Clear Hard Coat Films via Hybrid Multi-layer (HML) Vacuum Deposition

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Introduction

- Darly Custom Technology and Dah Young Vacuum Group
  - Facility locations
  - Core business
  - Key collaborations

- Clear & Transparent Hard Coats
  - Current technology
  - Solution coating issues

- HML Technology
  - Technology overview
  - Comparison of solution and vacuum coating
  - Competitive advantage
DAH YOUNG VACUUM TECHNICAL is a leader in:

- **Vacuum Coating**
- **Technology**
- **Equipment**
- **OEM Service**

- 1968 Established Dah Young Vacuum Technical Co., Ltd. (Taiwan)
- 1990 Invested in four packaging industry companies (China)
- 1995 Acquired Darly Custom Technology., Inc. (USA)
- 2002 Established Darly Photonics Composites Corp. (China)
- 2006 Established Subdivision Dah Young Shanghai (China)
Technology Development

1970
1980
1990
2000
2011

BATCH
Evaporation / Sputtering / E-beam Gun / PECVD
Ion Source / RF
Roll to Roll
Evaporation / Sputtering / HML / E-beam Gun
Plasma / Ion Source / IR

APPLICATIONS
Flexible RFID antenna
Flexible FCCL/FPC
Touch Panel / ITO Film
Flexible Speaker/Sensor
Flexible Photo-Voltaic
NCVM / NMVM
EMI Shielding
Polymer coating
Anti-Fingerprint
Dah Young Vacuum Technical Co., Ltd.

Company Profile
- Founded in 1968
- Capital: US $ 2.5 mil
- 50 Employees
- Plant area: 4,000 M²

Business Scope
- Equipment Manufacturing
- Process Development
- Technical Training

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Associated Companies

Darly Photonics Composite Materials Corp. (Shanghai, China)

Darly Custom Technology., Inc. (Connecticut, USA)

Business Scope

OEM Service & Production Items
Flexible Electronics, RFID Antenna, FCCL
ITO Film, EMI Shielding & NCVM

Technical Support
Laboratory Development
Product Development
Operator Technical Training

Research & Design Center
On September 15th 2011 Dah Young donated an HML tool that will be installed and operational in the fall of 2012.
Substrate Area Forecast for Flexible Electronics

<table>
<thead>
<tr>
<th>Year</th>
<th>Ultra-thin Glass</th>
<th>Metal Foil</th>
<th>Paper or Fabric</th>
<th>Plastic</th>
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<tbody>
<tr>
<td>2008</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>171</td>
</tr>
<tr>
<td>2009</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>355</td>
</tr>
<tr>
<td>2010</td>
<td>0</td>
<td>11</td>
<td>16</td>
<td>753</td>
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<tr>
<td>2011</td>
<td>0</td>
<td>27</td>
<td>38</td>
<td>1,488</td>
</tr>
<tr>
<td>2012</td>
<td>0</td>
<td>41</td>
<td>83</td>
<td>2,643</td>
</tr>
<tr>
<td>2013</td>
<td>1</td>
<td>57</td>
<td>83</td>
<td>4,145</td>
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<tr>
<td>2014</td>
<td>3</td>
<td>73</td>
<td>158</td>
<td>5,495</td>
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<tr>
<td>2015</td>
<td>5</td>
<td>89</td>
<td>221</td>
<td>6,679</td>
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<tr>
<td>2016</td>
<td>7</td>
<td>103</td>
<td>265</td>
<td>7,816</td>
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<td>2017</td>
<td>8</td>
<td>121</td>
<td>305</td>
<td>9,036</td>
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<tr>
<td>2018</td>
<td>11</td>
<td>137</td>
<td>335</td>
<td>10,410</td>
</tr>
</tbody>
</table>

Sum: 173, 362, 780, 1,553, 2,768, 4,362, 5,794, 7,040, 8,233, 9,503, 10,930

Source: “2008 Flexible Electronics and Displays Report” by DisplaySearch and FlexTech Alliance
Typical Resistive Touch Screen Structure

- Hard Coat
- PET Film
- ITO Coating
- Air Gap
- ITO Coating
- Glass or PET
- Spacer Dots
Hard Coat Requirements

- Hardness > 2H preferable > 3H
- Defect free
- Uniform thickness
- Transparent VLT > 88%
- Low Glare
- Anti-reflective
- Chemical resistant
- Humidity resistant
Control of Hard Coat Properties

- Hardness
  - Film thickness
  - Chemical formulation
- Defect free
  - Film Thickness
  - Adhesion
  - Process conditions

- Transparency
  - Film Thickness
  - Chemical formulation
- Glare and Haze
  - Surface roughness
- Anti-reflection
  - Film Thickness
  - Chemical formulation
Common Hard Coat Defects

- Blisters
- Curl
- Picture framing
- Reticulation
- Starry Night
- Cockle
- Blooming

- Craters
- Bénard–Marangoni Cells
- Mud cracking
- Delamination

- Orange Peel
Hardness
Hard organic precursors form brittle films when cured forcing HC formulations to incorporate flexible organic precursors. The resulting HC layer will be thicker to maintain the required hardness properties.

Abrasions resistance A thick film will produce a more robust coating.

Adhesion – Increased wet film mass prevents beading, enhances wetting and overcomes surface energy mismatch.

Control of defects
Shrinkage, curling and delamination can occur when organic precursors shrink during cure. HC formulations are required to incorporate soft components forcing the HC layer to be thicker to prevent these defects.

Optical properties – Reflection, interference and refractive index matching issues can be avoided by applying a uniform coating AND by selecting organic precursors with a refractive index that match the substrate.
Deposition of Hard Coat

- Film substrate with imperfections
- Plasma treatment to activate the substrate surface
- Leveling/Adhesion formulation vapor deposited and immediately cured
- Hard coat formulation deposited and immediately cured
Darly HML Advantage

- Layer thickness control
  - Less defects
  - Layer specialization – leveling/adhesion – hard coat
  - Use of thinner layers
  - Better control of optical properties

- Chemical formulation flexibility
  - Surface energy matching
  - Refractive index matching
  - Controlled evaporation

- Fast processing speeds

- Inherently clean environment - no clean room needed

- Environmentally friendly – solvent free process

- Lower operation costs – no need for large dryers
## Atmospheric vs. HML Vacuum Coated HC’s

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Atmospheric</th>
<th>HML Vacuum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of silica or other inorganic particles</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Viscosity limitations</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Typical solids loading</td>
<td>1-100%</td>
<td>100%</td>
</tr>
<tr>
<td>Wet coat weight</td>
<td>5-80μ</td>
<td>0.1-2μ</td>
</tr>
<tr>
<td>Final thickness</td>
<td>1-20μ</td>
<td>0.1-2μ</td>
</tr>
<tr>
<td>Average Line Speed</td>
<td>1-300 m/m</td>
<td>1-1000 m/m</td>
</tr>
<tr>
<td>Curing method</td>
<td>Thermal, UV &amp; E-beam</td>
<td>UV &amp; E-beam</td>
</tr>
</tbody>
</table>
System Schematic

1 meter diameter SS drum

Unwind  Rewind

1st Organic deposition unit

2nd Radiation curing source

Plasma treater

2nd Organic deposition unit

1st Radiation curing source

1st Organic deposition unit
System Specifications

- Able to process substrates up to 36 inches wide
- Available coating width of up to 34 inches
- Substrate roll diameter is 12 inches on a 6 inch core
- Coating thickness can be tuned from < 0.1 to 2.0 μm
- Dynamic speed range 0.1 – 100 m/min
- Compatible with many flexible substrates
Darly HML coater

HML Status on September 17\textsuperscript{th} 2011