PRODUCTION EQUIPMENT

For Thin-Film Solar Cells (CIGS & CdTe)
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.
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 20 %. The efficiency of modules is in a range from 13 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 machines and turn-key lines for the production of next generation solar cells.
SINGULUS Offers the Key Production Systems for Thin-Film Solar Cells

In the Solar segment SINGULUS TECHNOLOGIES is a leading supplier for new production solutions for crystalline and thin-film 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.

In the past business years, development and pilot lines for important process steps in the CIS/CIGS manufacturing were developed and delivered. For the production of CIS/CIGS solar cells SINGULUS TECHNOLOGIES has introduced and delivered new machines and offers all relevant manufacturing steps:

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

SINGULUS TECHNOLOGIES ...offers all Key Production Steps for a reliable CIS/CIGS Cell Manufacturing
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

A large number of SINGULUS TECHNOLOGIES CIS/CIGS systems have been installed worldwide. References from many parts of the world like China, Germany, India, Korea, USA, and Singapore, South Africa & Taiwan prove the know-how of the company.

SINGULUS TECHNOLOGIES continues to expand its development partnerships and provides thin-film solar cell manufacturers with sophisticated machine technology guaranteeing the cost-efficient production of thin-film solar cells. We were successful in offering the relevant production equipment for the demanding CIS/CIGS technology as a one-stop provider. Accordingly, SINGULUS TECHNOLOGIES’ product range today already covers all relevant production steps, which determine the efficiency of the modules. Overall, this contributes to up to 70% of the investment volume of a thin-film factory. SINGULUS TECHNOLOGIES will continue to work on this strong market position as a process-independent technological leader to maintain the leading position in this area. Production capacities for CIS/CIGS based cells should further rise in the coming years. Based on the CIS/CIGS processes SINGULUS TECHNOLOGIES is able to provide customers qualified production lines and has gained extensive know-how to reduce the production costs together with the customers, to increase the cell performance and to enhance the cell output.

SINGULUS TECHNOLOGIES

...offers the Key Production Steps for a reliable CdTe Cell Manufacturing
As part of the product family VITRUM the new processing machine, VITRUM II Cover, 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 Cover 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

*depends on application

The VITRUM II provides the platform for wet-chemical inline process steps: 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 NPetch.

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.

The design of the VITRUM II features the same type of piping for all liquid circuits and generously dimensioned installation compartments for optimized maintenance work. It offers a high cycle rate and due to the modular concept is easy to be integrated into existing production lines. With the new VITRUM II process cost can be reduced substantially.

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
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 the TENUIS 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.

**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
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, the developers at SINGULUS were 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.

SINGULUS TECHNOLOGIES offers wet processing systems from R & D, through pilot use, to full production range 80, 150 and 300 MW.

For a higher throughput, several production machines can be combined to a large production complex.
CISARIS
Selenisation Furnace 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 25 MWp per year (depending on configuration).

**Main Features**

- Second 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 550 °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
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 550 °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.
VISTARIS
Inline Sputtering Systems with Vertical Transport Orientation

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 solar and display 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 cells.
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 thru 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 x10⁻³ mbar
CIGS R&D Platform
The CIGS R&D Platform is a Development Tool for the Production and Thermal Treatment for Photovoltaic Applications

R&D Tool for CIGS Development

The new CIGS R&D Platform is a development tool for the production and thermal treatment of semiconductor layers based on e.g. copper, indium, and gallium for photovoltaic applications. With the CIGS R&D Platform, economic research of new manufacturing processes for CIS/CIGS semiconductor films can be realized. In this way, the highest level of efficiency of thin-film solar modules compared to existing concepts can be achieved. With the process results on the basis of the findings from the demonstration plant, industrial manufacturing processes can be developed and optimized, enabling higher cell performances as well as a significant reduction of manufacturing costs for thin-film photovoltaic modules per watt peak.

The CIGS R&D Platform contains a central handling unit and several process stations. In the process stations the thermal treatment as well as deposition of the complete layer stack can be conducted. The system is designed for glass substrates up to 300 mm x 300 mm and can be set up in the following configuration:

- Central handling platform
- Loading/unloading station
- Sputtering unit Mo (Step 1) – Cu, In, Ga (Step 3) – iZnO, AZO (Step 8)
- Selenium deposition (Step 4)
- Thermal treatment & selenization, sulphurization (Step 5)
- Laser scribing (Step 2, 7 and 9)
- Buffer layer module (Step 6)
SELENIUS Evaporation System
Processing Systems for Evaporation of CIS/CIGS Thin-Film Solar Cells

Evaporation System for Thin-Film Solar

The inline co-evaporation tool is based on the thermal evaporation of CIS/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 CIS/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
SINGULUS TECHNOLOGIES is an engineering company and develops and builds machines for economic and resource-efficient production processes. The range of use of the machines built by SINGULUS TECHNOLOGIES include vacuum thin-film and plasma coating, wet-chemical cleaning and etching processes as well as thermal processing technology.

For all machines, processes and applications SINGULUS TECHNOLOGIES utilizes its know-how in the areas of automation and process technology in order to provide additional, attractive work areas with innovative products next to the existing application areas of Solar, Semiconductors and Optical Disc.