The Push for Thin
Goal of Thin

• Thin means something different for each application
  
  – Reducing overall device thickness
  
  – Components in unused space
    • Back of a board
    • Inside or Under Chip
  
  – Higher power density

• Goal: Provide the tools you need
Where does the height go?

- As the thickness of device is reduced the percentage of height used for capacitance decreases quickly.
Traditional Molded Capacitors

- Traditional SMT Aluminum and Tantalum capacitors are injection molded.
- Injection molding limits the minimum thickness.
- Thinner encapsulant reduced the material flow across thinner regions, generating back pressure and irregular mixing.

As the thickness of the encapsulant or leadframe is reduced there is less support for the capacitor element during molding, increasing the chance the capacitor elements may move.
Where traditional methods run out

Usable capacitor height is decreased further when factoring in manufacturing tolerances

Tolerances within manufacturing process

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Advanced Packaging

KAP
KEMET Advanced Packaging - Process

- Capacitor lamination processed in such a way as the glass weave is compressed to the capacitor elements and provides thickness limits

Capacitor Thickness (typical) – (180µm - 200µm)
Encapsulant Thickness (glass weave) – (30µm – 60µm)
Copper foil (terminals) – (5µm - 10µm)
Total finished part thickness – 0.35mm – 0.25mm

Current development samples 3528 - 0.27mm thick
KAP - Terminal Forming

- Pockets cut into laminate form the basis for the terminals
- Copper plating is formed inside the pockets to connect the capacitor and the copper cladding layer

Copper plating into vias/pockets to form terminal connections

Copper etched to form discrete terminals and capacitors cut free from the laminate
KAP - Construction

- Resin with fillers form around the part during lamination.
- Fibers acting as spacing element to center the capacitor.
- Polymer, carbon, silver and copper cathode layers.

Terminal formed by copper cladding and plating.

SU3500 20.0kV 9.6mm x200 BSE-COMP
Target Capability of New Packaging vs. Traditional Progression to lower case height

KEMET Advanced Package = KAP

Volumetric Efficiency of Different Packaging Designs

<table>
<thead>
<tr>
<th>3528/Height *</th>
<th>1.0mm</th>
<th>0.8mm</th>
<th>0.6mm</th>
<th>0.4mm</th>
<th>0.2mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>16%</td>
<td>10%</td>
<td>1%</td>
<td>-19%</td>
<td>-76%</td>
</tr>
<tr>
<td>Facedown (Target)</td>
<td>48%</td>
<td>44%</td>
<td>38%</td>
<td>26%</td>
<td>-10%</td>
</tr>
<tr>
<td>Gen II</td>
<td>59%</td>
<td>54%</td>
<td>47%</td>
<td>32%</td>
<td>-12%</td>
</tr>
<tr>
<td>KAP</td>
<td>80%</td>
<td>77%</td>
<td>74%</td>
<td>67%</td>
<td>46%</td>
</tr>
</tbody>
</table>

Max Available Finished Anode Height (mm)

<table>
<thead>
<tr>
<th>3528/Height *</th>
<th>1.0mm</th>
<th>0.8mm</th>
<th>0.6mm</th>
<th>0.4mm</th>
<th>0.2mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>0.41</td>
<td>0.21</td>
<td>0.01</td>
<td>-0.19</td>
<td>-0.38</td>
</tr>
<tr>
<td>Facedown (Target)</td>
<td>0.76</td>
<td>0.56</td>
<td>0.36</td>
<td>0.16</td>
<td>-0.03</td>
</tr>
<tr>
<td>Gen II</td>
<td>0.76</td>
<td>0.56</td>
<td>0.36</td>
<td>0.16</td>
<td>-0.03</td>
</tr>
<tr>
<td>KAP</td>
<td>0.89</td>
<td>0.69</td>
<td>0.49</td>
<td>0.29</td>
<td>0.10</td>
</tr>
</tbody>
</table>

* Volumetric efficiency is based on construction design rules for ≤0.4mm, other limiting factors may exist above 0.4mm.

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Flexibility

- An added benefit of thinner capacitors is flexibility.
- As the capacitor elements approach ~200µm or less they exhibit flexibility.
- These flexible elements can be combined with a flexible laminate to form a functional capacitor.

Initial flexibility tests show stability in electrical performance of capacitor elements down to 5mm radius of bend.
Embedded/Integrated Capacitors
Removing the discrete component

- When looking at the percentage of height used for capacitance and factoring the board level in, we can further improve the volumetric efficiency by incorporating the component in the board.

Graph now shows part + board height, not just discrete component.

[Diagram showing comparison between traditional and Discrete component on a board, focusing on height efficiency.]
Board level height influence

- With thickness reduction and embedding the percentage of height used for capacitance is significantly increased in a given board footprint.
Embedded/Integrated Capacitor Construction

- Masking (barrier layer) (Red)
- Carbon (black)
- Conductive Polymer (blue – internal/external)
- Al foil 25-40µm
- Cu (plated layer)
- Etched
- Physical Vapor Deposited

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Embedded/Integrated
Current layer Construction

- Copper plated layer
- Ultra thin carbon ink
- Thin Electro-Chemical Polymer layer (ECPoly)
- Etched aluminum layer/internal polymer

~80um
Embedded/Integrated Capacitor - Process

Aluminum capacitor foil is patterned by removing the etched layer

Sheet of capacitors is applied to a transfer film and the excess material cut away to leave individual capacitors in a pattern

Conductive Polymer (ECPoly) is applied to the etched pads to form a thin dense external layer

1mm

Copper plating is applied over the external cathode layers

Etched layer removed and barrier layer applied inside troughs

Pads remaining include porous layer

Reverse of foil plated with copper etc.
Patterning and Transport Concept

Cross section

Transfer release film

Top view

Arrayed Sheets

Individual Taping

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Embedding or Integrating Concepts

Embeddable in a circuit board

Integrated into a chip

Possible connection methods:
- Wire bond
- Via plating
- Copper pillars
- etc.

Possible via location for cathode connection

<table>
<thead>
<tr>
<th>Capability</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>2V-50V+</td>
</tr>
<tr>
<td>Capacitor size</td>
<td>≤1mm</td>
</tr>
<tr>
<td>Cap thickness</td>
<td>~50µm</td>
</tr>
<tr>
<td>Capacitance</td>
<td>≥100µF/cm²</td>
</tr>
<tr>
<td>DC leakage</td>
<td>&lt;50 nA/CV</td>
</tr>
</tbody>
</table>

* Capabilities table values are highly dependent on application design

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Thank You!

Download at:
ec.kemet.com/ao-embedded-apec