VIAFFIRM™ THIN GLASS HANDLING TECHNOLOGY

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Outline/Agenda

- Motivation
- Advantages of glass packaging solutions
- Handling challenges
- Solutions to enable volume manufacture
- Examples showing advantages of glass based devices
- Summary
- Q & A

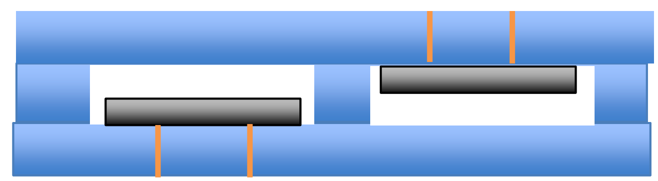
Thin glass addresses industry needs

New material solutions are needed to address needs in RF communications

- Low loss for 5G/mmWave
- Military
- Reduced footprint

Advanced packaging solutions are needed to extend industry performance targets

- Interposer
- Embedded die
- Hermetic



Material properties of glass provide attractive solutions

● (green)	Good
● (yellow)	Fair
● (red)	Poor

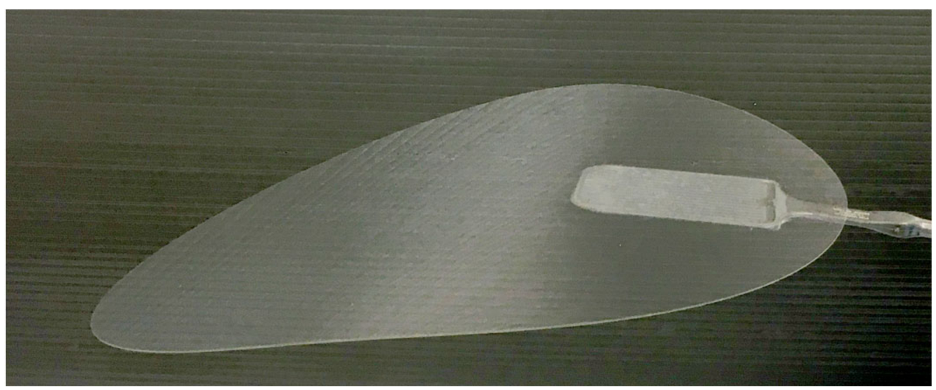
- ✓ Low loss
- ✓ CTE match
- ✓ Smooth
- ✓ Thin
- ✓ Cost-effective
- ✓ Scalable

Characteristic	Ideal property	Materials: Glass	Si	Organic	Ceramic
Electrical	• High resistivity • Loss loss, low k	Good	Poor	Good	Good
Physical	• Smooth surface • Large area scalability • Ultra thin	Good	Fair	Fair	Fair
Thermal	• High conductivity	Fair	Good	Poor	Fair
Mechanical	• High strength, modulus • Low warpage	Fair	Fair	Poor	Fair
Chemical	• Resistance to process chemistry	Good	Fair	Fair	Fair
Via and RDL cost	• Low cost for both	Fair	Poor	Fair	Poor
Reliability	• CTE match to Si and PWB	Good	Good	Fair	Fair
Cost/mm^2	• @25 um I/O pitch	Good	Poor	Poor	Poor

Handling glass < 200 um thick has challenges

Challenges for TGV in thin glass

- Handling <u>thin</u> glass in semiconductor fab environment
- Metallizing vias in a reliable, cost-effective way



New approach to enable thin glass

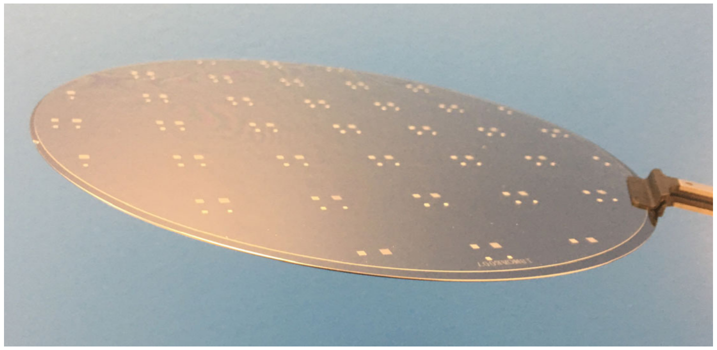
New approach:

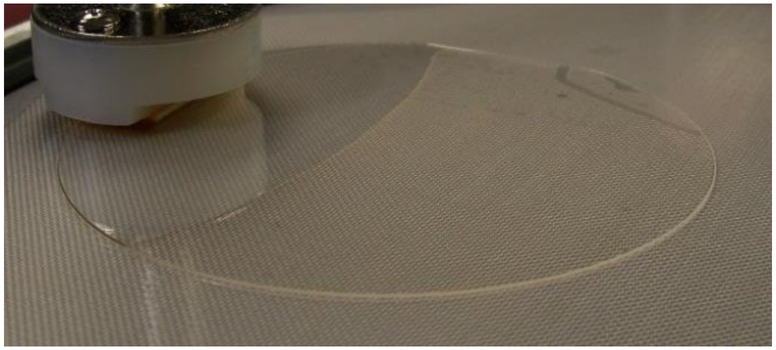
Thin glass with through-holes temporarily bonded to silicon handle wafer using Viaffirm™ technology

- Addresses flatness
- Equipment interface is Si wafer
- Provides path to existing metallization processes

Can be processed like a standard silicon wafer

Key aspects of Viaffirm® technology



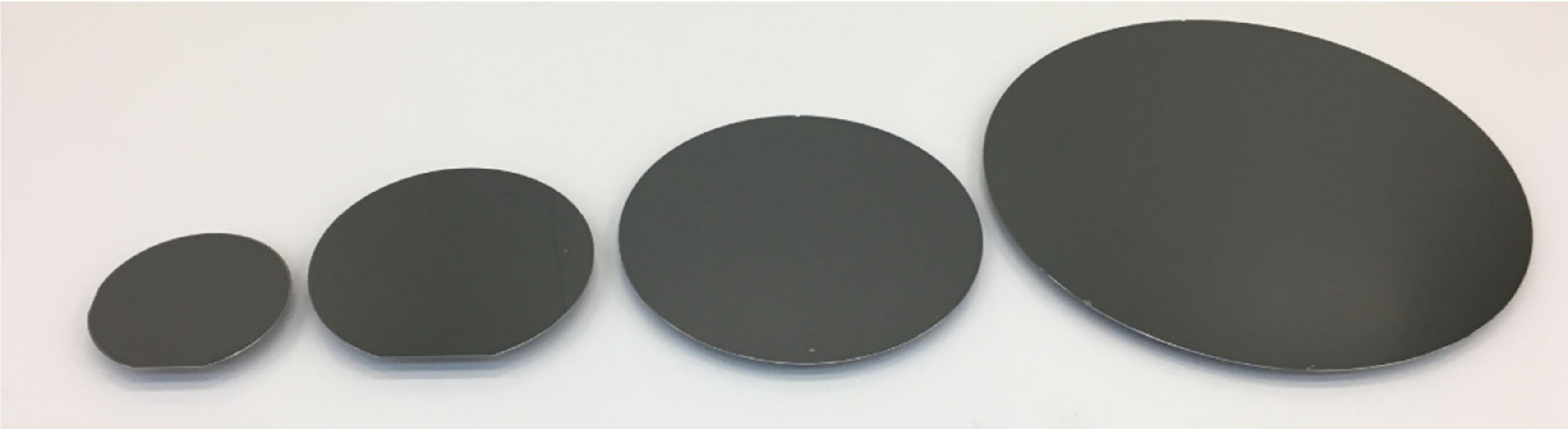


- Bond is temporary to ≥400º C
- <1 um thick layer
- No outgassing during vacuum processes
- Bond energy can be tailored
- Compatible with silicon processing (installed equipment base)

- Mechanical de-bond with low force
- Demonstrated with commercial volume tools (Suss, CEE)

Process scalability

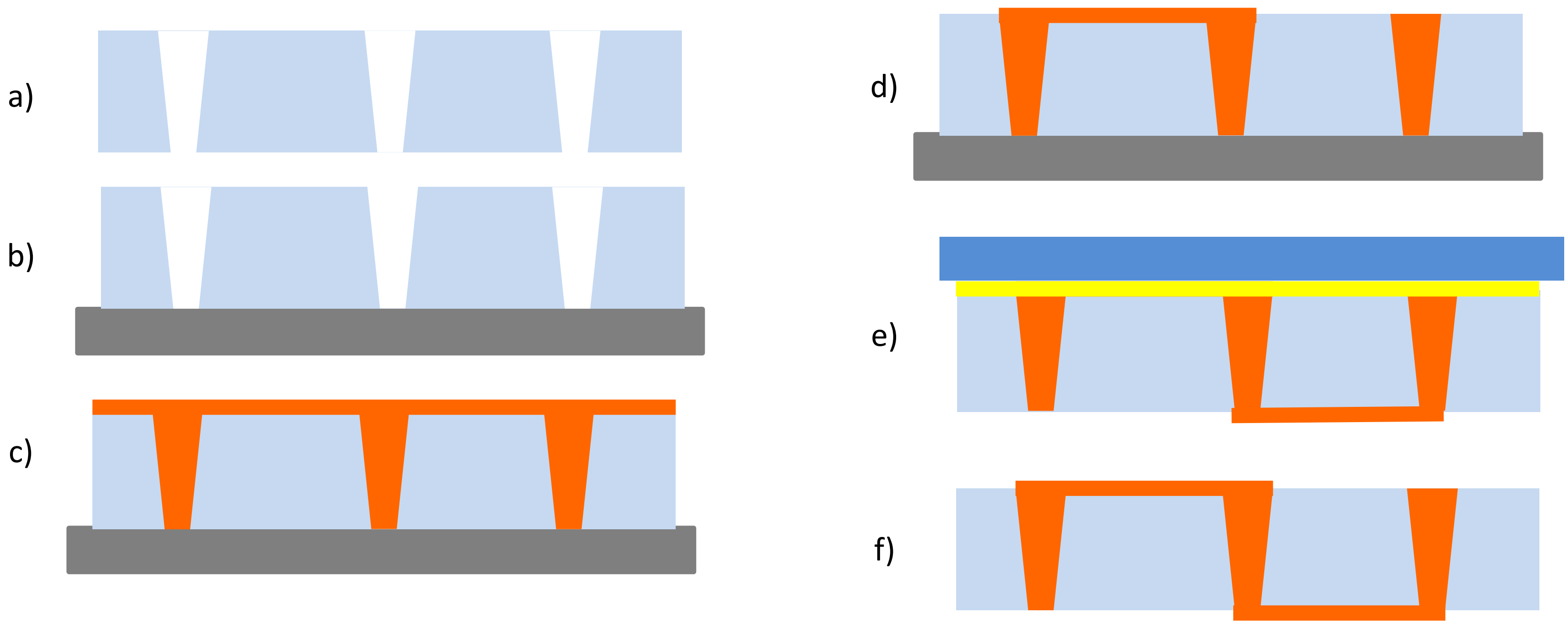
Demonstrated to 300 mm diameter (and beyond)



100 mm 150 mm 200 mm 300 mm

Mosaic Process Flow – Via fill

Leverage established processes for metallized TGV

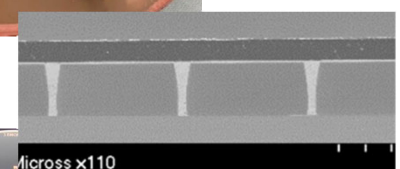


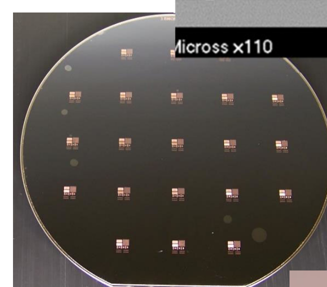
Via Fill on Mosaic bonded pair

- ~30 um via / 100 um glass on silicon handle
- MOCVD Seed layer / Cu plate
  - Void free via fill
- CMP:
  - Bond energy sufficient: no issues
- Post-CMP anneal (400 ºC)
  - No cracking at vias

After plating

Via fill





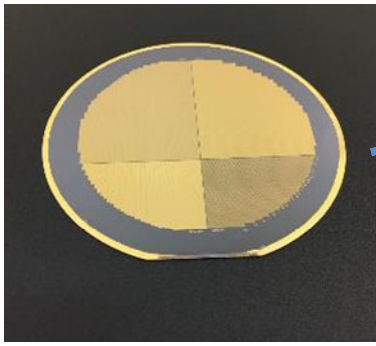
After CMP

After anneal

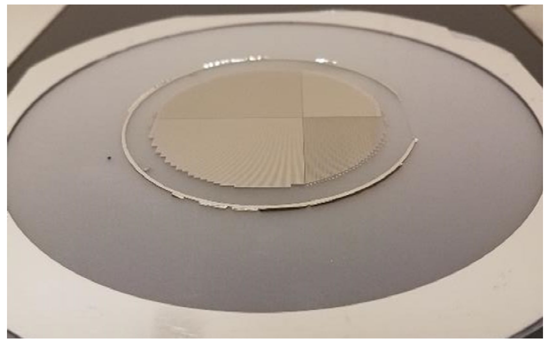
100x0.1 mm wafer – Plated and de-bonded

All wafers yielded

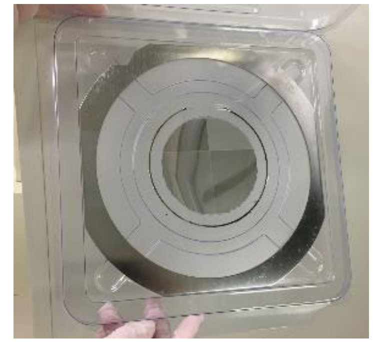
Metallized wafer on Si

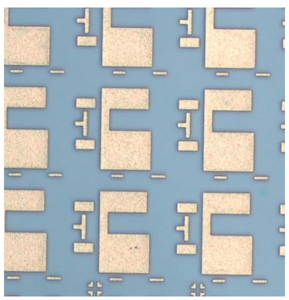


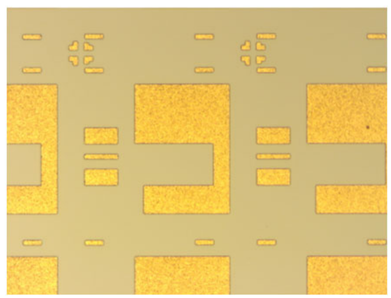
Thin glass supported by dicing tape after debond

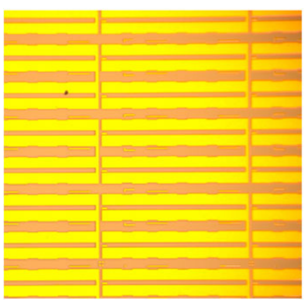


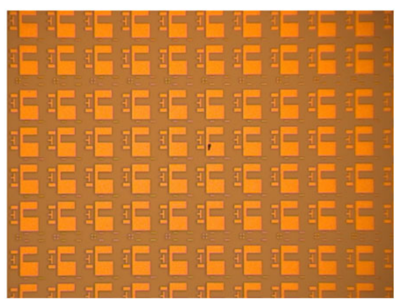
Reverse side of wafer, shown on dicing tape frame

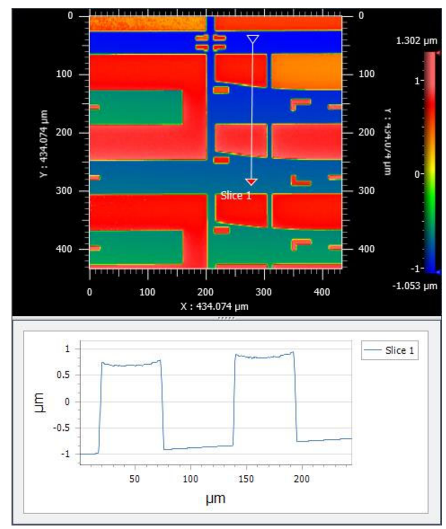








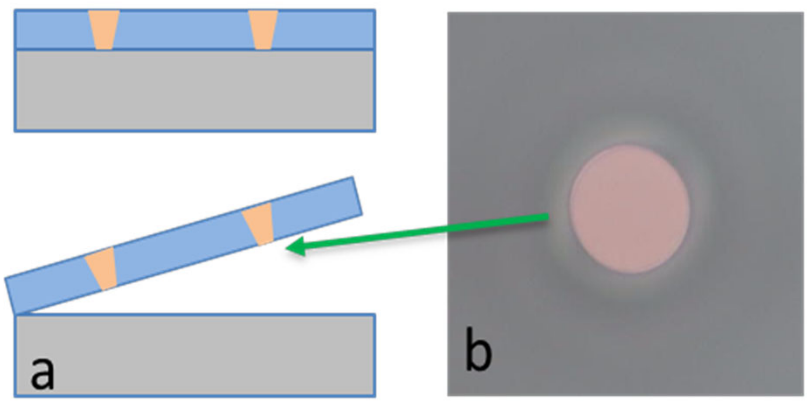


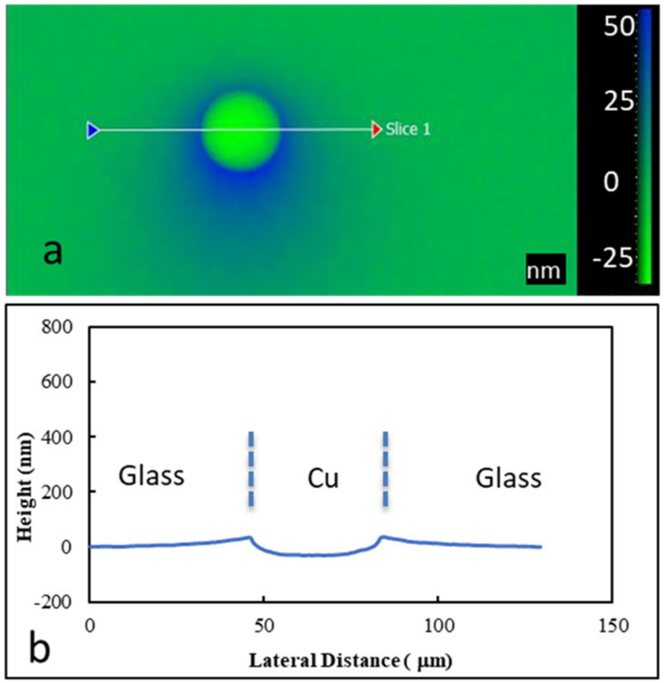


Mosaic Microsystems

TGV Planarity

Back side TGV planarity < 100 nm at de-bond





a) De-bond glass wafer and inspect via planarity after de-bond
   - No post-debond CMP

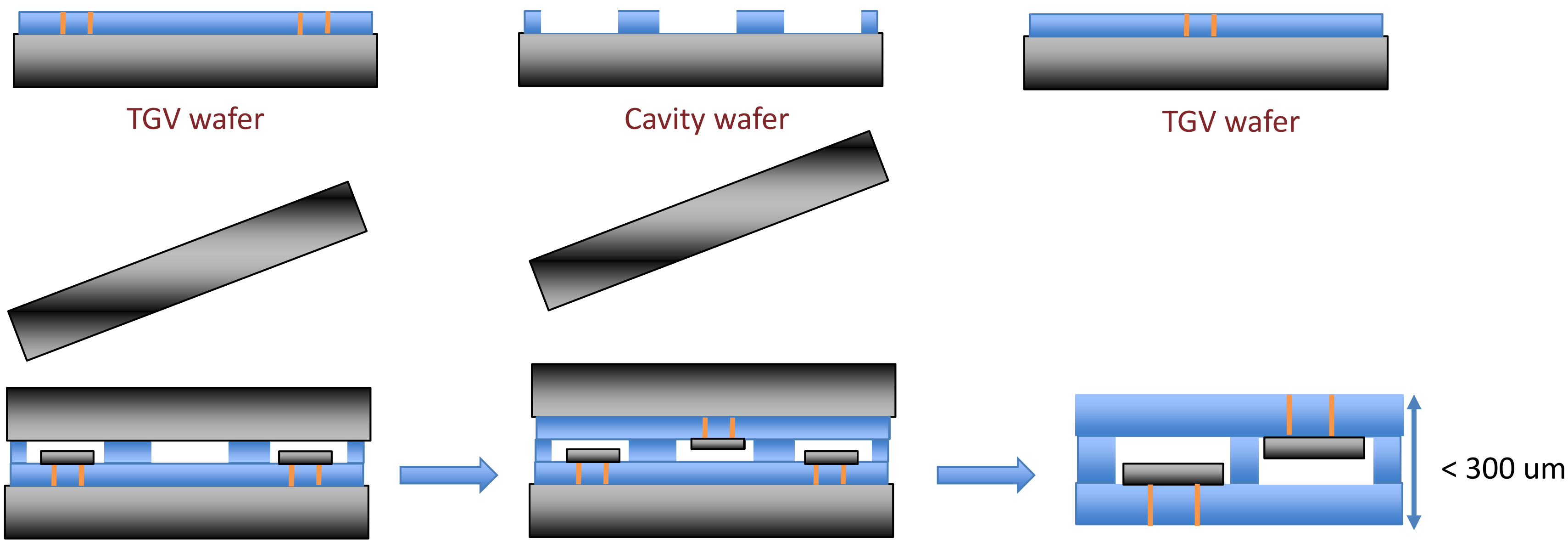
b) Top view of via after debond

- Measure roughness/planarity with white light interferometer (Zygo ZeGage™)
- Vias planar to < 100 nm

Opportunities for embedded die

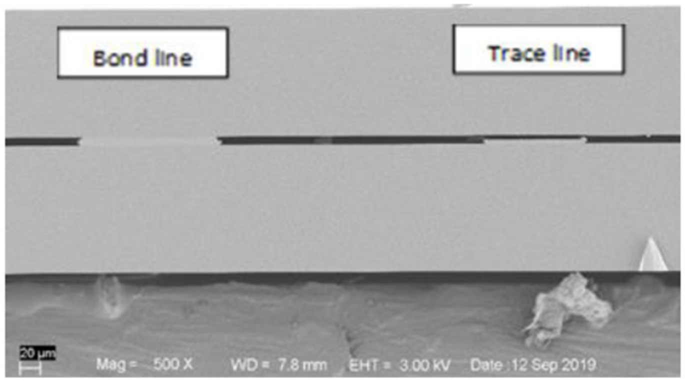
Viaffirm well-suited to make novel, hermetic devices

- Die level He leak performance has been demonstrated to < 1e-8 atm-cc/s

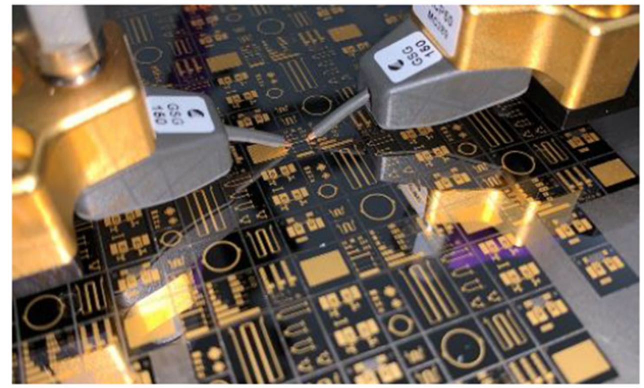


mmW packaging in glass

Wafers processed by GE Research
Contact: Todd Miller (millert@ge.com)



2-layer RF interposer cross section



2-layer RF interposer under test

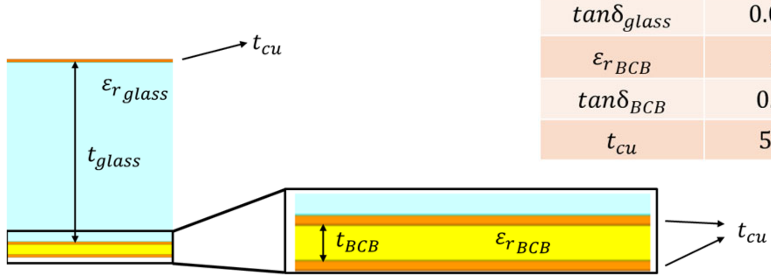
- 0.15 mm thick glass
- Thermal compression bond Au
- Analysis shows glass based approach can provide 50% lower loss with standard glass. More than 70% with fused silica
- In some applications you can realize >7x reduce package size volume (e.g. filters)
- Primary impact from roughness/skin effect, which is pronounced in these relatively designs that can have conductor lengths as long as 50 mm
    - Demonstrators to be built in 2021

Thin glass solutions for 5G – 28 GHz

Collaboration Between Mosaic and Fraunhofer IZM

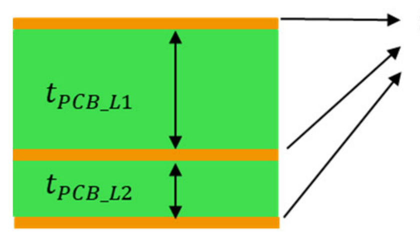
- Goals:
  - Characterize thin glass technology (BCB on fused silica glass) for mm-Wave 5G applications at 28 GHz
  - Design, fabrication and test of 2x2 aperture-coupled patch antenna arrays on thin glass for femtocells (10m-20m range)
  - Comparison between glass-based antennas and equivalent organic material-based solutions

Parameter	Value
t_{glass}	$200\ um$
t_{BCB}	$20\ um$
$\varepsilon_{r\,glass}$	3.8
$tan\delta_{glass}$	0.0002
$\varepsilon_{r\,BCB}$	2.8
$tan\delta_{BCB}$	0.001
t_{cu}	$5\ um$



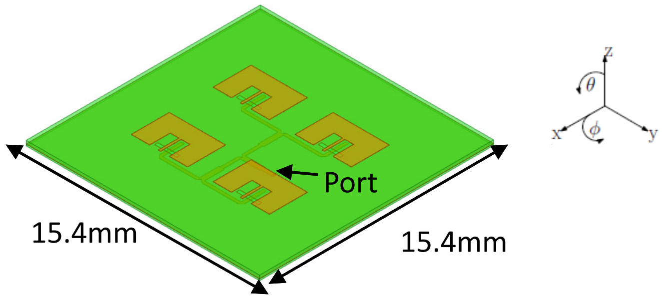
Investigated thin glass stack-up and material information

Parameter	Value
t_{PCB_L1}	$206\ um$
t_{PCB_L2}	$100\ um$
$\varepsilon_{r\,PCB}$	3.71
$tan\delta_{PCB}$	0.004
t_{cu}	$18\ um$

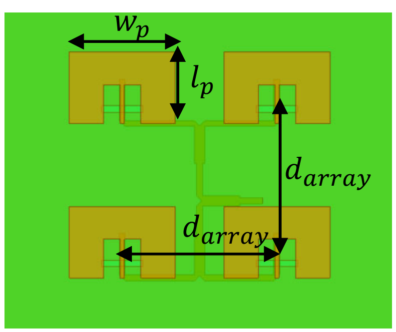


Investigated organic stack-up and material information

2x2 Aperture-Coupled Patch-Antenna Array – Geometry & Impedance Matching



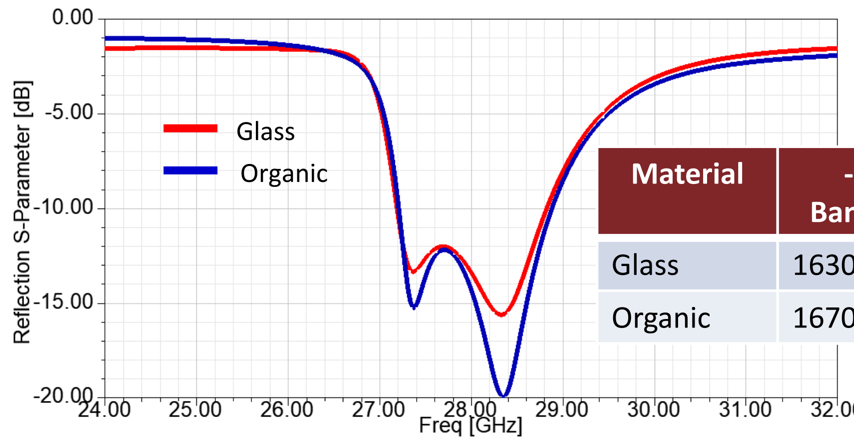
Simulated 3D antenna model



Top view

Parameter	Glass	Organic
l_p x w_p	$2505um$ x $3710u$	$2505um$ x $3710um$
d_{array}	$5400um$	$5400um$

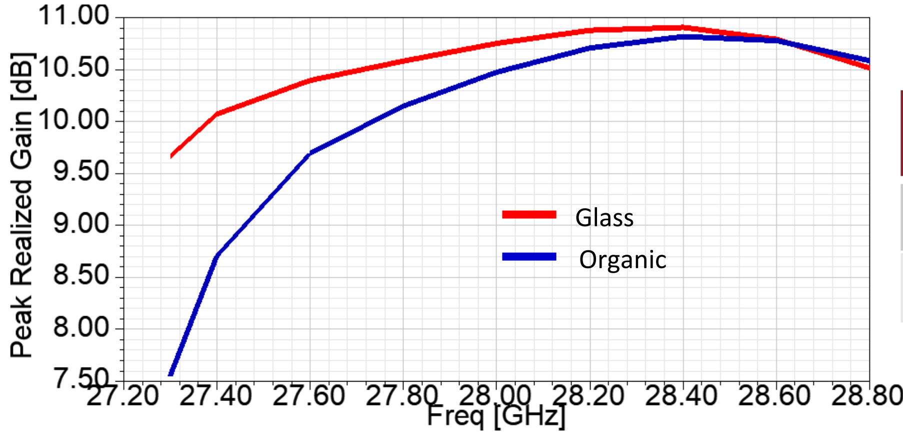
Simulated antenna array geometry



Material	-10dB Bandwidth
Glass	1630MHz
Organic	1670MHz

Simulated antenna array impedance matching

2x2 Aperture-Coupled Patch-Antenna Array – Radiation Pattern and Efficiency



Simulated antenna array peak gain

Material	Peak realized Gain	Radiation effieciency
Glass	10.9dBi@28 GHz	80%@28 GHz
Organic	10.5dBi@28 GHz	75.9%@28 GHz

Conclusion:

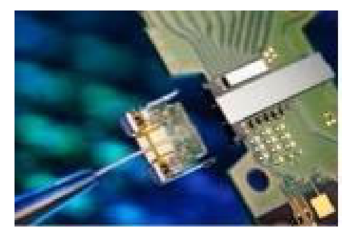
- Thin glass antenna array exhibits higher simulated peak gain and efficiency at 28 GHz and more stable maximum gain over the matched frequency band

Next steps:

- Fabrication of glass and organic material antenna arrays
- Validation of simulation by means of antenna matching and radiation pattern measurement

Summary

- Industry trends require new packaging solutions
- Viaffirm enables cost-effective manufacture for glass/TGV and other thin substrates in a high volume environment
- Several recent applications have demonstrated suitability to leverage existing processes for thin glass applications
- Broad potential application for RF filters/antenna, MEMS, packaging (interposers), hermetic designs, sensing etc.
- Unlocking the value of glass solutions
  - 2021 demonstrators for ESA, Radar and heterogeneous integration



Thank You!

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