



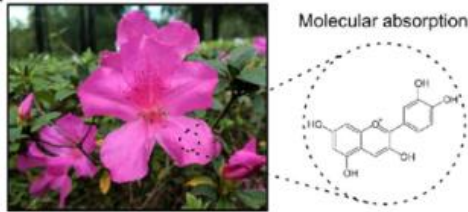
Colored BIPV façades and systems: experiences and lesson learned

PV Skin Bern 04/11/2025



Colors generated by absorption

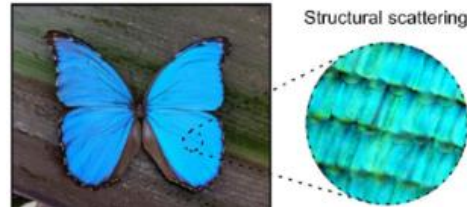
Pigments absorb certain wavelength of light and reflect the remaining ones



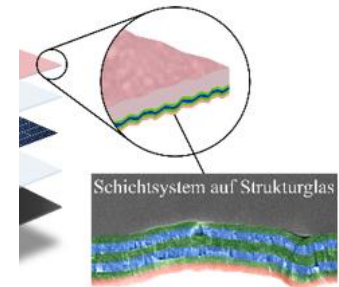
→ Ceramic printing

Colors generated by interference

The colors are generated by interference or diffraction at microstructures or multilayers



→ Vacuum coating

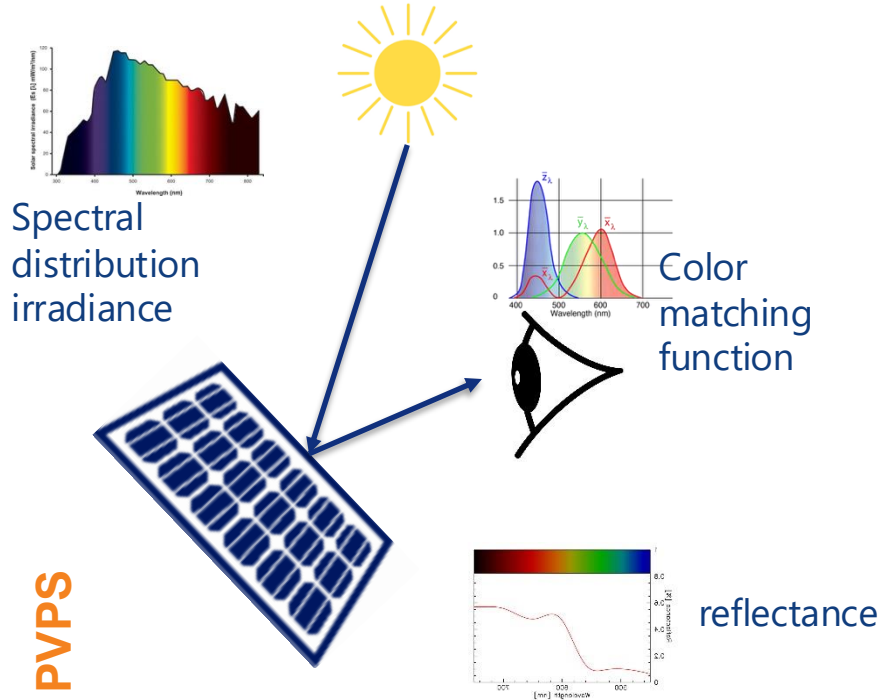


The color definition

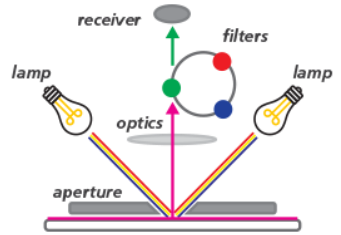


Color perception is subjective,
individual, and physiological

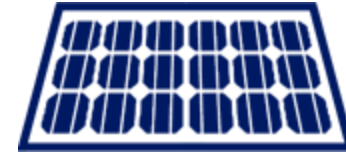
Objective, quantitative, and technical
color measurement



colorimeter



spectrometer



Measurement of Color



Colors are specified using RGB, XYZ, or **CIE Lab** values.

Advantage of the **CIE Lab** color scale is that it is perception-based and device-independent, enabling consistent and accurate color reproduction as it better reflects human color perception.

With the definition of dE, a simple and effective measurement of **color differences** is available.

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

ΔE Value	Description
0.0 - 1.0	No perceivable difference to the human eye, even under close inspection.
1.0 - 2.5	The difference is usually imperceptible, only with close observation.
2.5 - 4.0	The difference is noticeable to an average person.
4.0 - 5.0	The difference is clearly noticeable.

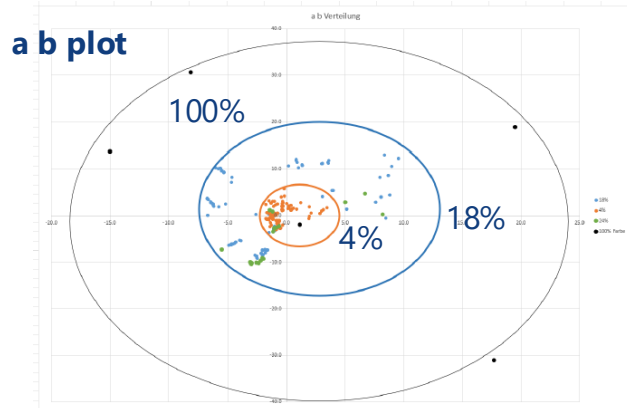
Difficulties of color measurement



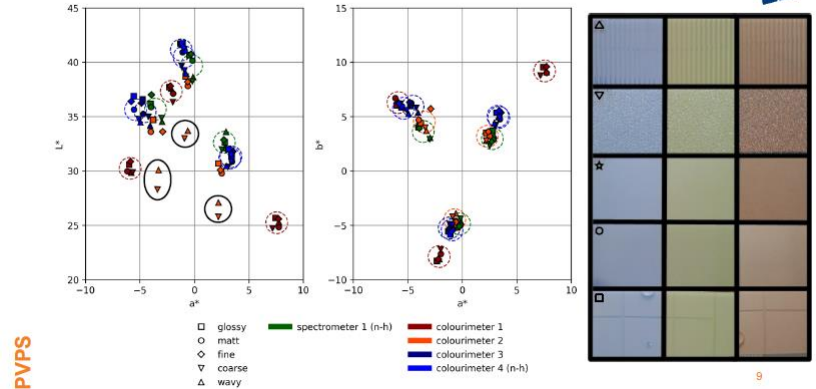
Low ink coverage is necessary to achieve high module efficiency (from 4% to 18%)

→ Difficulties to measure **L a b** value

The measured values depend on the color, the measuring devices, glass types, and measurement conditions.



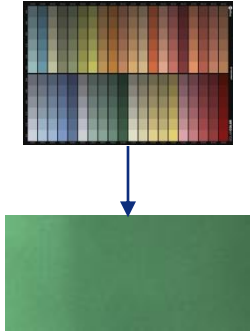
Effect of different glass surfaces (modules)



The color impression of PV module



1° Color selection



Source: Megasol –
Solarcolor Classic



2° Glas selection



3° Module BOM

Covered metallic parts
Cell technology
Ribbons
Busbars
Encapsulation



Final module



L a b color



L a b color + glass



L a b module

It is very important to manufacturer color samples and mock ups as reference for the future production.

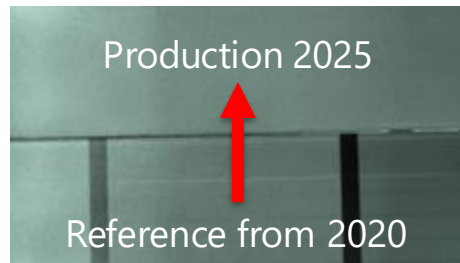
Challenge from project to production



After 2 – 4 years the manufacturer must produce modules **identical** to the mock-up.

For this:

- The printing or coating process must be 100% under control (ink, printer, oven, coating process, materials), but certain deviations are always possible.
- The same glass must be available.
- The cells and Module materials must be available.



	L*	a*	b*
Standard	32.4	-4.2	-0.5
Probe	30.8	-3.7	-0.2
Unterschied	-1.6	0.5	0.3
	Pass	Pass	Pass
SCI/D65/10°			
dE*ab=1.7 Pass			

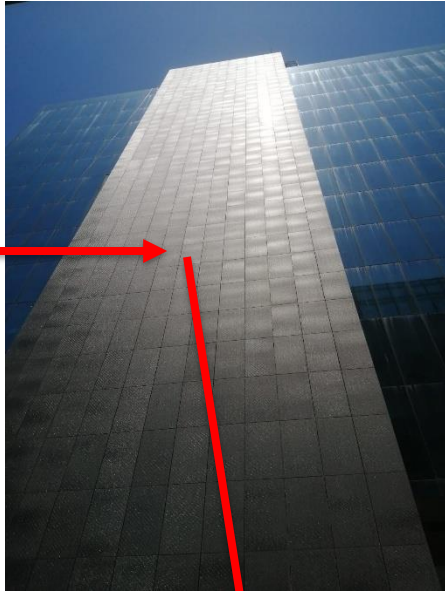
Project with ceramic printing



Printed dots on glass



Source: Megasol



module

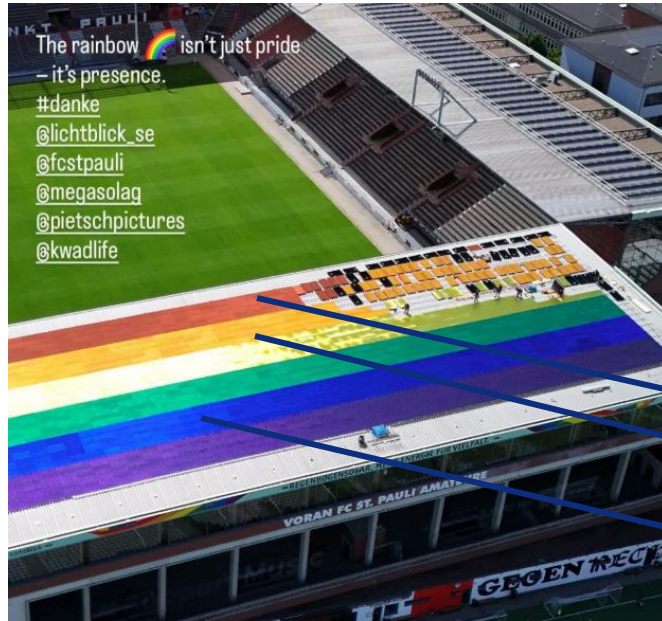
Special challenges

- Highly textured glass printed with a 4% grey coverage to ensure maximum power output
- **highest precision in printing**
- Delivery in 4 instalments several weeks apart
- **color stability in batch production with low color coverage**

Project with interference colors



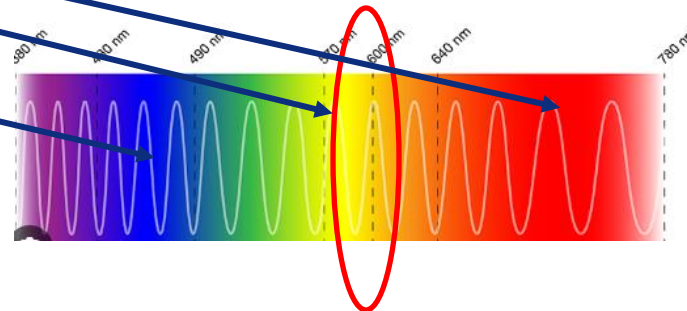
St Pauli stadium in Hamburg (DE)



Source: Megasol

Special challenges

- Color matching with interference colors (development of special morpho colors)
- High repeatability and homogeneity of colors in a very large batch. $dE < 1.5$!
- Small range for yellow and orange



Challenges from project to production



- Use the same measurement setups and instruments to compare L a b values
- Color reproducibility: the best results with **coverages over 10%**
 - For lower coverages mock-ups are very important (visual impression)
- Colors on **structured glass** are difficult to measure and reproduce (glass !)
- Colors as blue, green are easier to manage than grey or browns
- Very important to have reference samples and mock ups
- Best practice: **glass production in one batch**
- Interference colors have a good repeatability due to the vacuum coating process.

Difficult assessment due to angle and light dependence of color

Megasol Energie AG - Industriestrasse 3 - 4543 Deitingen - Switzerland

thomas.friesen@megasol.ch

www.megasol.ch

