Current & Developing Markets for UV LED Technology

February 27, 2013
Agenda

- UV LED Technology
  - Basics
  - Wavelength
  - Optics
  - Performance

- UV LED Curing process and Materials

- UV LED Benefits

- Current and Developing Markets
# Terms and Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Units</th>
<th>Impacted by…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Irradiance “Power Density”</td>
<td>Maximum Radiant Power per-unit-area</td>
<td>Watts per square centimeter (W/cm²)</td>
<td>Distance from light source</td>
</tr>
<tr>
<td>Dose “Energy Density”</td>
<td>Energy delivered to the media</td>
<td>Joules per square centimeter (J/cm² = W·s/cm²)</td>
<td>Line speed, emitting window size, peak irradiance</td>
</tr>
<tr>
<td>Total Input Power</td>
<td>Energy supplied to the UV system</td>
<td>Watts (W)</td>
<td>Input Voltage and current requirements of the system</td>
</tr>
<tr>
<td>Total Output Power</td>
<td>Sum of the UV energy delivered to the media</td>
<td>Watts (W)</td>
<td>Peak irradiance, emitting window size, light source efficiency</td>
</tr>
</tbody>
</table>
LED - Light Emitting Diodes

A solid-state device that produces light when an electrical current is allowed to flow from the positive (anode) side of the circuit to the negative (cathode) side.
UV LED = narrow band of high power UVA output
No harmful UVC or IR generation

Typically, lower wavelength LEDs have lower peak irradiance with increased cost per diode
Optics

- LEDs are a ‘divergent’ light source
  - Typical light emitting angle for UV LED light sources is wide
  - Typical working distance ~ 3 to 5mm

- Due to divergence, peak irradiance decreases with distance, but the overall energy (dose) remains the same with distance
Cooling: UV Output

- 70-85% of input power becomes heat generated by the LED
- The irradiance and temperature are inversely related
  - Lower temperature = More irradiance
- The PN-junction has a maximum temperature specified by the diode manufacturer which should not exceed for reliability
UV LED System Performance

LED output has increased over time, but the Array, Optics, and Thermal management design allowing an increase in UV Irradiance output……

……Significant economic improvements
## UV LED vs. Mercury Lamps

### UV Curing Systems

- **Lifetime**: > 20,000 hours
- **Environmental**: Mercury Free, Ozone Free
- **Input Power**: Small (~ half)
- **Maintenance**: Maintenance-free
- **On / Off**: Instant
- **Heat**: 60° C (lower)

### Mercury Lamps

- **Lifetime**: 500-2,000 hour bulb life
- **Environmental**: Mercury Waste, Ozone Generation
- **Input Power**: Large
- **Maintenance**: Bulb replacement & reflector cleaning
- **On / Off**: Minutes
- **Heat**: 350° C (higher)
UV Curing Process

- Material is applied to the media
- Material is exposed to UV Light
- Photo-initiator (PI) forms Free Radicals
- Binders (Oligomers and Monomers) form “Chains” with PI
- Chains join (cross-link) with each other resulting in “Polymerization” = “curing”
Curing depth & wavelength

- Different wavelengths have an impact on curing.
- Typically, shorter wavelengths are better at surface curing while longer wavelengths are better at through-cure and adhesion.
- Certain adhesives require 365nm for special properties or regulatory processes.
- A mix of increasingly powerful UV LED curing lamps and improved chemistry enables 395nm UV LED curing systems to provide both surface and through-cure.
Ink and Material Companies That Support LED
Historical Barriers to UV-LED Technology

- Peak Irradiance - Comparable TODAY
  - 2-3 years ago, output power was insufficient

- Chemistry/Material Formulation - Inks, Coatings and Adhesives now commercially available
  - And more coming on-line every day.

- Economic improvements -
  - Price point approaching parity with “traditional” curing technology for wide applications.

- Confidence in a “NEW” technology and challenges in integration
  - Moving beyond “Early Adopters” as technology continues to mature.

Many UV LED applications now commercially viable
### UV LED Benefits

<table>
<thead>
<tr>
<th>Advanced Capabilities</th>
<th>Operating Economic</th>
<th>Environmental Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat-sensitive, thin substrates</td>
<td>Energy Efficient</td>
<td>Mercury Free</td>
</tr>
<tr>
<td>Deep, through curing</td>
<td>Long Lifetime &amp; Low Maintenance</td>
<td>Ozone Free</td>
</tr>
<tr>
<td>Small, compact machines</td>
<td>Increased Yields</td>
<td>Workplace Safety</td>
</tr>
<tr>
<td>Controlled curing intensity</td>
<td>Low Operating Temperatures</td>
<td>UV-A Wavelength</td>
</tr>
</tbody>
</table>

**UV LED allows new functionality while improving existing processes**
Applications

- Inks
- Coatings
- Adhesives
UV LED Curing

**UV PRINTING**
- Digital Inkjet
- Screen
- Flexographic
- Offset

**UV COATINGS**
- Automotive
- Wood Coatings
- Vinyl
- Instruments

**UV ADHESIVES**
- Displays
- Medical
- Electronics
- Industrial
Digital Printing

- Applications: Product Identification, Coding Information, Packaging & labeling, Security Print, Printed Electronics

- Media Options: Self-adhesive labels, Papers, Plastic, Foils, Cardboard and paper, Porous and non-porous

- Benefits: High Throughput, Heat Sensitive Materials, Cost Savings
Screen Printing

Applications: Screen Printing, Commercial Print

Media Options: Plastic Cards & Films, Metallic Foils, Cardboard and paper, Porous and non-porous

Benefits: Heat Sensitive Materials, Cost Savings, Improves adhesive of ink to media
Flexographic Printing

- Applications: Flexo Printing

- Media Options: Paper, Film

- Benefits: Improved speed, low heat generation, economic improvements, heat sensitive materials
UV Coating Applications

- Applications: Wood, (Flooring, Cabinets, Doors) Automotive, Industrial
- Media Options: Wood, Vinyl, Instruments, Tile, Glass
- Benefits: Efficient, repeatable process, improved yields, safe operating environment
UV Adhesive Applications

’applications: Labels, Medical, Industrial, Optical Manufacturing

Media: Plastic, Glass, Hearing aids, Syringes, Electronics

Benefits: Consistent UV output, high quality adhesion, improved throughput, low heat
Summary of UV LED Curing

Substantial UV LED Benefits

- Advanced Capabilities
- Operating Economics
- Environmental Advantages

The Time is Now

- Process Stability
- Mercury Free
- High Yields

Broad Applicability
## Snapshot

<table>
<thead>
<tr>
<th>Expertise</th>
<th>UV LED solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Founded</td>
<td>2002</td>
</tr>
<tr>
<td>Headquarters</td>
<td>Portland, Oregon</td>
</tr>
<tr>
<td>Sales Channels</td>
<td>World-wide coverage</td>
</tr>
<tr>
<td>Research &amp; Development</td>
<td>&gt; 100 patents granted and applied for</td>
</tr>
<tr>
<td>Initial Market</td>
<td>UV LED Curing</td>
</tr>
</tbody>
</table>
THANK YOU

Richa Anand, Ph.D.
Product Marketing Manager
Richa_Anand@Phoseon.com