Conference Report on MBE 2008 for UKNC

The 15th International Conference of Molecular Beam Epitaxy was held at the University of British Columbia (UBC), Vancouver, Canada. The event ran from 2nd -8th August. The meeting presents itself as the "world's premier forum for discussion of new research on molecular beam epitaxy, extending from fundamental studies of crystal growth to manufacturing technology". As expected, the conference covered many aspects of MBE with sessions on both fundamental study and a variety of material systems. The nitrides had the largest presence of all the material systems, with nearly a fifth of the sessions dedicated to them. One of the three plenary talks was also dedicated to nitrides, highlighting the continuing importance of this material. This short report will give a overview of the nitride talks that, for me, stood out the most.

C. Skierbiszewski gave the nitride plenary talk entitled "Laser diodes by plasma assisted MBE: From blue to green". The talk included an historical overview of the quest, so far, to achieve blue laser diodes including major breakthroughs in growth by MBE drawing parallels with MOVCD throughout. The presenter proceeded to discuss their investigation into the effect of miscut bulk GaN substrates and p-doping with Mg. They found that certain miscut angles and orientations had to be avoided, as growth does not lead to parallel steps (which in turn leads to flat interfaces), though atomic steps are present. For example, growth on a 0.5^o miscut of [11-00] leads to straight steps, while the same angle miscut of [112-0] does not.

When considering p-type doping, it is important to bear in mind, that no post growth annealing can be performed. This would damage the material due to the low growth temperature inherently required from PA-MBE. It is possible to use Mg, but high concentrations can lead to polarity inversions. It was found that the use of a higher miscut angle can however, suppress this inversion. The talk concluded with an outline of the major issues and potential solutions of the so called "green gap", with regard to InGaN.

In order to get a bandgap in the green region, large concentrations of indium are required. Due to a higher growth temperature of the layer atop the QW, inhomogeneities in In content are introduced degrading the QW and leading to In intermixing and dislocation formation. The high In content introduces a large degree of strain which further accelerates In diffusion. High built-in electric fields and Auger recombination introduce further complications. Despite this, the authors presented PL results of IQE of 23% for 520nm. They found that for special conditions in the metal rich regime, the growth temperature not only limits In content, but also the growth rate of InGaN. Under such conditions, which include a much lower growth rate than expected, InGaN MQWs grown on high quality GaN substrate have excellent structural quality, surface morphology with parallel atomic steps and low TDD ($<10^4$cm-2). The author expressed his opinion that growth of nitride systems on non-polar surfaces will represent the way forward in ensuring that the nitrides fulfil their potential. Indeed, they have shown growth on non-polar surfaces leads to an improvement of PL results.

Another particularly interesting presentation was given by Cordier, focusing on their efforts to produce thick GaN epilayers free of curvature. Due to large differences in lattice constants and thermal expansion coefficeints between GaN and Si, serious problems of strain and consequently cracks are introduced into thick GaN epilayers. This work looked at compensating the strain in order to achieve crack-free, high-quality heterostructures. Thick GaN epilayers are desired in order to achieve lower threading dislocation densities (TDD), since they decrease as thickness increases. A side effect of increasing thickness however, is increased strain on the system and an enhanced conductivity of the epilayer. The effect of strain is further exacerbated, upon cooling the substrate after growth, where stress goes from compressive to tensile. Films, whereby the GaN layer was grown at differing temperatures, were produced by both NH3-MBE and PA-MBE. Strain was monitored in-situ with a LAYTEC Epicurve curvature sensor. The structure consisted of stress mitigation layers in order to compensate the strain (GaN layer sandwiched between AlN layers), a thick GaN layer (1.7um), a 5nm AlN layer, 21nm of AlGaN and finally a 5nm GaN capping layer.

GaN	5nm
AlGaN	21nm
AlN	1nm
GaN	1.7-2μm
AlN	28nm
GaN	250nm
AlN	40nm
Si	

The growth temperature of the thick GaN layer was found to have an important effect in determining the degree of wafer bowing. A difference of about 40^{o}C was found to be enough to take the wafer from concave to convex. For growth of the GaN layer under ammonia conditions, threading dislocation interaction occurs in the first few hundred nm which leads to annihilation. Increasing the growth temperature above 800^{o}C leads to a higher TDD and faster relaxation rates, resulting in crack generation. For GaN layers grown using a plasma source, thus lower growth temperatures, the relaxation rate is slow. This means that dislocation interaction does not occur, which leads to films with a higher TDD than those grown using an ammonia source. By plotting dislocation density versus wafer bowing, the authors show that curvature can be used as a degree of merit.

From a point of view of my own research, the most relevant talk of the conference was given by A. Yoshikawa. Studies of InN epitaxy on GaN templates, under both In- and N-polarity growth regimes, were performed using RF-MBE. The polarity of the InN was pre-selected based on the polarity of the GaN templates and checked in-situ after growth. It is already known that lower growth temperatures are required, compared to other III-N materials, in order to avoid InN decomposition. InN growth was shown to be possible under both In and N polarities. The effect of growth rate versus temperature under constant N flux for both regimes was investigated, with results presented in figure [1].

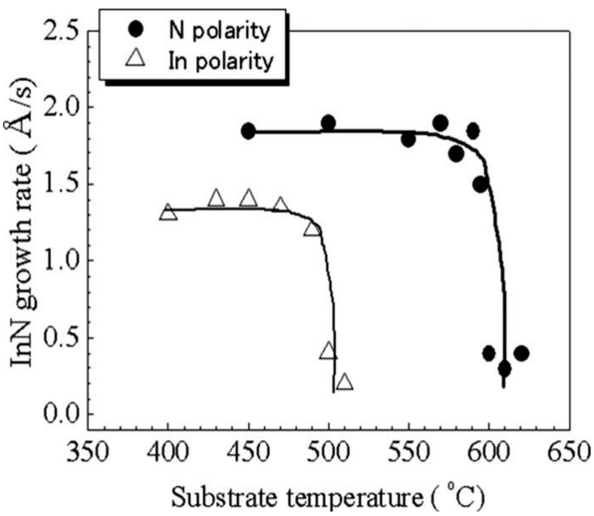

Figure 1: Temperature dependence of the growth rate of InN for both polarities. Taken from [1]

There are clearly two important results presented in this figure. The first is the temperature at which the growth rate can be seen to quickly decrease. For InN grown under In-polarity, this is seen at 500^{o}C, a whole 100^{o}C lower than that seen for InN grown under N-polarity. This means that the highest epitaxy temperatures for InN under In-polarity growth regime is about 100oC lower that that for N polarity. Above these respective temperatures, In droplets are observed on the surface and decomposition of InN was possible in both polarities. Since the epitaxy temperature for InN under In-polarity is remarkably lower than that of GaN, this may be a serious problem when fabricating InN-based III-N heterostructures under +c-polarity. The other important result, is that the growth rate itself is different depending on polarity, which is attributed to different In fluxes.

The authors went on investigate growth of 40 InN/GaN MQWs. Due to differences in growth temperature of InN wrt GaN, in order to achieve coherent growth, a critical thickness for InN of 1ML is required. Immiscibilty between InN and GaN leads to a self ordering process whereby an atomically flat and sharp interface is achieved. This structure effectively means that they inserted ultra-thin InN wells into a GaN matrix. The very thin InN layers, also mean that a higher growth temperature can be used, due to an increased bond strength.

My presentation on growth of ScN also attracted attention. The work focused on the use of ScN to act as a buffer layer for cubic GaN (c-GaN). c-GaN(100) is an interesting material due to the fact it is a non-polar form of GaN and therefore, the QCSE is not expected to be a problem as it is for conventional hexagonal GaN. In order to get growth of c-GaN on ScN, the ScN(100) orientation is required. This however, is not achieved when ScN is grown on c-GaN(100), despite the fact the two materials are lattice matched, nor GaAs(100). c-GaN(100)/ScN(100) is achieved when grown on ScAs(100) atop a GaAs(100) substrate.

Overall, the conference was a very gratifying experience, and I enjoyed meeting researchers from all over the world, particularly from outside Europe. I would like to thank UKNC and BACG for their generous financial support that enabled me to attend the conference.

J Hall

References:

[1] A. Yoshikawa, S. B. Che, N. Hashimoto, H. Saito, Y. Ishitani, and X. Q. Wang, J . Vac. Sci. Technol. B 26(4) 2008