REAL VALUE
QUALITY FROM SILICON TO SYSTEM
Real Value you can count on. This is our promise to our customers.

The use of solar power is noticeably increasing, and it has become the leader in renewable energies worldwide. Fortunately, a development that cannot be stopped – in favor of cleaner, safer and fairer energy production.

But solar is not always solar! Where others stand still, SolarWorld takes the decisive step further, developing quality standards beyond the norm and driving the development of new technologies. We are now putting 40 years of production and technology know-how to use in all our processes worldwide.

Our products must deliver what they promise. And under the real-world conditions that the modules are exposed to for at least 25 years. Our standards for the reliability of our products are defined and implemented globally at all production sites in equal measure. For our customers worldwide this means: “Quality made by SolarWorld.”

Real Value that pays off over the long term – this is our special commitment to our customers.”

Sunny regards,

Dr.-Ing. E. h. Frank Asbeck
CEO SolarWorld AG
Bill Yerkes founds Solar Technology International with the vision of manufacturing solar cells for use on Earth.

Solar Technology International becomes ARCO Solar upon its debut in Camarillo, California.

ARCO Solar installs the world’s first 1 megawatt solar power system and becomes market leader.

Frank Asbeck starts up SolarWorld AG.

Siemens Solar celebrates 100 megawatts of installed modules made in Camarillo.

Siemens is the first manufacturer to offer a 25-year guarantee.

Solar cell manufacturing starts in Freiberg.

SolarWorld acquires Shell Solar (formerly Siemens Solar).

SolarWorld acquires Ersol Solar Energy AG.


Siemens acquires ARCO Solar, creating Siemens Solar.

ARCO Solar is the first company to produce more than 1 megawatt of solar modules in a single year.

ASi Industries GmbH is founded in Arnstadt.

Bayer Solar GmbH is founded in Freiberg.

SolarWorld opens production facility in Hillsboro, Oregon, in the United States.

Solar cell manufacturing starts in Freiberg.

Production launches at world’s first fully automated solar module production in Freiberg.

Sunmodule Bisun starts mass production.

Production ramps up at Cell Fab 3 and module production in Arnstadt.

SolarWorld acquires Ersol Solar Energy AG.


Production launches at second module factory in Freiberg, doubling module production.

SolarWorld opens production facility in Hillsboro.

Entire building complex – featuring cell, wafer and module production, research and development center, vocational training center and new headquarters – is completed in Arnstadt.

Production begins at Cell Fab 2 in Arnstadt.

Start of PERC production in Arnstadt and Hillsboro.

Start of mono-crystallization in Arnstadt.

Ernst Kaesler starts up SolarWorld AG.

Siemens acquires ARCO Solar, creating Siemens Solar.

Siemens Solar is the first manufacturer to offer a 25-year guarantee.

SolarWorld opens production facility in Freiberg.

Logistics center opens in Freiberg.

SolarWorld acquires Ersol Solar Energy AG.


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SolarWorld AG is the largest and oldest manufacturer of silicon wafers in Europe. The company’s operation in Freiberg, Germany, has manufactured multi-crystalline wafers for the photovoltaic industry since 1994. In fact, many manufacturing processes and tools commonly used today were first developed at that facility. The process begins with highly pure silicon, which is melted in furnaces, crystallized under controlled cooling conditions and doped with the element boron. This boron-doped silicon constitutes the positive pole of a finished solar cell.

At the Arnstadt and Hillsboro facilities, our monocrystalline silicon crystals are produced via the Czochralski process, which uses a seed crystal to crystallize molten silicon in the form of a round mono-crystal. Arnstadt is the largest SolarWorld production site for monocrystals.

**CRystallization**

**A) Multi-Crystalline Production**

1. **Filling the Molds**: Semiconductor-pure silicon is poured into a coated mold made of highly pure quartz. The material is positively doped with boron. In all crystallization processes, cleanliness is crucial.

2. **A Look Inside a Furnace**: The silicon is melted at a temperature over 1,410 degrees Celsius.

3. **Finished Block**: The silicon melt is allowed to solidify in a controlled manner. A square block of multi-crystalline silicon is formed over a period of three days.

**B) Mono-Crystalline Production**

1. **Filling of Crucible**: Technicians fill a crucible with highly pure silicon, using boron to dope the silicon.

2. **Seed**: A small, highly pure silicon mono-crystal is dipped into the melt and partially melted.

3. **Rotating Crucible**: Via controlled cooling and counter-rotation of the crystal and crucible, the crystal grows continuously from the melt.

4. **Finished Mono-Crystal**: A more than 5-foot-long mono-crystal with a regular crystalline structure is created over three days.

**PROVEN QUALITY**: Crystallization is a process step that is critical in the efficiency of a finished solar cell. The cleaner, more even and more controlled the crystallization process is, the more charge carriers can be generated from incidental light and, in turn, used at the cell contacts to transmit electricity.
After cooling, the silicon block or mono-crystal is cut into columns, then further cut into wafers for use in solar cells. These wafers have the dimensions of the later solar cell, but they are not yet electrically conductive. SolarWorld has concentrated its global wafer production activities in Freiberg, Germany, where employees have gathered many years of experience. Some leading wafer-sawing technologies have been developed here. Modern technologies, such as sawing with a diamond wire, are driven forward by SolarWorld’s engineers.

**PROVEN QUALITY:** Every single wafer is measured automatically and sorted by thickness, surface quality and possible damage. A technician also checks each wafer box and typically gives each a quality stamp.

**AUTHENTIC FOCUS ON SUSTAINABILITY:** The SolarWorld wafer production facility in Freiberg, which won the German Sustainability Award, is highly efficient in terms of the consumption of water, energy and operating materials. Production byproducts are recycled and then reintroduced into the production process. Naturally, all waste water and emissions are professionally filtered. Excess heat from the furnaces is used to heat the building while a photovoltaic system on the roof provides clean electricity.
CELL PRODUCTION

The cleanliness of production rooms and equipment is a decisive factor in the quality and performance of solar cells. This is why wafers are processed into solar cells in clean rooms at all SolarWorld sites in Germany and the United States.

The front and the rear side of the silicon wafer are covered with electrical and optical layers, which make the wafer electrically active. Subsequently, the solar cell is measured and classified with precise measuring methods according to SolarWorlds’ strict specifications.

LEGEND

1. CLEANING: In multiple cleaning baths, damage caused by the sawing process is removed, and the surface of the wafer is textured.

2. DIFFUSION: A positive-negative (p-n) junction, responsible for separating electron-hole pairs, is formed via phosphorus diffusion. The wafer is now a solar cell. Acid oxide is then applied to remove a phosphorus glass layer created during diffusion.

3. LASER: A laser is used to heat the cell surface in the specific areas where a contact is to be subsequently made using silver paste. This step creates a selective emitter with high sheet resistance between the contact fingers and low sheet resistance below them, reducing electrical losses.

AUTHENTIC FOCUS ON SUSTAINABILITY: All auxiliary materials used in production are regularly evaluated both quantitatively and qualitatively. Every year, SolarWorld establishes environmental goals and measures to reduce the use of chemicals in cell production. The legal requirements for hazardous materials are scrupulously followed at all SolarWorld production sites. Despite an increase in production volumes and therefore in material use, the consumption of hazardous materials was sharply reduced in 2015.

PROVEN QUALITY: Fully automated facilities, end-to-end process and material monitoring, and continuous quality control throughout all production stages help ensure the incomparable standard of quality for which SolarWorld is known. Solar cells are produced according to the highest standards and measured according to strict specifications and precise measurement methods.
LEADING SOLUTIONS: This technology combines low manufacturing costs with high efficiency, which translates into a higher annual energy yield. Average cell efficiency rates of more than 20 percent are achieved in production, which result in module capacities of 300 watts (60-cell modules) and 350 watts (72-cell modules). SolarWorld began using PERC technology in mass production back in 2012 and has established it as the standard method of production in its facilities around the world.

INTELLIGENT CELL TECHNOLOGY FOR HIGH-PERFORMANCE MODULES

With both dielectric and metallic layers as well as local contacts on the back, advanced PERC solar cells are able to convert more light into electricity.

LEGEND

1. SURFACE TREATMENT: A blue anti-reflective coating is applied using a chemical vapor-deposition process. This coating minimizes optical losses and achieves an electrical passivation of the surface.
2. METALLIZATION: Front and back contacts are formed in a screen printing process. The position of the cells is accurately measured before each printing to ensure that print screens are properly aligned. Finally, the pastes are cured in a kiln.
3. EDGE ISOLATION: To electrically isolate the front from the back, either a groove is made on the front along the edge of the solar cell using a laser, or the back is etched.
4. CLASSIFICATION: One hundred percent of our solar cells are electrically and optically measured according to more than 150 parameters, then sorted according to performance and appearance. Our quality experts subsequently control every single solar cell before packaging.
MODULE PRODUCTION

In fully automated production, mono- or multi-crystalline solar cells are wired into a matrix, then sandwiched in a weather-proof laminate made of solar glass and films. The junction box and frame are mounted in fully automated stations. Modern production systems, continuous material monitoring and quality controls after each production step ensure a consistently high level of quality for SolarWorld modules.

LEGEND

1. CONNECTING SOLAR CELLS TO FORM STRINGS: Solar cells are soldered together in series to form strings; the front side of one cell is connected to the rear side of another cell.
2. CONNECTING THE STRINGS TO FORM A MATRIX: The strings are wired together at the ends to form a matrix. Next, a "sandwich" is created consisting of solar glass, embedding film layers and solar cells.
3. LAMINATING: A laminator is a large vacuum furnace that laminates solar glass, film and solar cells at roughly 150 degrees Celsius, creating a weather-resistant, water-proof unit. Every lay-up is subject to strict controls before and after lamination.
4. MOUNTING THE JUNCTION BOX: Robots install the junction box on the rear side of the laminate. The junction box is a single cast with welded joints, rather than soldered joints, to ensure maximum hold even under the highest loads.
5. FRAME: A fully automated framing station presses the laminate together with an aluminum frame and matching corner keys. The frame is filled with two-component silicone to make the solar module even more weather-resistant and prevent water from seeping inside.
6. DETERMINING PERFORMANCE AND QUALITY CONTROL: At the end, the performance of every single solar module is measured in a calibrated flasher under standard test conditions. In addition to performance and electrical insulation, the optical quality of every module is checked. The rear label gives information on type, performance and production site for each module.

PROVEN QUALITY: During the production process, all intermediate steps are electrically and optically measured and checked. The finished solar module is tested for performance and checked for optical quality before being packaged for shipment. Here, too, SolarWorld sets the standard. In the “Power Controlled” program of the TÜV (Technischer Überwachungsverein), SolarWorld’s measuring equipment is checked regularly to ensure proper calibration.
Research activities in Freiberg focus on the practical development and optimization of production processes with the aim of lowering production costs, increasing efficiency, and improving quality and process reliability. Using an in-house pilot production line at a state-of-the-art research and development center, new technologies and production processes are developed, tested and promptly transferred to mass production facilities. Laboratories for development, reliability testing and quality assurance continuously monitor materials, semi-finished products, prototypes and finished products. Research achievements can be seen at all levels of the value chain. For example, SolarWorld was the first manufacturer to bring PERC technology to mass production and set several world efficiency records. In 2015, the amount of raw materials used in wafer production has been reduced while solar cell efficiency has increased and the performance and durability of solar modules continuously has improved. In the same year, SolarWorld employees submitted 77 inventions, and 273 patent applications were active. The research work is supplemented by more than 500 improvement proposals from employees as part of our company suggestion plan.

Sustainability has been one of the central principles of SolarWorld AG from the very beginning. Despite tough competition and high cost pressure in the solar market, SolarWorld AG remains committed to sustainability as a core element of its brand. As a manufacturing company, SolarWorld addresses four key environmental themes: energy, emissions, water and waste. In these areas, SolarWorld has set specific and ambitious reduction targets to be achieved by 2020. SolarWorld provides an annual report on the progress. Energy consumption per watt-peak has been reduced by 17 percent in 2015, compared with the base year 2012. The goal is a reduction by 25 percent by 2020. Thanks to improved internal, waste-water treatment, the specific water consumption has been reduced by 27 percent in 2015, compared with 2012. Every year, the environmental performances of SolarWorld’s products are calculated by means of a life-cycle analysis and published in detail in a report to the Carbon Disclosure Project (CDP).

**RESEARCH AND DEVELOPMENT**

**SUSTAINABILITY**
The abundant energy the sun provides us with day after day can be converted to electricity using the photovoltaic effect. Silicon solar cells absorb light (photons) and generate excited charge carriers. This means that during absorption, negatively charged electrons are separated from their atoms by the energy of the light and can now move freely throughout the silicon. At the same time, positively charged "holes" are created that can also move freely. At the contacts, these charge carriers can now selectively move into the external circuit—the electrons flow to the front contacts and the holes move to the rear contacts of the solar cell.

This process works because during the production of solar cells, small amounts of foreign substances are added to the semiconductor material silicon to form positively and negatively charged layers. The commonly used substances are phosphorus (negative layer) and boron (positive layer). In the solar cell, the free electrons and the positive electron holes are separated at the junction between the positive and negative layers. The lifetime of the charge carriers must be long enough to prevent the electrons and holes from recombining during transport, neutralizing each other. This is the time in which electrons can move freely, a sensitive measure of the quality and purity of the wafer—almost one millisecond. The flow of charge carriers—electricity—is conducted as direct current from the contacts through the junction box on the back of the module. An inverter converts the direct current into grid-compatible alternating current as electricity that can either be fed into the utility grid or stored and used directly in a home or business.

**HOW IS ELECTRICITY PRODUCED FROM SUNLIGHT?**

By the way: The Frenchman Alexandre Edmond Becquerel (1820–1891) encountered the photoelectric effect during experiments in 1839. However, Albert Einstein was the first to provide a theoretical explanation for the effect in 1907. He received the Nobel Prize for Physics in 1921 for this achievement.

**SOLAR POWER – GOOD FOR YOU, GOOD FOR THE ENVIRONMENT**

Why consume energy when you can generate energy? With a SolarWorld solar system, you can:

- Save money now on your electric bill and lock in energy costs for years to come.
- Depending on the size of the solar system you choose to install, you can save an average of 50 percent of your electric bill or even eliminate it all together. Here’s an example: The average American household uses 920 kilowatt-hours a month. SolarWorld’s average installation accounts for an impressive 840 kWh a month.
- Increase your home’s value: Studies have shown that adding a solar system increases a home’s resale value and that homes featuring solar sell 15 percent faster than homes without solar.
- Decrease your carbon footprint. Carbon dioxide has been proven to cause global warming, which is wreaking havoc on our Earth—melting glaciers, eroding shorelines and endangering animals. Solar on your home reduces reliance on nonrenewable energy sources, and it can help conserve water.

SolarWorld’s customers benefit from our progressive system innovations. Around the world, we meet our customers’ desire for the greatest possible reliability, long-term performance and aesthetic integration. No matter which kind of roof—we always have the right solution. At SolarWorld AG, we guarantee maximum quality from raw material to complete solar systems. In our panel-testing laboratories, products and materials undergo meticulous and detailed inspections that exceed international standards. Our proven quality guarantees our customers get decades of high performance and the security that comes with investing in a reliable product. SolarWorld quality is the best buy in the long run.

**YOUR WAY TO YOUR OWN SOLAR POWER SYSTEM:**

Visit: www.solarworld.com