

### Improved Efficiency of CIGS Solar Cells by ALD ZnS Buffer Layer

*One of the most promising cells today is copper-indium-gallium-diselenide (CIGS). This thin film cell type is expected to mature shortly into a cost competitive technology. Atomic layer deposition (ALD) can be used to improve the efficiency of CIGS solar cells by more than 1 percentage point. This is achieved by depositing a dense and conformal zinc oxysulfide Zn(O,S) buffer layer. Using ALD conveniently eliminates the only liquid phase deposition step, chemical bath deposition (CBD), from the process flow, which in turn simplifies production routines and significantly reduces cost.*

The Thin Film System TFS 1200 from Beneq is designed for in-line or multi-module batch buffer layer deposition on CIGS. It can coat 1200 × 1600 (mm) panels at a throughput of up to 60 panels per hour equivalent to a total of 140 MW<sub>p</sub> per year.



### Coating specifications

Materials	Zn(O,S) (Zn,Mg)O (optional)						
Thickness	20 - 50 nm						
Process temperature	120 - 130 °C						
Throughput and productivity Beneq TFS 1200 in-line coating module	<table border="0"> <tr> <td>panel amount</td> <td>5 panels/h (for 50 nm Zn(O,S) coating)</td> </tr> <tr> <td>panel size</td> <td>1200 × 1200 (mm)</td> </tr> <tr> <td>annual capacity</td> <td>~ 6.5 MW<sub>p</sub>/a</td> </tr> </table>	panel amount	5 panels/h (for 50 nm Zn(O,S) coating)	panel size	1200 × 1200 (mm)	annual capacity	~ 6.5 MW <sub>p</sub> /a
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## Increased cell efficiency

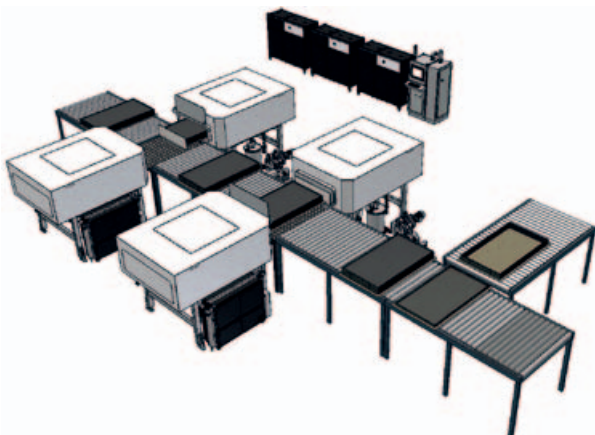
- Beneq ALD technology enables replacing the conventional cadmium sulfide (CdS) buffer layer with one with a higher band gap energy and light transmission, thus resulting in a more than 1 percentage point increase in unit efficiency.
- With ALD, it is possible to adjust and optimize the oxygen/sulfur (O/S) ratio of the film type for the CIGS panel.
- The intrinsic properties of ALD coatings, conformal and dense, enable enhanced blocking of pinholes in the CIGS cells.

## Adapted to industrial production

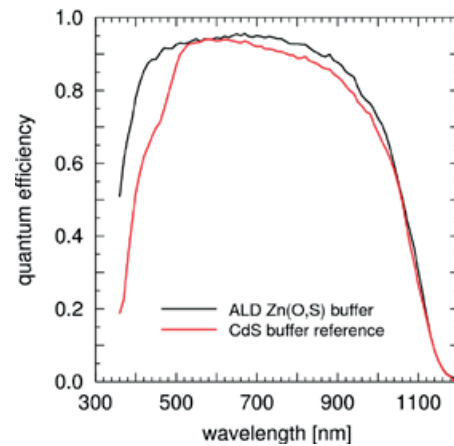
ALD offers a manufacturer of CIGS solar cells the opportunity to introduce cadmium-free buffer layers, which translates into less load on the environment and less stringent in-house material safety routines. There is no need for CBD in the manufacturing process flow. ALD is a dry coating process, which means there is no excessive water handling, no toxic effluents and no need for waste water purification. In addition, Beneq ALD equipment can be seamlessly integrated into the production line, alongside other vacuum deposition steps, resulting in negligible exposure of the substrate to atmospheric gases.

## TFS 1200 production system

- in-line or batch configuration
- thermal ALD process
- dry process in vacuum
- low cost-of-ownership



Beneq TFS 1200B batch system with four process modules.



Quantum efficiency of CIGS cells with ALD deposited Zn(O,S) (black line) and CBD deposited CdS (red line) buffer layers, as a function of wavelength. ALD processing results in improved performance both in the short wavelength region (better  $J_{sc}$ ) as well as the long wavelength region (higher  $V_{oc}$ ).

Zimmermann, U., Ruth, M. and Edoff, M., 21<sup>st</sup> European PV Solar Energy Conf. 2006, Dresden.



Since 2008, Beneq holds the world record in substrate size in ALD coating: 1200 × 1200 (mm).



Beneq WCS 500 Roll-to-Roll ALD system for flexible substrates including flexible CIGS solar cells.

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