GaN ON SiC OR GaN ON Si?

To plan for the networks of tomorrow, solutions must deliver performance, efficiency and value. GaN on SiC accepts the challenge.

It's no secret that end users have a voracious appetite for data. According to Cisco's annual Visual Networking Index, annual global IP traffic is projected to more than triple between today and 2022, reaching 4.8 zettabytes per year by 2022 from 1.5 ZB in 2017. By 2022, traffic from wireless and mobile devices will account for 71 percent of that total — a staggering 3.41 zettabytes annually.

To deliver the bandwidth required to accommodate that rising demand, the wireless industry is moving full steam ahead from today's 4G networks towards 5G. Meanwhile, telecom operators are laser focused on delivering the best customer experience possible while containing both capital and operation expenditures. As such, they require infrastructure and technologies that deliver performance, efficiency and value. 5G promises greater bandwidth and reduced latency but operates in higher frequency bands than traditional cellular networks, making achieving these goals both a technological and operational challenge.

The next generation of wireless base stations — both macro and small cell — need to incorporate technologies that deliver on these performance, efficiency and value requirements, and Gallium nitride (GaN) has emerged as a vital component. However, when evaluating GaN solutions, a common debate emerges: Which is the better solution for RF applications, Gallium nitride (GaN) on silicon (Si), or GaN on silicon carbide (SiC)?

While there are advantages to each approach, "infrastructure designers choose the solution that offers the best overall value," says John Palmour, co-founder and CTO of Wolfspeed. "Silicon is a relatively cheap substrate compared with silicon carbide, but has some distinct disadvantages as well. SiC devices lead to lower system costs and better performance compared with silicon and, because of that, GaN on SiC is proving to have that best overall value."

There are several key characteristics of GaN on SiC, a wide bandgap technology, that together make it the best option for use in the telecom and wireless industries:

THERMAL CONDUCTIVITY

On top of the list of GaN on SiC's key benefits are its **thermal conductivity advantages**. GaN on SiC has three times the thermal conductivity of GaN on Si, allowing devices to run at a much higher voltage and higher power density. Palmour explains: "If RF devices put out high watts per square centimeter, you also have to dissipate a high watts per square centimeter. The better the thermal conductivity, the easier it is to get that heat out. SiC has great thermal conductivity — much better than Si."

A PERFECT (MATERIAL) MATCH

GaN and SiC are **lattice-matched**, meaning the lattice structures between the epitaxial layers allows a region of band gap change to be formed without changing the crystal structure of the SiC substrate material. This creates a **lower defect density** of the crystals, reducing leakage, improving reliability and creating an overall superior product. In contrast, GaN on Si is a mismatched material system; the crystalline structure of Si doesn't align well with GaN. For GaN to grow on Si, a more complicated epistructure is required to keep the wafer from warping, impacting time, cost and performance of the semiconductor.

The crystal defect density determines how many **"good" devices** can be derived from the wafer. GaN on Si delivers fewer good devices than GaN on SiC because it has a higher defect density. GaN on SiC can operate at a higher electric field than GaN on Si, and — because more good devices are derived — the GaN on SiC chip can be about 20 percent smaller than those utilizing GaN on Si, says Simon Wood, senior director of RF product development and applications at Wolfspeed. "We can put more watts on a 6-inch wafer than can be done with GaN on silicon. Our contention is that makes up any price difference with silicon," he said.

This is a benefit in designing for 5G applications, where base station footprint is important.

A MATTER OF EFFICIENCY

While silicon has high resistivity at room temperature, wireless infrastructure generally operates "hot." At high temperatures, silicon is conductive, and RF coupling to the substrate can occur. When it is cooled, the GaN will shrink more than the silicon substrate. With this, some RF power to the substrate is lost, decreasing efficiency. Because of its close match with GaN, GaN on SiC does not suffer from these same temperature change issues.

In addition, the cost to grow the GaN epitaxy on silicon is more than the cost to grow GaN epitaxy on silicon carbide. This gives GaN on SiC significant efficiency and cost advantages over GaN on Si.

Understanding Total Lifecycle Costs

In the end, for service providers building out networks to support the continuously increasing appetite for data, it's all about lifecycle cost — kilowatt hours and the energy they are burning.

"The GaN on silicon vendors says that SiC is more expensive, and if you are only measuring that topline cost, that may be true," Palmour says. "But the advantages GaN on SiC brings from an overall value perspective makes GaN on Si and GaN on SiC comparable price-wise, with the undisputed technology advantages going to GaN on SiC."