Introduction to Low Temperature Soldering (LTS)
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Agenda

• Introduction & Motivation
• Breakthrough Technology
• Cost Savings
• Energy & Environment
• Faster Technology Scaling
Motivation for Low Temperature Reflow

Faster Technology Scaling

Energy & Emissions

Reduced Emissions saves 57 metric tons of CO₂ per oven/year

Reduced Electricity Saves > $8,500/oven/year

Process & Materials

Wave Solder Elimination

Solder Material Cost Reduction
History of Green Electronics

SMT Reflow Timeline

- Widespread adoption of Tin-Lead solders for SMT production of micro-electronics
- European, Japan and US mandates the removal of Pb-based solders from mass production
- Environmental, cost and scalability concerns inspire the need for low temperature processing

Year:
- 1985
- 1995
- 2006
- 2010
- 2017
Balance Between Social-technical responsibility

Social Responsibility vs Technical Requirements

- Technical requirements vs environmental friendly manufacturing
- Opportunity to adopt socially responsible MFG parameters without sacrificing product reliability
- LTS capability still under evaluation
- Gen 3 performance trending towards SAC capability

Social Responsibility Without Sacrificing Technical Capability
Example of Social-Technical Responsibility: Shock

Social Responsibility vs Technical Requirements

175-225G

Gold Star:
Technical overkill leads to highest reliability possible but may sacrifice “green”

125-175G

Happy Face:
The right mix of technical requirements and social responsibility can meet actual reliability needs

100-125G

Green Cloud:
Socially dominated MFG can lead to lower than required reliability capability

Example only. Does not imply actual capability targets

LTS Paste Offers a Unique Opportunity to Be Socially and Technically Responsible
Breakthrough Technology
Breakthrough Technology

LTS lowers reflow peak temp from 250°C → 190°C and reduces inherent board-to-package warpage by > 50%

Dynamic Warpage

- High (+)
- Low (0)
- High (-)

Reflo Temperature

- 25°C
- 200°C
- 250°C

Lower Temperature = Less Warpage

![Graph showing BGA Warpage as a function of temperature](image)

- 56% less warpage

- Units: 1, 2, 3, 4, 5, 6
Breakthrough Technology
Material: SnBi Paste

**Melting Point:**

- **SAC alloys**
  - SnAgCu (96.5/3/0.5)
  - SnAgCu (95.5/4/0.5)

- **Eutectic Tin-Lead Alloy**
  - SnPb(63/37)

- **Bismuth-Tin Eutectic Alloy**
  - BiSn(57/42) + Ag (x=0.4-1)

In use today for consumer TVs, White Goods, LED products

**SnBi Paste + SAC Sphere = Mixed Joint**
Module

LTS Solder Reliability Improvement via Dopants

Bismuth is Inherently more Brittle

SAC region
Bi-mixed region
Fracture Through IMC

Bi causes joint hardening and is prone to brittle fractures under mechanical shock and drop forces.

Breakthrough Technology: Increased Ductility

Bismuth is Inherently more Brittle

Path to Reduce Embrittlement

Dopants increase ductility through precipitation strengthening (Cu, Ni) or Grain size refinement (Co, Mn, Sb)

Material Engineering can Overcome Brittleness
Breakthrough Technology: Material Engineering

Decrease Bi Content

Less Bismuth = Lower Brittleness

Precipitation Strengthening - Cu,Ni doping

Lattice distortion impedes dislocation and strengthens alloy

Grain Size Refinement - Co, Mn, Sb doping

Finer grain size increases ductility

Multiple Paths to Overcome Brittleness
Breakthrough Technology: Improved Reliability

Material Engineering Improves Reliability
Cost Savings
Cost Saving: Reduced Electricity Consumption

40% Reduction in Electricity Consumption

<table>
<thead>
<tr>
<th>Measured Parameter</th>
<th>SAC Reflow</th>
<th>BiSnAg Reflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (RMS), amps</td>
<td>60.4</td>
<td>36.7</td>
</tr>
<tr>
<td>Power (Average), Kilowatts</td>
<td>29.3</td>
<td>17.8</td>
</tr>
</tbody>
</table>

- Significant cost reduction for High Volume Factory
- ~$9K USD per over per year
Cost Savings: Direct Cost Opportunity

- LTS enables single-pass process
- Low Tg, low cost components
- Equivalent reliability and joint strength
- Over $10M USD saved in volume production

<table>
<thead>
<tr>
<th>Process Temp</th>
<th>LT Reflow (190 C)</th>
<th>HT Reflow (250 C)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion Strength</td>
<td>2.4 kgf</td>
<td>2.28 kgf</td>
<td>Equal</td>
</tr>
<tr>
<td>Reliability</td>
<td>No issue</td>
<td>No issue</td>
<td>Equal</td>
</tr>
<tr>
<td>Component Cost</td>
<td>$2.66 (-$0.52)</td>
<td>$3.17</td>
<td>LTS better</td>
</tr>
</tbody>
</table>

LTS can Save Direct Operational Costs
Energy and Environment
Energy & Environment: CO₂ Reduction

LTS vs. SAC Reflow Electrical Usage

<table>
<thead>
<tr>
<th>Estimated SMT Process Energy Cost Comparison</th>
<th>SAC 305 Paste</th>
<th>Sn/Bi/Ag Paste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oven Energy Consumption (Kw)</td>
<td>29.5</td>
<td>17.8</td>
</tr>
<tr>
<td>80% Utilization (Hours/Wk)</td>
<td>134.4</td>
<td>134.4</td>
</tr>
<tr>
<td>CO₂ Metric ton p/kwh (EPA est)*</td>
<td>0.0007</td>
<td>0.0007</td>
</tr>
<tr>
<td>CO₂ emission per month</td>
<td>2.78</td>
<td>1.67</td>
</tr>
<tr>
<td>CO₂ Savings (metric tons per oven/week)</td>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>CO₂ Savings (metric tons per oven/yr)</td>
<td></td>
<td>57.2</td>
</tr>
</tbody>
</table>

- Significant CO₂ emission reduction for High Volume Factory
- 60 metric tons per oven per year
Energy & Environment: CO$_2$ Reduction

LTS potentially saves the computer assembly industry 35K – 50K **metric tons** of CO$_2$ every year

- Carbon equivalent of 33-50 Million pounds of Coal burned
- Power generated by 32 – 50 Wind Turbines

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**Electronics Manufacturers in China Must Join New Pollution Tracking System**

On January 23, 2017, the Chinese government published a list of industries, including computer, communications and electronic equipment manufacturing, that will be required to register under the new critical monitoring system outlined in November 2016. The system will track companies’ air and water discharges, **which may be taxed**. While more than 20 industries must register this year, computer, communications and electronic equipment manufacturers are included in the second wave of companies which must join the system by 2020.

IPC will continue to post updates as they become available.

Source: IPC Global Insight online magazine

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**LTS Enables Carbon Emission Reduction**
Faster Technology Scaling
Faster Technology Scaling
Lower Temperature Enables Tighter Pitch & Thinner Systems

Solder Bridge Defect due to compression
Non-Contact Defect due to expansion

Solder Bridge Risk
Risk of Solder Bridge Short

Risk of Non-Contact Opens

LTS Provides Design Freedom for Thin & Light Systems
Faster Technology Scaling

- Future Products will be thinner, lighter, with better performance products
- LTS enables design freedom – more options for system architectures

LTS Enables System Manufacturing to Keep Pace with Moore's Law
Conclusion

• Breakthrough Technology has enabled the advancement of Low Temperature Solder (LTS) Paste that meets process and reliability requirements
• LTS provides Production Cost Savings and Environmental Benefits
• LTS enables Faster Technology Scaling for Electronic Assembly