Fraunhofer ISC

FRAUNHOFER INSTITUTE FOR SILICATE RESEARCH ISC

A CLEAR FUTURE FOR GLASS

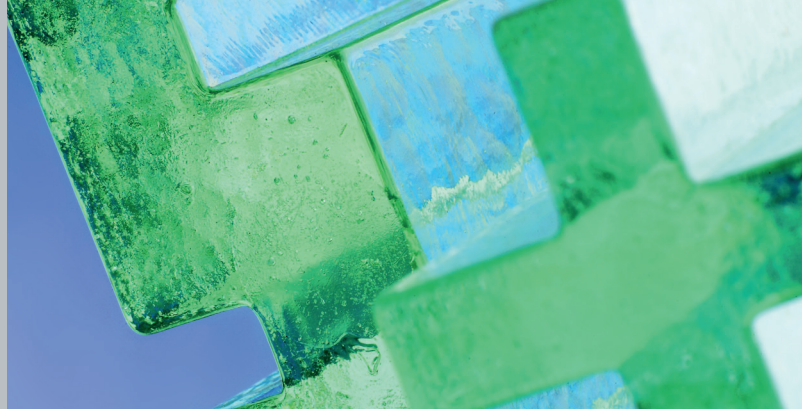
MATERIAL – DEVELOPMENT – CHARACTERIZATION

Do you have a specific problem with your glass materials or products?
Would you like to modify your materials, understand them better, compare or test them, or develop new materials?
Do you have questions about special methods and processes?

If so, just get in touch with us!
We are your point of contact for all glass-related questions:

Dr. Martin Kilo
Senior Manager Competence Team Glass
Phone +49 931 4100-234
martin.kilo@isc.fraunhofer.de
Neunerplatz 2, 97082 Würzburg, Germany

A PARTNER FOR INDUSTRY AND RESEARCH



A COMPETENT PARTNER FOR INDUSTRY

The Fraunhofer Institute for Silicate Research ISC was founded in 1926 on the initiative of the glass and ceramics industry. Since 1971 it has been based in the Fraunhofer-Gesellschaft, and glass continues to be one of its main areas of research and development.

Development of special types of glass, glass joints or glass coatings – these are just a few topics to illustrate the Institute's broad range of application-oriented R&D activities relating to glass.

Together with our partners and customers in industry and research, we develop new recipes for glass, new processing techniques, new functional coatings, new equipment for process control, and more.

Our aim is to provide industry with ready-made solutions that will optimize the time-to-market period for developing new products or improving existing ones, to safeguard the competitive advantages of our partners and customers.

OUR PORTFOLIO AT A GLANCE

We are certified according to EN ISO 9001:2008 for quality assurance, and offer the following range of services:

- Development of special glass
- Glass manufacture
- Development of technical processes for glass
- Glass characterization
- Analysis of glass properties
- Damage and failure analysis
- Functional coatings, both inorganic and hybrid
- Technical advice on all questions relating to glass technology
- Measurement and test technology
- Glass restoration and conservation

We offer the complete process chain, from material development and development of processing technologies, from production in technical scale right through to industrial production.

We are glad to deal with requirements and orders of all kinds, whether large or small. Our customers include both large organizations and small companies, and we provide our partners and customers with a reliable »On-demand development department«.

We look forward to hearing from you.

DEVELOPMENT AND MANUFACTURE OF SPECIAL GLASS

Special glass can be used in very different types of applications, e.g. as glass soldering, electrochemically active glass or optical glass. In this field we offer the following materials, processes and skills:

Low-temperature glass solder for laser packaging
In a cooperation with our sister institute in Aachen, the Fraunhofer ILT, we offer laser beam glass frit bonding for packaging of temperature-sensitive glass and silicon components, based on a newly developed unique low-melting glass solder and a laser bonding process.

Glass solders for high-temperature fuel cells (SOFC)
For joining metals and ceramics for applications at working temperatures of up to 1000 °C, gas-tight glass solders were developed that meet the following requirements:

- Processing temperatures < 1100 °C
- Working at temperatures of up to 1000 °C
- Thermal expansion 10 ppm/K
- Viscosity (1000 °C) > 10^5 Pa-s
- Good wettability of the materials to be joined
- Chemical compatibility
- Alkali-free and free from toxic elements

Other glass solders are available for both high and low temperatures. We will also be happy to develop glass solders to suit your specific requirements.

Electrochemically active glass
Certain glass compounds have a structure and composition that makes them suitable for storage and conduction of lithium ions. These properties are used by Fraunhofer ISC to develop new solid state lithium battery systems.

Color markings in glass by laser
Quality monitoring and product identification labeling are rendered secure against counterfeiting by the sub-surface marking of glass.

We have developed thermally and UV stable color markings based on chromophoric polyvalent ions. Glass that is marked by this process remains free of cracks and stress, so that this method is also suitable for thin and even tempered glass. 3D laser marking can also be used, for example, to insert tamperproof barcodes into glass.

DEVELOPMENT OF GLASS-CERAMICS

GLASS-CERAMICS DEVELOPMENT AND MANUFACTURING

We have many years of experience in the development of glass-ceramics in dental or other applications described below. We can realize properties such as:

- High flexural strength
- Cost-effective CAD-CAM machinability
- Optimized thermal expansion coefficient
- Translucency (depth effect) and opalescence
- Individually adaptable to the color of teeth

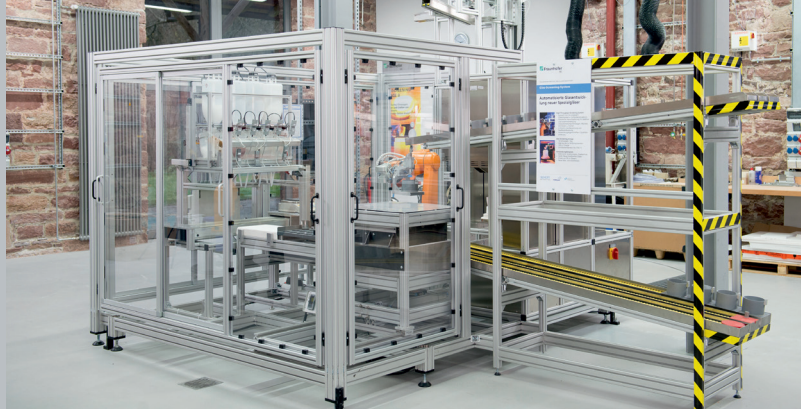
We also develop glass-ceramics for other applications, including:

- Crystallizing glass solders for joining technology
- Decorative glass and glass-ceramics
- Optical glass-ceramics
- Glass-ceramics for new battery systems

Pilot plants and small-batch manufacturing
On customer request, we develop small-scale glass production pilot plants. Alternatively, we can undertake the manufacture of special glass and glass-ceramics in quantities of up to 100 kg per annum. Depending on target properties, the glass may be manufactured from a variety of raw materials, at temperatures up to 1700 °C, and in semi-finished form (rods, blocks, tubes, fibers) or as frit or powder.

The REACH regulation and its consequences
In Regulation No. 907/2006, in the EU Official Journal L396 dated May 29, 2007, the EU made it compulsory to identify critical and toxic materials by 2018, register them and, where necessary, exchange them for other materials.

Fraunhofer ISC offers advice in this area, along with analyses of the materials, and where necessary develops new recipes and material compounds so as to reduce or wholly replace harmful components, in particular lead, arsenic, and antimon which are very common in traditional glass compositions. Just contact us, and we will find a solution.



Temperature measurement methods for process control

Fraunhofer ISC has developed methods for the rapid and precise 2- and 3-dimensional pyrometric temperature measurement in large-scale glass manufacture. This exploits a process developed jointly with Fraunhofer IWM for the simple manufacturing of curved tempered glass containing multiple bends. When a flat pane of glass is bent, this may result in large stress in the material. Spatially resolved precision temperature monitoring used for furnace control significantly reduces scrap and avoids subsequent breakage of the glass. In this project, a pyrometer with 2D scanner was developed for this purpose, featuring:

- 2D detection of heat radiation
- Fast-responding pyrometer with $\lambda = 3.9$ µm
- Temperature comparison using black-body radiation

Together with Fraunhofer IWM and the Fraunhofer Center HTL, we support cooperation partners in hot forming, by such means as:

- Precise 2D temperature measurement technology (also applicable to measurement of glass gob temperature)
- Bending of test panels under controlled conditions

Precise measurement of the glass temperature in the manufacture of hollow glassware
Development of a new measurement principle, including a reference measurement by cavity radiator at 1000 °C and a temperature precision of < ±1K, with a measurement time of less than 2 ms.

High-throughput screening technology

To focus and perfect its development work, Fraunhofer ISC has constructed a glass development plant that is unique in the world and supports the following processes:

- Selection of the basic glass type from a database or using computer simulation
- Statistical planning of trials for additives and ingredients
- Fully automatic weighing, mixing, melting and cooling
- In-situ/In-line assessment and feedback control
- Application properties and quality assurance

There are fourteen dosing stations, each with a capacity of 1 to 5 kg and a precision of +/-10 mg (at 1 kg) to +/-15 mg (at 5 kg). The melting furnace is equipped with five stations, and generates a melting temperature of 1700 °C (+/-2C). Up to sixteen samples can be produced per day and the fully automatic process guarantees precise repeatability.

REDRAWING GLASS FROM PREFORMS

This technology, developed by Fraunhofer ISC, enables the efficient production of glass micro-components with a constant non-spheric cross-section. We offer:

- Development of preforms with complex cross-sections, whilst preserving the precise internal and external geometry.
- Redrawing whilst maintaining the profile, with a reduction factor of up to 1000:1 in a single step.
- Manufacture of rods and fibers in diameters from 5 mm down to 50 µm, or from pre-cut components, in volumes of up to 10 kg per month.

Small batches of up to 100 pieces can be produced at Fraunhofer ISC. If required, production plants can also be constructed to suit your applications.

Low temperature glass joints for optics and precision mechanics

In collaboration with Fraunhofer IOF and Vistec Electron Beam GmbH, we have developed a low temperature process for joining different types of glass.

The stable and durable inorganic joint ensures high mechanical strength. There are only minor optical losses, and the system can be exposed to high doses of optical radiation.

Owing to the very low jointing temperature (< 100 °C), glass types with very different coefficients of thermal expansion can be bonded without inducing any stress.

Molecular sorting – processing high-quality glass

Processing of high-quality glass from old glass is the goal of one of Fraunhofer's internal development projects, in which Fraunhofer ISC is partnered by its project group IWKS. This involves such tasks as the extraction of contaminant elements (iron, lead, etc.) from the molten old glass. The project is investigating separation processes based on electrochemistry or complex chemistry in the melt, and also cold-extraction cleaning processes when the glass is cold.

Life-cycle analyses are carried out over the whole course of the project. Cost-effectiveness calculations are an important component in assessing the processes developed during the project.

GLASS ANALYSIS

FAILURE AND DAMAGE ANALYSIS

Together with the Center for Applied Analytics (Zentrum für Angewandte Analytik, ZAA), the Competence Team Glass offers its customers and partners various chemical and structural analysis methods, together with a whole range of analytical methods for the determination of the physical properties of glass, glass-ceramics and enamels.

For instance, it is important to understand the distribution of stresses in toughened architectural or automotive glass for reliable use. In cases where damage has occurred, measurement of stresses is often the key to identifying the cause of falilure.

We are ready to help with this, acting as partner to industry for the analysis of all types of damage involving glass, in such sectors as automotive, architecture, pharmaceuticals, or food and drink. We carry out fast and accurate analyses, interpret the results, and indicate the way to solve the identified problem.

Measuring the physical properties of glass and glass-ceramics

Test methods:

- Optical stress measurement
- Mechanical strength
- Optical properties (transmission, reflection, absorption spectra)
- Thermal properties (thermal expansion, glass transition, heat capacity)
- Viscosity
- Dielectric properties
- Glass structure analysis (XPS, NMR, XRD)

Chemical and structural analysis of glass and glass-ceramics

Typical applications include:

- Gravimetric silica and acid/base content determination
- Determination of boron content
- Testing hydrolytic, acid and base resistance
- Fe^{2+}/Fe^{3+}- and Cr(VI) determination
- Heavy metal analysis
- Glass composition (RFA or ICP)
- XRD, also at elevated temperatures

TEST LABORATORY AND APPLICATION CENTER, BRONNBACH

QUALITY ASSURANCE IN GLASS MANUFACTURING

At Fraunhofer ISC's Center of Device Development CeDeD, located in Bronnbach, thermo-optical analysis instruments are customized and produced. They can be used for the contact-free determination of several properties of glass at elevated temperatures and under varying conditions. The devices are put to use all over the world as they constitute a unique measuring tool for the monitoring and quality assurance of thermal processes, not only in the glass industry. CeDeD provides design, development and manufacturing from a single source to ensure that the individual requirements of its partners are fully met.

In-situ measurement of glass properties
For the in-situ measurement of glass properties, the TOMMIplus is available – an optical dilatometer, which is used to determine the following properties and metrics:

- Volume change and coefficient of expansion
- Wetting and adhesion behavior
- Bubble formation
- Weight loss
- Viscosity parameters: cantilever bending method, thread pulling method, rod penetration method
- Determination of Tg
- Glass crystallization temperature

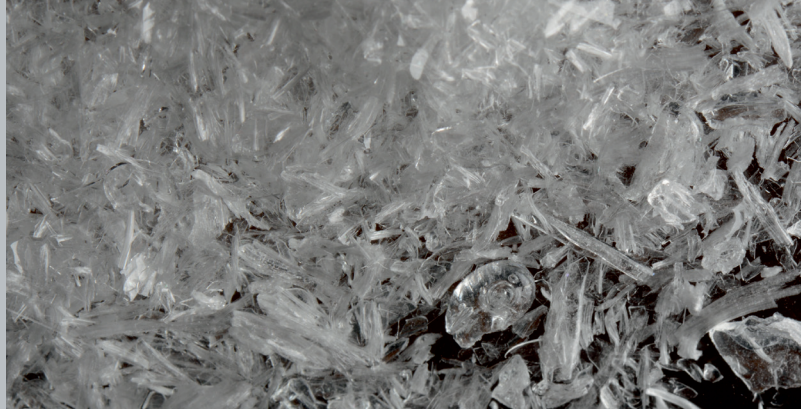
Investigation of batch heating
The capcity of the thermo-optical device allows the parallel in-situ measurement of several of the effects occurring during the heating of raw material powders. In particular, the mass-change and the de-gassing as well as the sintering and volume change can be determined in one single measurement.

Measuring the adhesive behavior of glass
To investigate adhesive behavior, material combinations of glass-bonding partners are heated under controlled conditions in TOMMIplus, in order to identify the following parameters:

- Cyclic tensile and pressure forces on material contact
- Optical detection of contact angle
- Fully automatic measurement of the adhesion temperature

  All these measurements can now be done fully automated using a robot-controlled sample changing system.

TOMMI *plus* is controlled by a standard PC and operated via a comfortable graphical user interface. Besides the data on dimensional changes, single images as well as time-lapsed videos of the thermal treatment can be obtained. The resolution of TOMMI *plus* is about 0.4 µm with very high reproducibility. It is optionally available with several loading stages and a balance for simultaneous gravimetric investigation of the sample.



GLASS IN THE CONSTRUCTION INDUSTRY

Glass is an important material in construction and architecture, and its possibilities are far from being exhausted. Fraunhofer ISC therefore lays strong emphasis on developing glass as a construction material, especially where ecological considerations and product safety are involved. Our services range from the development of special glass for selected applications, to recycling of plate glass and to functionalization or damage investigation.

Construction materials based on porous glass flakes
Walls and ceilings offer large surfaces that could be used to control room air-conditioning, but are still scarcely considered at all for such purposes. Nano-porous materials such as glass flakes can convert wall coverings into storage areas for moisture or heat – and by such innovative climate control techniques, energy can be saved. Added biocides or fungicides and phase-change materials (PCMs) act as a functionality to these wall coverings. Porous glass powder or flakes can be produced by leaching thermally separated glass with acids. This powder is already being successfully used and tested as a climate-regulating additive to paint and plaster, and a cost-effective production technique is currently under development.

Glass solders for vacuum insulating glass
Glass solders are outstandingly suited for use in vacuum insulating glass, and provide a durable and tight edge joint. Glass solder creates an homogenous joint that provides a rigid bond with a stable long-term seal. A special, selectively colored glass solder was developed at Fraunhofer ISC, that is suitable for selective laser-based jointing of glass.

In-vitro fiber corrosion testing of glass and rock wool
Glass wool and rock wool are classified as potentially carcinogenic building materials due to the limited biodegradability of the fibers within the human lung. An in-vitro test developed by Fraunhofer ISC estimates the half-life and carcinogenic potential of newly developed glass fibers, and substantially reduces the need for animal-based testing compared with previous methods.
The test meets the requirements of the Gütegemeinschaft Mineralwolle e.V. (RAL) and the European Certification Board for Mineral Wool Products (EUCEB).

Fraunhofer ISC is accredited as a RAL and EUCEB test institute for analysis of glass fibers.

COATING OF GLASS

FUNCTIONAL COATINGS IN ARCHITECTURE, SOLAR ENERGY SYSTEMS AND FOR DECORATION

The coating of glass is an economical and effective method for altering the properties of glasses, activating and functionalizing glass surfaces, and thus creating new products.

This is why the researchers of Fraunhofer ISC have develop-ed a range of coatings for glass surfaces. Both inorganic and hybrid sol-gel coatings are generally extremely resistant to scratches and wear when used as polymer-organic functional coatings. It is also possible to combine different functions in a single coating. All coatings can be tinted, and are applied using standard industrial procedures such as roller-coating, dipping and spraying.

For optical and technical glass fibers, Fraunhofer ISC has developed coatings that make these fibers more stable and durable or endow them with special functions. Fraunhofer ISC also has a range of material systems, developed in collaboration with partner organisations, and plants for pilot production of up to 100 kg batch use. These systems can be licensed or further developed with individual partners.

Inorganic systems

- Anti-reflection coatings for PV applications
- Anti-reflection coatings for architectural glasses
- Anti-reflection coatings with increased transmission for blue-spectrum light (480-500 nm), »feel-good glass«
- Dust-repellent spray-on coatings without high-temperature hardening, e.g. for PV applications
- Anti-soiling coatings
- High temperature resistance coatings (depending on the melting point of the substrate)
- Photo-catalytic coatings

Hybrid systems (ORMOCER®s)[1]

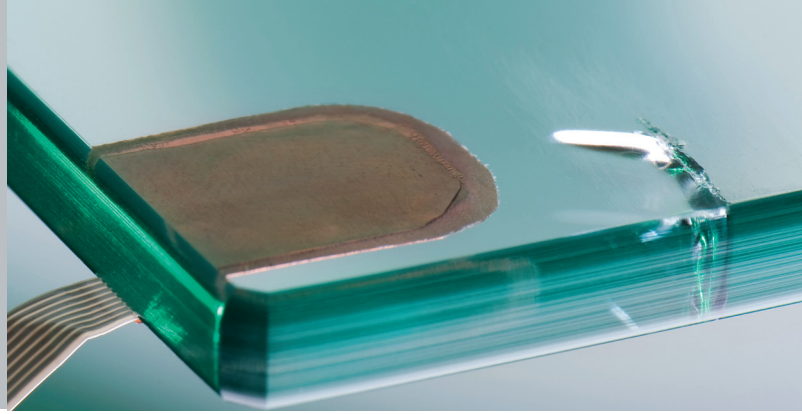
- Colored ORMOCER® coatings
- Drip-stop coatings
- Abrasion and dishwasher-resistant coatings
- Hydrophile coatings / hydrophobe coatings
- Photo-catalytic coatings

Functional layers for TCO coatings on glass

- Anti-reflection (optical adjustment required)
- Electrochrome coatings and systems
- Hydrophile (optical adjustment required)

1 Trademark of Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. in Germany

GLASS MONITORING AND PROTECTION



GLASS MONITORING: SAFETY WITH ON-LINE SENSORS

The Center Smart Materials CeSMa at Fraunhofer ISC specializes in adaptive materials. A prototype ultrasonic sensor was developed at CeSMa for a continuous on-line monitoring of architectural glass. This sensor does not primarily provide protection against burglars, but will detect the formation of tiny cracks or spalling in large sheets of glass in their initial state.

The sensors, which are only about 0.5 mm thick and of 2 cm^2 in size, can be embedded between laminated panes of glass, and use ultrasound to detect cracks as tiny as 5 mm in length in the surface of the panes. Only four sensors per square meter are needed, mounted at the edge of the pane.

The sensors are designed for safety glass or areas of glass that are difficult to access, in which the glass is exposed to extreme weathering environmental conditions. They can also be adapted for use in safety-related glass sheets in a production environment, e.g. in the food industry.

PROTECTING AND CONSERVING HISTORIC GLASS – MATERIALS, METHODS, DISSEMINATION

Historic glass requires special methods of conservation in order to reduce the continuous process of glass corrosion. With laboratories located in the Bronnbach Abbey, Fraunhofer ISC has spent many years researching the mechanisms of corrosion and the methods of protection, so as to preserve this irreplaceable and precious work of art for future generations. The ORMOCER® system was specially developed to protect glass against corrosion, permitting reversible conservation and restoration of damaged glass and enamels.

The work is supported by the latest methods from the field of analysis, so that sensitive artefacts can be examined without touching them. The important work of the R&D specialist is supported by the International International Convention Center of Cultural Heritage Preservation IZKK, also based in Bronnbach, which organizes day-seminars and congresses on all aspects of cultural heritage preservation.

This creates a lively center, which brings together technical specialists from all over the world on the topics of restoration and conservation. It also acts as a partner in the conception and organization of technical discussions between researchers, developers and users from different disciplines.

YOUR POINTS OF CONTACT

To help you address the person you need, here is a list of your points of contacts. We look forward to hearing from you.

Development of special glass and glass-ceramics, process technologies, glass in the building industry, REACH

Dr. Martin Kilo
martin.kilo@isc.fraunhofer.de
Phone +49 931 4100-234

Dr. Bernhard Durschang
bernhard.durschang@isc.fraunhofer.de
Phone +49 931 4100-304

Dr. Johanna Kron
johanna.kron@isc.fraunhofer.de
Phone +49 931 4100-233

Glass analysis, RAL/EUCEB testing of mineral fibers
Dr. Jürgen Meinhardt
juergen.meinhardt@isc.fraunhofer.de
Phone +49 931 4100-202

Center of Device Deveopment CeDeD and Test Laboratory and Application Center, Bronnbach
Dr. Andreas Diegeler
andreas.diegeler@isc.fraunhofer.de
Phone +49 9342 9221-702

Sensor monitoring of architectural glass
Dr. Bernhard Brunner
bernhard.brunner@isc.fraunhofer.de
Phone +49 931 4100-416

Glass coatings
Inorganic systems:
Walther Glaubitt
walther.glaubitt@isc.fraunhofer.de
Phone +49 931 4100-406

Hybrid systems/ORMOCER®s:
Dr. Klaus Rose
klaus.rose@isc.fraunhofer.de
Phone +49 931 4100-626

International Convention Center of Cultural Heritage Preservation IZKK
Sabrina Rota
sabrina.rota@isc.fraunhofer.de
Phone +49 9342 9221-710

Gabriele Maas-Diegeler
gabriele.maas-diegeler@isc.fraunhofer.de
Phone +49 9342 9221-704