1. Design of solar modules for building integration

PROSOL® solar elements are designed with a compound of two glass panes, which permanently protect the solar cells. The front pane which is facing the sun is made of highly transparent, heat strengthend white glass (PLANIDUR® - DIAMANT), so that as much as possible of the incident solar energy reaches the solar cells. The back pane is made of a conventional glass according to the static requirements, which is also heat strengthend. As the compound material, a highly transparent cast resin is used, which has been optimized especially for this application.
Depending on the application, the wiring of the solar elements can exit either via a junction box at the back side of the solar elements (see Figure 1) or at the front-side glass edge (see Figure 2).

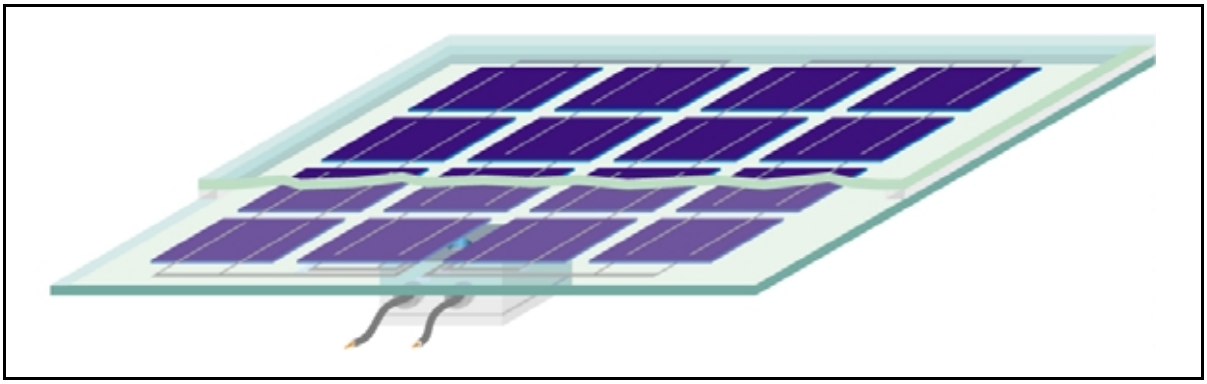


Figure 1: PROSOL® solar element with junction box

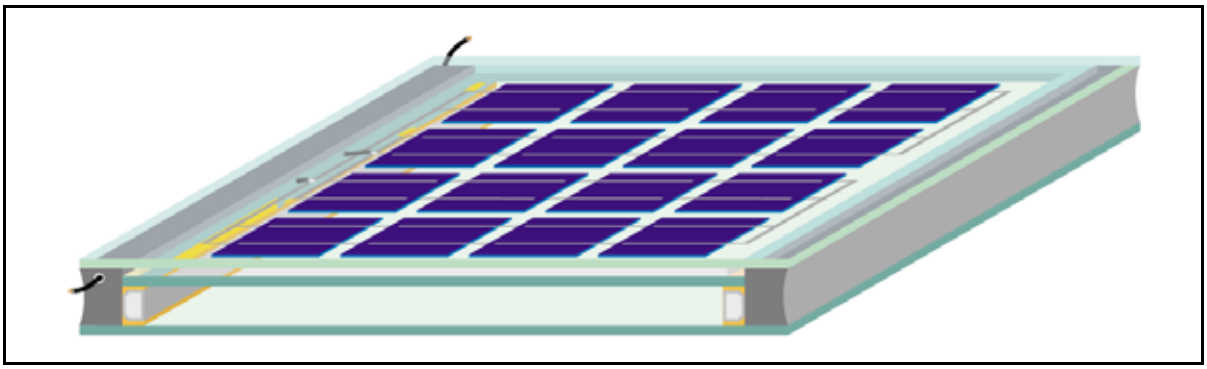


Figure 2: PROSOL® solar element as insulation glass with wire exit in the edge area

2. Architectural possibilities

The two main components of a solar element - glass and solar cell -, enable a number of design possibilities. The specific properties of several glass types can be combined with each other, which leads to multi-functional solar elements.

2.1 Element size

In principle, PROSOL® solar elements can be manufactured in any size between 30 * 30 cm and 200 * 320 cm. This makes it possible to consider any architecturally chosen grid size, and it is also possible to apply solar elements even on a complicated facade geometry. The glass sizes of front and back side (also the insulation glasses, if applicable) can have different sizes, so that e.g. single or multiple-sides step glasses are obtained.

2.2 Element format

In general, all glass formats, such as triangles or trapeziums, can be manufactured. Special forms with rounded edges or polygon shape are also possible. When the format is very extraordinary, one has to consider however, that the costs increase more than proportionally, compared with rectangular solar elements, and furthermore the solar elements often have to be made electrically inactive.
However, in order to achieve an architecturally esthetically pleasing appearance now and then such special elements are necessary, e.g. to cover the complete facade all the way to the edges with a continuous solar cell area.

2.3 Glass thickness

The thickness of a glass pane is in itself not a freely „choosable“ parameter, since it is to a large degree determined by the static requirements, the application situation and the applicable building code. The glass thickness of a solar element can however, within the above mentioned limits, be adapted to the building conditions.

2.4 Glass type

For the front glass pane of a solar element, we usually choose the thinnest possible pane of a low-iron and therefore highly transparent glass, type PLANILUX-DIAMANT®, in order to supply the solar irradiation to the solar cells with as little loss as possible. For the back glass pane basically any of the glass types that are available can be used, e.g. :

- Solidly colored, so called PARSOL® glass, available e.g. in the colors gray, bronze and blue.
- Color-coated, so called EMALIT® glass, where a ceramic color depending on the customers choice is burned in of the back side.
- Silk-screen-printed glass, where both the pattern and the color can be chosen according to the customers choices.
- Coated glasses, where metal oxide layers are coated on the glass back side, which have a reflective effect. These layers can be both clear or color-tinted.

- Security glasses with PVB-films, which enable the use in overhead-applications according to the DiBt-guidelines.
- Insulation glasses, which provide the heat insulation of the building. The building-side pane can be chosen almost at will.
- Noise protection glasses, which have noise dampening properties due to their glass structure.
- Sun protection glasses with a selectively reflecting metal oxide layer on the glass back side, which reflects the heat energy contained in the solar radiation. The visible light in contrast passes almost without hindrance, so that the interior of the building is both bright and cool in the summertime.

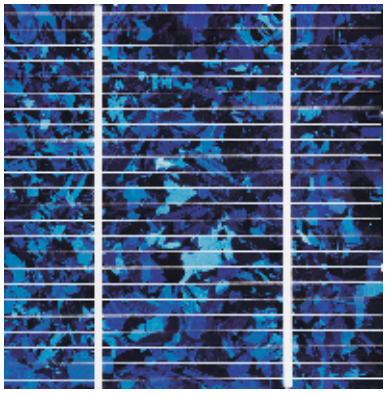
Combinations of various glass types in the same solar element are possible!

2.5 Glass mounting

PROSOL® solar elements can be mounted just like conventional glass element. Single- or multiple-sided mounting is possible, but also point-wise mounting or mounting in a „structural glazing“ system. Of course, the appropriate building codes have to be taken into consideration.

2.6 Cell types

Depending on the crystal structure of the solar cells one distinguishes polycrystalline, monocrystalline and so called thin-film solar cells. Polycrystalline cells have a lively shimmering structure, while monocrystalline cells have a homogeneous appearance. Thin-film solar cells are evaporated directly onto a carrier glass and have no crystal structure, therefore they are also called „amorphous“ cells. The efficiency of the commercially available monocrystalline cells is currently ca. 14 - 16%, of polycrystalline cells ca. 12 - 14% and of amorphous cells ca. 5 - 7%.



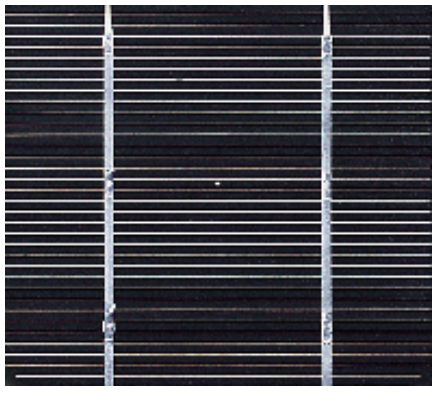


Figure 3: **Example of a polycrystalline and a monocrystalline solar cell. Original size ca. 100 x 100 mm.**

2.7 Cell size

Crystalline solar cells have typically sizes of 10 * 10 cm, 12,5 * 12, 5 cm, or 15 * 15,5 cm. By way of cutting, special formats can be manufactured. Polycrystalline cells are quadratic, while monocrystalline cells are usually pseudo-quadratic, namely with rounded edges. Since a short time, round monocrystalline cells with a diameter of ca. 160 mm are also available.

2.8 Cell format

Solar cells are normally rectangular or quadratic, with more or less rounded edges. This format can be varied almost at will by means of cutting. Cells that have been cut are however often not electrically connected.

2.9 Cell color

The color of solar cells is determined by the so called anti-reflection coating at the front side of the cells. The color ranges – depending on the manufacturer and cell technology – from blue, blue-black, gray, anthracite, to black. By modifying the anti-reflection coating (e.g. composition, thickness of the layers) other colors are possible, which however inevitably lead to a decreased electrical efficiency. Currently, the colors gold, bronze, brown, green, magenta, cyan, and purple are available. A solar cells without anti-reflection coating shimmers silver. The choice of cell color and glass color and their interaction is a well-suited instrument of esthetical architectural design.

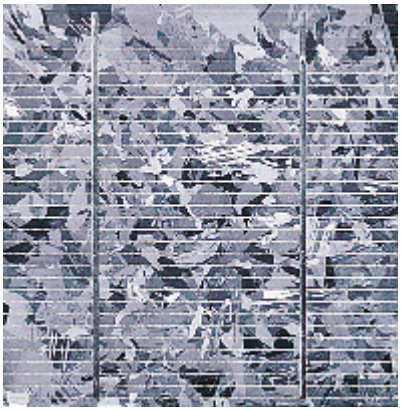


Figure 4: **Silver colored, polycrystalline solar cell.**

2.10 Cell distribution

The distribution of the solar cells within the glass compound can be chosen almost at will. The spacing of the cells towards each other and towards the glass edge can be chosen independent of each other. This is also an instrument to specifically adjust the transparency (both from a lighting and energetic point of view) and the shading. Both a symmetrical and an asymmetrical cell distribution are possible. We can also arrange partial groups of solar cells within the solar element.

2.11 Cell interconnection

The solar cells within the solar elements are connected electrically to so called „strings“. These strings can be oriented both horizontally and vertically in the solar element, depending on which preferred direction of the solar element in the facade is chosen by the architect. From an electrical viewpoint, the solar elements can be divided into one or more part areas, should this be desirable regarding the circuitry of the solar elements within the facade. A *physical* solar element is hence not necessarily identical with an *electrical* solar element.

In summary, we can see, that there is a number of parameters available for the esthetical design of the solar elements.