PRODUCTION EQUIPMENT

For Thin-Film Solar Modules (CIGS & CdTe)
Solar cells can be categorized according to the applied production process and used materials, for example in crystalline and thin-film solar cells.

In thin-film solar technology a large glass panel forms the base material, on which a relatively thin layer of 1 to 2 μm of photoactive compound is applied. Amongst others, alloys consisting of copper, indium, gallium and selenium or sulfur (CIGS), compounds of cadmium and tellurium (CdTe) or thin silicon layers are used in this process.

Due to a superior performance under low light intensities thin-film solar cells deliver electrical power already in the early morning and later evening hours or at clouded sky. In addition the panels are more tolerant against local shadowing. Also thin-film solar cells do not suffer so much in their performance at high solar panel temperatures occurring at full sun intensities. Furthermore, thin-film solar panels can be used as an architectural design element for the frontside or the roof of buildings due to their homogenous surface color and attractive visual appearance.

For CIGS cells the absorption layer is comprised of copper, indium, gallium as well as selenium and partly sulfur compounds. These thin-film cells have achieved laboratory efficiency levels of over 23 %. The efficiency of modules is in a range from 14 to 17 % depending on the module size. SINGULUS TECHNOLOGIES is increasingly consulted as a development partner for highly efficient solar cells and chosen as preferred machine supplier by leading solar cells producers for the relevant machines.

With our production equipment we are one of the few companies able to equip both efficiently running factories for the manufacturing of CIS/CIGS thin-film modules as well as single production equipment for the different manufacturing steps.

In the Solar segment SINGULUS TECHNOLOGIES is a leading supplier for new production solutions for thin-film and crystalline solar cells, offering lower production costs to increase the level of efficiency or achieve a higher level of efficiency.
SINGULUS TECHNOLOGIES has established itself in this market as a worldwide recognized machine supplier for technologies enabling a sustainable and chosen energy provision on the basis of renewable energies.

For the mass production of CIS/CIGS solar cells, SINGULUS TECHNOLOGIES has introduced and delivered new machines for all relevant manufacturing steps:

- Sputtering
- Evaporation
- RTP for selenization & sulphurisation
- Buffer layer deposition
- Wet-chemical cleaning
- Utilities

SINGULUS TECHNOLOGIES offers to its customers for CIS/CIGS:

- Manufacturing equipment built to highest international standards
- Process know-how and process licenses with partners to provide a stable process
- Highest yield and efficiency
- Education and staff training for engineers and operators
- Ramp-up support
- Worldwide after-sales service
- Future upgrade packages on request
As part of the product family the processing machine VITRUM II is dedicated to clean in a single working step wrap around coatings at rear sides and edges of thin-film solar panels. While the edges and the rear side are cleaned with brushes and chemicals the active layer is protected by means of a process hood.

Therefore, the VITRUM II is best suited for cleaning after dipping processes as well as for etching of undesirable coatings at rear side and edges, for example CdTe or CdS.

The modular design of the VITRUM II family allows the easy integration of different process steps according to the requirements of CIGS, a-Si or CdTe technology, such as etching, rear side and substrate edge etching, cleaning and single side coating.
Main Features

→ Modular design
→ Up to 30 % cost reduction
→ Better accessibility
→ Smaller footprint
→ Low cost of ownership
→ High throughput
→ High availability (uptime > 99 %*)
→ Standard and customer specific substrate sizes up to 2,600 mm
→ Parallel carrier transport for higher throughput
→ Reproducible process results

*depending on application

The VITRUM II provides the platform for wet-chemical inline process steps, e.g. in a CdTe manufacturing line it performs several process steps, starting with glass washing, removal of rear side coating, CdCl₂ deposition using a roller, CdCl₂ salt removal as well as chemical NP etch.

When producing a thin-film solar cell, VITRUM is capable of glass washing as well as TCO etching, KCN etching or NH₃ treatment respectively. In addition, it also provides NP, DAE and EDTA etching for substrate width up to 2,200 mm. With our newly developed and unique soft shower process, a homogeneous, reliable, and reproducible etching became reality. Furthermore, it features several advantages compared with inline dipping baths such as reduced process volume, saving energy, and chemicals as well as a higher process speed of up to 5 m/min with minimized carryover.

VITRUM II Clean

→ Inline cleaning equipment [2200/1400/600]
→ Pre-rinse and single side brush off [acid/caustic]
→ Inline final rinse [cascade cleaner], metal free
→ Inline standard cleaning, polishing, and brushing machine [glass corrosion]
→ Ultrasonic and megasonic support [particle removal]

VITRUM II Etch

→ Inline etching equipment [2200/1400/600]
→ Inline TCO etcher [HCl/HF]
→ Inline KCN etcher
→ Inline NP etcher
→ Inline CuCl₂ etcher
→ Inline developer for photoresist
→ Inline CdCl₂ salt removal

VITRUM II Cover

→ Inline etching equipment
→ Removal of wrap around coating at edges and rear side
→ Active layer protection [neither liquids nor vapors attack the active layer]

VITRUM II Coat

→ Inline wet deposition of thin salt films by means of a soft roller [e. g. CdCl₂, CuCl₂ or NaCl]
→ Automated process control
→ Single side coating
→ Very high material usage

Facility Management

SINGULUS TECHNOLOGIES also supplies:

→ Chemical supply and mixing systems
→ Waste water treatment
→ Exhaust scrubber
→ Water purification
TENUIS II
Modular System for Chemical Buffer Layer Deposition CIGS & CdTe Thin-Film Solar Cells

SINGULUS TECHNOLOGIES is the market leader for chemical buffer layer deposition for CIS/CIGS thin-film solar cells. With the development of a completely new concept for the TENUIS II system, SINGULUS TECHNOLOGIES will open up the way to cost-effective production. This machine is a central component for the manufacturing of CIS/CIGS thin-film solar cells.

The industrial manufacturing machines of TENUIS II type have a modular cluster system and enable both significant savings in terms of required floor space and the simultaneous one-sided coating of two substrates.

The TENUIS II also provides advantages upon commissioning and in the ramp-up stage. Because of the new cluster design, the commissioning can commence modularly after a short installation time and the first substrates can be coated. The following cluster can be assembled simultaneously or consecutively. Correspondingly, the TENUIS II meets the ever increasing demands of the market with respect to the reduction of the commissioning and ramp-up times.

The new generation of the TENUIS plant offers substantial cost advantages in the production of high performance CIS/CIGS thin-film solar cells. With application and temperature control, the process time has been reduced, bringing the positive effect of significantly higher production line output.

The new system makes it possible to use alternative buffer layer by replacing the intermediate layer system consisting of cadmium sulfide and zinc oxide by a combination of zinc oxide sulfide and zinc magnesium.
Due to new and unique concepts in terms of dosing and temperature control, SINGULUS TECHNOLOGIES was successful in reducing the process time by up to 30%, resulting in a considerably higher output in production. Furthermore, the costs are significantly reduced by temperature profiles adjusted to the process and by very efficient use of process chemicals, so that the new system consistently exploits the savings potential in the manufacturing of thin-film solar cells.

The TENUIS II offers substantial cost advantages in the production of high performance CIS/CIGS thin-film solar cells. Furthermore, the costs are significantly reduced by process adjusted temperatures and by the very efficient use of process chemicals, enabling the new plant to consistently exploit the savings potential in the manufacturing of thin-film solar cells. SINGULUS TECHNOLOGIES offers wet processing systems from R & D, through pilot use, to full production range of 150, 300 and more MW.

For a higher throughput, several production machines can be combined to a large production complex.

Main Characteristics

→ Standard reference process: highest efficiencies and low risk
→ More than 150 process modules in production (world leader)
→ Minimized chemical consumption
→ Fully automated inline system
→ Single side deposition incl. protection against backside contamination
→ Modular system (easy upgrade for higher throughput)
→ Reproducible process results
→ Automatic dosage and mixing system
→ Deposition systems for cadmium-free buffer layers
CISARIS – Selenization/Sulphurization
with High End Rapid Thermal Processing for an Optimized CIGS Absorber Formation

The CISARIS oven is an inline rapid thermal processing equipment designed for the CIGSSe absorber formation on large area glass substrates. CISARIS consists of a handling station, a vacuum tight process section, and a return conveyor and is optimized for the mass production of CIGS solar modules.

The main features of the CISARIS include a high uptime and mechanical yield, as well as a fast cycle time which, in combination with the robust selenisation process, leads to a production capacity of over 30 MWp per year (depending on configuration).

CISARIS is a proven innovative and reliable production tool, which has been newly developed at SINGULUS based on the previous generation of selenisation ovens.

CISARIS can safely handle the thermal processing of large glass substrates of over 1 sqm at temperatures up to 600 °C and beyond under a toxic and corrosive gas atmosphere. High heating and cooling rates, combined with an excellent temperature homogeneity during all process stages are the key factors, which allow the formation of an optimal CIGSSe absorber, required for the production of high efficiency thin-film solar modules.
Main Features

- Third generation inline selenisation furnace with optimized cycle time
- Rapid heating (up to ~ 4 °C/s) of large glass substrates with metal precursor coating (CIGSe)
- Homogeneous gas distribution and low gas consumption through optimized inlet system
- Introduction of H2S and H2Se gas at various stages of the process possible
- Uniform heating of large substrates up to 600 °C and beyond by using optimized IR radiators for achieving the required crystal structure

- Uniform cooling of substrates to avoid glass warpage
- Excellent temperature control (mean variation < 5 °C) at all process stages
- Process under vacuum or at atmospheric pressure possible
- Oxygen and water vapor free process atmosphere guaranteed through pump/purge cycles
- Excellent maintenance concept with maximum accessibility of all machine components
- Proven safety system based on a solid risk management and safety engineering
VISTARIS
Inline Sputtering Systems with Vertical Substrate Transport

VISTARIS Sputtering Systems

The SINGULUS TECHNOLOGIES system with the brand name VISTARIS was developed for the requirements in the photovoltaic industry. Inline sputtering systems are important in today’s CIGS & CdTe thin-film solar cell production. The VISTARIS system was designed to enhance the efficiency of thin-film solar cells, while cutting production costs by using the state-of-the-art technologies. For photovoltaic technology, SINGULUS TECHNOLOGIES develops and manufactures coating systems which can apply special layers and layer systems on different substrates.

Examples are transparent front or metallic back contact layers as well as multilayered precursors with a broad range of different materials. The main advantage of the system is that it can be used for vertical vacuum-based coating of glass substrates in the solar industry. In the market for thin-film photovoltaic SINGULUS TECHNOLOGIES adds another production stage to its range of processing systems for the manufacture of CIGS/CIS and CdTe modules.
Main Features

→ Integrated power supply design
→ No carrier return system necessary
→ Fully vertical substrate transport
→ Special designed carrier transport system
→ Load and Unload of substrate from the same side of the machine
→ Usage of rotatable cylindrical magnetrons for highest utilization of target material
→ Temperature processing before and during deposition available
→ Gas separation by dynamic slit valves and/or by individual lock chambers
→ Smallest machine footprint through turn chamber technology
→ Easy maintenance, low CoO
→ Fast target exchange, use any vendor target
→ Easy expansion possible
→ Vacuum base pressure: < 1 x 10⁻⁶ mbar
→ Typical process pressure: 2 - 5 x 10⁻³ mbar
HISTARIS Inline Sputtering Systems with Horizontal Substrate Transport

The SINGULUS TECHNOLOGIES system with the brand name HISTARIS was developed for the requirements in the photovoltaic industry but also for applications in large area sputtering like architectural glazing, fuel cells and mobile devices. In photovoltaics the Inline sputtering systems are important in today’s CIGS & CdTe thin-film solar cell production.

The HISTARIS system was designed to enhance the efficiency and cutting production costs by using the state-of-the-art technologies. The modular design includes process chambers equipped with rotatable magnetrons for the sputter deposition of high-performance TCO layers or several other materials, such as metals and metal oxides. Pre-treating modules for cleaning or etching can be added. With its unique modular design, the HISTARIS system is ideally suited for challenging layer stacks and flexible product mixes.

Examples are transparent front or metallic back contact layers as well as multilayered precursors with a broad range of different materials. The main advantage of the system is that it can be used for horizontal vacuum-based coating of glass substrates in the solar industry. Typical applications include anti-reflection layers, barrier layers and precursor layers but also different metallic layers such as Al, Cu, NiV and more.
For photovoltaic technology, SINGULUS TECHNOLOGIES develops and manufactures thin film deposition systems which can apply special layers and layer systems on different substrates. In the market for thin-film photovoltaic SINGULUS TECHNOLOGIES adds another production stage to its range of processing systems for the manufacture of CIGS & CdTe thin-film solar cells.

The HISTARIS is using an inline process in which the substrates are transported on specially designed carriers or directly on a customized roller drive system. Different automation options for loading and unloading are available.

**Main Features HISTARIS**

→ Modular machine concept
→ Integrated power supply design
→ Horizontal substrate transport – with and without carrier
→ Usage of rotatable cylindrical magnetron for highest utilization of target material
→ Highest deposition rates
→ Temperature processing before and during deposition available
→ Gas separation by dynamic slit valves and/or by individual lock chambers
→ Easy maintenance, low CoO
→ Fast target exchange, use any vendor target
→ Vacuum base pressure: < 1 x 10^-6 mbar
→ Typical process pressure: 2 - 5 x10^-3 mbar

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The Modularity of the HISTARIS System Allows a High Degree of Flexibility

**HISTARIS LAB**

<table>
<thead>
<tr>
<th>Loading</th>
<th>Load Chamber</th>
<th>Extension Chamber</th>
<th>Process 1</th>
<th>Process 2</th>
<th>Extension Chamber</th>
<th>Unloading</th>
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**HISTARIS STANDARD**

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<th>Process 2</th>
<th>Gas Separation</th>
<th>Process 3</th>
<th>Process 4</th>
<th>Extension Chamber</th>
<th>Load Chamber</th>
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**HISTARIS SPEED**

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<th>Buffer Chamber</th>
<th>Extension Chamber</th>
<th>Process 1</th>
<th>Process 2</th>
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<th>Process 3</th>
<th>Process 4</th>
<th>Extension Chamber</th>
<th>Load Chamber</th>
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**HISTARIS Speed**

![HISTARIS Speed Image](image-url)
SELENIUS Evaporation System
Processing Systems for Evaporation of CIGS Thin-Film Solar Cells

Evaporation System for Thin-Film Solar

The inline co-evaporation tool is based on the thermal evaporation of CIGS-related precursor materials. It is dedicated to the deposition of copper-indium-gallium-selenium layers for the purpose to form optimum precursor layers in the application of CIGS thin-film solar modules. The evaporation system consists of a handling station, multiple substrate heating/cooling stations and deposition chambers.

The inline evaporation system is offering proven thermal deposition technology, that delivers a high material utilization and excellent layer uniformities. In combination with a high uptime and yield, the system leads to a highly optimized and flexible production platform.

Main Features

→ Inline evaporation tool with high throughput capability
→ Modular chamber design for a flexible layout conception to meet the production requests of the customer
→ Optimized utilization of evaporation material through unique chamber design
→ High deposition rate and repeatability
→ Excellent flux uniformity
→ Easy and fast source refilling/replacement due to user friendly source positioning
→ Optimized maintenance concept for maximum machine availability/uptime
→ Excellent temperature uniformity during process sequence
→ Substrate Pre-Heating
→ In-situ monitoring of flux and temperature
→ Proven safety concept based on solid risk management and safety engineering
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,
- Surface engineering.

In all of these applications SINGULUS TECHNOLOGIES offers 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 obtaining 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 develops and assembles innovative machines and systems for efficient and resource-saving production processes, which are used worldwide in the solar, semiconductor, medical technology, consumer goods and optical disc sectors.

The company’s core competencies include various processes of coating technology, surface treatment and wet-chemical and thermal production processes.