

Atomic Layer Deposition for GaN Power Semiconductors

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Atomic layer deposition (ALD) is considered for deposition of different materials in power semiconductors, due to its excellent growth control and ability to grow high-quality material at relatively low temperatures. Several materials can be considered such as Al_2O_3 , HfAlO_x , AlN , SiN_x , and even GaN itself. One of the key issues is achieving low defect densities at the interfaces of these materials in the device (for instance in a structure as in Fig. 1). In this contribution several relevant ALD processes and surface treatments using Oxford Instruments equipment will be reported. Relevant plasma aspects will also be highlighted.

One possibility of doing surface treatments would be doing the treatment in situ, in the ALD tool itself (Fig. 2). This could be one of the known plasma surface treatments (e.g., H_2 , N_2 , NH_3 plasma). Another effect that can be used is the self-cleaning effect of $\text{Al}(\text{CH}_3)_3$ (TMA), which is the typical ALD precursor for Al_2O_3 . TMA is a reducing agent which can for instance reduce some compound semiconductor oxides, while forming Al_2O_3 . Recently, Kerr et al. reported a combined approach using an Oxford Instruments FlexAL[®] ALD reactor [1]. In their work they demonstrated that doing H_2 plasma exposures alternated by TMA exposures as a pretreatment resulted in low defect density (D_{it}) values. Another approach is the growing of ALD nitride interface layers such as reported by Liu et al. using an Oxford Instruments OpAL[®] reactor [2, 3]. In their work they demonstrated epitaxial growth of AlN on GaN on which they deposited ALD Al_2O_3 resulting in excellent device performance. These and similar approaches will be discussed. Also the ALD of GaN itself will be discussed (Fig. 3). GaN with relatively low impurity values was obtained, where it was found that the plasma parameters were most important. Such ALD GaN processes could be relevant for future GaN device structures.

Methods to control ion energy and UV photon flux during plasma ALD will be discussed as these can be important to obtain low damage conditions [4, 5]. As demands on power semiconductors become more stringent, deposition techniques with control at the nanoscale such as ALD will become required.

1. Kerr et al., *J. Chem. Phys.* **141**, 104702 (2014)
2. Liu et al., *IEEE Electron Device Lett.* **34**, 1106 (2013)
3. Liu et al., *Phys. Status Solidi C* **11**, 953 (2014)
4. Profijt et al., *J. Electrochem. Soc.* **158**, G88 (2011)
5. Profijt et al., *J. Vac. Sci. Technol. A* **31**, 01A106 (2013)

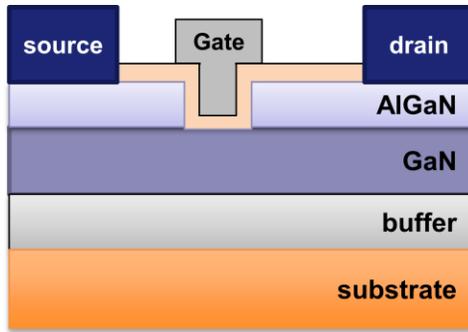


Fig. 1. A schematic cross-section of an AlGaIn/GaN metal-oxide-semiconductor high-electron-mobility transistor (MOS-HEMT) with a recessed-gate geometry and conformal gate dielectric. Due to the structure of the recessed gate, conformal deposition processes such as ALD are desired. The sensitive interfaces furthermore require low-damage processes, which thermal ALD and certain plasma ALD processes can provide.

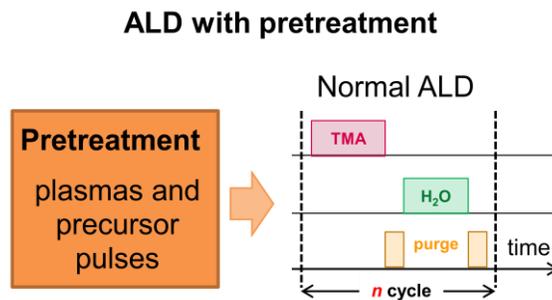


Fig. 2. Besides the capability to run ALD processes, an ALD tool can be used to run a variety of treatments. For instance pulses of plasma and precursor before an ALD process can be used to clean and condition a surface for low defect density and effective ALD nucleation.

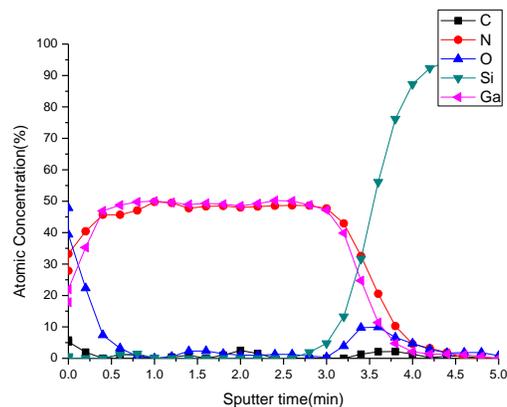


Fig. 3. An AES depth profile of ALD GaN film. Close to stoichiometric GaN was obtained using 350 °C table temperature, and an ALD cycle using triethyl gallium (TEGa) and 10 s H₂/N₂ plasma (30:10) at 400W power at 5 mTorr gas pressure.