**SINGULUS TECHNOLOGIES focuses on Photovoltaics: Smart Solutions for Crystalline Silicon & Thin Film Solar Technology**

SINGULUS TECHNOLOGIES is the world leader in manufacturing mass production equipment for Optical Discs CD/DVD/Blu-ray. In the Solar segment, SINGULUS and STANGL are cooperating with leading cell manufacturers in the development of new technologies and new plant concepts for improved cell concepts with higher efficiency and production technologies with decreasing production costs. The company’s target is to position itself at the forefront for the introduction of new technologies with respect to silicon as well as thin film solar technology. During times of cost pressures in the photovoltaics market, the interest regarding new plant concepts increases. In the coming years, SINGULUS will offer a broad product range of new machines for the photovoltaics industry, which will offer manufacturers of both silicon and thin-film cells new production technologies and particular cost advantages.

SINGULUS and SINGULUS STANGL SOLAR will systematically expand the solar activities. Both companies complement each other ideally in being able to offer a broad product range of machines and equipment for the photovoltaics industry in the coming years.

**Crystalline Silicon Solar Technology**

In the area of crystalline silicon solar technology, SINGULUS TECHNOLOGIES delivered the first SINGULAR inline coating machine for anti-reflective coating of silicon solar cells as well as STANGL’s newly developed inline cleaning system LINEA with the corresponding fully-automated wafer handling system in November 2009. Since that time, SINGULUS realized the first installation of a so-called front-end system. A European solar cell manufacturer accepted the first setup in early July 2010 including two LINEA and one SINGULAR system.

The company’s goal with respect to silicon solar technology is to assume a leading position in the market by launching new production technologies. In the future SINGULUS will not only supply individual machines and equipment for the silicon solar technology but will also actively market so-called front end systems as well as complete production systems for the cell production with process know-how in the solar market. SINGULUS and STANGL already possess the fundamental expertise for wet-chemical and AR-coating processes. This enhancement of the business model from single machines towards systems was also successful in the Optical Disc market some years ago.
SILEX – Wet Process Equipment for Cleaning, Texturing and PSG Removal

Today’s dominating solar cell concept is based on cells made from crystalline silicon. STANGL provides completely automated dry-in/dry-out solutions for wet treatment of Si wafers in standard and high-efficiency cell lines. Batch-type working wet benches (WB series) are the “workhorses” for cleaning and etching processes in Si-cell technology.

Main Features
- Proven, highly integrated design
- High throughput up to max. 1,500 or 3,000 wph
- High availability (uptime > 95 %)
- Low breakage rate (< 0,05 %)
- High flexibility in process sequence, wafer type, wafer size
- Wafer thickness down to 150 μm
- Internal automatic chemical bath management
- Reproducible process results by complex process parameter control
- Network communication support
- Carrier tracking and data logging
- Compliance with international safety regulations
STANGL Wet Process Machines in c-Si Solar Cell Production Lines

Si-Cell Production Step-by-Step:  
- **STANGL – SILEX**
- **STANGL**
- **SINGULUS**

- Wafer Multi/Mono
- Wafer Inspection
- Saw Damage Removal & Texturing
- Junction Formation
- Oxide Removal
- Precleaning
- Alkaline Saw Damage Removal & Texture
- Acidic Texturing (Isotexturing)
- Acidic Wafer Polishing/Thinning
- AR-Coating + Passivation, PECVD SiNx, H
- AR-Coating & Passivation, PECVD SiNx, H
- Solar Cell Testing & Sorting
- Edge Isolation
- Print & Fire Front-/Backside Contact
- Maintenance & Support:  Boat Cleaning, Wafer Rework, Chemical Supply Systems
Main Components

1 Housing
- Stable modular main frame, completely covered by PP-panels
- Main systems for bath management, electrical cabinets and process control units are integrated into housing
- Safety gas sensor system for detection of harmful gas concentrations (NOX, H2, HF)

2 Load / Unload Conveyor
- Manual or automated feed-in and take-out of wafer carriers
- Integrated carrier buffer with 6 positions
- Safety interlock of human or automation interaction
- RFID transponder identification

3 Central Robot Handling
- Automated AC servo booster handling system guarantees quick, reliable and gentle carrier motion
- Up to 3 parallel working x-z-robots
- Sensitive crash protection sensor system

4 Pre-Cleaning, Saw Damage Removal
- Initial organic and particle cleaning of incoming wafer material in hot alkaline cleaning mixtures (up to 80 °C)
- Optional ultrasonic power integration for improvement of cleaning efficiency

5 Alkaline Texturing (ALTEX)
- Preferably dedicated for texturing of monocrystalline Si wafers
- Removal of crystalline surface defects, forming random pyramids
- Uniform etching
- Compliant to international safety standards for explosive atmospheres

6 Acidic Texturing (ISOTEX)
- Preferred process for state-of-the-art texturing of multicrystalline Si wafers
- Removal of crystalline surface defects by using HF-HNO3 mixtures
- The high-flow bath recirculation in association with the effective chilling system guarantees excellent temperature control
- NOX-emission control during ongoing process and carrier transfer

7 Porous Si-Etch (PorSi)
- Short dip-treatment in a cold alkaline solution etches off the thin layer of porous silicon, caused by previous isotexturing step

8 Cleaning
- Acidic cleaning using HF and HCl for effective removal of metal contaminations and native oxides

9 Oxide Etch (PSG removal)
- Removal of P-doped SiO2-layer from wafers, formed during previous POCI-diffusion
- Self-limiting ambient DHF etch step

10 Rinsing
- Optimized rinsing technology in terms of
  - Fresh water flow
  - Partial water reclaim
  - Mechanical support and temperature enhancements
  - Intelligent combination of highly effective dump-spray rinse and water-saving multi-cascade overflow rinse

11 Drying
- Stress-free 2-step drying process ensures perfect uniform, chemical and spot-free drying of wafers down to 150 μm with lowest risk of breakage
- Compatible with all common low surface carrier types

12 Integrated Process Control
- Weight determination of wafer carriers pre- and post process for internal etch rate control
- Individual chemical bath management for filling and spiking of chemicals and DI-water
- Temperature control of all heated and cooled process steps
- Control of recirculation and injection flow rates
- Individual process time control
- Optional online/offline analysis of chemical compositions by titration, conductivity measurement and/or IR spectroscopy
- Resistivity measurement
- Process data storage and logging, 13 central machine control systems
- Siemens SIMATIC S7 PLC system
- Bus systems for internal communication of sub-assembly systems
- OPC interfaces for external data exchange

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<table>
<thead>
<tr>
<th>Main Features</th>
<th>WB-PSG1500 RL/LR</th>
<th>WB-PSG3000 RL/LR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimension L/W/H mm:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet bench</td>
<td>6700/2300/3060</td>
<td>8500/2300/3060</td>
</tr>
<tr>
<td>Option sump pump tank</td>
<td>within footprint</td>
<td>within footprint</td>
</tr>
<tr>
<td><strong>Capacity max.:</strong></td>
<td>1500 wph</td>
<td>3000 wph</td>
</tr>
<tr>
<td><strong>Wafer Material:</strong></td>
<td>Si, mono, multi, 156 x 156 mm, &gt; 150 µm</td>
<td></td>
</tr>
<tr>
<td><strong>Batch Size:</strong></td>
<td>100 wafer</td>
<td>200 wafer</td>
</tr>
<tr>
<td><strong>Utilities:</strong></td>
<td>( \text{N}_2, \text{CDA, DI-water} )</td>
<td>( \text{HF, KOH, HCl, IPA} )</td>
</tr>
<tr>
<td><strong>Exhaust:</strong></td>
<td>2700 m³/h</td>
<td>3600 m³/h</td>
</tr>
<tr>
<td><strong>Typical Cycle Time:</strong></td>
<td>270 s</td>
<td>270 s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Main Features</th>
<th>WB-ALTEX1500 RL/LR</th>
<th>WB-ALTEX3000 RL/LR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimension L/W/H mm:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet bench</td>
<td>13000/2300/3060</td>
<td>17000/2300/3060</td>
</tr>
<tr>
<td>Heater station</td>
<td>1200/1400/1200</td>
<td>1200/1060/2300</td>
</tr>
<tr>
<td>DI-water heater</td>
<td>800/600/1600</td>
<td>2500/1000/2300</td>
</tr>
<tr>
<td>Option sump pump tank</td>
<td>2500/500/600 per unit</td>
<td>2500/500/600 per unit</td>
</tr>
<tr>
<td><strong>Capacity max.:</strong></td>
<td>1500 wph</td>
<td>3000 wph</td>
</tr>
<tr>
<td><strong>Wafer Material:</strong></td>
<td>Si, mono, multi, 156 x 156 mm, &gt; 150 µm</td>
<td></td>
</tr>
<tr>
<td><strong>Batch Size:</strong></td>
<td>200 wafer</td>
<td>200 wafer</td>
</tr>
<tr>
<td><strong>Utilities:</strong></td>
<td>( \text{N}_2, \text{CDA, DI-water, PCW, tap water} )</td>
<td>waste drains ( \text{HF, KOH, HCl, IPA} )</td>
</tr>
<tr>
<td><strong>Exhaust:</strong></td>
<td>8000 m³/h</td>
<td>9500 m³/h</td>
</tr>
<tr>
<td><strong>Typical Cycle Time:</strong></td>
<td>270 s</td>
<td>270 s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Main Features</th>
<th>WB-ISOTEX1500 RL/LR</th>
<th>WB-ISOTEX3000 RL/LR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimension L/W/H mm:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet bench</td>
<td>15000/2300/3060</td>
<td>17000/2300/3060</td>
</tr>
<tr>
<td>Chiller station</td>
<td>800/1200/1500</td>
<td>1000/1000/2500</td>
</tr>
<tr>
<td>Day tank</td>
<td>integrated</td>
<td></td>
</tr>
<tr>
<td>Option sump pump tank</td>
<td>2500/500/600 per unit</td>
<td>2500/500/600 per unit</td>
</tr>
<tr>
<td><strong>Capacity:</strong></td>
<td>1500 wph</td>
<td>3000 wph</td>
</tr>
<tr>
<td><strong>Wafer Material:</strong></td>
<td>Si, multi, 156 x 156 mm, &gt; 150 µm</td>
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</tr>
<tr>
<td><strong>Batch Size:</strong></td>
<td>200 wafer</td>
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</tr>
<tr>
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<td>( \text{N}_2, \text{CDA, DI-water, PCW, tap water} )</td>
<td>waste drains ( \text{HF, KOH, HCl, HNO}_3, (\text{HAc}) )</td>
</tr>
<tr>
<td><strong>Exhaust:</strong></td>
<td>6500 m³/h</td>
<td>8500 m³/h</td>
</tr>
<tr>
<td><strong>Typical Cycle Time:</strong></td>
<td>120-270 s</td>
<td>120-270 s</td>
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