Development of a Suitable Flux Medium for Cleanable and No-Clean Solder Pastes Based on Tin-Bismuth-Silver Alloy

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- SnBi and SnBiAg alloys
- Composition of a flux medium
- Development of a cleanable SnBiAg paste
- Development of a no-clean SnBiAg paste
- Conclusions
- Q & A
SnBi and SnBiAg alloys

<table>
<thead>
<tr>
<th></th>
<th>Sn42Bi58</th>
<th>Sn42Bi57.6Ag0.4</th>
<th>Sn42Bi57Ag1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eutectic</td>
<td>138°C</td>
<td>139-140°C</td>
<td></td>
</tr>
<tr>
<td>High Strength</td>
<td>High Strength</td>
<td>High Strength</td>
<td></td>
</tr>
<tr>
<td>Brittle</td>
<td>Brittle</td>
<td>Less brittle</td>
<td></td>
</tr>
<tr>
<td>Poor reliability</td>
<td>Poor reliability</td>
<td>Better reliability</td>
<td></td>
</tr>
<tr>
<td>Sn16Pb32Bi52</td>
<td>risk (96°C)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SnBi and SnBiAg alloys

- RoHS implementation: no risk of Sn16Pb32Bi52 formation
- Less energy consumption
- Shorter cycle time
- Improved soldering yield for temperature sensitive components
- Pin in paste for temperature sensitive connectors
- Easier oven cleaning due to lower temperature
- Extended oven life
Composition of a flux medium

- Resins
- Activators
- Solvents
- Thixotrophic agents

FLUX MEDIUM
Composition of a flux medium

Rosins

- Role
  - Binder

- Rosins based on colophonium derivatives
- Hydrogenated, disproportionated, esterified...

- Acid index, glass transition temperature

<table>
<thead>
<tr>
<th>Rosin nature</th>
<th>Ia</th>
<th>Tg (°C)</th>
<th>color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully hydrogenated rosin</td>
<td>170</td>
<td>80</td>
<td>white</td>
</tr>
<tr>
<td>Partially dimerized rosin</td>
<td>160</td>
<td>95</td>
<td>brown</td>
</tr>
<tr>
<td>Acid modified rosin</td>
<td>200</td>
<td>130</td>
<td>white</td>
</tr>
<tr>
<td>Esterified rosin</td>
<td>20</td>
<td>&lt;0</td>
<td>amber</td>
</tr>
</tbody>
</table>
Composition of a flux medium
Rosins

- Color

- Solubility in solvents
Composition of a flux medium
Activators

- Role
  - Remove oxides (substrates, powder)

- Organic weak acids
- Halides (Hydrochlorides, hydrobromides)
- Halogens (Molecules with halogen atoms linked by weak covalent bond)
- Amines
Composition of a flux medium
Activators

- Melting point, boiling point, decomposition temperature
- Solubility
- Acid index

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Molecular formula</th>
<th>la</th>
</tr>
</thead>
<tbody>
<tr>
<td>malonic acid</td>
<td>HO₂C(CH₂)CO₂H</td>
<td>1073</td>
</tr>
<tr>
<td>succinic acid</td>
<td>HO₂C(CH₂)₂CO₂H</td>
<td>950</td>
</tr>
<tr>
<td>glutaric acid</td>
<td>HO₂C(CH₂)₃CO₂H</td>
<td>849</td>
</tr>
<tr>
<td>adipic acid</td>
<td>HO₂C(CH₂)₄CO₂H</td>
<td>768</td>
</tr>
<tr>
<td>pimelic acid</td>
<td>HO₂C(CH₂)₅CO₂H</td>
<td>700</td>
</tr>
<tr>
<td>suberic acid</td>
<td>HO₂C(CH₂)₆CO₂H</td>
<td>644</td>
</tr>
<tr>
<td>azelaic acid</td>
<td>HO₂C(CH₂)₇CO₂H</td>
<td>596</td>
</tr>
<tr>
<td>stearic acid</td>
<td>CH₃(CH₂)₁₆COOH</td>
<td>197</td>
</tr>
<tr>
<td>octanoic acid</td>
<td>CH₃(CH₂)₆COOH</td>
<td>389</td>
</tr>
<tr>
<td>malic acid</td>
<td>HO₂CCHOHCH₂CO₂H</td>
<td>837</td>
</tr>
</tbody>
</table>
Composition of a flux medium
Solvents

- **Role**
  - Dissolve chemical compounds
  - Stabilize flux medium

- Solvency power
- Boiling point, vapor pressure (high boiling point)
- Viscosity
- Surface tension
- Polarity
Composition of a flux medium
Solvents

- Key factor for printability, stability, reflow properties

Suitable for printing   Not suitable for printing
Composition of a flux medium
Thixotropic agents

- Role
  - Provide the right viscosity according to the shear stress applied
Composition of a flux medium

Solder Paste

- Flux medium designed according to the alloy
- Solvent boiling point
- Activator system suitable for the oxide nature of the alloy

<table>
<thead>
<tr>
<th>Alloy</th>
<th>SnAg3Cu0.5</th>
<th>Sn63Pb37</th>
<th>Sn91Zn9</th>
<th>Sn42Bi58</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mp (°C)</td>
<td>217</td>
<td>183</td>
<td>199</td>
<td>138</td>
</tr>
</tbody>
</table>
Development of a cleanable SnBiAg Solder Paste

- Lead-free low temperature
- Sn42Bi58 or Sn42Bi57.6Ag0.4
- Type 3, dispensable
- Wetting on ENIG
- Low microballing
- Cleanable residues with solvent cleaning process
- Thermal shock resistance (customer test)
Development of a cleanable SnBiAg Solder Paste

- State of the art / bibliographic research
- Know-how
- Lab tests / specific tests
- Formulation
- Customer tests
- Feedback / Optimization
Development of a cleanable SnBiAg Solder Paste

- Comparison of tensile strength resistivity of solder joints

<table>
<thead>
<tr>
<th>Paste Alloy</th>
<th>Paste</th>
<th>Tensile strength average (Newton)</th>
<th>Std deviation</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>SnPb</td>
<td>I1</td>
<td>76</td>
<td>5</td>
<td>87</td>
<td>66</td>
</tr>
<tr>
<td>SnBi</td>
<td>X1</td>
<td>57</td>
<td>23</td>
<td>99</td>
<td>20</td>
</tr>
<tr>
<td>SBA</td>
<td>X2</td>
<td>105</td>
<td>11</td>
<td>120</td>
<td>76</td>
</tr>
</tbody>
</table>

Choice = Sn42Bi57.6Ag0.4
Development of a cleanable SnBiAg Solder Paste

- Solderballing and wetting test on hotplate
- Criteria according to standard

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>5 solderballs maximum</td>
</tr>
<tr>
<td>Class 2</td>
<td>6 - 10 solderballs</td>
</tr>
<tr>
<td>Class 3</td>
<td>11 - 20 solderballs</td>
</tr>
<tr>
<td>Class 4</td>
<td>21 - 50 with possibility of a slight lisere</td>
</tr>
<tr>
<td>Class 5</td>
<td>&gt; 50 solderballs with clusters and lisere</td>
</tr>
</tbody>
</table>
Development of a cleanable SnBiAg Solder Paste

- Solderballing and wetting test on hotplate
- New criteria needed due to SnBiAg powder

Class 6 with oxides

Class 7 with oxides
Development of a cleanable SnBiAg Solder Paste

- Solderballing and wetting test on hotplate
Development of a cleanable SnBiAg Solder Paste

- Screening of rosins, activators, solvents
- Strong activators efficient against solderballing and oxides
- Some strong activators cause premature ageing of the paste
- Lower boiling point solvents improve solderballing performance
- Paste with low microballing are difficult to clean
Development of a cleanable SnBiAg Solder Paste

- Solderballing and wetting test on hotplate

 Flux medium A
 BAD

 Flux medium B
 OK
Development of a cleanable SnBiAg Solder Paste

- Viscosity
- Ageing at 25°C
- Manual cleaning
Development of a cleanable SnBiAg Solder Paste

- Viscosity
- Ageing at 25°C
Development of a cleanable SnBiAg Solder Paste

- 3 optimized solder pastes fully tested in the lab
- Dispensability
- Solderballing (hotplate/oven)
- Wettability on copper and ENIG (hotplate/oven)
- Cleanability (industrial process)
- Visual examination / ionic contamination

3 Propositions X3, X4, X5
## Development of a cleanable SnBiAg Solder Paste

### Customer tests

<table>
<thead>
<tr>
<th></th>
<th>X2</th>
<th>X3</th>
<th>X4</th>
<th>X5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispensing</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Wetting</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Microballs</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cleaning visual</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cleaning IC</td>
<td>1.41</td>
<td>&gt; 4</td>
<td>1.35</td>
<td>2.10</td>
</tr>
</tbody>
</table>
Development of a cleanable SnBiAg Solder Paste

- Customer tests

Less microballing => More difficult to clean

White residues and high ionic contamination
Development of a cleanable SnBiAg Solder Paste

- Optimization
- Decrease the number of microballs while keeping a sufficient residue cleanability
- Risk for some of the microballs to stay on the PCBA after cleaning
- Microballs accumulation in cleaning equipment leading to higher maintenance frequency

2 solder pastes X6 and X7
Development of a cleanable SnBiAg Solder Paste

Customer tests

<table>
<thead>
<tr>
<th></th>
<th>X6</th>
<th>X7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispensing</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wetting</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Microballs</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cleaning visual</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Cleaning IC</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Tensile strength (N)</td>
<td>93</td>
<td>93</td>
</tr>
</tbody>
</table>

X7 selected
Development of a cleanable SnBiAg Solder Paste

- Flux medium content adjustment
- Paste viscosity adjustment
- Pilot production
- Implementation 1 line / month
- Development time 6 months
- Implementation at customer 8 months
Development of a cleanable SnBiAg Solder Paste

An active Partnership with the Customer Allowed the Quick Development of a Customized SnBiAg Solder Paste
Development of a no-clean SnBiAg Solder Paste

- Low occurrence of microballs (solderballing test on hotplate and in oven)
- Printable solder paste (viscosity / printability test)
- No-clean solder paste (copper mirror, surface insulation resistance and electromigration)
- Halide-free / Halogen-free
### Development of a no-clean SnBiAg Solder Paste

- **Thermal profile range**

<table>
<thead>
<tr>
<th></th>
<th>Short</th>
<th>Medium</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total duration (s)</strong></td>
<td>240</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td><strong>Peak (° C)</strong></td>
<td>164</td>
<td>165</td>
<td>173</td>
</tr>
<tr>
<td><strong>TAL (s)</strong></td>
<td>35</td>
<td>56</td>
<td>90</td>
</tr>
</tbody>
</table>
Development of a no-clean SnBiAg Solder Paste

- Screening of ingredients, Design of experiment, Optimization by simplex method
- Solderballing class 3 maximum on hotplate and in oven with short, medium and long thermal profiles
- Viscosity 700-800 Pa.s
- Viscosity ageing test > 24 hours
- Copper mirror L (no attack of the copper)
- SIR > 100 megohmms and no dendrite growth
## Development of a no-clean SnBiAg Solder Paste

- **Printing performance**

### Table: Printing Performance

<table>
<thead>
<tr>
<th>Speed (mm/s)</th>
<th>30</th>
<th>50</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Pressure (kg)</td>
<td>3.5</td>
<td>4.0</td>
<td>5.5</td>
<td>6.5</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>
Development of a no-clean SnBiAg Solder Paste

- SIR

SIR 85/85/50V/B24

Time (min)

Resistance (Ohms)

M50 M38 M60 M92

SIR 85/85/50V/B24

Time (min)

Resistance (Ohms)

M50 M38 M60 M92
Development of a no-clean SnBiAg Solder Paste

- Customer test: focus on LEDs assembly
- Visual Meets IPC-A610E
- IMC Constant and uniform
- Thickness to PCB 1.7 to 2.5 microns
- Thickness to LED 1.6 to 1.7 microns
- Mean shear Res. 10889 gram
Conclusion

- Development of Sn42Bi57.6Ag0.4 type solder paste
- Cleanable version and No-Clean version
- Definition of the specifications
- Standardized and customized lab tests
- Formulation tools / know-how
- Industrial tests
- Close partnership between supplier and customer strongly accelerates the development
Thanks for your attention!

Any Questions?