SolR: in-line roll-to-roll application

LayTec has developed a new in-line monitoring system that is capable of measuring the properties of the layers throughout the solar cell manufacturing roll-to-roll processes: layer thickness of each layer, conductivity fingerprints of transparent color values, oxide layers, effective absorption and roughness. LayTec's contactless optical monitor SolR helps to keep the processes tightly within the specification limits by direct feed-back to the growth control system and statistical process control to identify and correct process derivations, accelerate development cycles, transfer established processes to new lines and re-establish conditions after maintenance.

SolR is based on specular spectroscopic reflectance measurements (500-1600 nm) and is applicable basically to all major PV thin-film structures: CIGS- and CdTe-based thin-film solar cells, a-Si/µc-Si tandem cells and anti-reflective coatings on mc-Si and c-Si solar wafers. Since light reflected from the surface and all interfaces within a layer stack interferes, the spectrum of the reflected light shows an interference pattern bearing information on the refractive index n, the index of absorption k and the thickness d of all layers so far deposited in the PV thin-film process. A special communicating system between several metrology stations in roll-to-roll production processes allows taking reflectance spectra after every single deposition step. The **SolR** system is adaptable to virtually any roll-to-roll process equipment. The small optical heads can be installed in-line as shown in **Fig. 1** and **Fig. 2.**

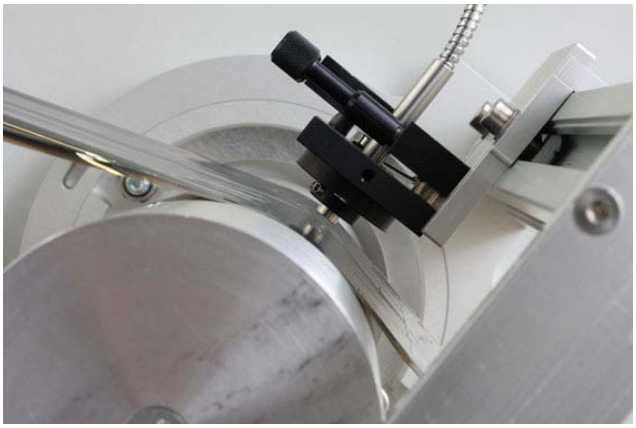

Fig. 1: Optical head of the SolR installed in a roll-to-roll system for investigation of CIGS-based structure on foil.

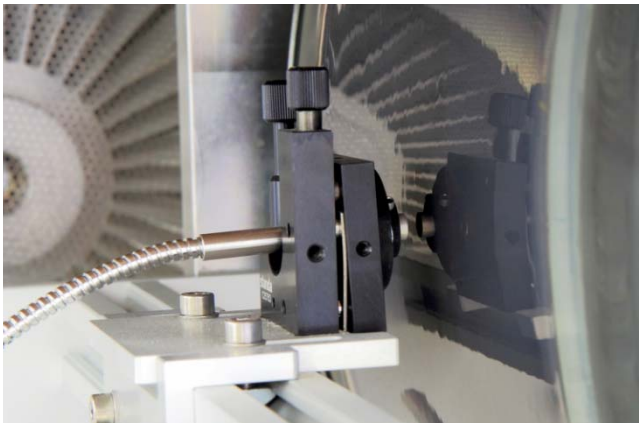

Fig. 2: Optical head of the SolR installed in a roll-to-roll TCO coater system.

The **SolR** control computer communicates with the production line control software to assure that measurements after each deposition step relate to the same position. To overcome the scattering of rough materials, we have developed focusing optical heads with large aperture for detecting specular reflection; the heads additionally suppress artefacts caused by substrate bow.

Fig. 3 shows real-time thickness measurements during a roll-to-roll process. The first two optical heads are measuring before and after the deposition of the CdS buffer (wet chemical process) on a flexible substrate. In the next step, after deposition of the i-ZnO layer and the Al:ZnO layer, film

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thickness measurements are performed in a similar way. **Fig. 3a** shows typical thickness measurements of the CIGS absorber layer (**Fig. 3a** lower curve) taken by the first measurement head and CdS buffer layer (**Fig 3a** upper curve) taken by the second measurement head. It can be seen that the thickness of the CIGS absorber layer is varying between 1900 and 2000 nm showing small fluctuations in process conditions. The thickness of the CdS buffer layer is slowly decreasing from approximately 65 nm to 50 nm as indicated by the red line. This is likely caused by source depletion.

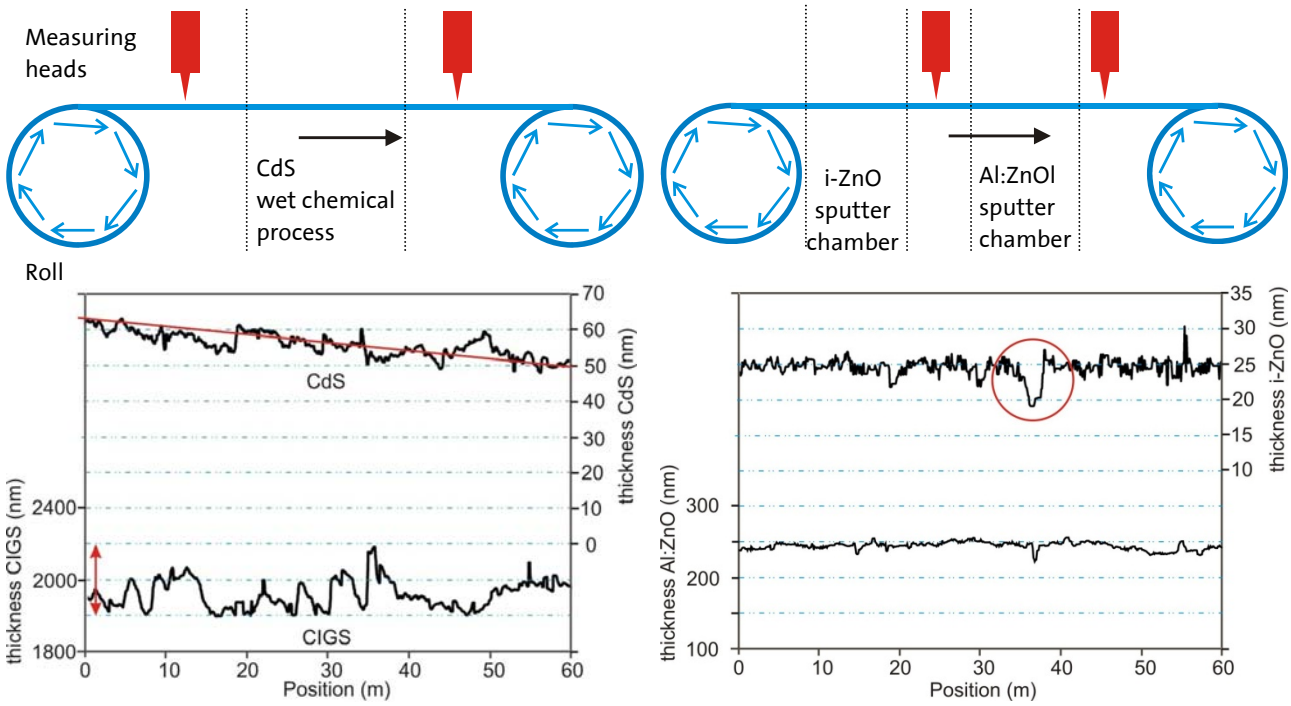

Fig. 3: In-line position resolved thickness measurements

3a) Thickness of the CIGS absorber (accuracy ± 1 %) and of the CdS buffer (accuracy ± 2 %) over position.

3b) Thickness of the i-ZnO and the Al:ZnO (accuracy ± 2%) over position.

The layer thicknesses of i-ZnO and Al:ZnO are shown in **Fig. 3b**. The i-ZnO shows mainly statistical deviations for a thickness of abound 25 nm, whereas for the Al:ZnO an additional drop in layer thickness at a band position of about 38 m was observed (red circle). The reason is unknown.

The measurement and the analysis is very fast and therefore all results can be obtained in real-time. This allows for a dense measurement points in transport direction. The multi-head concept of the **SolR** makes it possible to add numerous heads perpendicular to the transport direction. In result a 2D uniformity map of the process can be obtained.

SolR offers real-time access to roll-to-roll process variations and critical process deviations can be identified instantaneously. They may be caused by spitting, depletion of material sources, drift in temperature and others. By finding correlations between deposition parameters and film thickness drift effects in the manufacturing process can be minimized or compensated via feed-back control. First customers are using SolR for statistical process control and feed-back of process parameter like chemical bath concentration for CdS deposition. **SolR** helps to increase the mean efficiency of the produced modules. The production yield is increased as tight process control decreases the number of out-of-spec modules. For more information please visit www.laytec.de or contact info@laytec.de.