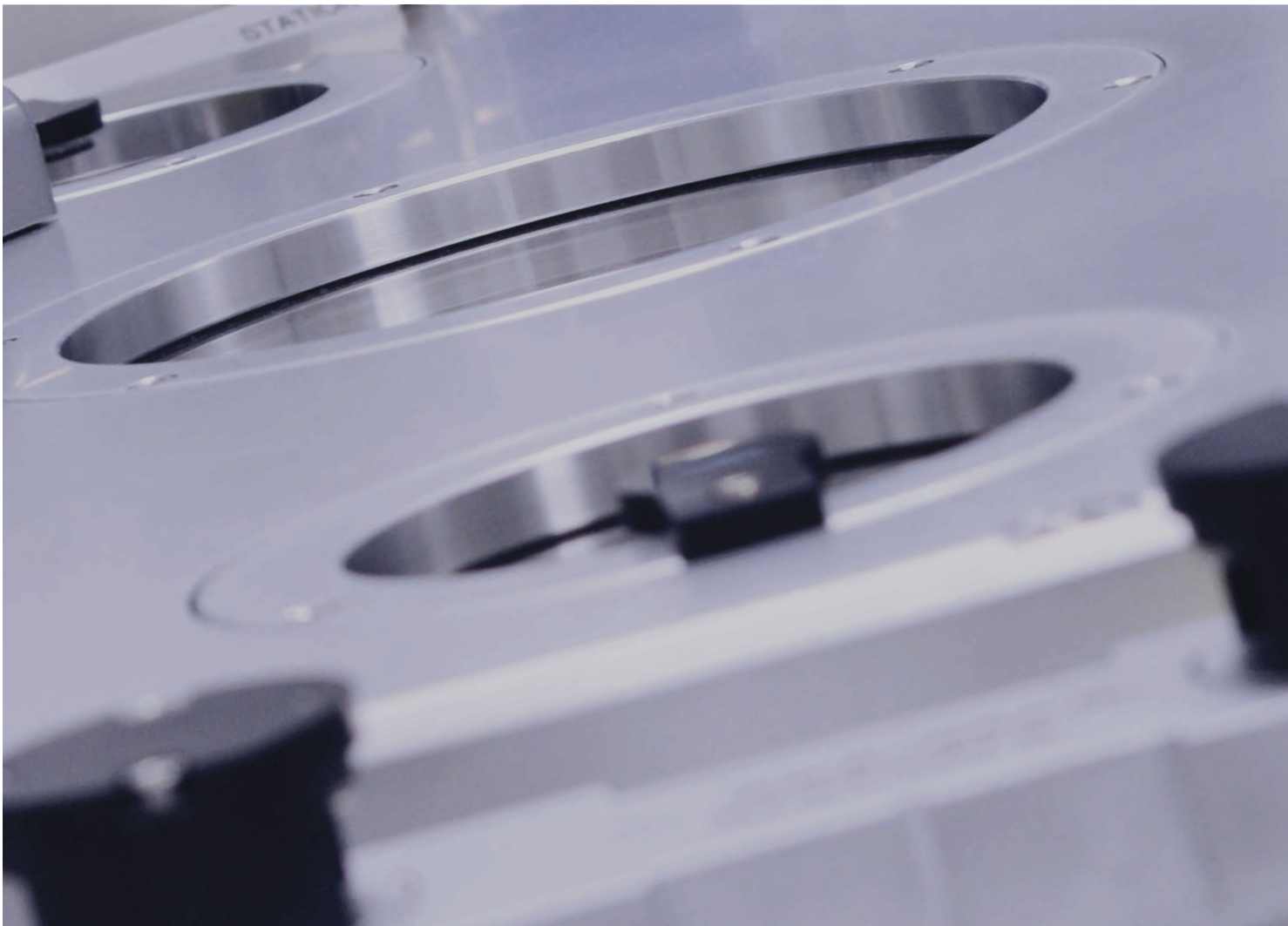




EV GROUP® | Products // Bonding // Permanent Bonding Systems

EVG® ComBond®



Introduction

The EVG ComBond high-vacuum wafer bonding platform marks a new milestone in EVG's unique portfolio of wafer bonding equipment and technology in response to market needs for more sophisticated integration processes. The application areas supported by ComBond range from advanced engineered substrates, stacked solar cells and power devices to high-end MEMS packaging, high-performance logic and "beyond CMOS" devices.

The modular cluster design of EVG's ComBond system allows for a highly flexible platform that can be tailored to various demanding customer needs both in R&D and high-throughput, high-volume manufacturing environments.

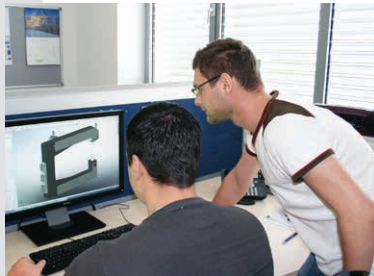
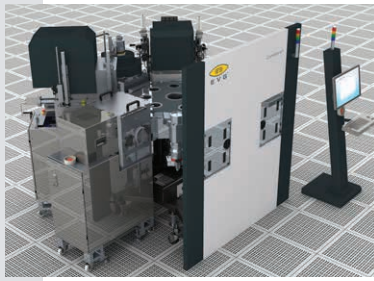
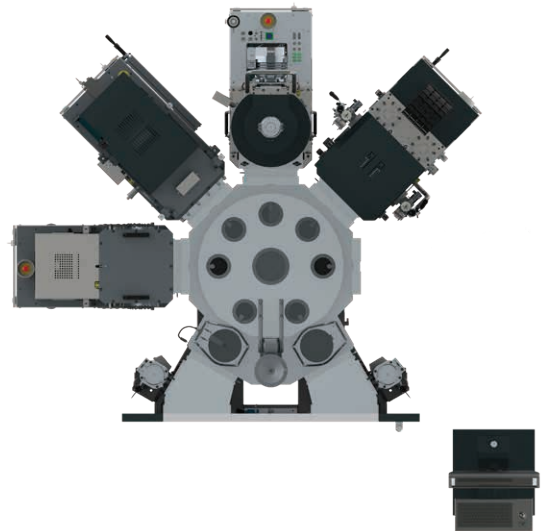
EVG's breakthrough wafer activation technology and high-vacuum handling and processing allow the formation of covalent bonds at room or low temperature for fabricating engineered substrates and device structures. The EVG ComBond facilitates the bonding of heterogeneous materials with different lattice constants and coefficients of thermal expansion (CTE) as well as the formation of electrically conductive bond interfaces by its unique oxide-removal process.

The EVG ComBond high-vacuum technology also enables low-temperature bonding of metals, such as Aluminum, that re-oxidize quickly in ambient environments. Void-free and particle-free bond interfaces and excellent bond strength can be achieved for all material combinations.

For vacuum encapsulation using aligned wafer bonding, the EVG ComBond system advances its bonding capability through the addition of programmable dehydration bake and getter activation modules and the optical alignment module with wafer clamping.

The high-vacuum handling and processing platform addresses rising demand for lower vacuum levels in leading-edge MEMS and other applications.

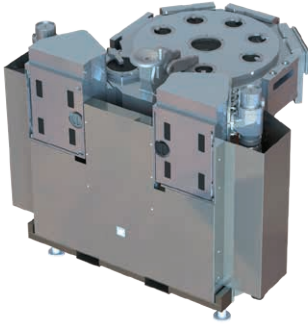
The EVG ComBond is a real breakthrough technology that facilitates the bonding of nearly "anything on anything" in wafer form and enables emerging device designs.



Product Overview

The EVG ComBond uses a high-vacuum handling cluster, which can support multiple modules, including CAM (ComBond Activation Module), bake modules for high-vacuum applications, an optical aligner based on EVG's industry standard SmartView aligner, wafer bonding with high-force capability, and elevated temperature for metal-based bonding. Additionally, the modular nature of the cluster tool allows for the addition of custom modules to meet specific customer requirements.

EVG ComBond® High-Vacuum Cluster

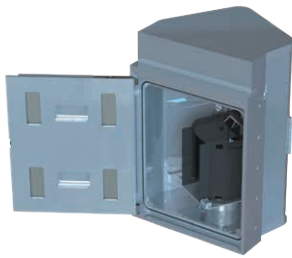


ComBond® High-Vacuum Cluster

The cluster maintains fully automated wafer transport and handling at a base pressure of $< 7 \cdot 10^{-8}$ mbar. The system provides:

- Manual, cassette or EFEM loading with load lock functionality
- Substrate handling robot
- Up to six free high-vacuum ports for process modules
- Bake-out option

The cluster with all process modules has a minimal cleanroom footprint. Process modules can be operated independently and are accessible for servicing without venting the cluster or leaving other process modules idle.



ComBond® Loading Stations

Cassettes:

- Double pitch for up to 12 substrates
- Directly loaded into the load lock

EFEM:

- Three to four standard cassettes or SMIF pods
- Substrates are loaded into a buffer of the load lock (unloaded from the buffer respectively)

EVG ComBond® Modules

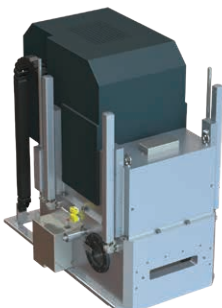


ComBond® Bond Module

Based on field-proven EVG modular bonding systems, the ComBond bond module supports wafer stacks of up to 4 mm, featuring EVG's standard process capacity and specifications, e.g. maximum bonding force and uniformity, temperature range and uniformity, and fast heating/cooling ramps.

Features of the bonding chamber include:

- Enhanced vacuum level of $< 5 \cdot 10^{-8}$ mbar to prevent surface oxide formation
- 25 mm of open space between heaters for reliable removal of outgassing products at elevated temperatures

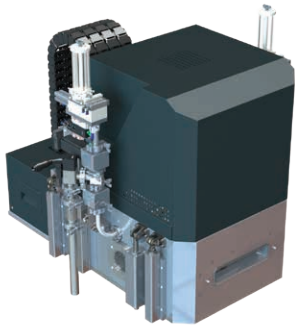


ComBond® Activation Module (CAM)

Direct, covalent room-temperature wafer bonding requires defined wafer surface conditions. The ComBond Activation Module (CAM) principle is based on a dry etch process that directs energized particles onto a surface. The standard module configuration features various process parameter settings that enable flexible process conditions for different materials and applications.

- The CAM surface treatment technology achieves:
- Oxide-free and particle-free surfaces with < 5 particles ($> 0.2 \mu\text{m}$) added per wafer
- Low surface roughness
- Uniform oxide removal and surface activation
- High throughput

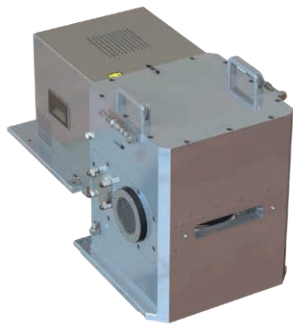
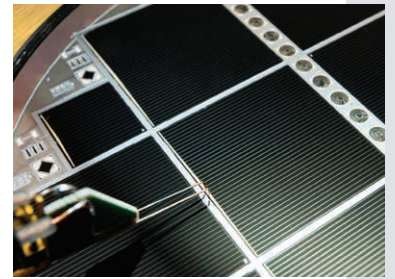
EVG ComBond® Modules



ComBond® Vacuum Align Module (VAM)

Based on the field-proven EVG SmartView aligner, the VAM has the capability to perform face-to-face alignment, backside alignment as well as infrared alignment. New features for the VAM are:

- Force up to 1000N
- Base pressure: $< 5 \cdot 10^{-8}$ mbar
- Magnetic spherical clamping unit for wafer fixing after alignment and wafer transfer to bond module
- Bake-out option

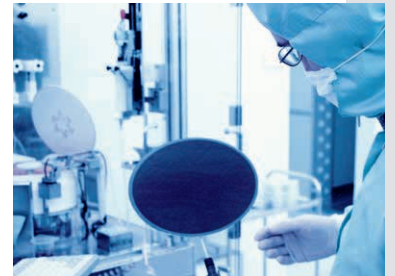


ComBond® Bake Module (BOM)

The ComBond Bake Module (BOM) is used to accelerate the removal of residual moisture gas prior to bonding the substrates. This results in improved bond quality as well as reduced gas pressure in potentially existing cavities.

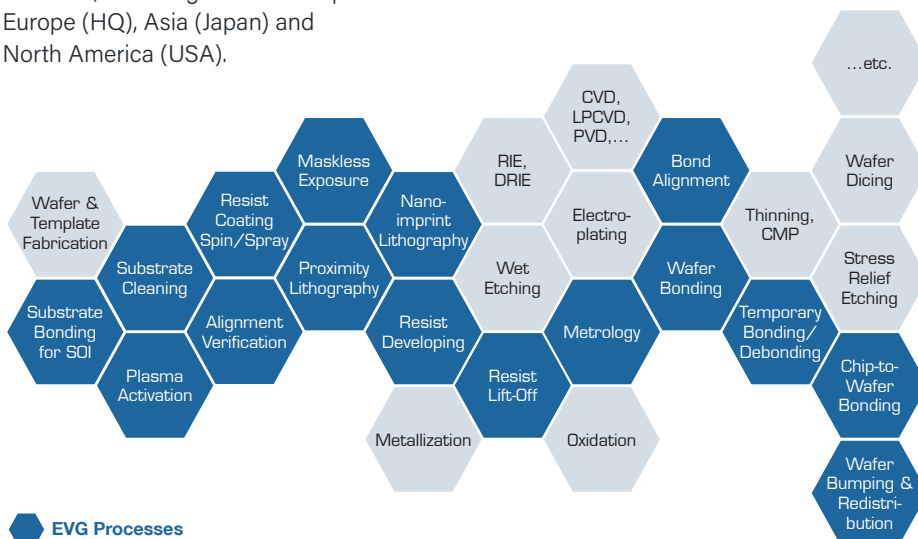
Features include:

- Special ceramic heaters for high cleanliness and efficient heat transfer
- Storage of up to six substrates simultaneously
- Max. temperature: 450°C
- Base pressure: $< 5 \cdot 10^{-8}$ mbar



Software and Support

The Windows-based, graphical user interface is designed with a strong focus on user-friendliness, and easily navigates the operator through each process step. Multi-language support, individual user account settings and integrated error logging / reporting and recovery can simplify the user's daily operation. All EVG systems can also communicate remotely. Thus, our service includes field-proven, real-time remote diagnostics and troubleshooting via secured connection, phone or email. EVG's experienced process engineers are ready to support you anytime thanks to our de-centralized worldwide support structure, including cleanroom space on three different continents: Europe (HQ), Asia (Japan) and North America (USA).



EVG Processes

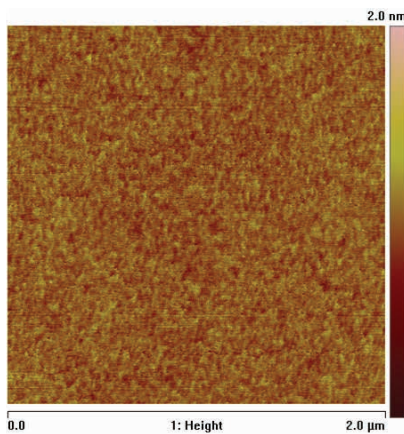
Process Results

The EVG ComBond technology is designed to enable high-vacuum wafer processing in high-volume production lines. It focuses on advanced engineered substrates for “beyond CMOS” applications, such as high-mobility transistors, high-performance/low-power logic and RF devices, photodetectors, power devices, stacked solar cells and special MEMS.

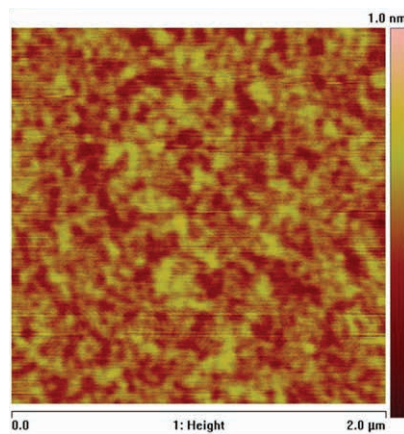
Key capabilities of the EVG ComBond are covalent and conductive bonding processes at room temperature or low temperatures. These processes facilitate the direct bonding integration of heterogeneous materials like germanium (Ge), gallium arsenide (GaAs), indium phosphide (InP), gallium nitride (GaN), crystalline silicon carbide (SiC) on silicon and other semiconductor substrates. Moreover, low-temperature metal-metal bonding and high-vacuum encapsulation of devices are enabled.

The crucial process is the effective removal of particle contamination and surface oxides, while maintaining rigorous requirements in cleanliness, surface roughness, and process uniformity. Bond interfaces with sufficient bond strength and a minimal defect area are achieved at low bonding temperatures. The analysis of the different process steps illustrates the successful implementation of the technology for various types of semiconductors as well as metals.

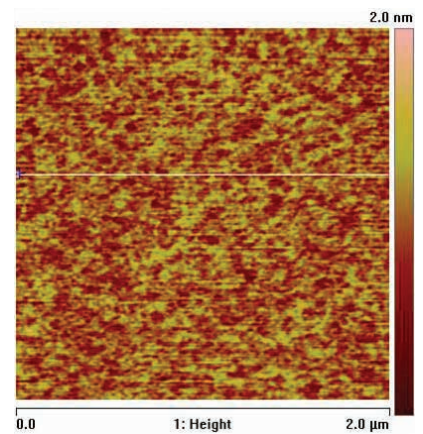
Surface Activation Results



Silicon: Roughness RMS (Rq) < 0.1 nm

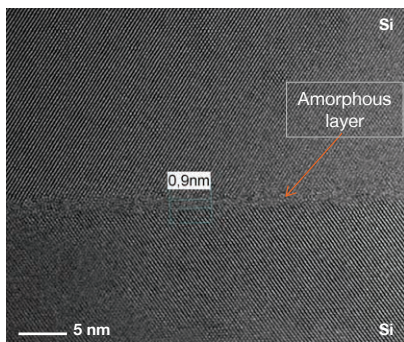


GaAs: Roughness RMS(Rq) < 0.1 nm*
*Courtesy of Fraunhofer ISE

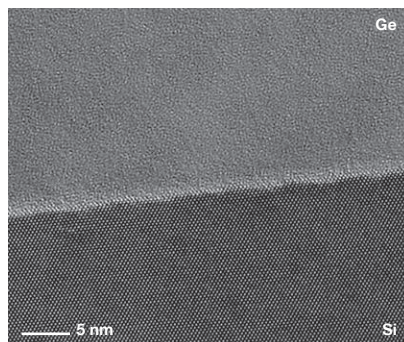


SiC: Roughness RMS (Rq) < 0.13 nm

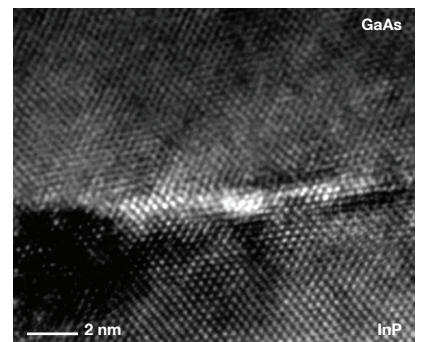
Post-bond Results



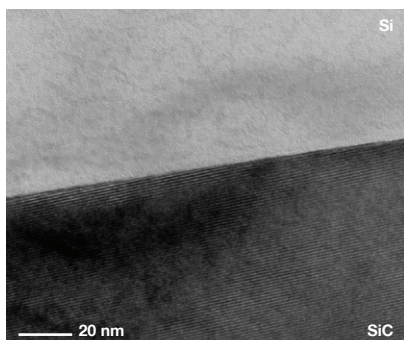
Silicon - Silicon Bond Interface



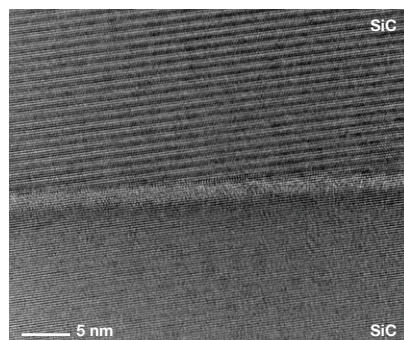
Ge - Si Bond Interface



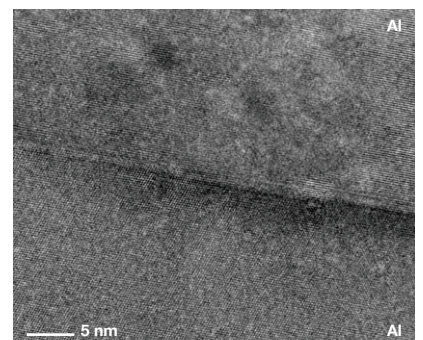
GaAs - InP Bond Interface*
*Courtesy of Fraunhofer ISE



SiC - Si Bond Interface



SiC - SiC Bond Interface



Al - Al Bond Interface



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