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High-yield Fabrication of Thin Glass Interposers

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Agenda

- About Glass: types & properties
- Through-glass via (TGV) formation
- Robust handling of thin glass
- Fabricating thin glass interposers
- Conclusion

Glass has excellent properties for interposers

Electrical

Environmental

Physical / Mechanical

Manufacturable

Property	Glass	Silicon	Organic
Low RF loss			
High resistivity			
Mechanical Stability			
Thermal Stability			
Thin form factor			
Large area			
Smooth Surfaces			
Narrow vias			
High density interconnect			

Glass types span a range of properties

Focus here on thin glass of two types:

High purity versions of **FS**

Fused silica → Pure SiO_2

- Excellent RF properties
- Extremely low CTE

ABS

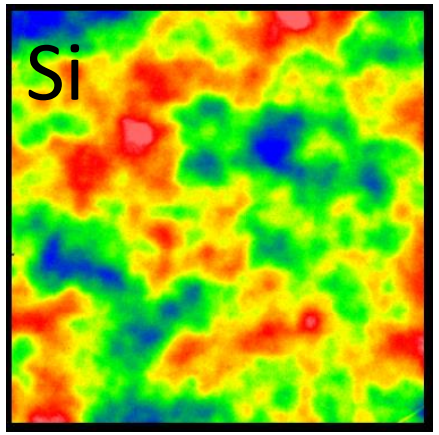
Aluminoborosilicates → Multicomponent glasses

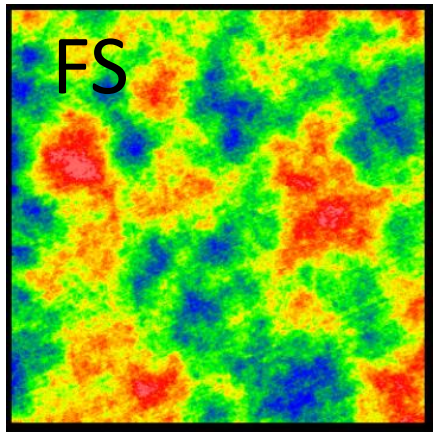
- Lower cost
- Available thin as manufactured
- CTE matched to silicon

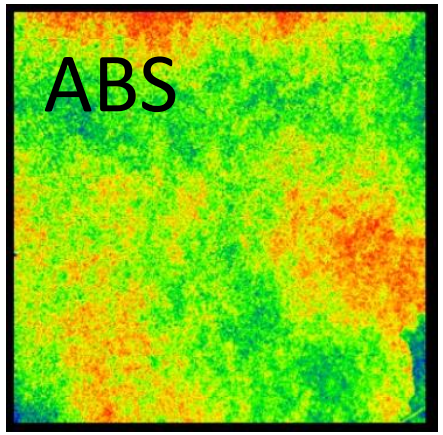
Glass Has Surface Properties Like Silicon

- Surface roughness affects patterning resolution, high- frequency loss
- FS (like Si wafers) are produced by grind + polish
- ABS glass can have comparable smoothness as manufactured (on both sides)

(spatial period < 50um)







Sq = 0.25nm

Sq = 0.43nm

Sq = 0.35nm

High precision TGVs are formed by laser/wet etch

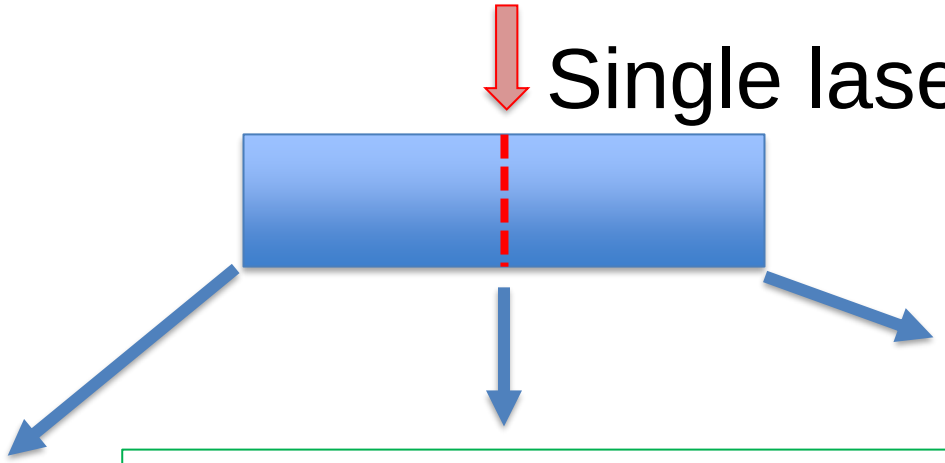
Laser-damage of glass followed by wet etch

- Highly aligned via position registration
- Allows design of size and shape
- Efficient process

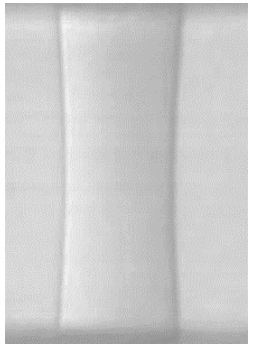
Single laser pulse per via

Batch wet etch for wafers

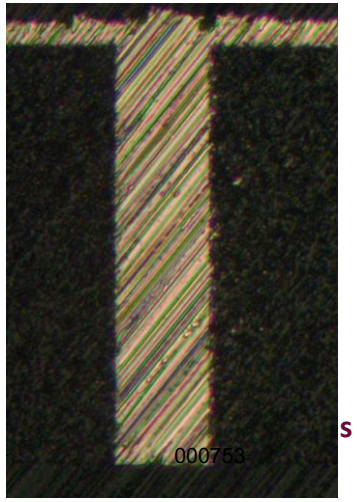
Via shape can be tuned to glass and to application



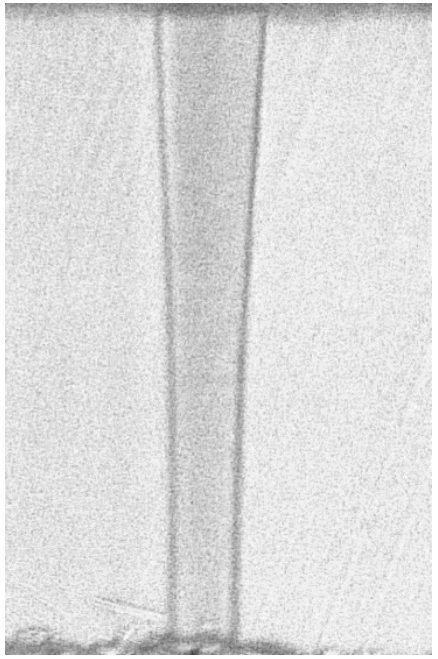
Hourglass via
(100µm-thick glass)



Columnar via
(150µm-thick glass)

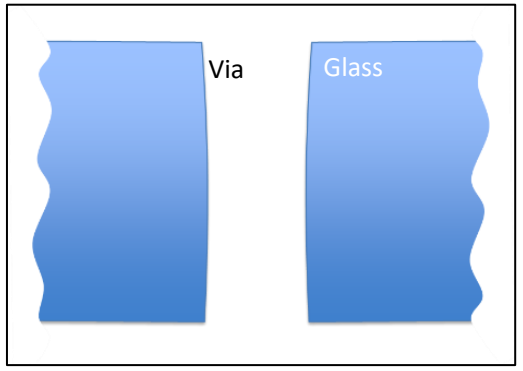


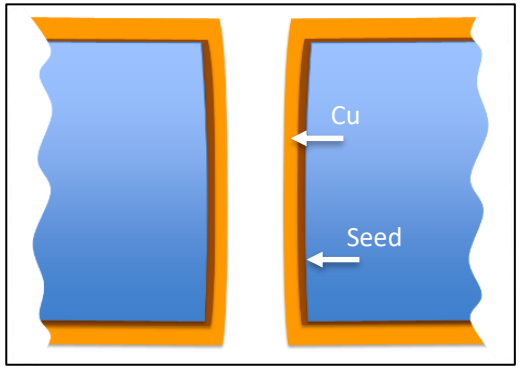
Tapered via
(170µm-thick glass)



How are vias metallized in thick glass?

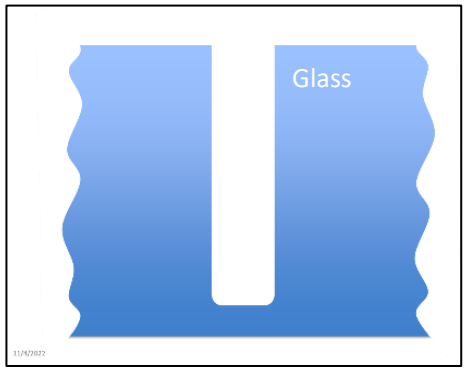
Conformal Plate

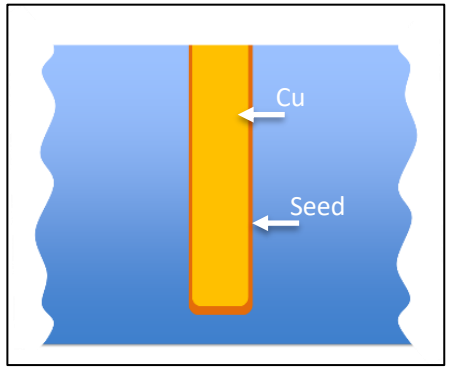


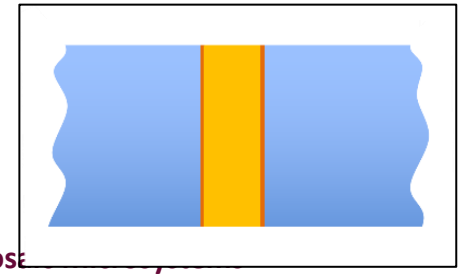


- Plating from both sides
- Thin wafer handling?
- Hermeticity?

Blind Fill with Backgrind







- Starts with thicker glass
- Leverages TSV plating infrastructure
- Good hermeticity
- Requires backgrind

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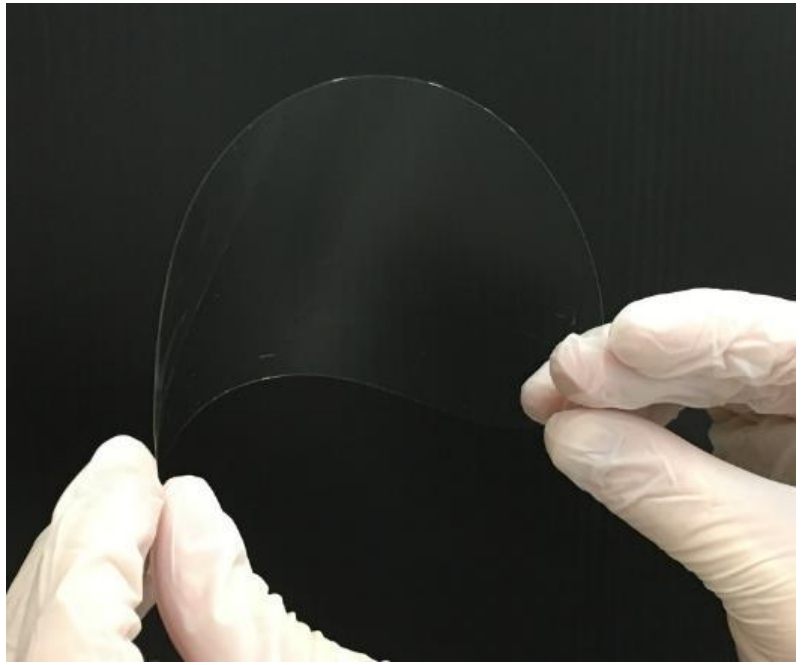
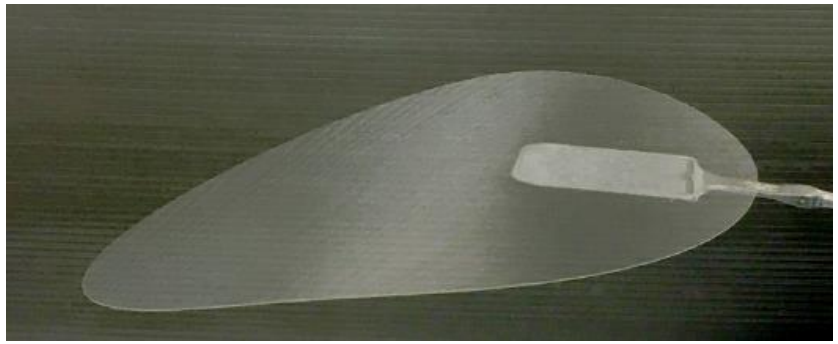
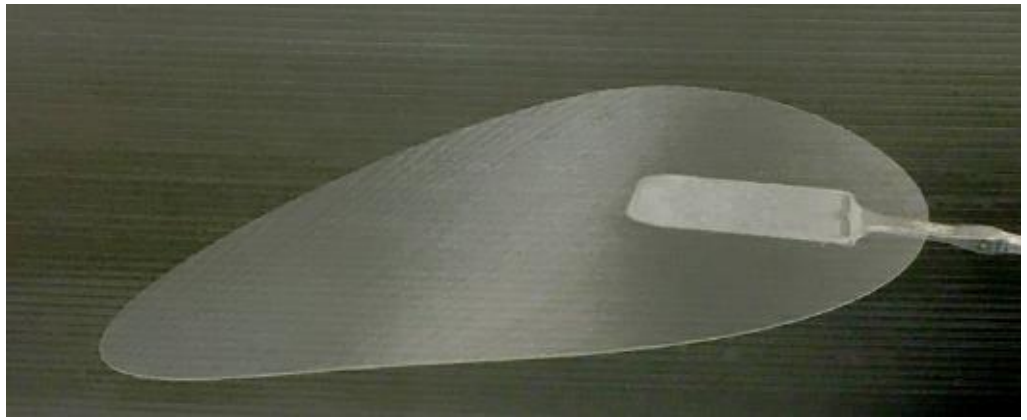
Thin glass presents handling challenges at via-fill and downstream





Temporary bonding creates a robust thin glass wafer handling solution

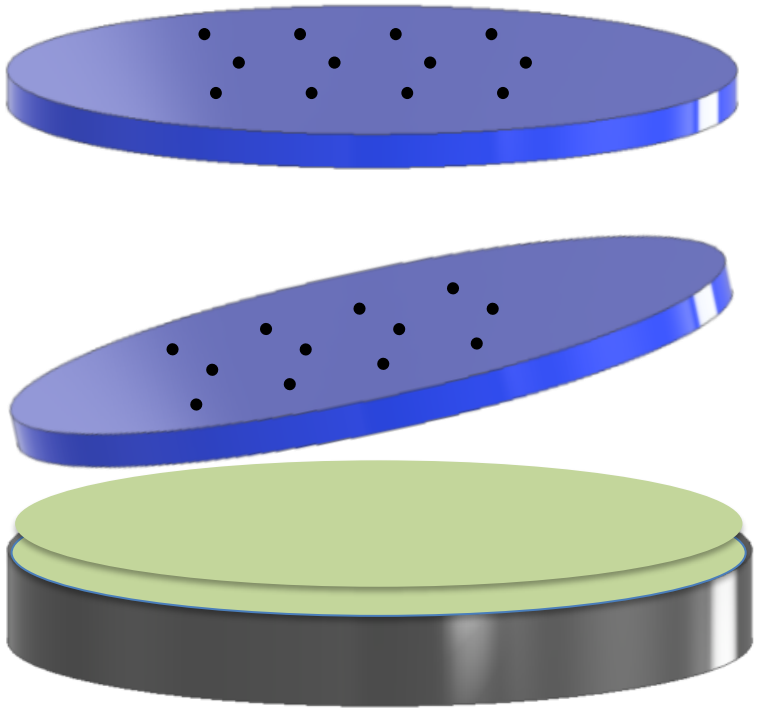


100 µm-thick glass with TGVs

Thin glass temporarily bonded to handle
→ Si or glass handle (as preferred)

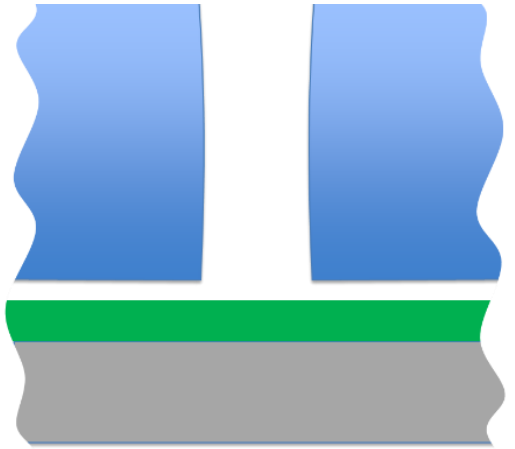
Known solution in packaging industry for thin substrates

Temporary bond properties can adversely affect TGV metallization

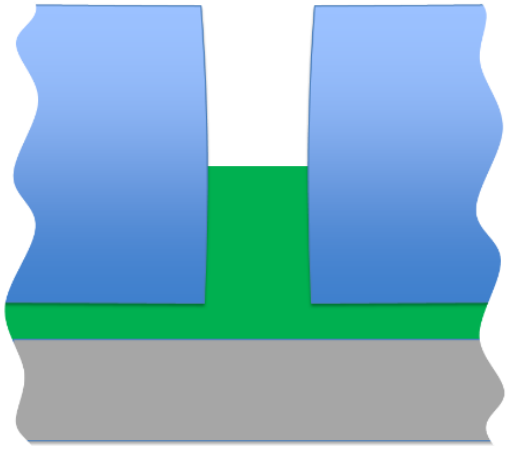


Create TGV

Temporary bond



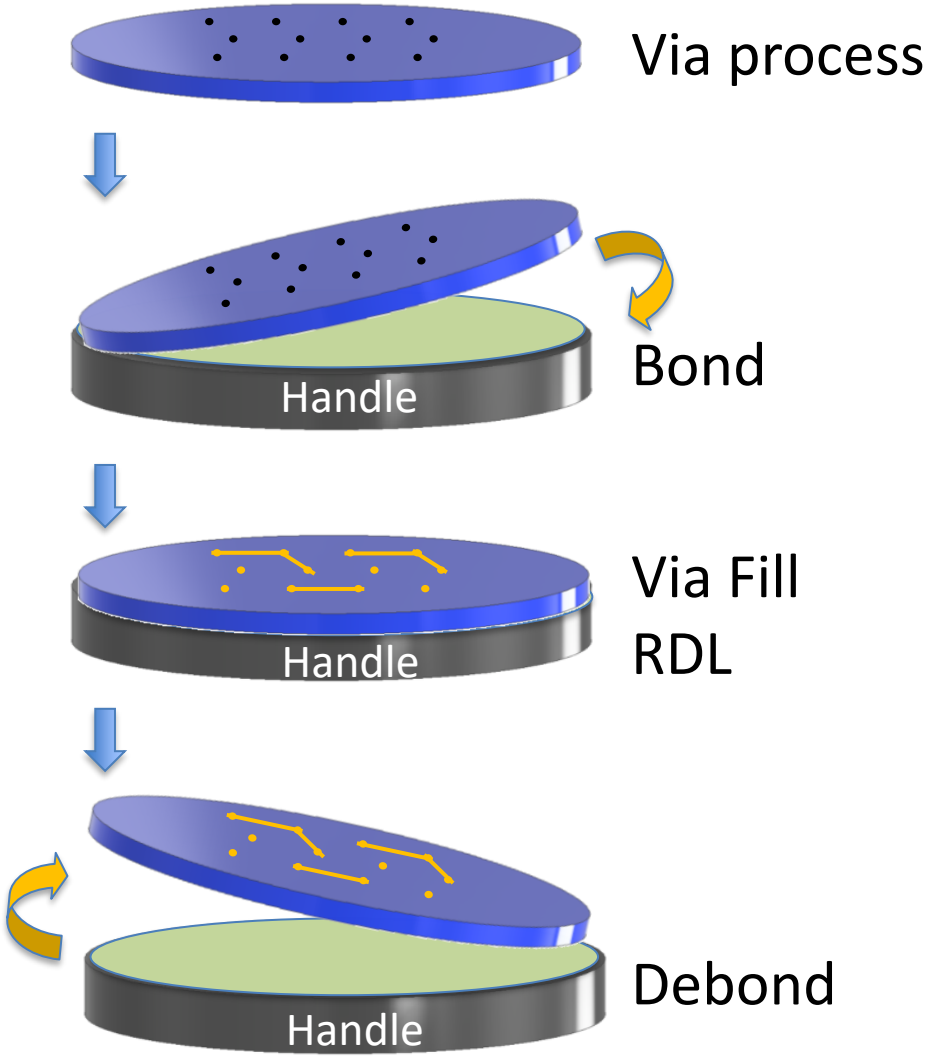
Polymeric adhesive



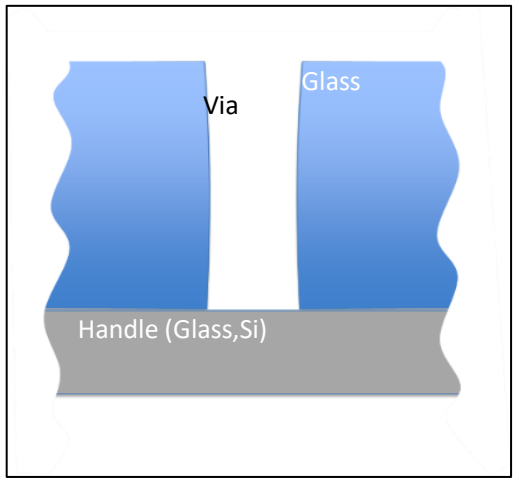
Fluid can wick into empty vias

A thin inorganic temporary bond provides a via-fill solution

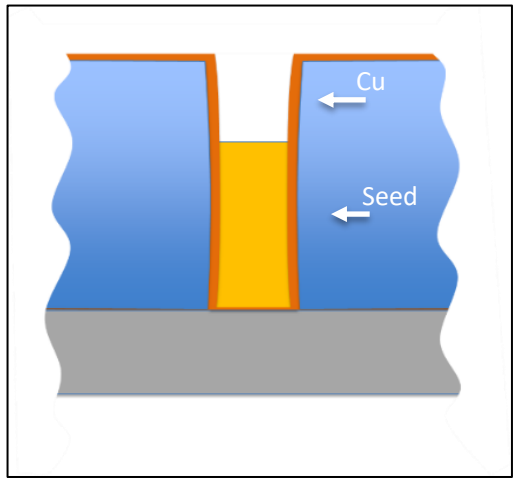
- Thin adhesion layer → Excellent flatness
- Extreme resistance to processing
- Chemically robust
  - *OK with Acids, Bases, Solvents*
- Thermally robust
  - *OK to 450°C*
- Vacuum-robust
  - *OK with plasma*



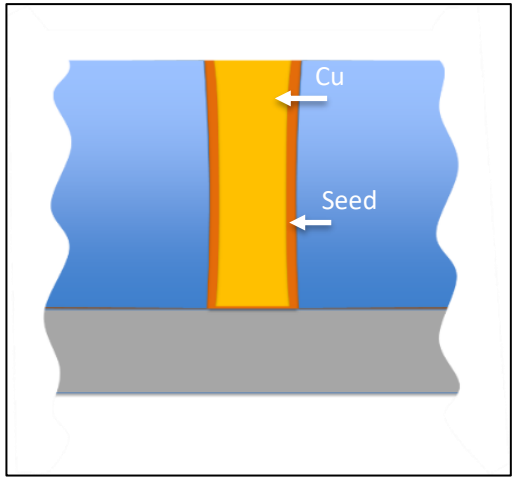
Thin glass “blind” via-fill approach is allowed by inorganic bond



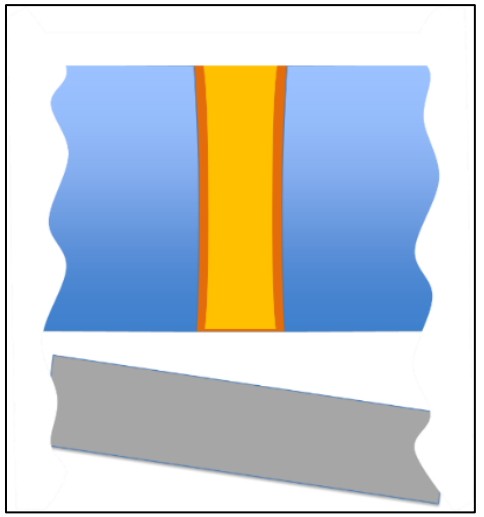
Blind via at bond to handle



Seed and bottom up fill



Robust to CMP



Debond reveal

Combines:

- Ease of handling thin glass with high yield
- Compatibility with industry TSV electroplating processes
- Backside reveal without grinding

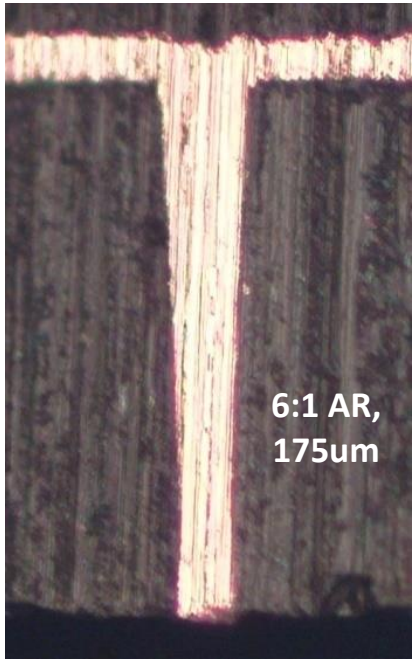
Different via shapes can be filled with “Bottom Up” chemistry

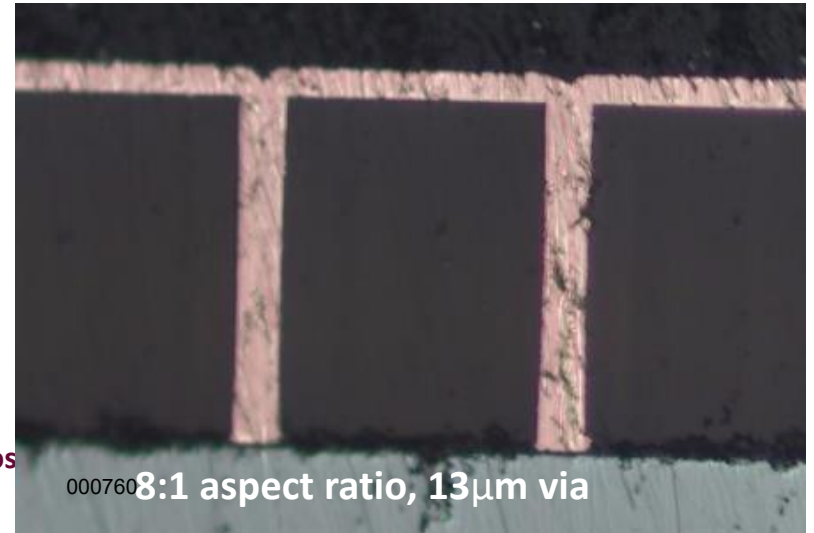
Process optimized across broad range:

- Glass thickness ~70 µm – 200 µm
  - 2.5: 1 aspect ratio
  - 8:1 aspect ratio
- Tapered or columnar

30 µm top diameter

35 µm top diameter





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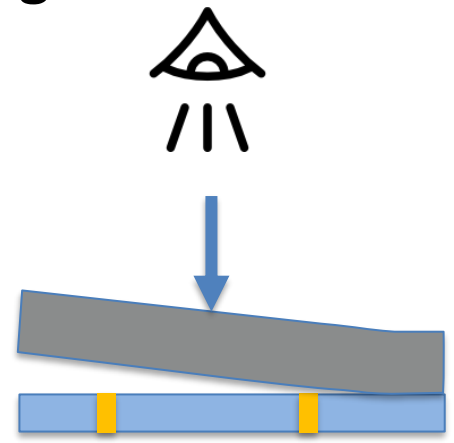
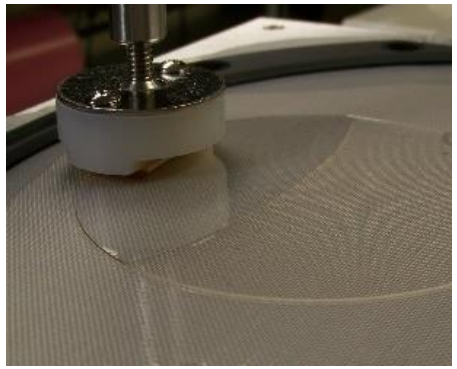
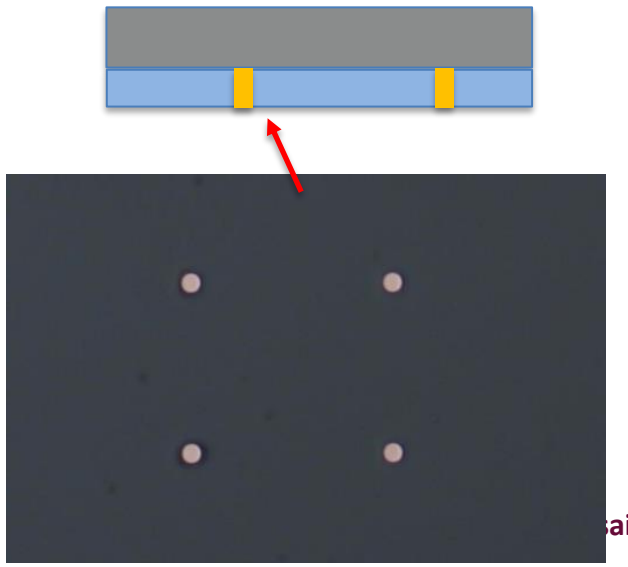
Mechanical debond protects device wafer

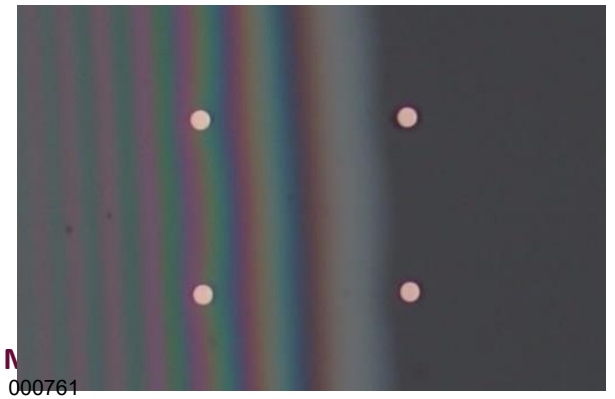
- Handle is pulled away from device
  - Commercial equipment exists for this mechanical debond
- Seed layer engineering
  - *Controls adhesion at via base*
- Filled vias peel off handle →simplified backside reveal!

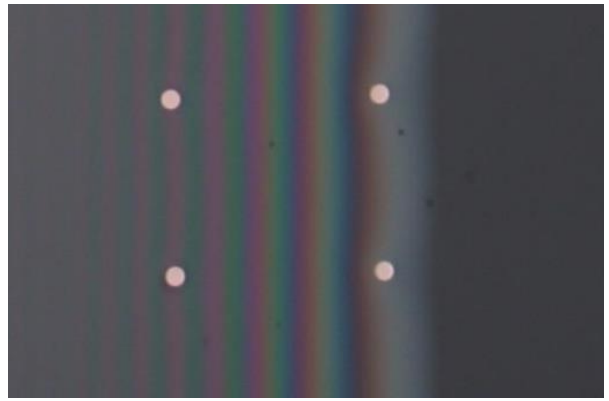
Viewed through glass handle



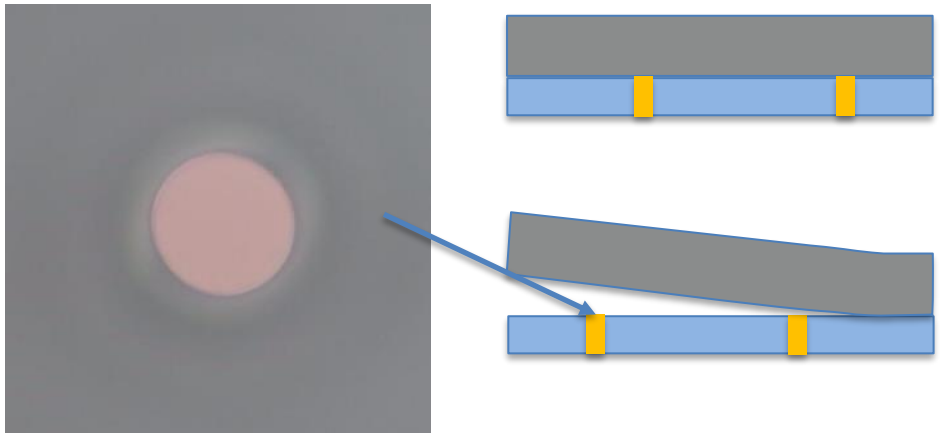








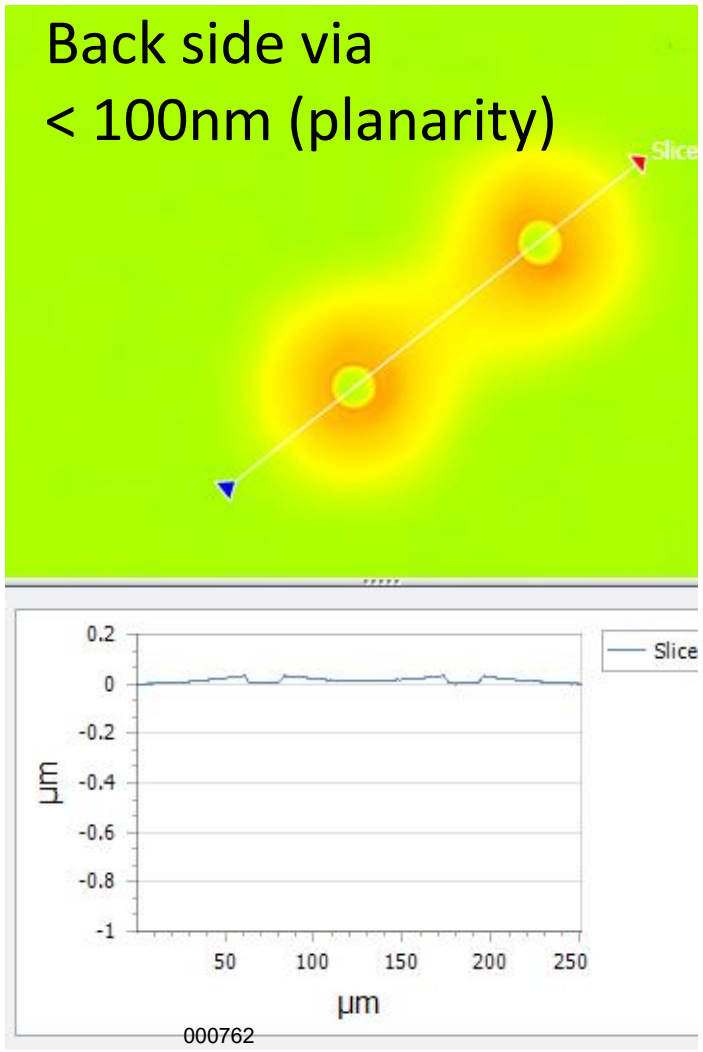
Mechanical debond yields a smooth via surface

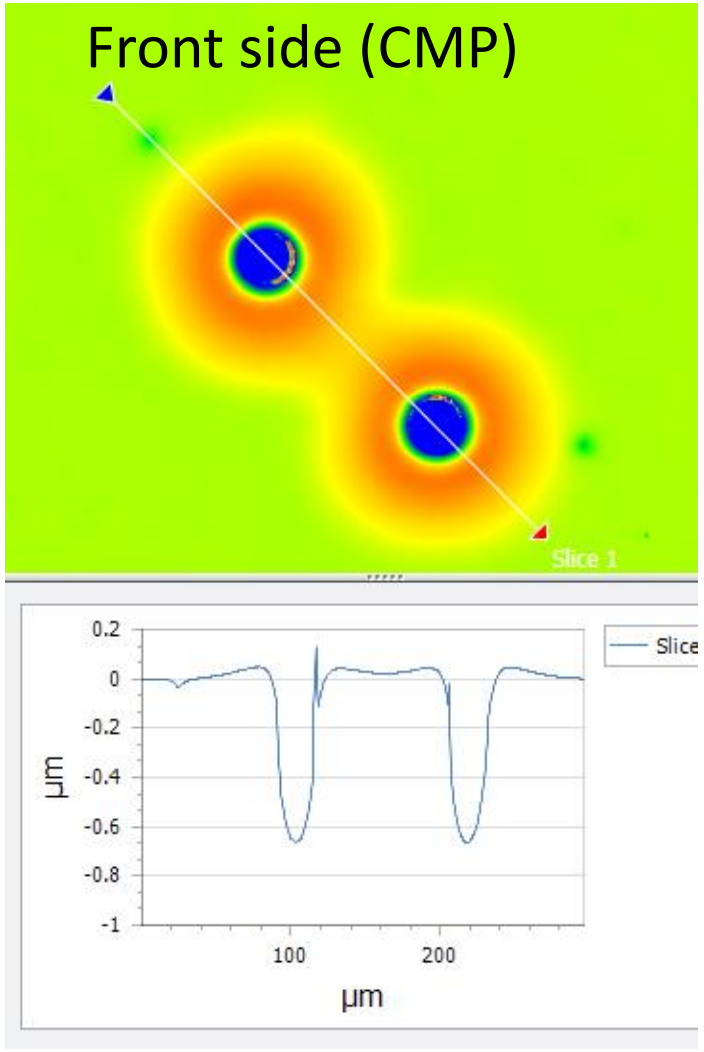


→smooth surface is obtained with no additional processing

- No residue (by XPS)

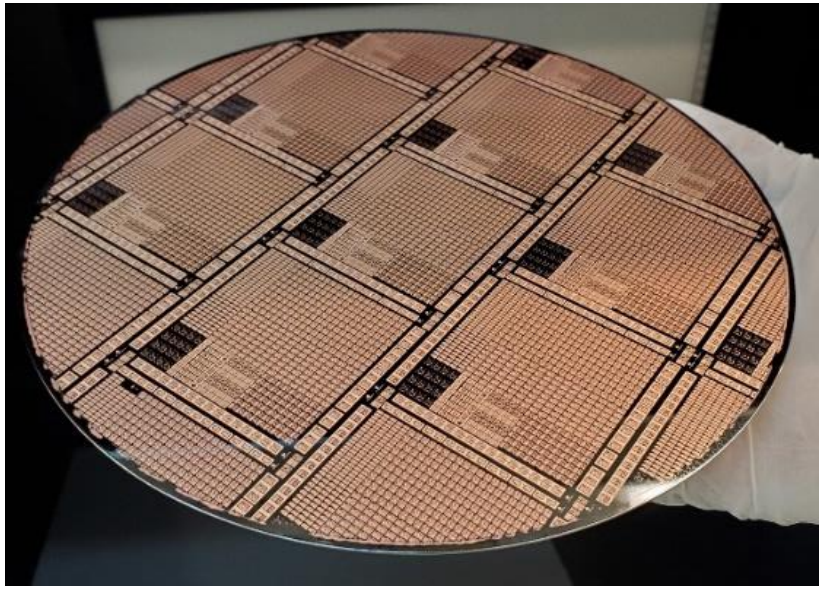
Optical profilometry:



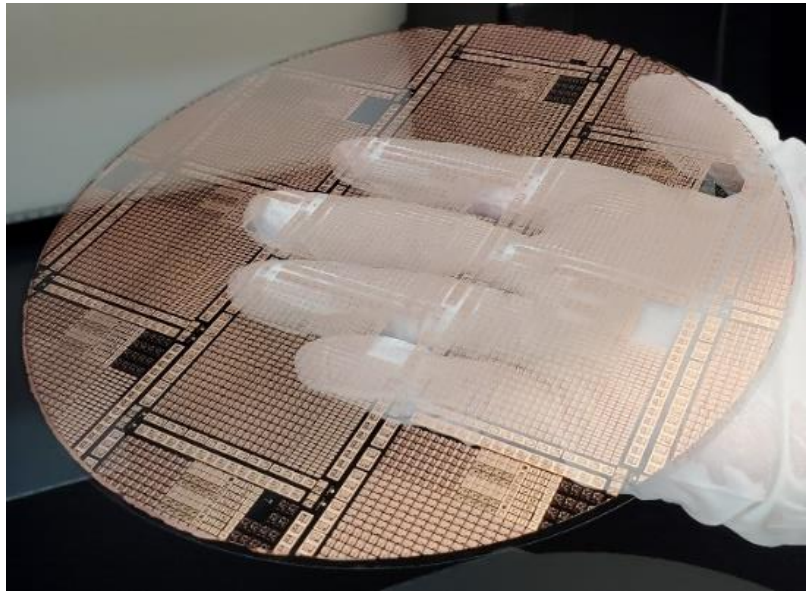


Debonded wafer can stay on dicing tape for singulation, or be removed for second-side processing

200mm wafer on handle



… and debonded

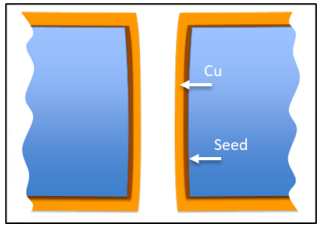


Through-glass vias can be very robust to temperature excursions

Coefficient of thermal expansion (CTE)

- CTE of ABS glass: ~3.4 ppm/°C
- CTE of Fused Silica: ~0.5 ppm/°C
- CTE of Copper: ~16.7 ppm/°C

- Mismatch in CTE must be managed
  - Simplest solution: Keep **via volume low** to keep **stress low**
- ABS will be more reliable than FS
- Conformal coatings can help (but this has other issues)

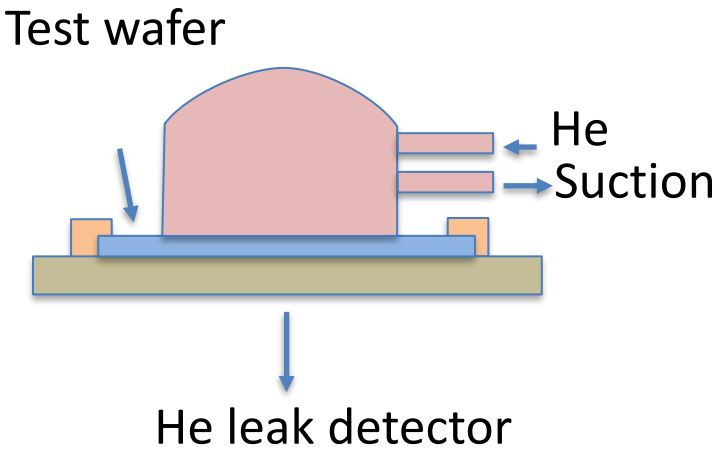


Wafer hermeticity is a good test of glass integrity

Sensitive test:

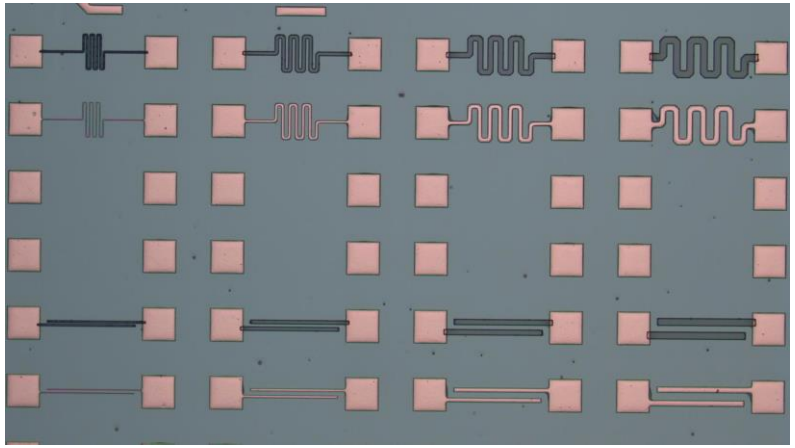
→System detection limit: ~1x10^{-9} atm-cc/s

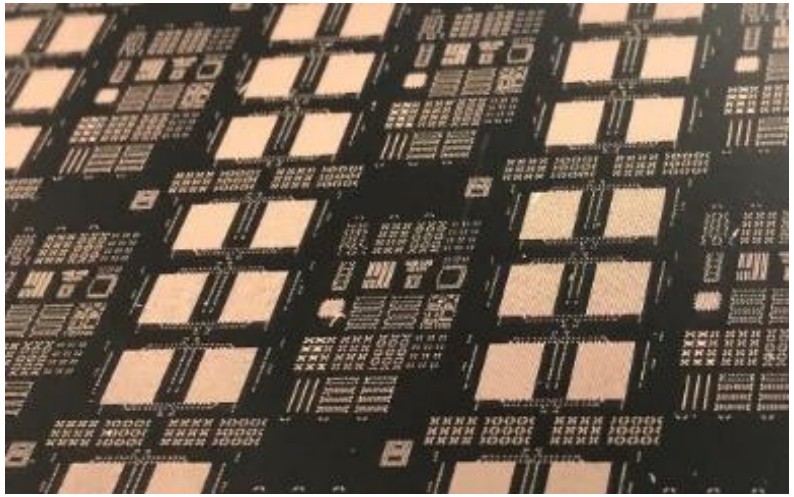
- Debonded wafer forms the seal between He gas inlet and He leak detector
- Thermally cycle wafer → retest



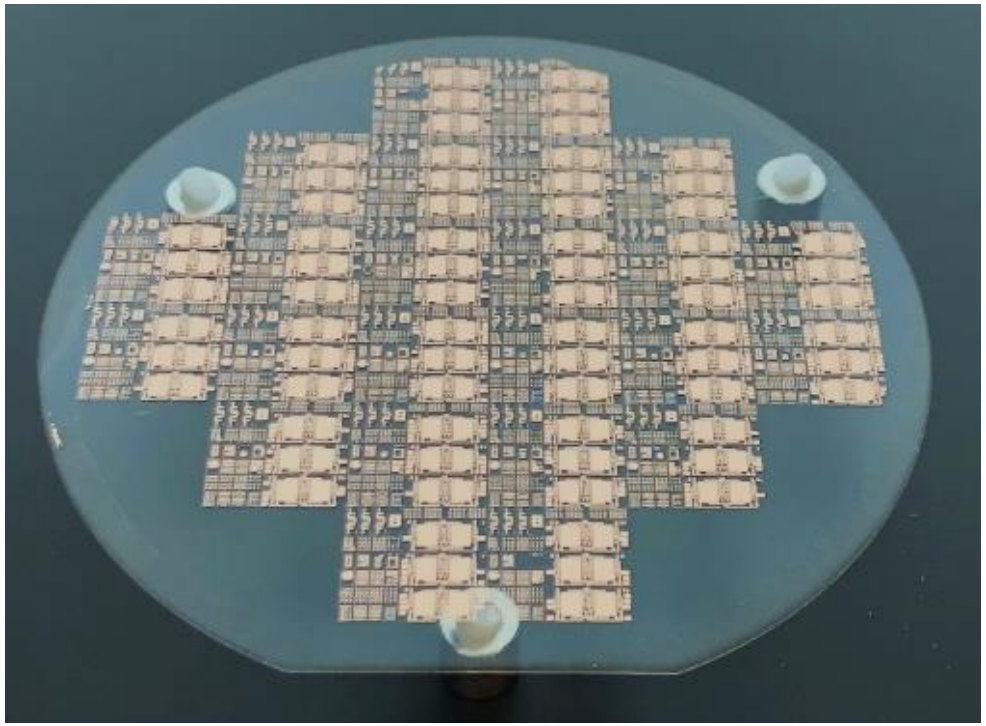
- ABS Hermeticity test (25um via):
  - Demonstrated full wafer (~30,000 vias) at detection limit
  - Thermal cycle to 450°C (90 minute hold) x 2
  - Wafer remained at He detection limit
- High Purity FS Hermeticity test (35um via)
  - Demonstrated full wafer at detection limit
  - Thermal cycle to 260°C → remained at detection limit
  - Thermal cycle to 350°C → significant leaks = cracks

Wafer on handle can get full metallization for redistribution layers and passive devices



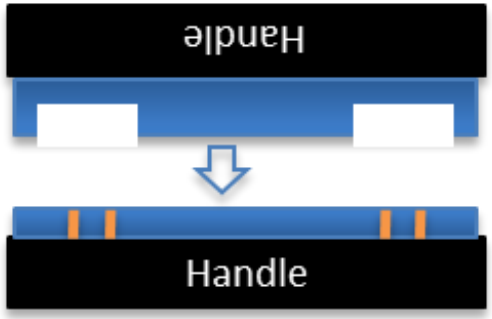


Ex. Copper metallization, with thin film resistor, and PBO passivation

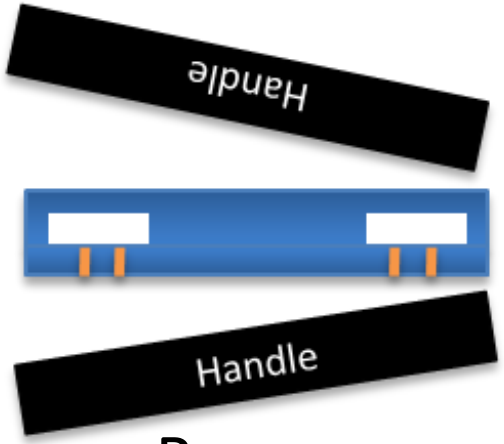


Temporary and permanent bonds allow complex stacks

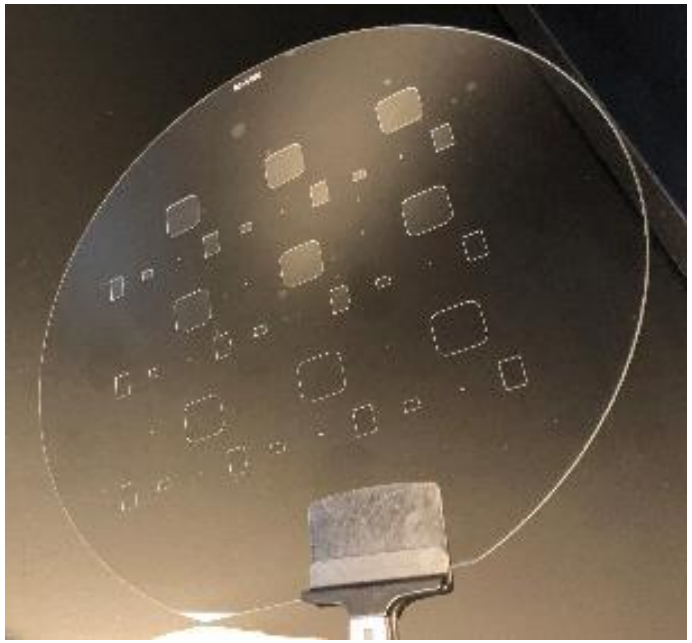
TGV wafer on temporary Handle



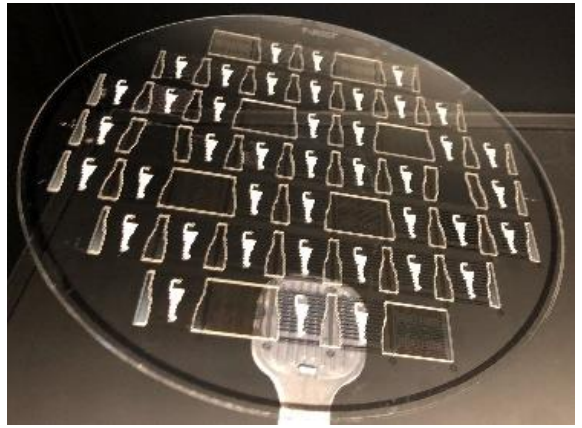
Permanently bond pocket glass to TGV wafer



Remove temporary Handles



Example: Chips hermetically embedded in a thin glass package



Conclusions

- Precision via formation, void-free Cu fill are enabled by a robust, inorganic, thin-glass temporary bond
- This approach facilitates glass integration into packaging flows
- Complex structures are enabled by bond properties

Acknowledgements

Mosaic technical team: Brian Harding, Lee Tutt, Devan Mederios, and Sabina Kanjic

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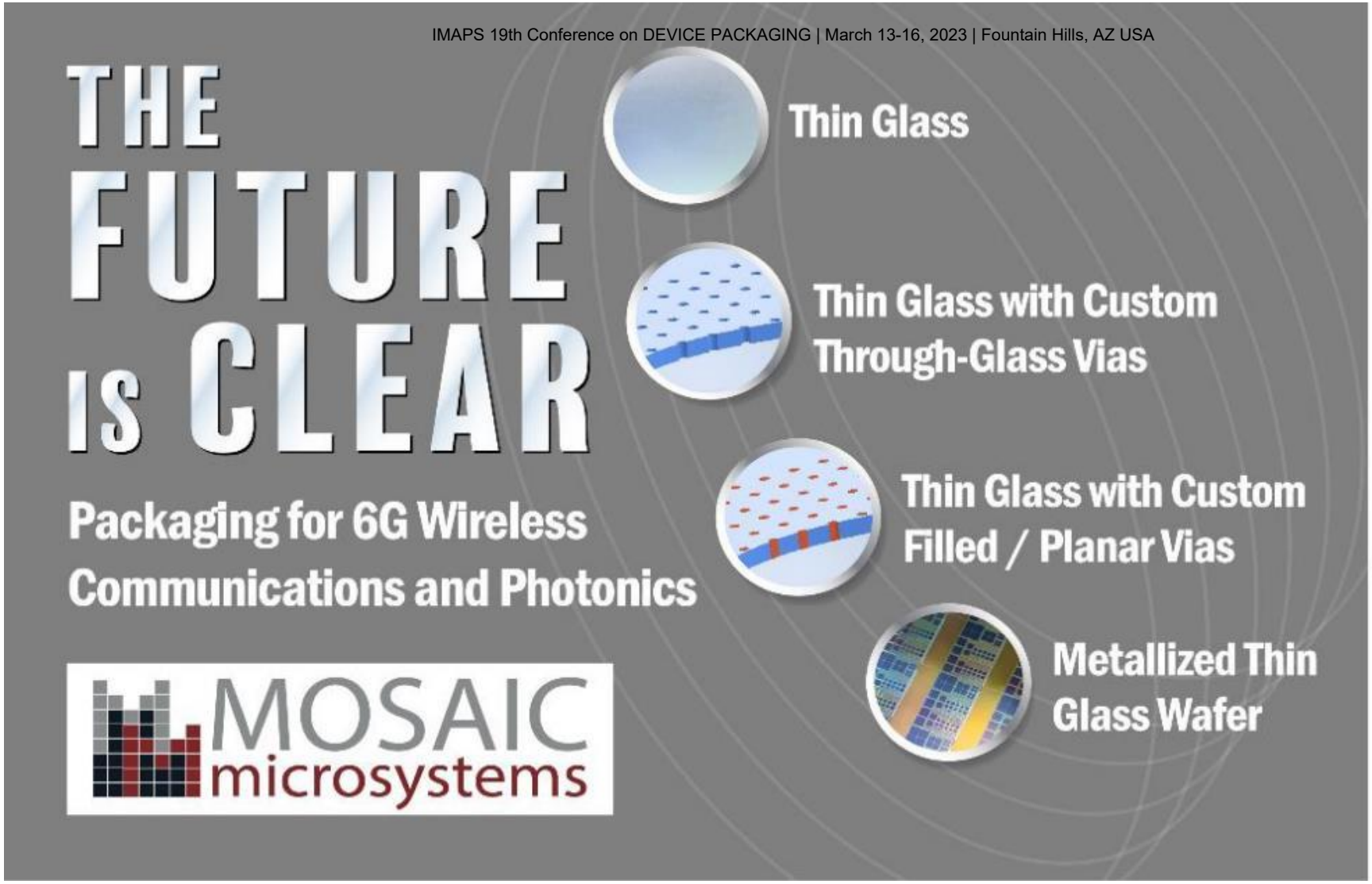
AFWERX



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