Pulsed MOCVD technique for lateral overgrowth of GaN on SiC with conducting buffer layers.

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In recent years, Epitaxial lateral overgrowth (ELOG) of GaN has been extensively used to reduce threading dislocation densities[5,6] in heteroepitaxy of GaN over sapphire and SiC substrates. Pendeo-epitaxy[8] and lateral overgrowth from trenches (LOFT)[9] methods have also been developed to reduce the dislocation densities in GaN layers. In the past, lateral overgrowths of GaN, on 6H-SiC[8, 10-12] have been carried out only with insulating AlN buffer layers. This precludes the fabrication of vertically conducting devices. Further, in all the previous reports, a growth temperature above 1050ºC was needed for lateral overgrowth with vertical sidewalls. The temperatures lower than 1000ºC invariably results in triangular geometry with large (1101) facets and narrow (0001) plane which makes fabrication of vertically conducting device structures extremely difficult.

We report a new "Pulsed Metalorganic Chemical Vapor Deposition (P-MOCVD)" technique for lateral overgrowth of GaN thin films on SiC with conducting buffer layers for vertically conducting devices. Growth was carried out at temperatures as low as 950 °C keeping a constant gallium flux while pulsing NH_3. We demonstrate that by varying the NH_3 pulse duration, growth morphology can be gradually changed from triangular to rectangular for the lateral overgrowth (Please see Figure 1). Even at a V/III ratio as low as 550, high quality smooth layers with (1100) vertical facets were successfully grown with lateral to vertical growth rate ratio as high as 4:1 (refer to Figure 2). The NH_3 "OFF" condition enhances migration of Ga atoms on the surface thereby increasing the density of Ga molecules for lateral growth. Thus even at growth temperatures lower than those used in conventional ELOG, this increase of Ga molecules allows higher growth rate along the lateral direction (under the NH_3 "ON" condition). Our data therefore suggests that under pulsed conditions, the (0001) surface acts as the main source for the movement of reactants to the sidewalls. This is possibly due to fast desorption of species from these (0001) surfaces. The PLOG material (lateral overgrowth material from PMOCVD) was then characterized.

AFM measurements (Figure 3) show the root mean square roughness of the laterally overgrown layers to be 7.0Å. Scanning thermal microscopy was used to measure a thermal conductivity of 1.7 and 1.5 W/cm-K respectively for the laterally overgrown film and the GaN deposition in the window region.

To compare the vertical conduction of the PLOG and the non-PLOG regions, Ni (50Å)/Al (100Å) n-ohmic contacts were made to the n+ SiC substrate. These were then annealed under N_2 ambient at 900 °C for two minutes. Stripe geometry Ti (200 Å)/Al (500 Å)/Au (1000 Å) electrodes were then deposited on the two regions (window and SiO_2 mask) using standard photolithography and lift-off procedures. The stripe dimensions were 4µm x 1000µm. These topside contacts were annealed at 900 °C for one minute in a N_2 ambient. In Figure 4, we include the current voltage characteristics from top stripe to the bottom ohmic contact. As seen from the data, we measure a total resistance of 100 ohms. This is nearly identical to that for the top stripe in the window region (non-ELOG material). We thus show that the PLOG process results in GaN buffer layers that are well suited to the fabrication of vertically conducting devices. In the paper we will discuss the pulsed growth and vertical conduction mechanism. Detailed characterization results will also be presented. Some preliminary results of comparing devices on PLOG and conventional GaN layers will also be discussed.

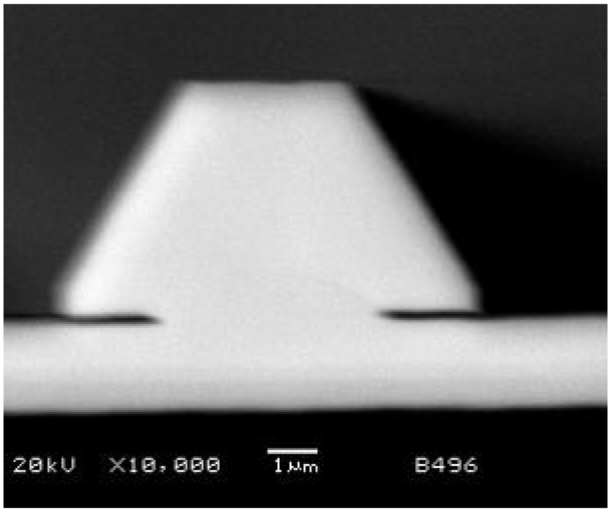

Figure 1. SEM images of lateral overgrowth GaN layers with zero NH_3 off time

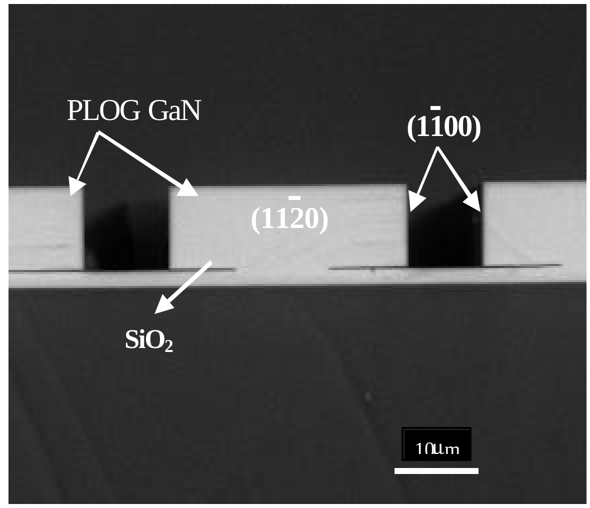

Figure 2. SEM images of lateral overgrowth GaN layers with NH_3 off time of 5 sec.

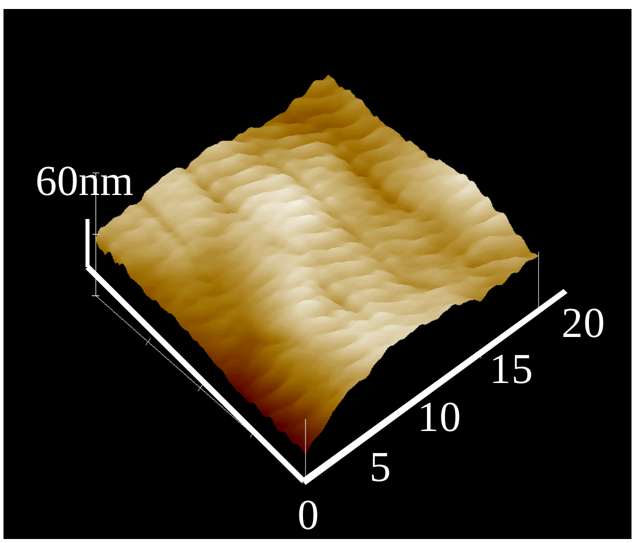

Figure 3 Atomic force microscopic image of 20x20 μm area of PLOG GaN sample

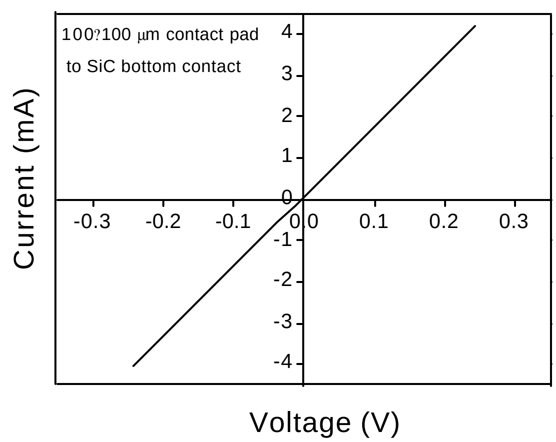

Figure 4 Current-voltage characteristics for a 100x100 μm electrode on conducting PLOG GaN layer