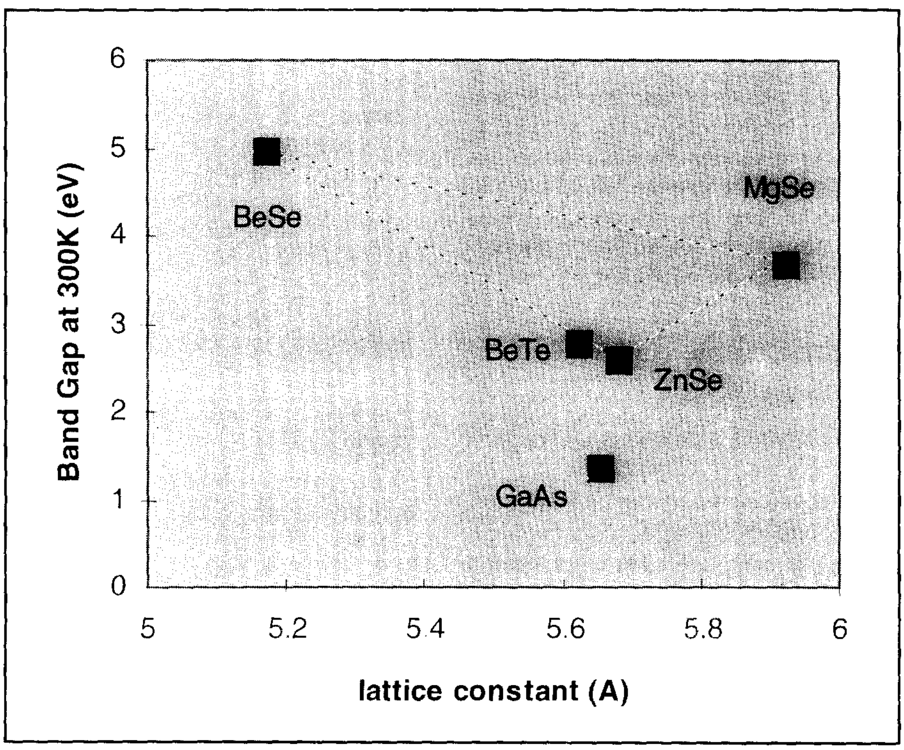
The International Symposium on Blue Lasers & LEDs

March 5th-7th — University Convention Centre, Chiba University, Japan

by Wyn Meredith

This was the third time that the II-VI and III-V blue emitting device communities had been brought together in one meeting (following meetings in California and Trieste). The aim was to provide a forum bringing together experts from both research fields in an attempt to solve common problems which block the realisation of commercially available blue LD's. With the announcement of the first GaN-based blue LD in January 96, and Sony's 100hr laser ZnMgSSe blue LD shortly after, the timing for this Symposium could not have been better. This was reflected by the fact that it was over-subscribed by nearly 100%, a modest meeting planned for about 200 turned into a major conference for nearly 500 in the last few weeks of planning.

In the symposium there were 27 invited papers and 104 contributed covering all aspects of ZnSe- and GaN-based blue LDs and LEDs: substrates, epitaxy, doping, characterisation and devices, and a session devoted to the future prospects of each effort. This conference gave an opportunity for II-VI researchers to see how much progress has been made in the GaN field, since up until the last year or so the scientific press have tended to concentrate on blue emission as being the domain of II-VI materials. This situation is rapidly changing, already funding for American II-VI labs has been drastically reduced and many Japanese II-VI labs are starting parallel GaN programmes. I have tried to give a balanced review on aspects covered in both material fields, but please excuse me if I have tended to go into more detail on II-VI issues.



Lattice constant vs. bandgap for the beryllium chalcogenides as compared with ZnSe and GaAs. (G. Landwehr, A. Waag, Univ. of Wurtzburg).

The best of both worlds

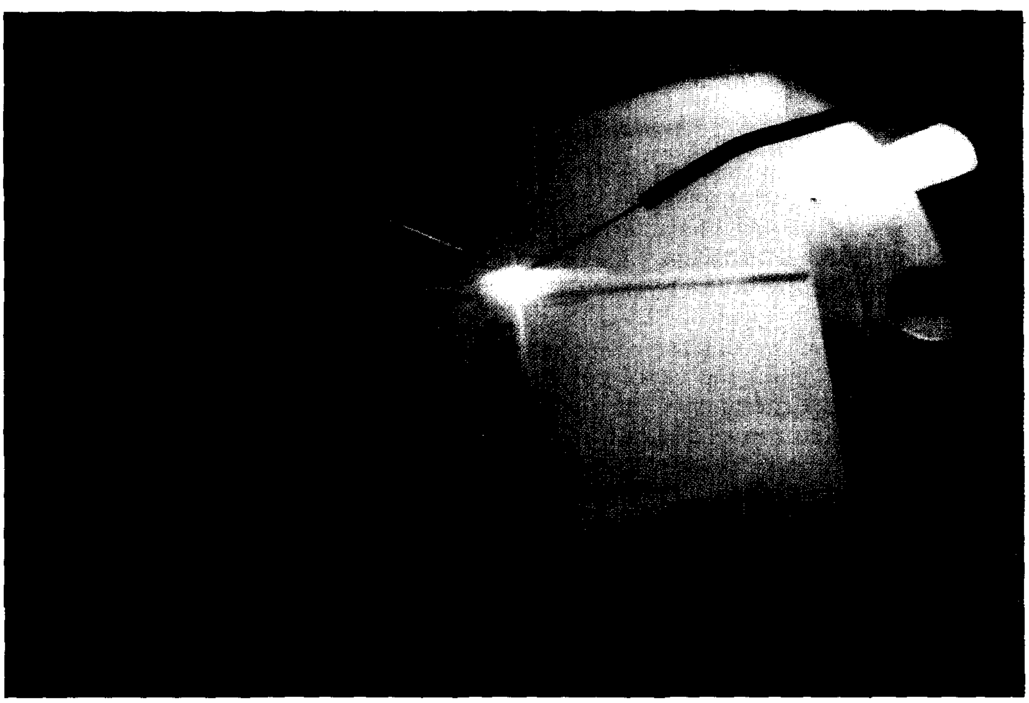
Sony still leads the II-VI initiative, and has made its position almost unassailable with the announcement of the 100 hr laser lifetime. This is a two orders of magnitude increase on the previous record which, for a time, crept up slowly from minutes to a few hours. Akira Ishibashi of Sony presented a talk which was similar to one given six months earlier at the International II-VI Conference in Edinburgh. (*III-Vs Review* Vol. 9, No.1, pp. 66). He said then that Sony believed that no catastrophically fast degradation process occurs with the II-VI LDs. The reliability will be established by eliminating pre-existing defects to prevent rapid degradation and slowing down gradual degradation mechanisms by reducing point defects in the structure. The reason for the sudden increase in lifetime appears to be due to the reduction of defects at the ZnSe/GaAs heterointerface. After a GaAs buffer layer is grown, exposure of the arsenic rich surface to a Zn flux results in a better 2D growth start, so reducing threading dislocations spreading from the GaAs substrate into the II-VI device. Other labs are using this procedure, but none have been as successful in increasing lifetimes as Sony. We can now only assume that Sony will strive to improve this method further and concentrate on composition control of the quaternary ZnMgSSe cladding layers to reduce the point defect density in attempting to further increase LD lifetimes.

	II-VI ZnSe	**III-V GaN**
Crystal structure	zincblend	wurtzite
n doping max. (cm^{-3})	C1:3x10^{20}	Si:2x10^{20}
p doping max. (cm^{-3})	N:2x10^{18}	Mg:2x10^{19}
d/a %	+0.25/GaAs	+16/Al_2O_3 +3.5/SiC
QW/barrier	ZnCdSe/ZnSSe	$In_{0.2}Ga_{0.8}N/In_{0.05}Ga_{0.95}N$
Device defect density	1x10^5 cm^{-3}	1x10^7- 1x10^{10}
λ(nm)	460	420
P_{th}	350mAcm^{-2}	8.7kAcm^{-2}
lifetime	100hrs CW (RT)	pulsed (RT)

A comparison of the current best II-VI (ZnSe) and III-V (GaN) blue laser performance.

Shuji Nakamura of Nichia Chemicals gave an excellent presentation outlining the operation of the first III-V GaN based Blue emitting LD. Stimulated emission was observed at 420nm at room temperature under pulsed current injection (660 mA). The structure consists of InGaN MQW layer with GaN guiding layers and AlGaN cladding layers, using Si as an n type dopant and Mg as a p type dopant, grown on a c-face (0001) sapphire substrate. He explained that an increased effort in III-V nitride research resulted in high crystalline quality AlGaN and InGaN and minimised the problems associated with self compensation in p-type AlGaN. One point that is worth mentioning is the fact that the structure was grown by MOVPE at atmospheric pressure, not MBE, which one could argue, makes the technology more suitable for large scale mass production. So far only Sony has managed to produce a MOVPE grown II-VI laser, and only at 77K pulsed operation. He concluded with a demonstration of an LED display, scrolling "Nichia Chemicals" across its screen using blue, green, red and yellow LEDs with impressive brightness. When questioned on the status of LED research within his corporation he replied that the blue LED research phase was finished, and they were now well into the production stage with commercial products possible in approximately 6 months.

There are, of course problems with the GaN-based laser, the major drawback being the substrate but there are still problems with ohmic contacting to p-type GaN and resistance to chemical etches, which hinders fabrication. Morkoc of the University of Illinois gave an excellent overview of the electrical properties of the nitrides. He explained that the best ohmic contacts to n type GaN exhibited contact resistivities $10^{-9}\Omega cm^2$, but to p-type, present metallisation techniques gave resistivities of $10^{-3}\Omega cm^2$ not good enough for the successful implementation of high power devices and LDs. This is a situation which mirrors the II-VI contacting problems.



Blue emitter at Nichia.

Substrates and Homoepitaxy

Another approach to lowering the defect densities in II-VIs is to eliminate misfit dislocations by growing on ZnSe substrates. Schetzina of North Carolina State University gave a presentation of the most recent results of devices grown on substrates supplied by Eagle-Picher laboratories. The best blue LED structures grown on these substrates produce 327 W at 10 mA, and green ZnTeSe based LEDs produce 1.3 mW at 10 mA, with some of the LEDs having lifetimes of over 10000 hrs. Blue laser diodes have also been fabricated on ZnSe substrates, emitting at 485 nm at 77K CW operation, 300K pulsed. In another collaboration, this time with Cree Research Inc. III-V GaN growth by MBE has been studied on GaN/SiC substrates. These consist of 3 µm of GaN grown on SiC by MOVPE at Cree, which exhibit XRD half widths of 85 arc sec. The aim of this is to replicate the quality of GaN films grown by MOVPE growth by MBE : defect densities of 10^8 cm^{-3} are quoted. Schetzina concluded by giving his opinion on which materials base would succeed in realising the production of Blue emitting devices. Clearly III-V LEDs will dominate the market since they are already available in production quantities. He suggested the key to cracking the III-V LD problem will be developing a suitable substrate. Given the current rapid growth of the GaN community it seems inevitable that this will happen, which will increase the already growing pressure on II-VI devices.

At the high pressure research centre, Polish Academy of Sciences, Sylwester Porowski and co-workers have been developing such substrates. Single crystal GaN platelets 4-5 mm long have been grown by bubbling nitrogen through liquid gallium at high pressure and temperature (20 kbar, 1400°C). Epitaxial GaN overgrown by MOVPE on these platelets show dominant excitonic features in their PL spectra, demonstrating the high quality of the layers. Porowski indicated that future work on the project will concentrate on increasing the platelet size by optimising the growth conditions.

New directions

Rather than decreasing the defect density in II-VI devices by using quality control measures, and accepting the problems associated with a mismatched heteroepitaxial system, some groups are taking an entirely different approach. One example is Gottfried Landwehr's group at Wurtzburg. They presented work on the growth of beryllium chalcogenides as candidates for blue and green LDs. LEDs have been fabricated using a ZnSe active layer with BeMgZnSe cladding layers and a BeTe-ZnSe pseudo-grading between the substrate and the cladding. Preliminary growths of LED devices resulted in relaxed structures which emitted at 458 nm with a lifetime quoted as 1000 hrs. Andreas Waag explained that the main advantage in using these compounds is the high structural quality and covalency, and a good ohmic contact to p-GaAs by BeTe-ZnSe pseudogradings. Worries were expressed from the floor about the safety of using Be as a matrix element, considering its high toxicity, but the reply was that it is quite safe using the normal handling procedures for ultra pure source elements.

Optoelectronic devices

The interest in optoelectronic devices seems to be growing within the II-VI and III-V communities as the LED and LD technology matures. The growth and fabrication of Vertical Cavity Surface Emitting Lasers (VCSELs) are certainly being considered by numerous II-VI groups and the conference prompted the first publication of a III-V GaN-based VCSELs by a collaboration between Advanced Technology Materials Inc. and the University of Massachusetts. An optically pumped structure showed lasing characteristics when pulsed at 2.0 $mWcm^{-2}$. The structure had a simple active layer of GaN with epitaxially grown Bragg stacks of AlGaN of two different compositions.

APA Optics Inc. reported on their recent experiments on GaN-based optoelectronic devices including AlGaN/GaN Heterostructure Field Effect Transistors (HFET) photodetectors and AlGaN photoconductive photodetectors. Depending on the Al content, these devices have cut-off wavelengths from 365 to 250 nm.

ZnSe based optoelectronic devices have been studied for some time at Heriot-Watt University, the latest development being piezoelectric quantum well modulators grown on (211) substrates.

The final oral presentation of the conference was entitled "Future Prospects in Blue/UV short wavelength Optoelectronic Devices", given by Yoon Soo Park of the Office of Naval Research. This was a review of GaN-based devices and reiterated the views of most of the preceding speakers: future nitride research must concentrate on developing better substrates and minimising impurities and defect levels in the materials.

Conclusion

The conference confirmed the trend of mounting pressure on II-VI research to reach the goal of mass production of blue LDs. The III-V Nitride system is not only a viable alternative, but a viable alternative which is gathering momentum at the expense of II-VI research. It certainly looks as if the race for production is between Sony and Nichia: Nichia may have the upper hand in LEDs, but Sony is still ahead in laser diode development.

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