Crystalline Solar Cells

Production Equipment for Photovoltaics
SINGULUS TECHNOLOGIES
Developer, Enabler and Supplier for Crystalline & Thin Film Solar

PRODUCTION EQUIPMENT
for Crystalline Solar Cells
SINGULUS TECHNOLOGIES

SINGULUS TECHNOLOGIES is a supplier of manufacturing solutions and production equipment for the markets Solar, Semiconductor and Optical Disc. With new machine concepts and manufacturing processes in the crystalline and thin-film solar technology SINGULUS TECHNOLOGIES establishes itself as development partner and equipment supplier for investments in new high-performance solar cell concepts. We have gained extensive know-how in vacuum coating, wet processing, thermal processing as well as automation and process integration.

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 (PERC/PERT), n-type material, IBC cell or heterojunction cells will drive the future of crystalline solar cells.

Process applications improving crystalline cell performance

- MATERIA equipment for poly silicon chunk etching, cleaning & drying
- GERULUS Wafer block pre-clean and deglue system
- SILEX II Batch wet processing equipment
- LINEA II Inline wet processing equipment
- LINEA II Single side polish etch for PERC solar cells
- SINGULAR XP – ICP-PECVD equipment for AR coating and rear side passivation
- PERCEUS Production package for PERC cells
- SOLARE – complete turnkey production lines
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)
GERULUS
Wafer Block Pre-Clean & Deglue System

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

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
SILEX II
Create the Wet Process Equipment to Your Own Specification with Standard Modules!

SILEX II SDE
LOAD | CLEAN / ETCH / RINSE | CLEAN / RINSE | CLEAN / RINSE | DRY | UNLOAD

SILEX II ALTEX
LOAD | CLEAN / RINSE | ETCH / RINSE | ETCH / RINSE | CLEAN / RINSE | DRY | UNLOAD

SILEX II CLEANTEX
LOAD | CLEAN / ETCH / RINSE | ETCH / RINSE | ETCH / RINSE | CLEAN / RINSE | CLEAN / RINSE | DRY | UNLOAD

SILEX II CLEAN
LOAD | CLEAN / RINSE | DRY | UNLOAD

SILEX II C-CLEAN
LOAD | CLEAN / RINSE | DRY | UNLOAD

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

The modular SILEX II batch system offers a wide range of process options. With respect to highest flexibility in configuration, the new generation of the SILEX II machines is characterized by a clear modular design and compact footprint. The SILEX II machine concept fulfill current and future requirements of capacity, flexibility, and stability for mass production.

The basic SILEX II system achieves an output of up to 3,000 wph, upscaling of batch size will cover tool capacity up to 6,000 wph, running with very low scrap rates down to 0.01 % and high process yield. Processing wafers with thickness down to 120 μm, the system follows the newest SEMI roadmap guidelines.

The core of the current and future batch process applications is the alkaline texturing process of mono-crystalline silicon, generating pyramidal-etched surfaces with optimal light trapping, passivation and contacting properties.

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 completely refrains from using flammable, volatile solvents such as Isopropanol (IPA) and enables a stable, wet-chemical texturing process for silicon wafers. Based on commercially available chemicals the process is adjustable to the individual requirements of standard and advanced cell technology. The second pillar of wet batch process applications in front-end cell production are wet cleaning processes. Advanced cleaning steps are going to become an indispensable part of existing present and future cell lines as a key for further improvement of cell performance and cost reduction. Ozone-based cleaning operations, applied on SILEX II wet bench, combine efficient organic and metal removal with appropriate surface conditioning. Due to low chemical cost and consumption, simple process control, and high metal removal efficiency, ozonized acidic cleaning baths are the perfect substitute for traditional, expensive multi-step RCA cleanings, known from semiconductor industry.

Main Features

- Versatile batch tool platform for wet processes in clean technology
- Flexible line configuration due to modular machine design (2/3/4/5-tank modules)
- Individual process sequencing by flexible software structure
- Advanced process control by onboard data-log and event tracking
- Complete metal-free design of process tank systems
- High throughput performance up to 3,000 wph
- High uptime ≥ 95 %
- Low breakage rate down to 0.01 %
- Wafer thickness down to 120 μm [post process]
- Compact footprint with integrated switch boxes
- Component kit prepared for batch size and capacity doubling
- Integration of common and advanced cleaning, etching and drying processes
- Upgradable by common and customized options
- Designed for container shipment
LINEA II
Inline Wet Process Equipment for Cleaning, Texturing and PSG Removal

SINGULUS TECHNOLOGIES provides complete automated dry-in/dry-out solutions for wet treatment of Si-wafers in standard and high-efficiency cell lines. Current and future market requirements of machines, processes, and materials for solar cell manufacturing sets new standards for cost reduction, productivity, process capability, and integrability of wet-chemical production. 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 etching systems. LINEA II is a horizontally working inline wet process platform for cleaning and etching of crystalline solar wafers. The SINGULUS LINEA II combines an advanced transportation system, sustainable and innovative processing modules with proven and efficient chemical etching and cleaning processes.

In addition to proven processes like texture etching, PSG etching or RCA cleaning, the focus is on newer applications with one or two side processes, such as polish etching, emitter etching, and ozone-based or ultrasonic cleaning respectively.

The highly integrated design, high throughput, high availability, and low breakage rate make LINEA II attractive for solar cell manufacturers worldwide.
**Main Characteristics**

**Effective, Economical, Flexible**

→ Platform for all inline processes  
→ From R&D tool to the fully integrated 10-lane facility  
→ Uniform media flow on wafer surface  
→ Consistent flow conditions from lane to lane  
→ Economical because of small bath volumes and high wafer throughput  
→ Fast media exchange on wafer surface  
→ Fast discharging of process reaction products  
→ Low exhaust volumes through intelligent airflow next to each lane  
→ Future-proof and flexible with modular process units  
→ Easy integration of new or additional process options

**Controlled, Precise, Intelligent**

→ Fully automated tool with integrated process control  
→ Compact process chambers with innovative media and process management  
→ Simple and robust wafer transport system without mechanical contacts on top side  
→ Shadow-free contact of the wafer surfaces with the process media  
→ Wafer tracking and wafer thickness measurement

**Safe, Clean, User-Friendly**

→ Safe for persons, environment, and in process  
→ Cleanroom compatible design according to ISO and SEMI standards  
→ Friction-free, gentle wafer transport through the process media  
→ Excellent accessibility of the process chamber from all sides through the separation of process and installation modules
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), n-type material, IBC cell or heterojunction cells will drive the future of crystalline solar cells.

Standard silicon solar cells have a textured front and rear side. In order to optimize the light trapping within the cell and the conditions for a good rear side passivation with local contacts, a planar rear surface is most suitable. The differently structured front and rear surfaces of the wafer make the implementation of a single side etching process step essential. For the market of silicon solar cells, SINGULUS presents a new production solution for rear side passivated silicon solar cells (e.g. PERC - Passivated Emitter and Rear Cell). This solution was developed especially for the upgrade of existing cell production lines. For the upgrade of a production line, three additional production steps, which SINGULUS offers solutions for, are required. Before coating the rear side is smoothed with a wet-chemical polish in a LINEA II Single Side Polish Etch machine.

The dielectric passivation layer is emitted in the ICP-PECVD machine SINGULAR. For the rear side contacts through a laser process, SINGULUS is closely cooperating with partners.

With the integration of these additional production steps into existing manufacturing lines PERC cells with levels of efficiency of over 20 % can be achieved.

SINGULUS TECHNOLOGIES offers for R&D single lane machines and versions with up to 10 lanes for high throughput.

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**LINEA II**

**Single Side Polish Etch for PERC Solar Cells**

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**Linea II SSE-PE**

**Technical Data**

| Linea II SSE-PE (Standard Production Tool) |  |
| Lanes | 6 |
| Dimensions | Process Compartment: 9500 * 1800 * 1400 |
| | Media Compartment: 9500 * 1000 * 2200 |
| Throughput | 3,600 wph |
| Wafer | 156 mm; > 150 µm; mono, multi, mono-cast |
| Utilities | N₂, CDA, DI-water, PCW, Tap Water |
| | HF, KOH, HCl, HF, HNO₃, Additives |
| | Waste Drains |
| | Exhaust |
| | Electrical Power 400 VAC 3/PE |
Rear Polishing:
→ Increase of internal reflection
→ Reduction of surface defects
→ Reduction of recombination centers
→ Longer carrier lifetime
→ Better passivation quality

LINEA II Tool:
→ Compact process chambers with innovative management of media and process
→ Simple and robust wafer transport system with no mechanical contact on top side
→ Shadow free contact of the wafer surfaces with process media
→ Friction-free, gentle wafer transport through process media
→ Excellent accessibility of the process chamber from all sides by the separation of process and installing modules
SINGULAR XP

The innovative SINGULAR XP Tool is based on Static Inline Production, which combines the Advantages of Inline Substrate Transport and Static Processing.

SINGULAR XP

Fully automated ICP-PECVD Production Platform

SINGULAR XP ICP-PECVD is a fully automated innovative and modular PECVD coating tool for the mass production of crystalline silicon solar cells. In addition, the SINGULAR system is being applied for the development of passivation layers for high-efficiency solar cells following conventional and new cell concepts. Thereby, the coating system meets the demands for both current and future PV cell production.

The SINGULAR system provides an automation module and a coating module. The coating module consists of several customizable vacuum chambers.

The innovative SINGULAR tool is based on static inline production which combines the advantages of inline substrate transport and static processing. It allows the coating of complex layers, such as layer stacks of different materials e.g. AlOx/SiNy. The key feature of the tool is the ICP-PECVD technology.

The inductively coupled plasma (ICP) excitation allows ideal control of film properties for various materials such as SiNx, AlOx, SiOxNy at high deposition rates. The process variability, the small tool footprint in combination with an excellent total “Cost Of Ownership” makes the SINGULAR system ideally suitable for upgrades of existing production lines.

Therewith, SINGULUS TECHNOLOGIES makes a valuable contribution to continuous improvements with respect to efficiency and manufacturing cost of PV modules, being a necessity to reduce the costs and enable the large-scale deployment of PV electricity. The solar cells from SINGULAR production system are PID-free due to the specifically designed coating technology.
SINGULAR – Facts

- Industrial proven multi-chamber ICP-PECVD coating tool
- Lowest cost of ownership
- Modular design for various processes (e.g. SiNx, SiOxNy, AlOx, a-Si ...)
- Single- and multi-layer capability
- Double-side coating capability
- Small footprint
- Integrated electrical and gas cabinets
- Efficient use of raw materials like electrical power, process gases ...
- Low noise level (no grey room necessary)

- High uptime
- Easy to operate
- Easy to maintain
- Inline cleaning processes available (e.g. for SiNx)
- Customized tool configuration, e.g. usage of special gases (e.g. TMB, phosphine, organic precursors like TMAl)
- Integrated automation solution
- Inline and cluster operation possible
- All types of automation cassettes suitable
PERCEUS
Production Package for PERC Cells

PERCEUS
The Solution to Optimize your Profit

PERC (Passivated Emitter and Rear Cell) is currently the only industrially, economically justifiable cell power increasing technology that meets the requirements for a good balance between manufacturing costs (US$/W) and efficiency, thus securing interesting payback periods for the investment.

SINGULUS presents PERCEUS, a new production solution for rear side passivated silicon solar cell. PERCEUS was developed to upgrade existing cell production lines to manufacture PERC-type silicon solar cells.

→ A wet-chemical process step polishes the rear side of the cell using a LINEA II Single Side Polish Etch.
→ The dielectric passivation layer on the rear of the solar cell, consisting of a layer stack of ICP-A1Ox and SiNx, is coated by the PECVD production tool SINGULAR XP.
→ For the final step, the rear contact formation done by Laser Contact Opening (LCO), SINGULUS TECHNOLOGIES is cooperating closely with partners.

An improved cell rear side with an ICP-A1Ox/SiNy double layer (ICP: „inductively coupled plasma“) enables this progress without „selective emitter“ technology. With the integration of these additional production steps into existing production lines, PERC cells with efficiencies of above 20 % can be made.
The commissioning of the first production line for crystalline solar cells which was supplied by SINGULUS TECHNOLOGIES took place on October 15, 2013. With this move, SINGULUS demonstrated the capability existing within the company to bring together expertise in vacuum coating technology and wet chemistry in supplying all key components of a complete cell production line. The main production steps involved in the manufacture of silicon solar cells, such as the wet-chemical facilities for texturing and cleaning as well as the vacuum systems for applying anti-reflective coatings are in-house developments of SINGULUS TECHNOLOGIES.

SINGULUS TECHNOLOGIES also started in 2014 a joint development project with an upgrade package for the production of PERC solar cells in Lithuania. This will further increase the level of efficiency. The respective machine was already delivered by SINGULUS TECHNOLOGIES. The trend in the solar industry towards ever thinner wafers for crystalline solar cells with higher levels of efficiency at the same time requires an improved surface passivation of the cell rear side.

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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. The central manufacturing steps for the production of crystalline solar cells are provided by SINGULUS: the texturing machine, the anti-reflective coating, the additional machine for the PSG cleaning as well as the automated wafer handling systems are proprietary developments by SINGULUS.

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SOLARE
Turn-key Production System for Crystalline Cells

01 Wafer Stack Splitting, Loading/Inspection
02 Saw Damage Etch (SDE) and Texturing
03 Junction Formation
04 Phosphorus Silicate Glass Removal/Edge Isolation
05 SINGULAR – ICP-PECVD Production Platform for Passivation and Anti-reflection Coatings
06/7 Printing/Firing
08 Testing/Sorting

SOLARE
Turn-key Production Systems for Standard Cells as well as new PERC Cells

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