## ALD Applications

## Room Van Rysselberghe - Session AA-WeM

## ALD for Semiconductor Applications I

**Moderators:** Adrien LaVoie, Lam Research Corp., Mike McSwiney, Intel, USA

11:15am **AA-WeM-3 Atomic Layer Epitaxy of GaN Directly on 4H-SiC using Ga–N Bonded Precursors***, P Rouf, N O'Brien, R Samii,* ***Henrik Pedersen,*** Linköping University, Sweden

Gallium nitride (GaN) is a key material in high electron mobility transistors (HEMT) based on the group 13-nitrides. These structures are routinely made by CVD at high temperatures (1000 °C) using trimethylgallium (TMG) and $NH_3$. These high deposition temperatures hinder the exploration of GaN films on temperature sensitive materials such as InN, which is highly desirable to integrate into HEMTs due to its high electron mobility. ALD is a low temperature alternative that could be used to deposit high quality GaN. GaN has previously been explored by ALD using trimethylgallium (TMG) or triethylgallium (TEG) together with $N_2/H_2$ plasma [1], $NH_3$ plasma [1] and thermal $NH_3$. However, these GaN films were found to be non-stochiometric and show high amounts of C and O impurities, which is undesirable in materials to be used in electronics.

Herein, we report on two alternative Ga precursors: tris(dimethylamido)gallium(III) **1** and tris(1,3-diisopropyltriazenide)gallium(III) **2** and their use in ALD in combination with $NH_3$ plasma to deposit GaN. These two precursors possess Ga–N bonds instead of Ga–C bonds like TMG and TEG. As the Ga–C bond is stronger than the Ga–N due to its more covalent nature of the bond, precursors with Ga–N bonds could potentially have a more favourable surface chemistry with lower impurity levels. Both **1** and **2** show self-limiting deposition behaviour for GaN growth. Precursor **1**saturates after 4s and 6s of $NH_3$ plasma exposure, with 10s purge between to give a growth rate of 1.4 Å/cycle. The growth remains constant at 1.4 Å/cycle between 130-250 ˚C. GaN growth from **2** shows a growth rate of 0.3 Å/cycle which is constant between 300-350 ˚C.

GaN deposition directly 4H-SiC (0001) using these ALD processes grew with the epitaxial relationships of GaN(0002)úúSiC (0002) and GaN (10-13) úú SiC (10-12). This set these ALD processes apart from traditional MOCVD of GaN as the later requires an AlN buffer layer for epitaxial growth of GaN on SiC.

The composition of the films was measured with RBS/ERDA. Precursor **1** gave GaN films with 45.7 at.% Ga, 47.2 at.% N, 3.1 at.% O, 2.8 at.% C, 1.2 at.% H, giving a Ga/N = 0.97. GaN grown from **2** has 48.8 at.% Ga and 46.4 at% N giving a Ga/N = 1.05. GaN from **2** contained 3 at.% O, 1.8 at.% H and no detectable carbon. Absorption measurements show the optical bandgap of the GaN to be 3.42 eV, which is close to the theatrical value of 3.4 eV. Fermi level measurements with XPS show that the fermi level is closer to the conduction band then the valence band, making the GaN film unintentionally n-type doped.

[1] Ozgit-Akgun, C. et al. *J. Mater. Chem. C* **2014**, *2* (12), 2123–2136.

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