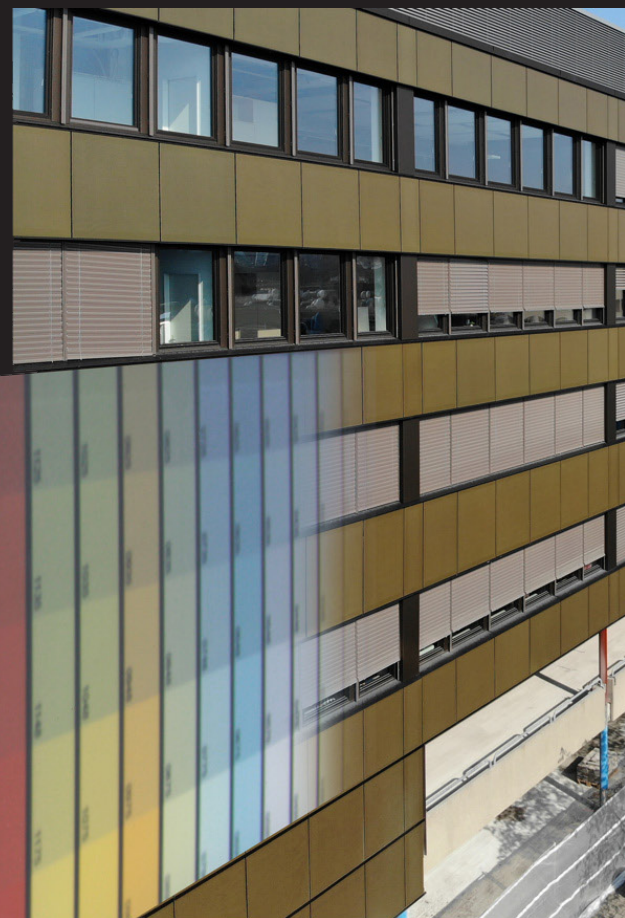

SOLARCOLOR

Guidelines for visual assessment of
BIPV modules

solarcolor.ch



SOLARCOLOR - Making character tangible

Glass surface, color, intensity: With the SOLARCOLOR color system, all optical requirements for solar modules can be determined and clearly recorded. SOLARCOLOR enables standardized devising and transparent cooperation between architect, builder, installer and manufacturer. The design expression of the solar module can be conveyed and verified on site thanks to sample boards. SOLARCOLOR closes a gap between conventional color systems and exclusively technical descriptions of solar modules.

Product description BIPV modules

Basically, BIPV modules consist of the following elements: Front glass, back glass, laminated films, solar cells, cell connectors, cross connectors, junction boxes with cables & connectors and other production-related elements. These elements are processed into a BIPV module by means of a lamination process and further manufacturing steps.

Guidelines

The guidelines for visual assessment of BIPV modules determine the visual tolerances of BIPV modules resulting from their components. The basis for this is the current EN standards. The existing standards for glass in building are often insufficient in practice and cannot be applied 1:1 to BIPV modules in some cases. The manual therefore supplements or adapts the applications that are not described without doubt or not at all in the standards.

The "Guidelines for visual assessment of BIPV modules" serves as delivery and sales guidelines for manufacturers of solar building materials who produce according to SOLARCOLOR.

Usage Tip:

The document is organized according to processing steps or products, which are described within a chapter. The final product BIPV module consists of its components and is thus assessed in a commutated manner.

Standard tolerances:

Standard tolerances are those tolerances which can be ensured in the normal production process without additional measures.

Special tolerances:

Special tolerances can be realized with additional measures in the production process. These must be determined and agreed in each individual case and are only valid if they have been confirmed accordingly by the contractor. For example, limit samples can be created to precisely define the color tolerance of BIPV modules.

Tolerances glass - base and cutting

Based on DIN EN 572, DIN EN 1249

Tolerances to nominal dimension of raw glass thickness

Mountain Lake A		Frost B, Fjord C & Crystal D		Other textured glasses	
Nominal thickness	Tolerance	Nominal thickness	Tolerance	Nominal thickness	Tolerance
2 - 6mm	± 0.5mm	2 - 6mm	±0.5mm	2 - 6mm	±0.8mm
8 - 10 mm	± 1mm	8 - 10mm	±1.0mm	7 - 10mm	±1.5 mm
12 - 15 mm	± 1.5mm	>10mm	ind. Agreement	>10mm	ind. Agreement
>15mm	ind. Agreement				

Outer dimensional tolerances of all glasses after cutting

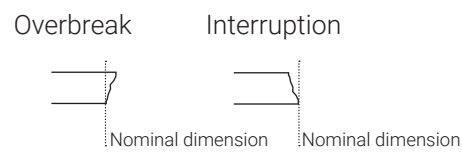
General length tolerance 1mm / linear meter edge length.

Edges overbreak and underbreak

The so-called skew fracture must be taken into account. Thus, the glass dimension can change by twice the skew break value.

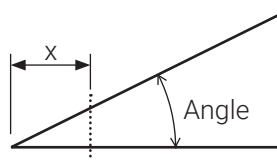
Oblique break values

Glass thickness	Maximum value
2mm - 8mm	±2mm
10mm - 12mm	±3mm
> 12mm	ind. Agreement



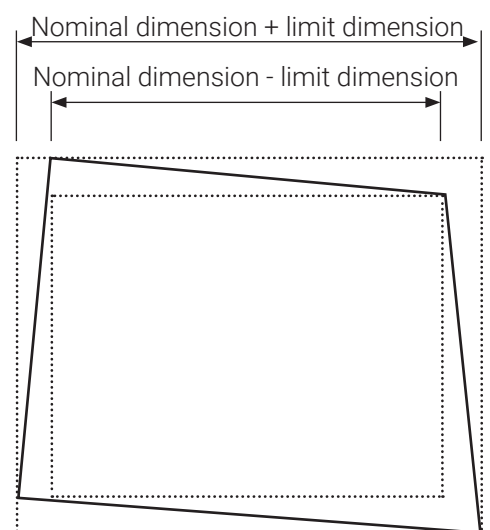
Possible demolition peak angle

Angle	Dimension "x"
< 12.5°	- 30mm
< 20°	- 18mm
< 35°	- 12mm
< 45°	- 8mm



Squareness

The slice must be in the frame of the rectangle with upper limit dimensions superimposed on the rectangle with lower limit dimensions, where the rectangles are parallel and have the same center. The limit dimension is ± 5mm by default.



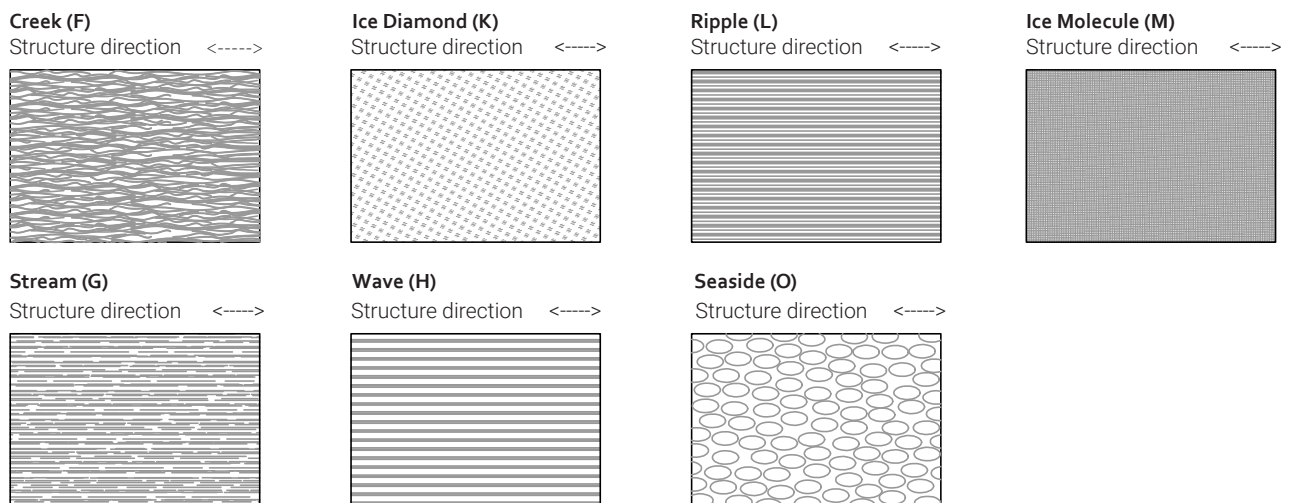
Glass tolerances - base and cutting

| V25.02 |

In accordance with DIN EN 572, DIN EN 1249

Structure

Mountain Lake A, Frost B, Fjord C, Crystal D and Glacier E do not have a clearly recognizable structural direction. For glass with a structural direction, the structural direction must be determined before cutting. Glasses are always cut parallel to a raw glass edge. For Creek F, Stream G, Wave H, Ice-Diamond K, Ripple L, Ice Molecule M and Seaside O, the structural directions are determined. If a glass not listed here is processed with a textured direction, this textured direction must be determined in advance. Otherwise, the textured direction is parallel to the height as standard. Various structured glass types can have an optical repetition or the structure direction is not exactly parallel to the raw glass edge. This does not constitute grounds for complaint.

**Visual defects raw glass**

For the assessment, the cut raw glass is placed 3m in front of a matt gray surface and viewed perpendicular to the glass surface at a distance of 1.5m. Visible optical defects are included in the assessment. Defects must not be marked beforehand.

Mountain Lake A, Frost B, Fjord C and Crystal D

Core defects (inclusions)	Visible inclusions not permitted
Spherical bubbles	Diameter < 2mm permissible, diameter > 2mm not permissible
Elongated bubbles	Width > 0.8mm not permitted, length > 10mm not permitted
Hair scraper	Permissible up to a total length of 150mm per m ²

Other textured glasses

Core defects (inclusions)	Visible inclusions not permitted
Spherical bubbles	Diameter < 5mm permissible, diameter > 5mm not permissible
Elongated bubbles	Width > 2mm not permitted, length > 25mm not permitted
Hair scraper	Permissible up to a total length of 150mm per m ²

Notes on frosted glasses

A frosted glass surface is more delicate than conventional glass. The glass can scratch more easily and cloudy "streaks" or smudges can appear. Such effects are a product characteristic of frosted glass surfaces and cannot be technically avoided, which is why they do not constitute grounds for complaint and are excluded from the above-mentioned tolerances.

Notes on the light scattering behavior of glass surfaces and coatings

Due to manufacturing processes, rolled and cast glass, as well as satin-finished glass and coated glass, may exhibit slight variations in surface geometry or coating formation within a single production batch. These subtle differences in microstructure or nanostructure affect light scattering behavior depending on the angle of incidence and the viewer's position, and are considered acceptable.

Glass tolerances - Processing

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Based on DIN EN 1249, EN12150, EN1863

Edge processing

Edgebanded edge: broken edge, moulding permissible, cut surface visible

Edge ground / routed to size (standard): Bare spots and scalloping are permissible

finely roughened / ground: matt without scallops, cut surface not visible

polished: shiny without scallops, cut surface not visible

The design in a higher quality edge finish is left to the manufacturer.

External dimensional tolerances after standard edge processing

<u>Nominal thickness</u>	<u>Length / Width</u>	<u>Tolerance for rectangular shapes</u>	<u>Tolerance for special shapes</u>
2 - 12mm	< 1m	± 2mm	± 3mm
	< 2m	± 2.5mm	± 4mm
	< 3m	± 3mm	± 5mm
	< 4m	± 3.5mm	± 6mm
	> 4m	ind. Agreement	ind. Agreement
> 12mm	< 1m	± 2.5mm	± 4mm
	< 2m	± 3mm	± 5mm
	< 3m	± 3.5mm	± 6mm
	< 4m	± 4.5mm	± 7mm
	> 4m	ind. Agreement	ind. Agreement

Tolerances for corner, edge and interior cut-outs

±5mm on position and dimensions

Drilled holes

<u>Diameter</u>	<u>Tolerance</u>
< 20mm	± 2mm
> 20mm	ind. Agreement

Position of the drill holes

Distance to fixed point 90° bottom left corner. The fixed point can vary for special shapes and may need to be defined.

<u>Distance to fixed point</u>	<u>Tolerance</u>
< 3m	± 3mm
< 4m	± 5mm
> 4m	ind. Agreement

Glass tolerances - hardening process

| V25.02 |

Based on DIN EN 12150, EN 1863

Permissible warping for rectangular shapes

	<u>General fault</u>	<u>Local fault</u>
Mountain Lake A, Frost B, Fjord C, Crystal D	3mm/m	0.5mm/300mm
Other structure glasses	4mm/m	0.5mm/300mm

Cutouts, holes, very narrow or special shapes can negatively affect the warp, therefore stronger warps are allowed.

Outer dimensional tolerances

<u>Nominal thickness</u>	<u>Length</u>	<u>Tolerance</u>
2 - 12mm<	2m	± 3mm
	< 3m	± 3.5mm
	< 4m	± 4.5mm
	> 4m	ind. Agreement
> 12mm	< 2m	± 3.5mm
	< 3m	± 4.5mm
	< 4m	± 5.5mm
	> 4m	ind. Agreement

Visual defects after the curing process

Due to the curing process, a chemical and mechanical change in the surface finish in the appearance of roll marks, haze and dot formation cannot be ruled out and is permissible.

Glass with SOLARCOLOR Classic

In this coloring process, SOLARCOLOR Classic is applied to the glass pane and then baked in the hardening process.

Glass with SOLARCOLOR Morpho

During this coloring process, SOLARCOLOR Morpho is applied to the glass pane, followed by the hardening process.

Test method for visual assessment

For evaluation, the coated (SC Classic or SC Morpho) and tempered glass is placed with the coated side directly (adjacent) in front of a matte black surface and viewed at a distance of 5m perpendicular to the glass surface. Any visible optical defects are included in the evaluation. Defects must not be marked beforehand and the tester must not be informed of any visual defects beforehand. have been informed and have not already viewed the glass up close. The max. viewing time per m² is 3 seconds.

Visual errors

Stains / scratches Ø > 5mm	Approved up to a total of 90mm ² / m ²
Stains / scratches Ø < 5mm	Unrestricted approved
Foreign body	Admitted (but is judged as a stain)
Uncoated glass edge up to 5mm	Unrestricted approval
Linear structural phenomena in the coating	Unrestricted approval

Addition: If the above-mentioned visual defects are no longer disturbing or recognizable after the manufacturing process to a BIPV module, they are still permissible (assessment according to "Test methods for the visual assessment of BIPV modules" in the following chapters).

Color tolerances

Due to technical production conditions, color deviations are possible.

Measurement method for color tolerances:

After the curing process, the coated glass⁽²⁾ is placed with the uncoated side on a black, matte surface and the color is measured using a colorimeter, which reflects the values of the L*a*b* color space. These values are compared with the color value of the sample glass⁽¹⁾. In the case of surfaces that are not fully coated (e.g. dot screens), the values are recorded several times and the values with the smallest difference are included in the evaluation.

$$L^*_{(1)} - L^*_{(2)} = dL^* \quad a^*_{(1)} - a^*_{(2)} = da^* \quad b^*_{(1)} - b^*_{(2)} = db^*$$

Then the following formula is applied for evaluation:

$$\sqrt{(dL^* \times dL^* + da^* \times da^* + db^* \times db^*)} = dE^*_{ab}$$

Permissible tolerance: $dE^*_{ab} = 5$

Position tolerances of the coating

<u>Length / Width</u>	<u>Tolerances for rectangular shapes</u>	<u>Tolerances for special shapes</u>
< 4m	± 5mm	± 10mm
> 4m	ind. Agreement	ind. Agreement

The test masses must be related to the center of the glass in each case.

Size tolerances of the coating

<u>Edge length of the printing area</u>	<u>Tolerances</u>
< 4000mm	± 5mm
> 4000mm	ind. Agreement

BIPV module tolerances

| V25.02 |

Based on DIN EN 12543

Thickness tolerances

The element thickness of BIPV modules must not exceed the sum of the thickness tolerances of the individual panes and the tolerance of the additional layers. For the individual glasses, the specified tolerance of the base glass. The additional layers (cells, foils, cross connectors, etc.) are 1.5mm with a tolerance of ± 1 mm, depending on the design.

Size tolerances

The individual panes can shift against each other during the lamination process. The permissible displacement tolerances are shown in the following table.

<u>Nominal thickness</u>	<u>Length / Width</u>	<u>Tolerance for rectangular shapes</u>	<u>Tolerance for special shapes</u>
4 - 14mm	< 4m	± 3 mm	± 5 mm
	> 4m	ind. Agreement	ind. Agreement
> 14mm	< 4m	± 4 mm	± 6 mm
	> 4m	ind. Agreement	ind. Agreement

To determine the permissible total offset tolerance, the dimensional tolerance of the individual pane must be added in each case.

Permissible warping for rectangular shapes

During the lamination process, the modules may warp slightly. The following warping is permissible and is added to the previous permissible warping of the glass used.

<u>General fault</u>	<u>Local fault</u>
5mm/m	1mm/30mm

Cutouts, holes, very narrow or special shapes can negatively affect the warp, therefore stronger warps are allowed.

Tolerances for socket position, cable and connector

The can position and thickness is subject to a tolerance of ± 5 mm. It should be noted that when the box is mounted, there is a "silicone bulge" around the box, which can be around 3mm wide. The length of the cables of the junction boxes may vary. If a measurement is available, a tolerance of ± 5 cm can be observed.

Tolerances cell layout

The cell layout (cells, busbars, cross connectors, etc.) may shift during the manufacturing process.

<u>Length / Width</u>	<u>Tolerances for rectangular shapes</u>	<u>Tolerances for special shapes</u>
< 4m	± 4 mm	± 6 mm
> 4m	ind. Agreement	ind. Agreement

The test masses must be referenced to the center of the PV module in each case.

Based on DIN EN 12543

Basis visual tolerances

The conditions defined under "Glass tolerances" apply as a basis.

Test method for visual assessment

When testing the visual quality of BIPV modules, the following specifications must be observed:

Viewing distance:	5m
Viewing angle:	Viewing angle which corresponds to general common use
Lighting conditions:	Normal, diffuse daylight
Markings:	Complaints must not be marked during viewing
Viewing time:	Viewing time, which corresponds to the generally usual viewing time, max. 3 seconds per m ² .

The evaluation according to the specifications below is carried out exclusively with the visual defects discovered and disturbing during the observation period, which are marked immediately after the observation. The inspecting person must not have been informed about any visual defects beforehand and must not have already viewed the module closely.

Visual defects after the manufacturing process to a BIPV module

Previously permissible visual defects (tolerances - glass) and the back of the module are excluded from the assessment. Cross connectors, cell connectors, covers, cross connector feed-through to the rear side and other technically necessary elements and precautions are also excluded from the assessment. Residues of the composite foils on the module edges are production-related and permissible.

Stains / scratches / bubbles $\varnothing > 5\text{mm}$	Approved up to a total of $90\text{mm}^2/\text{m}^2$
Stains / scratches / bubbles $\varnothing < 5\text{mm}$	Unrestricted approved
Foreign object	Admitted (is judged as a stain)

Cells

Solar cells are made of almost 100% silicon, a natural product, and may differ visually in color, especially when reordered, and therefore do not constitute grounds for complaint. The color of the cells influences the optical perception of modules.

Cross contacts / cell connectors / fingers

In addition to the cells, the cross-connectors, cell connectors and the so-called fingers are other essential components of a BIPV module. Depending on the batch or the combination with cell versions, these elements may be distinguishable differently and do not constitute grounds for complaint.

Color tolerance

Color tolerances cannot be excluded as a matter of principle, since these can occur due to several influences which cannot be avoided. In view of the following influences and other reasons, a perceptible color difference between modules may be apparent under certain light, weather and viewing conditions, which can be subjectively classified by the viewer as "disturbing" or also "not disturbing".

The following points must be taken into account and do not constitute grounds for complaint:

- > Color differences in the glass due to different batches, especially with subsequent deliveries
- > Color differences in the glass due to different glass thicknesses
- > Differences in the color of the glass according to "Glass - Tolerances"

When coated glass is processed into a BIPV module, the solar cells, laminated films and other laminated elements have a strong influence on the color.

Measurement method for color tolerances:

After the manufacturing process to a BIPV Module⁽²⁾, the color is measured by a colorimeter, which reflects the values of the L*a*b* color space. These values are compared with the color value of the release module⁽¹⁾. In the case of surfaces that are not fully homogeneous (e.g. point grid), the values are recorded several times and the values with the smallest difference are included in the evaluation.

$$L^*_{(1)} - L^*_{(2)} = dL^* \quad a^*_{(1)} - a^*_{(2)} = da^* \quad b^*_{(1)} - b^*_{(2)} = db^*$$

Then the following formula is applied for evaluation:

$$\sqrt{(dL^* \times dL^* + da^* \times da^* + db^* \times db^*)} = dE^*_{ab}$$

Permissible tolerance: $dE^*_{ab} = 5$

Sampling

The human eye reacts to colors in a differentiated manner. With blue tones, in contrast to green tones, the finest color differences can be perceived. The current lighting conditions play an essential role in this. Depending on the time of year or day, the viewing angle, weather, cloud cover or reflective surfaces, the color appears different. This can lead to discussions, as the objective assessment of the colors or color differences is a matter of judgment. If an objective evaluation standard for the color shade is desired by the customer, the procedure must be coordinated in advance with the manufacturer. It is important that in any case a 1:1 sampling takes place, which is approved by all parties involved. The exact boundary samples must be produced in duplicate and signed by both parties, only then will this be binding. Without such signed samples, explicitly signed as boundary samples, a certain look or color is not considered a reason for complaint.

Procedure for tolerance deviations

If BIPV modules deviate from the defined tolerances, this must be documented and reported before installation and within 5 days after receipt. The documentation must specify the deviation from the tolerance with measured values and images. If no complaint including documentation is made within this time limit or if the BIPV modules are further processed or installed, the visual appearance is deemed to have been accepted. Subsequent replacement is excluded.

In the event of slight, medium and severe tolerance deviations, the customer is entitled to a reduction in the purchase price of between 5 and 15%, depending on the severity. An exchange or replacement (only before installation or further processing) can only be considered in the case of exceptionally severe tolerance deviations.

Current guidelines

These guidelines are based on today's technical possibilities and can be adapted continuously. It is therefore advisable to request the latest version of the guidelines before placing an order.