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Is the time right for GaN - are its advantages over silicon more apparent?

Whether it is consumer electronics products, telecommunications hardware, electric vehicles or domestic appliances, exacting demands are now being put upon engineers to improve power conversion efficiencies, raise power density levels, extend battery lives and accelerate switching speeds. The electronics industry will become increasingly dependent on a new breed of power semiconductors utilising process technologies that are no longer Silicon (Si) based.

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With the capacity to reach performance benchmarks that weren't previously possible, Gallium Nitride (GaN) is now emerging as one of the process technologies that will shape the future of power system design.

GaN has had a major impact in several industry sectors over the last decade. In optoelectronics it has been instrumental in the development and proliferation of high brightness light emitting diodes (HBLEDs). In wireless communication it is already being employed in high power radio frequency (RF) devices. There is now huge potential for widespread adoption of GaN in power applications, with industry analysts Yole Research predicting that by 2020 the GaN power components business should be worth around $600 million annually.

For Yole's assessment of the market to be proven correct, a 100% compound annual growth rate (CAGR) will need to be witnessed over the next 5 years. There are, however, still numerous challenges to be tackled before that can happen.

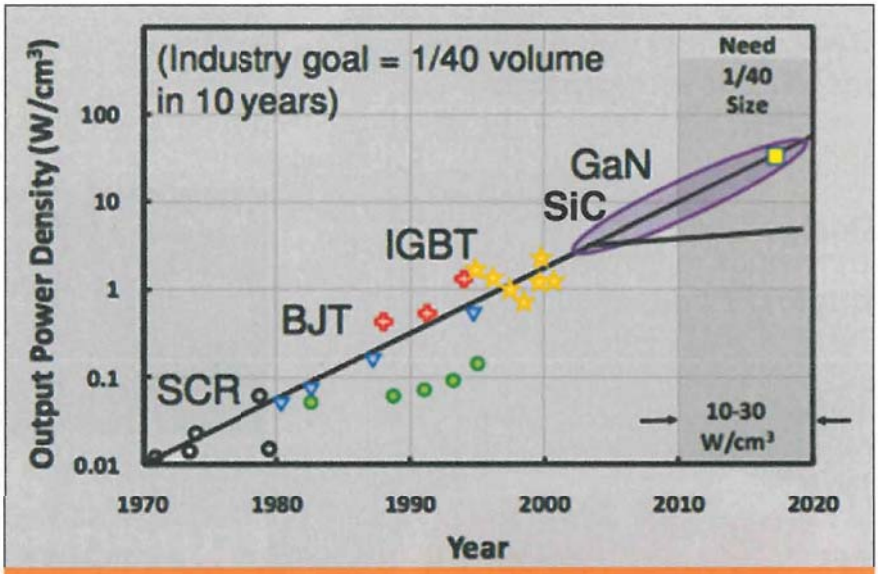

Figure 1- Potential improvements in power density using GaN

There is now huge potential for widespread adoption of GaN in power applications.

Why now?

Power system designs are experiencing greater space constraints. In the consumer electronics sector, for example, the compactness of the chargers being used for portable products is constantly becoming more streamlined. Likewise, the racks in data centres are becoming more packed. As a result, power densities need to be increased and power conversion efficiencies must be

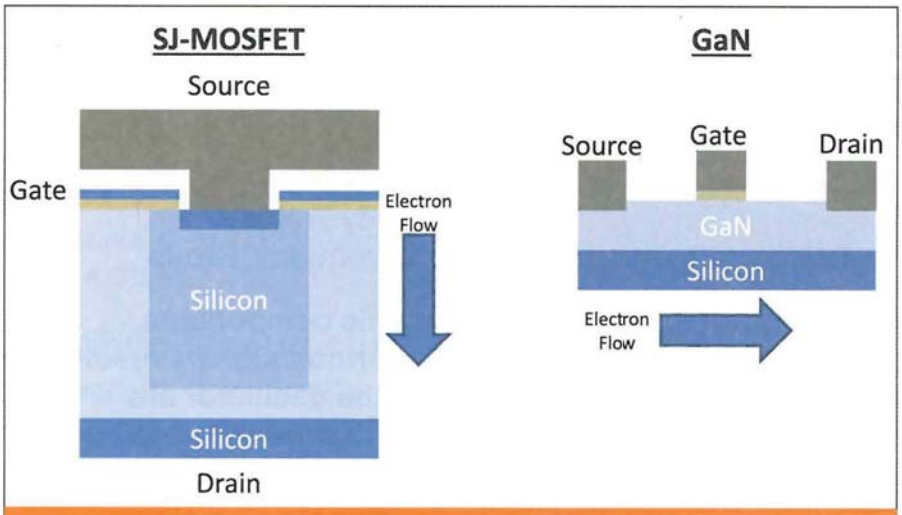

Figure 2- Similarities between GaN & Si manufacturing processes

improved, so that heat sinking mechanisms needed to accompany power ICs do not take up too much space. This has resulted in increased demands on power MOSFETs to operate at faster switching speeds.

The vast majority of current semiconductor process technologies are reliant on Si substrates. Long established Si processes have been the foundation of the electronics industry for many decades now. Though it has been an adequate means by which to carry out efficient power conversion, the time is approaching when it will not be enough. All that can be expected in the future is small incremental improvements in SI performances. Given that we seem destined to live in a power hungry society, alternative semiconductor technologies must be investigated.

What has GaN got going for it?

Si power devices are now starting to reach a stage where major performance improvements will be prevented from taking place. The unavoidable conclusion to be drawn from this is that Si's ability to support further technological advance is waning. There is now a clear need for something that is actually disruptive.

A certain degree of power conversion loss will be inherent within any power system design, but because of its wide bandgap, GaN exhibits significantly lower losses than Si. This translates into far better power conversion efficiencies. As a GaN die can be smaller than an equivalent Si die, devices based on this technology can be placed into package formats with reduced dimensions.

Due to its high mobility, GaN is extremely effective when used in circuits requiring high switching speeds.

Figure 1 shows the physical construction of a GaN HEMT device and how it is similar to existing MOSFET technology. The lateral electron flow in GaN provides both low conduction losses and low switching losses. Furthermore, increased switching speeds also help save space, as fewer passive components can be included in the power circuitry and the coils used in accompanying magnetic components can be much smaller. In addition, the greater power conversion efficiencies GaN offers mean that less heat needs to be dissipated - reducing the space that needs to be allocated for thermal management purposes.

Why has GaN been held up until now?

GaN possesses several key characteristics which set it apart from silicon and make it particularly well suited to power applications. However, the progression of GaN as a power device material has been slow. It is crucial for any chip technology to be able to offer high degrees of both uniformity and repeatability across their entirety, and previously this was something of an issue for GaN. As a result of the low yields stemming from GaN's production, Si has been able to offer considerable cost advantages which outweigh the performance shortfalls. This has allowed Si to hold on to its dominant position in power semiconductor production. That said, the fabrication processes relating to GaN are improving, with better yields being delivered, as well as demonstrating higher reliability.

GaN is in the enviable position that it can benefit from the fabrication infrastructure that is already in place for Si devices. By just adding only a few simple process steps with the same equipment, it can be applied to existing 6-inch and 8-inch CMOS Si manufacturing processes and, furthermore, can be scalable to 12-inch processes as soon as volume demands make it necessary.

With standard CMOS Si fabrication shifting to larger wafer sizes, there is a real opportunity for legacy manufacturing infrastructure originally for Si devices to remain in operation longer. This means that older chip production sites will get a second lease on life through switching their output to GaN. By driving the cost down in this way, new avenues will start to open up for GaN.

In the next few years, GaN will no longer just be considered as a niche semiconductor technology but will establish itself as commercially viable, large scale solution through which devices can be created which are capable of hitting price points that are more in line with silicon. Since last September, ON Semiconductor has been collaborating with Transphorm to bring GaN technology to the market. By combining Transphorm's knowledge of GaN with ON Semiconductor's expertise and portfolio of IP and volume production experience, the two companies will be able to bring power devices to market for next generation implementations.

Our demands for power are outpacing long-standing semiconductor technologies and something must be done to address this. When applied to power system designs, GaN has the capacity to enable dramatic performance improvements beyond what Si devices can achieve. As a result it is certain to have a huge part to play in the new era of power electronics - furnishing engineers with devices that enable greater efficiency, smaller form factors and faster switching speeds.

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