ALLOS-Veeco collaboration enables better GaN-on-silicon microLEDs

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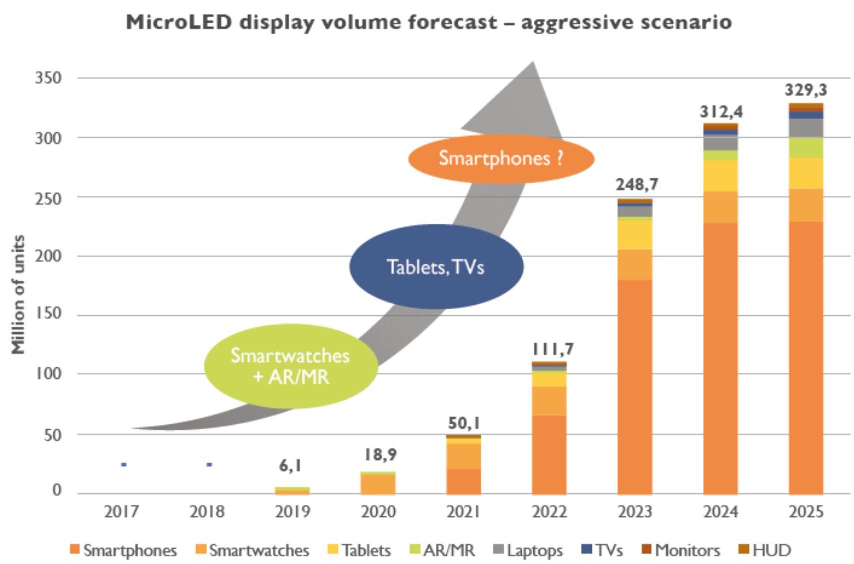
MicroLEDs have become a hot topic in the semiconductor field, propelled by the purchase of Luxvue by Apple in 2014. In the most optimistic scenario in our MicroLED Displays report, the market could reach 330 million units by 2025. And GaN-on-silicon is a promising platform for the large-scale manufacture of such microLEDs, as well as for power electronics and radio frequency (RF) devices.



(Source: MicroLED Displays report, Yole Développement, February 2017)

As an epitaxy tool manufacturer, Veeco leveraged the knowhow and intellectual property (IP) portfolio of ALLOS Semiconductors to demonstrate the Propel™ Power GaN MOCVD system, with impressive results. Therefore, Yole Développement has interviewed Alexander Loesing (AL), managing director of ALLOS, and Christopher Morath (CM), senior director, strategic marketing at Veeco. They explain their collaboration, what it offers to microLED manufacturing and the possible applications of GaN-on-silicon for microLEDs, power electronics and RF.

Yole Développement: Can you please explain us some background for Veeco's interest in micro LEDs, Christopher?

Christopher Morath: Veeco has been monitoring microLED as an emerging market for several years. We are looking for novel epitaxy solutions where Veeco can enable microLED displays. We also want to be ready for other opportunities for MOCVD equipment.

YD: Why do you think GaN-on-silicon will become the preferred solution for microLEDs when there are other substrate platforms that also provide good crystal quality?
CM: MicroLED is a new opportunity that will take advantage of the industry's plans for 200mm wafers to bring down cost. MicroLED in general promises to disrupt the supply chain because of the mass transfer requirement. There will no longer be stepwise development – in particular in terms of epitaxy uniformity and yield requirements which are interrelated with mass transfer. There's also a lot of optimization needed of the epitaxy stack and the process. You can't just take a stack that works well for general lighting, as driving current, operating regimes and microLED architectures are different. For all those reasons we view this as a turning point where there's room for new technologies to come into play, including GaN-on-silicon.

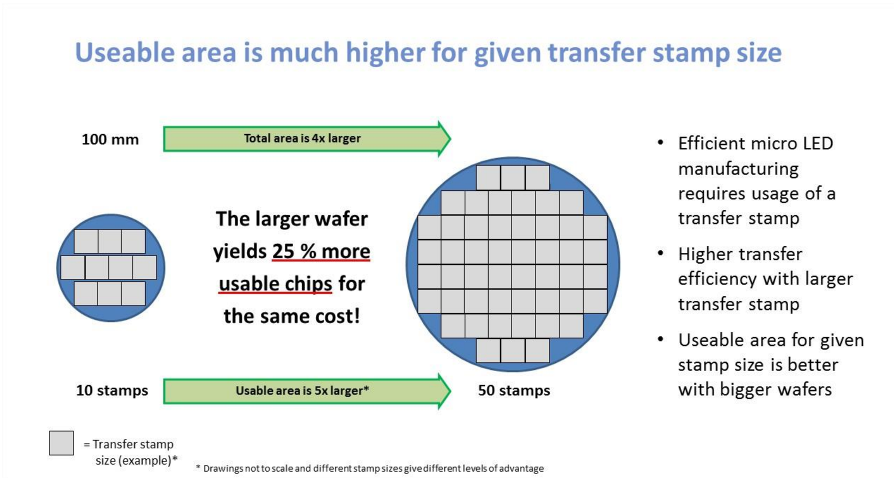
YD: Why did Veeco decide to work with ALLOS? What was the main value proposition you got from this collaboration?
CM: As an equipment manufacturer we strive for a demonstration recipe that adequately reflects what customers want to use. For LED lighting, we chose not to invest in GaN-on-silicon technology because it remains a relatively small market segment but think for microLED this could change. That's why we partnered with ALLOS, a leading GaN-on-silicon process technology provider. They have a lot of experience in different reactors, including Veeco's K465i™ so it was an efficient way to transfer the recipes from the K465i™ and to adapt them for the Propel™.

YD: What are the main challenges facing GaN-on-silicon for microLED applications?
Alexander Loesing: Growing anything on silicon - including microLED stacks - involves handling lattice mismatch and thermal expansion co-efficient mismatch. At the same time the big challenge is to achieve the high yield needed for micro LED displays. For this outstanding epiwafer uniformity is a crucial factor. Wavelength uniformity, for example, depends highly on the indium composition uniformity in the multi quantum wells (MQW) and that is extremely temperature-sensitive: 0.1˚C make a difference. At the same time the gas flow cools down the surface so must be managed. Strain and wafer bowing during MQW growth must also be tightly controlled.

YD: Hold on, just 0.1 °C temperature variation at around 1,000 °C temperature in the reactor chamber can make a difference? This sounds extremely challenging! How could you then achieve such results?
AL: Here two factors come together. First, our technology offers a key advantage over competing technologies: We can control the strain so precisely that we can adapt the growth of the MQW to the temperature profile of the reactor. This also allows us to grow crack-free, large diameter wafers with no wafer bow and excellent crystal quality. In principle we can realize this technology advantage on any MOCVD reactor model. However, as in microLED uniformity is of such paramount importance the right hardware becomes the second important factor. Here a single wafer reactor design has a natural advantage and in particular the excellent gas flow and temperature control of the Propel™ contribute significantly to the results.

YD: What about yield and cost?

AL: This is the most important question. With silicon larger wafer diameters are possible and unlock the associated cost savings form wafer size scaling seen in the IC and LED industry in the past. Additionally larger epiwafers are beneficial for microLEDs because of the use of transfer stamps. With transfer stamps you gain significant wafer surface area utilization and thus cost savings when using larger wafers [Figure 1]. Last but not least large wafers enable the economic use of high yielding single-wafer processes like in the IC industry and we believe with single-wafer reactors and the right recipe, it's possible to achieve the required breakthroughs for high yield and low cost.



(Courtesy of ALLOS)

YD: What are the main differences in GaN-on-silicon epitaxy between the different applications i.e. microLEDs, RF devices and power electronics?

AL: The obvious difference is that in LEDs you want a highly conductive layer for current spreading, whereas in RF and electronics you want the opposite. That is more to do with the functional stack you build. Another big difference is that the high level of doping with silicon or germanium causes additional tensile strain in the LED layers. This makes strain engineering even more important in LEDs than in power electronics.

YD: Are Veeco and ALLOS planning to make other demonstrations of their technology for RF and power electronics applications?

CM: We're considering them, but we're not ready to announce anything yet. Of course, the initial - and still the primary - target market for Propel™ GaN reactor was power electronics.

AL: ALLOS also has technology for RF and power electronics and in all three fields epitaxy is crucial for the yield of the final device. In all applications you face similar demands so reactors with, for example, optimized uniformity capability like this single-wafer reactor make a lot of sense for those applications as well.

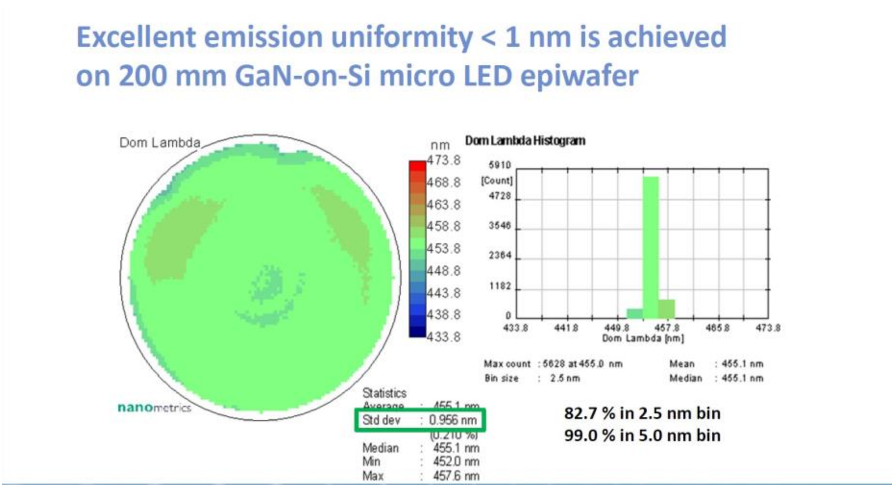
YD: Many demand that the epitaxy process must be CMOS compatible. Have you developed a process that has the potential for that?

AL: You are right, very important demand. Many want to use large wafer CMOS lines to save cost and increase yield – in particular to address these challenges in microLED. I see three main topics which need to be addressed and we have solutions for that:

1) Potential contamination from metals on the wafer surface can be solved with the normal cleaning processes available in CMOS lines.

2) Particle contamination is a big device failure and yield issue. Particles from the MOCVD process typically stem from the inefficiency of the chemical reactions in the reactor and how quickly the metalorganics move away from the wafer surface. Overall the answer to this is to get the chemistry as efficient as possible so that we don't have particle formation. Furthermore in multi-wafer chambers you always get some deposition in the carrier area and particles coming from that. For both single-wafer reactors offer a solution.

3) Also wafers must meet the physical dimensions for bow and thickness required for CMOS lines. For example, processing thick epiwafers in standard lines always requires extra work and attention. This is even more true when you have strong bow differences from wafer to wafer. Here ALLOS is offering a unique strain-engineering solution enabling flat 200 mm GaN-on-Si epiwafers which are only 725 µm thin.



(Courtesy of ALLOS)

YD: How many Propel™ GaN reactors is Veeco expecting to sell in the coming years and when will they become available? Will Veeco sell both the tool and the recipe as a bundle?

CM: Currently the business model is that Veeco sells the equipment and ALLOS separately transfers the recipe and licenses its IP. As for sales, we're a public company and don't provide a forward-looking forecast for equipment. Our view is that for microLEDs, the first volume products will be coming out between 2019 and 2020. In terms of equipment and the process, I think this is the right time to be developing: now through the end of 2018. It is a critical period for us to position ourselves in the market.

YD: How long does it typically take ALLOS to optimize the epitaxy process?
AL: The time differs from reactor to reactor and customer to customer. It was a very good experience working on the Propel™. In the end it's still the Turbodisc® idea like with the K465i™, so adjusting the recipe was as expected. Optimizing always takes a little time because there are small differences to consider, but we achieved the values that we published in less than one month. The tool has proven to work very predictable and stable.

YD: From your perspective, what has been the major advantage in combining ALLOS' knowhow and technology with Veeco's Propel?
AL: ALLOS works with the reactors our customers have and we have experience on many different tools. Our expectation is that we can deliver the best GaN-on-Si performance possible on any reactor. Depending on the specific requirements single-wafer chamber reactors can have decisive advantages over multi-wafer chamber ones. In the assignment we got from Veeco 200 mm high quality GaN-on-Si was required and wavelength uniformity was paramount to unleash cost and yield advantages for microLED manufacturing. In this situation we could show that a single-wafer chamber reactor like the Propel can show its advantages.

YD: Chris, is the debate single-wafer vs. multi-wafer tools already decided for you?
CM: Getting to a single bin or perfect uniformity is obviously the goal, and with the now demonstrated results we are very close to that. However - like in LED lighting - there is going to be a cost associated with this. Really, the question is "What's the value of uniformity?" I think that value depends on the details of the transfer process and driver compensation technology alongside a wide range of other factors. Perhaps different players might come to different answers, perhaps also over the course of time. Veeco has both the single-wafer reactor product and our EPIK® line of batch tools, and for the foreseeable future we see both MOCVD products - batch and single-wafer reactors - being important technologies for microLED display.

YD: What are the next steps for the commercialization of the Propel reactor?
CM: The Propel™ has been on the market for the last two years. We've made some improvements since product launch to improve the uniformity performance for microLED applications which are available now and can be utilized with process technology which is available for license from ALLOS.

YD: Who in the market value chain should be the first customer of the combination of ALLOS' technology and license and Veeco's reactor? Should it be display manufacturers, LED manufacturers or others?
AL: In the areas you mention we see many parties interested and active. Sooner or later many of them will look for super uniform, large diameter GaN-on-Si epiwafer technology. We are open to work with everyone as we don't have any exclusive agreements. Also it is inspiring to see how many different ideas are around in the industry - sometimes even very radically different to other approaches - which leaves plenty of opportunities to explore.

CM: I'm really pleased to see how rapidly we're able to get to this point in GaN-on-silicon, but I think there is still reluctance and some degree of inertia towards sapphire versus silicon that needs to be overcome. I think the best way to achieve that is by results. This was a very good start, and we will continue to improve. I really want to see display-level brightness results which involves optimizing some of the epitaxial stacks for use at the right drive current. I think ultimately, display level performance will convince people.

Sources: - -

INTERVIEWEES

Christopher Morath, senior director, MOCVD strategic marketing at Veeco Instruments

Christopher Morath is senior director, MOCVD strategic marketing at Veeco Instruments. He has held several roles at Veeco during the last 7 years in marketing, engineering, and general management and has been engaging the micro-LED ecosystem since 2015. Christopher holds an MBA from the Wharton School and a Ph.D. in condensed matter physics from Brown University

Alexander Loesing, managing director of ALLOS Semiconductors

In 2003 Alexander Loesing co-founded AZZURRO Semiconductors, a pioneering supplier of advanced GaN-on-Si epiwafers to the LED, power semiconductor and RF industry. As a member of the Executive Board he was responsible for establishing customer relationships with leading global semiconductor companies. ALLOS Semiconductors is an IP licensing company for GaN-on-Si patents and technology and was also co-founded by Alexander. Since 2014 ALLOS is helping clients from the semiconductor industry worldwide to master GaN-on-Si technology by granting IP rights and transferring ALLOS' epitaxial technology to its customers' reactors. As CMO of ALLOS, Alexander continues to be responsible for customer relationships