Case study

Improving PCBA Yield

Subrat Prajapati
Title:
Improve the Yield of PCBA from 82% to 92% at PCBA functional Test Stage.

Current situation: Present Rejection = 18%,
Sigma Level = 2.42

Scope of Project: Vendor PCB Assembly to Functional Testing of PCBA

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Measure</th>
<th>Defect Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield at PCBA functional testing</td>
<td>Percentage</td>
<td>Yield &lt; 92%</td>
</tr>
</tbody>
</table>

Project Black Belt: Subrat Prajapati
Effect of poor Soldering of PCBA

- Warranty failure = 2.7%,
  Annual rework cost = $43K
- Product *not storing* Data
- Product malfunctioning
- Central data Corrupted
- *Wrong misinterpretation* of data.

Challenge:
1. Solder Short in 15 mil Pitch IC.
2. BGA-ROHS part soldering in Non-ROHS Environment
SIPOC Diagram

**Suppliers**
- Company
- EMS supplier

**Inputs**
- PCB
- Components
- Solder paste
- Adhesive glue
- Flux
- Solder
- Stencil
- Process sheet
- Work Instruction
- GA (General Arrangement)

**Process**
- See Below
- Reflow Soldering - Component/Solder side
- Manual Mounting of PTH components
- Wave soldering (If applicable)

**Outputs**
- Working PCBA

**Customers**
- Company
- Meet to target PPM

**Requirements**
- PCB Components
- Solder paste
- Adhesive glue
- Flux
- Solder
- Stencil
- Process sheet
- Work Instruction
- GA (General Arrangement)

**Outputs**
- Storage of components, PCBs, Stencils e.t.c. & issue of components.

**Process**
- Storage of components, PCBs, Stencils e.t.c. & issue of components.
- Screen Printing
- Pick-Place M/c SMD Insertion
- Reflow Soldering - Component/Solder side
- Manual Mounting of PTH components
- Wave soldering (If applicable)
- Inspection & PCBA testing
Define

**Process Mapping**

1. Inspected Material from L&T
2. Binning / Kitting
3. Forming
4. Visual Inspection
5. Solder paste Printing machine
6. Pick & Place
   - Machine placement
   - Manual placement
   - Based on the Quantity (cut reel/loose components)
Process Mapping

1. Reflow Soldering
   - Manual Mounting of PTH components
   - Manual soldering done Temp=280 DegC
   - Visual Inspection & Quality data

   Rework any

   O/P
   - Testing of PCBA

Define
Defects at Test Jig stage related to Solderibility has been transformed to Pareto as below:

<table>
<thead>
<tr>
<th>Defects</th>
<th>Count</th>
<th>Percent</th>
<th>Cum %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solder short</td>
<td>82</td>
<td>73.9</td>
<td>73.9</td>
</tr>
<tr>
<td>Dry solder</td>
<td>16</td>
<td>14.4</td>
<td>88.3</td>
</tr>
<tr>
<td>No solder</td>
<td>8</td>
<td>7.2</td>
<td>95.5</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>4.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

SMD Defects - O/P of Reflow

Solder short in IC leads
<table>
<thead>
<tr>
<th>NEED</th>
<th>DRIVERS</th>
<th>CTQs</th>
<th>DEFECT DEFINITION</th>
<th>MEASURE FOR DEFECT</th>
<th>KANO STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce Solderibility Defect in PCBA</td>
<td><strong>Reflow process</strong></td>
<td>Good Solderibility As per IPC610</td>
<td>Any incidence solder short in Soldering of SMD component</td>
<td>No.of solder short after reflow In Video microscope inspection</td>
<td>Less the Better</td>
</tr>
<tr>
<td>Screen Printing Process</td>
<td><strong>Paste thickness Consistency</strong></td>
<td>Any incidence solder short in Soldering of SMD component</td>
<td>No.of solder short after reflow In Video microscope inspection</td>
<td>Less the Better</td>
<td></td>
</tr>
</tbody>
</table>

**CTQ Specification Table**
Vital Brainstorming output:

1. Stencil Design
2. Printing Parameters
3. Reflow Profile
4. Solder paste Storage, Type, height, slump
5. PCB Gerber Design
# Data collection plan

<table>
<thead>
<tr>
<th>Data collection plan for</th>
<th>Project</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCBA Solderibility failures in shop floor</td>
<td>Reduction of Solderibility problem in PCBA</td>
<td>10.10.2009</td>
</tr>
</tbody>
</table>

1. What is the need of this data collection? To find out the present status of PCBA failures & to validate it’s causes

2. Who will collect the data? SP

3. Location of data collection Reflow M/C - Vendor Programming/Testing - Screen printing machine

## DATA

<table>
<thead>
<tr>
<th>What</th>
<th>Measure type / data type</th>
<th>How measured</th>
<th>Sampling</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Continuous</td>
<td>Thermocouple reader Reflow</td>
<td>20 samples</td>
<td>Check Process capability</td>
</tr>
<tr>
<td>PCBA Failed</td>
<td>Discrete</td>
<td>At Test Jig stage</td>
<td>100 samples</td>
<td>Check failure rate before and after Implementation of solution</td>
</tr>
<tr>
<td>Solder Paste thickness</td>
<td>Continuous</td>
<td>Manufacturer Machine</td>
<td>30 samples</td>
<td>Paste Type may be factor in Solderibility</td>
</tr>
</tbody>
</table>
Vendor Visit

Screen Printing process

Measure
Observation: From Normal Distribution Summary shows Mean of Paste thickness observed is 7.8 mil (198 micron).
Cpk Analysis of Solder Paste Thickness

Screen Printing process

Process Capability Analysis of Paste Thickness

<table>
<thead>
<tr>
<th>Process Data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LSL</td>
<td>4.50000</td>
</tr>
<tr>
<td>Target</td>
<td>*</td>
</tr>
<tr>
<td>USL</td>
<td>7.00000</td>
</tr>
<tr>
<td>Sample Mean</td>
<td>7.82667</td>
</tr>
<tr>
<td>Sample N</td>
<td>30</td>
</tr>
<tr>
<td>StDev(Within)</td>
<td>1.15554</td>
</tr>
<tr>
<td>StDev(Overall)</td>
<td>0.97070</td>
</tr>
</tbody>
</table>

Data confirms Normality

Cpk = - 0.24

Concludes 80% of process is running outside USL, with Cpk= - 0.24
Mean Paste thickness = 7.8
Paste Thickness running out of Specification

As Stencil thickness is 5mil, Paste thickness = Stencil thickness + 2/ - 0.5 mil (ie; 4.5 – 7.0 mil Or 114-178 micron )as per common industry Standard.

Measure
Screen Printing process

1. Stencil

2. Stencil aperture

3. Solder paste

4. Solder paste

5. PCBA

Final Screen printing output

Analysis

Screen Printing process

114-178 micron (Expected)
Vital cause identified After Brainstorming

1. **Present** Stencil opening is 1:1 (PCB Pad vs Stencil aperture ratio) leading to excess amount of solder paste deposition, and solder short after reflow.

2. Presently using Solder Paste Type-3 of 25-45 micron granule size, in PCBA having IC of 15 mil pitch. As per 5 ball rule, this can be cut-off point. Decided to use Type-4 (20-38 micron) solder paste in order to get better solder paste transfer efficiency in 15 mil pitch IC through DOE

**Reduced** Aperture width ‘W’ by 5% in IC having Pitch =<20mil, to reduce paste volume on Pad hence reduce chance of solder short after reflow.
### Paste T3 vs T4 Hypothesis Testing

<table>
<thead>
<tr>
<th></th>
<th>Good</th>
<th>Bad</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T4</strong></td>
<td>57</td>
<td>15</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>51.51</td>
<td>20.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.586</td>
<td>1.472</td>
<td></td>
</tr>
<tr>
<td><strong>T3</strong></td>
<td>36</td>
<td>22</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>41.49</td>
<td>16.51</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.727</td>
<td>1.827</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>93</td>
<td>37</td>
<td>130</td>
</tr>
</tbody>
</table>

Chi-Sq = 4.612, DF = 1, **P-Value = 0.032**

P-value shows **Solder Paste T3/T4 has effect in Solderibility (solder short) in 15 Mil pitch IC**

### Reflow temperature effect on BGA soldering

<table>
<thead>
<tr>
<th></th>
<th>Good</th>
<th>Bad</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>56</td>
<td>32</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>64.60</td>
<td>23.40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.144</td>
<td>3.157</td>
<td></td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>82</td>
<td>18</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>73.40</td>
<td>26.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.007</td>
<td>2.778</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>138</td>
<td>50</td>
<td>188</td>
</tr>
</tbody>
</table>

Chi-Sq = 8.086, DF = 1, **P-Value = 0.004**

P-value shows **Reflow Temperature TPeak At 220 & 235 has effect in BGA soldering**
Test:
BGA Pull Test conducted as below-
Soldered BGA(at Tpeak=220:NonROHS profile)
has been pulled up by BGA Rework
Station at 190 DegC (As planned).

Observation:
Found 20% BGA Balls Came out in BGA & remaining
80% BGA Balls remain in Board.

Conclusion:
Good soldering Balls remain on Board after Pull Test.
Bad Soldering Balls came out with BGA package.
Shows BGA Balls are not melting on Board
At 220 DegC.

BGA manufacturer recommends 235 Peak Body
Temperature, will not be suitable to my PCBA having
non-ROHS parts.
Above RTS Profile to be Looked at for stable soldering of PCBA as well as BGA(ROHS Device) soldering in Non-ROHS environment.
# Cause Solution Matrix Planned

<table>
<thead>
<tr>
<th>Effect</th>
<th>Cause</th>
<th>Solution</th>
<th>Implementation Risk</th>
<th>Risk Addressed</th>
<th>Risk Closed</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solder Short</td>
<td>Screen Printing Paste Thickness variation</td>
<td>Machine Parameters Optimized</td>
<td>Solder short may increase</td>
<td>To be run in Pilot lot of 30 no PCBA for monitoring</td>
<td>Parameters Freeze</td>
<td>Machine Supervisor</td>
</tr>
<tr>
<td></td>
<td>Cleaning of ON-line Stencil reduced from 10 PCBA to 5 PCBA</td>
<td>Cycle time can increase</td>
<td>Cycle time to be monitored</td>
<td>Cycle time no change as Pick-place machine is having high cycle time than screen printing</td>
<td>Machine operator</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measurement of Paste Thickness Process Deployed</td>
<td>No Risk</td>
<td>No Risk</td>
<td>System Deployed</td>
<td>Quality Manager</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stencil Initiated with 5% reduction in aperture width in order to reduce paste volume in IC&lt;20mil pitch</td>
<td>May induce less solder problem</td>
<td>New stencil to be run in Pilot Lot of 30 numbers PCBA before deploying in production lot</td>
<td>Monitoring</td>
<td>Design/Process Dept -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reflow Profile</td>
<td>RSS may need more fine tuning for good Solderibility</td>
<td>To be monitored</td>
<td>Monitoring</td>
<td>Process Engineering</td>
<td></td>
</tr>
</tbody>
</table>
Design Of Experiment for Reflow Peak Temperature

Factor

Reflow Temperature
Body Peak

Levels

220

225

230

Solder Paste

T3

T4

Main Effects Plot (data means) for Result

Interaction Plot (data means) for Result

Temp

Solder Paste

Mean

Mean

Best

Best

220

225

230

T3

T4

T3

Solder Paste

T4
Screen Printing process  
Stencil 5% reduction & Type-4

Data confirms Normality

Cpk = 0.35

Concludes paste thickness lying outside USL reduces to 13% from 80%, with Cpk = 0.35 from -0.24
Mean Paste thickness = 6.0 from 7.8 mil
**Screen Printing process**

**I-Chart**
- UCL = 7.0
- LCL = 4.5
- CE = 0.0

**R-Chart**
- UCL = 3.0
- LCL = 0.0

**Boxplot of Data by Attribute**
- New Paste Thickness: [ ]
- Old Paste Thickness: [ ]

**Two-Sample T-Test and CI: Data, Attribute**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>SE Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Paste Thickn</td>
<td>30</td>
<td>6.007</td>
<td>0.880</td>
<td>0.16</td>
</tr>
<tr>
<td>Old Paste Thickn</td>
<td>30</td>
<td>7.827</td>
<td>0.962</td>
<td>0.18</td>
</tr>
</tbody>
</table>

**P-Value = 0.000**

P value signifies improvement.
Reflow process

New RSS - Ramp Soak Spike Profile Deployed

Benefit: Due to Soak time it is facilitating flux to get activated which is useful for expired IC, obsolesce IC (As in our case) for getting good Solderibility.
BGA checked in X-ray/Video scope

Pilot lot of 150 PCBA run and Quality confirms to IPC 610, class III.
Results & Controls

Solder Paste Thickness Variation From I-Chart before and After

Screen Printing process

I Chart of Data by Attribute

Old Paste Thickness

New Paste Thickness

Individual Value

Observation

UB = 7

X̄ = 6.007

LB = 4.5

I-mR Chart implemented at Vendor for monitoring of Paste thickness
## Requirements / Needs to ensure quality product.

<table>
<thead>
<tr>
<th>Process</th>
<th>Process Control Method</th>
<th>Benchmark</th>
<th>Actions / Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Printing</td>
<td>Control Chart</td>
<td>4.5 to 7 mils.</td>
<td>Vendor to maintain record &amp; display at measurement area.</td>
</tr>
<tr>
<td>Reflow</td>
<td>FTP</td>
<td>80%</td>
<td>We will guide for DPMO calculation for initial lot. Vendor to maintain record &amp; display.</td>
</tr>
<tr>
<td>Reflow</td>
<td>DPMO</td>
<td>5000</td>
<td>Vendor to maintain record &amp; display.</td>
</tr>
<tr>
<td>Programming / Testing</td>
<td>Yield</td>
<td>96%</td>
<td>Vendor to maintain records &amp; display.</td>
</tr>
<tr>
<td>Main Unit Assembly</td>
<td>Yield</td>
<td>98%</td>
<td>Vendor to maintain records &amp; display.</td>
</tr>
</tbody>
</table>

**Note:** Quality index matrix to be covered during Audit-I of ISO 9001:2000. Quality index matrix reports to be sent to us along with lot. Above Benchmark should be re-evaluated in every quarter based on target decided with vendor.
Results

Initial Sigma Level = 2.4

Final Sigma Level = 3.1

PCBA Trend

PWA-Yield

Before

New

Yield

94

82

94

Before

New
Thank You

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