

Real-time Film Thickness Monitoring of CIGS and CdTe Thin-Film Solar Cell Processes

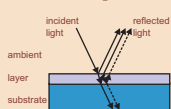
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Motivation

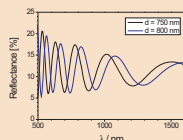
Mass production of thin film solar cells demands tools to monitor crucial properties of deposited functional layers during the production process. Only by such means drifts of thin-film parameters can be recognized and compensated as soon as they occur. For this purpose we have developed a modular metrology system measuring the **spectrally resolved optical reflectance** which can be integrated into in-line and roll-to-roll production lines.

Principle of the measurement



Light reflected from the surface (ambient-layer) interferes with light reflected from the interface (layer-substrate). This results in interference patterns in the spectrum of reflected light. The spectrum hence gives information on:

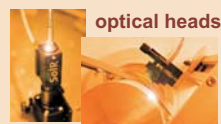
- n and k of substrate and all layers
- thickness of all layers



Example: Reflectance spectra of two TCO layers of different thickness d on a glass substrate

Optical setup and in-line sensor concept

Reflectance measurements are carried out by compact **fiber optical heads**, which are mounted to the production tool.



Up to three optical heads are connected to an **optical controller**, containing a light source and a spectral detector.

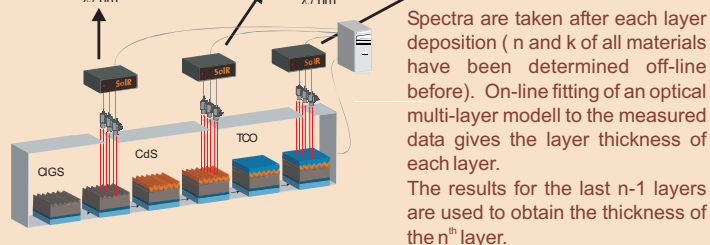
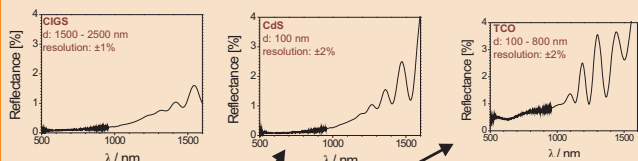


The optical controller transmits the measured spectra to a central **measurement computer**, which computes the desired layer properties (e.g. layer thickness) and communicates with the production line SPS (e.g. by profibus or TCP/IP interface). The central measurement computer supports several optical controller modules.

The modular concept allows an easy adaptation to various process requirements. A connection to the production line control system was established to identify the substrates (or roll positions).

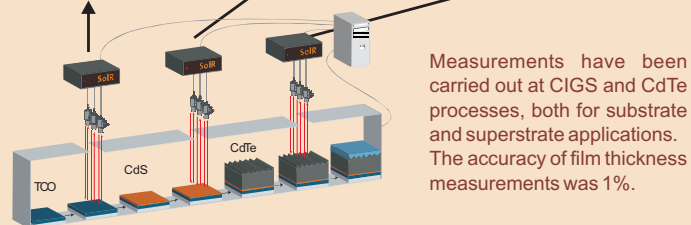
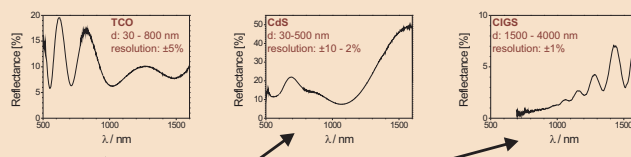
CIGS based solar cells

Measured spectra and typical resolution of layer thicknesses:



CdTe based solar cells

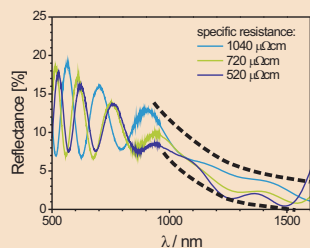
Measured spectra and typical resolution in layer thickness:



Monitoring of TCO conductivity

Free carriers absorb IR radiation. This results in a damping of the interference structures observed in the reflectance spectrum. The extend of damping is characteristic for the specific resistance of the TCO.

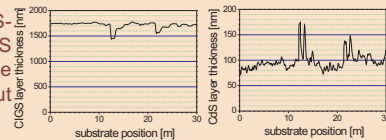
By in-line reflectance measurement TCO conductivity fingerprints were monitored immediately after the deposition and variations in the carrier density can be monitored on-line.



Reflectance spectra of three TCO-layers of different specific resistance on glass substrates. The exact resistance values were obtained by ex-situ measurements and can be used as calibration for the in-line characterisation by spectral reflectance measurements.

In-line results from roll-to-roll process

In a roll-to-roll CBD process a CdS layer was deposited on a Mo/CIGS coated tape. In-line reflectance measurements were carried out before and after the chemical bath.



The two graphs show the measured thicknesses of CIGS and CdS layer plotted against the position on the substrate (tape).

Summary

We have developed an in-line monitoring system to characterize

- the layer thickness of each layer and
- the conductivity of TCO-layers on-line

in thin film solar cell production processes. The measurement system is suitable for CIGS- and CdTe-based processes at this point of time. The characteristic layer properties are available immediately after each deposition step, allowing a permanent quality control at process time. The method is suitable for sheet based and roll-to-roll production.

Turn sun into gold!

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