## *SMA 5111: THE FINAL REPORT*

# *THE INVESTIGATION OF AlN BUFFER LAYER FOR THE GROWTH OF GaN ON Si SUBSTRATE*


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# Why is GaN..??

- →GaN compounds : high stable and robust materials
- → Offer good potential for application in a wide range of electro-optical devices (LEDs, LDs) in the visible and ultraviolet region due to its large direct energy bandgap (3.39eV at 300K)

# Difficulties ….

- Difficult to grow sufficiently large bulk single crystal GaN substrates

→ Employ heteroepitaxial growth of GaN thin films onto dissimilar substrate

- Lack of a suitable substrate material which have a lattice mismatched to and thermally compatible with GaN
- Many substrates have been tried : SiC,ZnO,Si,Sapphire, Spinel

# Using Si substrate…

- one of the most promising substrate for the heteroepitaxy
- high crystalline perfection, low cost and the availability of large size substrate
- presents a thermal conductivity comparable to GaN, three times higher than the one of sapphire and can be a good template for heat dissipation
- allows future integration of well-established Si electronics with GaN based photonic devices

# Difficulties…

- The incompatibilities between GaN and Si limit the quality of epitaxial layers
- High densities of dislocation
- Large tensile strain at room temperature during the post growth cooling , resulting in crack layers

→ Use buffer layer !

→ Various types of buffer layers  such as : AlN, SiC, AlAs, GaAs, HfN,MgO,….. have been tried

# Using AlN buffer layer

- Small lattice mismatch
- Provide a high densities of nucleation centers and promote the lateral growth of GaN
- can be grown within the same MOCVD system, being naturally incorporated into the entire growth process
- AlN is widely used as a buffer layer for GaN growth on sapphire. However the optimum growth conditions for AlN buffer layer on Si differ from those established for sapphire substrate

# The quality of AlN buffer layer with different growth methods

*(Jeong Wook Lee, Sung Hoon Jung, Hui Youn Shin, In-Hwan Lee, Cheol Woong Yang, Sang Hak Lee, Ji Beom Yoo , Journal of crystal growth 237-239(2002) )*

- the morphology and crystal quality of buffer layer is very important to GaN epitaxial growth
- AlN buffer layers were grown under different growth conditions to investigate the effect of buffer layer qualities on the GaN growth characteristics

- A smooth surface of GaN grown on polycrystalline AlN buffer layer was obtained in Fig (a) and (b). Figure (c) show the rough surface of GaN grown on AlN with RF sputtering method.
- the buffer layer with good crystal quality is required as an initial nucleation site for the growth of GaN epilayer.

→The epitaxial growth of AlN layer should be carried out using MOCVD or MOMBE.

# The effect of buffer growth parameters on the structural quality of the GaN layers

(S.Zamir, B.Mayer, E.Zolotoyabko, J.Salzman, Journal of crystal growth 218(2000))

- Investigate the influence of the AlN buffer layer growth temperature and growth duration on the morphology and preferred orientation of GaN films.
- Drastic enhancement of epitaxial registration was observed with increasing buffer growth temperature.
- A sharp transition in the growth mode occurred at 760°C
- For that temperature, optimal buffer layer growth duration was found.
- Use of March parameter as a figure of merit in X-ray diffraction testing of textured GaN films

- In the first interval, 700<$T$b<760°C, a step-like jump in intensity ratio by ~4 orders of magnitude is observed. It corresponds to the drastic reduction of $r$ from 0.56 to 0.095, which indicates a prominent enhancement of crystallite preferred orientation in the GaN layers.
- In the second interval, 760<$T$b<1100°C, a further increase of intensity ratio and reduction of $r$-values down to $r$=0.087 occurred, however the change rate is moderate, the improvement in crystalline quality is not as impressive, as below 760°C.

→ The AlN layer should be grown at temperatures higher than 760°C, and as close as possible to 1100°C, in order to get a more aligned GaN layer and to obtain a smooth GaN surface at shorter growth duration.

- *Understand the change in growth mode* at *T*b~760°C through SEM micrographs of thick AlN layers, grown at *T*b=700°C and *T*b=1010°C, together with their (0 0 2) AlN XRD profiles.

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- The AlN crystallites grown at 1010°C are about two times larger than those grown at 700°C
- The XRD peak intensity taken from the AlN layer, grown at 1010°C, is also about two times higher, indicating an increase of the total amount of AlN, as compared to the layer grown at 760°C.

→ Higher AlN growth temperature results in a slower AlN nucleation rate, but a faster rate of each individual AlN grain

- At temperatures $T_b$<700°C the poor coverage of the Si surface by AlN impedes effective nucleation of the GaN islands on top of it. The coverage increases very rapidly with increasing $T_b$, leading to the drastic improvement of the crystalline quality of the GaN films in the temperature range of 700°C<$T_b$<760°C.
- At $T_b$~760°C, AlN probably covers almost the entire Si surface.
- In the range 760°C<$T_b$<1100°C, only minor improvement in the GaN preferred orientation occurs due to an increase in the size of the AlN crystallites with increasing $T_b$ .

- For tb=1 min the GaN layer is composed of large crystallites (1–3 um in diameter), with a typical shape of hexagonal hillocks.
- For tb=8 min the GaN crystallites are of non-uniform shapes, sizes and orientations.
- For tb=5 min most of the crystallites are of the typical hexagon-like shape, and some of them are connected into short chains

- Concerning the buffer layer growth duration, *t*b, two findings should be mentioned.

→The first is an improvement of layer quality while increasing *t*b in the range of 1 min<*t*b<5 min

→The second is a deterioration of the layer quality with increasing *t*b, for *t*b>5 min

# *Conclusion*

- To get better quality of AlN buffer layer and high morphology of GaN film , the experiment should be carried out using MOCVD or MOMBE
- the buffer layer growth temperature should be in the vicinity of ~1100°C in order to obtain fast lateral GaN growth and a good crystalline quality of the GaN films
- At that temperature, the optimal buffer growth duration was found to be 5 min.
- need more experiments and more understanding of the nucleation and growth mechanism of AlN on Si and GaN on AlN.