Environmental monitoring of cultural heritage: Glass sensor measurements on stained glass windows – recent evaluations

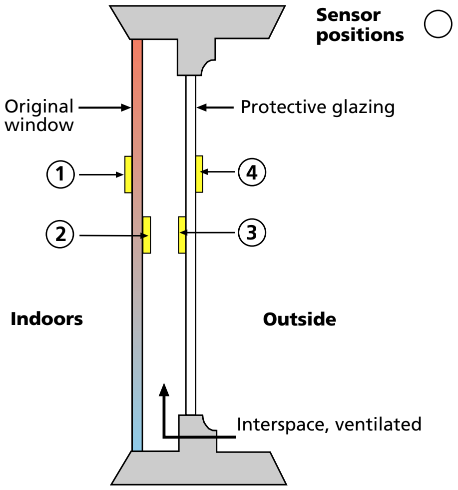


Figure 1
Schematical representation of the protective glazing system: Positions 1 - 4 represent the different micro-climatical areas (indoor climate, original window, interspace, protective glazing, outdoor weathering), indicating the crucial points for glass sensor environmental monitoring

Kurzdarstellung

Umweltwirkungsmessungen mit Hilfe der einfach zu handhabenden Glassensormethode erlauben eine Abschätzung des Risikopotentials für ein Objekt oder einen Standort in Bezug auf atmosphärische Einflüsse, sowohl im Innenraum als auch im Außenbereich. Integrativ erfasst werden alle Einflüsse über den gesamten Messzeitraum (3 bis 12 Monate), wobei auch Synergieeffekte eine Rolle spielen. Als aussagekräftig erweist sich der nach der analytischen Infrarot-spektroskopischen Auswertung vorliegende Extinktionswert (ΔE-Wert) des korrosionsempfindlichen Glassubstrats, der eine eindeutige Beurteilung der vorliegenden Gefährdung erlaubt.

Die Methode wird u. a. im Kulturgüterschutz seit über 15 Jahren erfolgreich angewendet. Ein aktuelles Praxisbeispiel bietet das EU-geförderte Projekt VIDRIO, in dem das Mikroklima schutzverglaster hochrangiger mittelalterlicher Kirchenglasfenster untersucht wurde: Nach Einsatz einer zusätzlichen Schutzverglasung an der Außenseite der Glasfront verbesserten sich die klimatischen Verhältnisse an der originalen Glasmalerei sprunghaft. Das Original ist durch dieses Schutzsystem nicht mehr der freien Bewitterung ausgesetzt und wird langfristig ohne direkte Eingriffe in die originale Substanz vorbeugend konserviert.

Initial situation

Artwork of cultural value is suffering from severe stress by environmental impacts. Outdoors, acidic rain caused by atmospherical pollutants like SO_2, NO_x, or chlorides, and harmful synergetic effects of ozone, condensation of humidity, temperature changes, and the attack of micro-organisms are endangering sensitive objects of art by physical and chemical attack.

In the case of precious stained glass church windows, climatic impact may cause glass leaching, encrustations, or corrosion and deterioration of the glass material as well as the decorative top glass paint, leading to a decrease in transparency up to the complete loss of original panel ornamentations.

As a preventive conservation measure, an increasing number of historical sites is safeguarded today by so-called protective glazings, i. e. modern glass windows installed as protective shields in front of the original panels to prevent outdoor weathering (Figure 1). The system is sealed against atmospheric impacts from outdoors, but the interspace between original and protective glazing is ventilated from inside so that distinct micro-climatical situations can develop which are typical for the orientation and location of the respective windows. Still, an evaluation of the established climate against critical atmospherical thresholds is indicated.

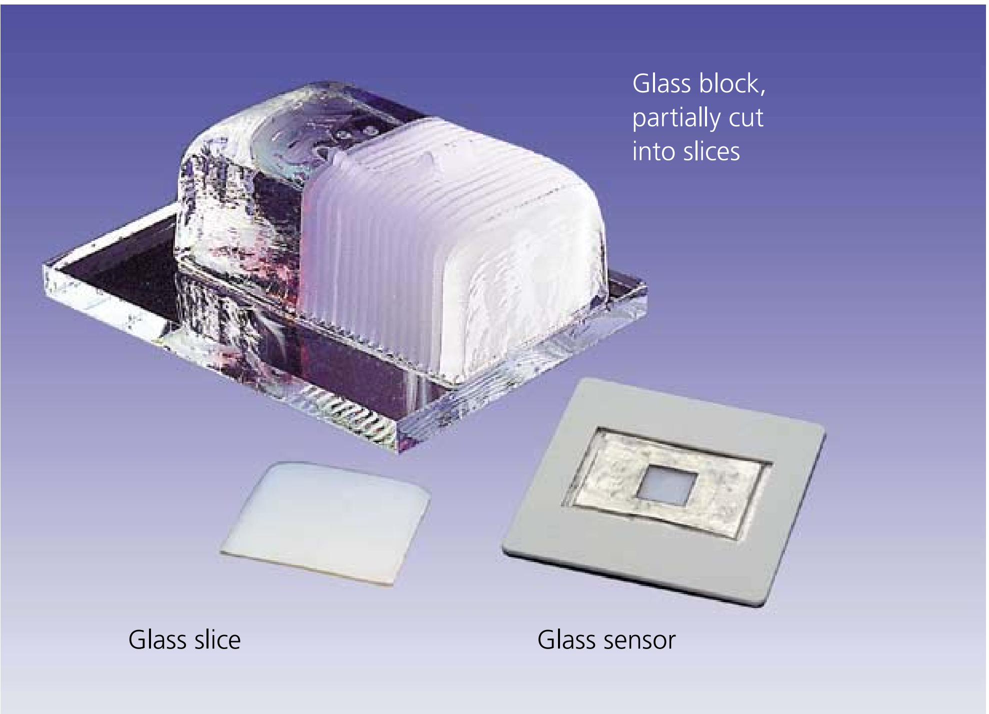
The method

The assessment of climatic conditions by easy-to-handle and low-cost techniques can be achieved by using standardized, highly sensitive test glasses as dosimeter materials. Due to its composition, the glass material is very susceptible to leaching and corrosion reactions caused by atmospheric impacts like humidity, rain, temperature changes, and acid attacks by pollutant gases like SO_2 and NO_x. As a result of the deterioration process, water concentrates in the bulk glass matrix together with protons (as hydronium ions). The water content present in the leached gel layer on the glass surface proportionally represents the corrosion degree and can be determined by instrumental analytics.

This sensor method can be applied for any kind of artwork material, monitoring the integral atmospherical impact around the object and thus allowing a final risk evaluation. This method, developed at the Fraunhofer ISC for environmental stress monitoring on artwork, has been widely used in many European countries over the last 15 years, especially for monitoring climate effects on stained glass windows (Figure 2). It can also be applied indoors, e.g. in museum display rooms, show cases and magazines.

A successful world-wide campaign for an industrial client has established the method as an early warning system for potential environmental risks caused by exhaust gases of production plants (see Fraunhofer ISC Annual Report 2003). The method is certified in Germany as German Technical Guideline VDI 3955/2.

Figure 2
Stained glass church window with fixed glass sensor (Gloucester, GB)



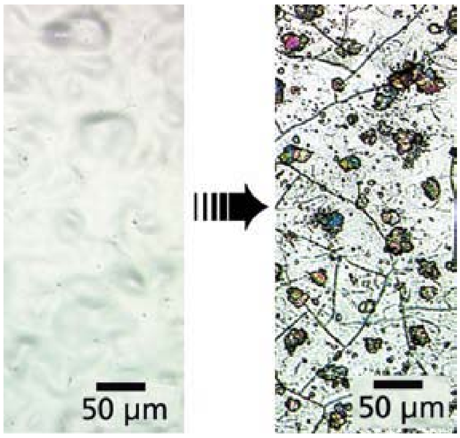


Figure 3b
Environmental effect on a freshly prepared glass sensor after exposure: microcracks and crystals have formed on the surface

Figure 3a
Preparation of glass sensors

Used as "stress dosimeters", the sensors allow the evaluation of long term risks in short term experiments, integrating all environmental influences as well as synergetic interactions (Figure 3). Exposure times of 3 -12 months are recommended. A distinct value, representing the environmental risk potential (ΔE-value; E: extinction), can finally be stated after instrumental FTIR-analysis (FTIR: Fourier Transform InfraRed Spectroscopy). A special analytical tool (ATR-IR spectroscopy; ATR: Attenuated Total Reflectance), applied on the sensor surface, allows the determination of damage origin via the determination of surface corrosion products.

Recent evaluations: The project VIDRIO

Together with partners from different countries like France, Italy, and Germany, the project VIDRIO (2002-2005), funded by the European Commission, was performed, evaluating the climatic conditions and the deposition behavior around stained glass church windows equipped with protective glazings. The glass sensor method was applied in addition to monitoring the relative humidity, the temperature effects, and the dew point variations in the interspace and on the originals. As pilot objects, monumental medieval churches in France (Basilica St. Urbain, Troyes, and St. Chapelle, Paris) and the Cologne Cathedral had been chosen.

Pollutant gases and the content of relative humidity in combination with condensation effects proved to be the main cause for glass degeneration, as was verified in detail by the glass sensor results.

Figure 4 shows the effect of protective glazings on the environmental risk potential, monitored by glass sensors, here shown for a distinct church window of the Basilica in Troyes (exposure time: 12 months). The environmental stress on the original surface (position 2) is significantly diminished compared to the outside conditions (position 4). Without additional outer glazing, the full atmospherical precipitation impact would continuously affect the susceptible original stained glass surface.

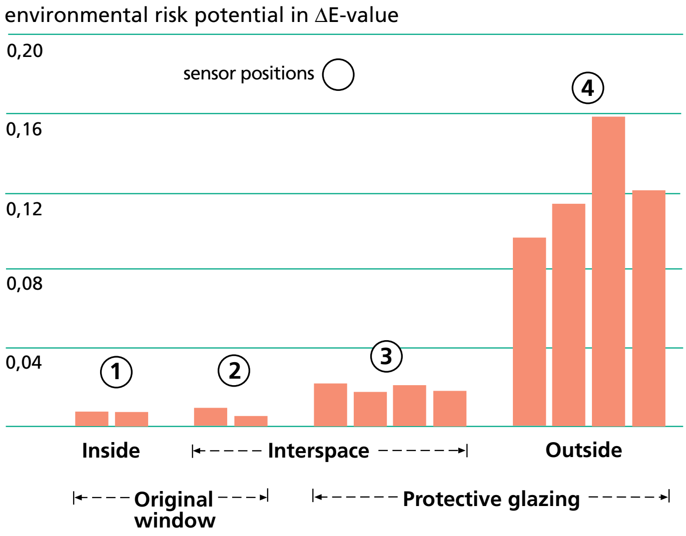


Figure 4
St. Urbain, Troyes, F, window '104'. ΔE-values, representing the improvement of climate conditions for the original window established by the presence of protective glazings (2 - 4 measurements on different height levels for each position)

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