Process Improvement Opportunities from New In-line Coating and Film Thickness Measurement Tools

2011 AIMCAL TECHNOLOGY OF THE YEAR
Innovative technology enables improved coating QA

- The core principle behind the thickness measurement is the exclusive new ‘ruggedized optical interference’ technique.
- Incident light is reflected from the top of the coated surface and refracted through the coating and reflected back again from the surface of the substrate.
- The reflected rays from the two surfaces interfere with each other forming an interference modulation of particular frequency corresponding to the thickness of the coating.
- Multiple light sources and sensory packages are used to support diverse applications.
- Powerful software and algorithms then analyze the interference spectrum to generate precise coating thickness.
Key features of new in-line measurement methods

Ruggedized optical interference technique

Fast, non-destructive and non-radioactive

Non-contact measurement of films and coatings

Measurement of wet or dry coatings

Suitable for static and in-line measurements

Current thickness ranges of new tools:

~ 0.15 µ to 200 µ
~ 0.10 lbs/ream to 130 lbs/ream
QA and production applications

**Corporate Teams**

QA Labs
R&D Centers
Incoming roll inspection

**Manufacturing Plants**

Production floor
QA work stations
Coating and material suppliers
In-process coating measurements
Advantages over traditional film weight methods

• Simultaneous measurement of single or dual layers
• Non-radioactive tools with minimal maintenance required
• Not based on differential measurement methods:
  ~ Only one system is sufficient to measure a layer of coating
  \textit{versus} two systems to generate differential measurement
• Wide thickness measurement range to include thinner coatings
  ~ 0.15 \(\mu\) to 200 \(\mu\)
  ~ 0.10 \textit{lbs/ream} to 130 \textit{lbs/ream}
• Flexible and versatile measurement technology:
  ~ Configurations for both lab and inline measurements
  ~ Ability to measure large number of dissimilar coatings due to
    broader wavelength region of operation.
Absolute coating thickness results in real-time

Automatic analysis of interference pattern provides precise thickness and coat weight results in:

- nanometers
- microns
- mils
- mg/sq. inch
- gsm
- lbs/ream

Operator simply sees clear and precise coating measurement thickness results

More reliable down web results, with:

- Automatic data recording and storage
- No manual recording/manipulation of data
- Easy integration to controls and PLCs
- Direct porting to SPC systems
View of multiple layer thickness on lab samples

- Simultaneous measurement of multiple film and adhesive layers
- Optical interference is utilized to determine thickness of layers
- Reflection generated from each interface on a multi-layer surface
- Thickness peaks shown for individual layers and combination of layers
Industrial coating & film thickness applications

- Polycarbonate films
- Anti-Reflective coatings
- Coated foils
- Barrier coatings
- UV coatings
- Scratch resistant coatings
- Solar control and specialty films
- Adhesive layers
- Polyethylene
- Pressure Sensitive Adhesive
- Silicone coatings
- Hardcoats
- Vacuum Deposited coatings
- Coated metallized films
Impact of technology on production and process control

Optimized coating utilization, with less over-application

Coating detection for clear coatings, finishes, foils and films

Non-destructive method reduces product spoilage

Reduced trial times for new equipment, materials and coatings

Immediate identification of web, equipment or application issues

Reduced sample testing and first piece inspection times

Advanced process automation with closed loop feedback control
Impact of new technology on coating quality

Streamlined film weight/coating thickness measurement steps

Elimination of non-value added web and sample QA processes

Claim reductions through QA certifications for each coated rolls

Ability to determine defects in intermediate layers on clear and opaque film and foil products

Identical coating measurement methodology to meet both in-line and off-line lab QA needs
Meeting production challenges on coated products

➢ **UV Hard Coat:**
  - Strong adhesion characteristics causing difficulty for layer removal gravimetric methods.
  - Coating applied is very thin making it challenging for existing measurement methodologies.

➢ **ePTFE Films:**
  - Provide a unique combination of porosity, chemical and heat resistance for venting and filtration applications.
  - Difficult to measure with traditional optical sensors.

➢ **Adhesive coatings:**
  - Ability to measure intermediate layer for Adhesive on a finished package.
  - Several thin Adhesive coatings that can only be exclusively measured with this technology because of thin applied layer of coating.
  - Currently applicable to solvent based adhesives
Measurement data on clear top coat layers

- Coating applied to facilitate printing on film substrates.
- Thin clear coated layer makes weigh strip weigh analysis difficult.
- Material properties of coating are very similar to substrate making it difficult for other tools to measure.
- Measurements were performed in the wet state and dry coating thickness is accurately estimated based on percentage of solids.

<table>
<thead>
<tr>
<th>Meas #</th>
<th>Wet Thickness</th>
<th>Estimated Dry Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>wet(µ)</td>
<td>dry(µ)</td>
</tr>
<tr>
<td>1</td>
<td>2.87</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>2.91</td>
<td>0.87</td>
</tr>
<tr>
<td>3</td>
<td>2.88</td>
<td>0.86</td>
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<tr>
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<tr>
<td>5</td>
<td>2.95</td>
<td>0.89</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>2.89</td>
<td>0.87</td>
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</table>
Correlation of wet and dry adhesive measurements

- Thickness of wet and dry in-line measurements taken over extended period of time on adhesive coating, with averages above
- Wet coating inspection performed immediately after application
- Strong correlation between wet and dry measurements

<table>
<thead>
<tr>
<th>Meas #</th>
<th>Wet Thickness (µ)</th>
<th>Dry Thickness (µ)</th>
<th>Correlation factor</th>
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<tr>
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<td>2</td>
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<tr>
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<td>5</td>
<td>22.20</td>
<td>4.52</td>
<td>4.91</td>
</tr>
</tbody>
</table>

$y = 0.1946x + 0.2212$

$R^2 = 0.9973$
Adhesive layer measurements on solar panel back sheets

- Individual adhesive layers that adhere substrate and do not delaminate if properly applied
- Coating uniformity and coverage is critical for adhesive coatings
- Difficult to perform coat weight analysis without off-line layer removal gravimetric methods
- Challenge for traditional measurement methods because coating is clear and is thinly applied
- Strong, favorable spectral response benefits with new in-line tools

<table>
<thead>
<tr>
<th>Meas #</th>
<th>Adhesive Thickness(µ)</th>
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<tr>
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<tr>
<td>2</td>
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<td>AVERAGE</td>
<td>8.16</td>
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Thickness measurement of ePTFE Films

- ePTFE films have pores making it difficult to measure with traditional optical sensors.
- Used in High Performance Fabrics, Medical Implants, Advanced Dielectric Materials etc..

<table>
<thead>
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<th>Meas #</th>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>4.16</td>
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<tr>
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<tr>
<td>4</td>
<td>4.15</td>
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<tr>
<td>5</td>
<td>4.21</td>
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</tbody>
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AVERAGE 4.15
Technology advancements for production and QA benefit

- **Ultra Thin Coating thickness Measurement Module:**

  - Minimum thickness limit for current configuration is 150nm (or 0.15 microns).

  - Core technology being expanded to measure ultra thin coatings ranging from 10 nanometers and above, to benefit:
    - Thin silicone coatings
    - Measurement of stretched films
    - Measurement of thin lubricious coatings
    - Measurement of pre-treatment coatings
    - Measurement of PV thin film coating layers
Summary of in-process measurement results

- The new ruggedized optical interference technology demonstrated an ability to measure several thin coated layers. Products measured include:
  - UV coatings
  - ePTFE films
  - Adhesives on solar panel back sheets
  - Top coats with identical material properties as underlying substrate

- In-line measurement technique showed excellent correlation from wet to dry measurement results

- Technology demonstrated ease of use and ability to measure clear coatings on clear substrates, as well as particularly thin coatings

- Technology demonstrated ability to measure intermediate layer in a film stack

- Continuous in-line results helped to reduce QA and set-up times
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