Stretching the limits – Ultra Thin Film metallization for capacitor applications.

Dr. Anye Chifen
Eiichi Sasaki
Takayoshi Hirono
1. The Company - ULVAC

2. Introduction: EWE – series
   - Schematic – cross section of EWE
   - Process description

3. Stretching the limits – Process evaluation
   - Product overview (processability)
   - Technical prospects & challenges

4. Outlook of Ultra Thin Film polymer capacitors
Outline

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4. Outlook of Ultra Thin Film polymer capacitors
## ULVAC Roll Coater History and Future

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method</strong></td>
<td>RH</td>
<td>Li/PET, Cu</td>
<td><strong>Evaporation</strong></td>
<td><strong>Decoration</strong></td>
<td>Al / PET, OPP, CPP</td>
<td><strong>Film Width</strong>: max. 3.2m</td>
<td><strong>Package/Barrier</strong></td>
</tr>
<tr>
<td><strong>Sputtering</strong></td>
<td>SPW Series</td>
<td>FCCL (Flexible Cu Clad Laminate)</td>
<td><strong>NiCr-Cu/PI, PET</strong></td>
<td><strong>Touch Panel</strong></td>
<td>SiOx, ITO/PET</td>
<td><strong>AR/IM/Environment</strong></td>
<td>Optical/PET</td>
</tr>
</tbody>
</table>

**EW Series**

- **Zn, Al / Paper, PET, OPP, Film Thickness**: PET 1.3μm, OPP 1.5μm

**SP Series**

- **Battery**
Applications - Web Coating Technology

Flexible Electronics
AR Film
Smart Phone
Film Capacitor
Hybrid Car
Magnetic Tape/
Storage
Film Package
Food
Barrier Film
Diverse App

Flexible Display
Cond. Film
Touch Panel
Film Capacitor
Conventional
Construction
Tool Parts
Decoration
Metallic Yarn
Stamp Foil
Labels

SPW Series
EWE Series
EWA EWJ Series

* All figures based by ULVAC calculation
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4. Outlook of Ultra Thin Film polymer capacitors
1. **Decoupling**: enables sudden transfers of current (energy) while maintaining stable voltage levels.

2. **Filtering**: removes or reduces unwanted AC voltages in applications such as AM radio, cellular phone or IC switching noise applications.

3. **Coupling**: blocks DC and passes AC component, for example, in smart meter applications.

4. **Timing and Waveshaping**: sets delay time in systems such as windshield wipers.

Source: Toyota, Shizuki
The outstanding design of the system is based on thermal evaporation of individual or combined metal layers to create the electrodes;

A) Zn + Ag (pre-nucleation $\rightarrow$ adhesion & protection),
B) Zn + Al (composites $\rightarrow$ reinforced metal layer), and
C) Al double layer (High ohmic ratio $\rightarrow$ reinforced layer).
1. High vacuum pump-set – mechanical-, diffusion pump, cryogenic system
2. Chamber – winding- / coating section
3. Evaporation (Al, Zinc, Ag)
4. Winding trolley: chilling and heating unit
5. Free margin oil evaporator
6. Bias & EB Bias
7. IR heater
8. Process control – industrial PC
9. Visualization
Outline

1. The Company - ULVAC
   - About ULVAC
   - History of ULVAC

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3. Stretching the limits – Process evaluation
   - Product overview (processability)
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4. Conclusion of EWE – series
Stretching the limits –

What is the future for metallized polymer for capacitors?
<table>
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<tr>
<th>Parameter</th>
<th>PET</th>
<th>PP</th>
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<tbody>
<tr>
<td>Relative permittivity @ 1 kHz</td>
<td>3.3</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Minimum film thickness (µm)</strong></td>
<td><strong>0.75</strong></td>
<td>2</td>
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<td>Moisture absorption (%)</td>
<td>Low</td>
<td>&lt;0.1</td>
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<td>100pf – 22µF</td>
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<td>Dissipation factor a 1 kHz</td>
<td>50 - 200</td>
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Properties of metallized film for capacitors

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### Specific aspects – to push the limits

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<th>Productivity</th>
<th>Performance</th>
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<td>• Segmented metallization</td>
<td>• Down-time</td>
<td>• Reliability</td>
</tr>
<tr>
<td>• Alloy deposition</td>
<td>• Web width</td>
<td>• material thickness</td>
</tr>
<tr>
<td>• Alternative materials</td>
<td>• Process speed</td>
<td>• Double metallization</td>
</tr>
</tbody>
</table>

- Productivity:
  - Down-time
  - Web width
  - Process speed

- Performance:
  - Reliability
  - Material thickness
  - Double metallization
<table>
<thead>
<tr>
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<th>EWE-060</th>
<th>EWE-080</th>
<th>EWE-110</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Web Width</strong></td>
<td>max. 670mm</td>
<td>max. 950mm</td>
<td>max. 1050mm</td>
</tr>
<tr>
<td><strong>Web Material</strong></td>
<td>OPP 2.0 ~ 6.0μm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Web Diameter</strong></td>
<td>φ650</td>
<td>φ650</td>
<td>Φ620</td>
</tr>
<tr>
<td><strong>Winding Speed</strong></td>
<td>100~1200 m/min</td>
<td>100~1200 m/min</td>
<td>100~1000 m/min</td>
</tr>
<tr>
<td><strong>Driving Motor</strong></td>
<td>8 motor system</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AL Boat Qty</strong></td>
<td>11</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td><strong>Process Winding Speed</strong></td>
<td>&gt; 750m/min (OPP 1.9µm ~ Al 5 Ω/□~)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Resistance Uniformity</strong></td>
<td>10Ω/□±10% Reference examples</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Depo. Length</strong></td>
<td>55,000m (OPP 2.0µ~)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Pattern accuracy</strong></td>
<td>&lt; 0.15 ± 0.03mm (Dep. speed &gt; 750m/min, OPP &gt; 2.0µm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Main Roller Temperature</strong></td>
<td>-20 ~ 20 °C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EWE – series: Precision at pattern printing

1. Susceptible to dirt from evaporation zone
2. Thermal damage of sleeve (heating vs. Cooling)
3. Accessibility / Ergonomics
4. Set-up before metallization
## EWE – series: Precision at pattern printing

<table>
<thead>
<tr>
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<th>ULVAC’s CONFIGURATION</th>
<th>OTHERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impression roller</td>
<td>Not cooled, integrated rdle roller</td>
<td>Main roller, coating drum</td>
</tr>
<tr>
<td>Oil evaporator</td>
<td>Temperature and pressure controlled, No doctor blade required</td>
<td>Temperature controlled, large volume of oil, with doctor blade on anilox</td>
</tr>
<tr>
<td>Positioning</td>
<td>Not in contact with metal deposition zone</td>
<td>Susceptible to dirt from evaporation</td>
</tr>
<tr>
<td>Web path stability</td>
<td>Guaranteed with motor driven rollers</td>
<td>Coating drum driven</td>
</tr>
<tr>
<td>Pattern precision &amp; reproducibility</td>
<td>Less than 0.15 (± 0.01)mm</td>
<td>Tolerance ± 0.03 mm</td>
</tr>
</tbody>
</table>
ULVAC’s Technology combined technology for Power Capacitors

Oil Patterning Technology

EB+DC Bias Technology

Essential for High voltage capacitor
ULVAC’s “Only One” Technology
Oil Pattering Technology (Flexographic Printing)
Flexographic Printing

Fuse: Width 0.2mm

<table>
<thead>
<tr>
<th>Measuring Point</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
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<tbody>
<tr>
<td>(mm)</td>
<td>0.3</td>
<td>0.25</td>
<td>0.2</td>
<td>0.15</td>
<td>0.1</td>
<td>0.05</td>
<td></td>
<td></td>
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OPP: 2.3μm, Speed: 750m/min, Resistance: 10Ω/□

Flexographic printing standard specification: 0.2mm ± 0.05mm
Actual: Set Value ± 0.02 ~ 0.03mm

Fuse Narrow Type: Width 0.16mm

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<tbody>
<tr>
<td>(mm)</td>
<td>0.25</td>
<td>0.23</td>
<td>0.21</td>
<td>0.19</td>
<td>0.17</td>
<td>0.15</td>
<td>0.13</td>
<td>0.11</td>
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OPP: 2.3μm, Speed: 750m/min, Resistance: 10Ω/□

Electrode Space Narrow Type: 0.16mm

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OPP: 2.3μm, Speed: 750m/min, Resistance: 100Ω/□
Film Pre/Post plasma surface treatment

1) SURFACE CLEANING OF BASE FILM
2) NEUTRALIZATION OF CHARGES ON METALLIZED FILM
3) REMOVAL OF IMPLANTED ELECTRONS SUBJECTED BY ELECTRON BEAM GUN
Film Pre/Post plasma surface treatment

<table>
<thead>
<tr>
<th>Size</th>
<th>W</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Double</td>
<td>100</td>
<td>200</td>
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**Effect**
- remove static electricity
- improve adhesion by cleaning

Electrostatic Charge (V) vs. Film Width

- With BMB
- Without BMB
Pumping capacity & design

1. Diffusion pumps installed for winding & coating zone
2. Reduction of permanent gas
3. Increased pumping speed
4. Chamber separation is crucial for pressure in coating section – ULVAC design
5. Pump down time: < 4 min (to achieve 1E-5 mbar)
6. Dimension of diffusion pump (winding & coating zones)
7. Additional root blower pump (WSU2001H & WHU7000) with holder pump.

→ The target is to reduce vacuum volume and increase productivity and performance
1. Free margin, after oil (protective) evaporator
   a) Individual nozzles are pressure monitored, temperature regulated
   b) Oil thickness is defined & controlled

2. Pattern oil evaporator
   a) Individual nozzles are pressure monitored, temperature regulated
   b) Separate process chamber & no doctorblade required

3. Plasma treater stations
   a) Tailored surface treatment

4. Winding concept upto 1100mm film width
   a) Individual nozzles are pressure monitored, temperature regulated
   b) Oil thickness controlled

Outlook for Ultra thin film for capacitor applications
(1) Expander / spreader rolls are direct driven
(2) Process control with high speed camera systems
(3) Wider substrates and process speed $\Rightarrow$ engineered surface of rollers
(4) Upgraded EB gun and heat management for sensitivity of thin film,
(5) Super efficient real time layer measuring system, 100 % quality control,
(6) Alternative materials and alloys to improve capacitance
Outlook for Ultra thin film → technical trend

Capacitance (μF)

- DC Capacitors (PPS 0.9 - 2.0μm)
- Aluminum electrolytic capacitor
- Tantalum Capacitor
- Ceramic Capacitor
- Film capacitor
- New Gen. Area
- HEV Area
- AC Capacitors (PP 4.0 - 8.0μm) - PP Double side
- Power Capacitors (PP 1.6 - 6.0μm)

Rated voltage (V)
Streching the limits – responding to the market

EWE is an outstanding roll to roll web coater series based on thermal evaporation of individual or combined metal layers to create the thin layers electrodes;

A) Zn + Ag (pre-nucleation $\rightarrow$ adhesion & protection),
B) Zn + Al (composites $\rightarrow$ reinforced metal layer), and
C) Al double layer (High ohmic ratio $\rightarrow$ reinforced layer).