CISARIS

Furnace with High End Rapid Thermal Processing for an Optimized CIGS Absorber Formation

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CISARIS – Selenization/Sulphurization

with High End Rapid Thermal Processing for an Optimized CIGS Absorber Formation

SINGULUS TECHNOLOGIES

Developer, Enabler and Supplier for CIS/CIGS and CdTe Solar Cells

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 a photoactive compound is applied. Amongst others, alloys consisting of copper, indium, gallium and selenium or sulfur (CIGS), compounds of cadmium and tellurium (CdTe) 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.

SINGULUS offers leading-edge production systems for CIGS & CdTe thin-film solar panels made of glass and flexible substrates:

- → *Cleaning and etching machines*
- → *Metal free glass washing machines*
- → *R & D tools for CIGS development*
- → *Selenisation & sulphurisation furnaces*
- → *Sputtering & evaporation systems*
- → *Deposition systems for cadmium-free buffer layers*

1 *Large production furnace CISARIS*
2 *LAB-CISARIS*

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CISARIS – Selenization/Sulphurization

with High End Rapid Thermal Processing (RTP) for an Optimized CIGS Absorber Formation

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.

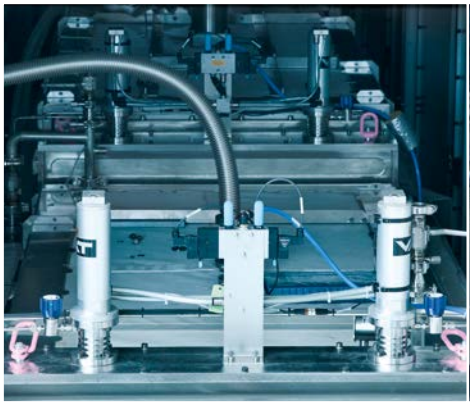
For CIGS cells the absorption layer is comprised of copper, indium, gallium as well as selenium and partly sulfur compounds. These thin-film cells have achieved laboratory efficiency levels of over 20 %. The efficiency of modules is in a range from 13 to 17 % depending on the module size. SINGULUS TECHNOLOGIES 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.

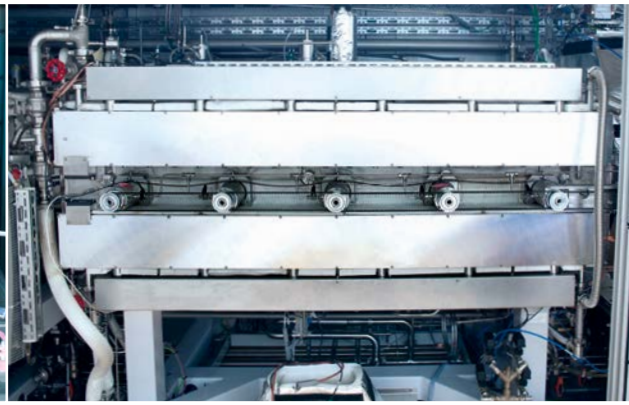
With our production equipment we are one of the few companies able to equip both efficiently running factories for the manufacturing of CIS/CIGS thin-film modules as well as single machines and turn-key lines for the production of next generation solar cells.

The CISARIS RTP furnace is an inline rapid thermal processing equipment, designed for the CIGS 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 CIS 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 and sulphurisation process, lead to a production capacity of over 25 MWp per year (depending on configuration, see page 7). CISARIS is a proven innovative and reliable equipment, which has been continously further developed at SINGULUS based on previous generations 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 solar modules.

Main Characteristics

- → Third generation inline selenisation & sulphurisation furnace with optimized cycle time
- → Rapid heating (up to ~ 4 °C/s) of large substrates with metal precursor coating (CIG)
- → Homogeneous gas distribution and low gas consumption through optimized inlet system
- → Introduction of H2S & 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 quality
- → Uniform cooling of the substrate to avoid glass warpage
- → Excellent temperature control (mean variation < 5 °C) at all process stages
- → Process under vacuum and at atmospheric pressure
- → Oxygen and water vapor free process atmosphere guaranteed through pump/purge cycles an continous gas monitoring
- → Excellent maintenance concept with maximum accessibility of all machine components
- → Proven safety system based on a solid risk management and safety engineering



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Key Components

The CISARIS machine consists of the following key components (example):

- Handling section:
  Transport of the substrates between the fab automation and the CISARIS
- Process section:
  - → Load chamber #1 (LC1):
    Pump and purge cycles to remove atmospheric residuals
  - → Load chamber #2 (LC2):
    First process gas inlet
  - → Heating section: (HC1/HC2/HC3/HC4/HC5)
    Five successive heating chambers for the formation of the CIGSSe absorber material including process gas inlet
  - → Cooling section: CC1/CC2
    Two successive cooling chambers for the cooling of the substrate down to the specified temperature
  - → Exit chamber (EC):
    Pump and purge cycles to remove toxic gases from the process chamber
- Return conveyor section:
  Returning the substrate to the handling system and additional cooling in a N2 atmosphere via forced convection in N2 cooling stations
- Periphery:
  - → Housing
  - → Cold traps (selenium absorbers)
  - → Oil heating system
  - → Pumping system
  - → Gas detection system
  - → Metrology

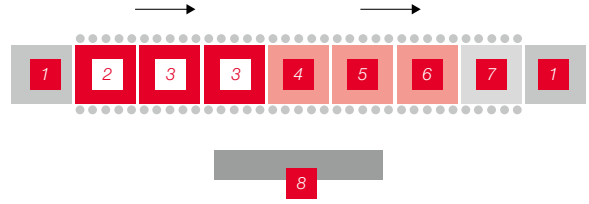
CISARIS – Production System

Technical Data

Material	CIG and CIGSe precursors on glass substrates	
Material Dimensions	approx. 1600 x 650 mm^2 (other substrate sizes on request)	
Material Thickness	2 - 3 mm (other thicknesses on request)	
Output	approx. 190.000 substrates/year	(example)
Footprint	36 x 10 m^2	(example)
Cycle Time	< 135 s	(example)
Uptime	> 85 % acc. SEMI E10	
Mechanical Target Yield	> 99,5 %	
Main Voltage	400 V 3AC/PE 50/60 Hz	
Other Required Utilities	cooling water, compressed air, process gases	

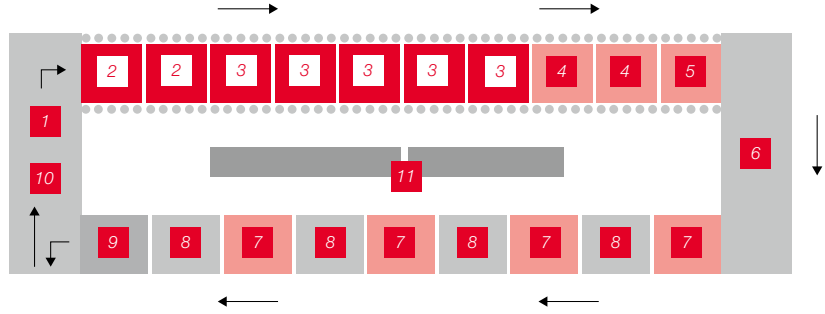
CISARIS Pilot Production Tool – H2Se/H2S Concept

1 *Transport cart for loading/ unloading*
2 *Entrance chamber*
3 *Heating/process chamber*
4 *Cooling chamber*
5 *Exit chamber*
6 *Cooling unit*
7 *Atm transition gate*
8 *Electrical cabinets*

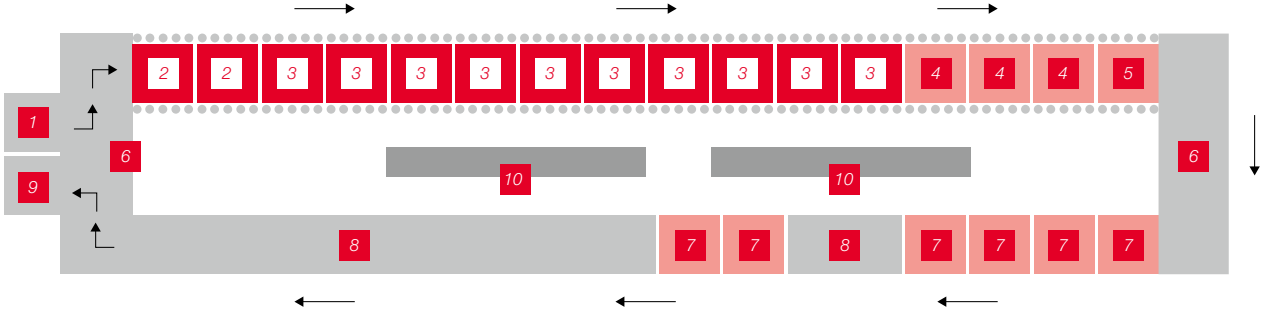


CISARIS Inline Diffusion Furnace for CIGS Solar Cells / approx. 25 MWp Throughput

1 *Handling station*
2 *Entrance chamber*
3 *Heating chamber*
4 *Cooling chamber*
5 *Exit chamber*
6 *Cross transport*
7 *Cooling units*
8 *Back transport*
9 *Atm transition gate*
10 *Substrate exchange station*
11 *Electrical cabinets*



CISARIS Inline Furnace H2Se/H2S Concept 60s Tact Time / approx. 50 MWp Throughput



1 *Loading*
2 *Entrance chamber*
3 *Heating/process chamber*
4 *Cooling chamber*
5 *Exit chamber*
6 *Cross transport*
7 *Cooling units*
8 *Back transport*
9 *Unloading*
10 *Electrical cabinets*

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THIN FILM DEPOSITION | SURFACE ENGINEERING | THERMAL PROCESSING | WET CHEMICAL

SINGULUS TECHNOLOGIES - Thin-Film Coating and Surface Treatment

SINGULUS TECHNOLOGIES develops and assembles innovative machines and systems for efficient thin-film coating and surface treatment processes, which are used worldwide in the Photovoltaics, Semiconductor, Medical Technology, Packaging, Glass & Automotive as well as Battery & Hydrogen markets. The company's core competencies include various processes of coating technology, surface treatment as well as wet-chemical and thermal production processes. SINGULUS TECHNOLOGIES sees sustainability as an opportunity to position itself with innovative products. In the focus are:

- → *Environmental awareness*
- → *Efficient use of resources*
- → *Avoidance of unnecessary CO_2 pollution*

SINGULUS TECHNOLOGIES attaches great importance to responsible and sustainable corporate governance.

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