Wafer-Level Glass Molding of Chalcogenide Glasses

High volume infrared optics production

EPIC Meeting on Wafer Level Optics

Neuchâtel, CH, Nov. 7th – 8th 2019

EPIC European Photonics Industry Consortium

Tim Grunwald, Jan-Helge Staasmeyer, Gang Liu

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Fraunhofer Gesellschaft

Institutes und sites

Key Figures

- 72 institutes
- 26 000 employees
- > 2.3 bn € annual fund for research

➔ **Largest organization for applied research in Europe**

Fraunhofer Society

- Founded in 1949
- Legal form: nonprofit association
- Headquarter in Munich, Germany

Goal

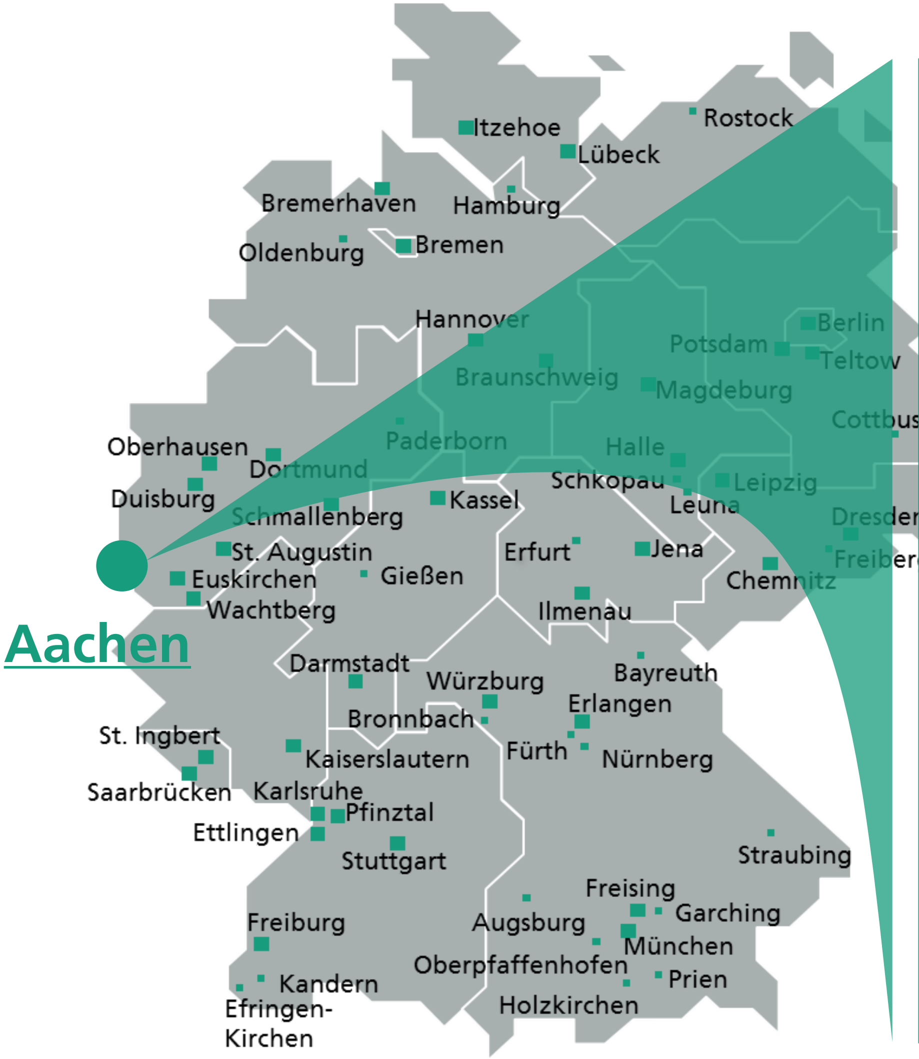
- Contract research for economy and society
- Transferring fundamental research to industrial application

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Fraunhofer Institute for Production Technology IPT

Overview



Fraunhofer IPT

459 Employees, thereof 214 permanently

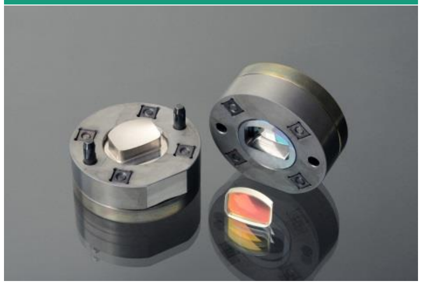
31 m € operating budget, thereof 13 m € Industry projects

Fraunhofer IPT is certified according to DIN EN ISO 9001:2015

Product Spectrum & Scope of Application

Aspherical Optics

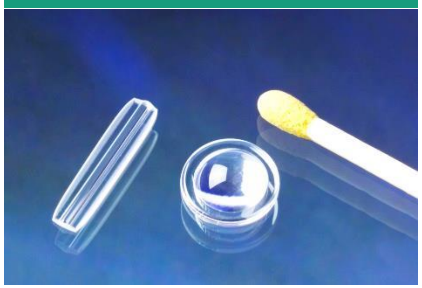
Freeform Optics



Lighting Optics

Diffractive Optics

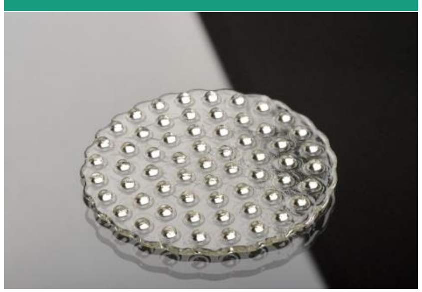
Micro Optics



Infrared Optics

Cylindric Lenses

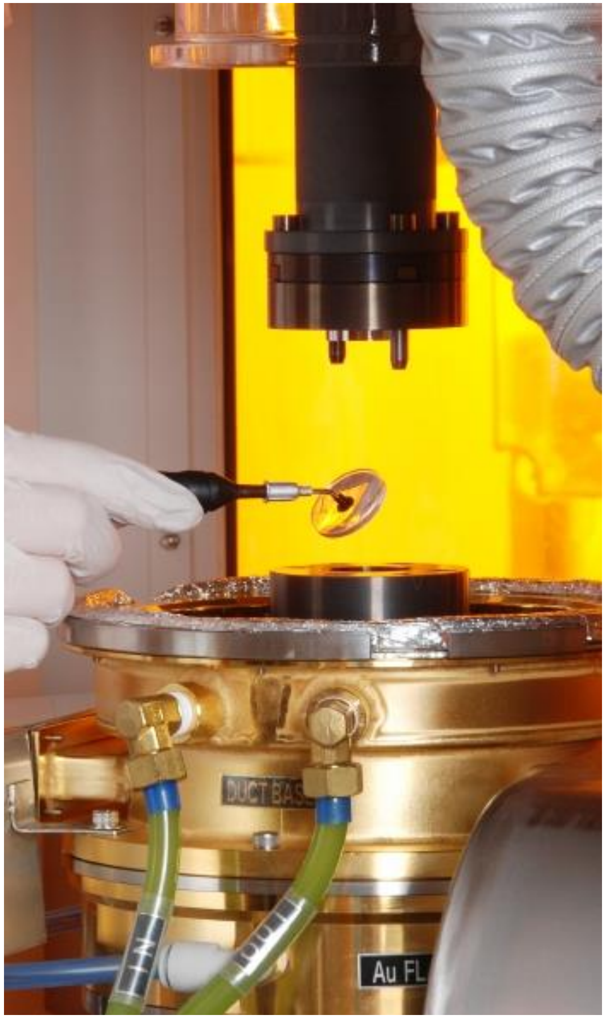
Lens Arrays

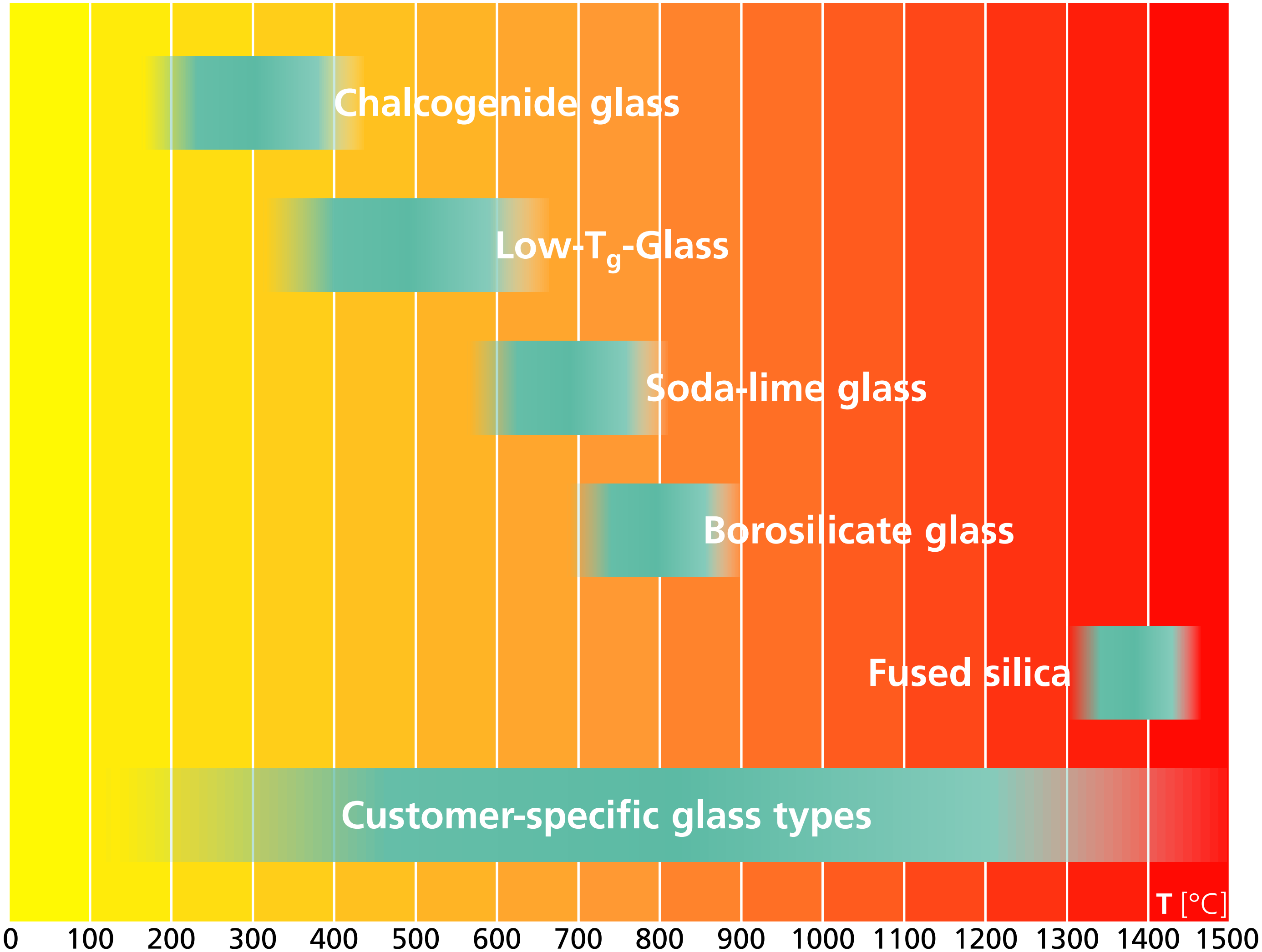


Wafer Optics

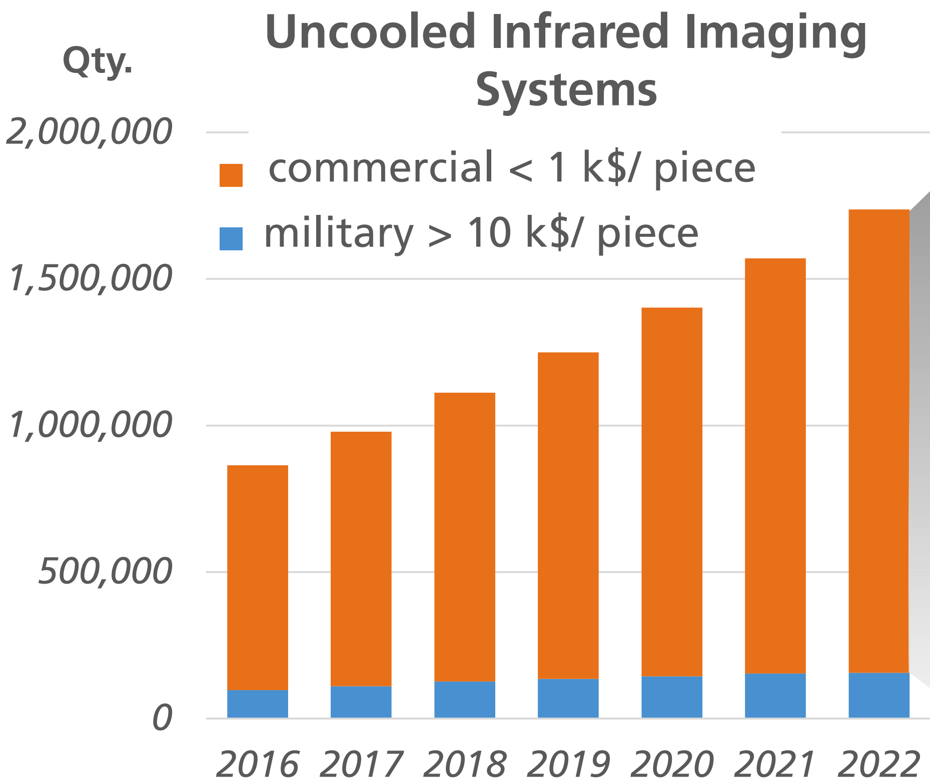
- Wide range of possible geometries
- Accuracies can be adjusted according to the field of application:
  - Imaging
  - Lighting
  - Laser Optics
- High reproducibility/ repeatability as a consequence of the molding process

Glass Types and Molding temperatures





Infrared Optics – Market, Application and Motivation



Mobile Thermography
Source: FLIR

Automotive Night Vision
Source: Autoliv

Low-Cost Presence Detection
Source: Panasonic

Motivation

The rising demand for low-cost, aspheric infrared optics can only be met with a scalable replicative production technology such as precision glass molding.

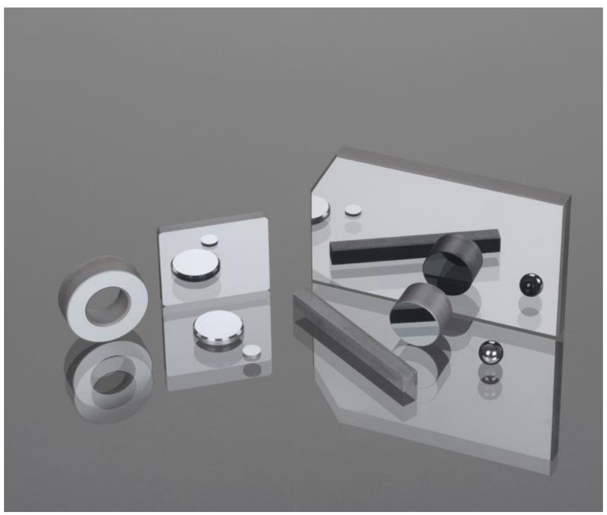
Source: Yole Uncooled Infrared Imaging Technology & Market Trends 2017

Fraunhofer IPT

WZL | RWTH AACHEN UNIVERSITY

Chalcogenide glass – Amorphous material for infrared optics

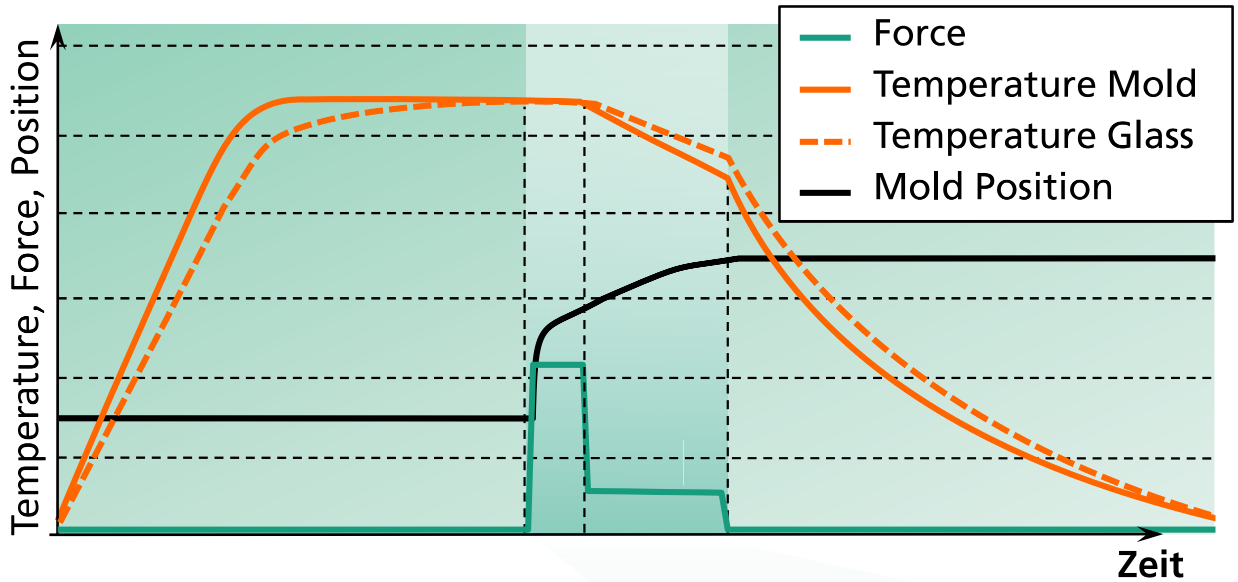
IV Carbon Group	V Nitrogen group	VI Chalcogen
C Carbon	**N** Nitrogen	**O** Oxygen
Si Silicon	**P** Phosphorus	**S** Sulfur
Ge Germanium	**As** Arsenic	**Se** Selenium
Sn Tin	**Sb** Antimony	**Te** Tellurium



- Covalently bonded chalcogenides of elements of group IV and V
- Cost-effective synthesis by glass melting compared to crystal growth processes
- Characteristic properties:

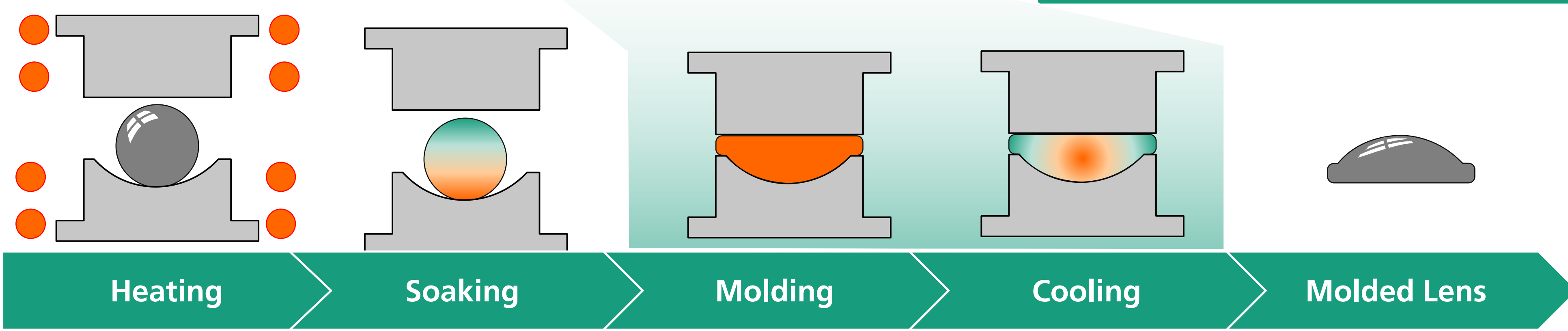
	Chalcogenide glass		Optical glass
Trade name	IG6 / IRG26	IG5 / IRG25	N-BK7
Composition	**As_2Se_3**	**$Ge_{28}Sb_{12}Se_{60}$**	≥9 Oxides (**SiO_2 , B_2O_3** ,…)
Transmission [µm]	1 – 12	1 – 11	0,35 – 1,9
Refractive index [1]	2,8	2,6	1,5
Tg [°C]	185	285	557
α [10^{-6}/K]	20,7	14	7,1

Precision glass molding of infrared optics – process overview



Precision Glass Molding

Pros	Cons
Low-costs due to scalability	Process development effort
Material efficiency	Time-to-Market



Project Overview »SKALIR« 2017 - 2020

- Project target: "Scalable replication of infrared lenses"
  - Cost reduction for precision molded infrared optics by a factor of 5 – 10 due to scalable mold concepts.

Single-Cavity

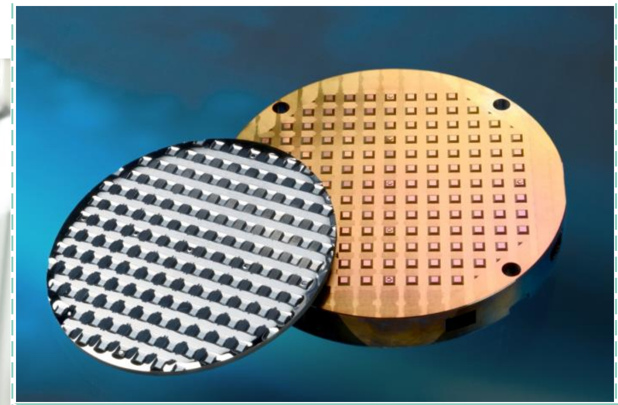
- One lens per cycle, however also large or complex lenses feasible

Multi-Cavity

- Rotational symmetric lenses smaller Ø20 mm

Wafer Level

- Lenses smaller Ø5 mm



1x
Lenses per cycle

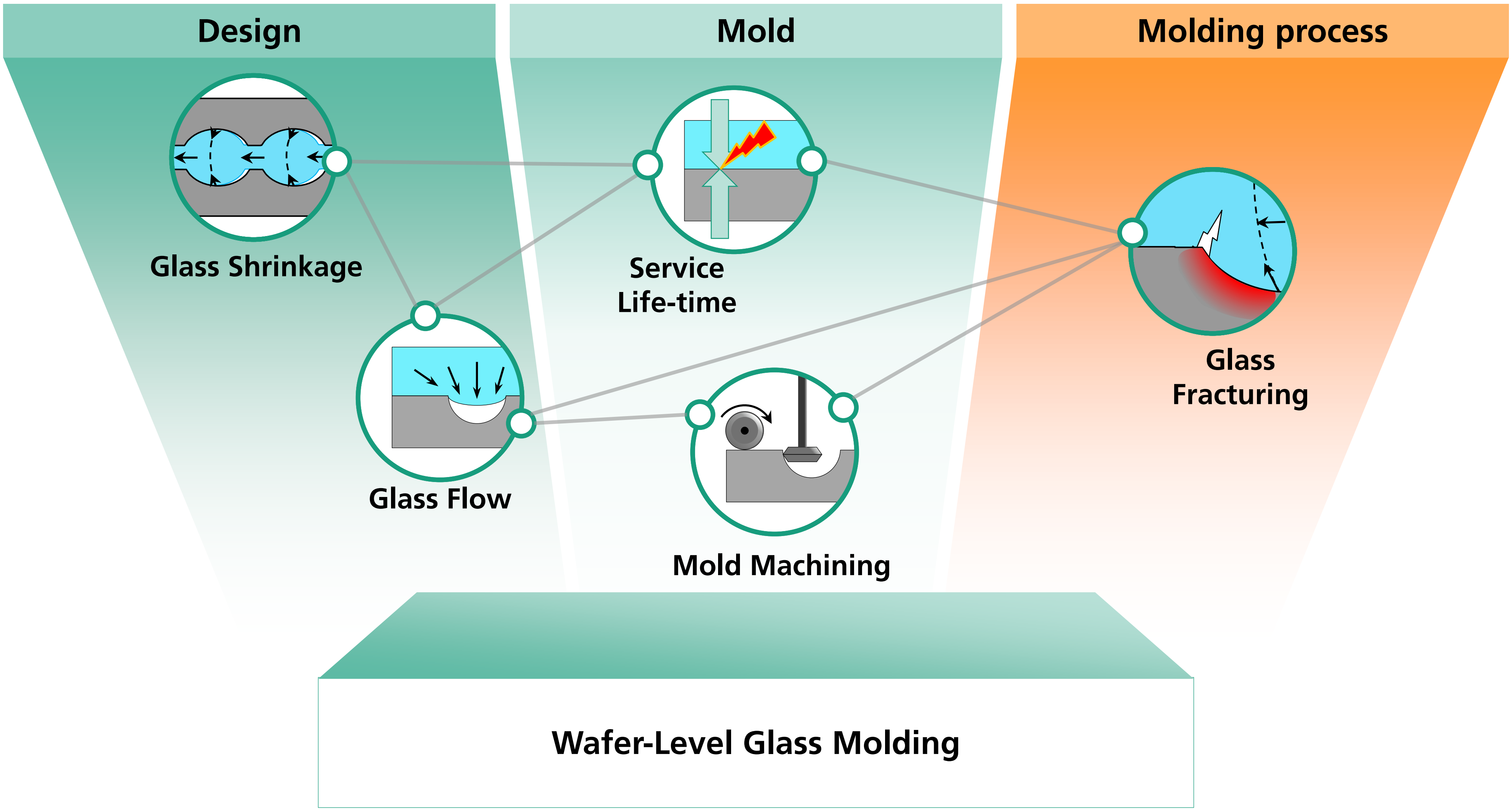
2-20x

~100x
Lenses per cycle

SKALIR

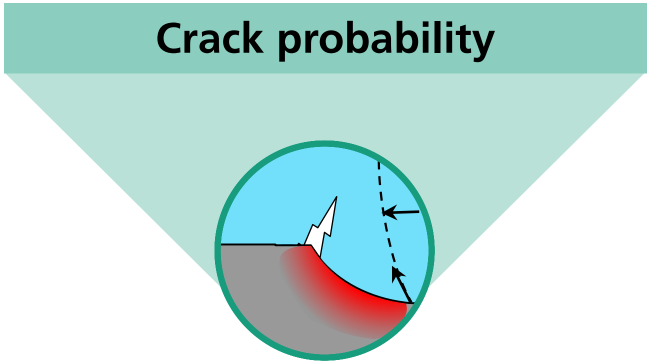
Challenges in molding chalcogenide glass on wafer scale

Challenge overview

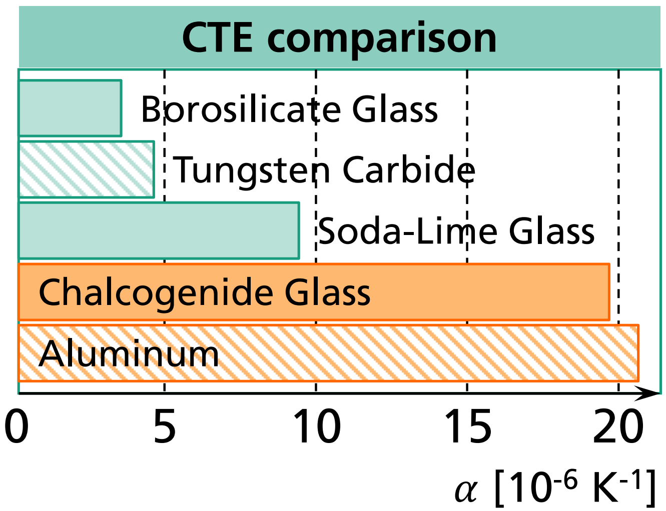


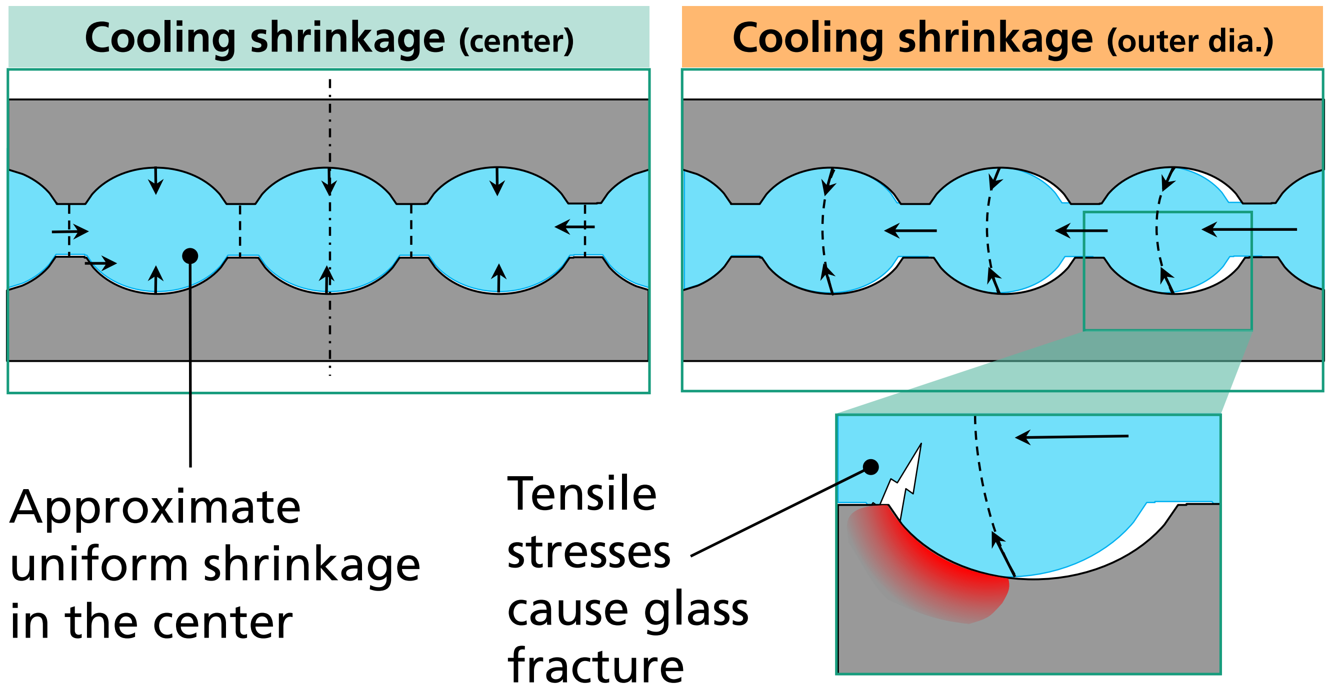
Challenges in molding chalcogenide glass on wafer scale

Challenge – Glass Wafer breakage

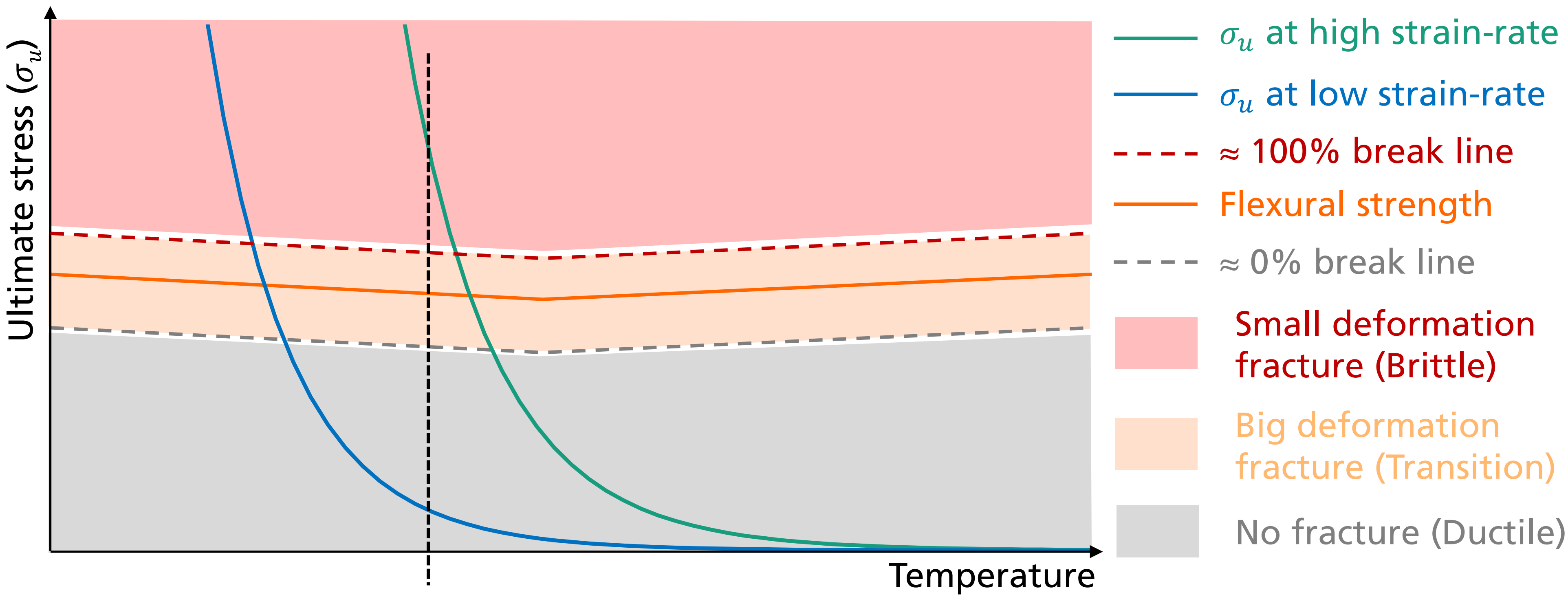


- Glass breakage observed more frequently with wafer-based processes compared to ball preforms
- Expansion and shrinkage while heating or cooling induce a higher risk of breakage, especially in the case of CTE-mismatches (tool/glass)





Fracture behavior of glass

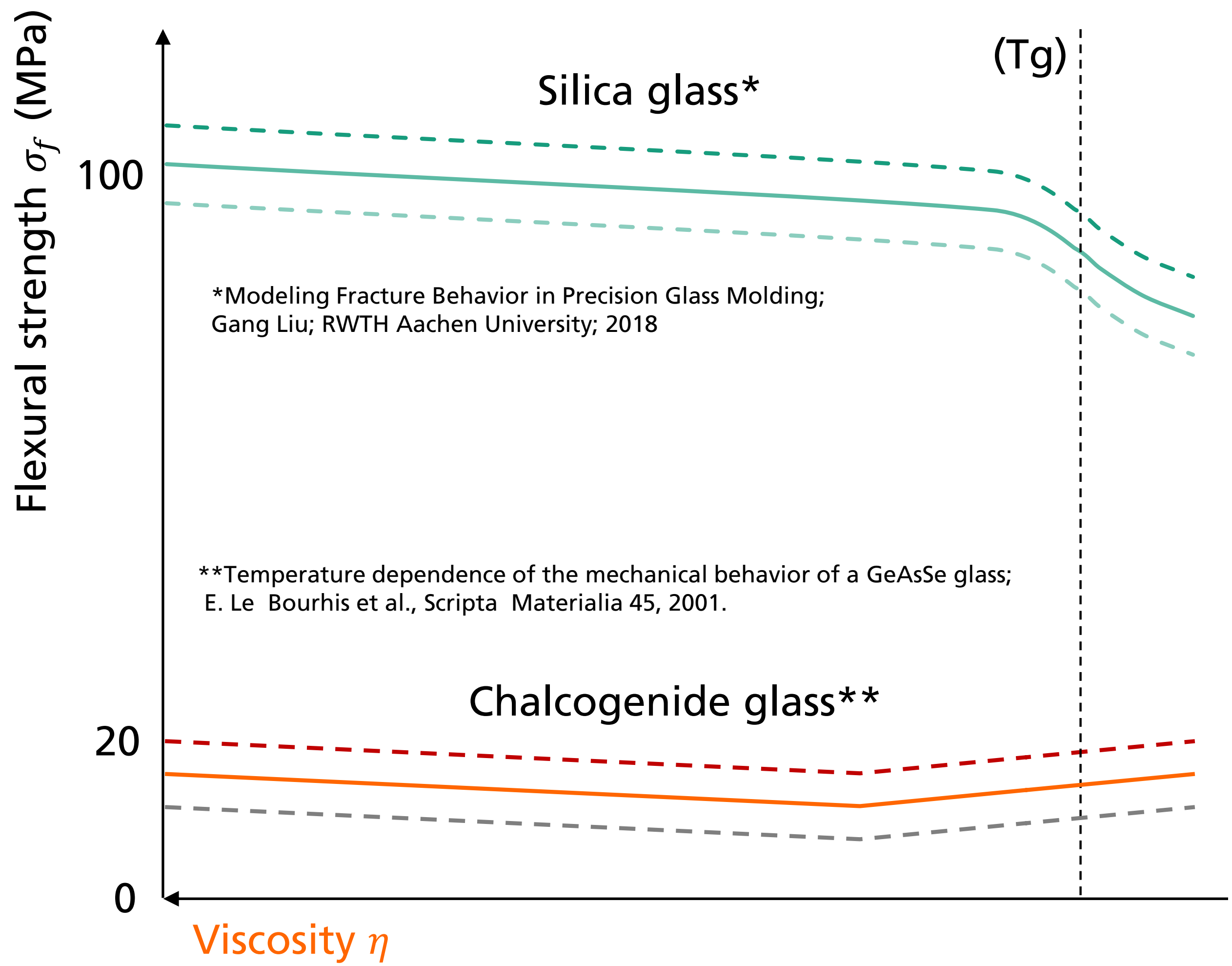


- Temperature and strain-rate determines σ_u, which determines the fracture behavior of glass
- Both brittle fracture and transition fracture of glass follows **Weibull statistics**, however their Weibull parameters (m_V and $(\sigma_0)_V$) are different

Weibull statistics
(fracture probability P_f)

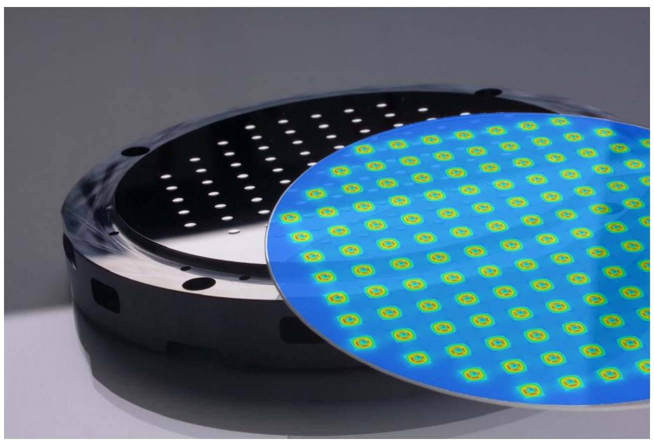
$$P_f = 1 - e^{-\int_V \left(\frac{\sigma}{(\sigma_0)_V}\right)^{m_V} dV} \qquad for \ \ \sigma > 0$$

Background: Glass material
Flexural strength: chalcogenide glass vs. silica glass



- Chalcogenide glass is much more fragile than silica glass
- The σ_f-η(temperature) curve of chalcogenide glass is also different from silica glass
- **Further study on the fracture of chalcogenide glass is necessary**

FEM-Simulation with advanced material models



Finite Element Method Simulation with advanced material models for chalcogenide glass

Functionality

- Visualization of glass flow

  → Mold design optimization

- Prediction of lens shrinkage

  → Aspheric mold compensation

- Calculation of fracture probability

  → Process optimization

Thank you for your kind attention!
Offers, Contact and Acknowledgement

What we can offer:
- Simulation studies in glass forming
- Process development
- Prototype manufacturing

What we are looking for:
- Application cases
- Inspiration for new developments
- Partners for bilateral or public-funded projects

Fraunhofer IPT

M.Sc.
Tim Grunwald
Head of Department "Fine Machining and Optics"
Fraunhofer Institute IPT
Steinbachstrasse 17 • D-52074 Aachen
Phone.: 0241 / 8904 – 408
gang.liu@ipt.fraunhofer.de

Fraunhofer IPT

M.Sc.
Jan-Helge Staasmeyer
Group Manager "Optics"

Fraunhofer IPT
Steinbachstraße 17 • D-52074 Aachen
Phone: +49 241 / 8904 - 568
Jan-helge.staasmeyer@ipt.fraunhofer.de

EUROPÄISCHE UNION
Investition in unsere Zukunft
Europäischer Fonds
für regionale Entwicklung

2014 – 2020
EFRE.NRW
Investitionen in Wachstum und Beschäftigung

Das Projekt »SKALIR« wird durch Mittel des Europäischen Fonds für regionale Entwicklung (EFRE) 2014-2020 gefördert.

Förderkennzeichen
EFRE-0800802

Many thanks to:

EPIC European Photonics Industry Consortium

SÜSS MicroTec

This presentation was presented at EPIC Meeting on Wafer Level Optics 2019

HOSTED BY

SÜSS MicroOptics

DINNER SPONSOR

SWISS PHOTONICS

GOLD SPONSOR

PIXAPP Photonic Packaging Pilot Line

SILVER SPONSORS

LAMDAS

Technobis group

BRONZE SPONSORS

NIL TECHNOLOGY

DELO INDUSTRIAL ADHESIVES

MIRPHAB ENABLING CHEMICAL SENSING

NTS OPTEL

PASSION

OptoSigma

EU initiatives funded by
www.photonics21.org

PHOTONICS21 PHOTONICS PUBLIC PRIVATE PARTNERSHIP