Low voltage EB equipment development to meet the challenges of the fast growing packaging market

Im Rangwalla
Energy Sciences
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Agenda

• Markets for Packaging

• Packaging Market Trends and demands from end users

• Chemistry and resin supplier challenges

• EB equipment developments to meet the market trends

• Conclusions
## EB Applications

<table>
<thead>
<tr>
<th>Coating</th>
<th>Ink</th>
<th>Adhesive</th>
<th>Crosslink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Converting</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Films</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Silicone</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tapes</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tires</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Furniture</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooring</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Note: The table indicates the applicability of EB technology in various materials and industries.
Total NA Packaging Market US$ 164 Billion
Flexible Packaging Largest Growth (US $31 Billion)
FPA 2016
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Total Flexible</td>
<td>$19.7 B</td>
<td>$24.9 B</td>
<td>$31.2 B</td>
</tr>
<tr>
<td>Packaging Industry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$ Growth Year</td>
<td>3.7%</td>
<td>5.1%</td>
<td>3.4%</td>
</tr>
</tbody>
</table>
Challenges Faced By the Flexible Packaging Industry Today

• Driving Technology in:
  – Portioned / Single Serve Packages
  – Customize preparation (food, cosmetic, supplement...)
  – Customize printing. Shorter Runs

• Driving Technology in:
  – Barrier Materials
  – Scavenging Technologies
  – Shelf life extensions
  – Increased Environmental Awareness Low to NO VOC
  – Reuse, reduce, recycle, bio-base resins
  – Reduce Carbon Footprint
Challenges Faced By the Flexible Packaging Industry Today

• **Driving Technologies In:**
  – Environmentally Friendly Energy Cured Ink Technology
  – Resin & film technology to meet the challenges
  – Energy Cured Coating Technology to eliminate laminates
  – Printing Press and other equipment technology to print higher viscosity energy cured inks
  – Curing equipment technology to meet the above mentioned challenges
  – Plates and other printing methods
Applications of EB Curing in Packaging

• Coatings replacing laminates

• EB Curing of Inks
  – EB Offset Inks
  – EB CI-Flexo Inks
  – EB curing digital inks

• EB X-linking
  – High Barrier Shrink Films
  – Vacuum Skin Packaging
Laminate Replacement with EB Lacquers

Concept

**CONVENTIONAL LAMINATION**

- 40 M White OPP
- Adhesive
- Printing Ink
- 18M Clear OPP

**MONO-FILM WITH EB LACQUER**

- 50 M White OPP
- EB Lacquer
- Printing Ink
Challenges To Meet the Laminate Replacement

• Film & Resin Suppliers to Meet the Packaging Requirements with Monolayer.

• Coating Supplier Challenges
  – Meet the Film Properties With a EB Cured Coating
  – Matte and Gloss Properties as Provided By Film
  – Soft Touch and other Properties
  – Abrasion and Scuff
  – COF
  – Temperature resistance
Challenges to Meet Laminate Replacement

• EB equipment Supplier Challenges
  – Wide Width Ranges 24 – 108 inches
  – High Speed 1500 feet/min
  – Continuous Operation with Minimum Downtime
  • Robust Window Foil Technology to Resist Chemicals From Coatings

Pre-Mature Foil Failure

EDX analysis
EB Offset Inks

• Not That Much Development from Ink and EB Equipment
• Good Development from Press supplier to Meet Flexible Packaging Challenge. (Print Various Substrates)
### EB CI-Flexo Inks
#### Major Printing Method for Flexible Packaging

<table>
<thead>
<tr>
<th>Print Type</th>
<th>2010</th>
<th>2013</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexo</td>
<td>64%</td>
<td>63%</td>
<td>66%</td>
</tr>
<tr>
<td>Gravure</td>
<td>9%</td>
<td>11%</td>
<td>15%</td>
</tr>
<tr>
<td>Offset &amp; Other</td>
<td>1%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Digital</td>
<td>n/a</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Unprinted</td>
<td>26%</td>
<td>22%</td>
<td>15%</td>
</tr>
</tbody>
</table>
EB CI-Flexo Process

EB Flexo Requirements:
- Only one EB curing station at end
- No inter-station curing or drying
- Wet-on-wet printing
  - No turn bars - Central Impression (CI) Press
  - Transfer of ink over wet ink
  - No back trapping
Challenges to Meet EB CI-Flexo

• Ink Suppliers Major Challenge
  – WETFlex: Wet Trapping achieved by evaporating a non-reactive diluent and increasing the viscosity of the applied layer.
  – GELFlex: Wet Trapping achieved by evaporating a non-reactive diluent and adjusting the Hansen’s solubility parameter to form an organo gel in the applied layer.
  – ELEX-ONE: Wet Trapping achieved by adjusting the surface tension of the applied layer.
Challenges to Meet EB CI-Flexo

• CI-Flexo Press Manufacturers:
  – Pumps and Mixers for High Viscosity Energy Cured Inks
  – Doctor Blades
  – Temperature and Rheology Control

• EB Equipment:
  – Wide Web
  – High Speed Up to 1500 feet/min
  – Continuous Operation, minimum downtime
Advantages of Digital Printing with EB Curing

• Very High Print Quality
• Very Cost Effective for JIT Printing and Short Runs
• Better Properties
  – Gloss
  – Solvent & Temperature Resistance
• In-Line Coating and laminating Possible
• Food Packaging Compliant
Digital Printing With EB Curing

• Crosslinking of HP Indigo Inks To Obtain Better Resistance Properties
  – Temperature resistance up to 175-200°C
    Important for Heat Sealing

• EB Curing of Inks applied By Digital
  – Higher Gloss
  – Better Chemical Resistance
  – Temperature Resistance
Challenges To Meet with EB-Digital Printing

• Ink Suppliers
  – Viscosity of Inks
  – Wet on Wet Printing

• Press Suppliers

• EB Equipment
  – Cost Effective Equipment
  – Small Size
  – Low Speed. (400-600 feet/min)
High Barrier Shrink Film Bags Double Bubble Process Using 3-Layers
Structure of High Barrier Shrink Film Bags

Structure: Total wall thickness about 65 Microns.

- Outer Layer = 48 microns (18% EVA + LDPE)
- Middle Layer = 7 microns (PVDC) O₂ Barrier (7 – 9 cc/m² / 24 Hrs)
- Inner Layer = 8 microns (18% EVA + LDPE)
Typical EB Conditions for this Application
125-70 kV, 50-80 kGy Double Pass
Typical Non-Drum EB System
Vacuum Skin Packaging (VSP)

The Vacuum Skin Packaging (VSP) process uses a tray and special films that gently surround the product and seal over the entire surface of the pack like a second skin, preserving shape, texture and product integrity for a premium retail presentation.

Appealing shelf presentation
• Reduced packaging size and volume takes up less shelf space, cheaper to transport
• Reduced purge, increased shelf life lowers food waste, improves stock management
• Shelf life increased to 2-6 weeks vs MAP trays (6-10 days)
Typical Structure of VSP Film

Structure: Typical 80 – 150 microns  (5 layers)

Outside

Surlyn Ionomer Provides Puncture, and other properties

Tie Layer

EVOH 44%  Provides O$_2$ Barrier < 10 cc/m$^2$/24 hrs

Tie Layer

Inside Sealant layer (LDPE/EVA)
Typical EB Conditions for this Application
125 kV, 120-150 kGy Chill Drum Preferred
150 kV with Chilled Drum Optional
Challenges to Meet with EB-Crosslinking

• Resin Suppliers:
  – Use Co-agents to achieve desired crosslink density at lower dose so can go higher in speed

• EB Equipment Supplier:
  – Higher Speed at Lower Voltages (Around 80 kV)
  – Higher Dose Speed at 125 kV
EB Equipment Challenges to Meet Market Requirements

- Foil Passivation: Resist Reactions with Coating Effluents like Si Resulting in Pre-Mature Foil Failure
- Improve Heat Transfer of the Foil to Meet High Speed requirements For EB Coatings and EB CI-Flexo Applications
- Window Body Development To Allow High Speeds Up to 1500 Feet\Min
- Small Size Cost Effective EB Units For Digital Printing
- Increase Speed Rating at 80 kV for High Barrier Shrink Film Applications
How Does An EB Work?

- FILAMENTS EMIT ELECTRONS.
- ELECTRONS ARE ACCELERATED USING HIGH VOLTAGE.
- ELECTRONS PASS THROUGH THE WINDOW FOIL AND STRIKE THE PRODUCT.
- ELECTRONS CAUSE MOLECULAR CHANGES IN THE PRODUCT.
Energy Absorbed By Various Thickness Titanium Foils as a Function of High Voltage
Heat Energy Deposited In Foil

**Power kW** =

High Voltage Absorbed $dE$ (kV) $\times$ Beam Current $I$ (mA)

*Note: It is imperative to keep the Foil Temperature < 450°C to prevent pre-mature foil failure.*
Typical Machine Yield As A Function Of High Voltage For 12.5 Micron Titanium Foil
Dose Speed Relationship

Dose (kGy) = K \times I \ (mA) / S \ (mpm)
## Machine Yield at Various Foil Thickness at its Optimum Operating Voltage

**Machine Width 1200 mm**

<table>
<thead>
<tr>
<th>High Voltage kV</th>
<th>Titanium Foil Thickness Microns</th>
<th>Machine Yield “K” Mrad/fpm/mA</th>
<th>Machine Yield “K”kGy/mpm/mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>12.5</td>
<td>7.30</td>
<td>22.0</td>
</tr>
<tr>
<td>110</td>
<td>10</td>
<td>8.45</td>
<td>26.0</td>
</tr>
<tr>
<td>95</td>
<td>7.5</td>
<td>9.71</td>
<td>29.6</td>
</tr>
<tr>
<td>80</td>
<td>5.0</td>
<td>10.50</td>
<td>32.0</td>
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Depth Dose Profiles of EB Equipment at its Optimum Operating Voltage as a Function of Titanium Foil Thickness

Product Gap = 10 mm

![Graph showing depth dose profiles at different operating voltages and titanium foil thicknesses.](image)
Window Body Improvements For Different EB Equipment

1 Window For 400-600 FPM Speed

2 Window For 1000-1200 FPM

3 Window For 1500 FPM
Conclusions

• Flexible Packaging Has the Largest Growth

• Energy Curing in Particular EB Curing Shows Good Promise

• Chemistry Development and EB Development Continues to Meet the Challenges
Thank You
Any

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