

Glass Package and Through Glass Via (TGV) for MEMS

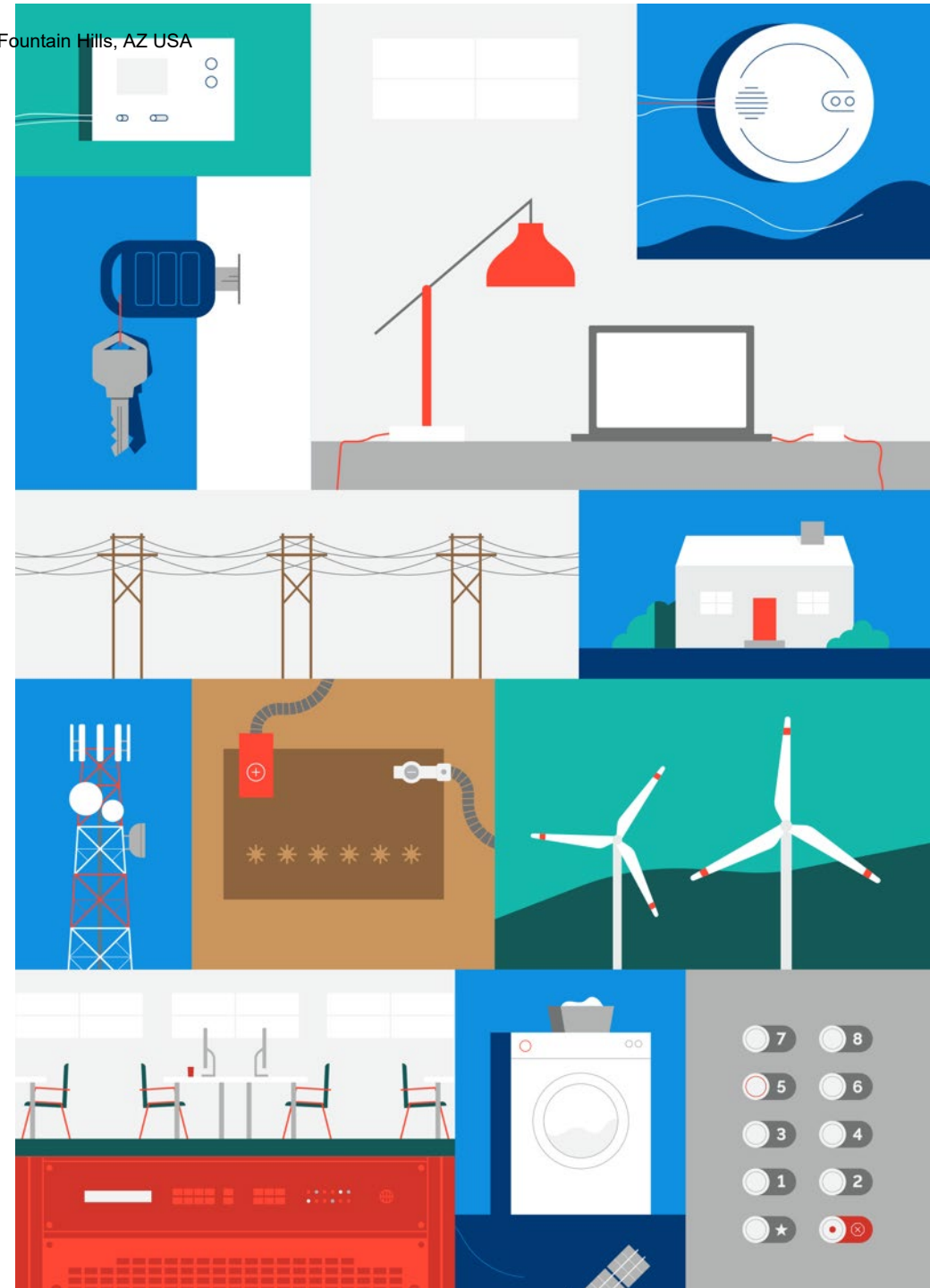
*Enabling the electrification of everything
Milliwatts-to-kilowatts, DC-to-light*

Aric Shorey
Director of Glass Technologies



**19TH INTERNATIONAL CONFERENCE & EXHIBITION ON
DEVICE PACKAGING**
FOUNTAIN HILLS, AZ • WWW.DEVICEPACKAGING.ORG • MARCH 13-16, 2023

000995



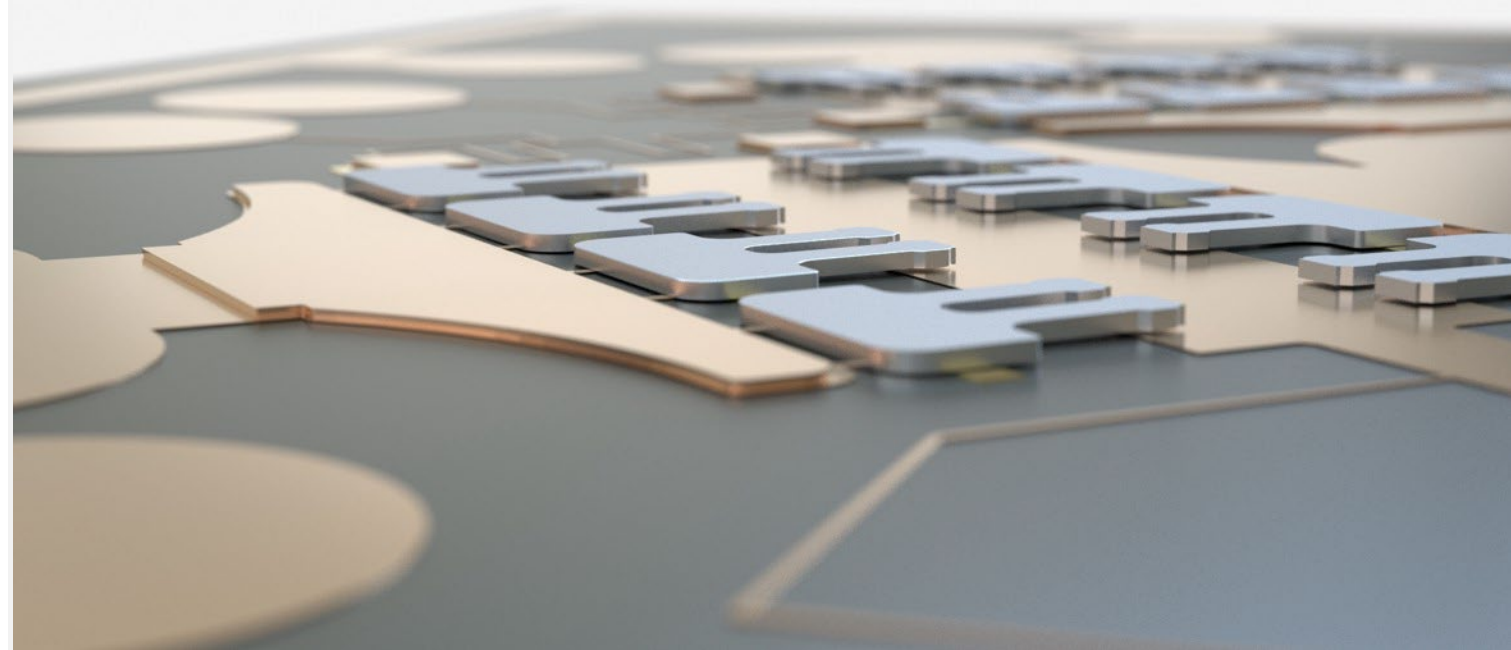
Agenda

- Overview of Menlo Microsystems and MEMS
 - Description of Menlo's Ideal Switch™
 - Advantages of glass-based design
- Discussion of glass supply chain
 - Supply chain is growing and maturing
 - Gaps are disappearing
 - New, exciting emerging capabilities for glass
 - Glass and Through Glass Vias (TGV) innovations
 - Novel structuring of glass
 - Maturing, vertically integrated suppliers
 - Metrology/Inspection



Who is Menlo Micro?

- A fabless Ideal Switch company based in Irvine, CA
- Created in the R&D labs at GE
- The world's smallest, most reliable, most efficient micro-mechanical switch
- Bringing disruptive performance to both Power and Communications (RF) systems
- Manufacturing switched product innovation on glass



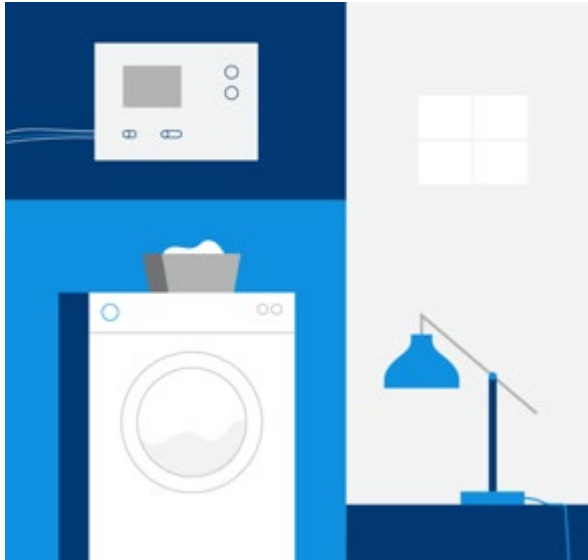
Smaller than a human hair, but can handle > 1000V

Today, switches are everywhere.

It's the most ubiquitous electronic component.

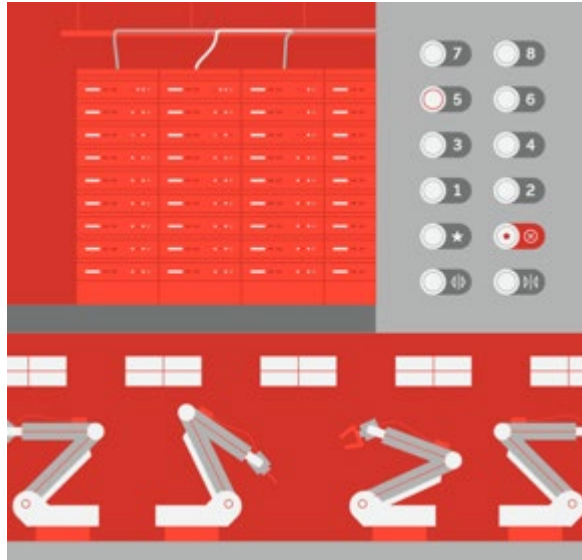
In our homes.

- Managing our heat, AC, & lights.
- Our appliances are loaded with them.
- Circuit breakers that keep it all safe.



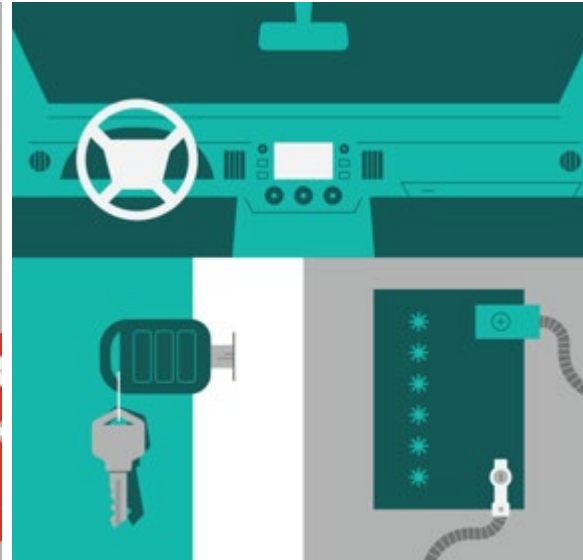
At work.

- Control the elevators, lighting, HVAC.
- All our computers, servers, comms.
- Manage factories and all equipment inside them.



In our cars.

- Unlock the doors and start the engine.
- Turn on and tune the radio.
- Control the wipers, windows.
- Manage the battery.



The world at large.

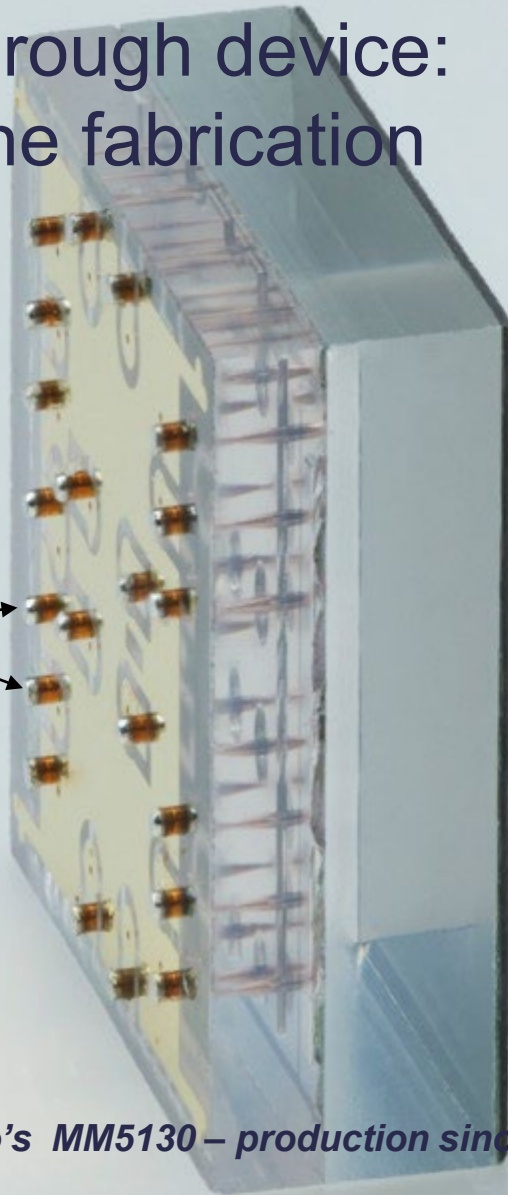
- Switches control the electricity flowing from power plants to the grid to our homes.
- Switches control the data zipping around the world to our computers and smartphones.



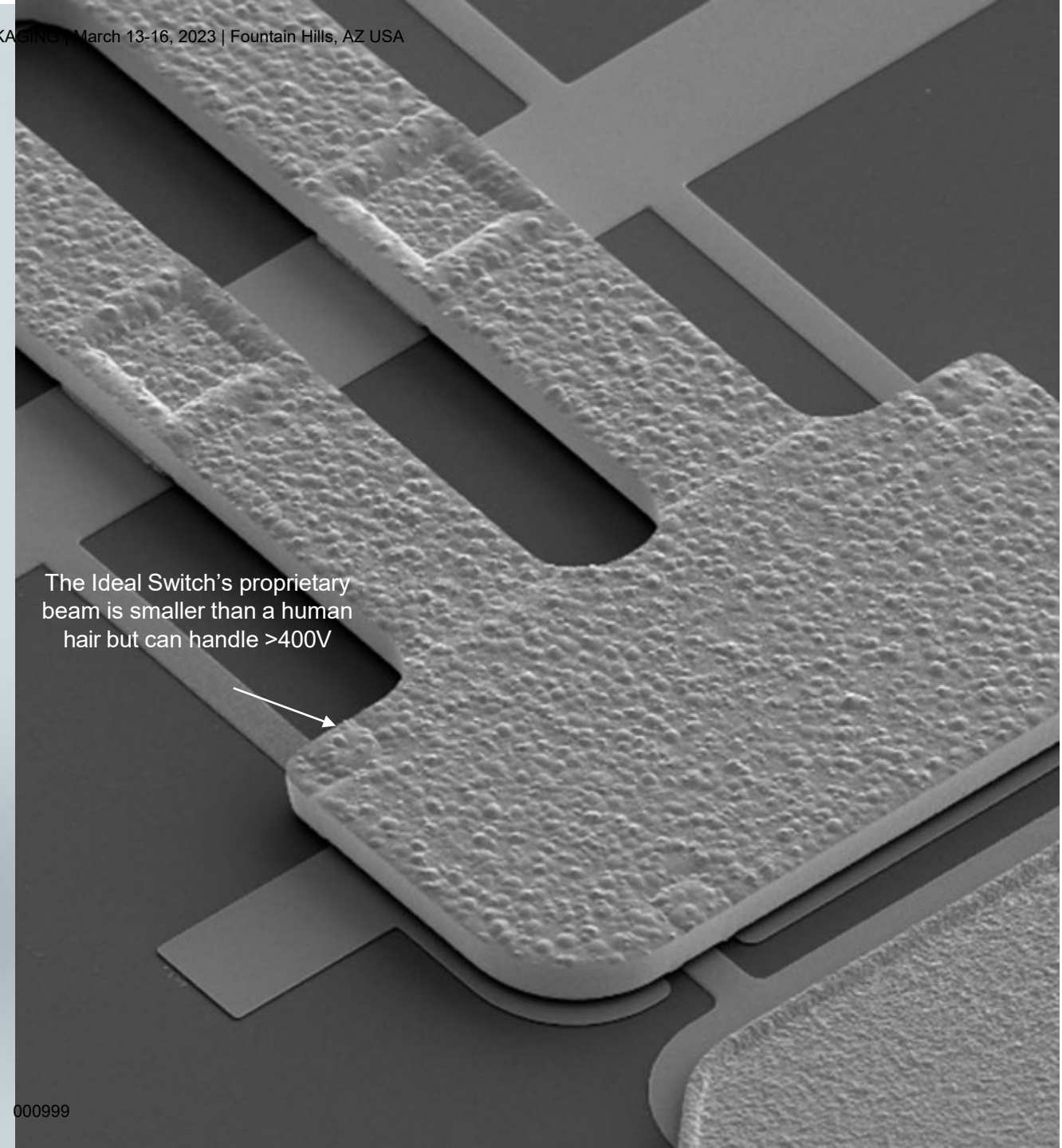
The see-through device: Dive into the fabrication

The Ideal Switch's
proprietary packaging

Close-up of Menlo's
revolutionary MEMS switch
chip scale packaged
product with hermetic
Through-Glass-Via (TGV)
technology



Side-view of Menlo's MM5130 – production since Q4-2020



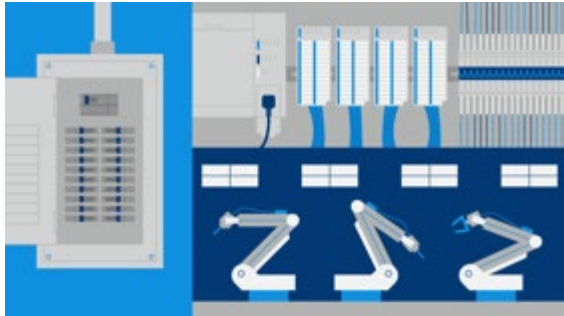
The Ideal Switch's proprietary
beam is smaller than a human
hair but can handle >400V

Ideal Switch Key Differentiators per Market Segment

The ideal switch solved key pain points for each power segment

Industrial Automation

- Robotics & PV Manufacturing
- Automotive Manufacturing
- Food & Beverage Manufacturing
- Pharmaceuticals Manufacturing



VALUE

Ideal switch is 10000x more reliable

- Reduce unplanned maintenance
- Reduce total cost of ownership

Buildings

- Commercial & Residential microgrids
- Solar/microinverter & energy storage
- HVAC and appliance controls
- Lighting/smart plug/GFCI



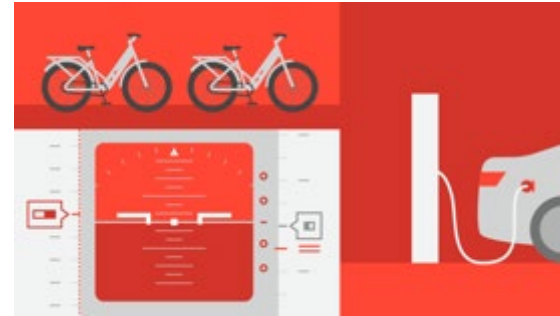
VALUE

Ideal switch is 25x more efficient

- Reduce baseload requirements
- Enable renewable integration

Transportation

- eMobility (EV, eBike)
- Battery management
- Advanced avionics
- Marine & Rail



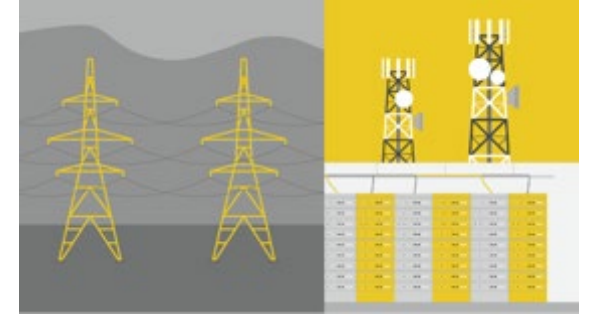
VALUE

Ideal switch is 99% smaller & lighter

- More transportable
- Capable of DC breaking

Electrical Infrastructure

- Power grid, LV switchgear
- Datacenter power distribution
- Communications equip. power distribution
- Electrification



VALUE

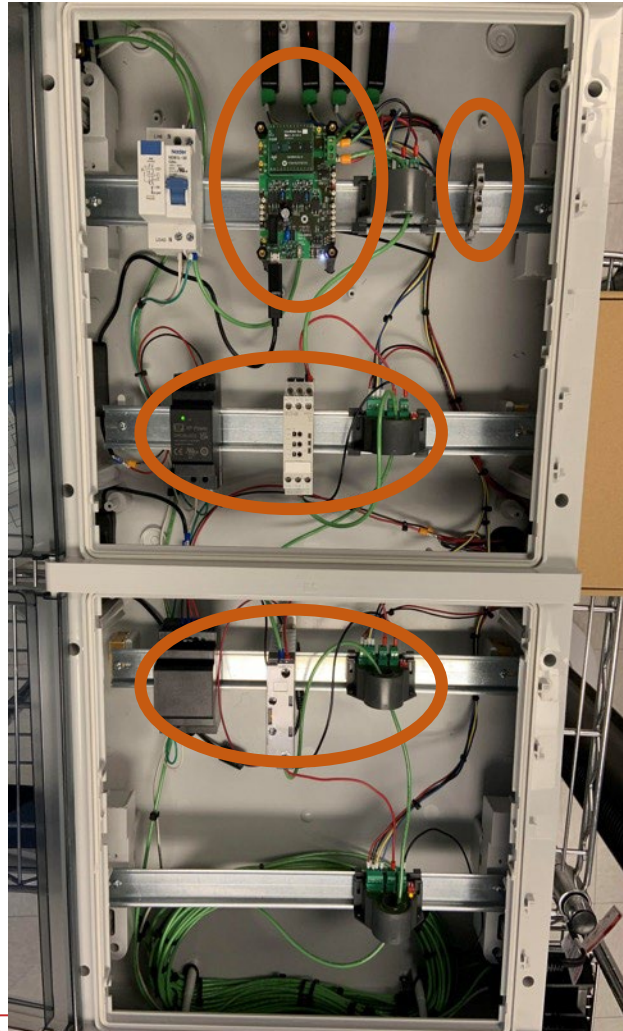
Ideal switch is scalable

- Brings efficiency and reliability to infrastructure

Ideal Switch Energy Savings Demo

Steady State Comparison of Ideal Switch vs. Other Relays under a continuous 1500W load

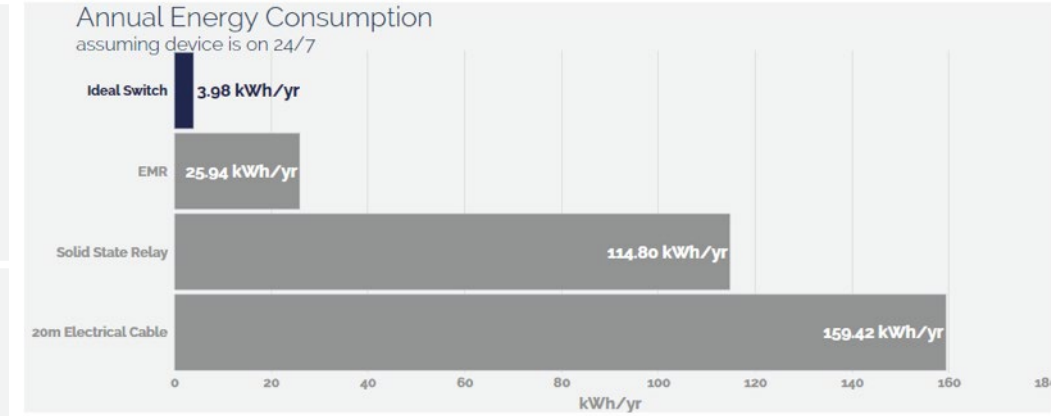
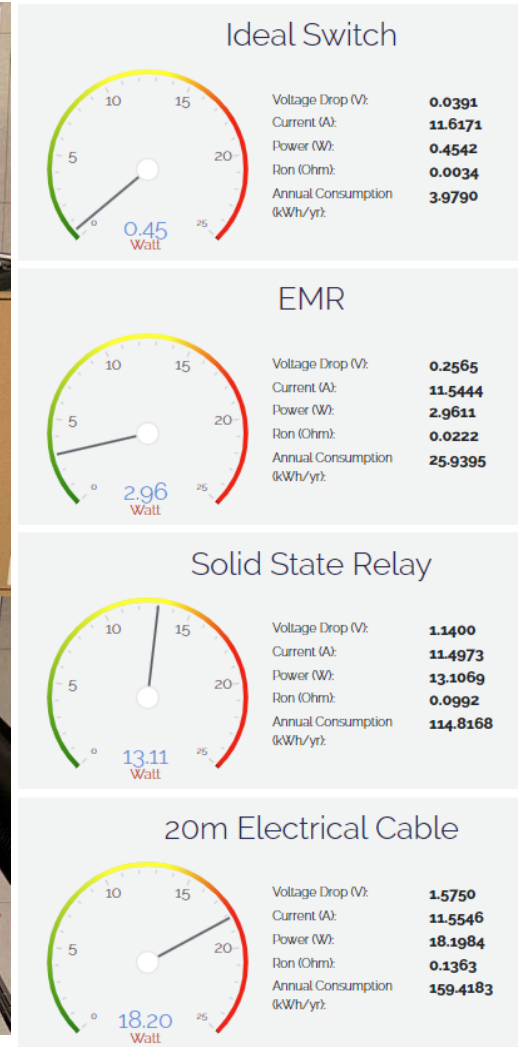
MM9105
Prototype &
MM9250 Concept



EMR with
Power Supply &
Energy Meter

SSR with
Power Supply &
Energy Meter

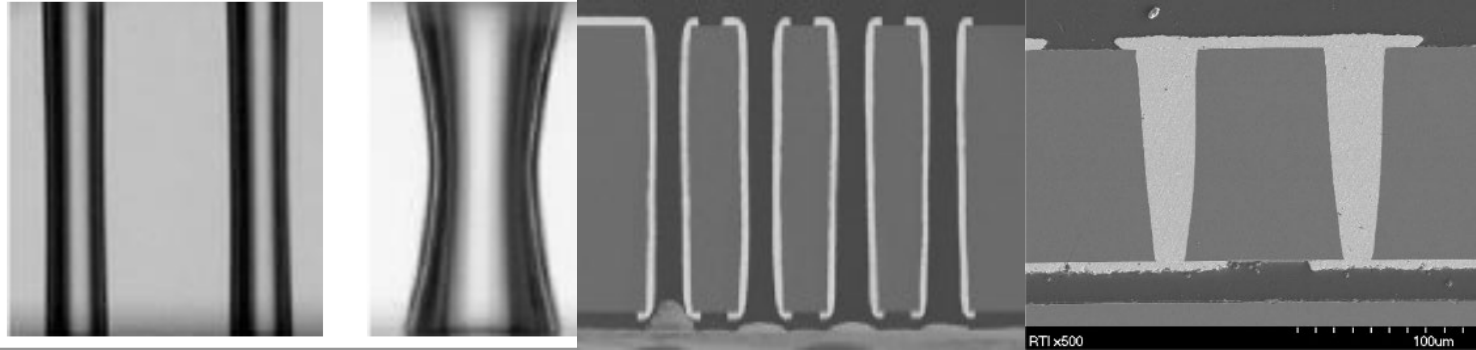
20m Wire
(12AWG)



- Ideal Switch offers the ability to save enormous amounts of energy over traditional relays used for power distribution and control
- The ability to miniaturize and include smart features like current and voltage monitoring saves precious space and cost
- The extreme reliability of Ideal Switch reduces system down-time and cost of maintenance for critical equipment and infrastructure

Through Glass Vias (TGV)

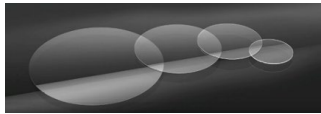
Options for TGV and associated products has matured with numerous new options emerging



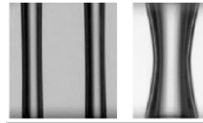
- Today, most TGV fabricated using laser-based process
 - Often hourglass shape due to the nature of the process but other geometries have been established
 - Early, high aspect ratio vias were limited to conformal fill or relatively low aspect ratio
 - Aspect Ratio = Thickness ÷ Via diameter
 - New techniques and processes have been established for fully filled higher aspect ratio parts
 - We are seeing both maturation of the supply chain as well as emerging capabilities will enable high volume, novel devices

Glass Supply Chain

Significant capability established in the past 5 years – much of it motivated by Menlo



Wafer Supply



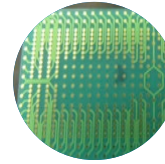
TGV Fabrication



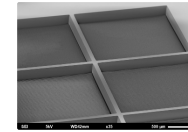
Inspection



Via Metallization



Surface
Metallization /RDL



Cavity



Device Assembly
and Test

- ❖ 5 years ago, many of these steps were in development with few suppliers
- ❖ Now there are several suppliers at each step, with a growing number of capabilities
- ❖ Much of the supply chain is still fragmented
 - Gap in fabs/foundries with integrated processes
 - Will highlight a couple of examples of vertically integrated companies
- ❖ The following slides highlight a number (not all) of the areas and players that are enhancing the growing glass packaging supply chain

SCHOTT Glass materials for MEMS application

Glass companies have a range of offerings that address different applications



Glass type		Glass with high CTE	Glass optimized for anodic bonding		Alkaline-free glass	Glass with lowest electrical & optical loss
Properties		D 263®	BOROFLOAT® 33	MEMpax®	AF 32® eco	8325 – RD material
Thermal properties						
CTE α (20 °C; 300 °C)	10^{-6} K^{-1}	7.2	3.25	3.26	3.2	3.29
Transformation point T_g	°C	557	525	532	717	467
Electrical properties						
Dielectric constant ϵ_r	5 GHz	6.3	4.5	4.4	5.1	4.05
	77 GHz	6.0	4.4	4.4	5.1	4.05
Dissipation factor $\tan \delta$ in 10^{-4}	5 GHz	101	73	73	49	17
	77 GHz	240	170	150	110	47



SCHOTT Glass products for MEMS application

Increasing number of processed offerings

Glass with flexible, high precision structures and geometries

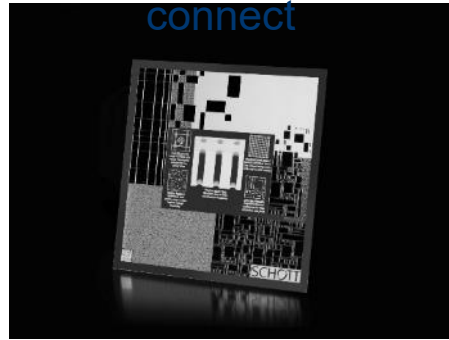
FLEXINITY®



- Flexible through structures
- Structure radius $\geq 100\mu\text{m}$
- Feature size and position tolerance $< 20\mu\text{m}$
- Virtually unlimited amount of structures

Glass with ultrafine, high density holes

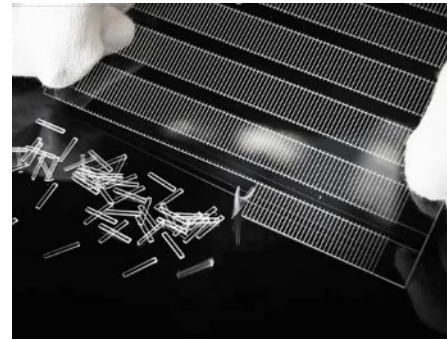
FLEXINITY®



- Round through structures
- Structure radius $\geq 25\mu\text{m}$
- Feature size and position tolerance down to $3\mu\text{m}$
- Virtually unlimited amount of structures

Solution for small thin glass components

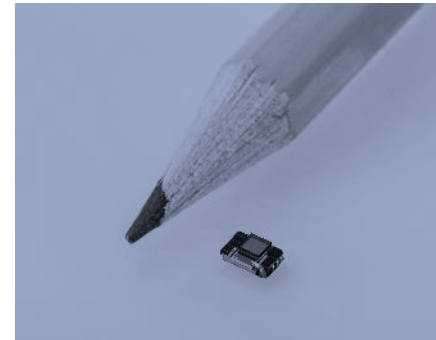
FLEXINITY® mini



- Glass parts between 10 mm and 1 mm
- High edge quality with minimal chipping.
- In-frame delivery for simple cleaning and coating possible

Room Temp. bonding for Glass to Si and Glass to Glass

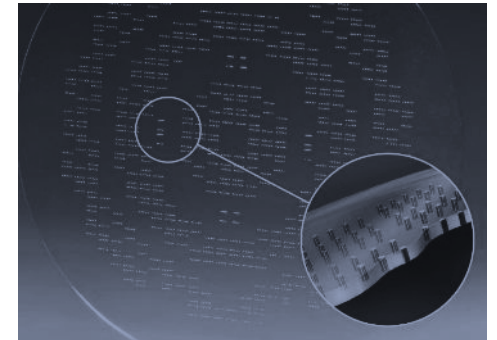
Glass Micro bonding



- Enables hermetic wafer level packaging
- Unique laser-based process without any need for additives or adhesives.
- Leakage rate less than $1.1 \times 10^{-11} \text{ atm cm}^3/\text{s air}$

Glass with hermetic Through Glass Vias

HermeS®



- Up to 30,000 TGVs per wafer (8")
- Via diameter as low as $80\mu\text{m}$ on a $200\mu\text{m}$ pitch
- Leakage rate less than $1 \times 10^{-9} \text{ Pa x m}^3/\text{s}$



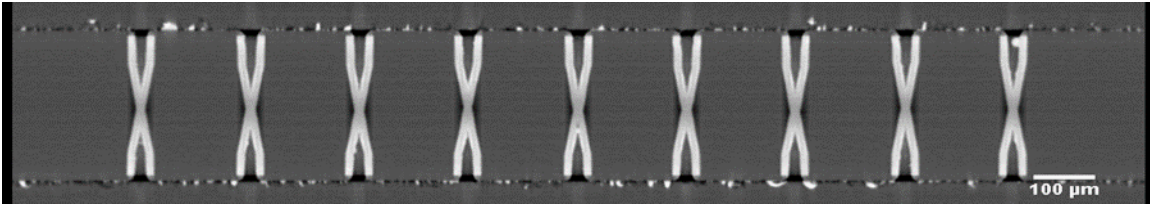
Demonstrated fabrication and metallization of various TGV geometries

Early TGV Innovator – has demonstrated thermo-mechanical reliability and He hermeticity



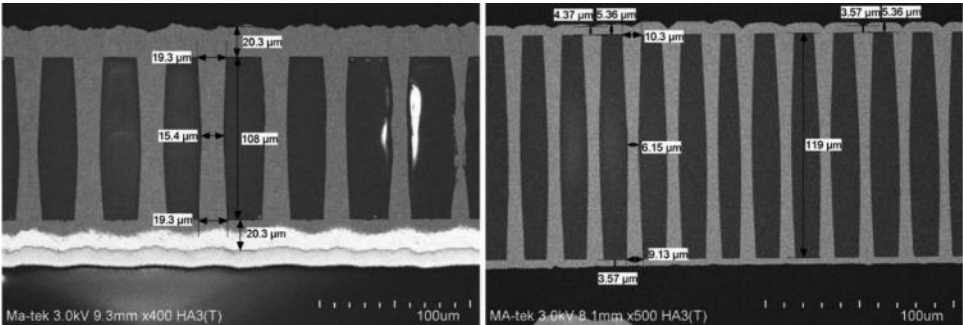
Standard Capabilities		
TGV (Glass + Vias)	Dimensions	Wafer: up to 300mm diameter Panel: up to 515 x 515mm
	Thickness	100µm - 400µm
	Via Diameter	30µm - 100µm No multiple diameter in the same parts
	Pitch	Min. 2x via diameter
	Process Control	Via position accuracy: $<\pm 10\mu\text{m}$

Conformal Plated “Pinched” Via

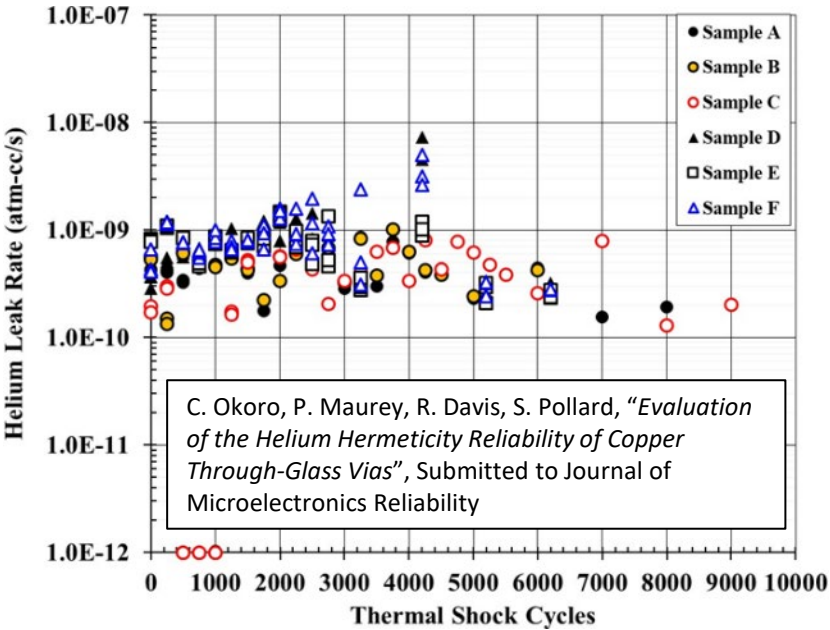


R. Vaddi, K. Kanungo, C. Okoro, S. Pollard, P. Mazumder, “Helium-tight and Thermo-Mechanically Reliable Metallized Through Glass Vias(TGV) by Conformal Pinched Via (CPV) Approach”, International Symposium of Microelectronics (IMAPS 2021), San Diego, CA

Fully Filled High Aspect Ratio TGV



Y-H. Chang, P-L. Tseng, J-C. Lin, J-C. Chen, M-C. Huang, H-Y. Lin, S. Pollard, P. Mazumder, “Defect-Free Filling of High Aspect Ratio Through Vias in Ultrathin Glass”, Journal of The Electrochemical Society, 166 (1) D3155-D3157 (2019)



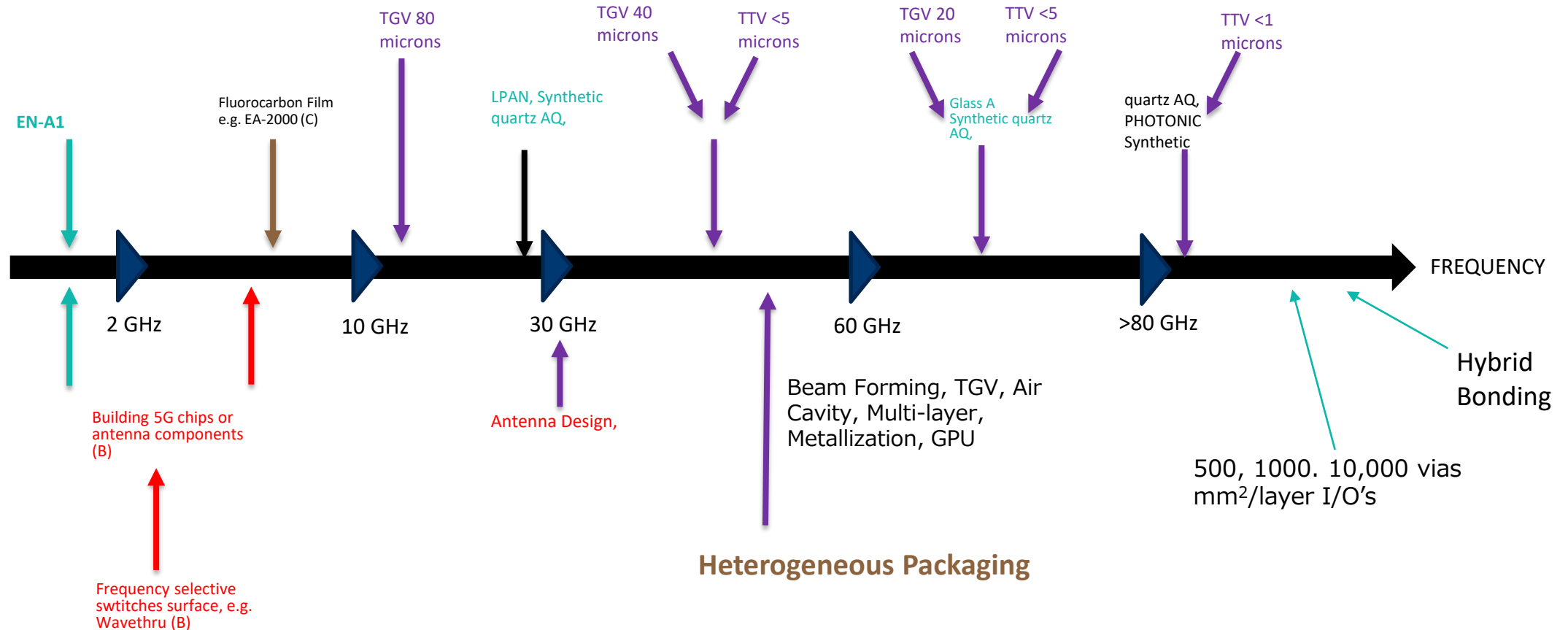
AGC Packaging Materials

Provides different glass solutions depending on application/operating frequency

- As frequency increases, materials, vias and precision changes
- Solutions for TGV, cavities, material composition, photonic arrays, glass core
- Also provide temporary handling solutions (carriers, FOWLP)

Materials and
TGV
Requirements

Applications

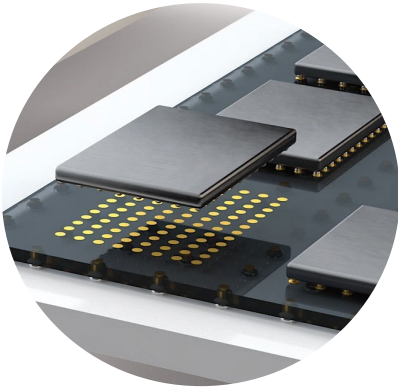
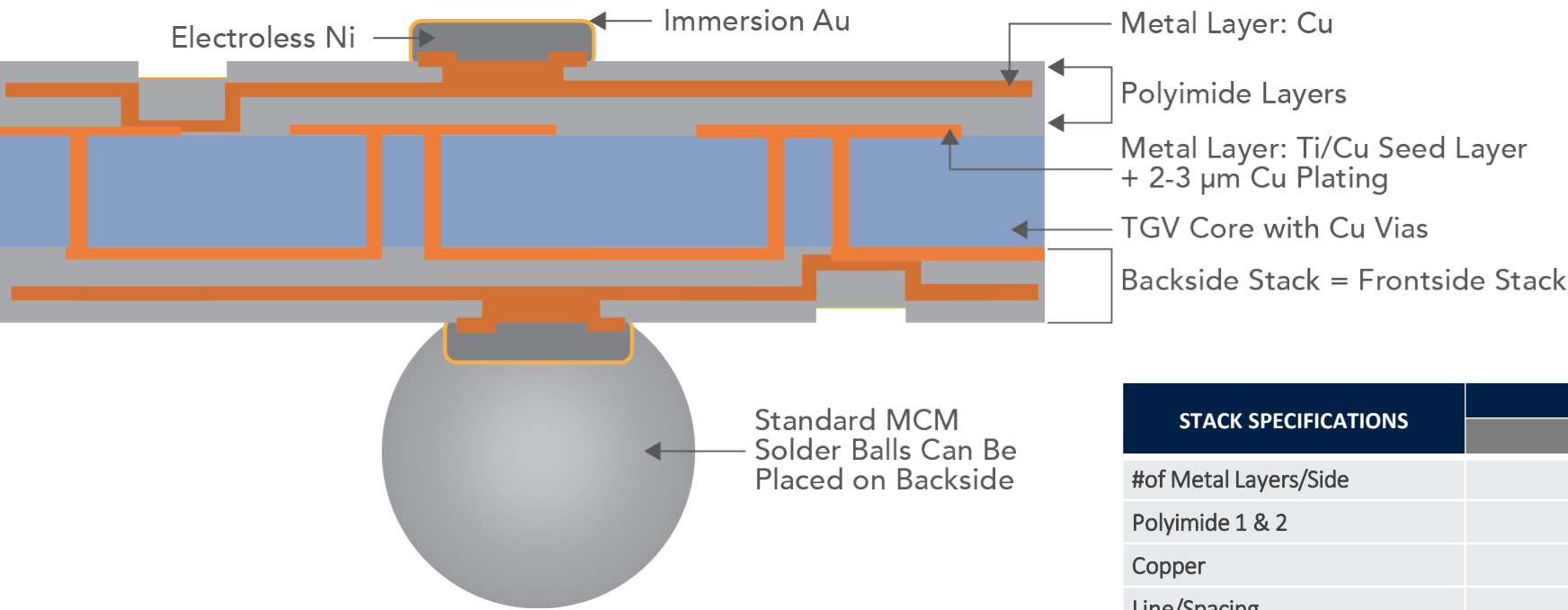




steve.hillerich@samtec.com

Samtec GLASS CORE TECHNOLOGY (GCT)

Vertically integrated in-house capabilities



STACK SPECIFICATIONS	CURRENT	ROADMAP
#of Metal Layers/Side	2	4
Polyimide 1 & 2	5 μm	
Copper	1-7 μm	
Line/Spacing	15 μm / 15 μm	10 μm / 10 μm
Glass Core Thickness	260~500 μm	<200 μm & >500 μm
Core Via Diameter	40~70 μm	30~60 μm
Core Via Pitch	2X Via Diameter	40 μm
Solder Ball Types	Sn63Pb37 / PbSn5 / PbSn10 / SAC	Cn/Sn Pillars



In-house GCT, circuit formation, and packaging expertise.

3DGS Photosensitive Glass-Ceramics



Contact Info:

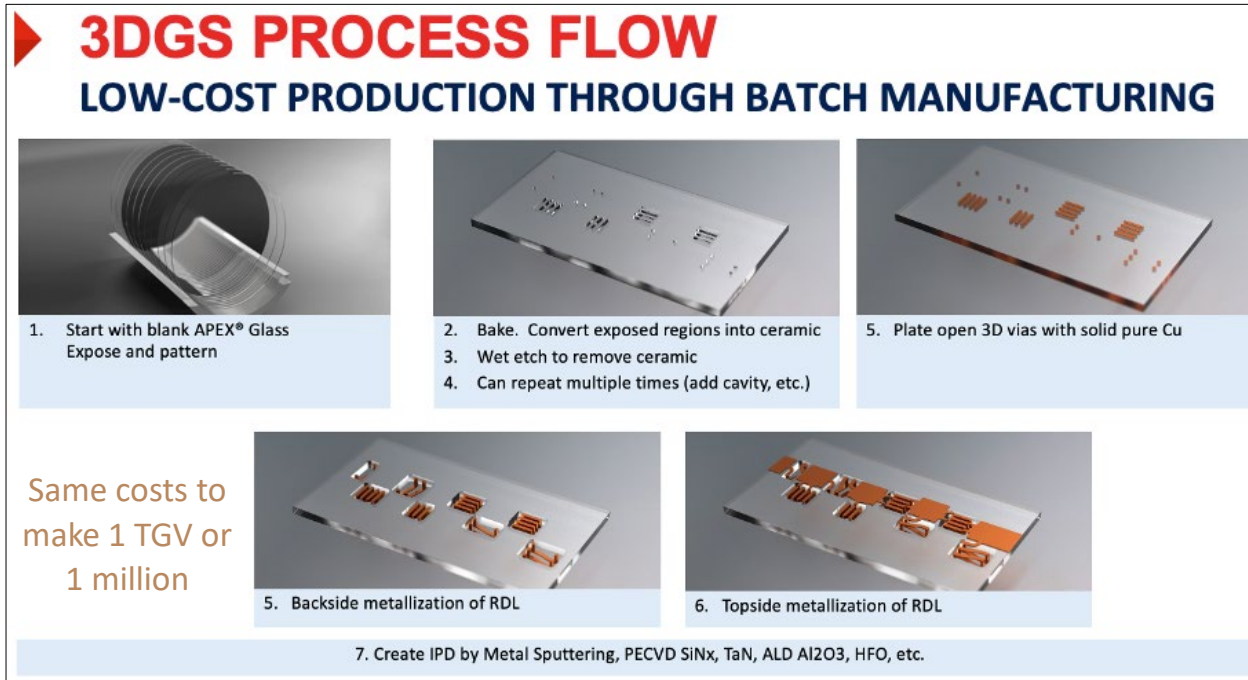
Jeb H Flemming, Founder & CTO

Jeb.Flemming@3DGSinc.comwww.3DGSinc.com

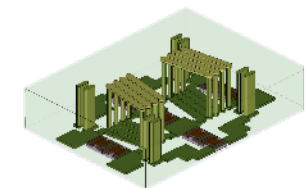
505-385-3217

3D Glass Solutions, Inc. (3DGS) utilizes photosensitive glass ceramics for novel glass solutions

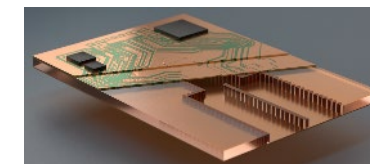
- 3DGS has a novel, disruptive technology for creating glass based Passive Components, at low cost and high volume
 - “Via Plus” manufacturing process to make TGVs plus cavities and conductor undercuts
- 3DGS offers full turn-key manufacturing capability from design, through production and test
- 3DGS components are easily integrated without performance sacrifice, allowing space, energy and weight savings
- 3DGS has developed product topologies to produce world class products from 1GHz to >250GHz



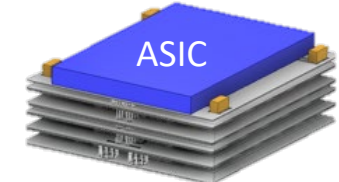
World's best High Q Inductor (SMD)
Q=145 @1GHz, 1nH, 0603mm



LC-Integrated Passive Devices
BPF, HPF, LPF, Baluns, couplers, diplexers, matching networks, LCR filters



Radio-on-Glass
(70 – 250GHz applications)
0.18dB/cm loss @140GHz
W, D, E Band Backhaul
Automotive Radar
Phased Array Systems

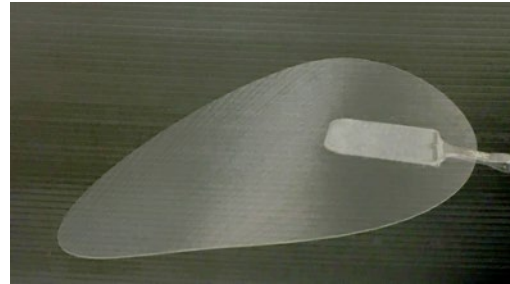


Heterogeneous Integration
5G / 6G RFFE
Transceivers
Beam forming
Tunable filters



Mosaic Microsystems

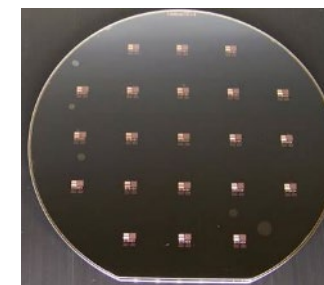
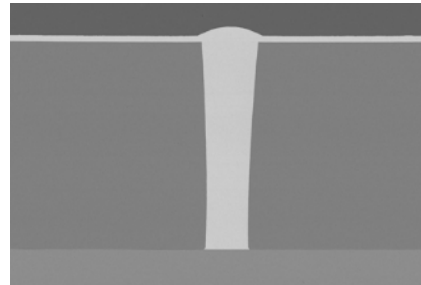
Mosaic's Viafirm® technology is a temporary bond that can be processed $\geq 450^{\circ}\text{C}$, with no outgassing during vacuum processing. This enables volume manufacturing of thin glass with Through Glass Vias in existing fab environment and process equipment



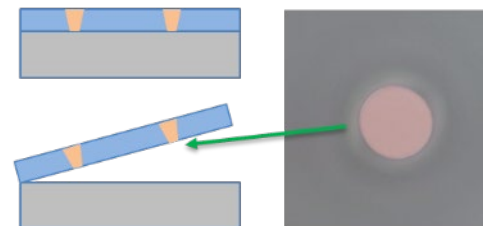
Mosaic's Viafirm® bond
Handling solution

Glass wafers 70 μm to 250 μm thick

- Fused silica for ultra-low loss
- Willow or AF32 for CTE match to Si



- Precision-placement of vias
- Tailored via profile
- Blind via-fill – aligns well with wafer based Si supply chain



Mechanical debond for
planar backside reveal

Microplex - High Aspect Ratio TGV

Thick film paste solutions enable fully filled high aspect ratio vias

Via-First Substrate Process

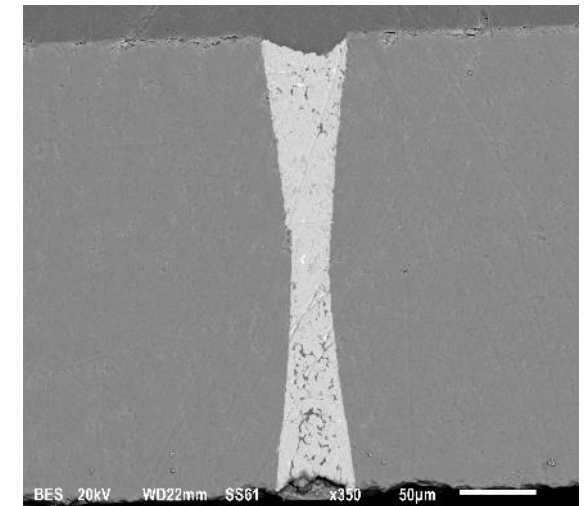
- Plating typically has challenges with large, high aspect ratio (A.R. >3) vias.
- Available for many substrates, including glass, fused silica, quartz, sapphire, and alumina.
- High Aspect Ratio: 8:1 with high yield, 15:1 for certain combinations of substrate and via metal.
- Tight pitch (via-to-via center) of 2x via diameter possible, 3x via diameter recommended.
- Substrate thickness typically ≥ 250 μm , max 700 μm . Via taper angle adjustable.
- Standard fill metal gold and silver
 - Copper is possible
 - Note metal conductor sintering temp is typically $> 500^{\circ}\text{C}$ (i.e., not CMOS-compatible).
 - Lower temperature, CMOS compatible solutions under evaluation.
 - Mechanically robust using frit bound sintered conductor grains.
- Flexibility to fill line or other structures (e.g., channels, selected closed vias, biocompatible)
- Demonstrated hermetic solutions in fused silica with 30 μm diameter vias or larger
- Substrates drilled, filled, polished and ready for subsequent thin film processes.



Contact:

<http://www.microplexinc.com/>

Email: clay@microplexinc.com



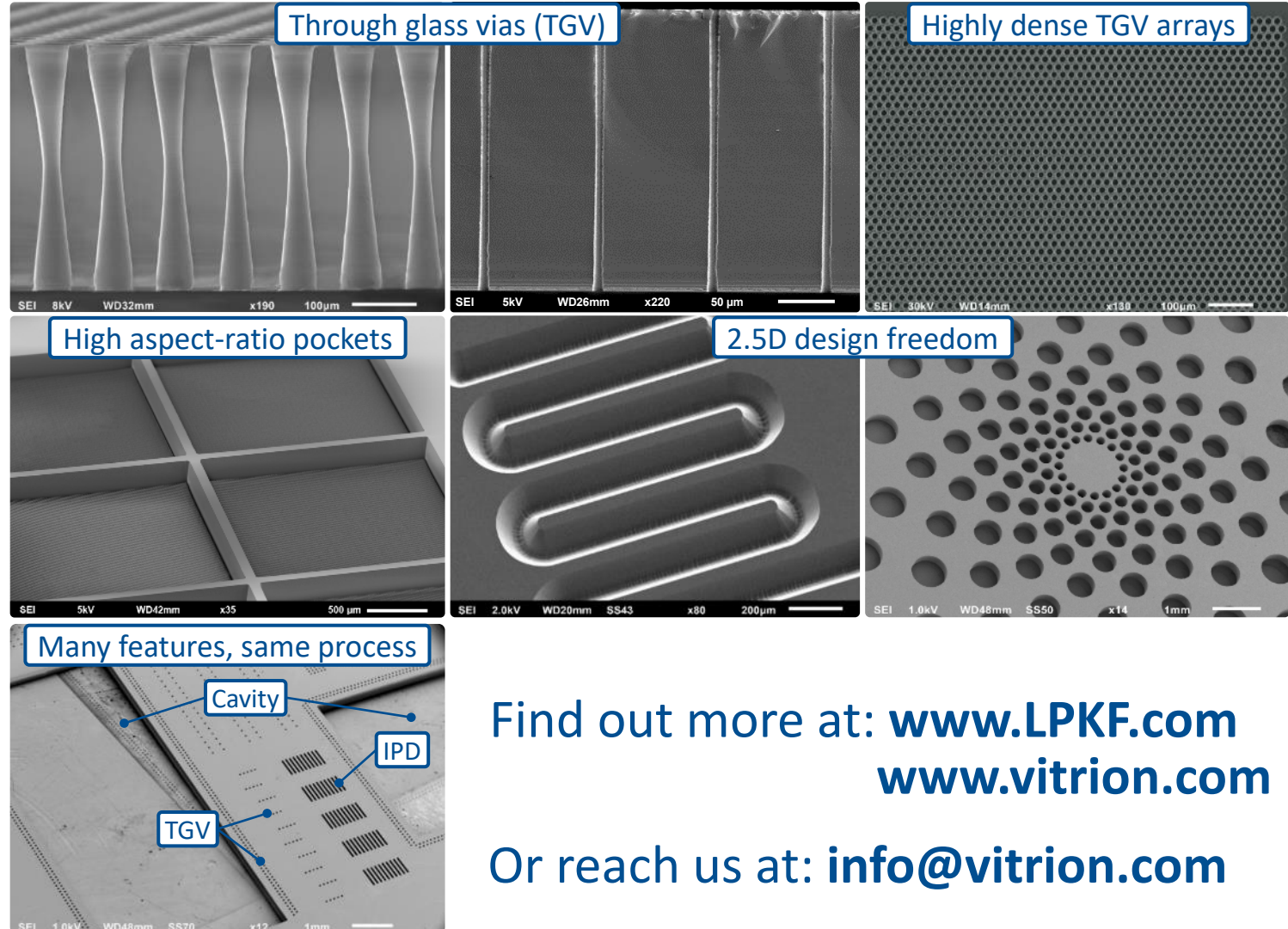
LIDE® - Advanced glass microprocessing

Novel structure through enhanced laser processing

LIDE

Laser Induced Deep Etching

- Two-step process:
 1. Laser patterning (no ablation)
 2. Highly anisotropic wet-etching
- Maskless process, direct-writing
- Complete design freedom – 2D and 2.5D capable
- No defects
 - No microcracks, chipping, internal thermal stress, vapors, debris
- Any glass type from any vendor
- High accuracy, highly capable process
- Automated processing of 6", 8" and 12" wafers, and panels up to 515 mm x 515 mm
- High-quality, high throughput, low-cost
- Mature technology with proven results in semiconductor industry



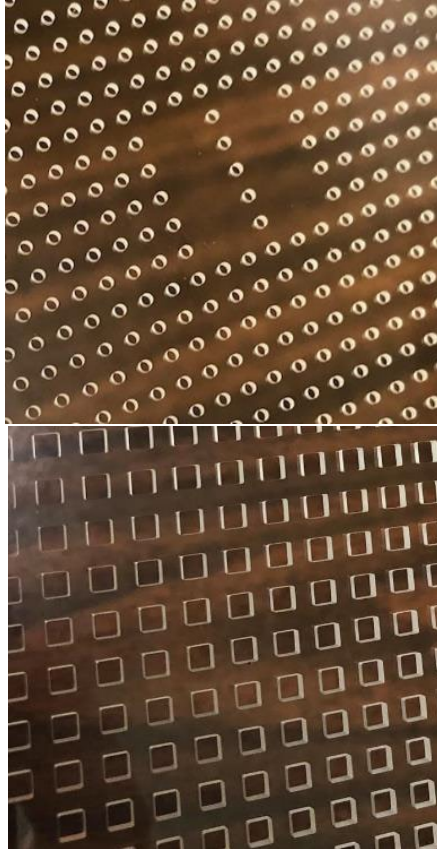
Find out more at: www.LPKF.com
www.vitron.com

Or reach us at: info@vitron.com

Swift Glass – Novel structuring of glass

New glass finishing technology enabling novel structuring of glass

Ultrasonic Machining



- 4", 6", 8" Diameter
- 500um Min Hole Dia.
- Circles and Square Vias
- Low Stress
- Hard Brittle Materials
- Glass, Silicon, Ceramic

- 4", 6", 8" Diameter
- 100um Min Hole Dia.
- Circles, Squares, Channels
- Low Stress
- Hard Brittle Materials
- Glass, Silicon, Ceramic



www.swiftglass.com

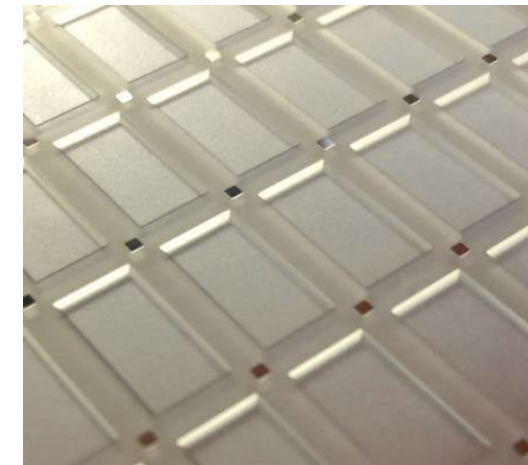
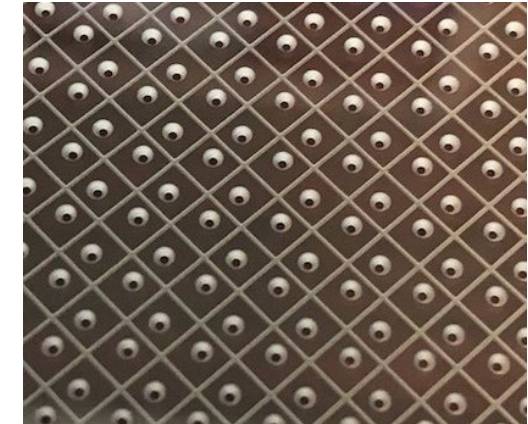
Jake Brolsma - jbrolsma@swiftglass.com

Double Side Polish Capabilities

- Up to 450mm in Diameter
- 300 um thickness to 10mm thick
- < 3um TTV

- <12 Angstrom Surface Finish
- 20/10 Scratch/Dig
- < 58um Bow
- < 10um Flatness

Microblast Machining



UNITY-SC TECHNOLOGIES FOR TGV & MEMS

High quality metrology and inspection tools suitable for glass substrates

For information

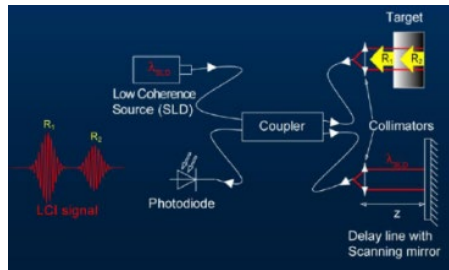
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512-413-5359



METROLOGY - TMAP

IR Interferometry: Time Domain Spectrometry
Confocal Chromatic
Full Field Interferometry



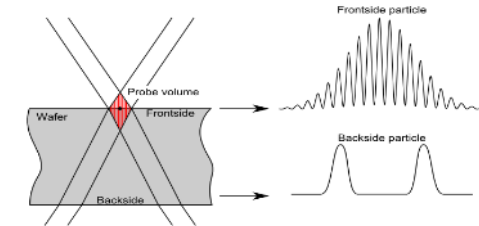
SLD: Wavelength 1.31μm

- Thickness Including Multi Wafer
- Total Thickness Variation
- Bow/Warp
- High Aspect Ratio TGV Depth
- TGV CD (Top And Bottom)
- Via Opening Topography
- RST Measurement
- Fill Topography
- Fill Roughness/Surface Roughness
- TGV Circularity
- TGV Positioning
- Step Functions, Cavity Dimensions
- WL & IR Microscopy



INSPECTION – LIGHTSPEED/EDGE

Defect Inspection – 50/110 Nm Sensitivity
Transparent Or Opaque Wafers
Discriminate Top And Bottom Defects
Automatic Defect Classification
Edge (Defect, Chipping, Crack Detection)



- Manufacturing defects
- Particles
- Haze
- Scratches
- Cracks
- All edge defects
- TGV defects
- Via cracks
- Etch defects

Lumina Instruments Inspection of Transparent Substrates

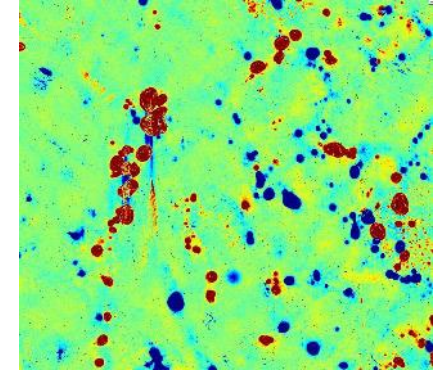
High quality tool for sensitive, high throughput wafer/panel inspection

- Inspect glass, quartz, sapphire, and compound semiconductors
- Automatically classify particles, scratches, cracks, inclusions, bubbles, residual stress and surface contamination all in a single system
- Measure bow and warp
- Offer both manual and fully automated systems for up to 300 mm diameter wafers, wafers in tape frame, and FOPLP panel size up to 600mm x 600mm
- Scan 300 mm glass wafer in two minutes

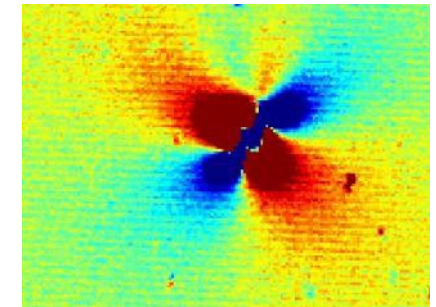
LUMINA
INSTRUMENTS

www.lumina-inst.com

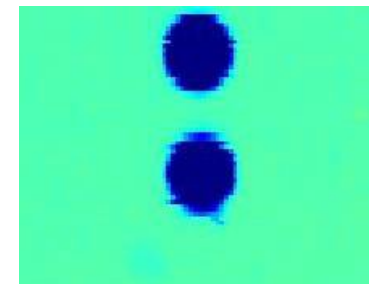
Contamination



Residual stress



Bubbles



Automated

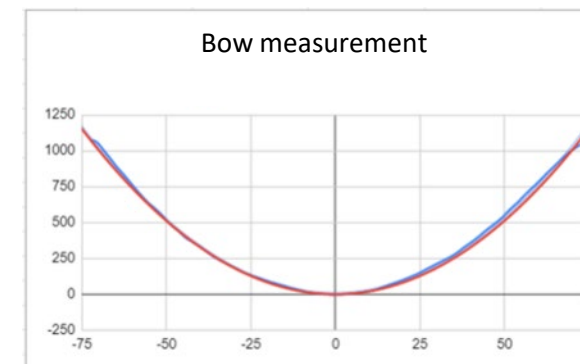


Manual



Separation distance determines the depth below the surface

Inclusions and Particles



Summary

- Glass substrate applications are expanding beyond microfluidics and optical devices: new fabrication and process integration techniques enable RF and Power expansion
- The MEMS industry has the processing techniques to establish glass processing and Menlo is driving enhanced fabrication capabilities across the supply chain
- Menlo has combined metal MEMS processing with glass to create next generation ohmic switch
- Menlo's Ideal Switch® is a demonstration of best-in-class RF and Power switch performance for a MEMS switch
- While still somewhat fragmented, the glass ecosystem is becoming a reality – vertically integrated capabilities are being established
- Supply chain developing and growing
 - New and exciting capabilities
 - Increased maturity

Thank you!

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