CS International 2024

Heterogenous Integration of Compound Semiconductors by W2W and D2W Bonding

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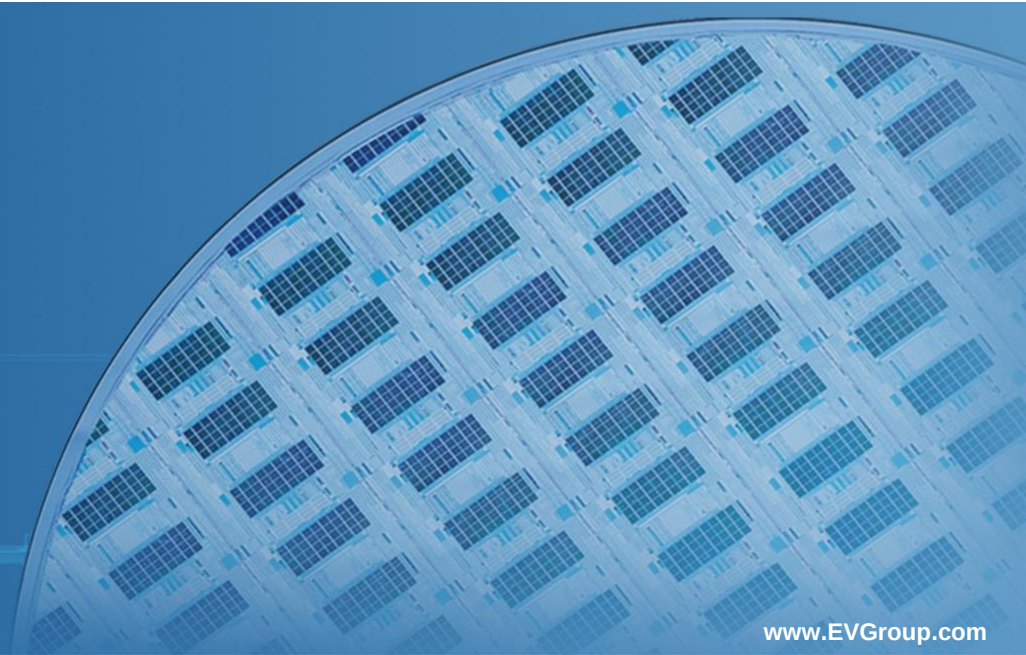
Business Development Manager



EV Group | At A Glance

Leading supplier of wafer processing equipment for the MEMS, nanotechnology and semiconductor markets

Founded in 1980 by DI Erich and Aya Maria Thallner. More than 1300 employees worldwide

Headquarters in Austria, with fully owned subsidiaries in the USA, Japan, South Korea, China and Taiwan

EV Group Headquarters

St. Florian am Inn, Austria

EVG Enables Full Process of µLED Displays Fabrication

Metrology

Wafer cleaning

Hybrid Bonding

Nanoimprint Lithography

Collective die to wafer transfer

Low temperature bonding

Color Conversion

Glass bonding

Resist processing

Temporary bonding

High precision bonding

Metal bonding

De-bonded carrier wafer

µLED Mass transfer

Waveguide NIL

Adhesive bonding

De-bonding

Wafer-level optics formation

< 8'' EPI wafer

12'' Carrier wafer

Reconstituted 12'' wafer

CMOS driver wafer

Singulated micro display

AR glasses

Wafer Processing

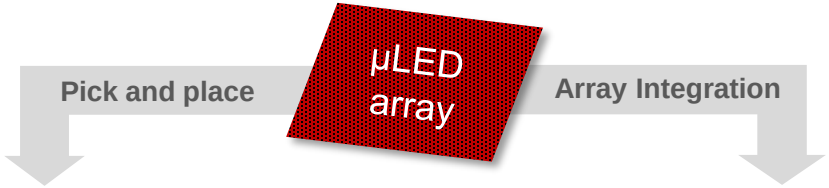
Epitaxial Transfer

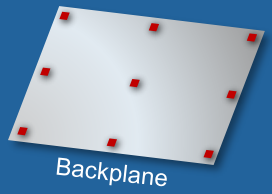
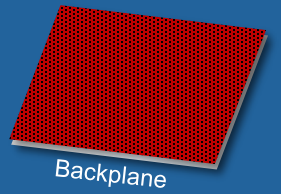
µLED Fabrication

Optics Formation

Waveguide Integration

µLED | End Products Overview

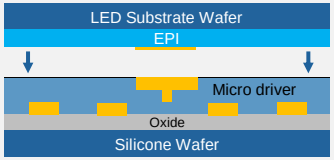


	Direct view display		Micro display
			
Product	**µLED Pixel**	**µLED Smart Pixel**	**µLED array on CMOS driver**
Applications	Smart watch, smart phone, laptop, TV…		AR, HUD, VR…
Further processing	Mass transfer		Integration with optics
Bottleneck	Mass transfer of the pixels		Extreme pixel pitch

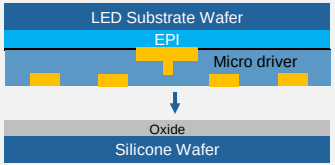
The following slides show a representative but not full list of EVG technologies for µLED displays manufacturing. The process flows vary significantly from company to company.

µLED | Smart Pixel Process Flow

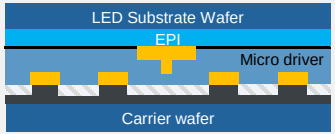
1. Adhesive bond, Metal aligned bond



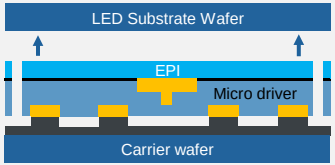
2. Carrier removal



3. Adhesive bonding

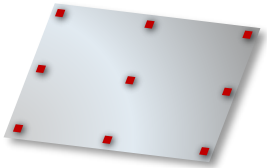


4. Substrate LLO, Patterning + Etching



Next step: mass transfer

Smart pixel process requires a wide range of bonding technologies, including adhesive and metal bonding

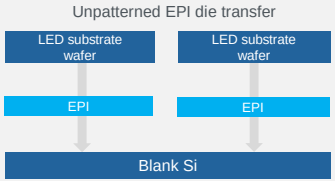


Direct View Display

EVG Technology	Application	Equipment
Ultra Thin Layer Transfer	CMOS driver substrate (SOI)	EVG850LT
IR-Laser Release	Alternative to thinning and wet oxide etching	EVG850DB
Adhesive bonding	EPI transfer + LED transfer	EVG5XX, EVG850, Gemini
Laser Lift Off	EPI substrate removal	EVG850DB
Metal Bonding	Integration	EVG5XX, Gemini

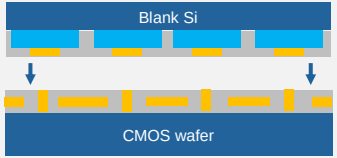
µLED | Micro Display Process Flow

1. LED wafer reconstitution

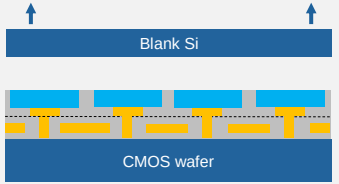


2. Reconstituted wafer planarization and patterning.

3. Hybrid bond

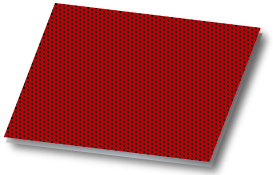


4. Carrier removal,



Next steps:
Optics, color conversion integration

µDisplay manufacturing requires high precision aligned bonding to fulfill the fine pixel Pitch requirements



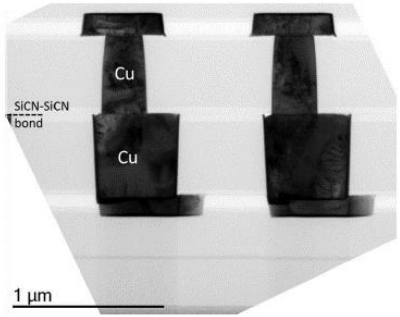
Micro Display

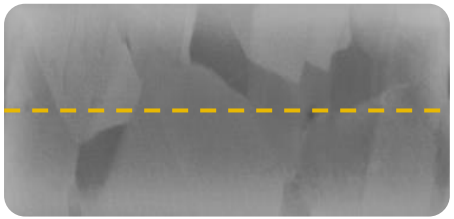
EVG Technology	Application	Equipment
Laser Lift Off	EPI substrate removal	EVG850DB
Wafer Reconstitution	Utilization of 300mm frontend semiconductor processing	EVG320
Hybrid bonding	Fine pitch bond of the µLED EPI wafer to the CMOS driver wafer	GEMINI FB
NIL	Optics formation	EVG7XXX
Spin & Spray coating	Color conversion layer deposition	EVG1XX

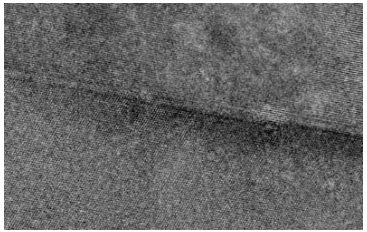
Wafer Bonding | µLEDs Integration Pitch

Wafer bonding is a key technology in heterogenous integration of compound semiconductor materials

		Pitch
No Interlayer	Anodic	
	Fusion	2 µm
	Hybrid	2 µm
Metal Interlayer	Thermo-Compression	5 µm
	Solder-based Eutectic/TLP	30 µm
Insulating Interlayer	Adhesive	30 µm
	Glass Frit	

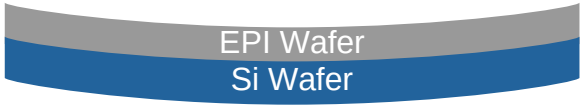






Wafer Bonding | Transient Liquid Phase Bonding

Reducing residual stress by lowering the bonding temperature



Bonding temperature needs to be minimized

Solution: Transient Liquid Phase (TLP) Bonding

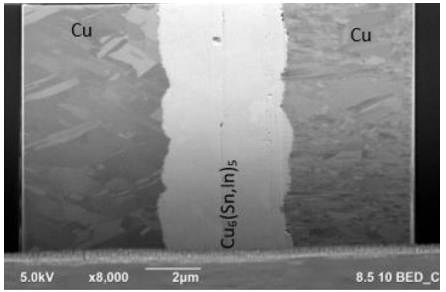
- Bonding at lower temperature
- Re-melting temperatures much higher than bonding temperature

Transient Liquid Phase Bonding	
Au-In	180 °C
Cu-Sn	250-280 °C
Ni-Sn	280-300 °C
Ag-Sn	250-280 °C
Ag-In	180 °C
Cu-In	170-180 °C
Cu-In-Sn	150 °C

Bonding temperatures of available TLP material systems are clearly below commonly utilized eutectic, anodic or glass frit bonding

Latest Developments:

Successful bonding of Cu-In-Sn @ 150 °C

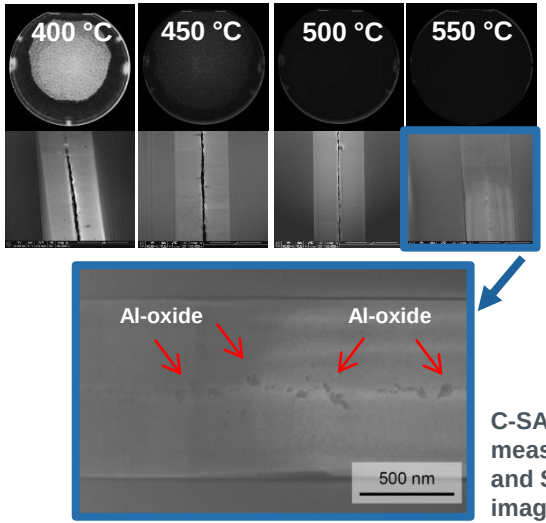


Wafer Bonding | ComBond®

ComBond® technology allows for low-temperature oxide-free metal bonding (e.g. Al-Al)

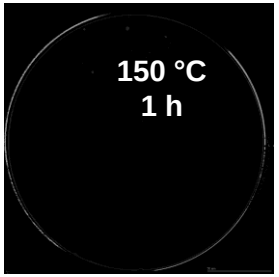
Conventional Bonding

Increasing temperature leads to increasing bond interface quality



C-SAM measurements and SEM images

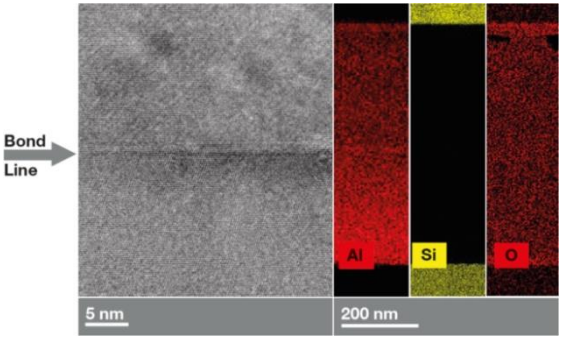
EVG Combond®



High bond quality and strength at low temperature

No O_2 concentration difference between bulk and interface

No aluminum oxide precipitates



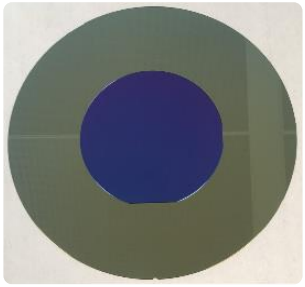
Heterogenous Wafer Bonding I Different Substrate Dimension

Bonding of wafers of different size enables seamless integration of EPI and CMOS wafers

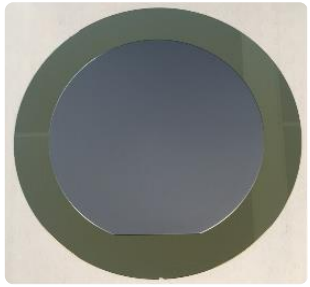
Smart View NT2 3δ < 150nm*

Smart View NT3 3δ < 150nm*

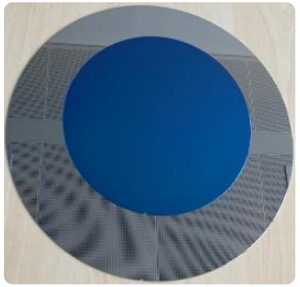
100 mm GaAs / GaN	150 mm GaAs / GaN	200 mm Si	300 mm Si



100 mm / 200 mm

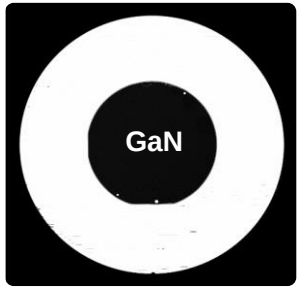


150 mm / 200 mm



200 mm / 300 mm

Bonding area > 99%



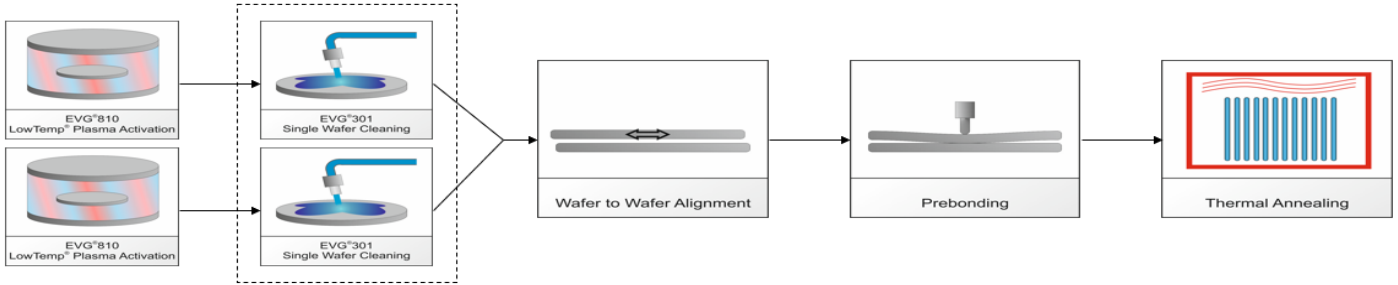
100 mm / 200 mm

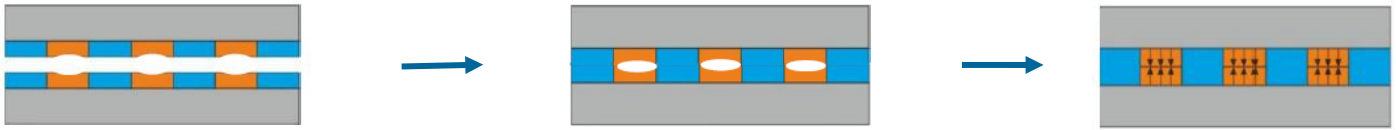
150 mm / 200 mm

Scanning Acoustic Microscopy

*LED applications

Wafer Bonding | Fusion and Hybrid Bonding

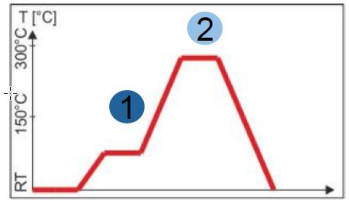




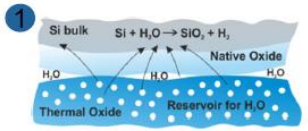
Wet cleaning and plasma activation are applicable for surface preparation.

Wet cleaning can include the use of chemicals for metal oxide removal

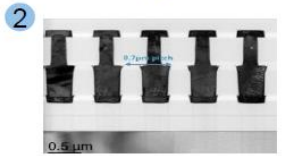
Wafers will be aligned using F2F optical alignment. Once aligned, wafers will be contacted at room temperature.



Annealing Process

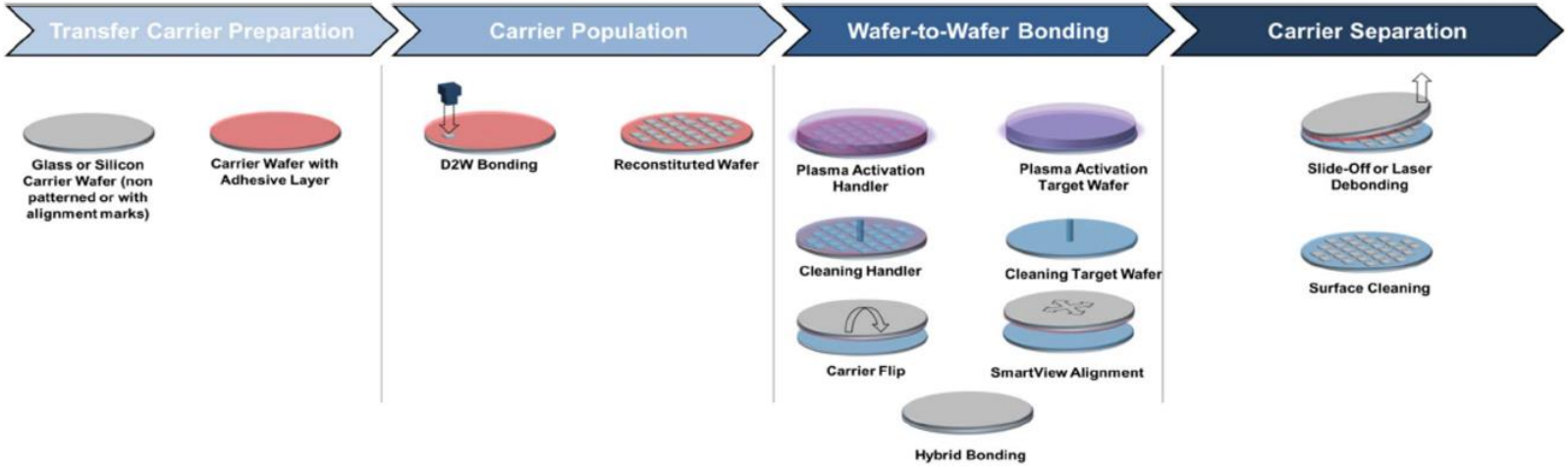


Dielectric layer Annealing



Interconnect gap closure due to different CTE of Dielectric bonding material and interconnect material

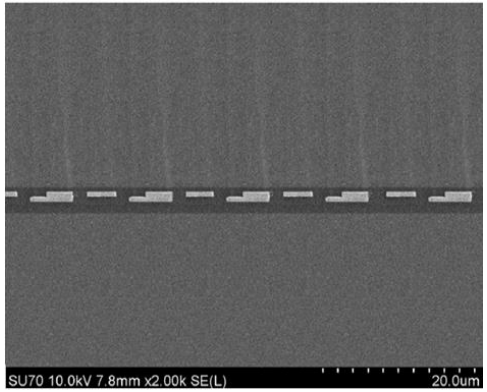
D2W Bonding | Collective D2W Process Flow



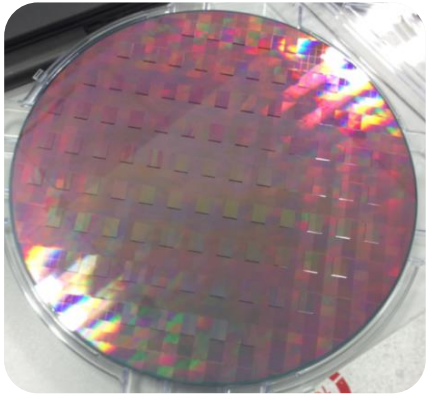
Transfer Method	Pro's	Con's	Maturity
Collective Die Transfer by Reconstituted Carrier	▪ Proven technology ▪ Die Activation and cleaning equivalent to W2W hybrid bonding ▪ Oxide management ▪ Rework on carrier feasible	▪ Error propagation of D2W + W2W alignment ▪ Cost of carrier prep, utilization and clean ▪ Die thickness needs to be in narrow range	Application specific volume production proven for several years

Collective D2W Bonding | Process Results – Hybrid Bonding

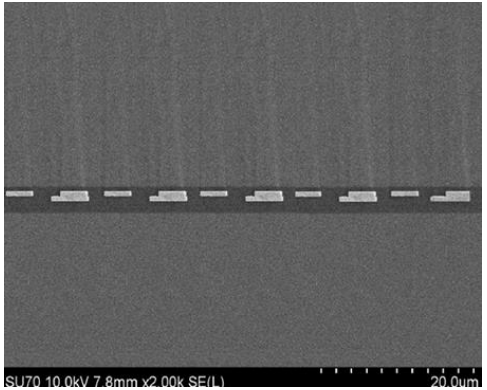
Edge Die



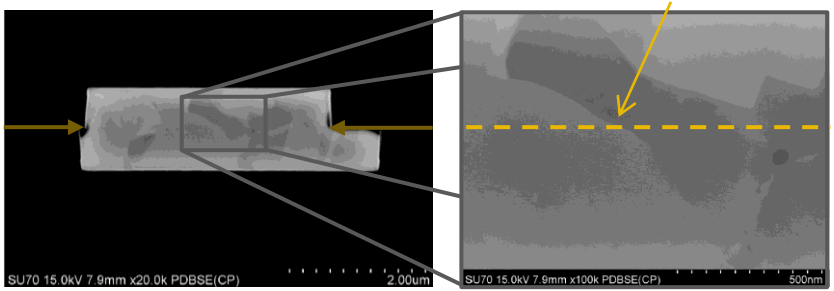
300mm 10x14 Dies



Center Die



Bond Interface



- High Die transfer rate and alignment accuracy < 2µm
- TEM evaluation of mechanical contact of the bonding pads and Cu grain growth across the bonding interface

µLED Displays Manufacturing | Summary

EVG is market leader in **wafer bonding**, a **key technology** for µLED displays manufacturing. Our solutions go beyond bonding and enable many **AR** and **VR** applications for the industry leaders.

Other Key Technologies for µLED manufacturing

- Waveguides nanoimprint
- Wafer-level micro-optics
- Mass transfer

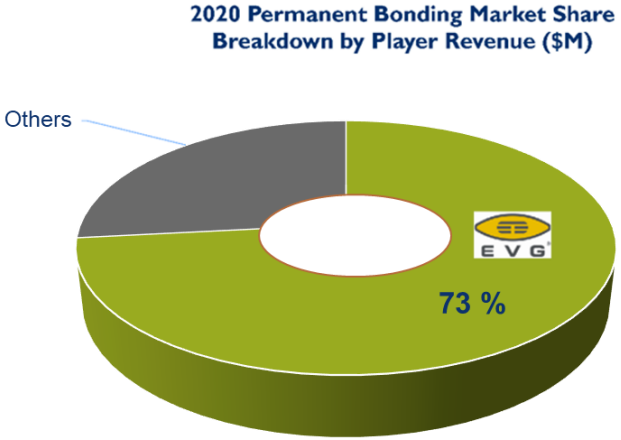


Image adapted from "Bonding and Lithography Equipment Market for Moore than Moore Devices | Report | Yole Développement | 2021"

Bonding Technologies

ComBond® | Fusion Bonding | Metal Bonding | Glass Frit Bonding | Anodic Bonding | Adhesive Bonding

Thank you!

Dr. Bernd Dielacher, Business Development Manager, b.dielacher@evgroup.com