SUNdidactics
SolarEnergyDidactics
SolarEducation
SolarEngineering
Photovoltaics+Solarthermal
innovative Solarsysteme für Schule und Ausbildung
innovative solar- systems for school, college, technical education

NILS ISFH
Kooperationspartner NILS-ISFH
Vertrieb
Auslieferung
Rechnungsservice
Solartechnik
Solardidaktik
Solare Wissenschaft
Sales
Delivery
Accounting
Solar didactics
Solar science

Photovoltaik-System SUSE
Solartechnik
Experimentiergeräte
Solare Experimente
von der Grundschule bis zum Abitur
Solar technology
Experimentation devices
Solar experiments

BNE
Bildung für nachhaltige Entwicklung
Education for Sustainable Development

Solardidactic – Solarzellen - Solarmodule – PV- Experimentiergeräte – PV –Experimentieranleitungen - Solarthermie- Experimentiergeräte
didaktische Konzepte – Solarberatung – Fortbildung - solare Aus- und Weiterbildung - Solarspielzeug
Solardidactics + solar cells + solar modules + photovoltaic experiment devices + solar toys + solar education and training

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The manufacturing of a standard industrial solar cell (basic principle)

QR manufactoring EN

1. Silicon (Si) wafer, p-doped with boron during manufacturing of the wafer

Si
wafer
p-doped

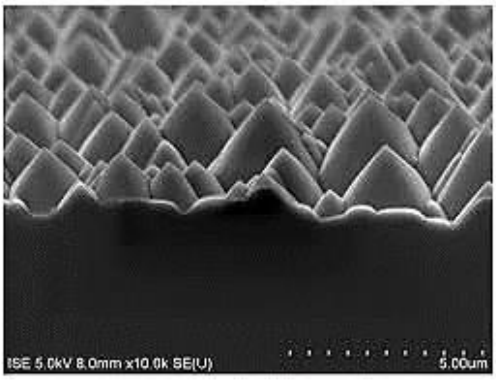
Silicon disc, high-purity Si, monocrystalline or polycrystalline
Standard dimensions: 156,75 x 156,75 mm (6 inches x 6 inches),
thickness ca. 0,18 mm = 180 µm.
In the PV industry, bigger wafer sizes up to 210 mm are already in use!
P- doping with boron (is already inserted into the melt during manufacturing)

2. Texturing with lye

Texture

The top side is treated with lye, roughening the smooth surface.
Because oft the orientation oft the crystals, pyramids with a height of 1 µm – 3µm form in a monocrystalline wafer. The texture serves to lessen the reflection of light at the surface. The scanning electron microscope image on the right-hand side shows the texture viewed from the side.

Pyramid shaped texturing oft the wafer surface



3. n- doping with phosphorus (P)

Texture
top surface
n-doped,
otherwise
p-doped

In a furnace, phosphoryl trichloride ($POCl_3$) flows over the surface of the Si wafer at 900°C – 950°C. The [P] atoms penetrate the surface to a depth of ca. 0,2 µm. There, **the p-n junction** forms, which is important for the separation of charge in the solar cell.

4. Coating of the front side with anti-reflective layer composed of Si_3N_4 (Silicon nitride)

In a plasma process in a vacuum at ca. 300°C, a transparent, ca. 75 nm (=0,000075 mm) thick Si_3N_4 layer is applied, this layer is transparent, but we see blue-black, it blocks the reflection of incoming light at the Si surface, that means as much light as possible goes into the Si wafer. The visible dark blue color is an optical effect: see "Colors of thin platelets".

5. Coating of the back side with anti-reflective layer stack

In a plasma process, a ca. 5 – 20 nm thick aluminium oxide (Al_2O_3) layer is applied, on top of that a 70 – 120 nm thick layer of Si_3N_4 is applied again.
Like on the front side, the goal is to improve the passivation, i.e. to not lose the generated charge carriers, as well as to lessen the light losses at the same time. In the case of the back side, this means, that light penetrating through the front side of the solar cell is reflected once again to go through the Si wafer another time and be able to generate more charge carriers.

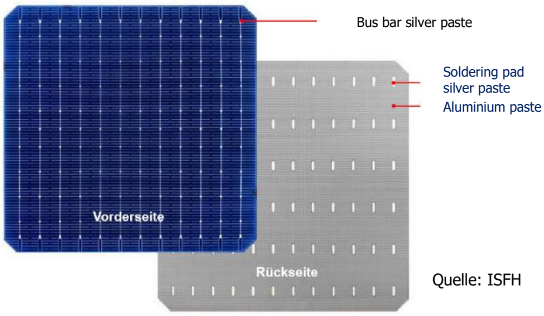
6. **Opening of contacts via laser process**

The dielectric Al_2O_3 layer on the back side of the solar cell is opened with a laser process, i.e. the layers are locally evaporated with a laser beam. The openings are dots with a diameter of 20 – 50 µm.

7. **Coating of the back side with aluminium and local silver pads = positive pole of the solar cell**

The **back side** of the solar cell is coated with a thin aluminium layer (10 – 20 µm) via screen printing, this is the positive pole of the solar cell. Because aluminium can’t be soldered, the back side also receives additional regions of pure silver (soldering pads), where conductors can be soldered on.

8. **Application of the silver front side grid = negative pole of the solar cell**



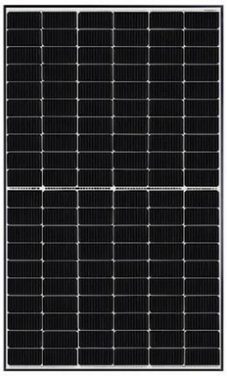
Quelle: ISFH

Via screen printing, very thin, parallel running electric conductors made of silver are applied, as well as wider conductors serving as a bus bar to solder on electric conductors.
The contact fingers have to be very thin (20 – 30 µm), because no light can penetrate into the solar cell through silver. The silver prints are subsequently burned in at 800°C – 900°C.

Now the solar cell is finished and ready to be used.

In bright sunshine (S = 1000 W/m²) its open circuit voltage V_{OC} is ca. 0,68 V and the maximum current I_{SC} (short circuit current) ca. 10 A, the electric power is ca. 5,5 W. The cost at present is 1,3 € (0,25 €/W_P) because of mass manufacturing, the biggest manufacturer globally is China.

Subsequently (usually) 60 solar cells are connected in series and installed under hail-proof glass and a robust frame to form a solar module, at present the power is ca. 300 – 350 W per module.
Many solar modules are then connected on roofs or free-standing, forming big solar generators, a power up to many MW is possible.

		
Solar module by Solarwatt Power ~320 W 60 solar cells in internal series connection in 6 rows with 10 solar cells each.	**Solar module by Hanwha Q Cells Power ~335 W** Series connection of 60 half solar cells in 2 parallel strings.	**Example of a bifacial solar module**, i.e. light is brought into the solar module from the front and back side.

Source: W.R. Schanz and S. Bordihn, ISFH