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The Manager

Company Announcements Platform

ASX Limited

BLUGLASS 2014 AGM

CHIEF OPERATIONS AND TECHNOLOGY OFFICER'S ADDRESS

SLIDE 27 – TECHNOLOGY UPDATE

Good morning, my name is Ian Mann and I am the Chief Operations and Technology Officer at BluGlass and I will be presenting a technical update on the progress over the last 12 months and will be looking at the opportunities for commercialising the RPCVD technology in more detail. Before launching into the detail though, I realise that most are very keen to know how we are tracking on the RPCVD p-GaN LED efficiency compared to MOCVD - so the short answer is that we have not matched the performance of MOCVD at this point in time but we have made such significant progress to have received a series of commercial queries including requests for detailed data, request for quotes, and just recently our first purchase order to trial RPCVD.

SLIDE 28 –BENEFITS OF RPCVD FOR LEDS

To give some context for the next slides and to refresh everyone's memory, I would like to recap just one of the RPCVD value propositions, which is for low temperature p-GaN. This figure shows a simplified LED structure of which the p-GaN layer is of immediate interest when successfully grown at low temperature. The p-GaN layer is grown on top of the multi-quantum-well (MQW) region which is made of alternating layers of gallium nitride and indium gallium nitride (InGaN) and it is the MQW that is the active region of the LED critical for light generation.

InGaN must be grown at low enough temperatures to incorporate sufficient indium to get, for example, blue light emission. Once the MQW region has been grown, the next layer to be grown is one of several p-GaN layers (including p-AlGaN) on-top of this temperature sensitive active region. The high temperature growth of p-GaN negatively affects the active region and can degrade the optical performance of InGaN layers, reducing the efficiency of the quantum-wells and therefore the light output of the LED. This effect is more prominent the larger the temperature difference between the p-GaN and MQW growth temperatures of which I will touch on again later when we discuss green and yellow LEDs.

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SLIDE 29 HB LED: LOW TEMPERATURE p-GaN

We grow LED wafers on our MOCVD system and measure the performance to compare it with a similar LED wafers that are grown under the exact same MOCVD growth conditions with the exception of the p-GaN layer which we grow using RPCVD. Essentially we make a partial LED structure with MOCVD that stops above the MQW and then complete the LED by growing p-GaN with RPCVD. With this LED structure in mind I want to focus on the technical progress starting with a critical plasma source upgrade, followed by the LED device work.

SLIDE 30 – 2013/14 TECHNICAL PROGRESS (1)

Last year, right at the time of our AGM we implemented an enhanced plasma source capable of producing a very high density of active nitrogen. The rationale was twofold: 1) a higher density of active nitrogen allows for additional metal organic to be used so that the p-GaN layers (and other forms of GaN) can be grown faster while maintaining film quality OR conversely, that films can be grown slower while maintaining film quality but using less power to the plasmas which is important for growth initiation, 2) for scaling to larger volume chambers more active nitrogen is needed – the new plasma design served as a test for the larger BLG-300 system, which has been a very successful implementation.

Fully demonstrating the new plasma source took some time to realise. We initially struggled with unanticipated plasma reliability issues, but once these were resolved through engineering improvements we found the plasma to be our most stable and highest density setup to date and we believe this is a major factor in our RPCVD progress. With this new source we were able to both increase the growth rate (by 50%) in our p-GaN films and improve the surface roughness. The image on right lower section of the slide is a measure of the reflectivity during growths comparing the old and new plasma source – the trace with the greater number of oscillations is indicative of a faster growth rate.

SLIDE 31 – 2013/14 TECHNICAL PROGRESS (2)

With our MOCVD capability on site we could readily work on both key aspects of the integration of the RPCVD + MOCVD demonstration. While it is obvious that the last layer grown in MOCVD becomes the starting growth surface for RPCVD, it has not been trivial to get the optimum (in terms of the LED performance) ending conditions of MOCVD or starting conditions for RPCVD. The last layer(s) grown in MOCVD must protect the MQW from the subsequent cool down in MOCVD, the transfer to the RPCVD chamber, and the RPCVD growth start. We have worked hard on developing these conditions and the majority of our LED improvements have come from these integration aspects.

To illustrate through one example; the two upper images show the surface roughness (using a technique called Atomic Force Microscopy) of two different MOCVD growths, one is simply a GaN template and the other is a MQW – the MQW is considerably rougher than the bare GaN. We have found we need to use different starting RPCVD conditions depending on the roughness of the surface being grown on. A key area where we have been very successful in growing on these rougher MQWs is in minimising oxygen impurities at the RPCVD p-GaN / MOCVD MQW interface by incorporating some process innovations within the RPCVD chamber itself.

In combining these improvements, the new plasma source, MOCVD final growth process, and the RPCVD growth starting conditions we were able to make very significant improvement over earlier LED efforts. The results have been very encouraging and we continue to improve. The image to the right shows a blue LED wafer grown with BLG-180 RPCVD p-GaN on a MQW grown on our MOCVD system.

SLIDE 32 – 2013/14 TECHNICAL PROGRESS (3)

You may recall last year we identified the requirement as stated by key industry players of the need to demonstrate that RPCVD could be scaled. We also recognised the need for a second RPCVD system to accelerate progress and to address other RPCVD applications. Over the course of the year we were successful in upgrading the facility and commissioning the new RPCVD (BLG-300) system, but more importantly, successfully demonstrating the technology transfer from one vendor platform to another (the image on the upper right shows the scale between our two RPCVD systems).

Earlier this month we announced that using the BLG-300, we had been successful in achieving p-GaN electrical properties on par with our results from the BLG-180. We are now very pleased to state that since that time, the LED device results obtained from the BLG-300 are rapidly approaching our best BLG-180 LED device results. We believe this early success was enabled by the new hardware design combined with the latest process improvements that were first established on our smaller BLG-180 system and then shown to be equally applicable to the larger system – all very good signs of RPCVD scalability. The image on the lower right shows some of the early promising LED results (RPCVD p-GaN grown on MOCVD MQWs).

With the new system we have also commenced work for growing low temperature GaN on silicon wafers. I would also like to reiterate that in addition to potential customers continued interest in the p-GaN and GaN on silicon technology enablers, there is also interest in exploring other applications of which I would like to briefly touch on the recurring areas of inquiry.

SLIDE 33 – HB LED: p-GaN AND MQW GROWN USING RPCVD

While we have been working on the top layer of the LED (the p-GaN) as a commercial demonstration of the RPCVD capability, a number of LED manufacturers have expressed interest in a low temperature RPCVD system for growing both the MQW and p-GaN. The goal would be to grow the p-GaN and MQW at the same temperature to minimise any thermal degradation of the MQW and to reduce the time required to grow the MQW region. This approach also avoids interrupting the growth of these two critical regions compared to an RPCVD p-GaN growth only. The MQW and p-GaN processes of LED manufacturers are often the critical ones (involving considerable tightly held IP) in contributing to the overall LED performance. We have started growths in both RPCVD systems to test this. Significantly more effort will be required to improve the overall performance. However, the second RPCVD system allows for a dramatic increase in our productivity for pursuing MQWs grown by RPCVD while continuing the p-GaN development within the same growth run. We will also continue to use the MOCVD system to provide the underlying thick GaN templates.

SLIDE 34 – HB LED: LOW TEMPERATURE GaN ON SILICON

LED manufacturers continue to look for ways to reduce cost – one option is to replace the commonly used sapphire wafer with silicon, for example Toshiba, Samsung, and Plessey (UK) are pursuing LED manufacturing on silicon. However GaN on silicon is prone to cracking and bowing during manufacturing due to a large lattice and thermal mismatch. Notably, the thermal mismatch can lead to severe bowing (and cracking) during the cool-down from the high temperatures used in MOCVD growth. This is illustrated in the images on the lower left of the slide with data from an MOCVD growth of GaN on Si.

RPCVD has the potential to address this issue for larger silicon substrates simply by growing the LED at lower temperatures leading to reduced bowing and eliminating cracking. We are now in a good position to increase the GaN/Si work with the new BLG-300 due the ability to use larger substrates – up to 200mm. In order to take advantage of the low temperature growth, the entire LED structure is needed to be grown at low temperature. BluGlass was fortunate to receive a $3M Australian Government Grant early last year to develop RPCVD for LEDs on silicon.

SLIDE 35 –POWER ELECTRONICS: LOW TEMPERATURE GaN ON SILICON

The semiconductor industry is also actively pursuing nitride materials in markets outside of LEDs. One of these includes the emerging market of power electronics using GaN on silicon – applications include the power conversion for consumer devices such as PCs, mobile phones and power supplies. The electrical properties of GaN on silicon should enable higher switching frequencies, higher blocking voltages, lower switching losses, better thermal conductivity and higher operating temperatures.

RPCVD GaN on silicon, grown at low temperature, has the potential to reduce the complexity of growth of the nitride layers for similar reasons stated above for LEDs. In a similar fashion to LEDs, to take advantage of low temperature to assist in the bowing issue, the entire GaN based power electronic structure is needed to be grown at low temperature. However, the structure is considerably simpler than an LED. The image shows the basic material structure that is used to fabricate High Electron Mobility Transistor (HEMT) devices – the key building block for power electronic applications.

SLIDE 36 –NITRIDES FOR SPECIFIC APPLICATIONS: TECHNICAL PRIMER

Before I introduce a few other application areas I wanted to give a bit more technical background to provide some context for the various applications. The diagram included on the slide shows a plot describing how different alloys of nitrides can, for example, lead to different light emission or absorption. Aluminum, indium and gallium are the main metals used to derive the various properties but you can appreciate that these in principal can be combined to achieve a full range of properties.

SLIDE 36 –NITRIDES FOR SPECIFIC APPLICATIONS: TECHNICAL PRIMER (Continued)

However in practice it has proven very difficult to achieve high quality films grown with conventional MOCVD for a full range of compositions of these materials. For example, AlN growth using MOCVD requires very high temperatures and growth rates can be very slow. InN requires growth at very low temperatures and many would argue cannot be grown with standard MOCVD with any reasonable effectiveness. This is due to the use of ammonia (NH_3) in MOCVD which requires high temperature to dissociate in effective quantities in a growth chamber. This provides some potential unique opportunities for RPCVD whereby active nitrogen is supplied independent of temperature.

The wavelength dependency inset figure shows where these different compositions can be useful: In-rich InGaN for solar, green or yellow LEDs / laser diodes, Al-rich AlGaN for UV LEDs or even complicated intermediate compositions of InAlGaN that can be very useful for lattice matching if the film quality can be maintained over a wide range of compositions. These aspects are very active areas for new opportunities for nitride applications including RPCVD.

SLIDE 37 –CONCENTRATED PHOTOVOLTAICS (CPV): INDIUM RICH InGaN

Tuning of InGaN composition with low temperature RPCVD enables indium rich InGaN compositions not readily accessible with MOCVD. A multi-junction InGaN solar cell has the potential for very high efficiency, in excess of the conventional CPV cells today that are based on Ge/InGAs/InGaP.

SLIDE 38 –GREEN AND YELLOW LEDS (AND LASER DIODES): LOW TEMPERATURE p-GAN AND INDIUM RICH InGaN

Green LEDs are potentially important for RGB (Red, Green and Blue) LED applications that enable the device to have full colour control. The LED industry is very interested in the possibility of a cost effective RGB (or RGBY) solution to create more natural looking light and is expected to be popular for segments of the general lighting market. Similarly yellow LEDs can be used to replace the relatively expensive and less efficient yellow phosphor coating and could find use in the general lighting market. Yellow LEDs (and laser diodes) are also of interest for certain medical applications.

Longer wavelength nitride based LEDs or Laser Diodes (such as green, yellow or red) require indium rich MQWs. This requires growing the MQW at lower temperatures (even lower than for blue) which in turn amplifies the MQW degradation issue when growing higher temperature p-GaN on top. RPCVD can potentially combine the low temperature advantage to obtain indium rich MQWs and the lower temperature p-GaN to achieve very high efficiency long wavelength devices.

SLIDE 39 –UV LED: ALUMINUM Rich AlGaN

UV LEDs are being targeted for critically important applications such as providing a low cost solution to water purification. LEDs are used that emit UV with sufficient intensity to kill disease infecting bacteria.

MOCVD grown UV LEDs currently exhibit low efficiencies - significant improvement is required to address this market. One issue with MOCVD is the requirement for high quality Al rich AlGaN structures that are very difficult to achieve in conventional MOCVD reactors where the maximum operating temperature is limited to below what is required to produce high quality Al rich AlGaN.

Slide 40 – RPCVD AlN TEMPLATES

Another potential use for RPCVD is in growing high quality AlN templates at lower temperatures than is possible in MOCVD. These types of templates can be used in many of the typical GaN applications including LEDs (including UV LEDs) and power electronics applications. This could provide an opportunity to sell RPCVD grown wafers to the industry to manufacture MOCVD grown devices with improved performance.

After having reviewed these applications I wanted to reiterate that it is not our intention to develop each and every one of these technologies but primarily to highlight that these are the areas that we envision future BluGlass customers will seek to take advantage of RPCVD. Importantly many of the applications share common building blocks such as p-GaN and AlGaN. As tabled earlier by Giles, BluGlass is looking at the different commercial paths that are best suited for the various markets.

Slide 41 – THANK YOU

Just in closing, the progress made in the last year has been substantial and those who may have visited our facilities a year ago would note the marked change and the jump in activity level with the new systems all up and running. I would like to personally acknowledge and thank the BluGlass technology team and support staff for their continuous dedicated effort.

Thank you for your attention today.

The RPCVD technology, because of its low temperature and highly flexible nature, offers many potential benefits over existing technologies including higher efficiency and lower cost.

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