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

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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 density, 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 shows the measured breakdown voltage of Gd\textsubscript{2}O\textsubscript{3} on Si(111) for contact sizes ranging from 100\textmu m to 1000\textmu m in diameter. The high breakdown voltage (4.0MV/cm) measured for Gd\textsubscript{2}O\textsubscript{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\textsubscript{2}O\textsubscript{3}/Si(111) wafers capped with a thin silicon layer was used to test the stability of Er\textsubscript{2}O\textsubscript{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 5\texttimes10\textmu  m scans and XRD patterns with no secondary phase formation. The absence of secondary phases in the XRD spectrum indicates that the Er\textsubscript{2}O\textsubscript{3} layers are stable under the growth conditions employed for GaN growth. The θ-20 scan for GaN/AIN/Si/Er\textsubscript{2}O\textsubscript{3}/Si(111) is shown in Figure 2.

Figure 1 shows the measured breakdown voltage of Gd\textsubscript{2}O\textsubscript{3} on Si(111) as a function of contact size. The average breakdown voltage of Gd\textsubscript{2}O\textsubscript{3} is 4.0MV/cm.

Figure 1  
\textit{Figure 1} Breakdown voltage of Gd\textsubscript{2}O\textsubscript{3} grown epitaxially on Si(111) as a function of contact size. The average breakdown voltage of Gd\textsubscript{2}O\textsubscript{3} is 4.0MV/cm.

Further growth details and structural characterization results regarding the growth of GaN on Er\textsubscript{2}O\textsubscript{3}/Si templates will be discussed in the presentation.