~~Future~~ Present Foundry Model for III-V Manufacturing

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Abstract

This paper will discuss the evolving fabless, foundry-based model to produce VCSEL devices to meet the growing worldwide demand. How did we get here and what happens next will be addressed. What does a state-of-the-art III-V foundry look like today? We will attempt to answer how III-V chip suppliers compete and differentiate from one another in a world where everyone has access to III-V foundries. The goal is to inform and start a discussion on how fabless III-V chip companies will evolve and see what can be gleaned from the Silicon fabless industry.

INTRODUCTION

VCSELs are everywhere; in your optical mouse, in your cellphone, in the data center, and, soon, they will be in your automobile. How did this happen? The first 3 decades of VCSEL expansion relied on in-house cleanroom facilities that produced III-V epitaxial wafers and fabricated implanted and oxide-confined VCSELs. Each supplier had their own proprietary factory and processes with 10s to 100s of millions of dollars' worth of equipment. This was not an endeavor that small companies or startups could compete with without massive capital expenditure and years of development.

Over the past 5+ years or so, the in-house model for III-V VCSEL manufacturing has been changing in a big way. The ability to fabricate state-of-the-art VCSELs has been developed in foundries that are available to everyone. No longer is there the capital expenditure barrier, nor the time and commitment needed from investors to fund such developments. The availability of shared III-V foundries has caused many shifts in the VCSEL industry. Traditional optical component companies have accelerated their consolidations to stay ahead of the cost curve. Some have embraced the foundry model and began to manufacture their VCSELs outside of their own cleanroom facilities. At the same time, smaller players are emerging and taking advantage of the shared foundry capabilities with minimal investment and designs in hand.

NOTHING NEW

This, of course, is nothing new. The Silicon industry shifted to the fabless foundry model back in the 1980s. Looking at the logos below of fabless chip suppliers, that emerged out of the likes of IBM, Intel, HP, Texas Instruments, and others, which were vertically integrated, is quite eye opening. List below from Investopia.com [1].

Figure 1 Leading fabless Silicon chip companies

These fabless chip suppliers were able to focus their time and money on the design of innovative chip solutions rather than on the fabrication facilities, process development, equipment, and maintenance. The III-V industry is just at the beginning of this fabless revolution and a long ways from the Silicon industry. For example, the earlier adopters in III-V foundry production still had to work with these foundries to bring up key VCSEL process technologies. This is an important point. Not all foundry's offering III-V VCSEL manufacturing have the same state-of-the-art capabilities. The gap is narrowing, but there are clear early movers ahead of others. Over the next year(s) multiple foundries will begin to have equivalent state-of-the-art III-V processing capabilities. Eventually, chip designers will no longer need to also be fabrication process experts and will rely solely on a set of design rules provided by the foundry.

WHAT IS STATE-OF-THE-ART III-V FOUNDRY?

The following is a list of what a state-of-the-art III-V foundry is capable of doing at the time of this writing, 2019. Note: Specific details may have been left off due to the proprietary nature of information.

1) Fabrication of 6" GaAs wafers
2) Cassette-to-cassette wafer handling for all process steps
3) Photolithography with < +/- 0.5um variation across wafer
4) Oxidation with < +/- 0.5um variation across wafer (mostly limited by lithography and etching)
5) Dry etch capability for trench, mesa, dielectric, and other etching
6) Dielectric deposition control < +/- 10nm variation across wafer
7) Various metallization combinations including deposition, sputtering, and plating
8) Backside processing of 100um thinned wafer (lithography, etching, deposition, plating…)
9) Wafer-level testing of whole wafer (light output/emitter, near field, far field…)

10) Automatic optical inspection of each chip post dicing
11) Capacity to meet consumer, automotive, industrial, internet market demands

Figure 2 Example of the investment in equipment that foundries provide.

As noted above, these III-V foundry capabilities are still far from matching the Silicon foundry's capabilities. However, they are the state-of-the-art for III-V chip fabrication and is enabling 1,000s of 6" wafers to be processed per week with high yields to match the growing worldwide VCSEL demand. Capacity is enabled by significant capital investments provided by the foundry as demonstrated in Figure 2 below showing the rows and rows of test equipment necessary to meet demand. Figure 3 below providing an example of the control of oxidation aperture from run-to-run with a variation of <0.2um across a 6" wafer.

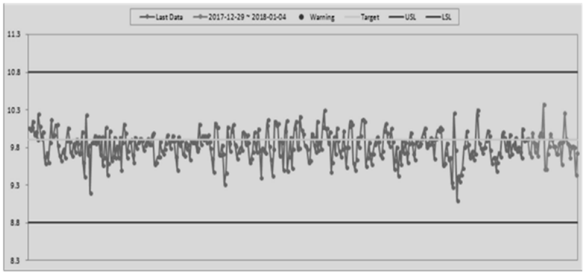

Figure 3 Example of foundry capability of oxidation aperture targeting from run-to-run with an average variation across 6" wafer of < 0.2um.

HOW DO VCSEL SUPPLIERS DIFFERENTIATE?

If everyone has access to state-of-the-art foundries, then how do chip suppliers differentiate? This is going to be the question to answer for the future of III-V industry. Let's take a look at some of the possibilities.

Performance, Power, Cost: The BIG 3 will continue to drive III-V chip innovation. Higher speed, higher power, better reliability, improvements in performance will always be needed. But…What is the cost for the performance improvements in terms of dissipation power and product cost. The trend has always been to have improved performance at the same or lower power dissipation. This is especially true to power sensitive (battery operated) products such as cellphones, tablets, and laptops. Cost is also the constant trend downward. It gets increasingly difficult to add features without significant increases in pricing. Apple, of course, does this extremely well, but, there are very few like Apple.

One stop shop, Convenience: Customers of III-V chip suppliers are typically module integrators or final product producers. Therefore, they would prefer to work with fewer vendors than more. A chip supplier that can supply VCSELs, PIN detectors, edge-emitting lasers, laser drivers, and receiver ICs provide a total solution vs. just a component. This is where Broadcom excels with the acquisition of Avago and exiting the transceiver market to become an integrated circuit and optical component supplier.

IP, Intellectual Property: Foundries are quickly becoming the keeper of IP and know-how. They are reluctant to work with customers that have unique IP, which limits their reach in providing foundry service to the world. This will become a major issue in the III-V foundry space. As we learn from the Silicon industry, companies such as Cadence and Synopsis become giant owners of IP through innovation and acquisition.

Niche Application, Industrial temperature, Defense, Aerospace: There is, of course, niche applications with

very special performance and reliability requirements that may be too small a market for mainstream chip suppliers. Industrial temperature ranges from -40°C to 95°C, or automotive/defense applications up to 125°C require special III-V solutions.

Integration: What is meant here is the addition of features to a simple VCSEL device. For example, integration of collimating lenses, a detector, or driver circuitry to simplify the module integrators work and provide a cost effective solution.

Time-To-Market: This can be very important to certain customers that have strict deadlines, competitive schedules, or quick product cycles. Fabless chip suppliers can move quickly to design new products without the worry to purchase and install new capacity. They rely on the foundries to have extra capacity, and contracts to insure that the extra capacity is available when needed. A smaller team of designers can thus compete with a medium or large size company that require personnel to manage their vertically integrated infrastructure (fab, facilities, maintenance, logistics, procurement…).

CONCLUSION

The III-V industry has just begun the transition to a fabless foundry-based chip supplier model. There is much to learn from the Silicon industry. It is an exciting time for the III-V industry and also a frightening time for established vertically integrated III-V component companies that are slow to adapt. The next few years and decade will see much accelerated changes in the III-V manufacture space.

REFERENCES

[1] www.investopia.com

ACRONYMS

VCSEL: Vertical Cavity Surface Emitting Laser
IP: Intellectual Property