Maintaining Gap Uniformity in the Application of Liquid, Anti-reflective and CVD coatings onto Flexible and Flat Glass Solar Panels

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Introduction

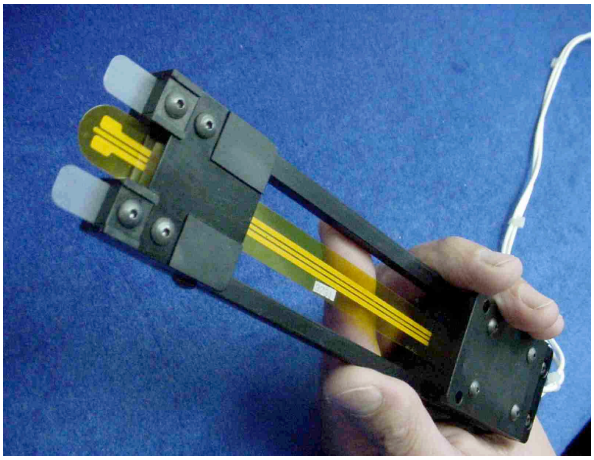
According to the European Photovoltaic Industry Association (EPIA), the driving forces in the photovoltaic industry are the reduction of cost per kilowatt-hour and module efficiency. Capacitec has been on the forefront of assisting engineers at PV Solar panel and module manufacturers as well as PV Manufacturing Machinery and Equipment to enhance this efficiency. This is achieved by providing non-contact displacement and gap sensor solutions to maintain gap uniformity in the application of liquid, anti-reflective and Transparent Conductive Oxide (TCO) coatings as well as in maintaining 300°C gap uniformity on extruder dies used in the production of films used in solar panel modules.

Controlling Gaps in Liquid Coating Processes

For the past 15 years Capacitec has been working closely with leading global manufacturers of labels, tapes and films as well as slot die coaters to develop systems to precisely measure coater gaps. These new systems have made dramatic improvements over traditional gap measurement methods achieving coater gap uniformity better than 0.25 microns with gaps as thin as 110 microns across the full length of the coater die. A typical non-contact capacitive gap measurement solution includes sensor wands, special wand holders (see Figure 1), and signal conditioning electronics and software. (See Figure 1) This technology is now being transferred to the Solar Panel Manufacturing industry.

According to the Nanosolar™ website “Printing is by far the simplest, highest-yield, and most capital-efficient technique for depositing thin films. Printing is extremely fast; the equipment involved is easy to use and maintain; and it works in plain air (no vacuum chamber required). Another key advantage of a printable CIGS ink is that one can print it just where one wants it to be, achieving high materials utilization of the semiconductor material.”

In this type of application special ink is applied to a highly conductive metal foil substrate using a roll-to-roll process. Capacitive sensors could be placed on the ink deposition head to control the gap and parallelism between the coater head and the metal foil substrate. The benefit of precise measurement of this distance is improved PV module efficiency due to enhanced ink thickness repeatability across the full width of the various applied layers.



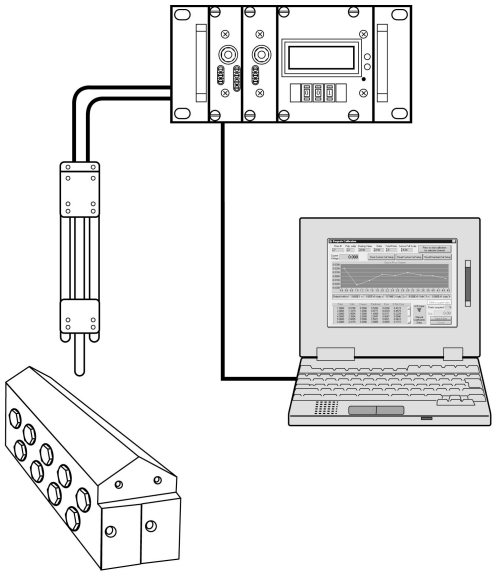


Figure 1: Sensor Wand Holder and Complete Slot Die Coater System

Another solar liquid coating application where Capacitec non-contact gap sensors can be used is in Organic Photovoltaic Technology, a solar technology that is quickly emerging to compete with silicon based 1st and 2nd generation solar technologies. The light-weight flexible solar panels produced by this method can absorb specific and broad spectrum wavelengths capturing indoor as well as outdoor light at up to 70° off-axis. As in other liquid coating methods, Capacitec lab based or shop floor slot die coater gap measurement system offer very high levels of precision as seen in Figure 2.

Feature	***Lab based system (System 1)***	***Shop floor system (System 2)***	***Benefits of shop floor system***
Calibration/ # of channels	Full set of calibrations for up to 8 channels	*1 or 2 calibrations*	*Simplified for shop floor use*
Calibrated range and accuracy	Typical range from starting thickness is 250 microns = 10VDC Resolution: ± 0.025 microns Accuracy: ± 0.5 microns Repeatability: ± 0.25 microns	*Typical range from starting thickness is* *500 microns = 10VDC* *Resolution: ± 0.05 microns* *Accuracy: ± 1.0 microns* *Repeatability: ± 0.5 microns*	*Can measure more gaps with fewer sensor wands at lower sensitivity*
Power	120/240 VAC	*±15 VDC supplied by rechargeable portable battery pack or 120/220 VAC*	*Portability, ability to reach limited access locations*
Connection to data acquisition and host computer	Analog input to PC laptop based Capacitec Bargrafx software	• *Built-in data logger* • *RS232 to host*	*Portability, convenience on shop floor*

Figure 2: Lab based vs. Shop Floor Portable “electronic feeler gage” system.

Anti-reflective Coatings

To get maximum efficiency when converting solar power into electricity, customers look for a solar panel module that can absorb nearly every single photon of light. To help achieve this goal, solar panel manufacturers utilize new antireflective coating methods that are highly efficient and cost effective while absorbing sunlight from nearly all angles.

Since minimizing reflections from the top cover of solar panels increases conversion efficiencies, anti-reflective coatings (AFC) can deliver an additional 0.3% to 0.6% power conversion. Anti-reflective coatings are deposited on flexible and flat glass solar panel transparent surfaces using CVD as well as liquid coating methods such as slot die and cascade methods. Capacitec uses the same coating gap measurement methods found in the *Controlling Gaps in Liquid Coating Processes* and *CVD Coating* sections of this paper.

Maintaining 300°C Gap Uniformity on Extruder Dies

At ECS 2009, Capacitec is introducing the new 300°C non-contact gap measurement sensor wand.

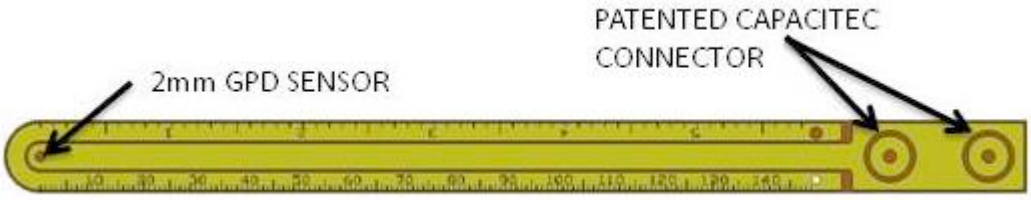


Figure 3: Dual sensor non-contact gap wand measures extruder lips during operation

This new sensor wand functions the same as standard dual sensor wands except it opens up new possibilities for use in considerably hotter extrusion and coating die processes. Currently there are no electronic gap gauging tools to confirm gap sizes in adjustable extruder dies operating at 300°C. This measurement is important because the gap width changes in relationship to the thermal expansion of the extruder die lip between ambient and production temperatures. The new Capacitec high temperature extruder die gap measurement system now allow users to accurately confirm gap sizes before starting production as well as after the adjustable dies have been reset from sized gap settings. It also allows extruder die manufacturers to study the true position and repeatability of their adjustable die setting processes.

CVD coatings

Capacitec is supplying high temperature (600°C) gap sensors to a European producer of Flexible Solar Cell Laminates that uses a roll-to-roll production process in the deposition of various active and non-active ultra thin layers. The top transparent conductive oxide layer (TCO) is deposited by chemical

vapor deposition under atmospheric pressure (APCVD) onto a temporary carrier foil. To control the position of the coater head, Capacitec supplies four high temperature sensors that are positioned next to the coater head on a custom fixture that measure both the gap and parallelism between the coater head and the metal roller at production temperatures. This constant measurement ensures that the gap and parallelism are maintained, with resulting coater uniformity, during long production runs.

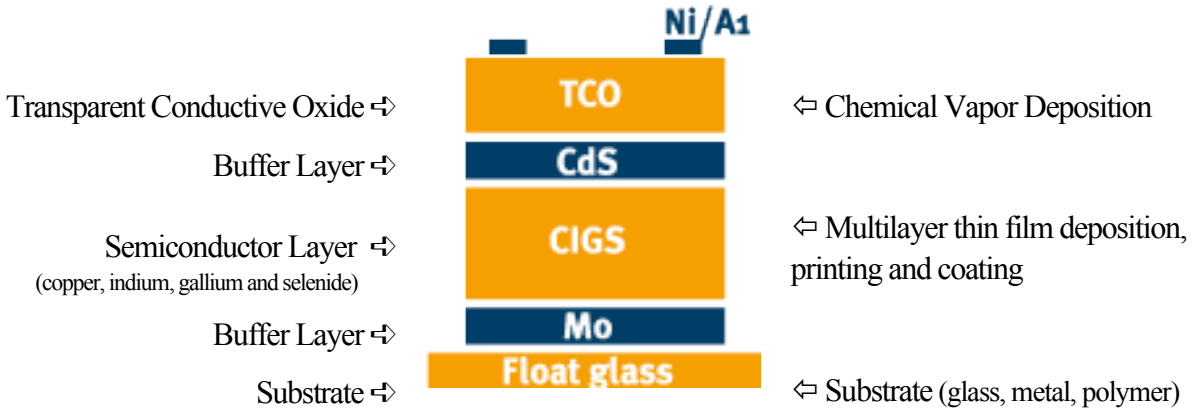


Figure 4: Cross section of layers in a thin film CIGS solar panel

A roll-to-roll production process is used in the deposition of various active and non-active ultra thin layers onto the solar cell metal foil. This process offers important cost saving advantages in large scale production. There are a number of roll-to-roll steps from the deposition of the transparent top layer and the amorphous silicon layers to the final reflective metal backing.

Figure 5: Flexible Solar Cell Laminate Production

This presentation shows how Capacitec is on the forefront of assisting engineers at PV Solar panel and module manufacturers as well as PV Manufacturing Machinery and Equipment producers to reduce of cost per kilowatt-hour while enhancing solar panel module efficiency. This is achieved by providing non-contact displacement and gap sensor solutions to maintain gap uniformity in the application of liquid, anti-reflecting and Transparent Conductive Oxide (TCO) coatings as well as in maintaining 300°C gap in the application of anti-reflective and other coatings applied by high temperature extruders.