

Specialty devices are the unsung heroes of modern life. For many in the semiconductor industry today, the spotlight is on the SiC and GaN power devices used in automotive, green energy, fast-charge consumer electronics (CE), and high-performance computing (HPC) applications (Figures 1 and 2).

However, specialty devices are more than just power devices. They are a broad class of semiconductor components delivering a variety of functions across multiple industry segments, including microelectromechanical systems (MEMS) in automobiles and CE to radio frequency (RF) filters for 5G/6G communications.

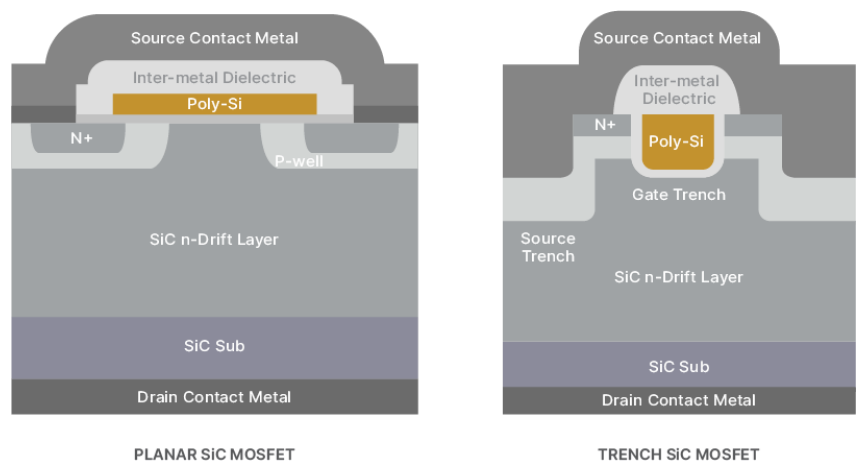


Figure 1: Planar SiC MOSFET and trench SiC MOSFET

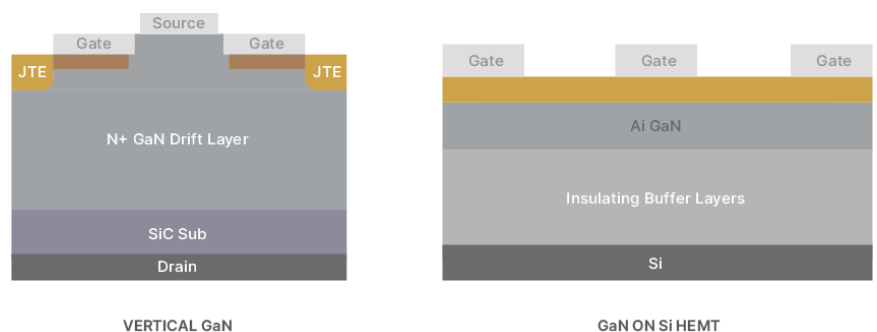


Figure 2: Vertical GaN and GaN on Si high electron mobility transistor (HEMT)

The Specialty Device Surge Part 1: Wafer Size Transitions Are Powering the Future of Specialty Devices and Bringing New Challenges

By Christopher Haire,
 Onto Innovation

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Photonics are another type of specialty device making industry waves. Previously viewed as something of a dark horse in the specialty sphere, photonics have made a comeback. Today, photonics are being used for 3D sensing in multiple CE applications such as smartphone user verification and 3D imaging, automotive applications in which scanning lasers are used in advanced driver assistance systems (ADAS); and telecommunications applications where photonics have long been used as optical transceivers

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supporting the conversion of copper wiring to optical fiber communications in data centers. While these applications and others exist for photonics, the killer photonics application is shaping up to be co-packaged optics (CPO), which enables optical communications directly from packaged XPU devices supporting AI applications.

When it comes to the broad category of specialty devices, nearly all of them are either manufactured on or previously manufactured on 150mm or 200mm wafers. However, specialty devices are moving to larger wafer sizes, either 200mm or 300mm depending on device type.

With many specialty devices scaling to larger wafer sizes, the semiconductor industry faces new challenges in process control. After all, specialty devices are known for delivering specialized features or capabilities based on a unique process step or material that often requires a customized inspection and metrology solution.

To optimize the manufacturing process, real-time process control — powered by data analytics and software — has become an indispensable requirement in specialty device fabrication. To scale specialty technologies for high-volume manufacturing, manufacturers need integrated solutions and specialty-focused platforms offering flexibility, precision, and automation across multiple wafer sizes.

In this three-part blog series, we will begin by discussing one of the most important trends in specialty devices, the transition to larger wafer sizes and what this means for specific devices. The following blogs will focus on the challenges facing the manufacturing of specialty devices and the solutions addressing these challenges.

From Niche Applications to Mainstream Products

Originally, specialty devices were referred to as More-than-Moore devices because the use of these devices went beyond the simple node scaling of traditional CMOS devices. They also were being enabled by one or more “specialty” materials or process steps. In fact, the semiconductor industry did not start using the term “specialty devices” until these devices transitioned from niche applications to mainstream products and high-volume production.

But what exactly are the benefits of these specialty materials? Let’s consider the case of specialty power devices.

The compound semiconductors used in power specialty devices, SiC and GaN, can handle high voltages more efficiently than traditional Si. They provide the ability to switch high voltages in increasingly smaller areas and at higher speeds than their silicon-based counterparts. They do this without the elaborate cooling that would otherwise be required. As these materials scale to larger

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wafer sizes, they necessitate upgrades in wafer fabrication equipment, inspection, and metrology tools.

Transitioning Wafer Sizes

Specialty devices have long been the domain of 150mm and 200mm wafers, with CMOS image sensors (CIS) and power management devices being the exception. That's all changing.

On the compound semiconductor front, the high demand for GaN-based high-power, fast-switching technologies is motivating a wafer size transition from 200mm to 300mm while SiC power devices are transitioning from 150mm to 200mm in high-volume manufacturing. In addition, photonics technologies now span wafer sizes of 150mm to 300mm, and MEMS devices are offered at 300mm.

As more specialty device technologies move into high-volume manufacturing, we can expect to see a greater demand for 300mm silicon, glass, and compound semiconductor-based wafer applications. However, this transition to larger wafer sizes introduces unique challenges for each specialty device type. These devices and their challenges include:

MEMS: Larger substrates and diverse materials (Si, glass, thick metals) require tighter process control of etch depth and CD, feature height across bowed or warped wafers, and surface roughness.

SiC Power: As SiC power moves to 200mm, inspection and metrology must expand sampling, deal with increased crystal defects, and support device architecture transitions profiling complex trench MOSFETs (e.g., top/bottom CD) without killing throughput. Insufficient sampling on larger wafers creates blind spots that hurt yield and cost of ownership.

GaN Power: Moving GaN to 300mm wafers increases within-wafer variation, requiring more measurement points and precise control of trench/HEMT critical dimensions to maintain uniform performance, while dealing with increasingly brittle and bowed or warped materials.

Photonics and CPO: Co-packaged optics require metrology tools designed for die-to-die and wafer bonding (voids, Cu dishing, film variation), sub micron alignment, and warpage, which affects optical coupling on larger wafers and multi die assemblies.

CIS: CIS stacks drive high sampling density for overlay and CD uniformity. These stacks require integrated chemical mechanical planarization metrology and analytical tools to catch excursions quickly as die counts and wafer diameters increase.



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To meet these challenges and others, manufacturers need upgraded metrology and inspection tools, many of which will come from suppliers with a long-standing relationship with specialty technologies. These suppliers are best prepared to meet the wafer handling, on-wafer materials, and cost-of-ownership requirements that have become synonymous with the specialty device markets.

Conclusion

The emergence of specialty devices as a vibrant market of their own is driven by the increasing complexity and functionality of end products. Even in mature markets, such as smartphone and automotive, manufacturers continue to innovate by adding new features, which, in turn, fuels demand for additional specialty devices.

In our next blog, we will further explore the many challenges facing each type of specialty device. We hope you join us as we discuss those challenges and, in part three of our series, the solutions that are available in the specialty space today.

Biography

Christopher Haire is a marketing content specialist at Onto Innovation and a former business journalist.