Entegris

Enabling the SiC Era:

End-to-End Wafer Processing Solutions

White paper

Silicon carbide (SiC) has become essential to next-generation power and radio frequency (RF) devices due to the material's wide bandgap, high breakdown field, and thermal conductivity. However, the path from a single crystal boule to finished device includes complex and costly processing steps that challenge both performance and yield. As SiC demand accelerates – driven by end markets such as electric vehicles, renewable energy, data centers, and industrial systems – manufacturers need integrated SiC processing solutions that address performance, cost of ownership (CoO), and scalability.

Entegris offers a comprehensive portfolio of materials and products that support the entire SiC wafer processing chain, from crystal growth and substrate preparation to final device fabrication – together with unmatched expertise and understanding of the challenges these steps pose. This white paper spotlights Entegris' proficiency and offerings in three core areas:

- Advanced graphite with tantalum carbide (TaC) coatings for crystal growth
- High-performance chemical-mechanical planarization (CMP) slurries, pads, and cleaners for substrate processing
- Proprietary epi rings for stable, low-defect SiC epitaxy

Together, these solutions help device manufacturers reduce costs, improve yield, and achieve cleaner, more uniform materials at scale.

GRAPHITE TECHNOLOGY FOR CRYSTAL GROWTH

Producing defect-free SiC boules via physical vapor transport (PVT) requires ultra-pure, high-performance components that can withstand extreme temperatures and corrosive environments. Different furnace components – including crucibles, deflectors, and seed brackets – can be customized with specific graphite grades and coating chemistries, enabling performance tuning for growth of 150 mm and 200 mm SiC boules.

Entegris' graphite components, coated with TaC, are designed specifically for this purpose. The underlying graphite core, which undergoes proprietary purification and surface preparation steps before TaC coating, offers the ideal platform. The specialized Entegris graphite materials are precision engineered to enable development of tailored solutions by targeting critical performance requirements, including:

- High purity
- Dimensional stability under thermal stress
- Optimized thermal expansion compatible with the TaC coating
- Excellent structural integrity and thickness control

Moreover, Entegris is working to further improve TaC deposition processes and cost structures. Early-stage evaluations show promising performance in adhesion strength and coating stability. The company's legacy in high-end graphite applications – from aerospace and biomedical implants to semiconductor processing – provides a solid foundation for success in SiC crystal growth.

THE CHALLENGE OF SIC SUBSTRATE PREPARATION

Once boules (large, cylindrical ingots of single-crystal silicon carbide) are sliced into wafers, achieving a defect-free, mirror-smooth surface becomes the next challenge. SiC's hardness makes mechanical polishing alone impractical, while its brittleness raises the risk of surface damage if processing conditions are not tightly controlled. These difficulties intensify as wafer sizes increase, making uniformity across the surface even harder to maintain.

CMP is therefore indispensable for preparing SiC wafers for epitaxy and device fabrication as the wafer moves from boule to polished substrate. The process must deliver high material removal rates while achieving excellent surface finish and minimal subsurface damage. Traditional CMP consumables, developed for silicon, often cannot balance these requirements for SiC, leading to slow throughput or poor surface quality. Entegris' CMP portfolio was developed specifically to overcome these limitations, delivering industry-leading rate, reusability, and cost advantages.

HIGH-PERFORMANCE SLURRY TECHNOLOGY

Entegris' G11 high-rate slurry represents a breakthrough in addressing the fundamental CMP challenges. Key attributes include dilutability, with high removal rate; excellent surface finish; and simplified maintenance and handling due to very low solids content.

At removal rates of 7.4 µm/hr under standard polishing pressures, and more than 10 µm/hr at higher pressure-velocity conditions, the slurry enables wafer manufacturers to meet throughput requirements that were once out of reach. For fabs transitioning to 200 mm wafer production, such performance is essential to avoid bottlenecks and maintain cost competitiveness.

Removal rate alone, however, is not sufficient. The G11 slurry offers high-rate performance without sacrificing the fine surface finish needed for defect-sensitive epitaxy. This is achieved through optimized abrasive particle chemistry and Entegris' proprietary formulation designed specifically for SiC's hardness and brittleness.

Another defining feature of the slurry technology is its recyclability. By maintaining high removal rates under diluted conditions, the slurry supports re-use and recycling strategies that reduce chemical consumption and waste. This not only lowers CoO but also aligns with the semiconductor industry's broader push toward sustainability and resource efficiency.

SYNERGISTIC PAD TECHNOLOGY

Entegris pads are engineered to complement high-rate slurries, offering:

- 9% boost in removal rate through pad optimization
- Excellent toughness for extended pad lifetime
- Large pad diameters (up to 46 in.) to support multiple CMP platforms
- Profile control via sub-pad architecture for better wafer edge uniformity

Slurry performance is directly tied to pad design – Entegris' pad technology was developed with this in mind. When paired with the G11 slurry, Entegris pads can boost removal rates by approximately 9%, demonstrating the synergy of co-optimized consumables. More importantly, the pads extend lifetime well beyond conventional alternatives, providing a critical economic advantage. Longer pad life means fewer changeouts, reduced downtime, and more consistent process performance over extended polishing runs.

Pad engineering also addresses one of the trickiest aspects of SiC CMP: edge uniformity. At wafer diameters of 200 mm, maintaining consistent removal across the entire surface is challenging, particularly at the edges where pad deformation often causes over-polish or non-uniformity. Entegris' pad designs, including the use of sub-pads to control pad protrusion, mitigate these issues and ensure a more uniform surface profile.

Extending pad life reduces operational interruptions and increases fab utilization. Combined with the slurry's recyclability, the pads represent a cornerstone of Entegris' strategy to deliver lower total CoO while also supporting higher yield and reliability.

ADVANCED POST-CMP CLEANING PORTFOLIO

Cleaning chemistries are tuned to minimize post-polish defectivity and support pad longevity, delivering defect control, ease of use, and compatibility across SiC CMP workflow. They include:

- PCL185/186: Slurry-neutralizing cleaners for wafers and pads
- PCL565: Alkali-based chemistry effective on alumina, silica, diamond, zirconia residues
- One cleaner: All-in-one solution (H_2O_2-free) for pad and wafer cleaning

Once polishing is complete, wafers must undergo thorough cleaning to prepare them for subsequent process steps, particularly epitaxy. This stage is critical because any residual abrasive particles, slurry chemicals, or organic contaminants can cause defects in the epitaxial layer or even lead to device failure. SiC manufacturers are especially sensitive to defectivity at this stage because power devices must maintain performance over long lifetimes and in harsh operating environments.

Entegris addresses these needs with a comprehensive portfolio of cleaning chemistries. The PCL 185/186 formulations act as pad cleaning and slurry neutralization agents, breaking down residual slurry compounds and preventing re-deposition onto wafer surfaces. When combined with PCL 565, an alkali-based cleaner, fabs can reliably remove particles of alumina, silica, diamond, or zirconia – the abrasives most commonly used in CMP. This two-step cleaning sequence delivers industry-leading defect performance and ensures wafers are ready for subsequent epitaxial deposition.

For fabs seeking simplicity, Entegris' "one cleaner" solution offers a consolidated alternative. Free of hydrogen peroxide, this chemistry provides both wafer and pad cleaning capability in a single step, reducing process complexity and chemical inventory requirements. By minimizing the number of chemistries needed while maintaining strong defectivity control, fabs gain process flexibility without compromising performance.

NEXT-GENERATION SiC EPI RINGS: SUPERSiC™-3C TECHNOLOGY

While CMP ensures substrates are flat, smooth, and defect-free, epitaxial deposition determines the quality of the active device layer. The components used within the epi reactor, particularly epi rings, have a direct influence on uniformity, yield, and cost of operation.

Entegris' next-generation SUPERSiC™-3C epi rings consist of fully converted SiC from purified graphite, forming a robust, thermally stable base that is then coated with a proprietary 3-mil chemical vapor deposition (CVD) SiC layer to provide a dense and smooth surface for the final application. This design offers exceptional resistance to aggressive epitaxy chemistries, while delivering superior mechanical integrity and stability, even under repeated high-temperature cycles.

A key advantage of SUPERSiC™-3C epi rings is their ability to be refurbished. A two-level approach has been developed; at Level 1, parasitic SiC deposits can be removed without compromising the integrity of the base material, allowing the rings to be reused multiple times. Level 2 offers removal of the CVD SiC coating as well before recoating and proprietary post-processing steps to deliver a high-quality part back to the customer. This significantly reduces consumable costs and waste, aligning with fabs' goals of lowering CoO and advancing sustainability.

Beyond epitaxy, this platform opens doors for use in other demanding semiconductor applications, from ion implantation to metal-organic CVD (MOCVD), as well as in aerospace and defense optics where thermal stability and surface polish are critical. For SiC manufacturing, however, its most immediate impact lies in enabling high-quality epitaxial layers that are essential for high-performance, reliable power devices.

CONCLUSION

As demand for SiC accelerates and manufacturers expand capacity, the ability to rely on a single partner for end-to-end solutions is a powerful differentiator. Entegris has developed novel solutions for the entire SiC process, ensuring that device manufacturers, foundries, and fabs can scale SiC with confidence, meeting both performance and economic requirements.

On top of technical performance, what further sets Entegris apart is the products' ability to reduce total CoO and advance sustainability. Recyclable slurries, long-life pads, effective cleaning chemistries, and refurbishable epi rings all contribute to lowering waste and extending consumable lifetimes, supporting fabs' environmental goals while improving profitability.

By combining innovation, integration, and proven expertise, Entegris stands as the partner of choice for fabs seeking to unlock the full potential of silicon carbide.

To learn how we can help solve your SiC wafer-processing challenges, contact Entegris today.

ABOUT ENTEGRIS

Entegris is a world-class supplier of advanced materials and process solutions for the semiconductor and other high-tech industries. Entegris is ISO 9001 certified and has manufacturing, customer service, and/or research facilities in the United States, Canada, China, France, Germany, Israel, Japan, Malaysia, Singapore, South Korea, and Taiwan. Additional information can be found at entegris.com.

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