EVG®

Chemnitzer Seminar – Materials and Nanotechnologies for MEMS Packaging'18

Advances in High Vacuum Encapsulation for MEMS Packaging based on Metallic Bonding Interfaces

Bernhard REBHAN, Senior Scientist Wafer Bonding

Product Categories

EVG

EVG is a global supplier of:

- Wafer Bonders
- Temporary Bonders / Debonders
- Aligners
- Coaters / Developers
- Cleaners
- Inspection / Metrology Systems

EV Group holds the dominant share of the market for wafer bonding equipment and is a technology leader in lithography for advanced packaging and nanotechnology.

Markets and Typical End Products

Advanced Packaging
3D Interconnect

CMOS Image Sensors

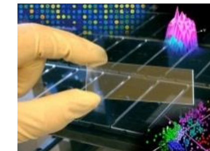
Compound Semiconductor
Silicon-Based Power Devices

LEDs

MEMS
(Micro Electro Mechanical Systems)

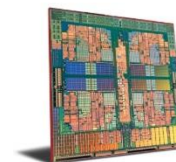
Motion sensors

Nanotechnology



DNA chips / micro labs

SOI (Silicon On Insulator)
Engineered Substrates



Micro processor wafers

Global Presence

Fully owned subsidiaries
Representatives

EV Group Inc.
Albany, NY

EV Group Inc.
Tempe, AZ

EVG Headquarters
St. Florian / Inn, Austria

EV Group Korea Ltd.
Seoul

EV Group China Ltd.
Shanghai

EV Group Japan KK
Yokohama

EV Group Japan KK
Fukuoka

EV Group Taiwan Ltd.
EVG-Jointech Corp.
Chung-Li

EVG North America

EVG Japan

EV Taiwan

EVG Korea

EVG China

- Background and Motivation
- Process Equipment
- Process Results
- Summary & Conclusions

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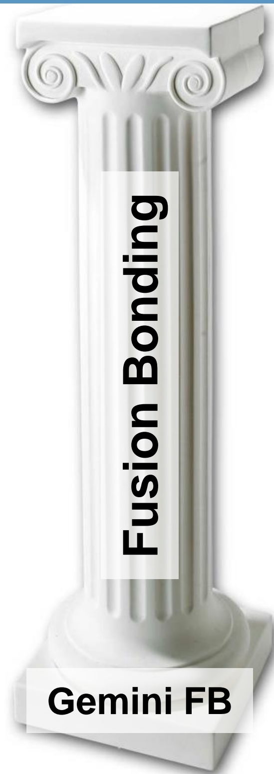
Background and Motivation

EVG

EVG's Wafer Bonding Equipment Portfolio



Pressure:
p = 1 atm

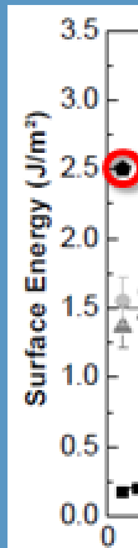
Vacuum level:
$p > 10^{-6}$ mbar

Vacuum level:
$p < 2 \times 10^{-8}$ mbar

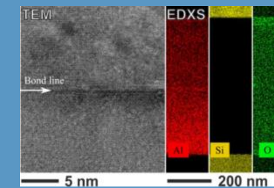
Background and Motivation

- EVG®580 ComBond® (*in-situ* high vacuum) system for
  - Engineered substrates by wafer bonding
  - High vacuum encapsulation by wafer bonding

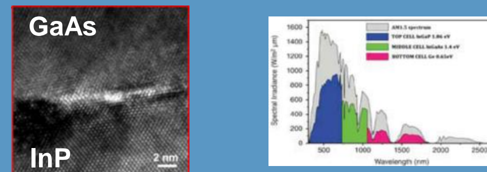
Covalent Bonding



Oxide-free Al-Al wafer bonding



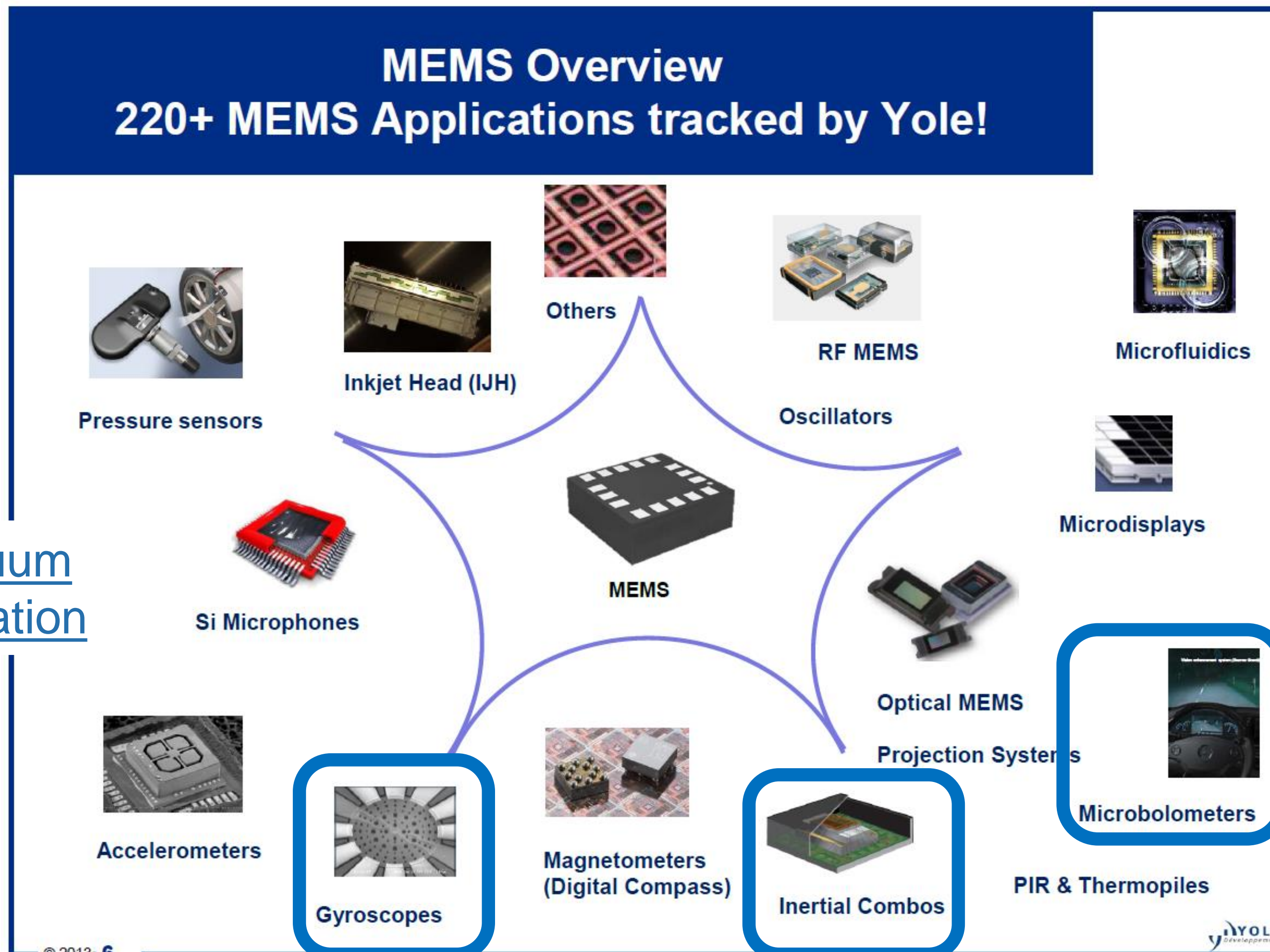
Heterogeneous Material Integration



Vacuum Encapsulation

Background and Motivation

High vacuum encapsulation



Extracted from Yole roadmap (2013)

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Process Equipment

Process Equipment

EVG®

Module Bay C

Module Bay D

Module Bay B

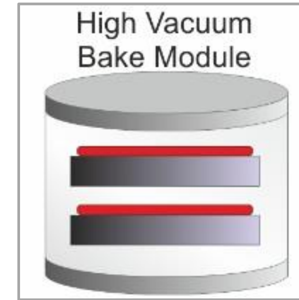
Module Bay E

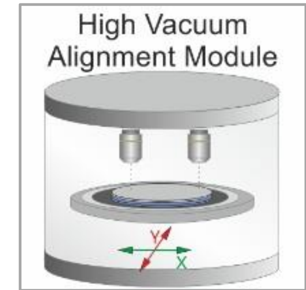
Module Bay A

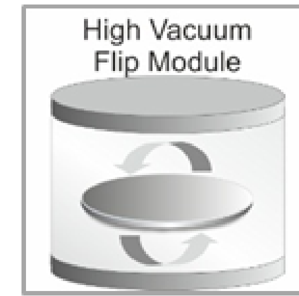
Module Bay F

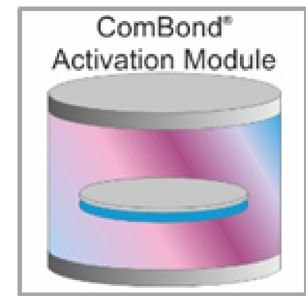
LP1

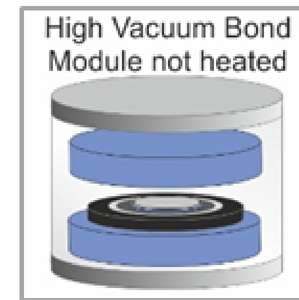
LP2

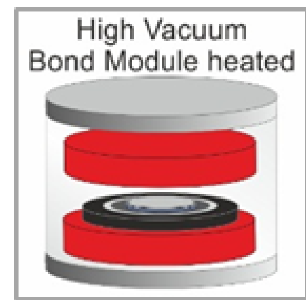






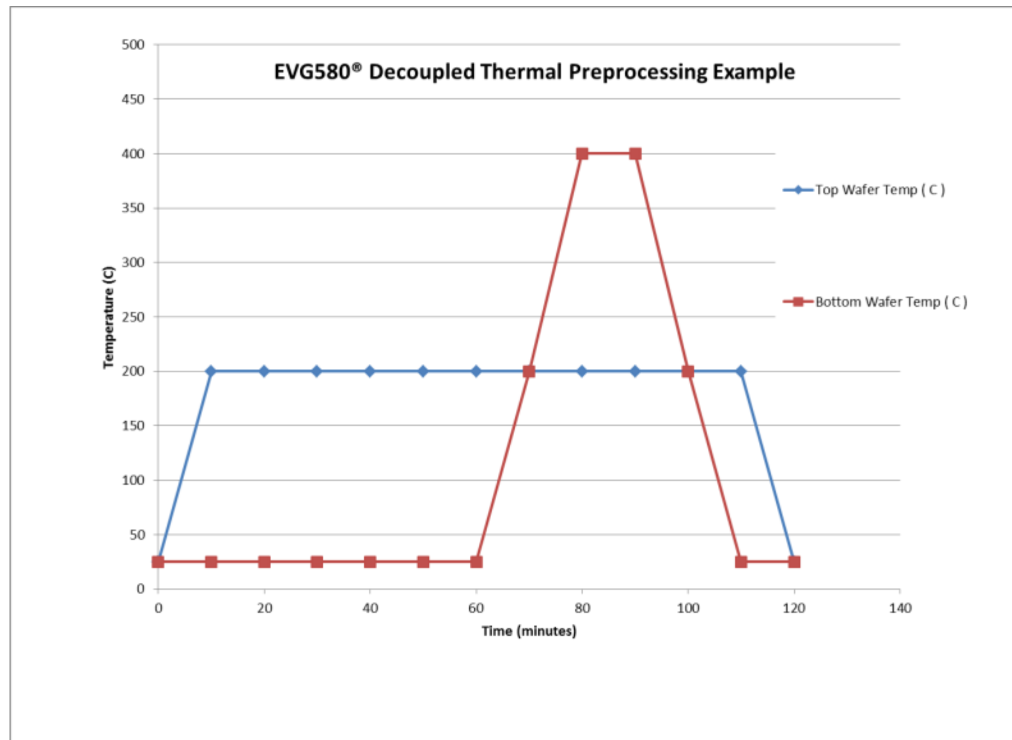






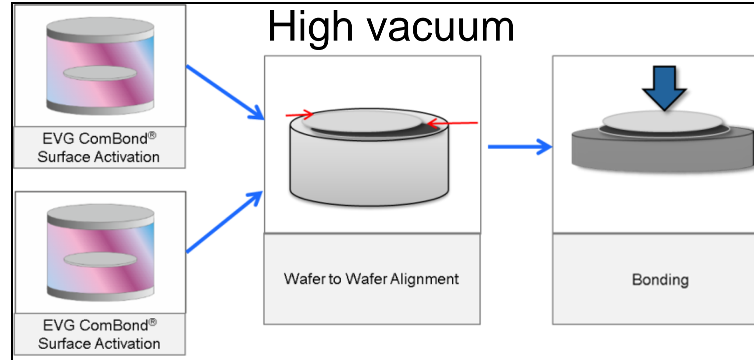
EVG

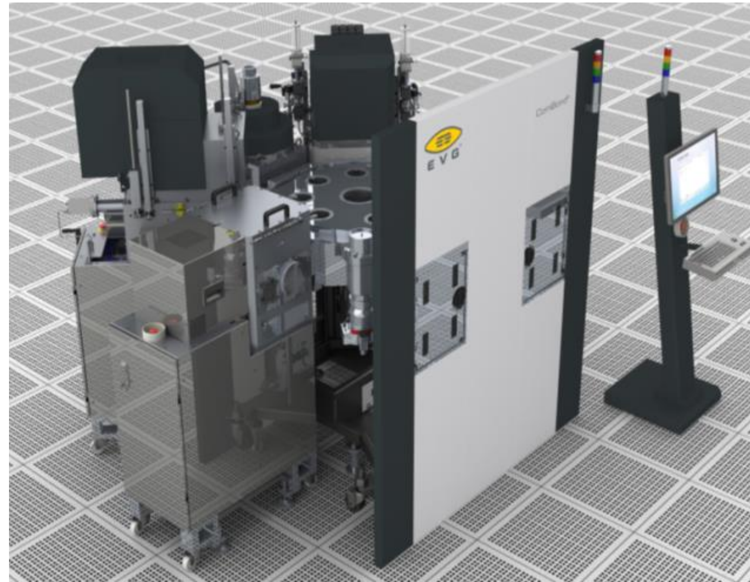
- Improved getter activation due to separate preprocessing of top and bottom wafer.
  - Getter wafer can be activated at a high temperature
  - Other wafer can be baked out at lower temperature if required.



Process Equipment

Used Process Flow and System





EVG ComBond®

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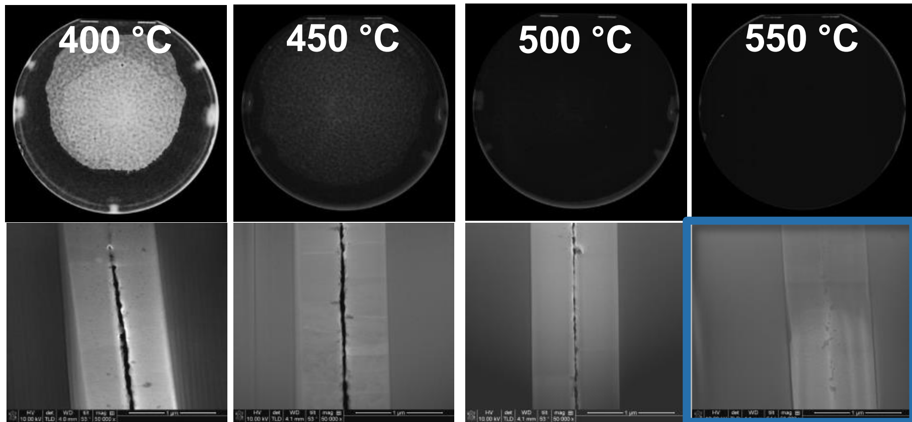
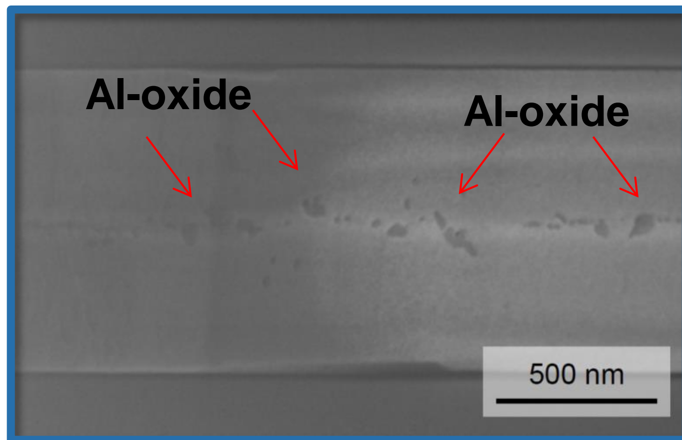
Process Results

Results – Al-Al

Conventional Bonder (EVG®520IS)

1.9 Mpa, 400-550 °C, 2 h



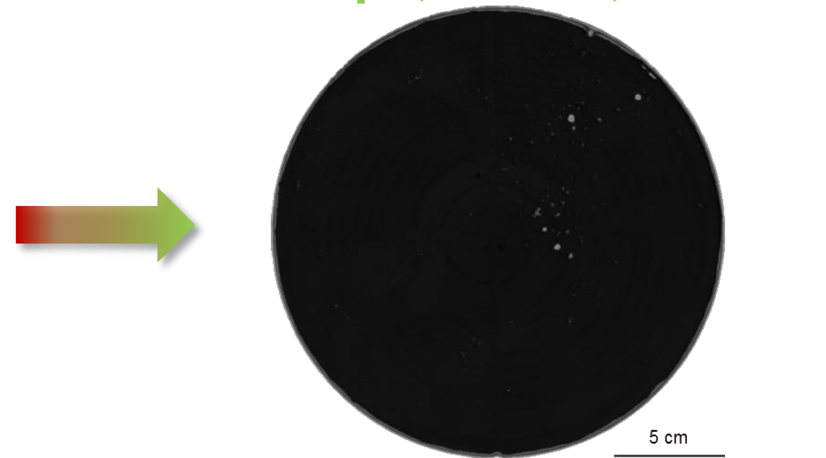


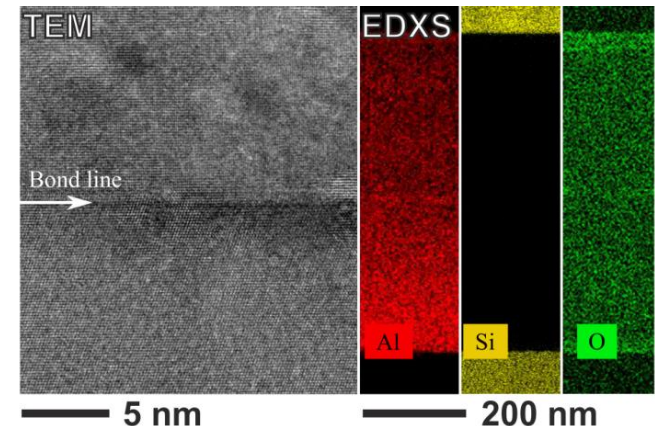
SEM cross-section.

*Dragoi et al., Microsyst Technol, **18** (7-8), pp 1065–1075 (2012)*

EVG ComBond®

1.9 Mpa, 150 °C, 1.5 h

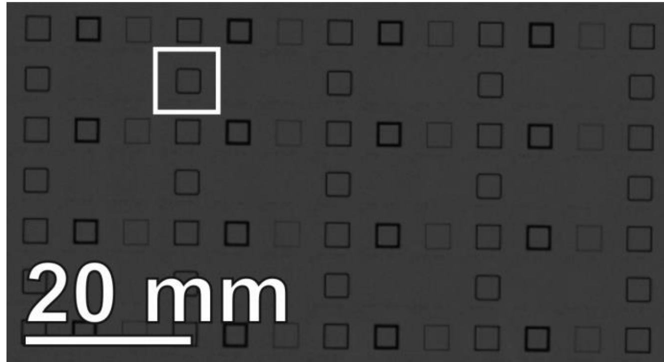


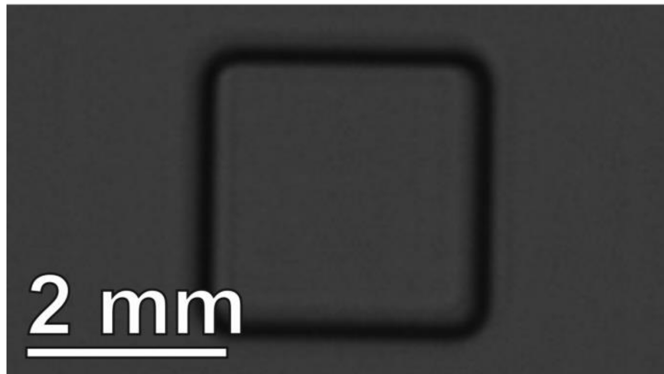


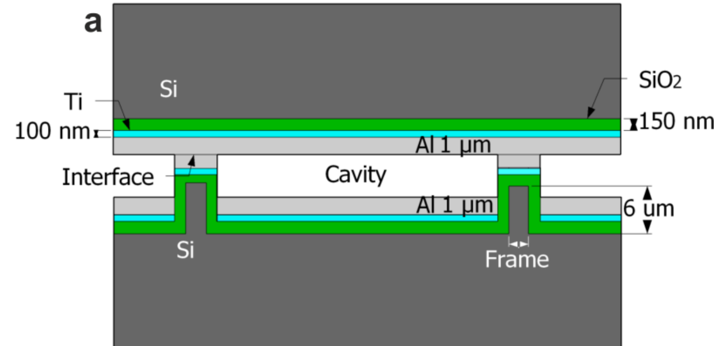
TEM cross-section.

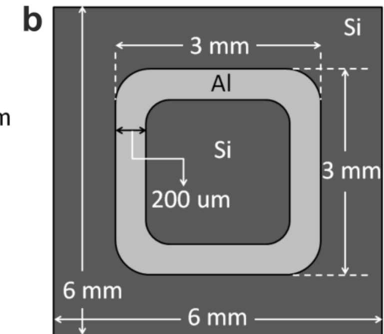
Hinterreiter et al., «Surface pretreated low-temperature aluminum–aluminum wafer bonding", Microsyst Technol, (2017)

Results – Al-Al







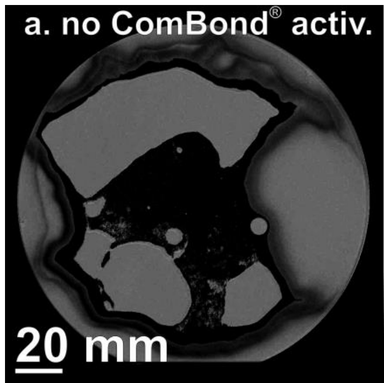


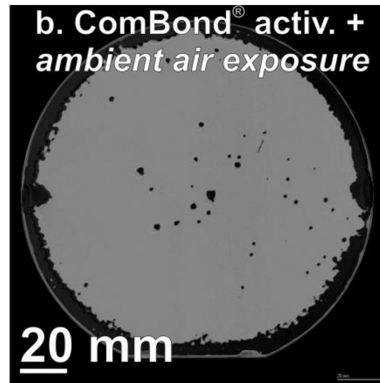
Bonding Temp.	Dicing Yield	Bond Strength	Standard Deviation
100°C	100%	23.13 MPa	9.54 MPa
150°C	100%	36.67 MPa	17.69 MPa

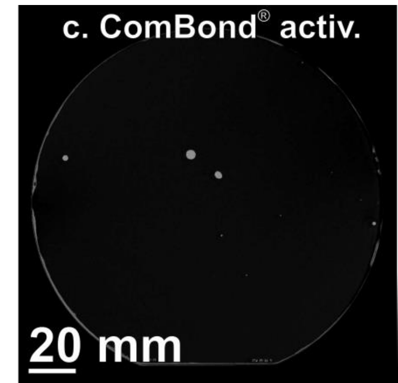
Substrate size = 150 mm diameter; bonding force 60 kN (114 MPa)
C-SAM (left) of Al-Al bonded at 100°C / 1 h: closed frames
Dicing yield and bond strength tests (right) showed high bond strength and 100% dicing yield

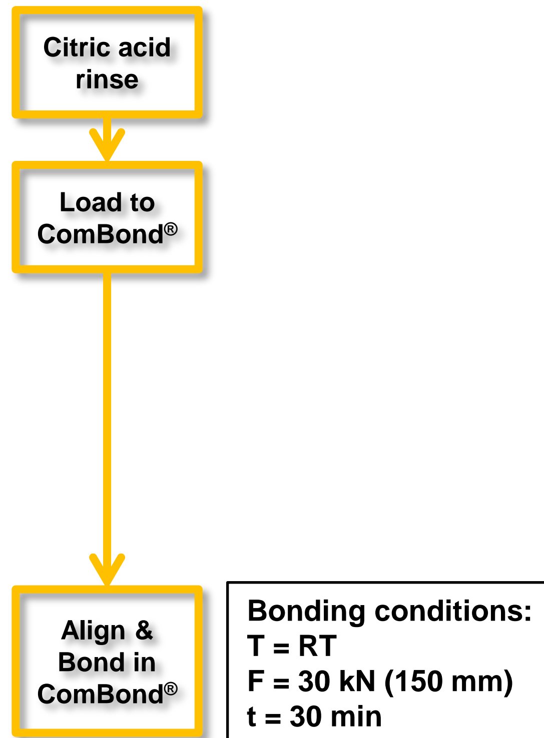
Rebhan et al., ECS Transactions, 75 (9) 15-24 (2016)

Results – Cu-Cu

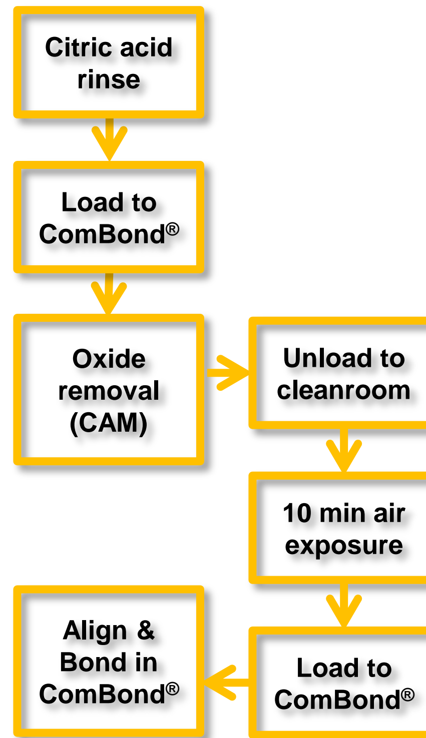


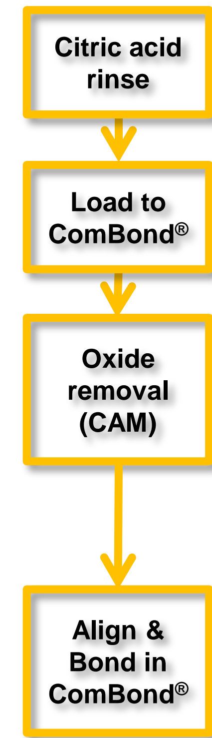






Bonding conditions:
T = RT
F = 30 kN (150 mm)
t = 30 min



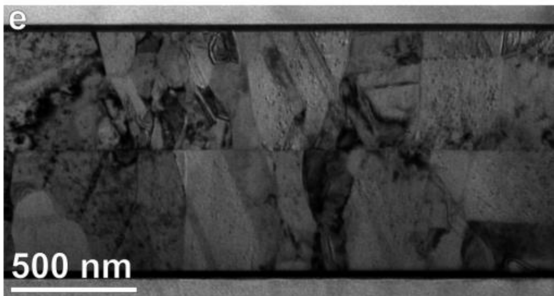


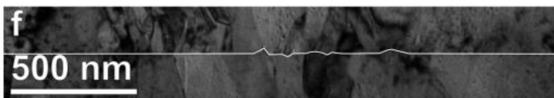
Results – Cu-Cu

Sample "c"

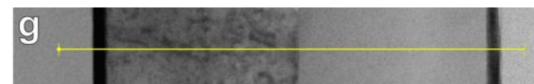
SEM

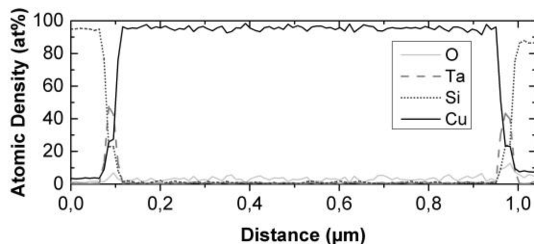
TEM





EDX

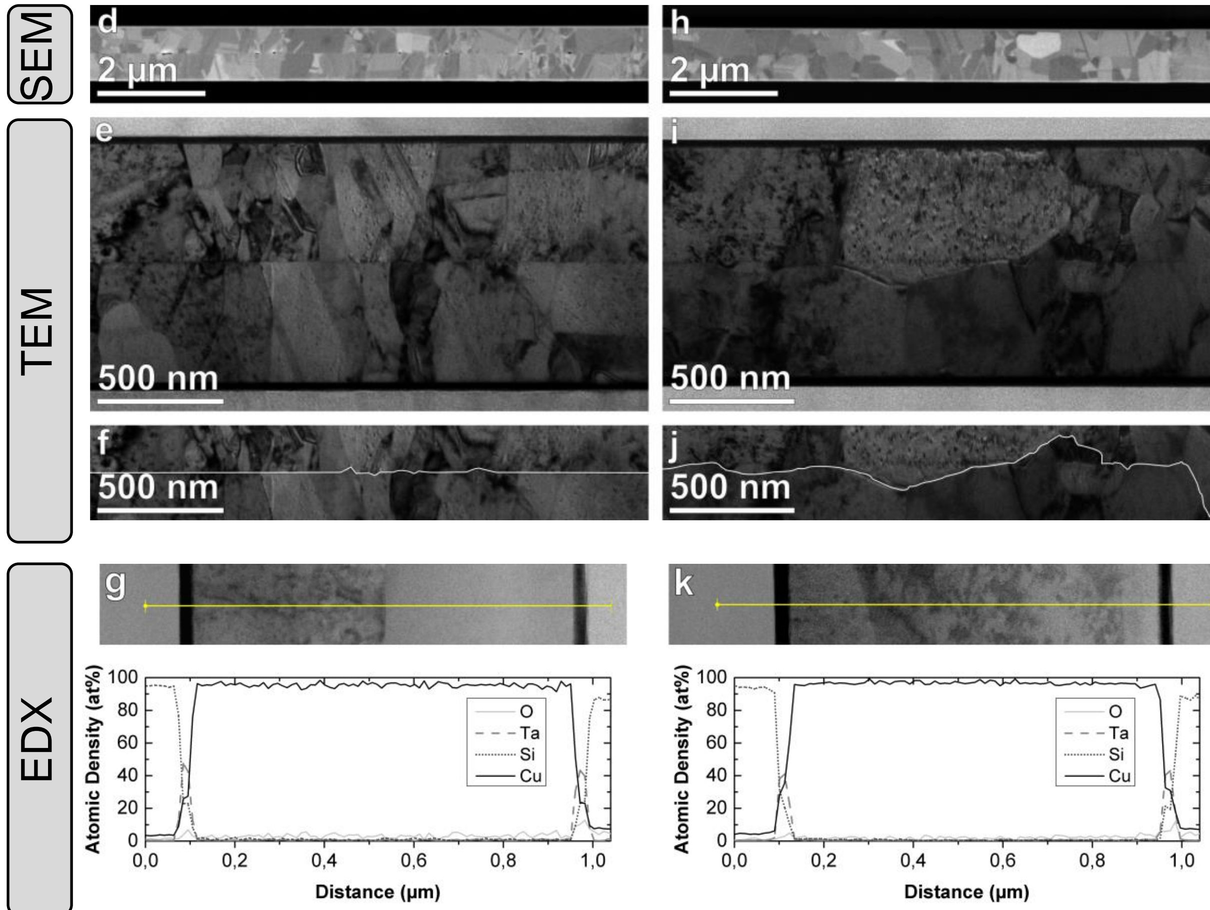




SEM, TEM & EDX of the sample processed using *in-situ* ComBond® process flow. Cu-Cu bonded at room temperature before (d-g) and after (h-k) annealing @200°C / 5 h: moderate and significant grain growth across the initial bonding interface, respectively; no oxide at/near the initial bonding interface.

B. Rebhan and V. Dragoi, Proc. of SPIE Vol. 10246 102461H (2017)

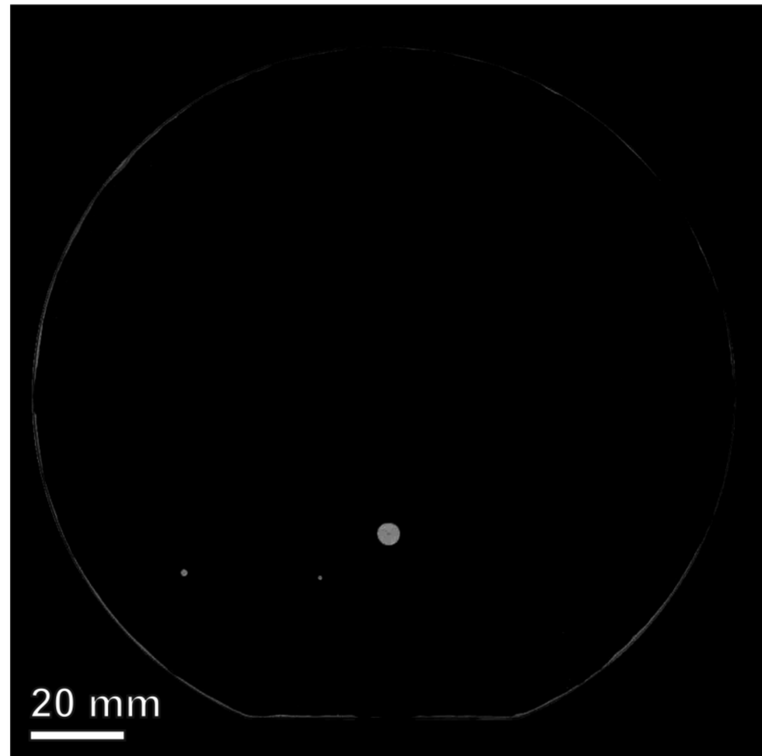
Results – Cu-Cu



SEM, TEM & EDX of the sample processed using *in-situ* ComBond® process flow. Cu-Cu bonded at room temperature before (d-g) and after (h-k) annealing @200°C / 5 h: moderate and significant grain growth across the initial bonding interface, respectively; no oxide at/near the initial bonding interface.

B. Rebhan and V. Dragoi, Proc. of SPIE Vol. 10246 102461H (2017)

Results – Au-Au



Bonding conditions:
T = RT
F = 30 kN (150 mm)
t = 30 min

Feasibility study of Au-Au bond

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Summary & Conclusions

Conclusions

EVG®

- The EVG ComBond® system is a modular platform which enables high vacuum MEMS encapsulation.
- As the native oxide is removed *in-situ* it also allows the usage of materials with challenging oxide layers (Al) for metal bonding.
- Successful demonstration of low temperature metal wafer bonding:
  - Oxide-free interfaces
  - Al-Al @100°C & 150°C
  - Cu-Cu @RT
  - Au-Au @RT

  - Low temperature bonding is an enabling technology for materials with CTE mismatch

Thank you!

Bernhard REBHAN b.rebhan@evgroup.com

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