SMART SOLUTIONS TO DRIVE THE FUTURE

Overview

Company and Products

Photovoltaik
## Agenda

<table>
<thead>
<tr>
<th></th>
<th>Agenda Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SINGULUS Technologies AG - Fundamental</td>
</tr>
<tr>
<td>2</td>
<td>Overview Singulus Group Product Portfolio</td>
</tr>
<tr>
<td>3</td>
<td>Overview Product Portfolio Photovoltaik</td>
</tr>
<tr>
<td>4</td>
<td>Product Portfolio Crystalline</td>
</tr>
<tr>
<td>5</td>
<td>Product Portfolio Thin Film</td>
</tr>
<tr>
<td>6</td>
<td>Tenuis Gen 2 CBD Toolset</td>
</tr>
<tr>
<td>7</td>
<td>Washing- and Etching Technology</td>
</tr>
</tbody>
</table>
Fundamental Informations

The Cooperated Headquarter
Milestones
Worldwide Connected
Singulus Technologies AG

Cooperated Headquarter
Kahl/Main - Germany

<table>
<thead>
<tr>
<th>Financial Key Figures 2011</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>160,0 Million Euro</td>
</tr>
<tr>
<td>EBITDA</td>
<td>18,5 Million Euro</td>
</tr>
<tr>
<td>Employees (31.12)</td>
<td>455</td>
</tr>
</tbody>
</table>
Milestones Singulus Technologies AG

- Foundation SINGULUS Technologies
- IPO SINGULUS Technologies AG at TecDAX
- Acquisition in Mastering & Moulding
- 2. Mastering Acquisition
- First Sales of Blu-ray Production Systems
- Acquisition of STANGL
- Entry into PV Market
- Acquisition of HamaTech
- Acquisition of Blu-ray from Oerlikon
- 1st Delivery of SINGULAR
- 1st CISARIS Order
- Market leader Blu-ray *
- New Order for TIMARIS
- New Solar Products
- Major CISARIS Order

- 1995
- 1996
- 1997
- 2001
- 2002
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012

- 2007
- 2008
- 2009
- 2010
- 2011
- 2012

* according to own assessment
Singulus Technologies AG – Fundamental

Milestones Singulus Stangl Solar GmbH

Foundation STANGL as a family enterprise

Development CBD f. Buffer Layer (Single Side System)

1988

1992

2004

2006

2007

2008

2009

2010

2011

2012

Introduction VITRUM Platform

Gen 2 Market Introductions of SILEX, VITRUM and TENUIS Platform’s

SINGULUS acquired 51% of STANGL

Delivery first PV production equipment (c-Si)

Delivery first TENUIS CBD mass production equipment

SINGULUS acquired 100% of STANGL

New Facility SINGULUS STANGL SOLAR GmbH

Market Introduction SINGULUS IPA Free Texturing Additive

Milestones only PV related
Worldwide Connected

- Headquarter Singulus
- Headquarter Stangl
- Sales & Service Subsidiaries
- Repr.
Agenda

Group Product Portfolio
Singulus Group Product Portfolio

- **Optical Disc**
  Mastering, Molding and Replication for all disc formats CD – DVD – Blu-ray

- **Solar**
  Coating (Vacuum Applications), Wet Processing and Systems Business for Crystalline and Thin Film

- **Semiconductor**
  Advanced Vacuum Coating applications for MRAM, Thin Film Heads and Sensors
Overview Product Placement at the Photovoltaik Sector’s PV Product Portfolio’s

- Thin Film Product Portfolio
- System Business Crystalline
Overview Solar Product Placement

Mono Crystalline

Multi Crystalline

Silicon Wafer

Thin Film

Thin Silicon Film

Semiconductor Compound Based

Thin Film II-VI

Amorphous (a-Si)

Tandem (a-Si/c-Si)

Thin Film (c-Si)

CIS/CIGS

CdTe
Photovoltaic Product Portfolio

Crystalline Product Portfolio

**MATERIA PCE**
Poly Silicon Chunk Etching, Cleaning and Drying

**GERULUS**
Wafer Block Pre-Cleaning and Degluing System

**SILEX**
IPA-Free System for Cleaning, Texturing and PSG Removal

**LINEA**
Inline System for Cleaning, Texturing and PSG removal
Crystalline Product Portfolio

**SINGULUAR**
- Static Inline
- ICP-PECVD
- Anti Reflection Coating

**REAR SIDE PVD**
- Market Introduction soon

**POLISH ETCH (PERC CELL)**
- Back Side Polish
Photovoltaic Product Portfolio

Thin Film – CIGS/CdTe – Product Portfolio (Wet Applications)

**TENUIS**
CBD System on glass for single sided CdS Buffer Layer

**IMPEDIO**
CBD System on foil for single sided CdS Buffer Layer

**VITRUM**
Cleaning, Etching, Coating of glass substrates

**ILGAR**
APCVD Tool for Cd-free alternative Buffer Layer InCl2
Thin Film – CIGS/CdTe – Product Portfolio (Dry Applications)

**CISARIS**
Selenisation *
Furnace for CIGS Absorber Formation

**SPUTTER (PVD)**
Vertical High Vacuum Inline (Mo, CuGa, In, TCO)

**EVAPORATION**
Co-Evaporation System (e.g. Cu, In, Ga)

**R&D PLATFORM**
Integrated CIGS Cell R&D Tool

* and/or Sulphurization – depending on the process
Agenda

- Tenuis Gen2 Overview
- Tenuis Production Line 100 MW
- Comparsion Batch vs. Tenuis System
Tenuis Gen2 Basic Features

- Proven process based on Gen 1 (more the 130 modules in field/operation)
- Increases cell efficiency by app. 0.1-0.2% abs.
- Process time reduction up to 30% by RTB support
- Cost saving 30% and 50% footprint reduction vs. Gen 1 System
- Lowest possible chemical consumption
- Prepared for Zn(O)S altern. Buffer
- In Line Process Chamber Cleaning
- RTB System (Rapid-Temp.-Booster)
- New Dosing System (5 times faster)
- Optimizes Water Recycling Concept (reduction of running costs by approx. 30%) ZERO liquid
# Tenuis Gen2 Overview

## Tenuis Gen 1 vs. Gen 2

<table>
<thead>
<tr>
<th></th>
<th>Tenuis Gen 1</th>
<th>Tenuis Gen 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass Parameter/size max.</td>
<td>1600 x 1200 mm</td>
<td>1600 x 1200 mm</td>
</tr>
<tr>
<td>Process Time per Substrate *</td>
<td>780 sec.</td>
<td>300-700 sec.</td>
</tr>
<tr>
<td>Efficiency Increase</td>
<td>--</td>
<td>0.1-0.2 % absolute</td>
</tr>
<tr>
<td>Inline process Chamber cleaning **</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Process Chamber design</td>
<td>GFK</td>
<td>Titan/PP</td>
</tr>
<tr>
<td>cleaning cycle for process chamber</td>
<td>up to 850 depositions</td>
<td>up to 1500 depositions</td>
</tr>
<tr>
<td>Chemical Supply tank system</td>
<td>Decentral</td>
<td>central</td>
</tr>
<tr>
<td>Temperature Profile</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Alternative Buffer</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Heating Concept</td>
<td>via fluid heating</td>
<td>via RTB</td>
</tr>
<tr>
<td>Inline temperature measurements</td>
<td>No</td>
<td>Yes (via Pyrometer)</td>
</tr>
</tbody>
</table>
Tenuis Gen2 Overview

Schematic View Process Module 1200x600 mm (4 Substrates)
The new dosage system bring the following advantages to TENUIS Gen 2:

- Improvement of dosage time (chemical fill on substrate - closed media level < 10 sec.)
- Not spot’s according pump supply instead of gravity drain on substrate
- Optional integrated heating-system (jacket heating) with max. 45-50°C
- Rest Chemical volume < 5ml after dosage-step
- Separate dosage line for THS (not via dosage system)
Flexible programmable Dosage Recipes

Dosage DI-Water
- Dosage NH4OH
- Dosage Cd-Salt
- Dosage THS
- Dosage Pre-Mixed NH4OH / Cd-Salt / DI-Water

Dosage Example 1 – Step-by-Step – Advanced Recipe
Dosage Example 2 – Pre-mixed – Standard Recipe
Agenda

Tenuis Gen2 Production Line 100 MW
Tenuis Production Line 100 MW

Improved 100 MW Layout with 20 sec. cycle-time (1200x600 mm)

- Reduction of footprint
- Reduction of CAPEX
- Maintenance Improvement
- Compact Design (all-in-execution)
- Installation and Start-Up time schedule improvement
Tenuis Gen 2 Production Line 100 MW

Improved 100 MW Layout with 20 sec. cycle-time (1200x600 mm)

Dosage tank system

VITRUM Final Rinse System

Loading-/Unloading Conveyer

Optional VITRUM KCN Etching System

9x Process Module (ã 4x 1200x600 substrates)

6-axis Robots on linear handling system

Feed OUT

Feed IN

RTB SYstem
# Tenuis Gen 2 Production Line 100 MW

## Tenuis Gen2 Scope of Supply (with optional equipment)

### TENUIS Production Line

**TOTAL PACKAGE SOLUTION**

<table>
<thead>
<tr>
<th>CBD – Process with pre and post treatment</th>
<th>Chemical supply systems</th>
<th>Customized Facility</th>
<th>Customer Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>TENUIS Process Module</td>
<td>Cd-salt</td>
<td>Waste water treatment with recycling</td>
<td>After sales service</td>
</tr>
<tr>
<td>VITRUM KCN</td>
<td>THS-salt</td>
<td>DI-Water plant</td>
<td>Process support</td>
</tr>
<tr>
<td>VITRUM Clean</td>
<td>NH4OH</td>
<td>Exhaust scrubber</td>
<td>R&amp;D of alternative buffer</td>
</tr>
<tr>
<td>Automation</td>
<td>H2SO4</td>
<td></td>
<td>Training</td>
</tr>
<tr>
<td>MES connection</td>
<td>H2O2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vacuum station</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Agenda

Comparison TENUIS vs. BATCH
## Advantages TENUIS Single Side CBD vs. Batch Applications

<table>
<thead>
<tr>
<th></th>
<th>Batch</th>
<th>Tenuis Gen2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deposition Side</strong></td>
<td>--</td>
<td>Double sided</td>
</tr>
<tr>
<td><strong>Chemical Consumption</strong></td>
<td>--</td>
<td>20 l/m²</td>
</tr>
<tr>
<td><strong>Temperature Uniformity</strong></td>
<td>++</td>
<td>+/- 2°C</td>
</tr>
<tr>
<td><strong>Layer uniformity</strong></td>
<td>O</td>
<td>+/- 5%</td>
</tr>
<tr>
<td><strong>Uptime</strong></td>
<td>--</td>
<td>appr. 85%</td>
</tr>
<tr>
<td><strong>RC incl. WWT per watt</strong></td>
<td>--</td>
<td>0,05 €</td>
</tr>
<tr>
<td><strong>Efficiency Increase</strong></td>
<td>--</td>
<td>No</td>
</tr>
<tr>
<td><strong>add. Equipment Cost for BSR</strong></td>
<td>--</td>
<td>appr. 750.000 €</td>
</tr>
<tr>
<td><strong>RC of BSR per watt</strong></td>
<td>--</td>
<td>0,01 €</td>
</tr>
<tr>
<td><strong>Temperature Profiles</strong></td>
<td>--</td>
<td>No</td>
</tr>
<tr>
<td><strong>Subsequent dosing steps</strong></td>
<td>--</td>
<td>No</td>
</tr>
<tr>
<td><strong>Accelerated process optimization</strong></td>
<td>--</td>
<td>Same recipe for all samples</td>
</tr>
</tbody>
</table>

* RC = Running Cost | ** according RTB System; depending on Absorber | *** BSR = Back Side Removal
Agenda

- CdS vs. ZnS Buffer Layer
Alternative Buffer Layer

CdS Buffer Layer Deposition – CdS Baseline Process

Dosage System – Pre Mixed Solution

- Dosage DI-Water
- Dosage NH4OH
- Dosage CdSO4 (Cd-Salt)
- Dosage THS (separate dosage line)

Rinse Start (DI)

Process time 300 seconds @ 50 nm

Substrate Glass with Absorber
Substrate surface temperature

Hotplate 65°C

Cds Buffer Layer 50nm

Rinse process (DI)
Alternative Buffer Layer

ZnS Buffer Layer Deposition – Baseline Process

Dosage System – Pre Mixed Solution

- Dosage DI-Water
- Dosage NH4OH
- Dosage ZnSO4 (Zn-Salt)
- Dosage THS (separate dosage line)

Dosage System

- Process (Reaction) Start
  - Process time 800 seconds @ 25 nm

- Process (Reaction) End
  - Rinse process (DI)

- Rinse Start (DI)
  - ZnS Buffer Layer 20 nm
  - Substrate Glass with Absorber

- Hotplate 80°C Substrate surface temperature

- Annealing Process 600 sec. @ 150°C

* excluding the Annealing Process
### Alternative Buffer Layer

**ZnS Buffer Layer Deposition – Optimized**

**Dosage System – Pre Mixed Solution**
- **Dosage DI-Water**
- **Dosage NH4OH**
- **Dosage ZnSO4 (Zn-Salt)**
- **Dosage THS (separate dosage line)**
- **Dosage H2O2 (separate dosage line) - Acceleration additive**
- **Rinse Start (DI)**

**Process (Reaction) Start**
**Process (Reaction) End**

**Process time**
300 seconds @ 25 nm

**Substrate Glass with Absorber**

**ZnS Buffer Layer 20 nm**

**Hotplate 80°C Substrate surface temperature**

**Annealing Process**
600 sec. @ 150°C

*excluding the Annealing Process*
Agenda

Washing Technology
VITRUM GEN 2 – One platform for all wet applications
VITRUM GEN 2 – Pre- and post-treatment

VITRUM ETCH KCN
Etching of metallic phases with KCN

VITRUM ETCH NH₄OH
Etching of oxides, preconditioning of the absorber

VITRUM ETCH COVER
Single Side etching (e.g. removal of CdS after batch CBD)
Vitrum Washing Technology

**VITRUM GEN 2 – Facts**

- Proven process based on Gen 1
- Over 60 systems installed in field
- Optimized chemical and DI-water consumption
- Unique cascade rinsing concept
- New designed air knifes to minimize the drag over
- Completely metal free to increase efficiency
- Flow for every spray bar couple individually adjustable
- Optimized spray pattern with cone jet and flat jet nozzles
- Automated refreshment on conductivity adjustable
- Tear 1 suppliers (Iwaki, GF, GEMÜ, SMC, Festo, Siemens)
Vitrum Washing Technology

VITRUM GEN 2 – Installation compartment

- Generous installation compartment
- Quality pumps, magnetically coupled, high reliability
- High flow filters with difference pressure measurement
- Identical circulation lines --> minimized spare parts
- Integrated double safety compartment (chemicals split)
- Optical flowmeter with limit contact, (electronic flowmeter, optional)
VITRUM GEN 2 – Software

- New designed software based on WinCC
- Very user friendly, all relevant parameters are displayed, recorded and adjustable
- Hardware is realized via Siemens S7
- Different interfaces (Ethernet, Profi-Bus, SECS/GEM, MES)
Vitrum Washing Technology

VITRUM GEN 2 – Feed In Glass Cleaner

- High Pressure and Separol removal section (metal free)
- Brush off section and 3-fold cascaded rinsing section
- Optimized water consumption
- Built for non-stop utilization: 24/7, 360 days/year
- High availability (uptime > 98%)
- High throughput (max. 100 mm/sec)
  @ 1200x600 mm: **12 seconds tag-time**
- Metal free rinsing and drying section
- Fully automated process control
- System executed to process Glass Substrates and flexible Foil Material (stainless steel)
VITRUM GEN 2 – Single Side Etch

Single side etching tool:

- protection of the active layer by process cover
- pencil and rear side etching with brushes and chemicals
- Automated process control

Only tool on the market with the ability to clean the backside and the edges without any harm to the active layers.
Questions & Answers

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