EFFICIENT UV TECHNOLOGY DESIGNS FOR METAL PACKAGING
ASIA CAN TECH CONFERENCE

Kuala Lumpur, November 7-9 2016, John Clark
• UV Market Penetration
• UV Technology
• UV Systems – Overview
• Designing an Efficient UV “SYSTEM”
• Drivers & Benefits for UV Curing
• Future – What’s Next
UV Curing - *Invisible but Everywhere™*

You depend on it

You Live in it

You fly it

You drive it

You walk on it

You talk on it

You stick it

You watch it

You drink it

You listen to it
UV CURING PROCESSES

UV Curable Inks, Paints, Coatings & Adhesives are used across the spectrum of manufacturing processes... Including Metal Packing

Proven to be a very robust process.

Proven Reliability in Demanding 24/7 Manufacturing Operations.

Exceptional process stability and repeatability.
UV curing is a chemical process in which polymerization is initiated with UV light energy (200-425nm). Requires photo-initiators in the formulation. Happens very rapidly – Fractions of a second to seconds. (UV is > 1000’s X Faster than Thermal Reaction). Line-of-sight process.
THERMAL vs. UV

**Thermal**
Evaporative Process

- Coating
  - Vehicles and Resins
  - Additives and Pigments
  - Solvent
  [Solvents Evaporate]

**UV**
Photochemical Process

- Coating
  - Resin Solids (monomers, oligomers)
  - Additives and Pigments
  - Photoinitiators
  [No Mass Transfer]
OVERVIEW OF UV SYSTEM INSTALLATION
UV LAMP TECHNOLOGY
RF Electrodeless Bulb, Electrode ARC Lamp & LED

Fusion - Electrodeless Bulb

Electrode Type Arc Lamp

UV LED – High Powered 365, 385, 395, 405 nm
UV CURING SYSTEM COMPONENTS

UV Bulbs

UV Reflectors

UV Irradiator

Power Supply & Control Consoles
KEY ELEMENTS OF UV CURING

UV Energy J/cm²

total energy arriving at the surface per unit area (or total accumulated photon quantity arriving at the surface)
inversely proportional to speed

UV (Peak) Irradiance W/cm²

radiant power arriving at the surface per unit area
characteristic of the lamp output power, bulb diameter, geometry & efficiency of reflector, distance to the work surface
independent of speed

Spectral output of the bulb

wavelength distribution

Heat - Infrared Energy
• Allows general comparison of lamps
• Describes electrical input only
• Provides no information about irradiance/intensity
• Provides no information about spectral distribution
CURE SPEED OF BLACK INK

- Using same ink formulation
- Higher power improves cure speed
- Longer wavelength from D bulb matches PI absorption
- Longer wavelength has better depth of cure, therefore better adhesion
## COMPARISON OF CURE BLACK INK

<table>
<thead>
<tr>
<th>Lamp Class – Input Power</th>
<th>300 Watts/Inch</th>
<th>300 Watts/Inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulb Type</td>
<td>H Bulb Medium Pressure Mercury</td>
<td>H Bulb Medium Pressure Mercury</td>
</tr>
<tr>
<td>Lamp Type</td>
<td>RF Powered Electrodeless Lamp</td>
<td>Electrode Arc Lamp</td>
</tr>
<tr>
<td>Bulb Diameter</td>
<td>9mm</td>
<td>23mm</td>
</tr>
<tr>
<td>Peak Intensity (Irradiance) mW/cm²</td>
<td>915 mW/cm² ~ 90% Higher</td>
<td>480 mW/cm²</td>
</tr>
<tr>
<td>Total Energy at Cure Speed (mJ/cm²)</td>
<td>435 mJ/cm² ~ 30% Less</td>
<td>620 mJ/cm²</td>
</tr>
<tr>
<td>Cure Speed</td>
<td>68 FPM &gt; 40% Increase in Line Speed with a 30% Less Total Energy Required</td>
<td>48 FPM</td>
</tr>
</tbody>
</table>

## COMPARISON OF CURE DEPTH BLACK INK

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th># of Passes</th>
<th>Peak Intensity mW/cm²</th>
<th>Depth of Cure (mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 W/cm D Bulb</td>
<td>1</td>
<td>3200</td>
<td>1.0 mils</td>
</tr>
<tr>
<td>120 W/cm D Bulb</td>
<td>2</td>
<td>3200</td>
<td>1.5 mils</td>
</tr>
<tr>
<td>240 W/cm D Bulb</td>
<td>1</td>
<td>6400</td>
<td>2.0 mils</td>
</tr>
</tbody>
</table>
EFFECT OF INCREASING UV IRRADIANCE

Increasing UV Irradiance:
• 75% Less energy is needed to reach same cure level
• Equals faster cure speed

UV Energy needed to reach 150 MEK rubs with a 12µ UV clear coat
PEAK IRRADIANCE & TOTAL ENERGY

- **Peak Irradiance**
- **Irradiance Profile** (Independent of speed)
- **Area Under the Graph**
  Represents the UV Energy, J/cm²
  (Depends on speed and irradiance)

Distance or Time

1  2  3  4  5  6  7  8  9  10  11
TO ACHIEVE HIGH PEAK INTENSITY

- Use an elliptical highly focused reflector
- Reduce bulb diameter to increase peak intensity
- Increase the lamp power
- Run the substrate through the focal plane of the UV light source

Figure 2  Typical Irradiance Profiles
UV SPECTRAL OUTPUT DISTRIBUTION

H Bulb (13 mm)

D Bulb (13 mm)

V Bulb (13 mm)

Q Bulb (13 mm)
Surface Cure at short wavelengths

- H-bulb
- BPh
OVERLAP OF TYPICAL PHOTOINITIATOR & D BULB

Depth of cure at longer wavelengths
SUMMARY

- Use high peak intensity to achieve faster speeds and better through cure
- Select longer wavelength UV for improved depth of cure
- Select bulb spectra to match the absorption profile of PI
- UV chemistry can be responsive to both peak irradiance (Intensity $W/cm^2$) as well as total energy ($J/cm^2$)
- Techniques are available to reduce or add heat as needed
A SUCCESSFUL UV PROCESS....PARTNERSHIP

Partnership between... End User

Ink, coating, adhesive

Application Equipment

UV lamp system

Successful Finished Product $$$

$$$

End User
MAIN DRIVERS FOR ADOPTION OF UV CURING

• Increased production speed, fast and cool cure.

• Environmental compliance issues, green technology, reduced energy requirement, Little to Zero VOC’s, HAP’s, CO2.

• Improved physical properties and product performance.

• Enabling Technology.

• Easy retrofit conversion, requires very little space.

• Cost-effective, lower applied cost, less waste, reduced WIP.
Energy Cure UV/EB Applications continue to be a growth market

Industrial and Eco-friendly Coatings Drive the UV-cured resins market (BCC Research 01/2016).

- Global UV resins market to reach $4.6 billion by 2020 a CAGR of 8.7%.
- Industrial coatings largest segment, reaching $2.0 billion a CAGR of 8.8%.
- Key drivers: stringent emission laws, fast process speeds, and new applications

UV Curable Resins Market worth 697.2 Kilotons by 2018 (Markets and Markets 2015).

- Asia-Pacific largest and fastest growing market; China & Japan the leading followed by Korea & Taiwan.

UV Curable Resins Market Analysis, Market Size and Regional Outlook 2015 – 2022 (Grand View Research).

- Rapid industrialization in Asia-Pacific driving demand for UV curable coatings.
- North America a major regional market with high demand for coatings and adhesive applications.
- US a major market for food and beverage packaging (coatings and inks).
- China, India, South East Asia projected to account for majority of UV curable resin demand by 2022.
<table>
<thead>
<tr>
<th>Year</th>
<th>North America (Metric Tons '000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>77.3</td>
</tr>
<tr>
<td>2003</td>
<td>84.1</td>
</tr>
<tr>
<td>2005</td>
<td>97.5</td>
</tr>
<tr>
<td>2007</td>
<td>110.8</td>
</tr>
<tr>
<td>2009</td>
<td>112.1</td>
</tr>
<tr>
<td>2011</td>
<td>122.0</td>
</tr>
<tr>
<td>2013</td>
<td>132.6</td>
</tr>
<tr>
<td>2015</td>
<td>142.7</td>
</tr>
</tbody>
</table>
### UV and EB Formulated Product Sales Growth in North America, by Volume

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales Growth (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>4.7%</td>
</tr>
<tr>
<td>2016</td>
<td>4.9%</td>
</tr>
<tr>
<td>Next 3 yr. Annual Avg</td>
<td>5.5%</td>
</tr>
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</table>

October 6, 2016 (IUCRC)
WHAT NEXT – UV LED TECHNOLOGY

• The UV-curing LED market represented $20 million in 2008 grew to $90 million in 2014 a CAGR of 28.5%.
• Growth in UV curing with LED is likely to continue thru 2018.
• Transitioning from ink-jet, flexo, offset to industrial applications.
• Growth spurred by the increased availability of LED specific UV curable formulations, and improved performance (output power) of LED systems.
• Energy conservation and operational economics key drivers for adoption of this technology.
• New and improved designs and continued development will drive this technology into the main stream.
UV-LED TECHNOLOGY - 2011 TO 2016 UV SALES

Sales 2011
- 10% UV-LED
- 90% Traditional UV Lamp

Sales 2016
- 28% UV-LED
- 72% Traditional UV Lamp

October 6, 2016 (IUCRC)
FUTURE GROWTH POTENTIAL AND OPPORTUNITIES FOR UV CURING

• Geographic: Asia Pacific particularly China and India, but also Korea and Taiwan. Digital print/flexible packaging USA.

• Equipment: UV-LED continued improvement hardware and chemistry, plus potential impact of mercury legislation

• Materials: Smart Coatings (innovation) Improved performance characteristics (incremental).

• Applications: Automotive light-weighting, metal packaging, displays, touch pads, wearables, digital printing, and field applied
THANK YOU

ANY QUESTIONS?