Fraunhofer IZM

Fraunhofer Institute for Reliability and Microintegration IZM

Electronic Packaging Days 2025

Julian Schwietering

Photonic Glass Core Substrates for Data Centers and Optical Computing

Starting with a Quote

Intel press release September 18, 2023

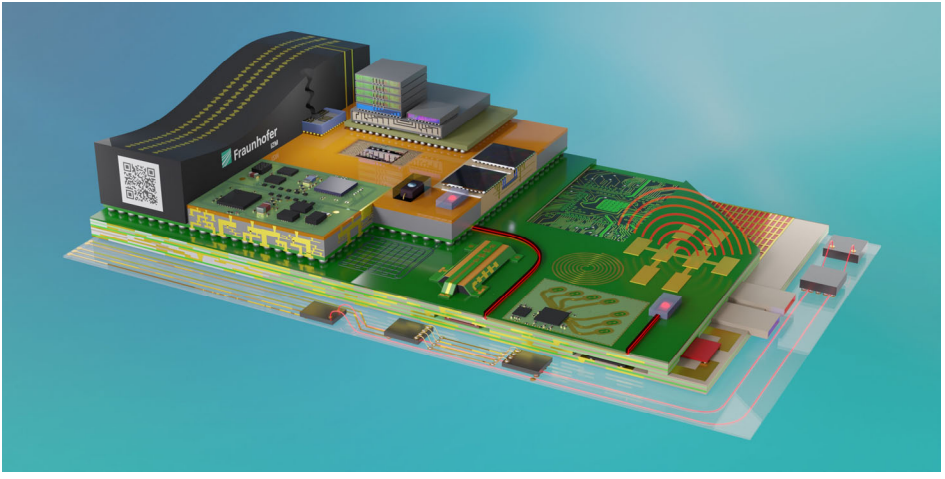
*"**By the end of the decade**, the semiconductor industry will likely **reach its limits** on being able to scale transistors on a silicon package **using organic materials**, which use more power and include limitations like shrinkage and warping."*
*"… **glass offers distinctive properties** such as ultra-low flatness and better thermal and mechanical stability, resulting in much higher interconnect density in a substrate."*

Fraunhofer IZM Publication 2003

*"Due to the fact of the **increasing requirements in thermal and mechanical stability** in PCB's it is a promising concept to laminate thin **glass** foils in between the conventionally used substrate layers."*

Our Mission at Fraunhofer IZM… includes Glass inside Circuit Boards

More than 20 years of experience with electrical and optical functionalization of glass



And we named it:

Electrical

-

Optical

-

Circuit Board

How we should have named it

pGCS

Glass Core Substrates: What is a Substrate?

Definition of Yolé

[1]

- IC substrate: “laminated layers stacked one on top of the other, forming a packaged module […] a substrate is a material that provides the surface on which a chip is deposited or fabricated”

- Advanced IC substates: “are substrates used for advanced packaging platforms […] this includes FC BGA, FC CSP, SiP, FO, and 2.5D/3D”

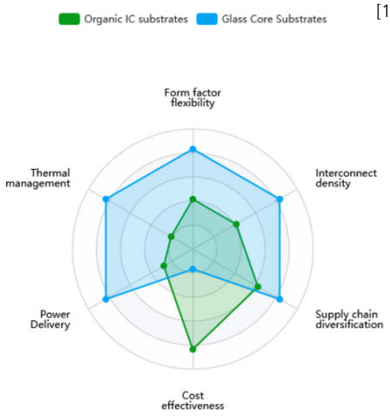
- High-end IC substrates: “most advanced IC substrates in terms of L/S below 15/15 µm, layer count, and pump pitch.”

[1] Hachemi, Bilal; Tan, Yik Yee; Chitoraga, Stefan; Pereira, Gabriela (2025): Status of The Advanced IC Substrate Industry. Market and Technology Report. Yole Group.

What are the requirements for a substrate for advanced packaging and high-end IC Substrate?

- Form factor flexibility
- Thermal management
- Interconnect density
- Power Delivery
- Supply chain diversification
- Cost effectiveness

[1]



Will switching to glass alone solve all future challenges?

[1] Hachemi, Bilal; Tan, Yik Yee; Chitoraga, Stefan; Pereira, Gabriela (2025): Status of The Advanced IC Substrate Industry. Market and Technology Report. Yole Group.

Future Challenges

…and how optical waveguides can provide the solution

- ✘ Increasing data traffic leads to rising energy consumption
- ✘ Increasing size of substrates leads to longer transmission lines
- ✘ Smaller distances between wiring lead to crosstalk
- ✘ Demand for more layers

Optical Waveguides

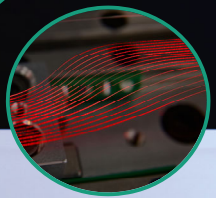
- ✔ enable higher energy efficiency
- ✔ have significantly fewer loss
- ✔ enable higher data rates per channel
- ✔ allow crossings so only one layer is needed

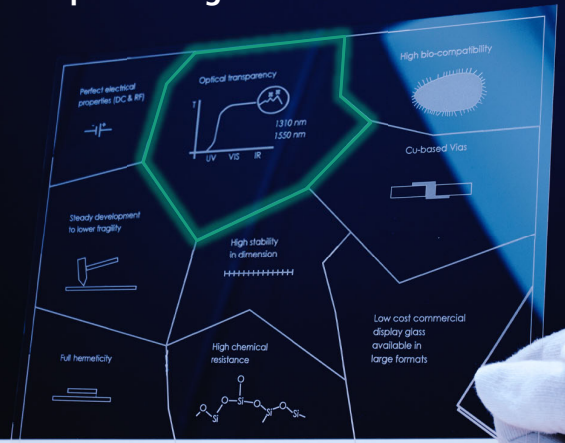
One important property for future photonic glass core substrates is:

Optical transparency

1310nm,
1550nm

Waveguides





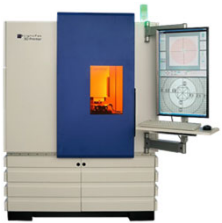
Optical Waveguides in Glass – Fabrication methods

Two methods are available at IZM to integrate waveguides into glass.

fs-Laser writing of waveguides

- direct writing of waveguides
- flexible 3D process

Machine at Fraunhofer IZM



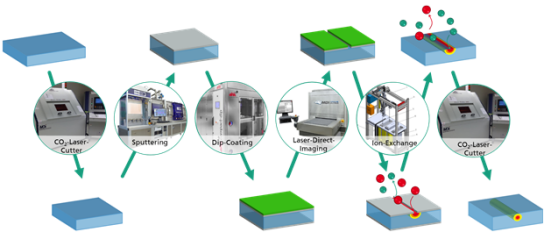
© LightFab

&

Ion exchange

- lithography based multi batch process to create waveguides
- much more robust process

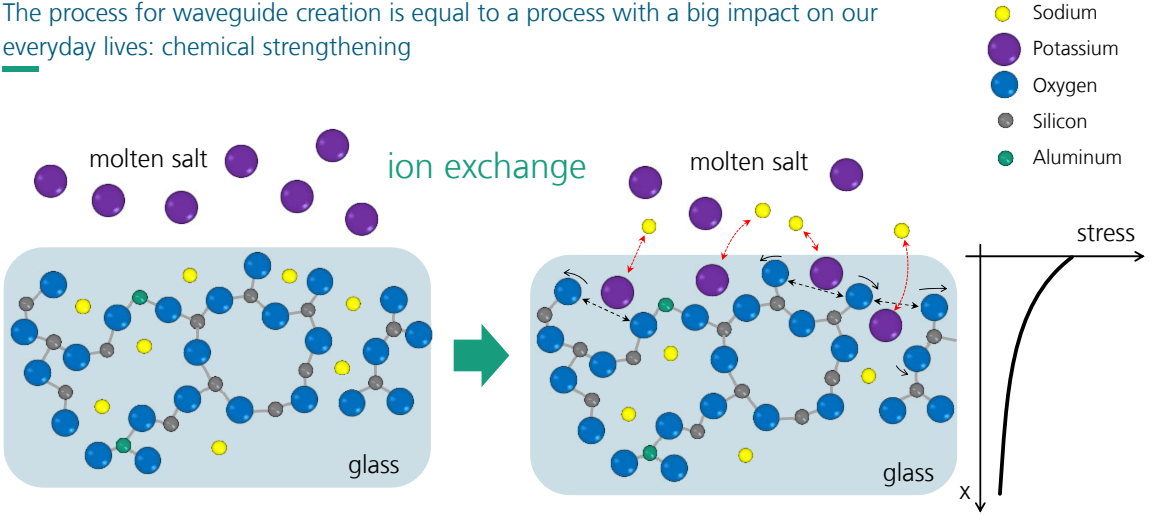
Process chain at Fraunhofer IZM



November 10, 2025

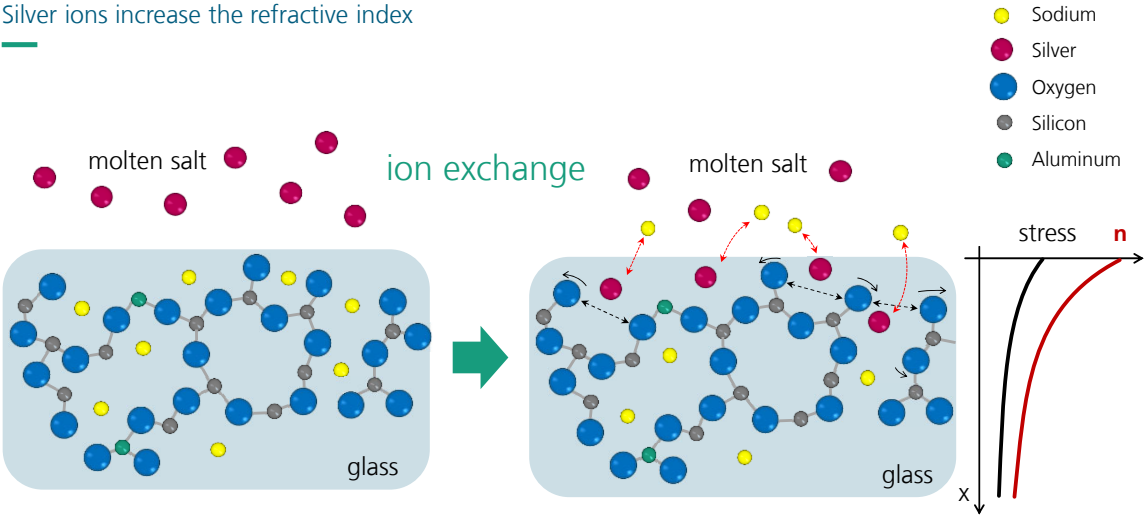
Optical Waveguides in Glass – Ion Exchange

The process for waveguide creation is equal to a process with a big impact on our everyday lives: chemical strengthening



Optical Waveguides in Glass – Ion Exchange

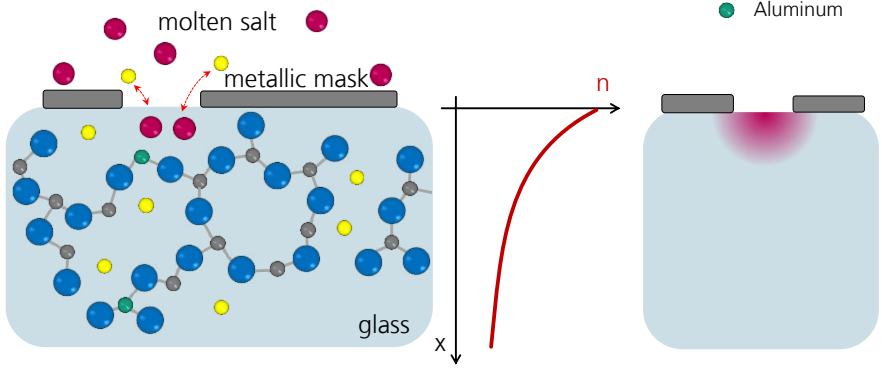
Silver ions increase the refractive index



Optical Waveguides in Glass – Ion Exchange

The diffusion through a mask creates surface waveguides

1) Ion exchange

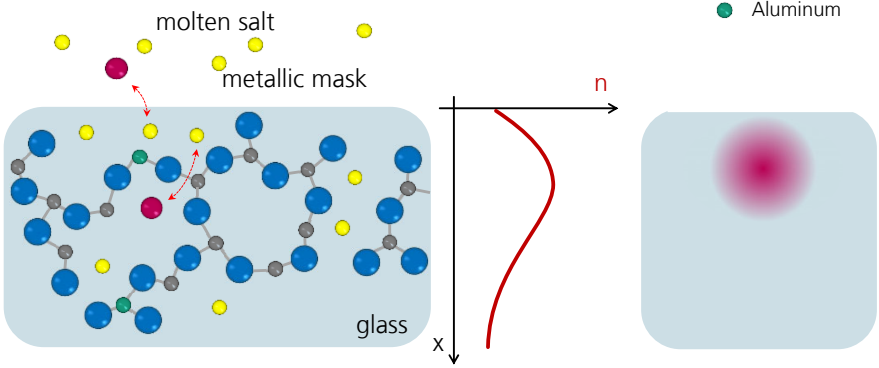


Optical Waveguides in Glass – Ion Exchange

Burying the waveguides can be achieved with a second ion exchange.

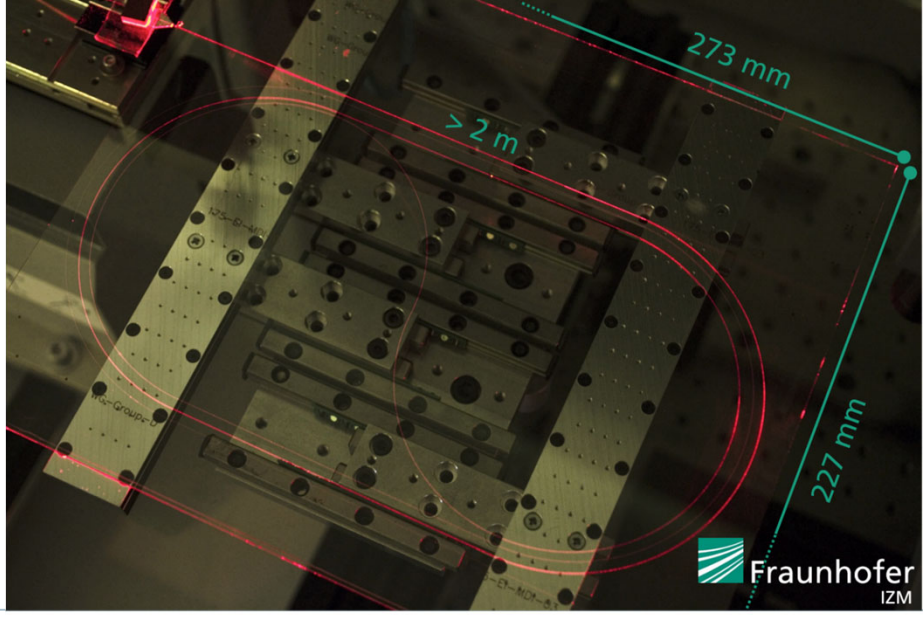
Sodium
Silver
Oxygen
Silicon
Aluminum

2) Reverse ion exchange to bury the waveguides



Waveguides
@ IZM

- $\alpha < 0.1$dB/cm @ 533 - 1550nm
- Single mode & multi mode
- Low coupling loss to fibers



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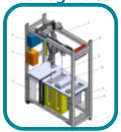
Optical waveguides in glass enable photonic GCS completely created at IZM

Fiber-Board-Coupling

Gluing, Welding

Waveguides



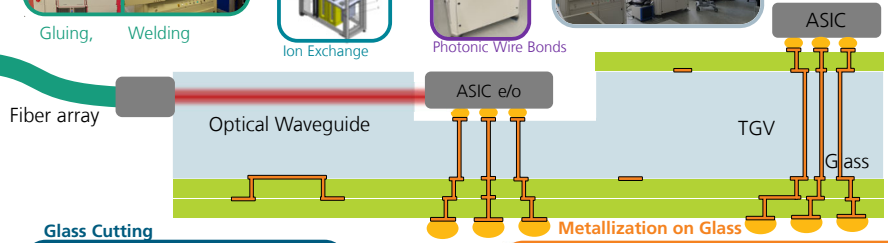
Ion Exchange

PWB

Photonic Wire Bonds

Chip Assembly

Glass Structuring



In addition:

- Testing: waveguides & electrical circuits, mechanics
- Inspection: AOI, REM, FIB, …
- Layer deposition: Lamination, PVD, CVD
- Etching: KOH, Plasma, molten salts, ….

Glass Cutting

Blade, Wheel, CO2-Laser

Cleaning, Sputtering, Coating, LDI, Plating & Etching

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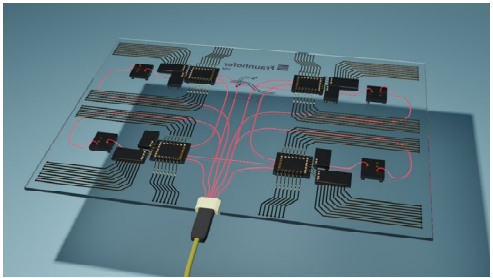
Where are the processes already in use in IZM?

In multiple projects:

SPOC

Scalable Packaging for All-Optical CV Quantum Computing



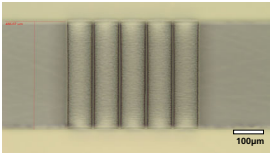
AKHETONICS

BERLIN

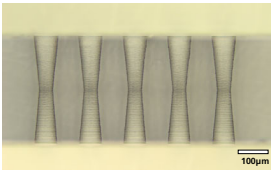
Kofinanziert von der Europäischen Union

HICONNECTS

Heterogeneous Integration for Connectivity and Sustainability



Straight TGVs



α=5° Hourglass - TGVs

Bundesministerium für Forschung, Technologie und Raumfahrt

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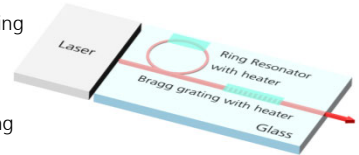
Where are the processes already in use in IZM?

In multiple projects:

ISABELLA

Glass based hybrid integrated and frequency-stabilized lasers

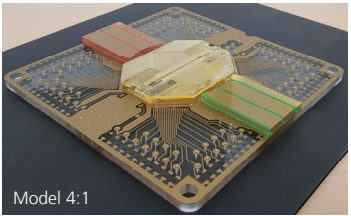
- Integrated ring resonators
- Integrated Bragg grating



WAVECARRIER

Monolithic Glass Carrier for ion trap-based Quantum Computing

- Waveguides for visible wavelength
- Selective Laser etching manufactured carrier



Sacher Lasertechnik | 10^-9 mbar VACOM | hhu Heinrich Heine Universität Düsseldorf | Bundesministerium für Forschung, Technologie und Raumfahrt | JG|U Johannes Gutenberg Universität Mainz | Bundesministerium für Forschung, Technologie und Raumfahrt

Thank you for your attention

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Fraunhofer Institute for Reliability
and Microintegration IZM

Contact

Julian Schwietering
Group Leader OIT
Team Leader EOCB
Optical Interconnection Technology (OIT)
Electrical-Optical Circuit Board (EOCB)
julian.schwietering@izm.fraunhofer.de
www.izm.fraunhofer.de/EOCB