PRODUCTION EQUIPMENT

High-Performance Crystalline Solar Cells (PERC, HJT, IBC, HBC, TOPCon)
SINGULUS TECHNOLOGIES develops technologies for economical and resource-efficient production processes. The core competencies are vacuum thin-film technologies, wet-chemical processes, surface technologies and thermal processing technologies. SINGULUS TECHNOLOGIES taps new work areas with these competencies and develops innovative solutions.

For all processes and applications SINGULUS TECHNOLOGIES uses its know-how in the segments automation and process technologies as well as the integration of production steps and works on transferring these solutions to additional areas of application.

SINGULUS TECHNOLOGIES works on expanding this expertise in the existing segments to new markets and develops new ideas for innovative product solutions. SINGULUS TECHNOLOGIES is one of the world’s leading drivers of innovations for technologic areas with high growth potential. This includes renewable energies, the entire area of entertainment, ever increasing mobility, semiconductor technologies as well as consumer goods of any kind.
SINGULUS TECHNOLOGIES
PV Technology Powers the World

SINGULUS TECHNOLOGIES provides technology solutions for both crystalline and thin-film high-performance solar cell platforms. Our production equipment improves efficiencies and reduces manufacturing costs. With our production equipment we improve cell efficiency and reduce manufacturing costs. Take a closer look at these production machines for thin-film solar cells (CIGS, CdTe, Perovskite) and high-performance crystalline solar cells (PERC, HJT, IBC, HBC, TOPCon).

SINGULUS TECHNOLOGIES’ expertise includes vacuum thin-film coating (PECVD, sputtering, evaporation), surface engineering, wet-chemical processes and thermal processing.

SINGULUS TECHNOLOGIES cooperates with cell manufacturers worldwide and develops processes, which improve the efficiency of solar cells and at the same time reduce production costs. Evolutionary improvement in cell concepts like PERC (PERL/PERT), bifacial PV systems as well as transitions towards n-type material, heterojunction cells or IBC cells will drive the future of crystalline solar cells.

For silicon solar cells SINGULUS TECHNOLOGIES offers production systems:
→ Inline sputtering systems
→ PECVD coating equipment
→ IPA-free wet process equipment – batch & inline
→ Wet process equipment for poly silicon chunk etching, cleaning & drying
→ Single side polish etch & rear side passivation systems for PERC cells
→ Turn-key production lines for all cell types
→ Ingot, wafer & module production
→ Utilities for all cell concepts and production steps

Bifacial Solar Cells based on PERC Technology

Bifacial solar cells are light harvesting on both, front and rear side, e.g. by reflected irradiation from the ground (albedo).

Bifacial solar cells based on PERC technology enable significantly higher energy yield than conventional cells. A standard rear passivated solar cell on p-type mc Material (AlOx + SiNy) is used. Depending on mounting condition and albedo illumination of rear side (typically 20 % – 30 %), the module has a power equivalent of 330 W – 350 W.

SINGULUS TECHNOLOGIES offers proven production equipment for the manufacturing of bifacial solar cells based on PERC technology.
SINGULUS TECHNOLOGIES developed a new machine concept with the product name MATERIA PCE/OCC for the cleaning of Si chunks, Si-Off-Cuts and ingot saw off cuts for the manufacturing of solar wafer.

In the MATERIA, silicon is cleared of interfering particles, organic and metallic contaminations. With state-of-the-art technology, the fully automated and intelligent carrier management achieves a maximum throughput. With very good process results, the efficient process steps and the economical use of water and chemical substances as well as the low energy consumption reduce the cost of operation compared with the traditionally available machines.

Main Features

→ Surface cleaning & metal removal
→ Revolving barrel system
→ Smart DI rinse system
→ Clean, spot free & dry chunks
→ Excellent process results (metal values sufficiently lower than competitors)
Virtually all silicon based wafers are cut by wire saw technology. The SINGULUS Pre-clean & Deglue system processes the wafers after being cut. This includes removal of slurry as well as degluing the wafers from their carrier beam.

The GERULUS system can be configured in a wide range to adapt all kinds of slurry and glue types. To guarantee lowest possible water and surfactant consumption, the system can be equipped with a water & SiC recycling system.

**Main Features**

- Patented wafer block cleaning
- Proven, highly integrated design
- High throughput up to 7,200 wph
- Built for non-stop utilization: 24/7, 360 days/year
- High availability (uptime ≥ 95 %)
- Sophisticated pre-cleaning concept for best process results and minimal process times
- Compliance with international safety regulations

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1. Transport cart
2. Input buffer
3. Pre clean-bath
4. Deglue chamber
5. Output buffer
6. Installation area
7. Waste water pump stations (optional)
8. Hot DI water station (optional)
9. Surfactant dosage
10. Dirt and pure water tanks
11. Centrifuge
**GENERIS PECVD**

*Inline Plasma Enhanced Chemical Vapor Deposition System for AlOₓ and SiNᵧ on PERC Solar Cells*

One main focus during solar cell production is on cost per Wp. Passivated emitter and rear cell technology (PERC) is a comparatively low-cost approach to achieve conversion efficiencies close to 22%. The newly developed GENERIS PECVD system is a horizontal inline tool designed for the special needs in photovoltaic mass production.

PERC solar cells are coated on both sides with dielectric passivation layers. Rear side passivation is achieved by deposition of a thin AlOₓ-layer capped by SiNᵧ. On the front side, a layer of SiN, serves for both, passivation and anti-reflective coating (ARC). The system is ideally suited for cost effective mass production with high uptime, short cleaning interruptions and maximum utilization of raw materials. Full substrate temperature control during the whole process enables optimum layer performance at temperatures in the range of 450 °C.

The GENERIS PECVD system allows for deposition on both sides of the wafer without vacuum interruption. The usage of both the processes of AlOₓ and SiNᵧ, are realized by a gas separation chamber. Thus GENERIS PECVD can be configured to individual needs:

→ AlOₓ + SiNᵧ on rear and SiNᵧ on front for the complete PERC process
→ AlOₓ + SiNᵧ for PERC rear side passivation
→ SiNᵧ on front and/or rear for ARC and/or rear capping layer only

Especially the first configuration in which all PECVD layers are deposited in one tool represents a cost attractive straight forward solution for newly installed PERC fabs.

The system is using an inline process in which the substrates are transported on specially designed carriers for wafer size up to M4. The carrier return system is located below the machine under clean environmental conditions. Different automation options for loading and unloading are available.

For the future, GENERIS PECVD is as well ready to serve in the production of more advanced and ultra high efficiency cell architectures like PERT; IBC, passivated and carrier selective contacts e.g. TOPCon, POLO.
**Inductively Coupled Linear Plasma Sources (ICP)**

- Mild coating process, no damage to emitter or interfaces
- High dynamic deposition rates for both AlOx and SiNx, thus reduced number of plasma sources, reduced power consumption
- Economic gas consumption and usage
- Shortest cleaning and maintenance interruption

**Summary GENERIS PECVD:**

- Adaptable to every solar cell architecture
- Throughput scalable, number and sequence of process modules configurable
- IC-PECVD guarantees mild coating process, no damage to emitter or interfaces
- Full control on wafer temperature during the whole process sequence
- Complete PECVD sequence without vacuum interruption
- Economic gas consumption and utilization
- For wafer size up to M4
- Chamber and tray design to minimize parasitic deposition
- Tray return system under clean atmosphere
- 5200 wafer/h, uptime ≥ 92%
LINEX
Inline Wet Process Equipment for Cleaning, Alkaline & Acidic Etching, Single Side Treatment, Polish Etch & PSG Removal & Inline Ozone Applications

LINEX
Inline Wet Process Equipment

SINGULUS TECHNOLOGIES provides complete automated dry-in/dry-out solutions for wet-chemical treatment of Si-wafers in standard high-efficiency cell lines.

The ongoing evolution of proven concepts in process management and the integration of innovative approaches are the basis for the development of a new generation of horizontal wet processing systems.

LINEX is an inline wet processing platform with horizontal substrate transport for Si wafers. The SINGULUS TECHNOLOGIES LINEX system combines an advanced transportation system and sustainable/innovative processing modules with proven and efficient chemical treatment.

In addition to proven processes, the focus is on new applications such as single side treatment, polish etching, emitter etching and ozone applications. The highly integrated design, high throughput, high availability and low breakage rates make LINEX very attractive for solar cell manufacturers worldwide.
Main Characteristics LINEX

Typical Performance Characteristics
→ Inline from R & D tool to the fully integrated 10 lane system
→ Alkaline process up to 90 °C possible in 5 or 10 lane systems
→ Polish etch up to 10 μm
→ Integration of ozone
→ Uniform media flow on wafer surface
→ Consistent flow conditions from lane to lane
→ Easy integration of new or additional process options
→ High uptime up to 98 %
→ High throughput and best performance
→ Low cost of ownership
→ Low breakage rate down to 0.01 %
→ Best footprint
→ SSE application up to 5 μm

Controlled – Precise – Intelligent
→ Fully automated inline wet process equipment with integrated process control
→ Compact process modules with innovative media and process management
→ Simple and robust wafer transport system
→ Shadow-free contact of the wafer top surface with the process media
→ Wafer tracking and wafer thickness measurement

Safe – Clean – User Friendly
→ Safe for operators, environment and for reliable processing
→ Cleanroom compatible design according to ISO and SEMI standards
→ Gentle wafer transport through the process media
→ Excellent accessibility of the process modules from all sides
SILEX II Batch Wet Processing Equipment

The SILEX II ALTEX machine is designed to apply IPA-free texturing processes, offering substantial cost advantages compared to traditional etching systems. This texturing process can be adjusted to the individual requirements of standard and advanced cell technologies.

The SILEX II CLEANTEX combines common etching and cleaning steps of monocrystalline Si with advanced cleaning and conditioning processes. Efficient cleaning steps are an indispensable requirement to improve cell efficiencies and reduce operation costs. Ozone-based cleaning operations, applied on SILEX II wet bench, combine efficient organic and metal removal with an appropriate surface conditioning. Due to low chemical costs and consumption, simple process control and high metal removal efficiency, ozonized cleaning baths are the perfect substitute for traditional, expensive multi-step RCA cleanings, known from the semiconductor industry.

The SILEX II CLEAN is provided to run dedicated cleaning sequences for pre- or post-deposition processes. Depending on cell process flow and requirement the configuration can be designed individually, involving RCA or Ozone based cleanings as well as slight etching steps.
**Common and Advanced Process Applications**

- Organic Cleaning
- Metal Cleaning
- Surface Conditioning
- Cascade Overflow
- Dump-Spray System
- Combination Rinse
- Hot/Cold Water Treatment
- Hot Air, N₂ Drying
- Alkaline Texturing
- Acidic Texturing
- Chemical Polishing/Thinning
- Metal and Oxide Etch

**Typical Features**

- High throughput performance up to 6000 wph
- High uptime up to 95%
- Low breakage rate down to 0.01%
- Wafer thickness down to 120 µm
- Individual, flexible process sequencing
- Onboard scheduler software for throughput tuning
- Onboard performance analyzer software
- Ozone-enhanced cleaning and etching processes
- Short and stable IPA-free texturing process
- Appropriate and effective rinsing and drying
**Sputtering Competence**

SINGULUS TECHNOLOGIES develops equipment and technologies for economical and resource-efficient production processes. The core competencies are vacuum thin-film technologies, wet-chemical processes, surface- and thermal processing technologies. SINGULUS TECHNOLOGIES taps new work areas with these competencies and develops innovative solutions.

For all processes and applications, SINGULUS TECHNOLOGIES uses its know-how in automation and process technologies as well as the integration of production steps and works on transferring these solutions to additional areas of application.

One main focus during the solar cell production is the efficiency. Heterojunction cell technology (HJT) achieves conversion efficiencies of more than 22 % as well as reduced manufacturing costs. The newly developed GENERIS PVD system is a horizontal inline sputter tool designed for the special requirements in photovoltaic high efficiency cell production.

Heterojunction cells are coated on both sides with transparent conductive oxide (TCO) layers by PVD (physical vapor deposition). The GENERIS PVD is ideally suited for challenging layer stacks i.e. TCO layers like ITO and AZO providing maximum optical transmittance, matched refractive index, optimum electrical conductivity as well as charge carrier mobility, which are key-parameters in heterojunction cell technology. Sputter damage to the amorphous silicon layer stack does not occur. A full substrate temperature control during the whole process enables optimum layer performance at temperatures ≤ 200 °C.
With the GENERIS PVD sputtering system, contact layers can be deposited on the front and rear of the Si wafers without the need to turn the wafers between coating processes and without vacuum interruption. Annealing of sputtered layers is integrated optionally. Also full area metal coatings, e.g. Ag can be deposited within the same system. By using rotatable sputtering magnetrons, highest target utilization is achieved and offers lowest production costs.

Other typical applications include anti-reflection layers, barrier layers and precursor layers but also different metallic layers such as Al, Cu, NiV, etc. The GENERIS PVD is using an inline process in which the substrates are transported on specially designed carriers, providing edge isolation simultaneously. The carrier return system is located below the machine under clean environmental conditions. Different automation options for loading and unloading are available.

Typical Performance Characteristics
GENERIS PVD

→ Sputtering materials: ITO, AZO and metals like Ag, NiV, Cu, Al etc.
→ Parallel processing of several substrates [Si wafers]
→ Available in 3 versions:
  → GENERIS LAB
  → GENERIS PVD 3000 for approx. 2600 wph
  → GENERIS PVD 5000 for approx. 5200 wph
→ Modular configuration
→ Low cost of ownership and high uptime
→ Top down and bottom up sputtering configurable
→ Sputter sequence configurable
→ Full temperature control throughout the whole process
→ Rotatable cylindrical magnetrons for highest utilization of target material
→ Single end and double end version selectable
→ Manual or semi-automated lab versions on request

The Modularity of the GENERIS PVD System Allows a High Degree of Flexibility
SINGULUS TECHNOLOGIES cooperates with cell manufacturers worldwide and develops processes which improve the efficiency of solar cells and at the same time reduce production costs. Evolutionary improvement in cell concepts like BSF, PERC (PERL/PERT) and also transitions to n-type material, heterojunction or IBC cells will drive the future of crystalline solar cells. SINGULUS TECHNOLOGIES proves the efficiency of the competencies centralized in the company for the delivery of all essential systems up to the complete manufacturing line.

SINGULUS TECHNOLOGIES offers all the services necessary to build a turn-key solar cell production line. This service includes the planning and technical design of the production building, all supplies and additional equipment. Depending on the planned manufacturing capacity, the technical plans including the investment needs are created. SINGULUS TECHNOLOGIES offers not only the cell production line, but also the upstream ingot wafer production and solar module line with the complete accessories.

**Scope of Services**

- Optimized building including facilities and utilities
- Complete ingot and wafer line
- Cell-line equipment and services in packages of increasing content such as
  - SINGULUS equipment package
  - On-site project engineering/management package for complete equipment
- Ramp-up and process commissioning and efficiency guarantees
- SINGULUS TECHNOLOGIES turn-key solutions
- Module line for “standard” or “building integrated”
- Planning, installation and commissioning of complete solar plants
- “1/2/3 year(s) after FAT production support” for all equipment
The requirements to modern high end and highly productive production lines can only be fulfilled when the utilities correspond to the site requirements. To ensure this, SINGULUS TECHNOLOGIES designs, builds and offers production related utility equipment and services for advanced technology facilities such as:

- Energy/photovoltaics,
- Life sciences,
- Medical & chemical,
- Semiconductor as well as
- Surface engineering.

In all of these applications we can offer our customers high quality EPC solutions (engineering, procurement and construction) considering not only the quality and quantity of the consumables and utilities but also respecting all human and environmental safety aspects following the international and local regulations.

**Consulting and Planning**

- Site evaluation & selection
- Feasibility studies
- Site master planning
- Programming and concept design studies
- General studies & simulations
- Process technology and equipment evaluation
- Sustainability analyses and energy efficiency audits
- Costs and schedule models
- CoO calculations

**Design and Engineering**

- Basic, preliminary and detailed design in all engineering disciplines
- Facility system integration
- Space management
- Building information modeling
- Permits, code & environmental compliance
- Value engineering & cost optimization
- Early package development
- Support getting licenses
- Engineering, construction and general contracting (EPCM & EPC)

**(Pre) Construction and Project Management**

- Commercial management
- Design management
- Space management
- Construction management
- Contractor supervision
- Start-up & commissioning
- As-built documentation
- Warranty management
- Engineering, construction and general contracting (EPCM & EPC)

**Installation, Services, Maintenance**

- Process equipment services
- Sustaining infrastructural services
- Facility system optimization & benchmarking
- Work package installations
- Technical staffing
- Engineering, construction and general contracting (EPCM & EPC)
SINGULUS TECHNOLOGIES – Innovations for New Technologies

SINGULUS TECHNOLOGIES builds innovative machines and systems for efficient and resource-friendly production processes. SINGULUS TECHNOLOGIES’ strategy is to take advantage of its existing core competencies and to expand these further.

The core competencies include vacuum coating, surface processing, wet-chemical and thermal production processes. The company offers machines, which are used worldwide in the solar, semiconductor, medical technology, consumer goods and optical disc sectors. For all of the machines, processes and applications SINGULUS TECHNOLOGIES harnesses its automation and process technology expertise.