Increasing role of glass in the semiconductor applications: Market, technology trends, supply chain evolution and challenges

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GBC

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Santosh KUMAR
Senior Director & Principal Analyst
santosh.kumar@yole.fr

Global Business Council

YOLE Développement

AGENDA

- Glass substrate for semiconductor devices
- Application segmentation
- Material supplier and manufacturing supply chain
- Focus on TGV Interposer
- Glass as package substrate material

BENEFITS OF GLASS

General properties and drivers for the semiconductor arena

Glass could offer better performance than any other type of substrate

Optical properties

- High transparency (visible to IR)
- Low fluorescence

Electrical properties

- Low insertion loss
- Electrical isolator
- High resistivity

Why glass in the field of semiconductor?

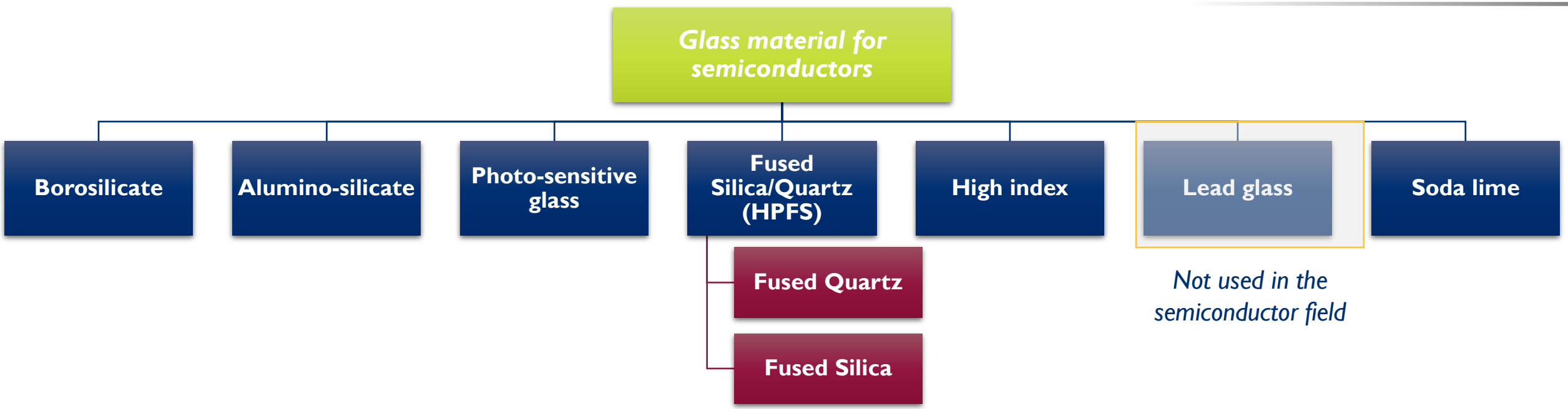
Chemical & mechanical properties

- High chemical resistance and chemically inert
- Isotropic material
- Good mechanical stability
- Low thermal expansion (CTE mismatch with Si)

Cost efficient and flexible material

- No grinding and polishing due to the good roughness
- Available in various formats (wafer, panel, tubes) and thicknesses (thin & thick)

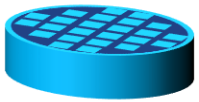
TYPE OF GLASS MATERIAL IN THE SEMICONDUCTOR FIELD



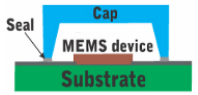
- Borosilicate (Borofloat) is predominantly used in the semiconductor field and is the most widespread material in all existing functionalities. It remains the predominant substrate with more than 90% of the semiconductor market. In terms of functionality, borosilicate is the preferred material and fits very well with WLCapping.
- Aluminosilicate is typically used for permanent substrates, as well as glass carriers. This type of glass material does not enable the WLCapping functionality via anodic bonding since it is alkali-free, without Na+, which is required for a successful anodic bonding process. This glass is widely used for LCD applications
- HPFS use is limited to niche applications. Despite the better properties that this material exhibits in terms of purity and temperature capabilities, the price of HPFS is 5 times more expensive compared to borosilicate/aluminosilicate, which limits further adoption. Besides, it cannot be applied for some functionalities such as glass carrier. Indeed, the CTE of HPFS is 6 times lower than silicon which will lead to CTE mismatch and warpage issues.
- Soda lime and lead glass are not typically glass materials used in semiconductors. Those materials are considered unrefined and can lead to contamination and small bubbles. However, modified soda lime is used for glass displays in smartphone devices.

GLASS SUBSTRATE FOR SEMICONDUCTOR DEVICES

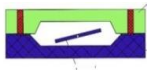
	Permanent Substrate	Temporary Substrate
Wafer-based	***Glass-based*** product	***Glass based*** process
Panel-based		



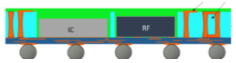
Permanent Substrate



WLC

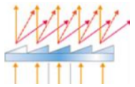


TGV interposer

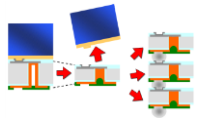


Lens

WLOptics

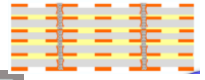


DOE

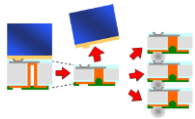


Glass carrier

Permanent Substrate



IR cut filter

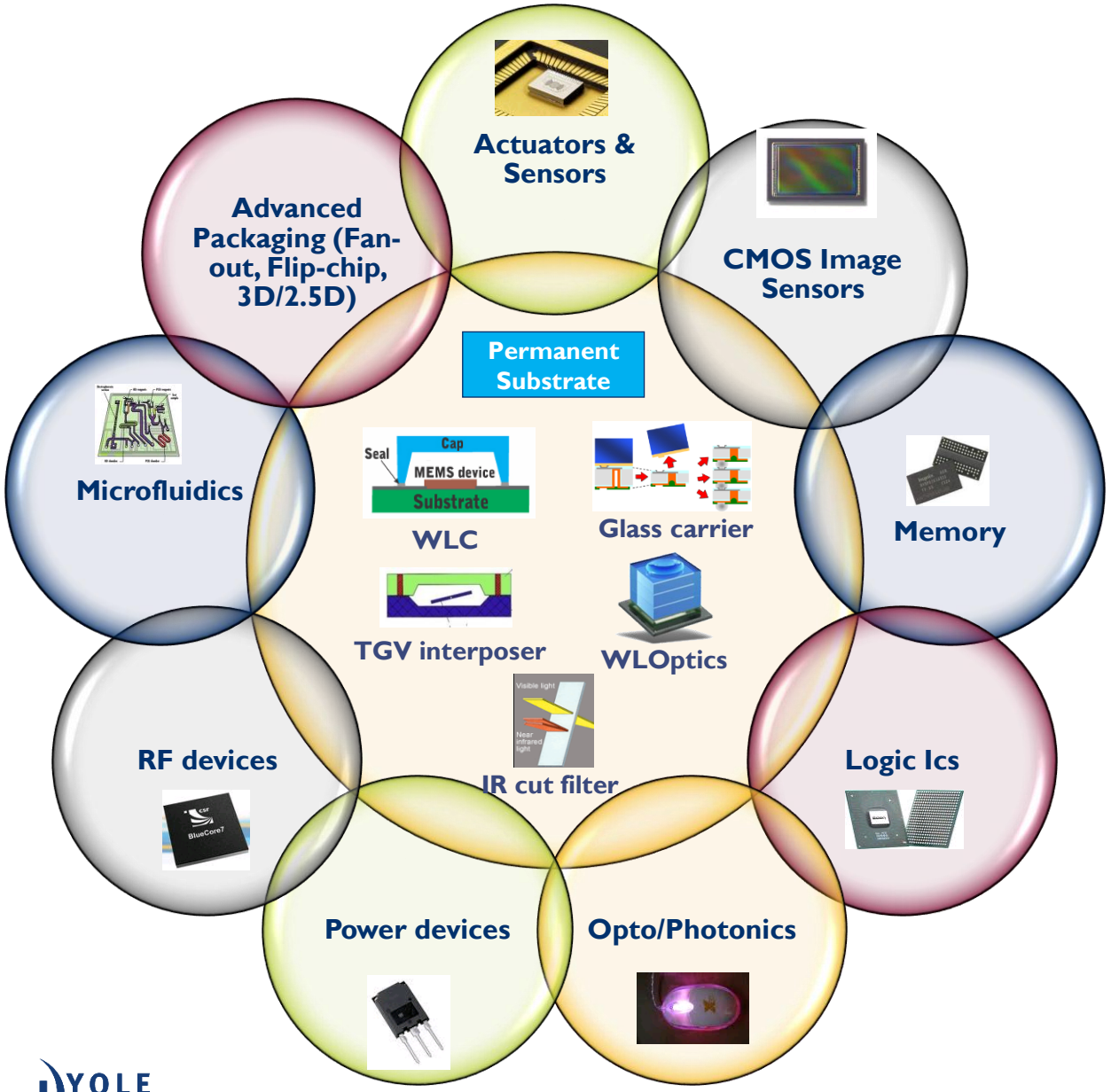


Glass carrier

Glass substrate is applied as a permanent material and remains in the final product

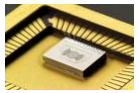
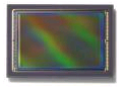
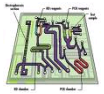
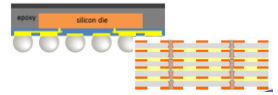
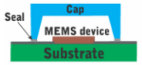
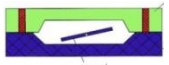
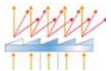
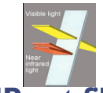
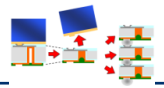
- **Glass substrate is applied for temporary use in the process flow and then removed after the IC device is processed**
- **This temporary substrate is used for the fabrication of device but does not remain in the final product**

GLASS FUNCTIONALITIES SEGMENTATION IN THE SEMICONDUCTOR DEVICES



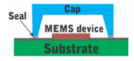
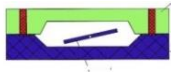
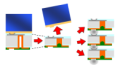
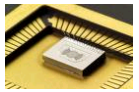
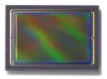
- The glass material market can be structured in different ways and thus can adopt various functionalities within the IC devices in the field of Semiconductor
  - Support glass substrate as a permanent substrate
    - The support substrate undergoes many fabrication process steps such as etching, deposition of materials, photolithographic patterning
  - WLCapping
    - WLCapping is based on a mechanical sawing of a wafer cap above the sensor
      - The wafer cap (WLC) seals the package at the wafer-level
  - 3D TGV/ Glass Interposer
    - An interposer is a structure which contains Vertical through Via electrical connections from top to underside (TSV for interposer or TGV for glass interposers)
  - **Multilayer IC Package substrate (Fan-out, flip-chip,)**
  - WLOptics split into two main wafer-level elements
    - Refractive optical elements based on lenses structures so-called Wafer-Level-Lens
    - Diffractive optical elements (DOE)
      - µoptics applications (for AR, Silicon photonic devices)
  - IR cut filter
    - The role of IR cut filter is to keep IR away from CMOS which are sensitive to infra-red
  - Glass carrier
    - A carrier wafer is used as a temporary substrate to provide mechanical support for the thin wafer (Si device wafer)

GLASS SUBSTRATES APPLICATIVE SEGMENTATION MATRIX

Functionality \ Applications		Device								Package type
		Actuators & Sensors	CIS Imaging	Memory	Logic	RF devices	Power	Photonic devices	µfluidics/ Biochips	Advanced packaging
										
Glass-based product	Permanent Substrate	✓	✓		✓	✓	✓	✓	✓	✓
	WLC 	✓	✓			✓	✓		✓	
	TGV interposer 	✓	✓	✓		✓	✓	✓	✓	
	WLOptics   Lens		✓					✓		
	 *DOE*		✓					✓		
	 IR cut filter		✓							
Glass based process	Glass carriers 	✓		✓	✓		✓	✓		✓

✓ On production ✓ On developement/evaluation

SEGMENTATION - TYPE OF GLASS VS FUNCTIONALITIES

IC devices applicability \ Functionality			Functionality: Permanent substrate	WLC	TGV interposer	Glass carrier	WLOptics
							
Actuators & Sensors 	MEMS-based	MEMS pressure sensors		✓	✓		
		Inertial MEMS: accelero, gyroscope	✓				
		Optical MEMS: DLP, micro-mirrors	✓	✓			
	ICs/CMOS-based	Ambient light sensors		✓		✓	
		Fingerprint sensors				✓	
Imaging 	ICs/CMOS-based	Camera module: WLCSP cover		✓			✓
Memory & logic ICs	ICs/CMOS-based	IC packaging	✓		✓	✓	

✓ On production

✓ On developement/evaluation

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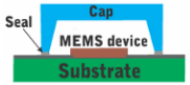
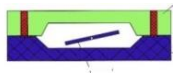
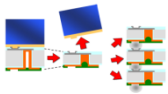
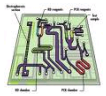
SEGMENTATION - TYPE OF GLASS VS FUNCTIONALITIES

IC devices applicability \ Functionality			Functionality				
			Permanent substrate	WLC	TGV interposer	Glass carrier	WLOptics
							
RF 	MEMS-based	RF IPD	✓		✓		
	ICs/CMOS-based	RF MEMS: BAW, SAW		✓			
Power devices 	MEMS-based	Power switches (RF Power)	✓	✓	✓		
	ICs/CMOS-based	IGBTs, MOSFETs				✓	
Photonics 	ICs/CMOS-based	Transceivers	✓				✓
µfluidics 	MEMS-based	BioMEMS	✓	✓			

✓ On production

✓ On developement/evaluation

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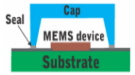
GLASS APPLICATION ROADMAP

Today | **Middle-term term (~3 years)** | **Longer term (>5 years)**

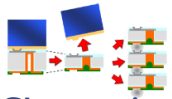
Actuators & Sensors

Permanent Substrate



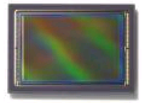
WLC

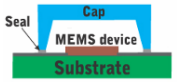
TGV interposer



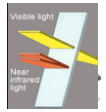
Glass carrier

CIS



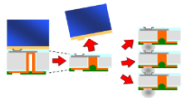


WLC



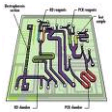
IR cut filter

Power devices



Glass carrier

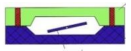
Microfluidics



Permanent Substrate

WLC

TGV interposer



Photonics/ Opto

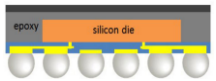
Permanent Substrate

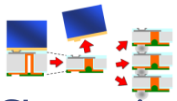
RF devices

Permanent Substrate

WLC

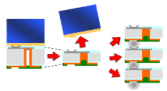
FO WLP





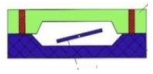
Glass carrier

Memory



Glass carrier

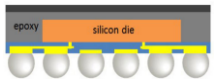
RF devices

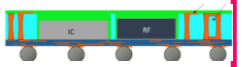


TGV interposer

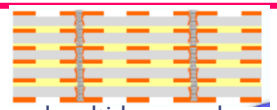
CIS

WLAutofocus





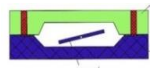
FO WLP Glass embedded fan-out



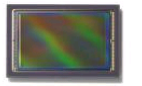
Glass based multi-layer package substrate to support various application: HPC, network, data centres etc.

Memory

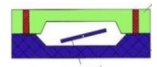
Logic



TGV interposer

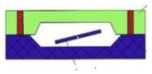


CIS



TGV interposer

Optical photonic



TGV interposer

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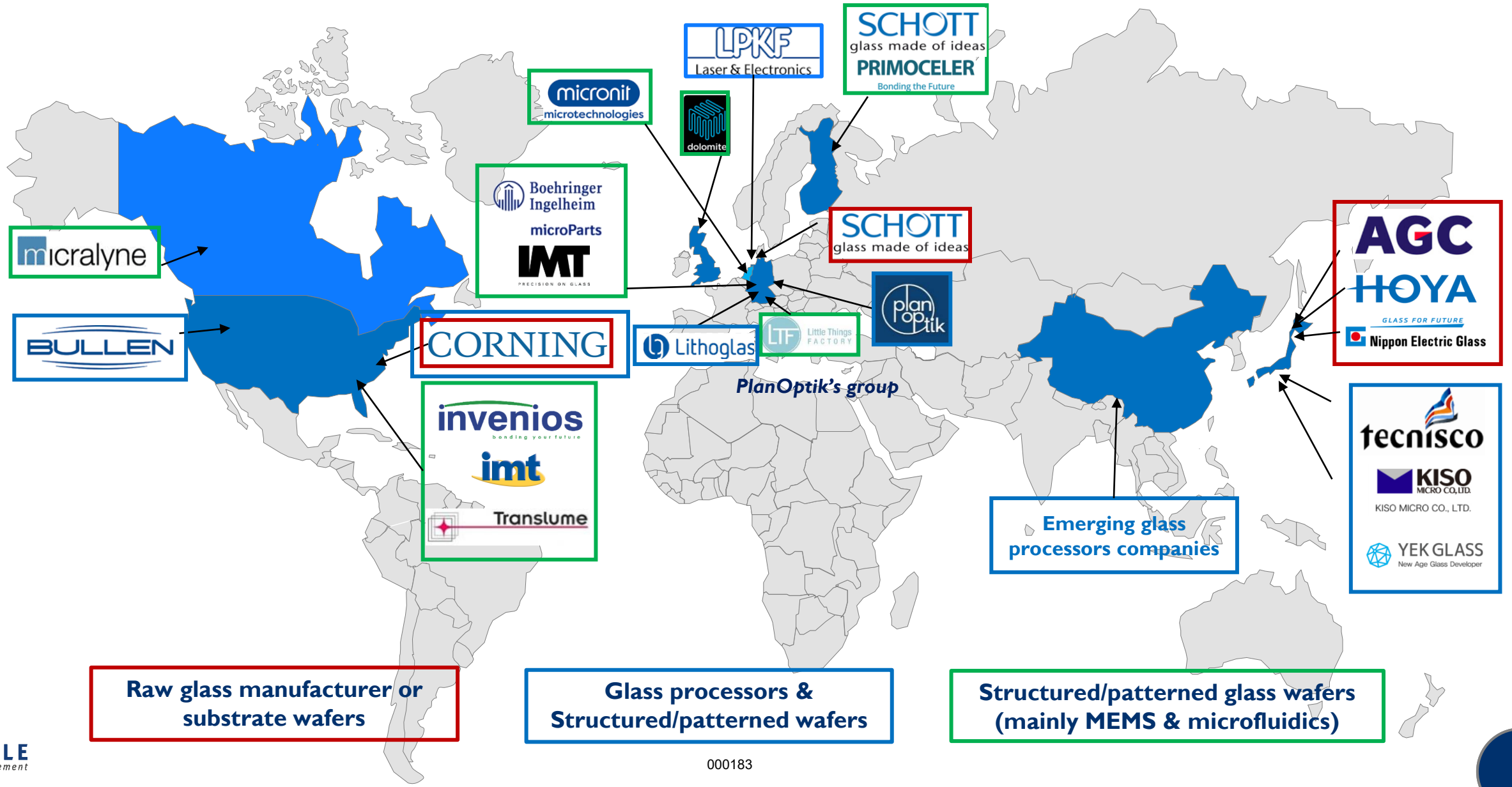
GLASS MATERIAL SUPPLIERS – COMPETITIVE LANDSCAPE



GLASS MATERIAL SUPPLIERS – SEGMENTATION BY BUSINESS MODEL

- There are three categories of glass players providing different functionalities of the glass substrate

Raw glass manufacturer or substrate wafers

SCHOTT glass made of ideas, CORNING, AGC, HOYA, GLASS FOR FUTURE Nippon Electric Glass

- Raw material manufacturers provide raw glass material and have limited wafer process capabilities.
- Their main focus is to offer raw material and blank substrate

Glass processors & Structured/patterned wafers

plan optik, tecnisco, LPKF Laser & Electronics, BULLEN, CORNING

- Those players are processors which means they pattern and structure glass wafers from raw material provided by raw material suppliers. They typically purchase wafers from Schott, Corning, AGC…and then structure the wafers and make products ouf ot the raw material
- Their core competencies focus on pre-processed, patterned wafers to address various applications

Structured/patterned glass wafers (mainly MEMS & microfluidics)

micronit microtechnologies, micralyne, invenios bonding your future, IMT PRECISION ON GLASS, imt, PRIMOCELER Bonding the Future

- This category is typically composed of glass foundries which start from blank or pre-patterned wafers. However, the difference between them and a typical foundry such as Silex, is that they are doing their own products
- This category focus mainly on microfluidic devices such as fluidics, micro-reactors

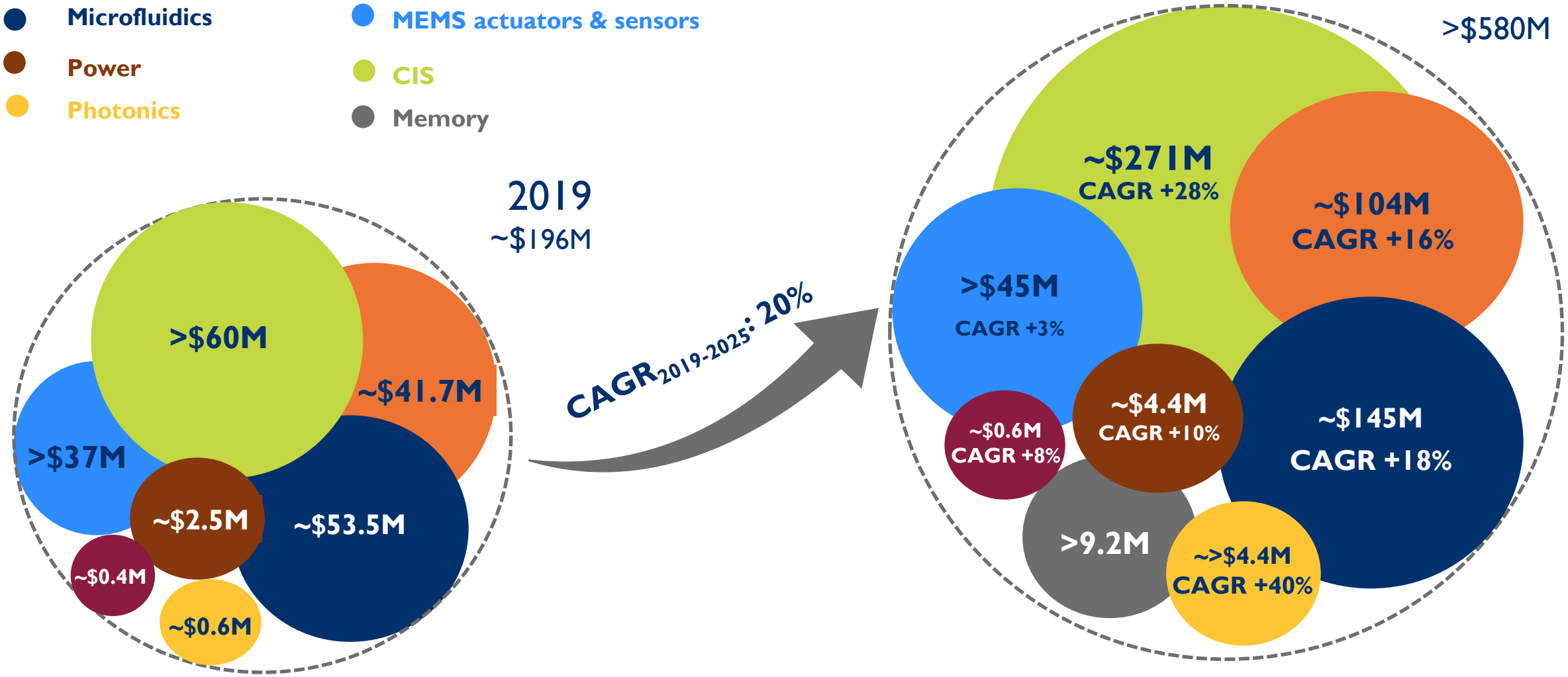
GLASS PLAYERS CAPABILITIES (Non Exhaustive list)

	Raw glass manufacturer /substrate wafers	*Glass processors & Structured/ patterned wafers*	Process capabilities							
			TGV holes drilling	Channels/ cavity etching	Bonding/ Capping	Polishing	Wafer coating technologies (IR, AR …)	Dicing	Lithography	Metrology
SCHOTT			✓	✓	✓	✓	✓	✓		✓
CORNING			✓			✓	✓			
AGC			✓	✓		✓	✓			
GLASS FOR FUTURE Nippon Electric Glass						✓				
HOYA			✓			✓				
plan optik / LTF Little Things FACTORY			✓	✓		✓	✓	✓		
tecnisco				✓		✓				
BULLEN				✓		✓		✓		
LPKF Laser & Electronics			✓	✓						

2019 - 2025 OVERALL GLASS WAFER REVENUE FOR SEMICONDUCTOR DEVICES

-- Glass wafer revenue for semiconductor devices

- FO WLP
- Microfluidics
- Power
- Photonics
- RF devices
- MEMS actuators & sensors
- CIS
- Memory



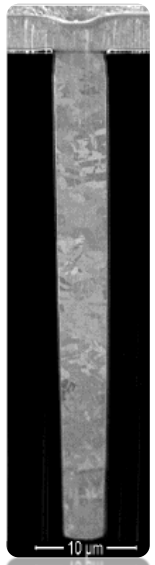
TGV interposer

TGV MANUFACTURING PROCESS

- TGV substrate cannot be applied for fabricating active devices like in silicon wafer; however, it is considered as a good candidate to be applied as an interposer due to its low manufacturing cost, good high-frequency performance, and small CTE mismatch

TGV Module

TGV formation Glass hole → **TGV seed layer deposition** → **Dielectric formation** → **TGV filling** → **Plating and seed etching**



TGV formation

- Via formation is performed by etching technologies, either laser drilling, electrical discharge or alternative technologies

TGV seed layer

- Seed layer are applied by PVD technology or alternative

Dielectric formation

TGV filling

- Vias are filled with mostly Copper Cu with different technologies

- There are six key process steps in making a TGV in a glass substrate

TGV INTERPOSER - DRIVERS

- Glass is an attractive material used as wafer or panel substrate already used for Wafer-Level-Capping of image sensors or photonics as well as MEMS devices due to its good properties in terms of transparency and good electrical properties
- TGV gained strong interest and is a good candidate to be used as an interposer because of its higher electrical and mechanical properties compared to the TSV.

Advantages

- **Low loss**
- **Low dielectric constant**
- **High resistivity**
- **Larger panel size than Si wafer**
- **Smooth surface (low TTV)**
- **Low warpage and bow**

POTENTIAL APPLICATIONS THAT COULD INTEGRATE TGV INTERPOSER

RF : Field of mm W for 5G	• Uniformity • How to change the ratio and viscosity of the material to make it more uniform when it is applied on panel size • RF IPD at low cost
Photonic packaging	• Greater integration
High RF Power switch	• Small-form factor • High-frequency • High-power operation
Medical (microfluidics devices)	• combination RF + single module/sensor for chemical sensors, DNA, blood, sugar (combined with a wireless nano sensor for fluidic testing)
microLED	• Signal routing is the major challenge in microLED tiling but routing through the glass (TGV) currently appears the least realistic due to process integration issues
CMOS Image Sensors	• To increase the density and reduce form factor • Larger pixel would be required and will drive the demand for TGV glass interposer • Structure: based on a multi integration (CIS on one side, other devices will be integrated on the other side)
High-end memory starting with high density memory (HBM) and FPGA	• To offer a cost-effective solution to the Silicon interposer • However, already behind the schedule and it is not considered as the primary solution

TGV TECHNOLOGY - DRAWBACKS AND LIMITATIONS

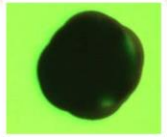
Challenges

Technical challenges

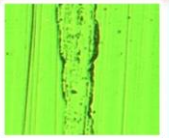
Industrial challenges

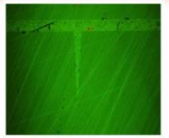
DETAILS

- **TGV formation: How to control the cost structure of the glass interposer and get cost-effective glass via**
- **How to fill the via while keeping cost as low as possible?**
- **Cost effective via formation and metallization (seed layer)**
- **Bumping & interconnection**
- **Inspection**


Top side Chipping

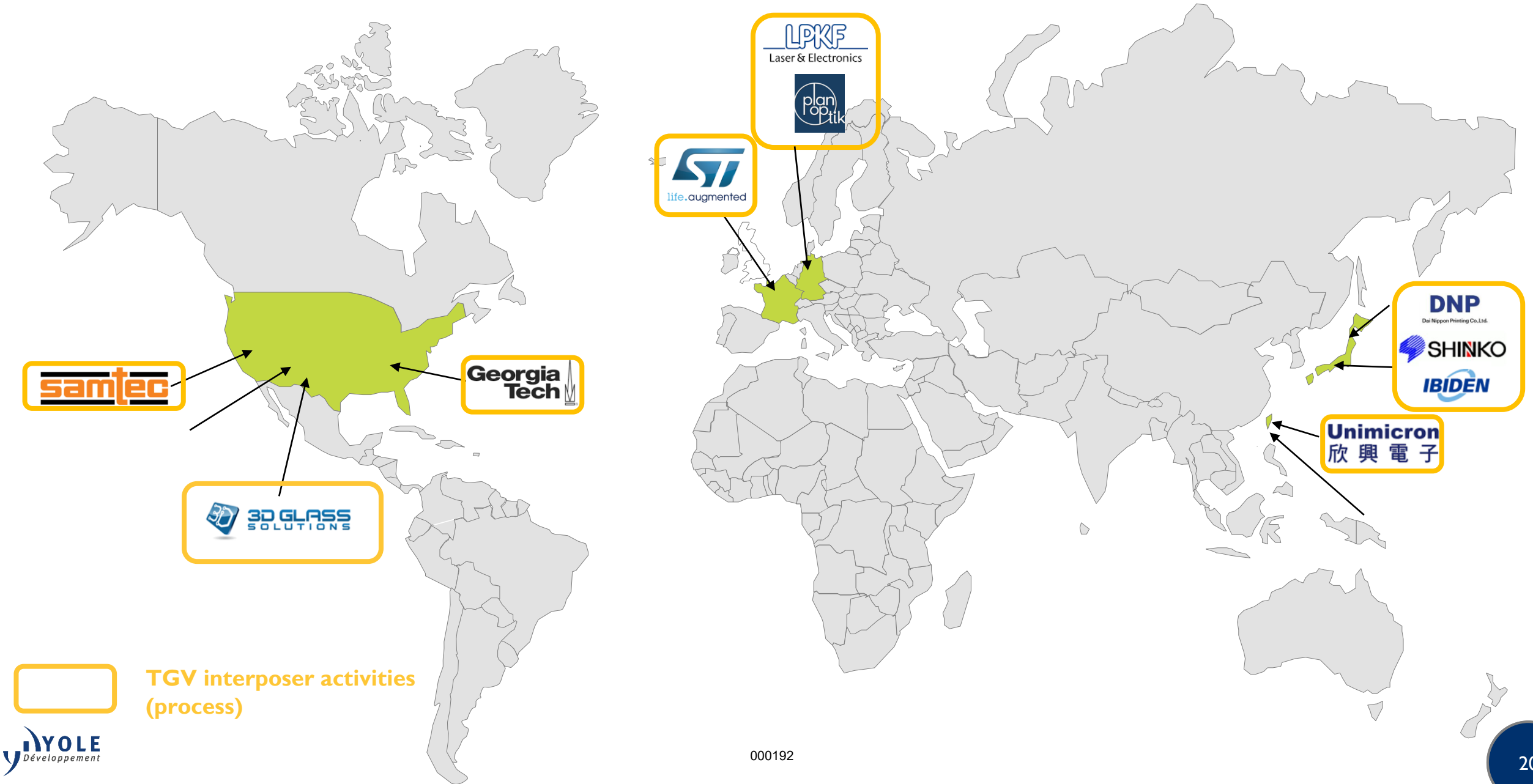

Deep cracks


Rough side wall


tapering

- **Supply chain: who is going to take care of the metallization and assembly process**
- **Process integration**
- **Standardization**
- **Yield**
- **Cost**

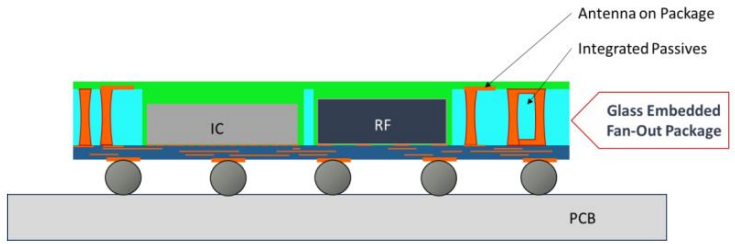
TGV INTERPOSER PLAYERS

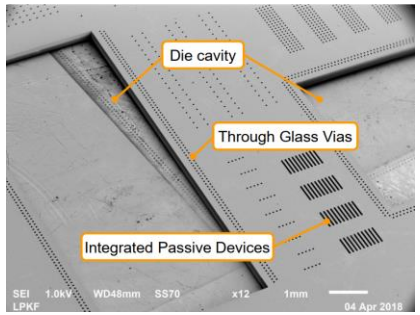


RECENT TGV DEVELOPMENT

- TGV interposer has become an appealing solution for numerous areas of Advanced IC substrates to replace the core substrate to create 3D integrated circuits integrating a stack of more than two chips of different die-size into one package
- With the use of Laser Induced Deep Etching technology (LIDE) glass, LPKF has introduced a TGV concept based on glass embedded where glass material is used as a replacement of epoxy compound to reduce the die positions errors as well as the moisture (LIDE Vitrion technology)

LPKF Laser & Electronics



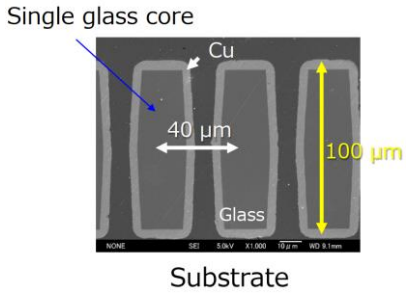


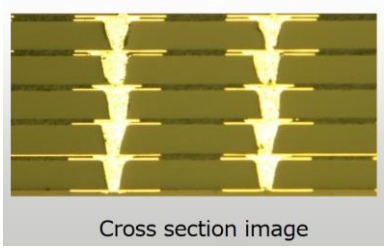
LPKF Courtesy

60µm diameter
Less than 500µm depth

- Fujitsu has developed a technology so-called G-ALCS technology for high-end packaging to reduce the warpage issues, CTE, as well as improve the thermal durability. Such process could serve a wide range of applications such as 5G, HPC, Data center.

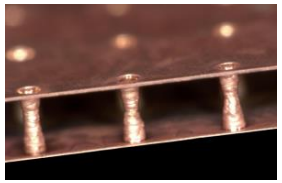
FUJITSU





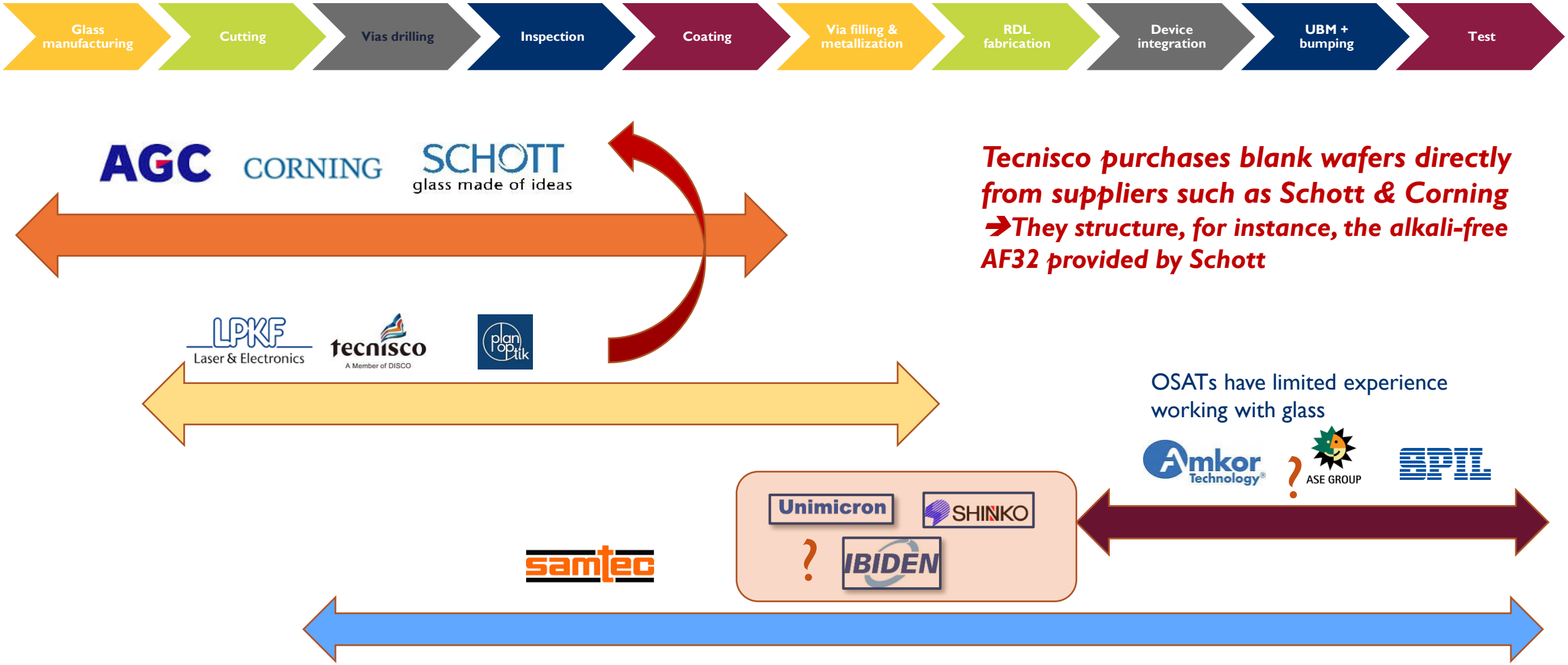
Fujitsu 's Stacked Via demonstration (40 µm diameter, 100 µm depth)

- PlanOptik developed a Cu filled interposer with hole diameters down to 100 µm (depending on wafer thickness)for the following applications
  - Interposer for 3D stacking
  - Glass circuit board to replace the PCB material over the glass



PlanOptik courtesy

TGV INTERPOSER – SUPPLY CHAIN

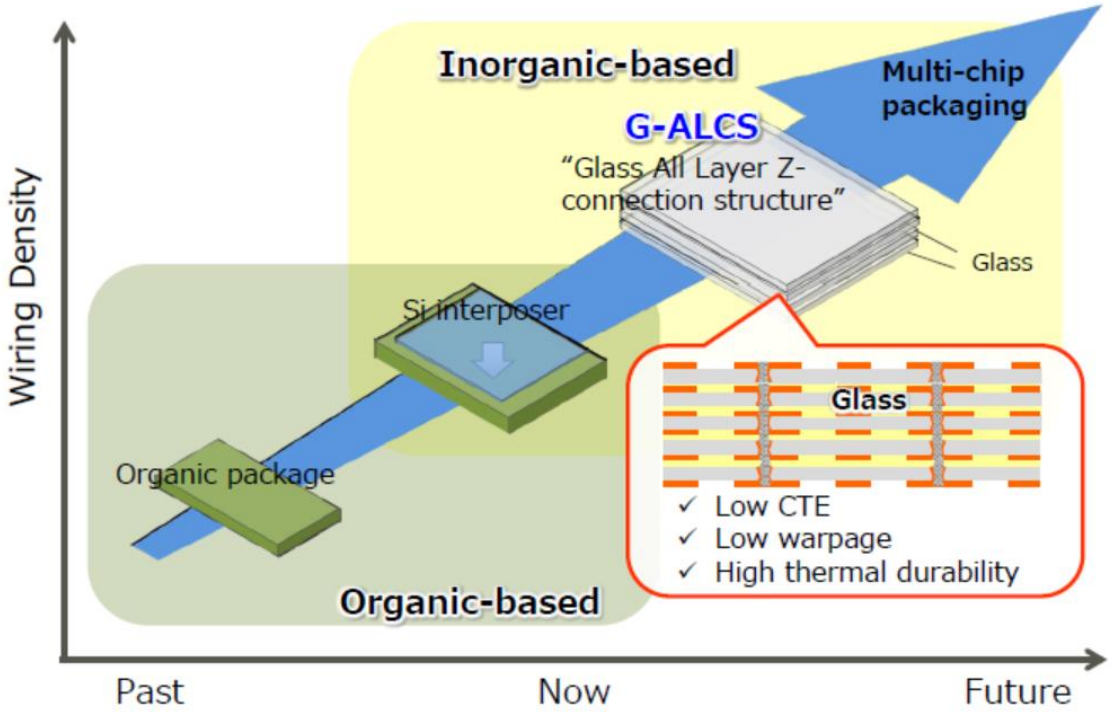


Glass as a packaging substrate material

GLASS BASED SUBSTRATE FOR ADVANCED PACKAGING

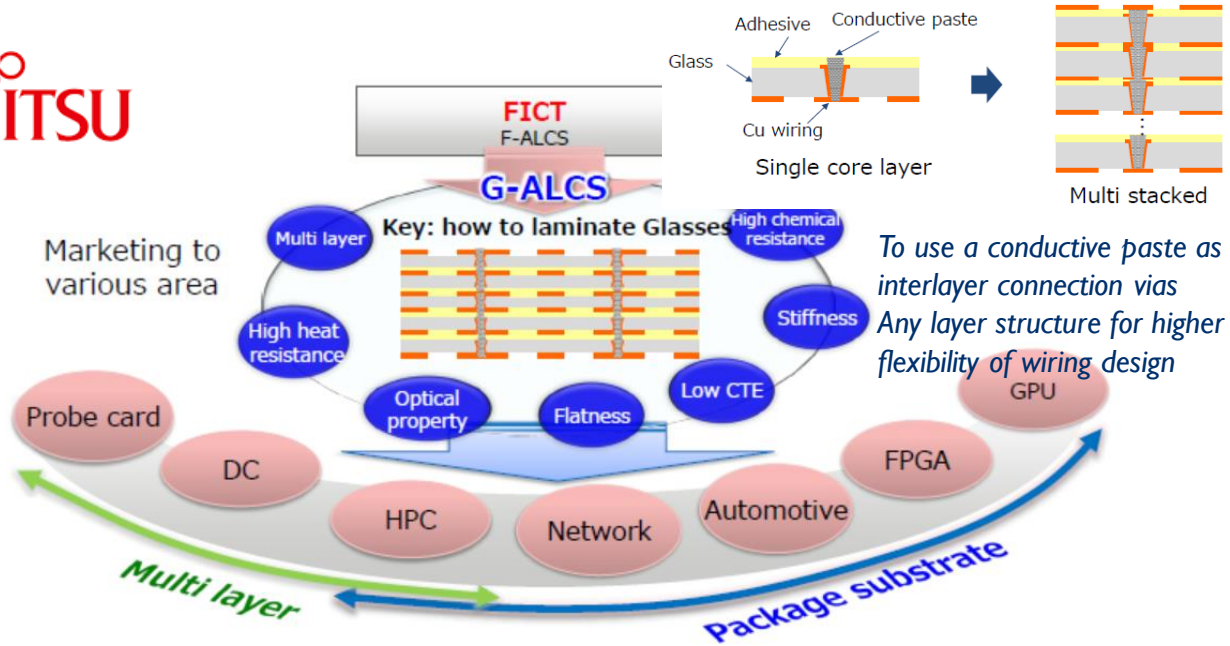
Glass has high potential to be used as the package substrate material and various players are working on it.

Glass as a substitute of organic substrate



FUJITSU

The advantages of G-ALCS technology are high thermal stability, low loss, flatness, low CTE, low warpage, stiffness and low moisture absorption.



To use a conductive paste as interlayer connection vias
Any layer structure for higher flexibility of wiring design

Glass (with TGV) as a CORE for BU substrate and RDL/interconnections fabricated on it

BroadPak 2.5D/3D Technologies

intel

Unimicron 欣興電子

Yole Développement
From Technologies to Market

Thank you for your attention!

If you have questions, please contact

santosh.kumar@yole.fr