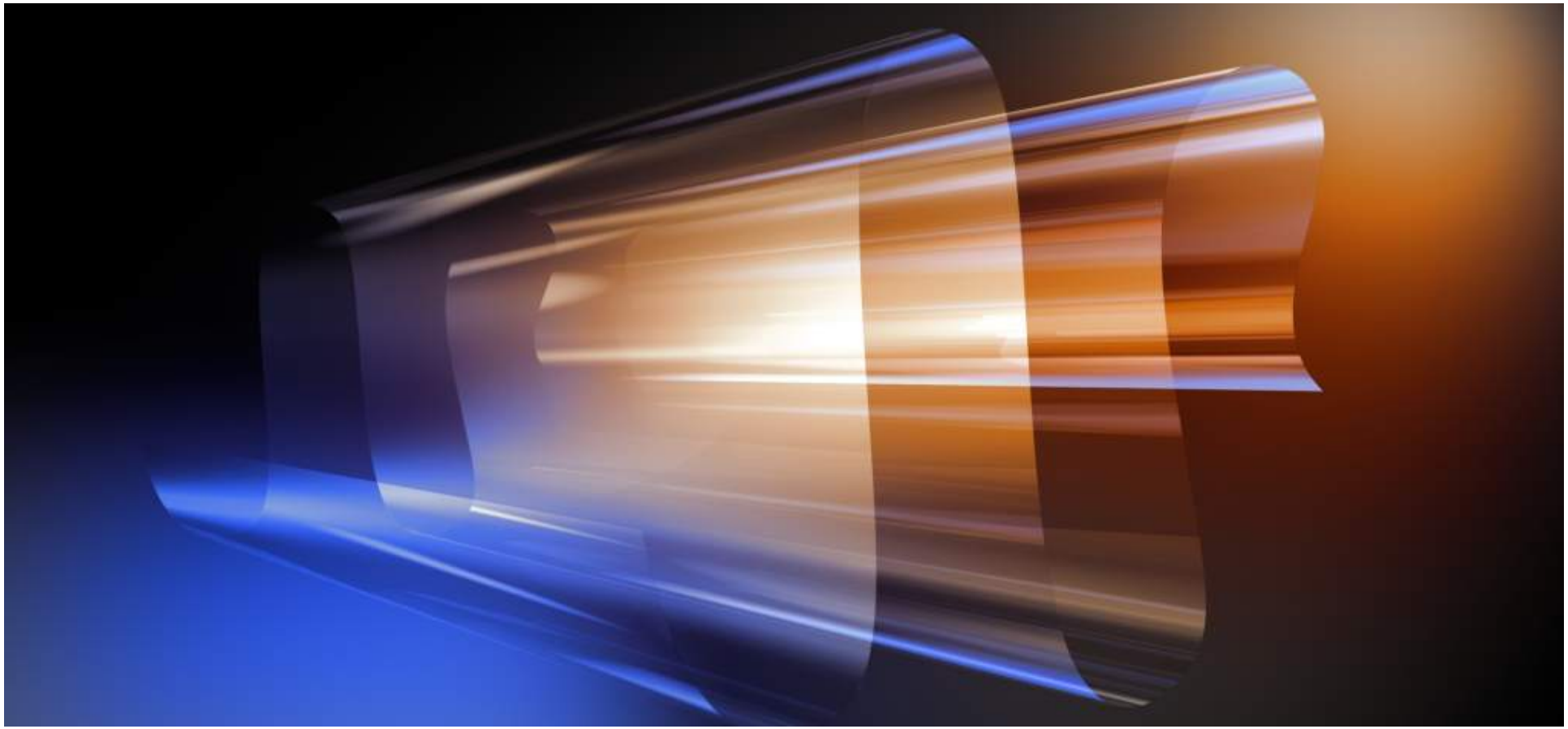


Ultra-Thin Glass as a High Performance Substrate

Dr. Elmar Günther, SCHOTT AG

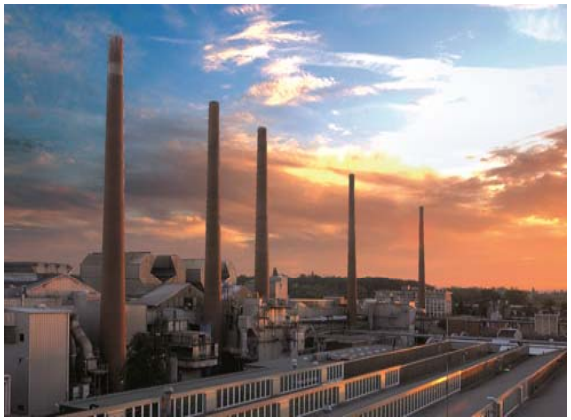
Development and Exploitation of Processes for Thin Flexible Glass – Oxford, May 14th, 2014

SCHOTT is a globally active technology group with headquarters in Mainz, Germany.

SCHOTT is an international technology group with more than 125 years of experience in the areas of specialty glasses, materials and advanced technologies.

We rank as number one in the world with many of our products.

We are committed to managing our business in a sustainable manner and supporting our employees, society and the environment.



SCHOTT
glass made of ideas

Key Figures

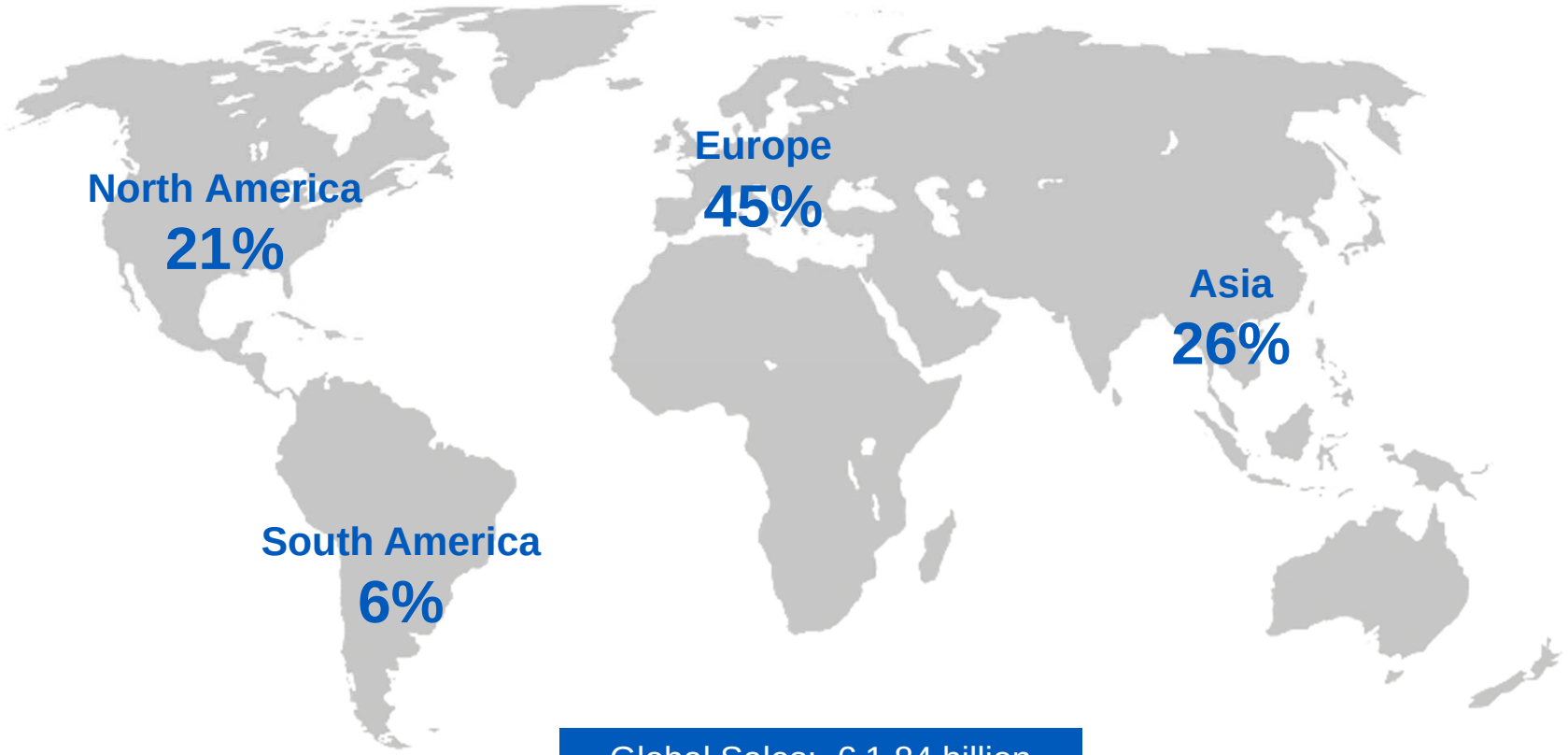
Fiscal Year 2012/13

€ 1.84 billion	Worldwide sales, 85 % of which was generated outside Germany
€ 118 million	EBIT
€ 122 million	Capital expenditure on property, plant and equipment
15,400	Employees, 5,300 of whom are based in Germany
In 35 countries	Production sites and sales offices

SCHOTT
glass made of ideas

Sales by Region

Fiscal Year 2012/13



Global Sales: € 1.84 billion

SCHOTT
glass made of ideas

R&D: Innovation Leadership the Key to Maintaining our Market positions.

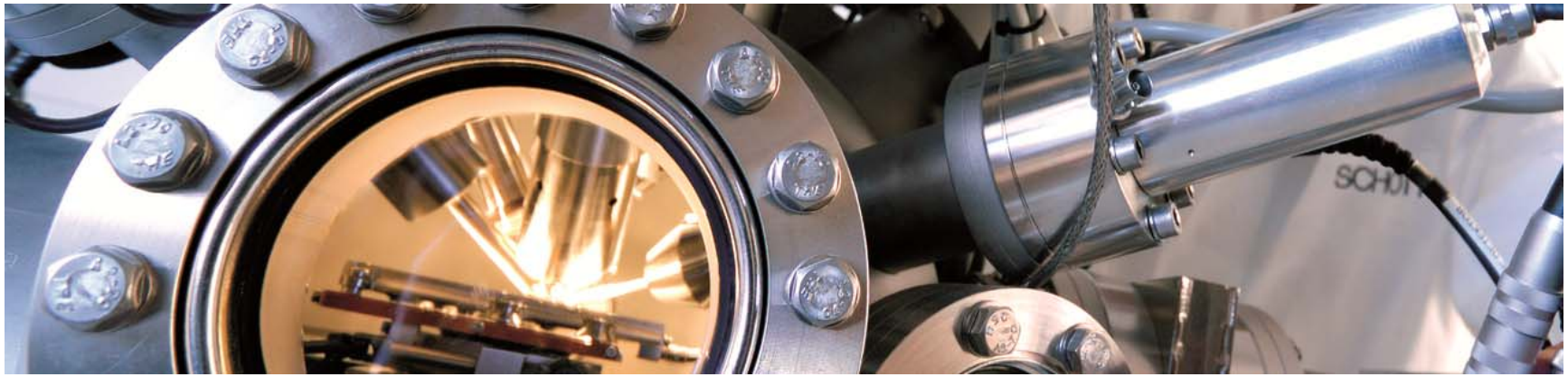
A global network with more than 600 R&D employees all over the world

- The Otto Schott Research Center in Mainz
- The Development Center in Duryea, Pennsylvania (USA)
- Technical Support Centers in Europe, North America and Asia

Main focuses of development work

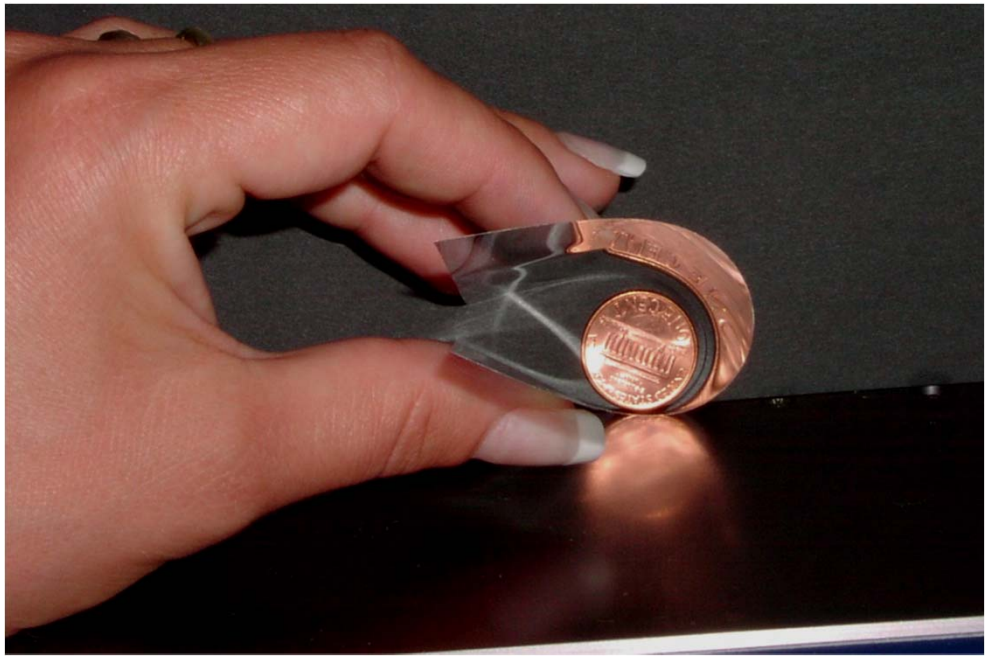
- New and improved glasses and glass-ceramics
- Process development in the areas of melting and hot forming
- Coating technologies
- Application development

New product rate: over 30 % of sales



SCHOTT
glass made of ideas

More than 10 years experience with Ultra-Thin Glass melting, hot forming and processing.



Initial publications/ conference presentations

- Thin Glass Polymer Systems as Substrates for Displays, SID 2002
- Ultra-Thin Flexible Glass Substrates, MRS 2003
- Processing Flexible Glass Sheets, Flexible Microelectronics&Displays Conference, USDC, 2004

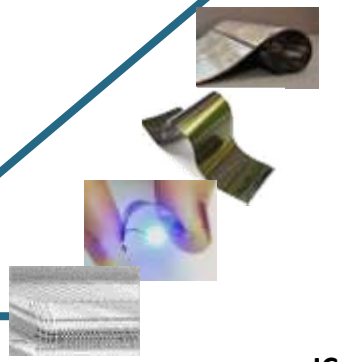
Ultrathin Glass: Substrate for Thin, Flexible and Printable Electronics.

Mega trends

- Energy
- Urbanization
- Mobility
- "Smart" Technology
- Materials
- Infrastructure

Tech trends

- Flex. /Printed Electronics
- OLED
- OPV
- Advanced batteries
- IC 3D Integration



Ultrathin Glasses (<100um)

Ultrathin glass properties

1	2	3	4	5
Flexible, rollable	Lightweight, thin	High chemical and thermal stab.	High transmission	High scratch and scrub resistance

New technical trends are generating demands for ultrathin glasses.

SCHOTT
glass made of ideas

Ultra-Thin Glass as a high performance material with potential to substitute various substrates.

Polymer

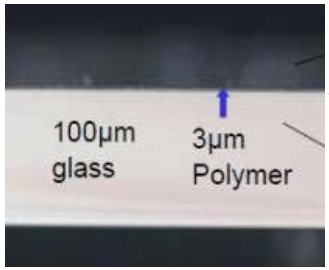
+ Low density & light weight
+ Low Young's modulus & flexible
+ Unbreakable & easy to handle
- Low gas / water barrier
- Low thermal tolerance

Glass

+ Smooth surface
+ Good gas / water barrier
+ Low CTE & good thermal tolerance
+ Good transmittance
- Brittle & difficult handling

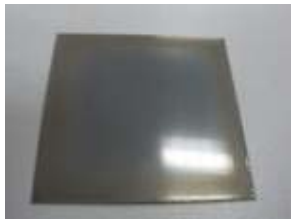
Metal

+ Relatively low cost
+ Easy to handle
+ Good gas / water barrier
+ Good thermal tolerance
+ Low resistivity
+ High thermal conductivity
- Heavy
- Rough surface
- Not transparent



Laminate or Coating

Laminate or Coating



Glass/Polymer Composite

+ high breakage strength: Easy-to-handle
+ Good gas / water barrier
+ can be transparent

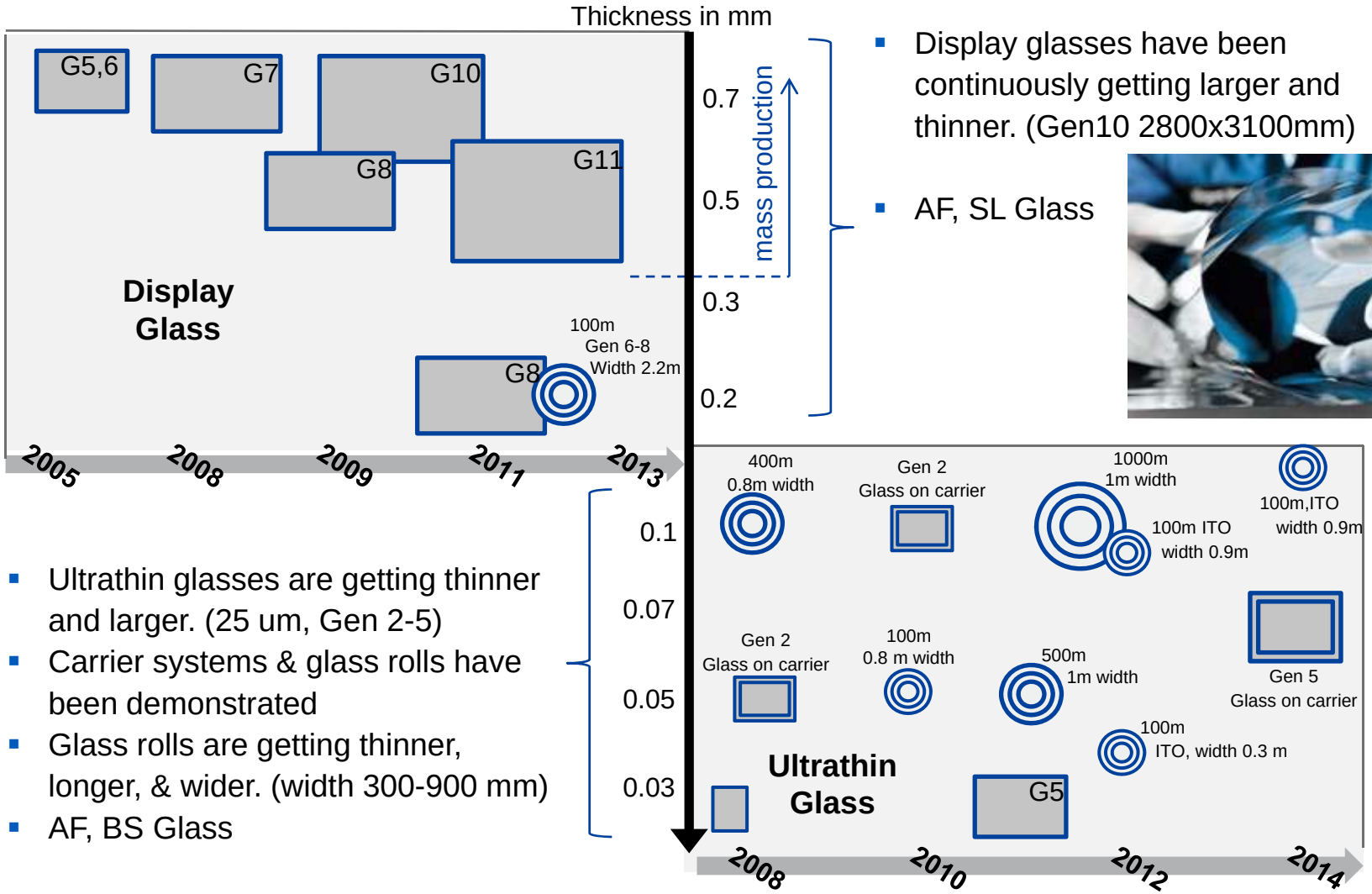
Glass/Metal Composite

+ high breakage strength: Easy-to-handle
+ High temperature tolerance
+ low surface roughness
+ Good chemical durability.

Glass composite materials can combine advantages of different material types.

SCHOTT glass made of ideas

Key Development Trends of Thin Glasses for Electronics.



- Display glasses have been continuously getting larger and thinner. (Gen10 2800x3100mm)
- AF, SL Glass

- Ultrathin glasses are getting thinner and larger. (25 um, Gen 2-5)
- Carrier systems & glass rolls have been demonstrated
- Glass rolls are getting thinner, longer, & wider. (width 300-900 mm)
- AF, BS Glass

Consumer electronics mass applications have driven thin glass development in the direction of larger and thinner to increase productivity and functional performance.

SCHOTT
glass made of ideas

Various application fields of Printed/Flexible Electronics possible.

OLED Displays

Source: AndroidPIT,

OLED Lighting

Source: “LEDs Magazine” by Laura Peters,

Thin Film Solar Cells/OPV

Source: Sun Flare Systems

Thin Film Batteries

Source: KAIST,

Thin Film Capacitors

Source: “SeanBreeden.com”

Touch Sensors

Source: “Solid State Technology®”

Printed Circuits

Source: Printed s.r.o.

RFID

Source: Fujitsu

EPD

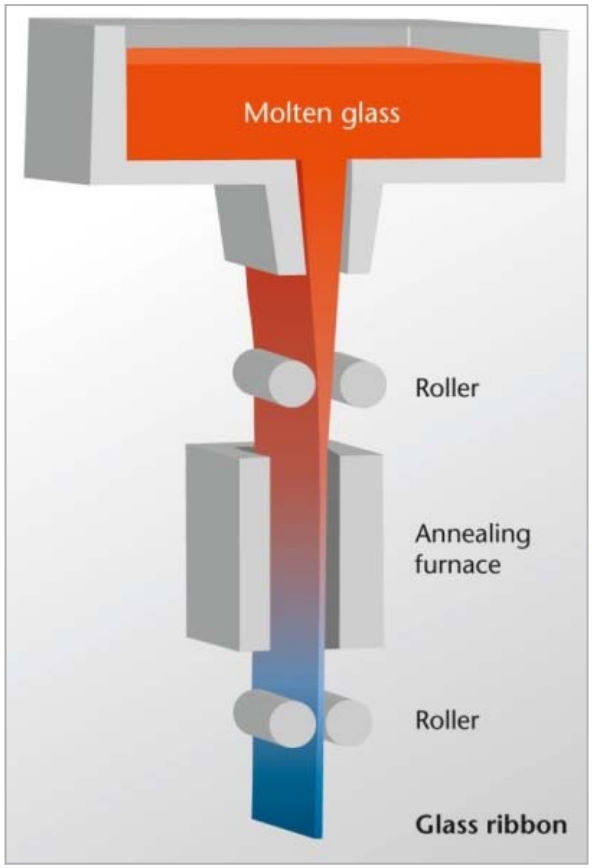
Source: “TabTimes” by Doug Drinkwater,

Ultrathin glasses can be used as substrates and encapsulation solution in different fields of printed and flexible electronic applications.

SCHOTT
glass made of ideas

SCHOTT uses the Down-Draw technology – Most preferred for producing glass with thicknesses lower than 100 um.

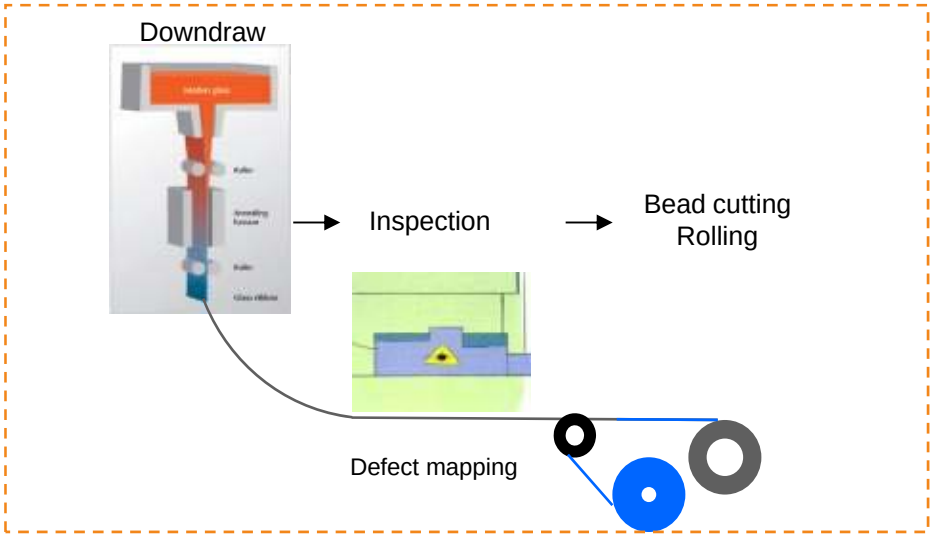
Down-draw process



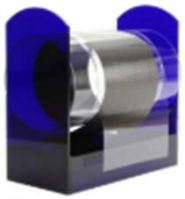
SCHOTT
glass made of ideas

Ultra-Thin Glass is produced on roll and on sheets.

- Glasses with thickness below 100µm, down to 25µm
- Produced with down-draw process in rolls and sheets
- Compatible with roll to roll (R2R), roll to sheet (R2S) as well as sheet to sheet (S2S) process

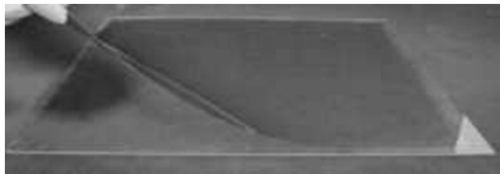


- Glass on roll



- Cut-to-size sheets

- Cut-to-size sheets on carrier glass



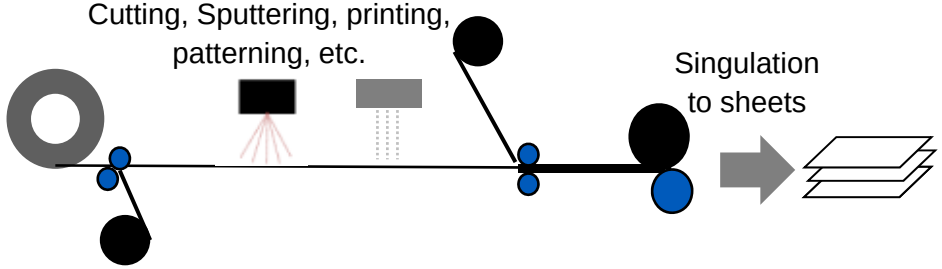
Packaged & shipped to customers

Ultrathin glasses are produced as rolls and can be further processed for “roll to roll”, “roll to sheet”, or “sheet to sheet” processes.

SCHOTT glass made of ideas

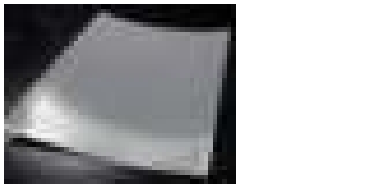
Processing in R2R, R2S and S2S possible.

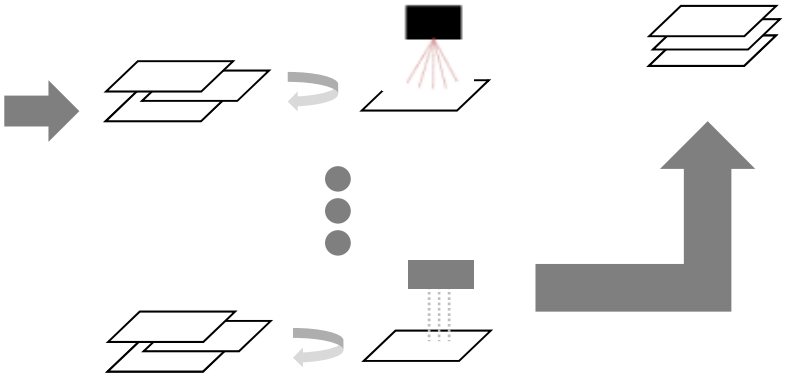
Processing options



“Roll-to-roll” / “Roll-to-sheet” process

“Batch” / “sheet-to-sheet” process



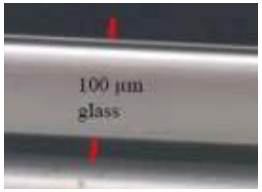


Up to now, no standard processes for ultrathin glass exists. Typically processes are customized and have to be specifically developed and adjusted.

SCHOTT glass made of ideas

Ultrathin Glass Processing Technologies / Tool box.

Cutting



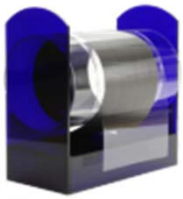
Inspection

Cleaning

Source: S-Tec Corp

Processing Technologies

Packaging



Coating

Carrier systems/ Roll to Roll

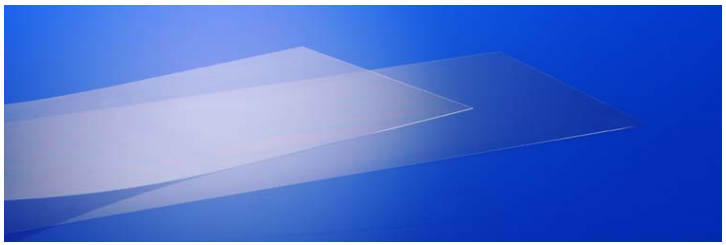
Lamination

Processing technologies are the key enablers of usage of ultrathin glass in printed electronics. Handling of ultrathin glasses in the production processes is a key challenge.

SCHOTT
glass made of ideas

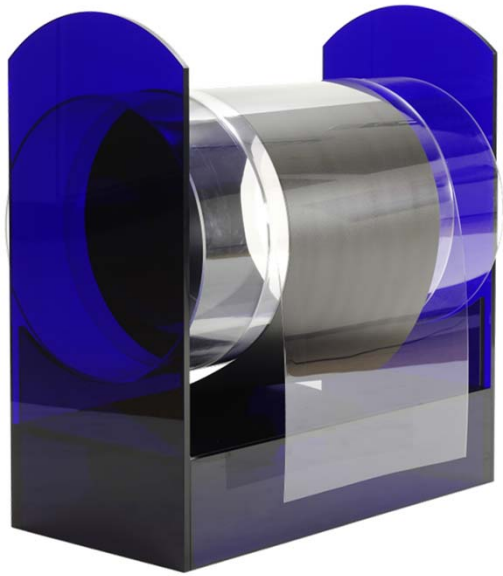
Ultra-thin and flexible glass from SCHOTT AG is available as cut-to-size sheet and on roll.

Glass sheet



- **D263 Borosilicate Glass/ AF32eco alkaline-free glass**
- **Nominal thickness: 25, 50, 70, 100 micron**
- **Gross width up to 600 mm**
- **Cut-to-size format**

Glass roll



- **AF32eco alkaline-free glass**
- **Nominal thickness: 50 micron**
- **Gross width up to 600 mm**
- **Standard length on roll: 10- 500 m**
- **Several kilometers of various glass thicknesses successfully rolled and unrolled**
- **Rolls shipped to customers**

SCHOTT
glass made of ideas

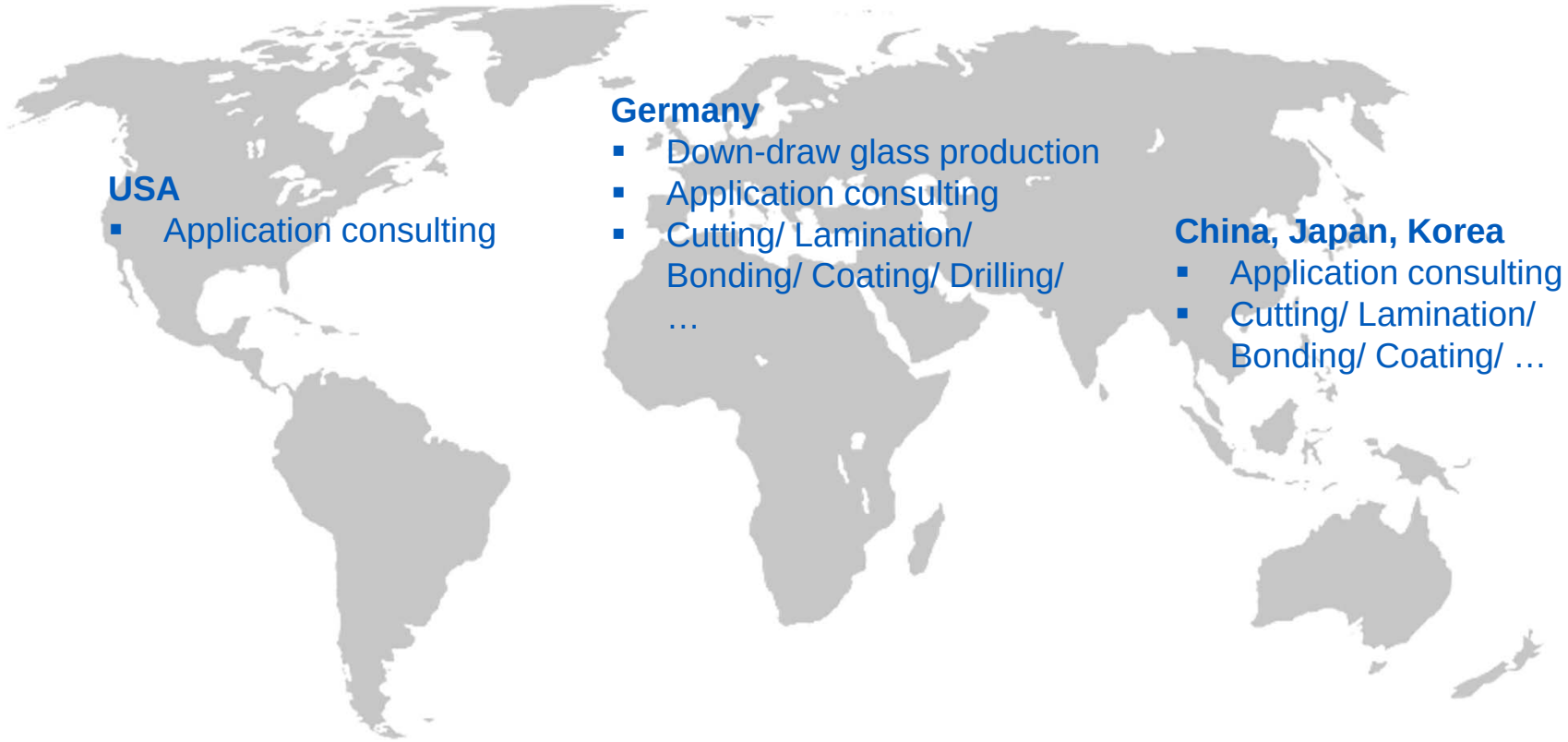
Latest developments of SCHOTT Ultra Thin Glass with significant product innovations.

- Glass on roll 640mm net width (w/o beads) by mid 2014 – significant increase of glass ribbon width
- R2R bead cutting process in ramp-up at production site in Germany
- R2R lamination process under development
- Sheet processing capabilities already available – Lamination, bonding/ de-bonding, etc.
- … more about to come.

SCHOTT
glass made of ideas

SCHOTT Ultra-thin glass serves its customers with local engineering and processing.

Local hubs for application engineering and processing



SCHOTT
glass made of ideas