanoscale Science and Engineering

8:40am **TF1+PS-FrM-2 Growth of c-axis Textured AlN PVD Film on a 2D-MoS₂ Seed Layer***, **Julien Patouillard,*** STMicroelectronics, France*; E. Blanquet, A. Mantoux,* SIMaP, CNRS, University Grenoble Alpes, France*; F. Gianesello,* STMicroelectronics, France*; M. Bernard, S. Cadot, R. Gassilloud, C. Raynaud,* Commissariat à L'énergie Atomique, France

Aluminum nitride (AlN) is a piezoelectric and wide bang gap material which crystallizes in a hexagonal wurtzite structure. This material arouses a certain interest in various fields of microelectronics, in particular radiofrequency (RF) devices [1–3]. Its deposition process is well-known and appears to be reproducible, using either epi-like chemical deposition solutions, or N_2-based physical deposition with Al-target. In particular, AlN deposited by Physical Vapor Deposition (PVD) exhibits a relatively large electromechanical coupling coefficient $k_t^2 \approx 6{,}5\%$. [2]

Due to the lack of bulk AlN substrates and the large lattice mismatch between AlN and silicon, AlN is usually epitaxially grown on sapphire or silicon carbide (SiC) substrates at high growth temperature (≈1000 °C) to achieve higher crystalline quality and hence better device performance [4,5]. However, high cost, limited wafer size or differences in thermal expansion coefficient between AlN and these substrates drastically limit the integration and applications of AlN.

In recent years, the emergence of 2-Dimensional (2D) materials and particularly 2D-Transition Metal Dichalcogenides (2D-TMDs) seems to be a promising approach for the growth of III-nitride. Among 2D-TMDs, MoS_2 is one of the most widely studied materials due to its availability [6,7]. MoS_2 has a natural two-dimensional structure with the sandwich-like S-Mo-S layers serving as building blocks, in which the atoms in the layer are bonded with strong covalent bonding, while the layers are packed together with weak interlayer forces [8,9]. It also presents a hexagonal structure with a close lattice matching with III-nitride (1 % to 3 %) and a chemical compatibility enabling the direct growth of these materials [4,5].

In this presentation, we will demonstrate the direct growth of c-axis textured AlN films deposited by PVD on a well-controlled and uniform MoS_2thin film elaborated by Atomic Layer Deposition (ALD). We will show how 2D materials can be advantageously implemented to improve the texturation of AlN on silicon substrate. Hence, in figure 1, the crystal quality of AlN is assessed by X-Ray Diffraction (XRD) measurements using the Rocking Curve (RC) technique. The FWMH of the omega peak at 18° (Theta 36,04° of (002)) gives a direct information on the mosaicity of the AlN layer. AlN Growth on 2D-MoS_2 seed induces a strong reduction of FWMH compared to Si-based substrate, indicating the preferential reorientation of the AlN matrix along the (002) axis, perpendicular to the substrate surface. This orientation is expected to boost the piezoelectric coefficient, which opens new field of applications on Si substrate.

9:00am **TF1+PS-FrM-3 Synthesis and Hardness of Thin-Film High-Entropy Transition Metal Ceramics***, **Nathaniel McIlwaine,*** The Pennsylvania State University*; M. Hossain,* Pacific Northwest National Lab*; J. Maria,* The Pennsylvania State University

High entropy carbides (HECs) are single phase, multicomponent materials that possess a high degree of configurational entropy on cation lattice sites and can possess enhanced thermal and mechanical properties compared to binary transition metal carbides. Group IIIB, IVB, VB, and VIB transition metal HECs with high hardness and high melting temperatures are prospective materials for refractory applications such as advanced armor, cutting tools, and spacecraft thermal protection systems.

HECs are chemically disordered crystals containing components inclined to form ternary solid solution compounds and carbon deficient phases. Multicomponent carbides produced by conventional reactive sputtering techniques, such as radio frequency (RF) and direct current (DC), are hindered in overall film quality due to uncontrolled microstructure and stoichiometry. This work is focused on the synthesis of HECs through reactive bipolar high-power impulse magnetron sputtering (HiPIMS) to overcome these conventional challenges. Through HiPIMS, HEC crystals structurally and compositionally transform as a function of the carbon to metal ratio (C/M), providing access to metallic, ceramic, and composite carbides. By increasing the methane flow rate during sputtering, this introduces a carbon-deficient metallic (C/M < 1), transitions to a stoichiometric ceramic zone (C/M ∼ 1), and finally culminate in an excess-carbon, nanocomposite regime (C/M > 1) at high methane flow rates. Combinations of X-ray diffraction, Raman spectroscopy, scanning electron microscopy, X-ray photoelectron spectroscopy, and nanoindentation/microindentation hardness measurements form these three zones. Achieving the stoichiometric ceramic zone is of particular interest to maximize the hardness of a given HEC composition. HiPIMS is able to produce HECs with ceramic zones over a larger range of methane flow rates than RF or DC sputtering.

9:20am **TF1+PS-FrM-4 Structural Evolution and Thermoelectric Properties of Flexible Mg₂Sn Films Prepared by Magnetron Co-sputtering***, **Sara Kim**, S. Kang, N. Kim,* Chosun University, Republic of Korea

Thermoelectric (TE) materials are capable of harvesting waste heat and converting it into useful electrical power which contributes significantly to improved energy efficiency. Recently, the development of flexible TE materials and devices has become a significant focus in the thermoelectric field due to the need for wearable and autonomous devices. The flexible TE materials can effectively harvest waste-heat from hot surfaces in a wide temperature range for applying to power generation in industry and human life. The anti-fluorite Mg_2X (X = Si, Ge, Sn)compounds have attracted great attention owing totheir non-toxicity, low manufacturing cost, light weight, and flexibility [1]. In this study, several un-doped Mg-Sn films were deposited onto polyimide substrates by radio frequency magnetron co-sputtering with Mg and Sn targets. Mg sputtering power was fixed while Sn sputtering power was varied to prepare Mg-Sn films with different stoichiometry. Then, Mg and Sn sputtering time was varied to prepare films with different thicknesses while the sputtering power was fixed. The TE performances as well as the flexibilityof the samples were analyzed in terms of point defects and structural evolution of the samples during flexibility test. Folding tests with different folding cycles were carried out for flexibility evaluation of the samples. The structural properties, chemical composition, and Hall characteristics of the Mg-Sn thin films before and after the folding test were analyzed using X-ray diffraction, energy dispersive X-ray spectroscopy, and Hall effect measurement system, respectively. The electrical resistivity and Seebeck coefficient as a function of temperature were simultaneously measured up to 703 K. Acknowledgement: This work was supported by the Gwangju·Jeonnam Local Energy Cluster Manpower Training of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Trade, Industry and Energy (No. 20214000000560). [1] J. I. Tani, and H. Ishikawa, Thin Solid Films 692, 137601 (2019).

Author Index

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