Cleaning Technology Innovations Needed To Clean Highly Density Assemblies

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Latin America Manager
What to know...

= Good

= Bad.
THANK YOU FOR COMING
Why Clean?

Cleaning is the removal of undesired materials from surfaces without changing the surface in an unacceptable manner.
Cleaning is not new!!
Assembly Residues

- Risk premature failure
- Improper functionality
Product Longevity

- Aerospace and Military Devices
- Automotive Systems
  - (Airbag control, engine controls, etc.)
- Commercial Products
  - (White goods, appliances, etc.)
- Industrial Applications
  - (Pump Controls, HVAC Controls, etc.)
- Consumer Electronics
  - (GPS devices, portable electronics, etc.)

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What is The Cost of Not Cleaning?
Designing Printed Circuit Cards

- Reliability standards are harder to meet
  - Densely populated assemblies
  - Miniaturization
  - Higher applied voltages
  - Higher frequency signals
  - Lead-free soldering
No-Clean Flux

- Initially, spacing between conductors was larger
- Residues posed minimal reliability risks
- In many applications, cleaning was not required

Or Low Residue
As we like to call it!

IBM PC - 1982
IBM PC - 1998
Current

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Common Technology

As the distance between conductors narrow

- Z-Axis of the component reduces
- Flux residues bridge conductors
- Residues under component gaps pose a reliability risk

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Miniaturization

Past

Present

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Common Problem

Polarity Drives ECM

What needs to be present?

- Residue
- Moisture
- Energy (bias)
Conformal Coating

It is a thin plastic protective film “conforming” to the surface of a PCB
Protects the assembly from corrosion in harsh environments.
It is a breathing membrane that allows air (that may contain moisture) to move in and out through it.
Complex Solution

Numerous factors to consider

1. Optimize Board Design
2. Select a Cleanable Solder Paste
3. Control the Reflow Process
4. Determine the Best Fit Cleaning Agent
5. Material Compatibility Considerations
6. Cleaning Machine Energy
7. Control the process
Cleaning Process Factors

PCB Board Design
- Component Selection
- Solder Mask Definition
- Miniaturization
- Placement
- Z-Axis
- Material Compatibility

Solder Paste / Flux
- Alloy
- Flux Composition
- Heat Exposure
- Cleaning Agent Match

Cleaning Agent
- Reuse / Recovery
- Environmental Health / Safety
- Temperature
- Static Cleaning Rate
- Use Rate
- Time
- Concentration
- Fluid Management
- Automation / Control
- Through-put
- Energy Consumption
- Dynamic Cleaning Rate
- Shadowing Effects

Cleaning Machine
- IDEAL Cleaning CONDITION
  No unwanted visible/ionic residue on surface and under components

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Component Spacing and Pitch
HDI Components

Challenge

• Assemblies are rarely designed for cleanability
  – Spacing is only getting tighter
  – Non reacted flux activators pose reliability risk

Solution

✓ Design for cleanability
✓ Design the cleaning process
  – Allows flux removal under low standoff devices


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Z-Axis Offset

Higher gap heights components
– Open the process window
– Creates a flow channel
– Reduces time to clean
Soils

• **Flux/Pastes Residues**

  Typically a combination of Non-polar (rosin/resins) & Polar activators plus functional additives.

  – **Types (Leaded & Lead-free)**
    - No Cleans
      – Low solids - low corrosive or electrochemical properties
      – Many contain rosin to encapsulate residues
      – Organic acids and rosins as activators
    - Water Soluble (OA)
      – Highly active, thus solder well but attack metals
      – Organic acids and halides as activators
      – Cleaning necessary, typically with heated DI wash
    - RMA’s (older material, precursor to no clean)

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Soils

What about other contaminants?

- Residues can be classified into three categories
  1. Polar or Ionic
  2. Non-polar or nonionic *Such as no clean flux*
  3. Particulate

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Reflow Profile

Ramp to Spike

Ramp Soak Spike

<table>
<thead>
<tr>
<th>RATE OF RISE 2°C/SEC MAX</th>
<th>RAMP TO 150°C (302°F)</th>
<th>PROGRESS THROUGH 150°C-175°C (302°F-347°F)</th>
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<tr>
<td>Short Profiles</td>
<td>≤ 75 Sec</td>
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Cleaning Agent Contribution

- Lowers surface tension
  - 20-30 dynes/cm
- “Dissolve-it”
  - Solubility theorems
  - Augmented with heat, pressure, and flow
- Rate of solubility
  - Dependent on soil properties
  - Temperature effect in dissolving residue
  - Concentration of solvent needed to dissolve residue

“LIKE DISSolves LIKE”
Surface Tension

**Physics:** Ability of a liquid to spread out *or* under an area

**Low Surface Tension = Skinny liquid**

*High Surface Tension*  
*Low Surface Tension*

25%


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What is Solubility?

How well a soil(s) is dissolved.

• Solubility of the soils drive the cleaning process.
  - Polar Soils need polar cleaning agents
  - Non-Polar needs non-polar cleaning agents

“Like Dissolves Like”

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What is Solubility?

• IPA is a very poor cleaner for reflowed fluxes
  ✓ It is not able to solubilize well most reflowed fluxes (no-clean, Pb-free, etc.) used in electronics manufacturing today.
  ✓ Consequently, it’s a very poor choice for PCB defluxing, manual or automated.

• For manual cleaning,
  ✓ It requires a lot of labor to achieve an apparently clean surface
    ✓ Labor ≠ Free, which means HIGHER PROCESS COST !!
  ✓ In reality, surface is not likely to be free of residue due to lack of solubility.
Cleaning Technology Building Blocks

- Excellent Compatibility
- Complete Water Solubility
- Wide Process Window
- Low Cost of Ownership
- No More White Residue
- No More Dull Solder Joints

Protects all sensitive metals from corrosion or etch

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Achieving Solutions
Solution #1 – Optimize PCB Design

Eliminate ALL BTC’s
Solution #1 – Optimize PCB Design

BTC’s complicate the issue

• Activators may not fully react during soldering
• BTC normally have tighter pitch
  – Higher risk of current leakage and ECM
• BTC’s Nature:
  – capillary action of the flux tends to under fill the component
  – Less surface area means more flux in that area.
  – Longer soak times (to prevent defects) may cause oxidations and polymerization
  – All this equals **CLEANING IS MORE DIFFICULT**

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Solution #1 – Optimize PCB Design

PCB Layout

- Spacing between components, placement
- QFN Stencil Design- Use a 45° cross hatch pattern for the thermal land instead of window pane to promote flux escape from the solder joint (no intersections)

Plexus/Kyzen Clean Test Vehicle

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Solution #1 – Optimize PCB Design

Solder Mask Considerations:

• No Solder Mask: Caps, Resistors and QFN’s
• Removing solder mask between pads, increases the standoff gap

✓ Improves cleaning Results

Avoid using solder mask within QFN land pattern for maximum cleanability and solder joint reliability

Maximize the gap by removing the solder mask

Source: Scott, Nelson, Harris Corp

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Solution #1 – Optimize PCB Design

Solder Mask Considerations:

In the QFN Arena, *Even If*…

- Routing of peripheral lands to the thermal land cannot be avoided
  - *Solder mask stripes* should be applied *only* over the circuit lines and not around the entire thermal pad (window pane)

- Avoid solder mask defining the thermal land

Example of solder mask stripes instead of ‘window pane’

Flux has been allowed to escape from the thermal land solder joint

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Source: Scott, Nelson, Harris Corp
Solution #2 – Select a Cleanable Solder Paste

Most Engineers select solder paste based on:

- Better print release
- Reduced voiding
- Better stencil life
- Reduced defects
  - ie. graping, head in pillow, tombstoning, etc

Make “Cleanability” part of the qualification

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Solution #3 – Rethink Heat Exposure
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Ramp Soak Spike

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Solution #3 – Rethink Heat Exposure

Multiple Heating Exposures

- Can change the nature of the paste/flux
- A second reflow often renders the soil un-cleanable
Solution #3 – Rethink Heat Exposure

Water Soluble Flux Residues Are Heat Sensitive

– When exposed to elevated temperatures and extended exposure times,
  • Residues may crystalize
  • No longer soluble in water
  • Common in hand soldering
Solution #3 – Rethink Heat Exposure

Heat Complicates Cleaning
Soils can cross link and polymerize

Avoid Extra Heat When Possible
a) Clean after each step: wave, reflow(s), hand soldering, selective soldering, and baking out
b) Optimize the reflow profiles
c) Avoid excess time and temperature when hand soldering.

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Solution #4 – Determine the Best Fit Chemistry

Cleaning Matched to Soils

Heat Exposure

Solder Flux / Residues

Cleaning Agent

Gap Height

Cleaning Equipment

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Solution #4 – Determine the Best Fit Chemistry

- Match cleaning agent to the:
  - Soil(s)
  - Cleaning equipment
  - Doesn’t affect other surfaces negatively (i.e., material compatibility)
  - Hydrophilic Properties – Easily Rinsed
Solution #4 – Determine the Best Fit Chemistry

Factors / Levels

1. Cleaning Agents
   a) 7N Aqueous

2. Solder Pastes
   a) 10 – Sn/Pb No Clean
   b) 10 – SAC No Clean
   c) 10 – SAC OA

3. Wash Time
   a) 10 minutes

4. Wash Temperature
   a) 20°C
   b) 40°C
   c) 60°C

5. Wash Concentration
   a) 10%
   b) 15%
   c) 20%

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Solution #4 – Determine the Best Fit Chemistry

Match the Cleaning Agent to Soil for NC SAC 305 Solder Pastes

Data Means

- **Product ID**
  - Aqueous 1
  - Aqueous 2
  - Aqueous 3
  - Aqueous 4
  - Aqueous 5
  - Aqueous 6
  - Aqueous 7

- **Conc.**
  - NC Solder Paste 1
  - NC Solder Paste 2
  - NC Solder Paste 3
  - NC Solder Paste 4

- **Temp**
  - 20
  - 40
  - 60

- **Soil ID**
  - NC Solder Paste 1
  - NC Solder Paste 2
  - NC Solder Paste 3
  - NC Solder Paste 4

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Solution #4 – Determine the Best Fit Chemistry

- Poorly matching a cleaning agent will:
  - Narrow the processing window
  - Impingement energy may not be sufficient
Solution #4 – Determine the Best Fit Chemistry

Material Compatibility

<table>
<thead>
<tr>
<th>Laminates</th>
<th>Surface finishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastics</td>
<td>Components</td>
</tr>
<tr>
<td>Labels</td>
<td>Part marking</td>
</tr>
<tr>
<td>Entrapment</td>
<td>Coatings</td>
</tr>
<tr>
<td>Sealants</td>
<td>Adhesive Bond Strength</td>
</tr>
</tbody>
</table>
Solution #5 – Cleaning Equipment

Cleaning Agent Matched to Equipment

- Heat Exposure
- Solder Flux / Residues
- Cleaning Agent
- Cleaning Equipment
- Gap Height

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Solution #5 – Cleaning Equipment

Select the proper energy to do the job!

- Eight top-level aspects impact the effectiveness of the cleaning process

  - Cleaning Agent
  - Concentration
  - Equipment
  - Pressure
  - Time / Speed
  - Temperature
  - Rinsing
  - Drying

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Solution #5 – Cleaning Equipment

Equipment/Chemistry Match

A. Spray in Air Inline or Batch
   - Ultrasonic Chemistries Will likely foam
     □ Not engineered with defoaming agents

B. Ultrasonic Machines
   - Spray in Air chemistries typically do not have the same cavitation properties (decreases energy)
   - Contain defoaming agents
     □ More difficult to rinse.

C. Vapor Degreasers
   Solvents not used properly can be hazardous
Solution #5 – Cleaning Equipment

Solubility Drives Energy Needs

• Very soluble
  – finger salts
  – water soluble flux residue

• High solubility
  – soft flux residue
  – rosin

• Marginal solubility
  – requires heat and physical energy
  – hard residue flux
  – no-clean flux

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Solution #5 – Cleaning Equipment

Mechanical Energy

- Two key factors
  - Potential energy
    - Potential energy driven by cleaning agent match to residue
  - Kinetic energy
    - Kinetic energy is driven by pressure and velocity
    - Can be maximized by nozzle and pump design

Energy is just as important in the RINSE as it is in the wash.
Solution #5 – Cleaning Equipment

Delivering Cleaning Agent

- To clean under bottom termination components
  - Nozzle type needs both flow and pressure
  - Positioning needs to overcome shadowing

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Solution #5 – Cleaning Equipment

Cleaning Basket Design

- The goal is to remove shadowing effects

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Solution #5 – Cleaning Equipment

Inline Cleaning Equipment

- Inline cleaning equipment can be significantly improved by
  - Designing coherent jets
  - Combination of fan-jets and coherent jets
  - Angling jets
  - Providing a combination of soak and spray

- Performance is improved when
  - Cleaning material exhibits a high static cleaning rate for the soil

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Solution #5 – Cleaning Equipment

Coherent Jets
Source: Austin American Technology

Coherent/Fan Jets
Source: Speedline Technologies

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Solution #5 – Cleaning Equipment
Spray In Air + Flood

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Solution #6 – Process Control

A. Understand the influencing factors and their cause and effect.

B. Create a stable upstream process

C. Confirm testing results with
   - Hardware consistent with the application
   - In current cleaning equipment
In Conclusion
• PCB Design
  – Include cleanability in the design criteria
  – Remove solder mask when possible

• Solder Materials and Other Contaminants
  – Understand the properties of the residues
  – Ensure they are cleanable

• Reflow Process
  – Optimize your profile
  – Minimize heat exposure
  – Clean after each step if possible
    • reflow(s), wave, hand soldering, selective soldering, & baking out
• **Cleaning Agent**
  – Match cleaning agent to soils
  – Match cleaning agent to cleaning equipment

• **Cleaning Equipment**
  – Energy needed to complement cleaning agent
    • Gap height and spacing between conductors
    • Soil difficulty
  – Process Parameters
    • Rinse cycle is as important as wash cycle

• **Process Control**
  – Understand the influencing factors and their cause and effect.
  – Create a stable upstream process
  – Confirm testing results under normal production conditions

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Solutions

Achieving Success Sometimes Requires Trade-Offs

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Is it Achievable?

1210 chip cap:

We clean this every day!
QUESTIONS

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• mikeb@kyzen.com