

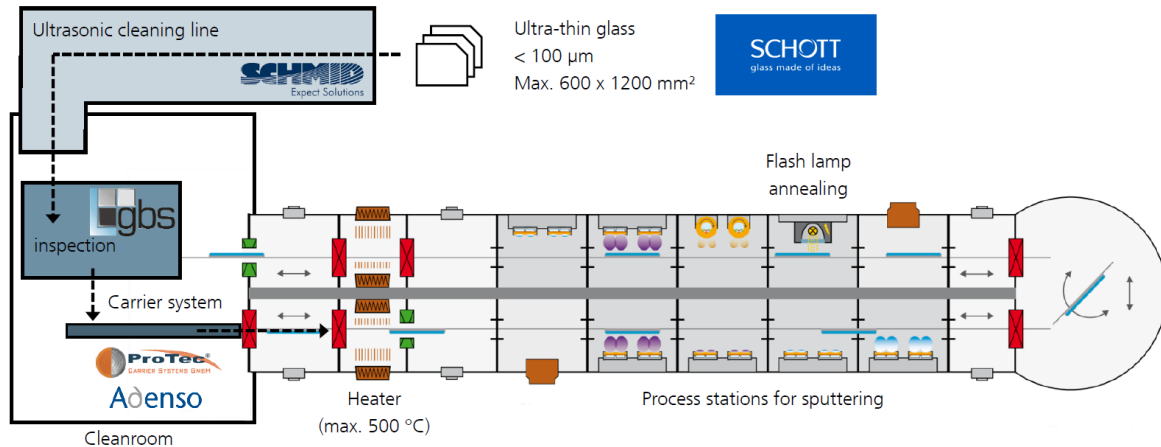


On November 13 and 14, 2023, the 34th meeting of the IAK "Research & Technology" took place as an online event. A total of 50 participants learned about current research projects in the field of flat glass and exchanged views on innovation management.

1. Wiebke Langgemach (Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP); Dr. Christoph Hermanns (MDI GmbH)
CUSTOM - Investigation of the material behavior of ultra-thin flexible glass in a layered composite

The Fraunhofer FEP (Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology) is mainly concerned with thin-film technologies and electron beam technologies and often operates at Technology Readiness Level 3 to 7, i.e. between academic research and industrial production. In the CUSTOM project, together with the Fraunhofer Institute for Microstructure of Materials and Systems (IMWS), insights were gained into the edge strength and fatigue behavior of thin glass as well as the influence of selected coating and separation processes on these properties. The aim was to increase process reliability in the processing of thin glass, i.e. in particular to shorten the area of "infant mortality", i.e. early failure, on the bathtub curve.

Flexible glass with a thickness of less than 100 µm was examined. Some of the results were obtained on uncoated glass and some of the tests were carried out on coated glass. To investigate the fatigue behavior, the samples cut with a diamond tip were clamped horizontally. The cut sides, which were also the coated sides, were aligned downwards. If the results obtained under cyclic loading are compared with those of a normal fracture test, a clear shift to the left can be seen in the Weibull distribution for the cyclically tested samples. This means that the strength is significantly lower under cyclic loading. Furthermore, it was found that the effect is more pronounced with uncoated glass than with coated glass. At lower failure values, the origin of the fracture is found particularly frequently in the edge area; at higher failure strengths, the origin of the fracture is predominantly in the middle area of the sample. It was also found that annealing the ITO coating significantly reduces the strength. As a result, handling after tempering is more demanding than before tempering.



Picture 1: Process line for reliable processing of ultra-thin glasses at Fraunhofer FEP (Source: Lecture by Ms. Langgemach)

2. Dr. Heinrich Ostendarp (Hegla GmbH & Co. KG): *Laser technology for faster and better cutting of laminated safety glass*

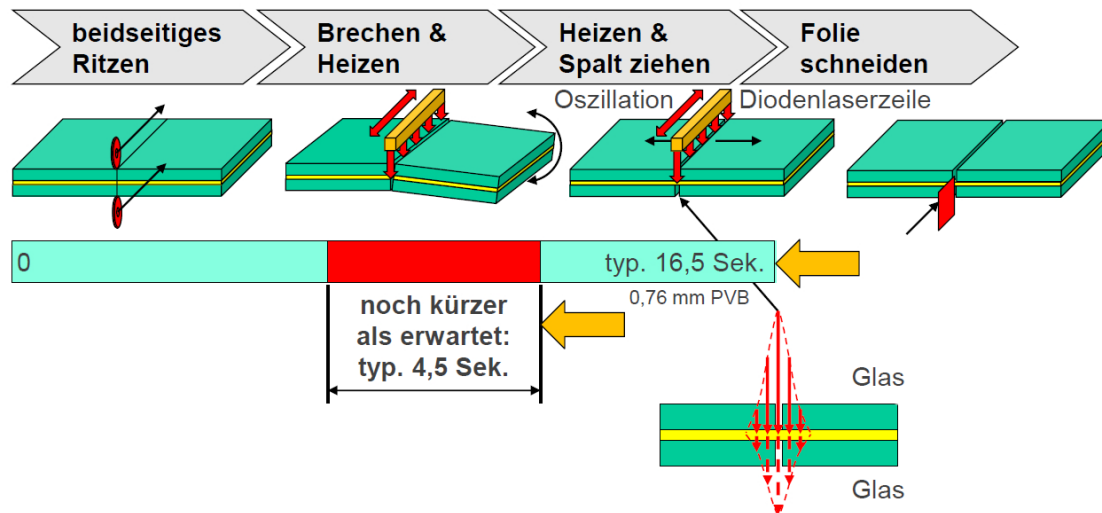
An example of the potential of laser technology in the processing of glass was given in the second presentation of the event. The task of the research project was to cut laminated safety glass faster and better. Within two years, the technology of cutting using a laser diode array was developed and brought to market maturity. 50% of the systems sold now have this technology.

Conventional cutting of laminated safety glass (LSG) using infrared heaters to heat and separate the sheets takes around 29 seconds. Around 50% of the time is needed for heating alone. This technology also heats a large area that extends well beyond the separation area and thus also causes delamination in the future edge area. The technology to be developed should therefore be faster and more precise in terms of location and time. In particular, linear heating is necessary.

The energy sources under consideration, such as other IR techniques, microwave heating or laser technology, did not initially lead to success. One of the challenges was that a line up to 6 m long had to be heated evenly. The technology developed here generates a 2.5 mm wide heating line that uses an oscillating movement of a diode array to evenly heat exactly where it is needed, namely in the film, while the surrounding glass area is only heated to a minimum. This enables a sharp separation of the film, and the edges show significantly better weathering behavior.

The diode array is available in three different lengths, and laser class 1 makes it possible to work without special precautions. The interior is monitored by a camera. The shorter heating time significantly reduces the electricity costs for heating. For the overall process, including glass transport, this results in a productivity increase of approx. 16%.

Diodenlaserzeile für VSG- Zuschnitt, Hegla- Patent



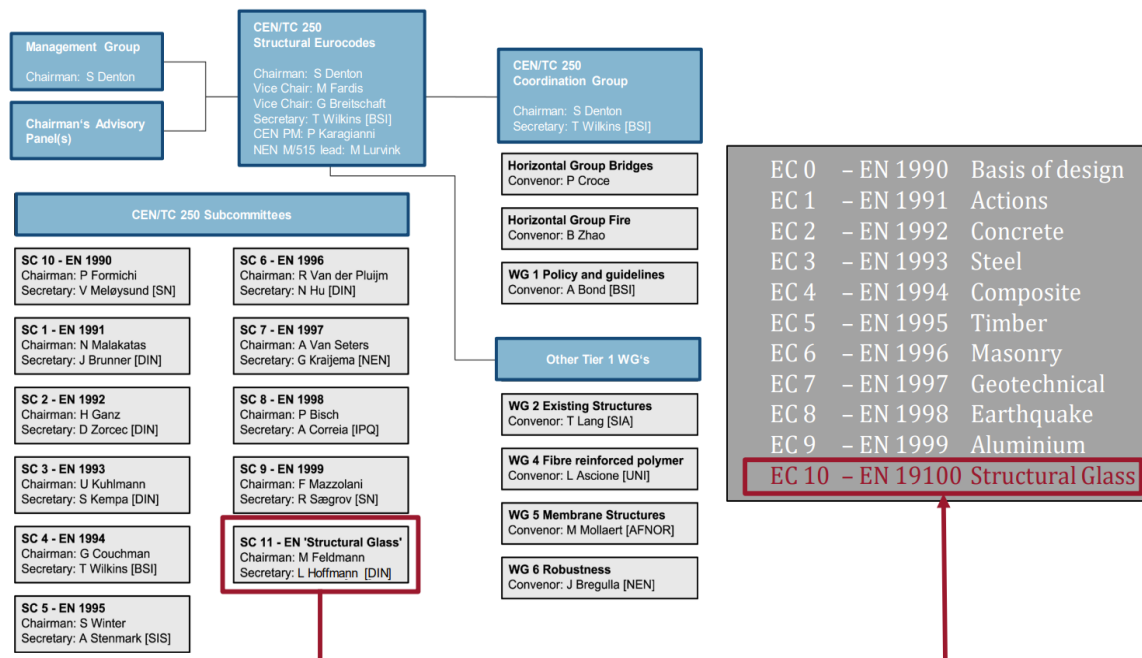
Picture 2: New procedure for cutting laminated safety glass (Source: Lecture by Dr. Ostendarp)

3. Maximilian Laurs (RWTH Aachen): *Cold bent glass - in the light of European standardization*

In this presentation, glazing was considered from the point of view of standardization. They are a small specialty in the field of structural engineering calculations. Structural glass construction must reflect representativeness, but also demonstrate strength and robustness (for example, guaranteeing the stability of the overall structure in the event of a pane failing). At the same time, the requirements in the construction industry are also increasing in terms of sustainability. The process of cold bending glass can contribute to this, as neither the initial glazing nor any replacement requires a high energy input to produce the shape or supporting structure. The resulting structures are somewhat more complex to calculate.

Large construction projects are usually international projects. A uniform understanding of the requirements and calculation rules reduces complexity and sources of error. The existing Euro Code series in the construction industry is now being gradually expanded to include the building material glass as EURO Code 10. From 2028, the national standards governing the use of glass in construction will be withdrawn and replaced by the Euro Code with the respective national annex. The distinction to product standards is made by the risk assessment of the component. As soon as the component assumes a structural function, the Euro-code must be applied. However, some of the requirements will remain national law, for example requirements for the type of glazing with regard to fall protection for people. Part 1 of the standard makes statements on basic design and the applicable materials such as monoglasses, laminated glasses and insulating glasses (KNS glasses as float glass, polished wired glass, drawn flat glass, ornamental glass, wired ornamental glass, toughened safety glass, ESG-H, partially toughened glass, chemically toughened glass; aluminum silicate glasses are then also permitted). Part 2 deals with components subject to transverse loads,

i.e. the impact of a stone on a pane, for example. This part is primarily concerned with laminated glass; cold-bent glass is also dealt with in this part. The part contains various model types for calculation, and load and support situations are also taken into account. Part 3 deals with axially loaded components and calculation methods for connections. The normal, unbroken state, the fracture state and the post-fracture state are all considered.

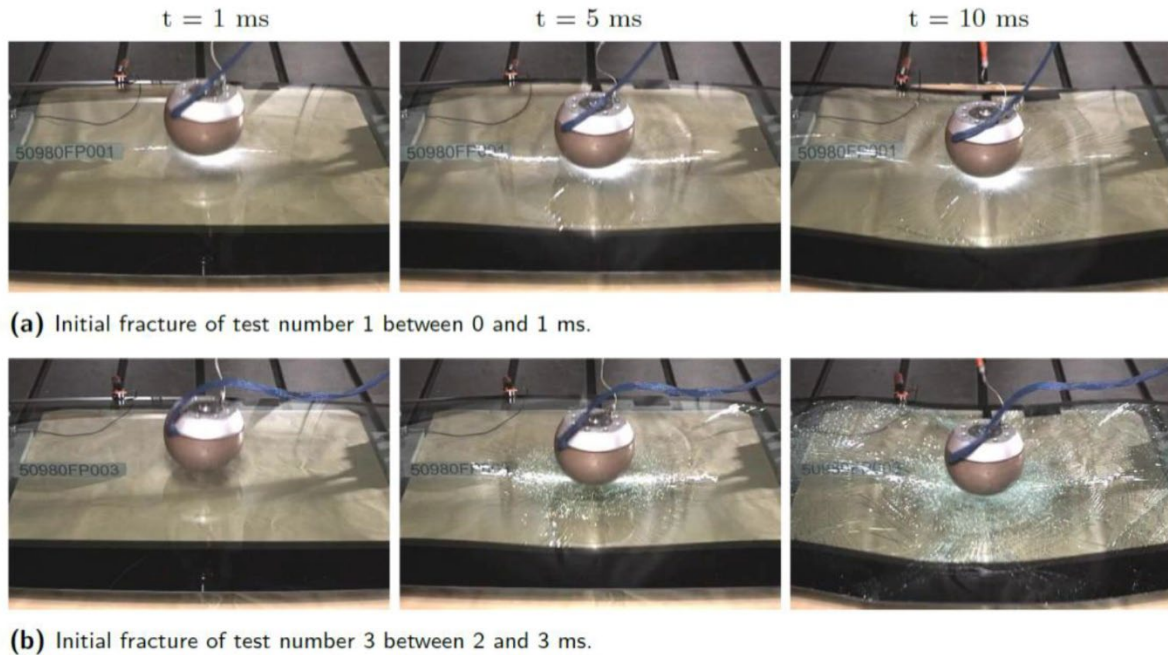


Picture 3: Structure of the EUROCODE standardization area [Source: Prof. Moritz Feldmann, EUROCODE Conference 2023]

4. Dr. Christian Alter (Technical University of Central Hesse): *Breakage behavior of glass in head impact protection*

The behavior of glass when considering head impact protection for the automotive industry was the subject of the presentation by Dr. Christian Alter from the TH Mittelhessen. The still high number of fatal accidents involving pedestrians is a key driver for the investigations. At the same time, proof that the load case of head impact has been considered will be required in future for the approval of a vehicle in Europe.

As part of the research project, a special impactor is fired at the windshield of the car for the load case of head impact, the acceleration is measured and evaluated as an injury criterion (HIC - head injury criterion). The acceleration curve depends on the fracture behavior of the glass. This was analyzed in relation to the elastic range, the formation of radial cracks and ring cracks and the movement pattern of the fracture area. However, the strength of glass is subject to significant statistical scatter. This is based, among other things, on various causes of breakage. These were also analyzed. On the basis of all these investigations, prediction models for the load case of head impact are developed, taking into account the stochastic failure of glass, in order to shorten the development time of a vehicle.



Picture 4: images on brand-new windshields with 4.5 kg Euro NCAP adult head impactor: different times before fracture starts with different fracture patterns [Source: A Methodology for Stochastic Simulation of Head Impact on Windshields, Appl. Mech. 2023, 4(1), 179-190; <https://doi.org/10.3390/applmech4010010>]

The original condition of the windshield and its changes are also represented in an FEM model. The windshield is represented by a coincident shell-solid-shell model. The shells represent the glass, the solid element represents the PVB film. Shear stresses can then be transferred by connecting the shell elements to the upper and lower geometric nodes of the solid element. The crack propagation is then simulated in the model by reducing the strength node by node. Based on the Weibull distribution and the fracture stresses of the slice surfaces, the initial crack sizes were determined by back calculation and subsequently mapped to the finite element mesh. This was then subjected to the load in the simulation. It was checked whether and when the fracture toughness was exceeded and thus a failure of the structure occurred. The work on post-fracture behavior and residual stiffness is still being continued.

5. Dr. Matthias Seel (GCC/TU Darmstadt): *The Glass Competence Center of the University of Darmstadt - Partner for research in the field of glass applications*

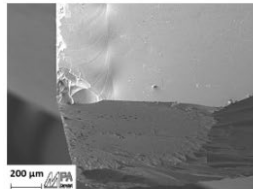
Dr. Seel presented the Glass Competence Centre in Darmstadt. Here, knowledge from the fields of civil engineering and materials science is combined in relation to glass. Flat glass processing can be carried out in many areas and used for training purposes. Research, simulation and practical work go hand in hand. One aim of the center is to distribute and collect knowledge on all aspects of glass processing. Glass sheets up to a size of 3.30 m by 2.50 m can be processed here. In addition to cutting and laminating systems, there is also a bonding laboratory and an optical laboratory, 3D printing is just as possible as outdoor weathering. The testing technology is mainly operated and provided by the MPA. In addition to classic strength tests, adhesives are also tested in various temperature ranges, edge strengths are

examined and detailed images up to the resolution of the transmission electron microscope are available.



Glasbearbeitungsmaschinen

Acht verschiedene Glasbearbeitungsmaschinen einer konventionellen Flachglasbearbeitung sowie innovative Maschinenteknologie zur Glasbe- & verarbeitung stehen im GCC zur Verfügung.



Laborräume und Prüfmaschinen

Im GCC befinden sich drei speziell ausgestattete Laborräume. Jeder dieser Laborräume ist spezifiziert auf einen Themenbereich.



Fassadenprüfstand und Freibewitterungsfläche

An der Südfassade des GCC befindet sich ein spezieller Fassadenprüfstand. Darüber hinaus verfügt das GCC über eine Freibewitterungsfläche, um die Alterungsprozesse bei Glas und Glasprodukten zu untersuchen.

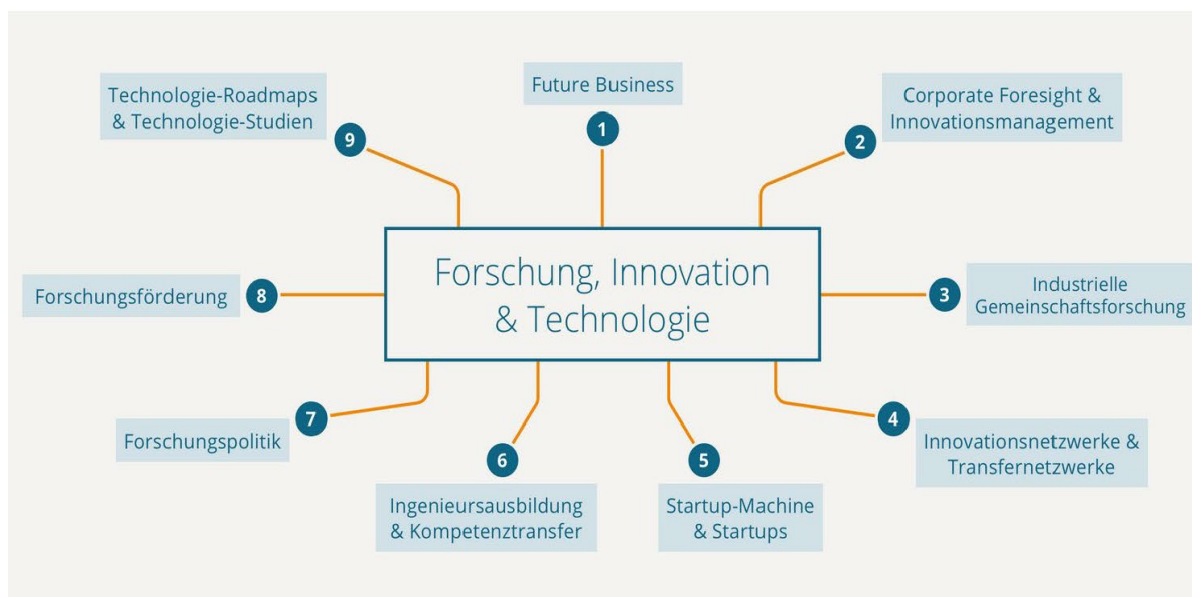
Picture 5: Equipment and possibilities at the Glass Competence Center Darmstadt

Current research projects are concerned, for example, with thermally induced stresses (solar radiation and shading), edge strengths and the possibilities of keeping these as high as possible via the machine control system or with calculation methods for the fracture and residual load-bearing capacity of glass laminates. The size of the degree of prestressing and its effect on crack propagation is also currently being investigated. Other important topics include the evaluation of anisotropies, the optical detection of nickel sulphide inclusions with the potential for a critical increase in volume, 3D printing of glass on glass (e.g. for glass-glass connecting elements) and the mechanical optimization of vacuum insulation glass. The topic of sustainability is also being addressed at the GCC; for example, various post-treatments of glass surfaces have been investigated in order to be able to reuse the glass in the most qualified way possible. The Glass Competence Center Darmstadt and the Materials Testing Institute also produce expert reports and are actively involved in the creation of standards.

6. Dr. Beate Stahl (VDMA e.V.): Tax incentives for research

Financial support for research projects and innovations can be obtained through joint industrial research, collaborative research and, since 2020, tax incentives for research. Tax-incentivized research funding in particular is a comparatively simple instrument; the funding is open to all topics and has a high success rate (80%). Personnel costs for basic research, industrial research and experimental development are funded. Traditional contract research with a contractor from the EU/EEA can also be funded, but in this case 60% of the total amount is used as the assessment basis.

To apply, the first step is to prove that the project is actually an R&D project. This is proven by a certificate from the BMBF and cannot be challenged by the tax office (www.bescheinigung-forschungszulage.de). The application for assessment of the research allowance is then submitted to the tax office. This can only be done once per year, i.e. in the case of several research projects, the costs from different projects must be combined in one application. The funding rate is 25% in each case, up to a maximum of EUR 1 million per (affiliated) company and year. This funding can be applied retrospectively, so it is generally applicable to projects that have been rejected for other funding, e.g. ZIM. Payment is made as a tax refund.



Picture 5: VDMA offers in the field of research and innovation

The VDMA advises companies in a monthly Q&A session. The next dates are February 28 and March 18. You can find more information here: <https://www.vdma.org/forschungsforderung>.

We would like to thank all the speakers and guests once again for their presentations and discussions.

The **next meeting** of the IAK Research and Technology will take place as a **live event in Frankfurt** in spring 2024.

Gesine Bergmann
Frankfurt, 07.12.2023