Thin Film Glass Based Solar Cell Applications Using KLA-Tencor Profilers

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Introduction

As solar cell production evolves, significant hurdles will need to be overcome to meet both cost and efficiency requirements. The majority of these obstacles will be process related and can be addressed using stylus based metrology.

The Solar Cell market is growing at approximately 37% per year. The current investment of roughly $2B per year is expected to increase by an order of magnitude by 2008, as this is truly the only "green" energy available. Today roughly 80% of the Solar Cell industry is dedicated to silicon based substrates, which accounts for nearly half of the overall silicon demand.[1] However, as the silicon supply becomes stretched and substrate prices increase, manufacturers are developing technologies which use alternative substrates, such as glass and stainless. Thin Film solar cell annual new capacity was at 60 MW in 2006 and it is projected to increase to 430 MW by 2010.[2]

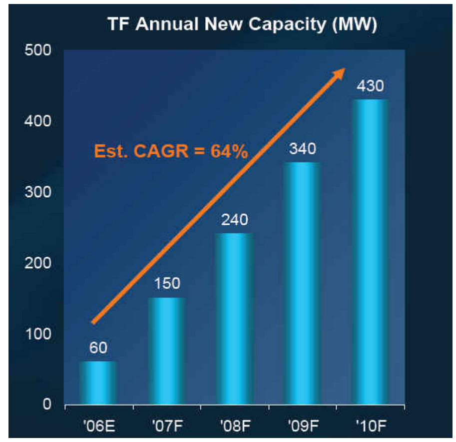

Figure 1. *"Applied Materials Going Solar"* New York , September 5th 2006.

With thin film substrates being cheaper to manufacture, providing higher efficiency and ease of manufacturing over silicone, they are rapidly becoming the number one choice for the PV industry.

Process

The Thin Film Glass based Solar Cell production begins with the glass substrate. The glass is cleaned then a Base Electrode is deposited after which the Isolation Scribe is cut. Next the Precursors are deposited and the Absorber and the Junction are formed. This is followed by the cutting of the Interconnect Vias and the deposition of the Transparent Conductor. The Isolation Vias are cut next and the leads are attached. Last step of the process is the testing of the circuits. Within this process, metrology is required to maximize efficiency and increase yield. Stylus based profilometry addresses many of the key metrology requirements. While most measurements such as roughness and film thickness are typical measurements, the KLA-Tencor P-16+ stylus profiler also offers what may be prove to be the most critical measurement of all: 3D Stress.

Applications

From the first step of the Solar Cell process, profilometry is critical to maximizing yield. As soon as the glass substrate is cleaned, a bare substrate bow measurement is performed. This measurement can prevent end of line yield loss and device malfunction. A sample of substrates are measured to determine the process control limits which predict cell performance. Bow can be measured in either 2D or 3D, but 3D is preferable.

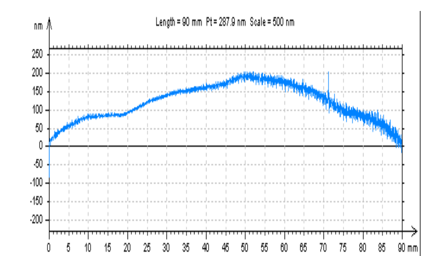

Figure 1: 2D bow measurement of a float glass substrate. No surface texture.

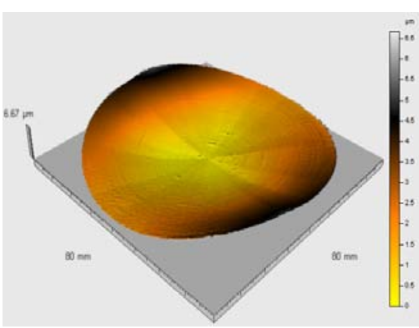

Figure 2: 3D bow measurement of a bare silicon wafer.

Next a roughness measurement is performed on the glass. This is a very critical measurement in the process, as this affects the light trapping ability of the device as well as the adhesion between the molybdenum (Mo) electrode and the CIS (copper-indium-gallium, selenium-sulphur) absorber. The P-16+ can, besides calculating 2D roughness parameters, determine the 3D roughness parameters (e.g. Sa, Sq) using ISO definitions making it suitable for both R&D and production environments. The ASIQ 2D stylus profiler can determine the 2D roughness parameters such as Ra and Rq via ISO defined filtering algorithms including the Gaussian, Robust Gaussian, and the Double Gaussian filters, ideal for transportability. Both systems use ISO compliant filtering and parameter definitions to ensure global compatibility.

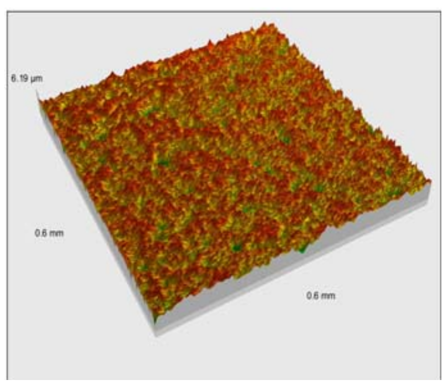

Figure 3: 3D plot of a Solar Cell after the roughening process.

A 3D stress measurement is made after the electrode has been sputtered on the substrate. Stress occurs as a result of a thermal expansion mismatch between the film and substrate[3]. At this step the process yields can be increased by properly controlling the number one cause of PV yield loss which is cracking. Since stress is typically not homogeneous across a substrate, full substrate stress measurements are highly recommended with the P-16+. Stress quantification is completed in two separate steps. The first step is to measure the pre-deposition substrate bow, already achieved in a previous step in the metrology process above. Next, after the Mo coating is deposited the bow is examined. By comparing the "pre" deposition bow with the "post" deposition bow values, the difference in the radius of curvature between the two is calculated via a fifth order polynomial fit, and the stress is subsequently calculated via Stoney's equation, given below.

$$\sigma = \frac{1}{6R}\frac{E}{(1-\upsilon)}\frac{t_s^2}{t_f}$$

$$= \frac{1}{6}\frac{E}{(1-\upsilon)}\frac{t_s^2}{t_f}\left[\frac{1}{R_F} - \frac{1}{R_s}\right]$$

where

$$\frac{E}{(1-\upsilon)} = \text{Biaxial Elastic Modulus}$$

and

σ = stress
t_s = substrate thickness
t_f = film thickness
R = Change in Radius of Curvature (RoC)
R_s = RoC of Substrate
R_f = RoC of Substrate with Film
E = Young's Modulus of substrate
υ = Poisson's Ratio

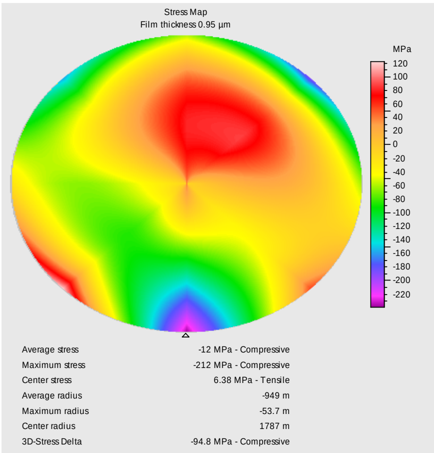

Figure 5: Typical 3D stress measurement after film deposition.

After the isolation scribe has been cut in the molybdenum (Mo) base electrode layer a step height measurement is performed. The height of the molybdenum electrode (0.35 µm thick) will affect the efficiency of the device. High Mo layer thicknesses will result in too much resistance in the device. Small Mo layer thicknesses will short the device. The layer thickness can be accurately measured using the UltraLite® capacitive sensor on the P-16+ and the transducer based sensor on the ASIQ.

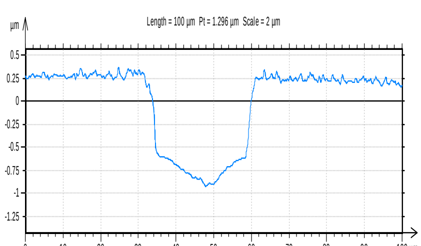

Figure 4: Isolation Scribe measurement in the Mo electrode.

Before the mechanical scribing through the CIS layer is performed a 3D stress measurement is done to check for any stress induced by the thermal process during the CIS formation. A height measurement is performed after the mechanical scribing through the CIS is complete. The thickness of the absorber is essential to control as this will dictate the amount of energy that the cell will produce.

After the transparent conductor layer is CVDed in the Mo substrate in the interconnect via connecting the Mo and the ZnO electrodes of adjacent cells and the mechanical scribing through the zinc oxide (ZnO) and CIS absorber layers is done to isolate adjacent cells, a thickness measurement is performed. The depth of the scribing is critical to achieve. If the cells are not isolated properly this will lead to the entire cell not functioning at all.

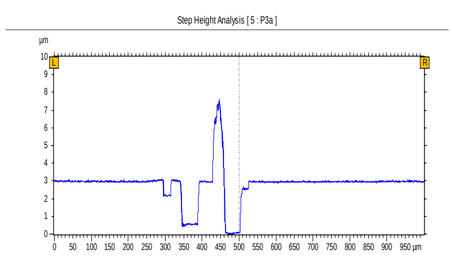

Figure 6: Mechanical scribing measurement through ZnO and CIS absorber.

Conclusions

KLA-Tencor profilers meet the step by step metrology requirements of the Photovoltaic industry. Six major process steps have been identified where stylus based metrology is highly recommended to maximize yield and efficiency. These steps include bare substrate bow measurements, surface texture roughness measurements, bow measurements of substrate with polybdenum layer deposited and full substrate stress measurements. Stylus profilometry had proven to serve as a versatile technology that offers a range of scan length capabilities to cover a breadth of applications.

References

1. "*Photovoltaic Activities*", Gaetan Rull and Jean-Chrisophe Eloy. Yole Developpment, 2006.

2. *"Applied Materials Going Solar"* New York , September 5th 2006.

3. *"Material Science of Thin Films"*, Chapter 12, p 711-712, Milton Ohring, 2nd Ed., 2002.