Real time in-process wet or dry thickness measurement of thin films and discrete layers in R2R applications

Presented by: Steve Polemitis
Author: Vivek Komaragiri
SpecMetrix Systems (Sensory Analytics)
4413 West Market Street
Greensboro NC 27407 USA
www.specmetrix.com
Tel: 336-315-6090
Fax: 336-315-6030
vivek@specmetrix.com

Abstract: Real time measurement of applied coatings in roll-to-roll applications is critical to improving the overall quality of the end product and process efficiency. Conventional inline measurement tools fall short as an accurate in-process measurement option as applied coatings become thinner. As a result, manufacturers face significant challenges in applying and verifying the correct amount of applied coatings. The availability of new high speed non-contact measurement alternatives that accurately measure the thickness or coat weight of thin films in roll-to-roll applications will improve accuracy, minimize process control issues and reduce costs by minimizing over application. The presented measurement technique is actively being used to precisely measure real time thickness of wet and dry applied coatings in the sub-micron range. Measurement data and summary results will be presented on numerous R2R coating applications, including a review of the repeatability, stability and accuracy of the measurement method.

Background: Thin film layers and coatings are applied to various products to achieve important functional and finish characteristics. In many cases, coatings are applied to improve surface properties of the substrate, such as appearance, adhesion, corrosion resistance, wear resistance, and scratch resistance. Traditional web and coating measurements have been generally accomplished through mechanical sample testing methods or through the use of an earlier generation of in-line coat weight measurement methodologies such as total weight gauges. The current mechanical methods for determining the coating thickness on coated products are not only labor intensive and time consuming, but the selected sample sizes used for taking measurements are insufficient to assure quality across the web and for the length of the coated roll or product. Mechanical methods also face additional challenges when measuring multiple layers of coating or clear coatings applied onto clear substrates.

In addition to the rapidly increasing costs of monitoring, maintaining and disposing of radioactive measurement options, beta and x-ray gauges are often not sensitive enough to precisely measure thinner films and coatings (< 5 microns) and requiring expensive load bearing traversing mechanisms. Coat weight determination using beta, gamma, x-ray or other total weight gauges require a differential measurement wherein a base material is measured along with the combined thickness of the base + coated layers. The difference of the results is then used to calculate the coat weight of the coated layer. While generally accurate if proper calibration is maintained, this approach requires a minimum of two sensors and scanners, thereby increasing the cost of the measurement solution for manufacturers. Measuring web products with multiple layers using nuclear gauging also adds cost and complexity as additional sensor/bridge combinations may be required at each stage where a layer is applied. Beyond nuclear and other administratively burdensome solutions, in-process measurement techniques such as UV and IR absorption gauges rely on various inferential means for measurement, as opposed to measuring the absolute thickness of a film package or a specific film or coating layer.

Optical interference based techniques, on the other hand, are well known for precision and have been proven to be reliable, although their use has been generally limited to laboratory or certain stable and repetitive production environments such as semiconductor wafer and chip fabrication. Although there have been limited earlier attempts to bring optical interference based tools to the production floor, the variability inherent in production environments and product substrates have limited the expansion of these non-contact and non-hazardous techniques from moving webs until recently. New ROI optical technologies exclusively incorporate a proven ruggedized optical interference (ROI) technology that has been developed to meet production needs by using proprietary algorithms, software and advanced optics to accurately and precisely monitor coating thickness as low as 0.2 microns. Use of this technology is in active production and QA use across the metal packaging, coil coating, aerospace, industrial coating and coated film industries.

ROI optical methods use modular designs and are flexibly configured to monitor real-time wet or dry coating and film thickness measurements in-process or offline. The systems can simultaneously monitor multiple layers of coating on or across a web at up to 150 measurements per second. Since the system only relies on change of refractive index between the coated layer and the substrates, there is no need for dual systems to produce single layer measurement results, and the evaluation of clear coatings or finishes on clear materials are not treated differently than any other coating or film combination.

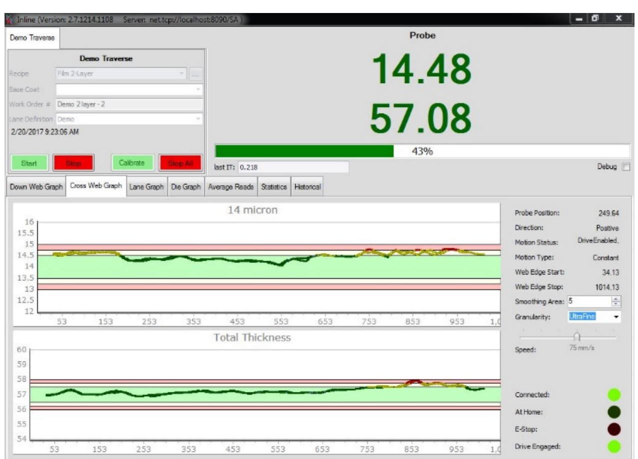
Also, the ROI optical method presented here is designed to work well even on non-smooth coatings and does not require clean room environment as it can easily handle challenges like web flutter by dynamically making necessary light detection adjustments and also uniquely handle obtaining measurements even with wrinkles on the coated web. Some of the other unique features include not needing calibration standards for each coating and the distance between sensor and the moving need not be exact. The ROI technology also works on several different coating applications like roll-to-roll, roll-to-sheet and slot die coating processes.

System Demonstration and Test Results: Testing and trials were performed over different types of thin film coatings and discrete layers for various roll to roll, roll to sheet, and slot die coating processes. The results presented for some of the coatings include scratch resistant, heat seal, embossable and barrier coatings. The technology is also substrate independent and works on coatings applied over most substrates like film (OPT/PE/OPP etc..), Foil, Polycarbonate to name a small set of substrates. The principal objectives of the trials were to determine the applicability and effectiveness of ROI optical instruments to monitor the coating thickness of thin coatings and other film packages that have proven difficult for more traditional measurement technologies currently in use within R2R processing.

Instrumentation and Software: The following configuration was utilized for the presented demonstration and test effort and forms the basis for the sizeable number of systems using this exclusive ROI optical technology which are in active production use at global R2R coated product manufacturers.

Instrumentation: The principle hardware components used are custom light sources, spectrometers and optical packages. The light sources used are stabilized Halogen light sources that are selected for use over a broad range of wavelengths. The advanced optical package used in the ROI technology enables extremely rapid capture of reflectance data within short time intervals; thereby enabling the system to take up to 150 measurements per second in-process. Multiple fixed points on the web can be inspected and measured for coating thickness simultaneously and continuously using multi- channel systems. Alternate single frame scanning bridge configurations can be used to enable a single lightweight probe to quickly and accurately scan the moving web and provide a manufacturer with real-time coating and film measurement data.

Software: The system software and user interface options have been designed for maximum flexibility, ease of use and for minimal actions required for an operator. The software includes a customer database of coating recipes that are periodically updated with new coatings as the need arises. The system operator simply selects the coating or film package from the drop-down list and presses the Start button. The system then continuously displays thickness readouts along with a moving average trend that visually indicates the applied coating thickness and continuously monitors whether it falls within the desired quality control limits. Thickness readings are color coded to differentiate measured thicknesses in or out of specification and other identified production tolerances. Below is a sample screenshot showing the display of the sequential measurements from a coated web with wo coating layers.



<u>Figure 1</u>: *SpecMetrix In-line* dual-channel software screen configuration

All thickness measurements herein were recorded by the system on-line immediately after the coating is applied as well as after the coating was cured. The ability of the system to monitor wet coating thickness enables production personnel to adjust the coating application earlier in the coating process and to accurately determine dry coating thickness from the measured wet coating thickness. The various testing efforts and results for R2R coating and thin film applications follow below:

Measurement Results:

Provided below are measurement results on some of selected coatings that are applied in roll-to-roll application process.

Adhesive on Polypropylene:

	Adhesive	Polypropylene Film
	thickness(µ)	thickness(µ)
1	35.56	127.45
2	36.25	126.98
3	35.45	127.34
4	36.54	126.66
5	35.47	126.59
6	35.69	126.81
7	35.24	126.36
8	36.54	127.66
9	35.48	126.601
10	35.29	126.41

Table 2: Label Application with polypropylene film

UV Embossing:

	UV Curable coating
Meas#	thickness(µ)
1	105.14
2	106.21
3	105.45
4	105.92
5	106.54

Table 3: UV curable embossed coating applied on PET substrate

Barrier Coatings:

	Barrier Coating
Meas#	thickness(μ)
1	0.544
2	0.538
3	0.527
4	0.547
5	0.542

Table 4: Thin barrier coating on a film for food packaging

Conclusion: The critical importance of continuous process improvement and cost-reduction efforts and the growing need to move to greener production processes are impacting manufacturers and converters and creating the need for new tools to facilitate those valuable efforts. Inefficient coat weight measurement methodologies that involve time-consuming checks at the beginning and the end of rolls do not guarantee the coating application throughout the entire coating run. There are even greater measurement challenges involved if the manufactured product package includes thin coated layers or clear layers. Total weight solutions require major capital equipment expenditures that strain capital equipment budgets and create challenging ROI justification efforts.

The presented in-line ROI coating and thin film thickness measurement technology is a proven and cost-effective new means to generate real-time coating process data in a non-contact, non-destructive and non-radioactive manner on a wide variety of R2R applications down to the sub-micron range. The data obtained from the included trials and measurement results confirms that manufacturers and converters of R2R coated film, foil and extruded products now have an enhanced capability to monitor and precisely control their coating application processes to better assure their end product quality. More precise coating thickness measurements can be accurately taken on wet and dry coatings, to include the simultaneous thickness measurement of multiple film or coating layers. This low maintenance method provides a new capability to measure coatings on individual film package layers, to include UV embossing, barrier coatings on thin films and adhesives on polypropylene will provide product manufacturers with added process control and an important new tool to help verify product quality, avoid customer claims and to reduce production costs.