Growth of GaN by MOCVD on Rare Earth Oxide on Si(111)

F. Erdem Arkun[a], Rytis Dargis[a], Andrew Clark[a], Robin S. Smith[a], Michael Lebby[a]
Jeffrey M. Leathersich[b], F. Shahedipour-Sandvik[b]
a. Translucent Inc.
952 Commercial St. Palo Alto, CA 94303
b. College of Nanoscale Science and Engineering, State University of New York, Albany, NY 12203

Increased global power demands and penetration of new technologies such as solar energy conversion, hybrid and electric vehicles (EV) require efficient power conversion systems capable of switching large currents at high voltages with minimal loss. The current technology based on silicon LDMOS devices are reaching their limit in terms of speed and efficiency of power conversion.
One of the emerging contenders for efficient power conversion is based on GaN, which combines high breakdown voltage and low specific on resistance Ronsp, making this material an ideal candidate for such applications. The possibility of growing a AlGaN/GaN heterostructure and formation of a two dimensional electron gas (2DEG) in this material system creates high electron densit, high electron mobility channel, and results in HEMT devices with enhanced performance. The high breakdown voltage of GaN allows large blocking voltages and makes this material system ideal for power conversion applications. Growth of GaN on silicon is very attractive for power devices due to the cost and size benefit of silicon along with the high thermal conductivity of silicon. Many different buffer schemes based on AlN/Si has been implemented for growth of GaN on silicon. All of these schemes make use of an AlN buffer layer grown at high temperature on silicon wafers which results in the formation of a conductive layer at the interface due to diffusion of aluminum at high growth temperatures. This thin conductive layer in turn limits the performance of AlGaN/GaN HEMT devices at high drain biases by causing the device to breakdown at the substrate.
Growth of rare earth oxide epitaxial films on Si(111) substrates and subsequent growth of GaN on this buffer make this material system especially attractive as templates for growth of GaN. Growth of GaN directly onto an oxide layer will eliminate the formation of a conductive layer formed by unintentional doping of the silicon substrate. In this respect the large bandgap of the REO materials coupled with the excellent structural stability at high temperatures makes the REO/Si(111) material system a viable buffer technology for GaN based devices. In addition to the structural properties of the REO materials, the insulating properties will potentially remedy breakdown of devices at the buffer-substrate interface.

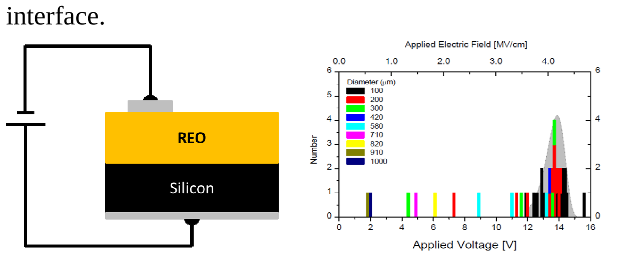

Figure 1 *Breakdown voltage of Gd_2O_3 grown epitaxially on Si(111) as a function of contact size. The average breakdown voltage of Gd_2O_3 is 4.0MV/cm.*

Figure 1 shows the measured breakdown voltage of Gd_2O_3 on Si(111) for contact sizes ranging from 100µm to 1000µm in diameter. The high breakdown voltage (4.0MV/cm) measured for Gd_2O_3 on Si is better than that of GaN and may potentially improve the breakdown voltage of AlGaN/GaN devices on REO/Si templates.

The current paper discusses use of a REO insulating layer between the silicon substrate and GaN layer to increase the breakdown voltage of HEMTs without increasing the GaN buffer thickness.
Two types of templates were used for the growth of GaN. In the first case, Er_2O_3/Si(111) wafers capped with a thin silicon layer was used to test the stability of Er_2O_3 in MOCVD growth conditions. In the second set of wafer templates, uncapped bare oxides are used for MOCVD growth of GaN. Initial results from Si-capped oxides show smooth surfaces with ~1nm rms values over 5µmx5µm scans and XRD patterns with no secondary phase formation. The absence of secondary phases in the XRD spectrum indicates that the Er_2O_3 layers are stable under the growth conditions employed for GaN growth. The θ-2θ scan for GaN/AlN/Si/Er_2O_3/Si(111) is shown in Figure 2.

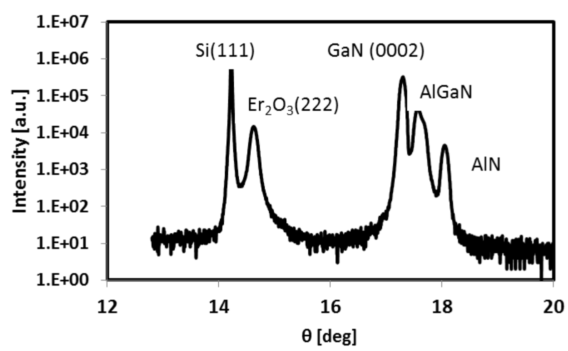

Figure 1 *Theta-2theta scan of GaN grown on Si-capped Er_2O_3 on silicon*

GaN growth directly onto Er_2O_3/Si wafer template was performed via a low temperature GaN buffer layer with only N_2 carrier gas in the MOCVD reactor. The presence of hydrogen in the gas stream at the initial growth stage is found to reduce the oxide and results in poor structural and surface quality. The thickness, III/V ratio, and growth temperature of the low temperature GaN buffer layer were determined to be critical for the GaN layer over grown at high temperature. Smooth films have been obtained by using this growth scheme. Figure 3 shows the atomic force microscope image of an as grown GaN/Er_2O_3/Si(111) wafer surface.

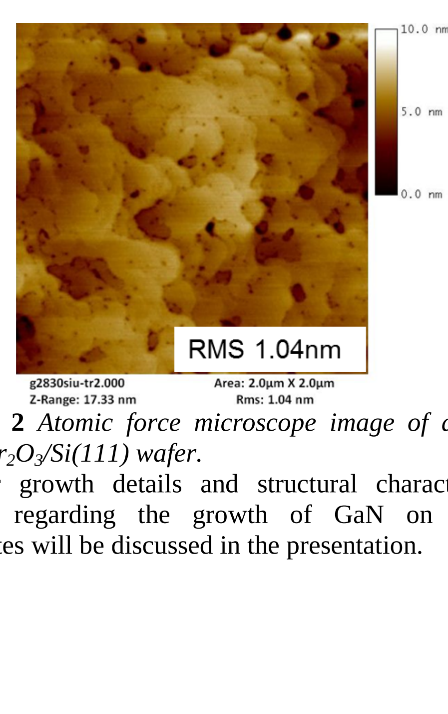

Figure 2 *Atomic force microscope image of as grown GaN/Er_2O_3/Si(111) wafer.*

Further growth details and structural characterization results regarding the growth of GaN on Er_2O_3/Si templates will be discussed in the presentation.