Cleaning Underneath BGAs

BEST Electronics Soldering Technologies

August 21, 2012

KYZEN

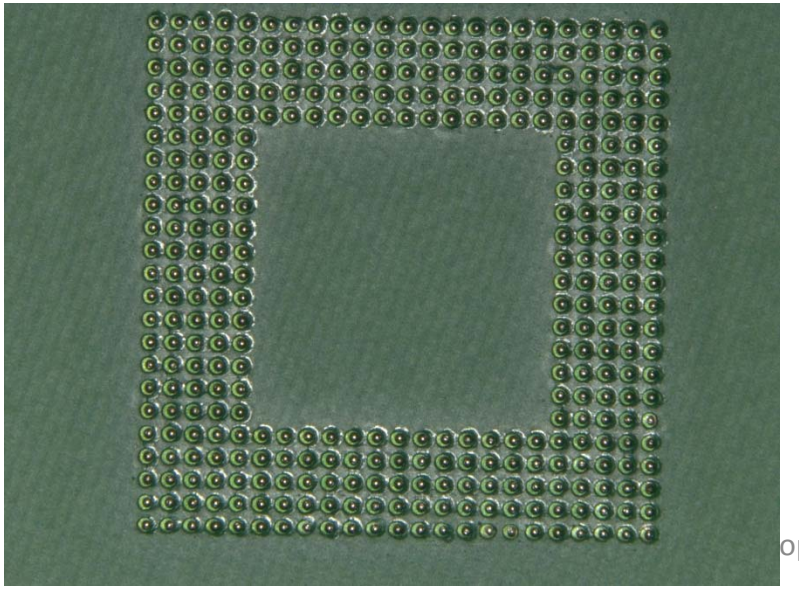
Providing In-Process Cleaning Chemistries
and Technical Services Worldwide

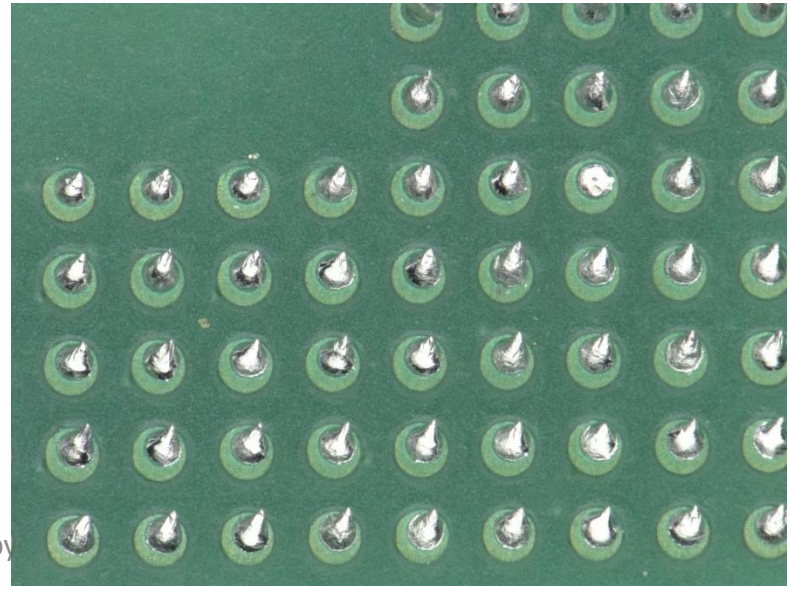
Agenda

- Introduction
- BGA Cleaning Considerations
- Designing the Cleaning Process
- Factors that Affect Cleaning
- Conclusions

Ball Grid Assemblies

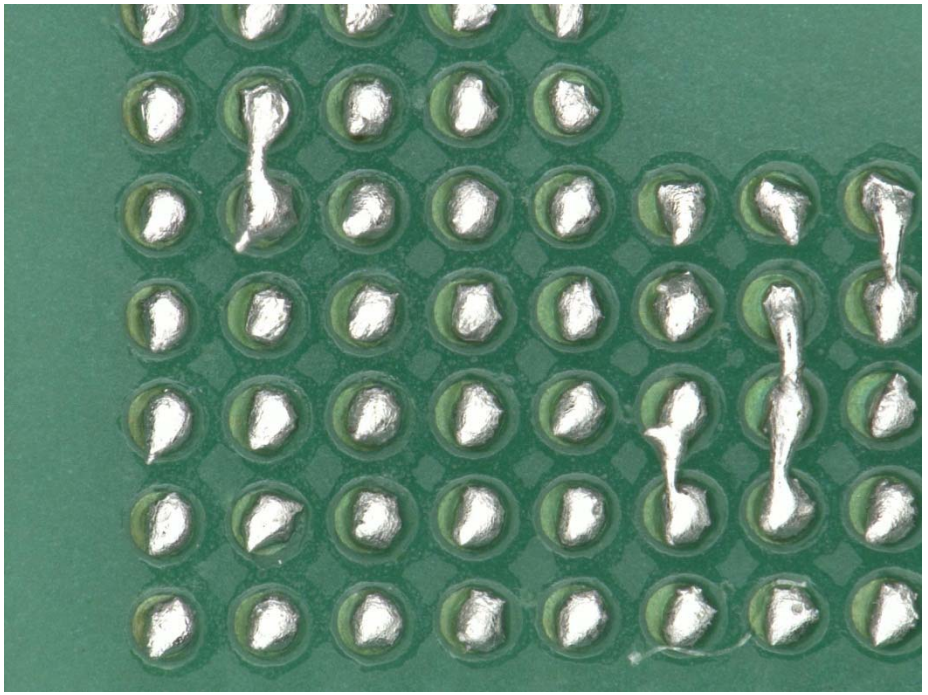
- How clean is clean enough?
  - More challenging to answer as conductors and circuit traces are increasingly narrower
  - What is acceptably clean for one segment of the industry may be unacceptable for more demanding segments





Residues on BGAs

- May increase the risk of
  - Premature failure
  - Improper function



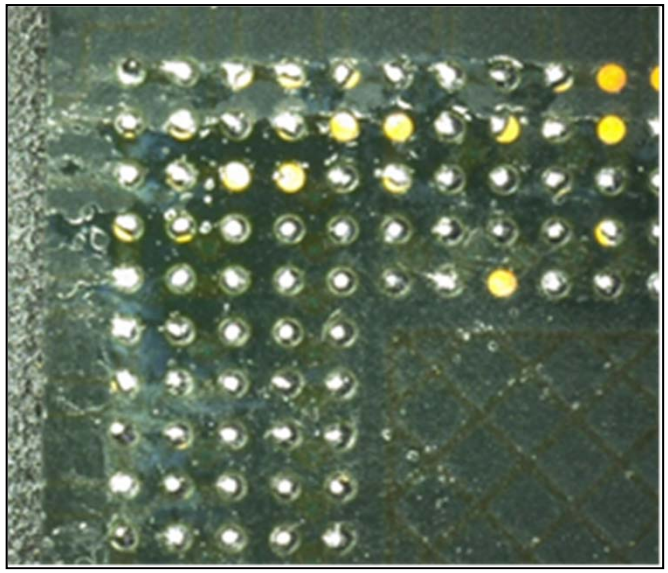
BGA CLEANING CONSIDERATIONS

Technology Evolution

- Jobs needed to be done by products
  - Technology powered devices continue to miniaturize
  - More interconnects result in
    - Tighter pitch
    - Lower standoff (Z-Axis)
- Narrow distances between conductors requires
  - Higher levels of cleanliness

Z-Axis

- As the standoff height gap reduces
  - Flux residue capillary forces underfill device
  - Flux residues now bridge conductors
  - May create the potential for
    - Electro-chemical migration
    - Electro-migration



µBGA with 0.40 mm pitch

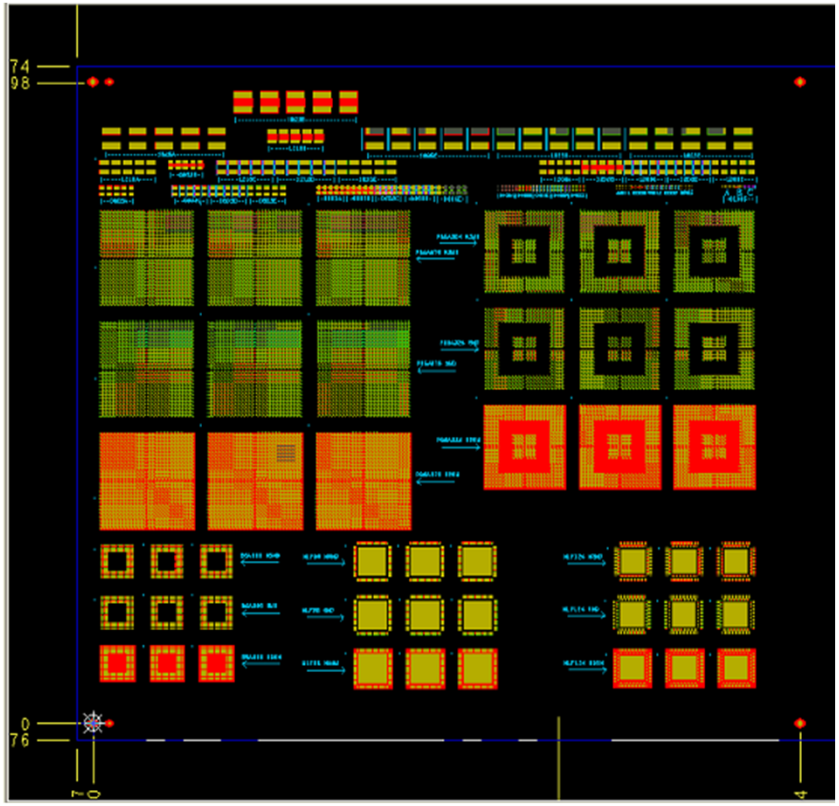
Factors to Consider

- BGA circuit trace width
- BGA standoff gap
- Solder Paste / Paste Flux Selection
- Package Placement
- Solder Paste Reflow (Heat Exposure)
- Solder mask definition
- Cleaning Agent
- Mechanical effects

DESIGNING THE CLEANING PROCESS

Bottom Termination Components

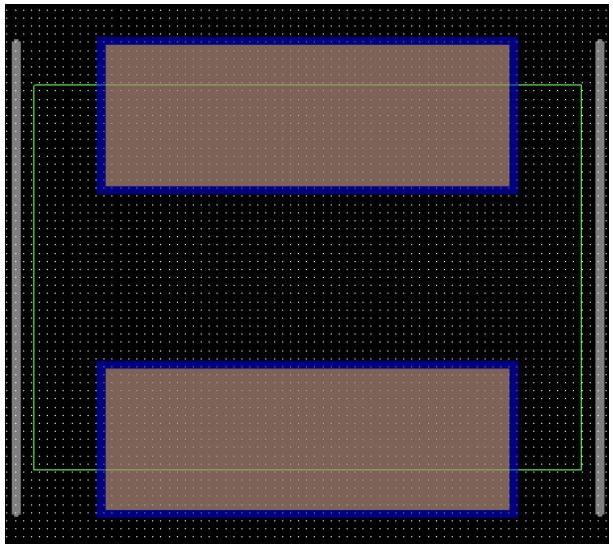
- Layout influence the clearance gaps
  - Component selection
  - Solder mask definition
  - Placement

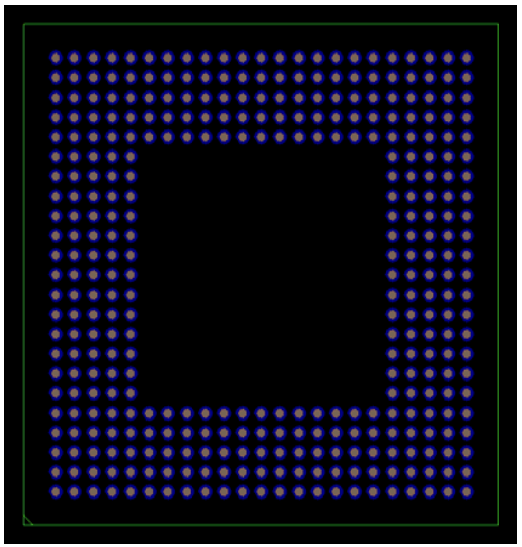


Plexus/Kyzen Clean Test Vehicle

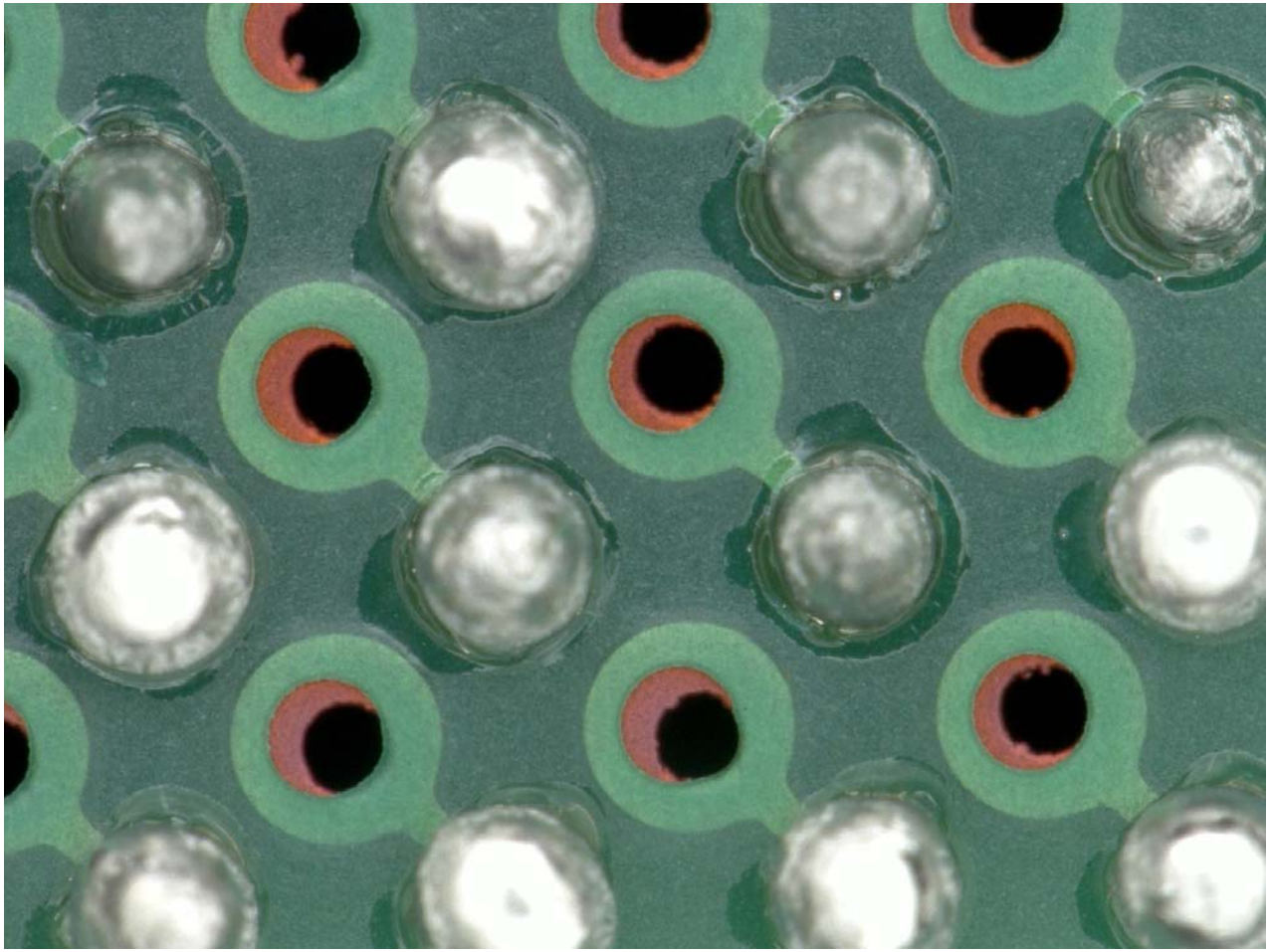
Solder Mask Defined Pads

- Very little preclearance on
  - Each side of the connection
  - 2-4 mils preclearance per side
  - Solder mask is present between pads



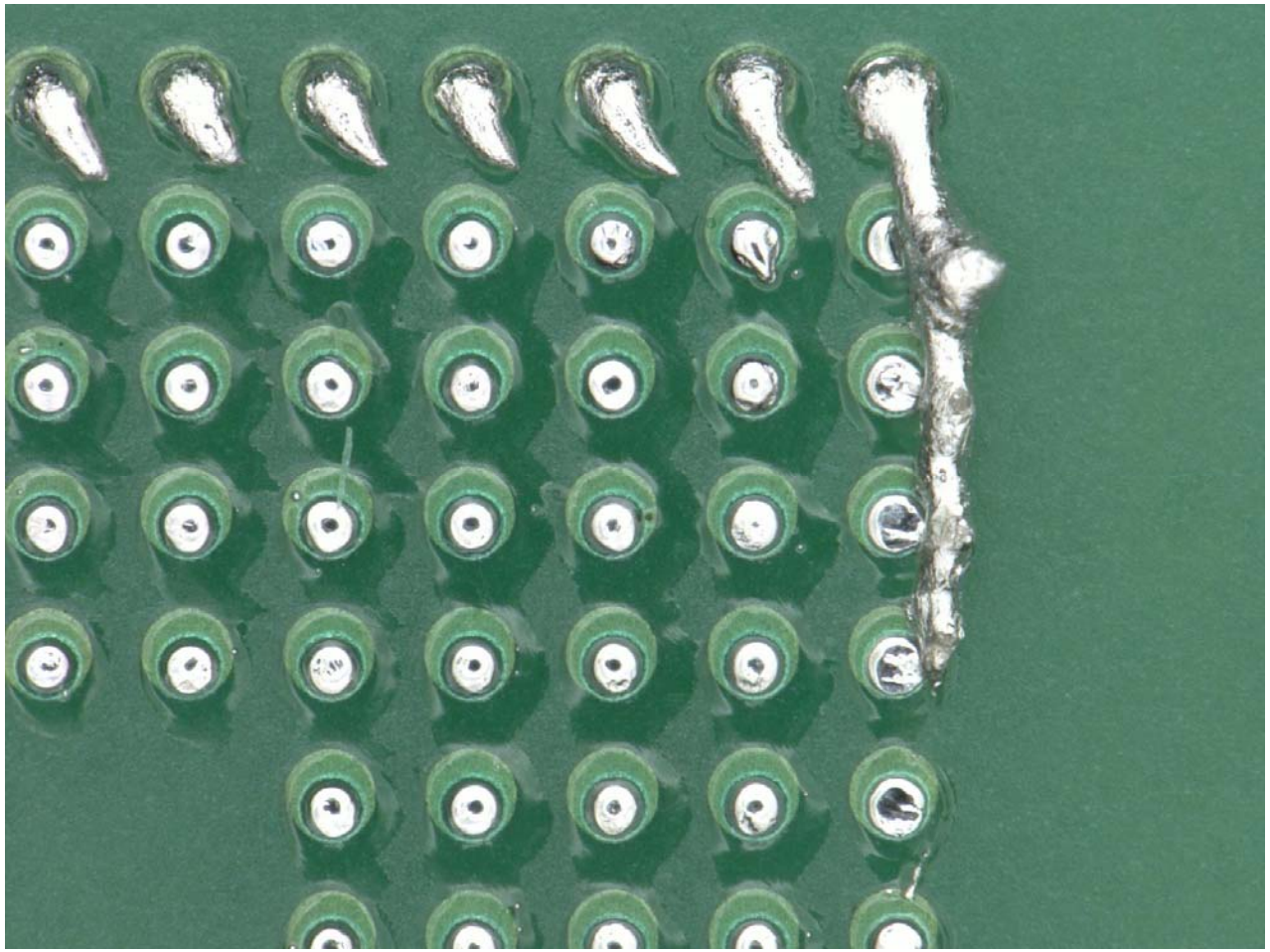


Solder Mask Defined



Wide Pitch

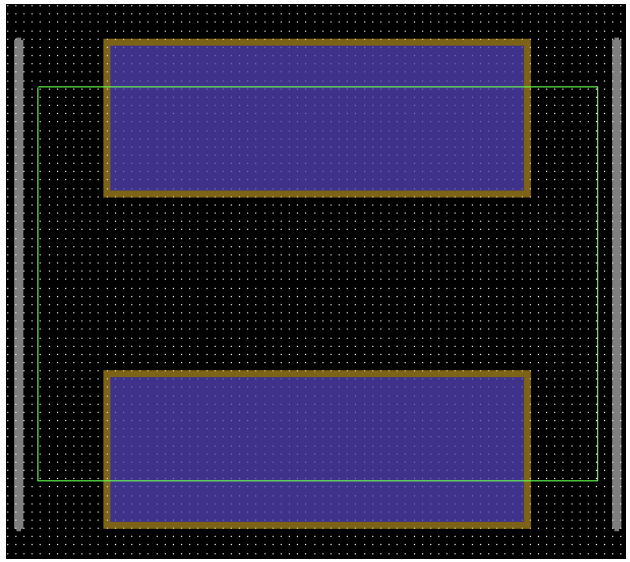
Solder Mask Defined

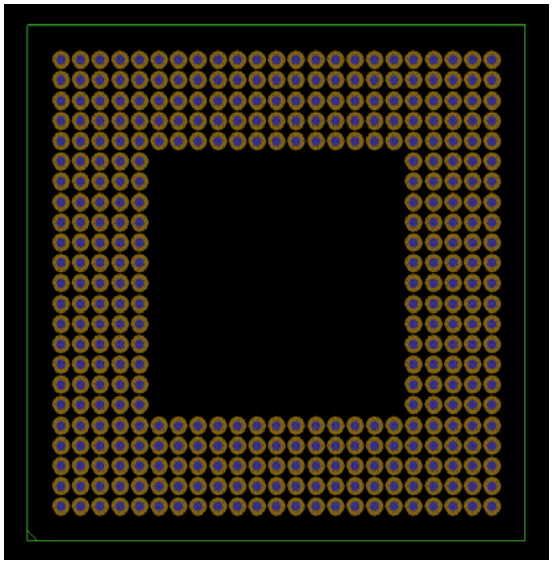


Narrow Pitch

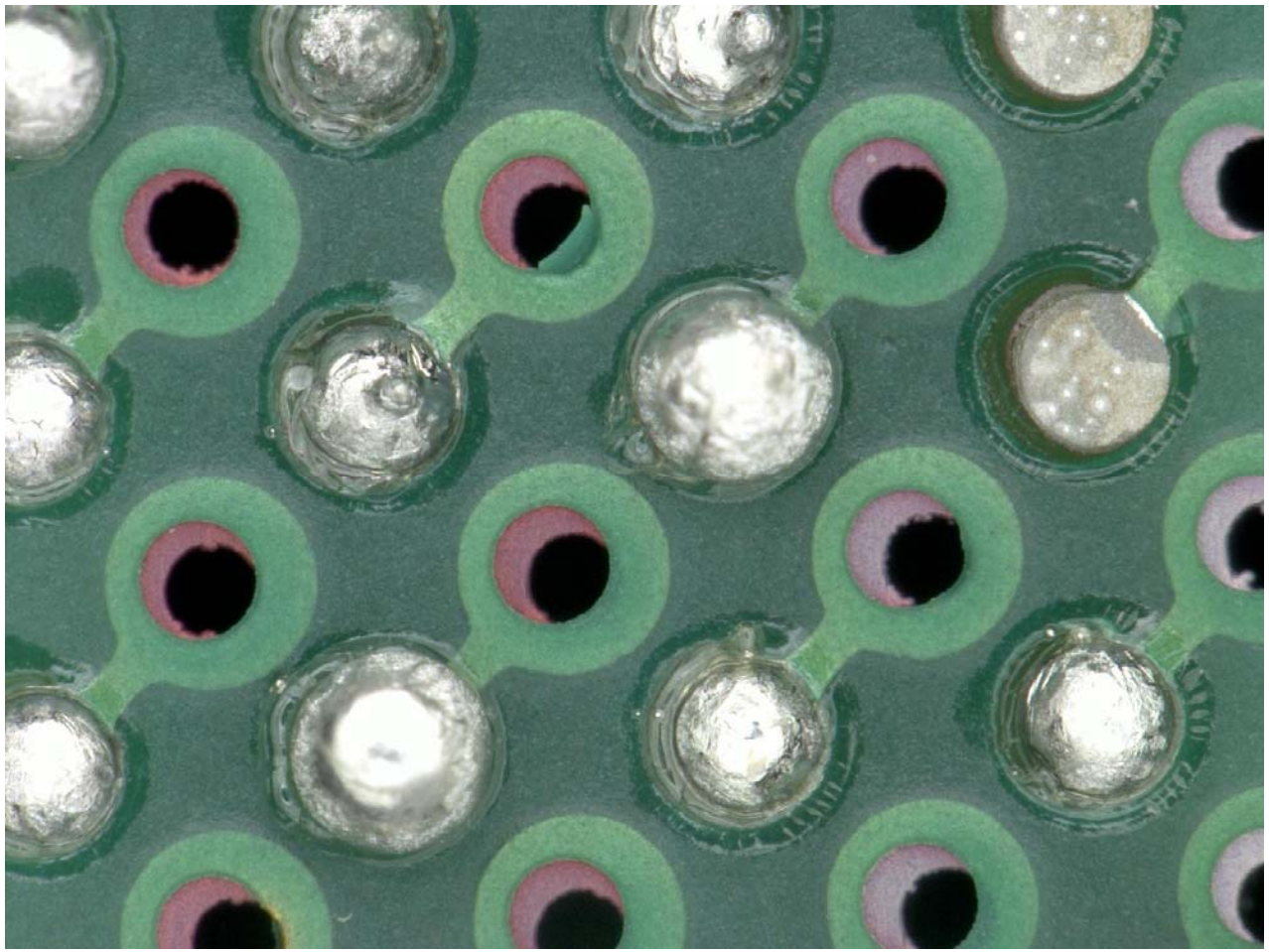
Non-Solder Mask Defined Pads

- Non-solder mask defined pads
  - Removes solder mask in the pad areas
    - Flux pools around component
  - Solder mask between pads



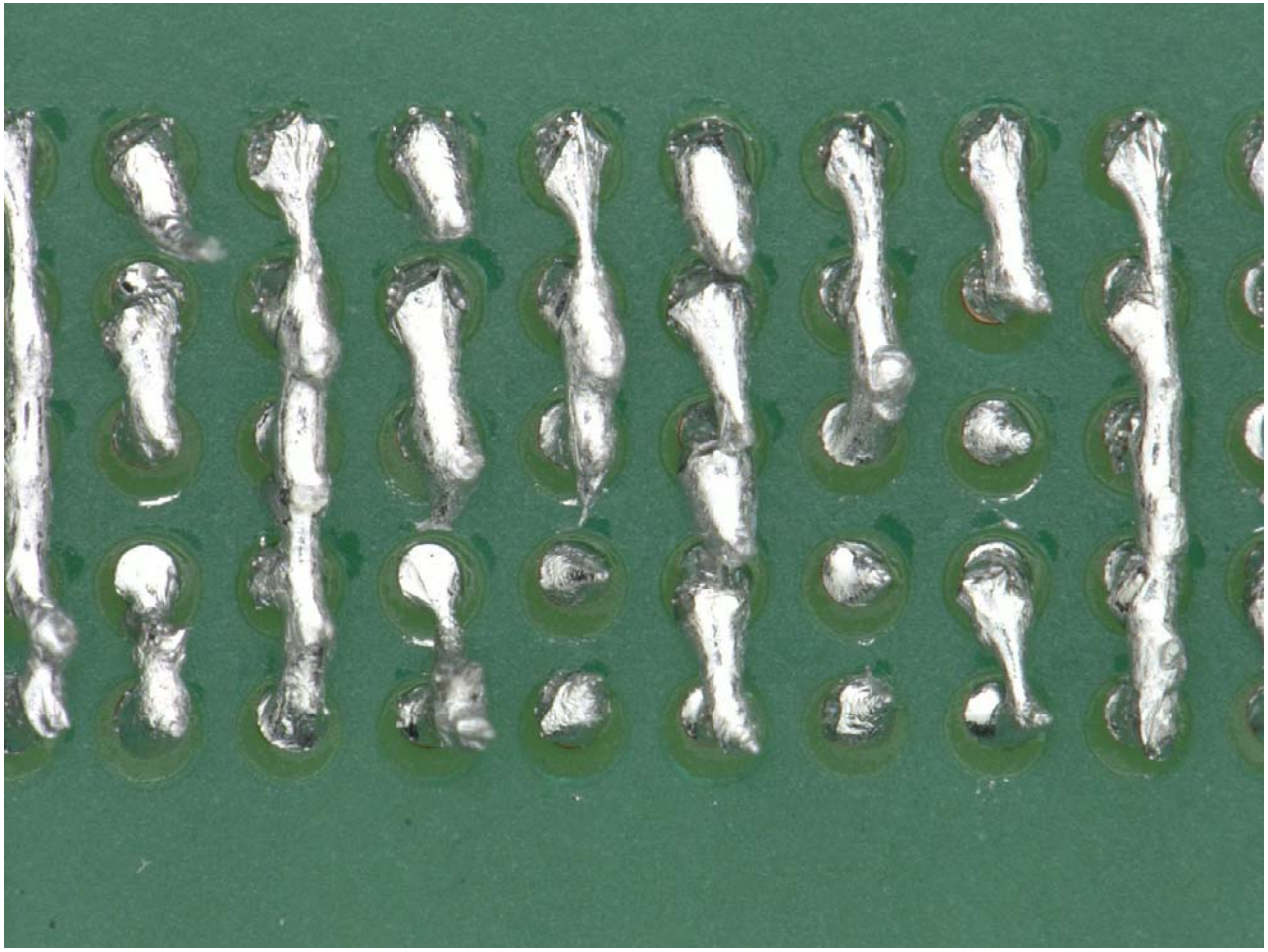


Non Solder Mask Defined



Wide Pitch

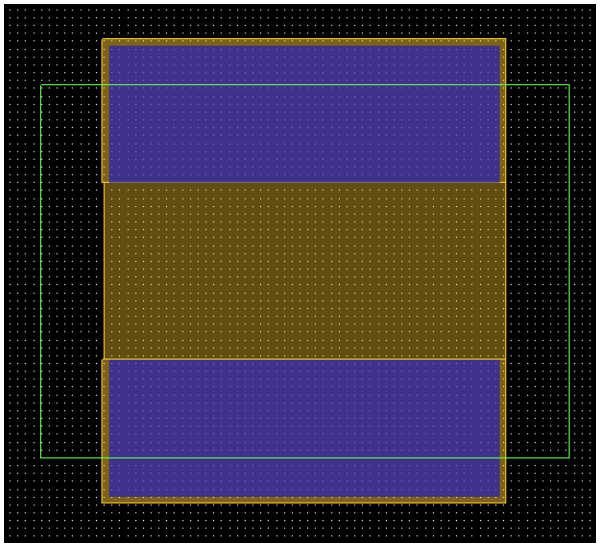
Non Solder Mask Defined

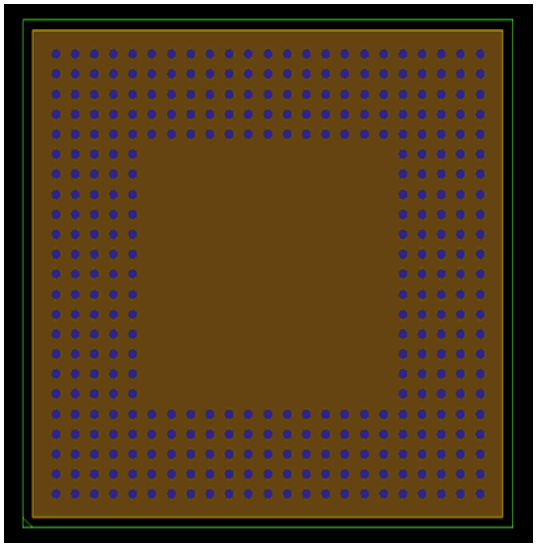


Narrow Pitch

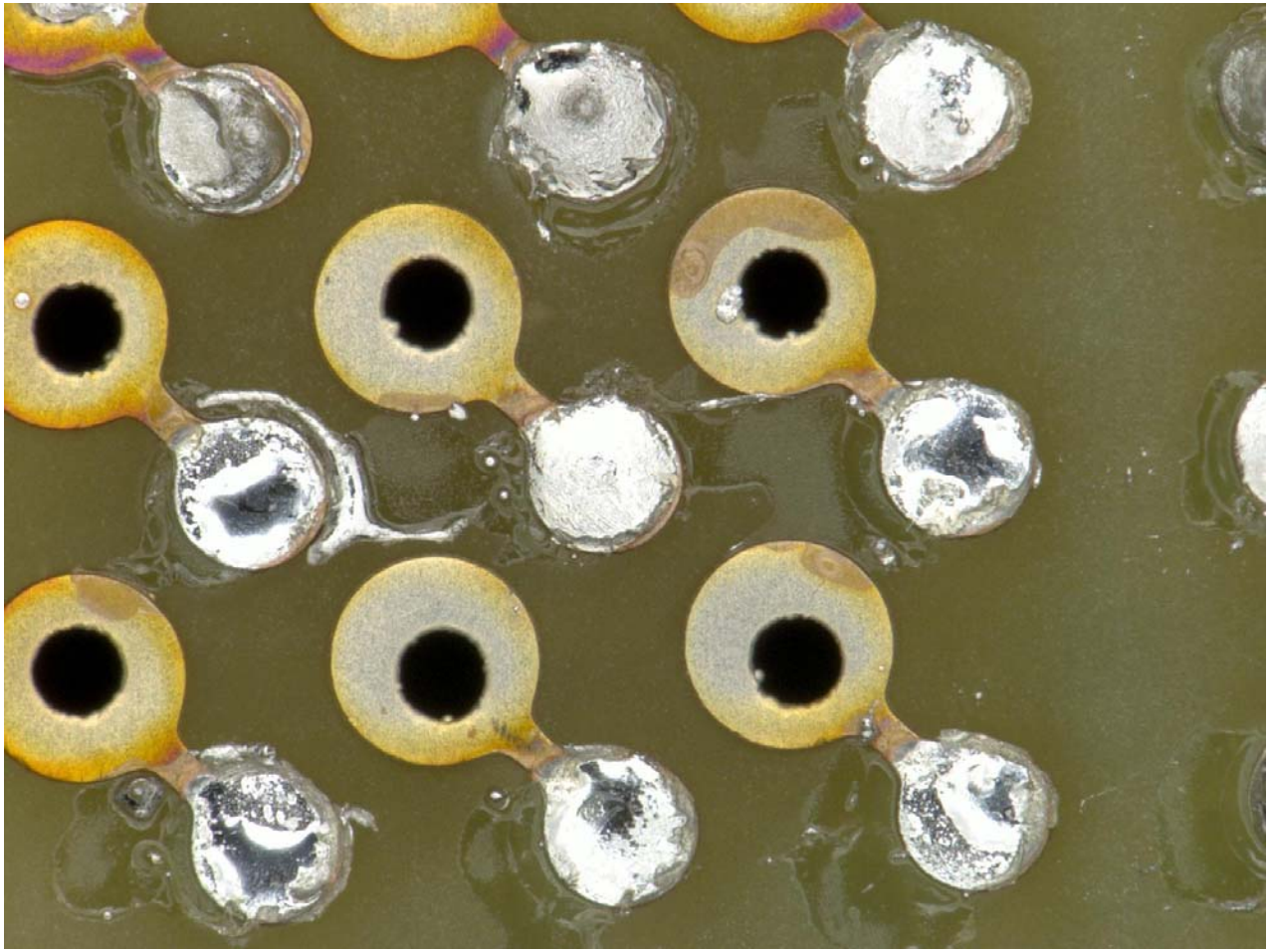
No Solder Mask on Pads

- Removes the solder mask in both
  - Pad area
  - Under the component
  - Increases the standoff gap



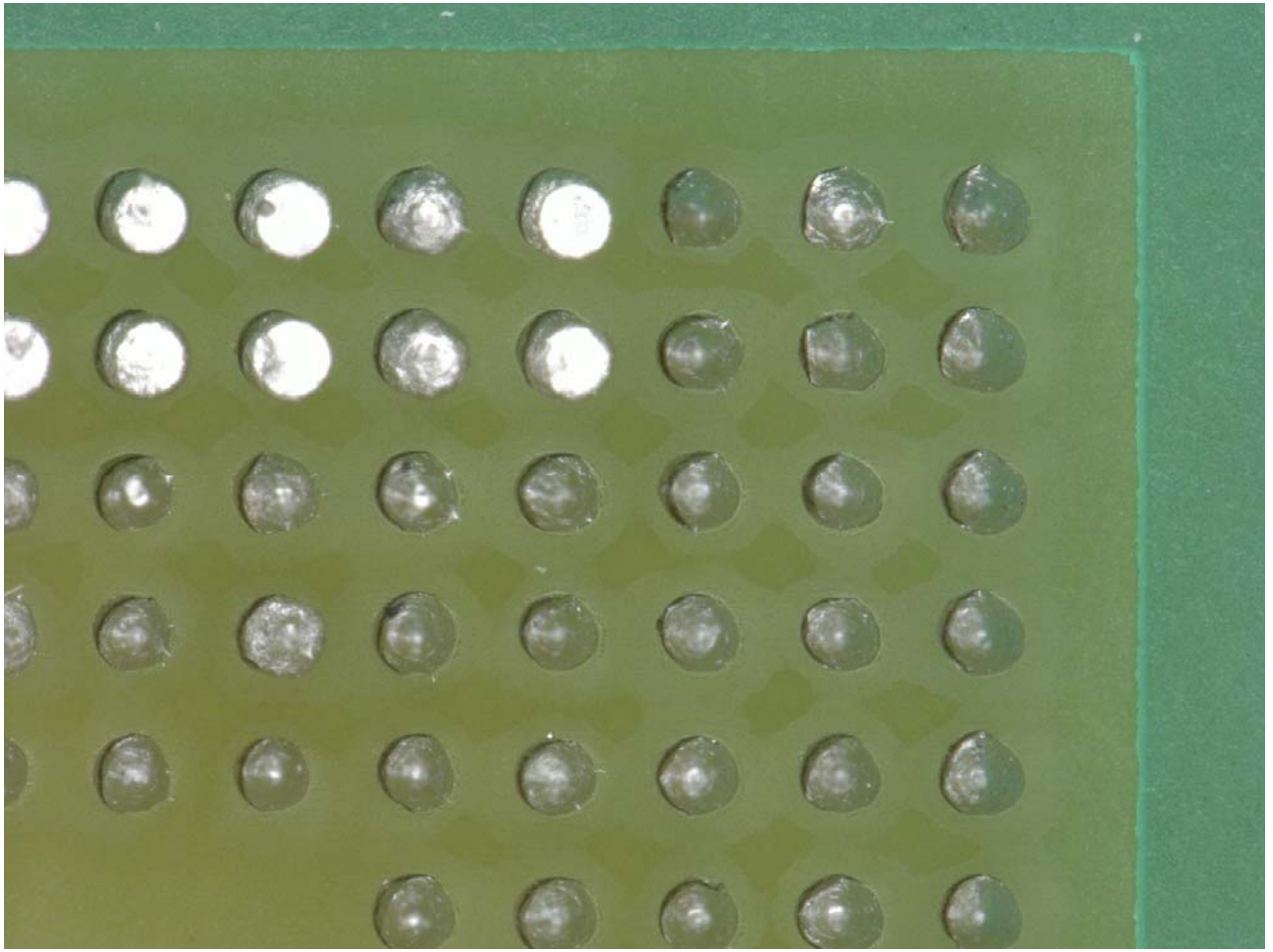


No Solder Mask



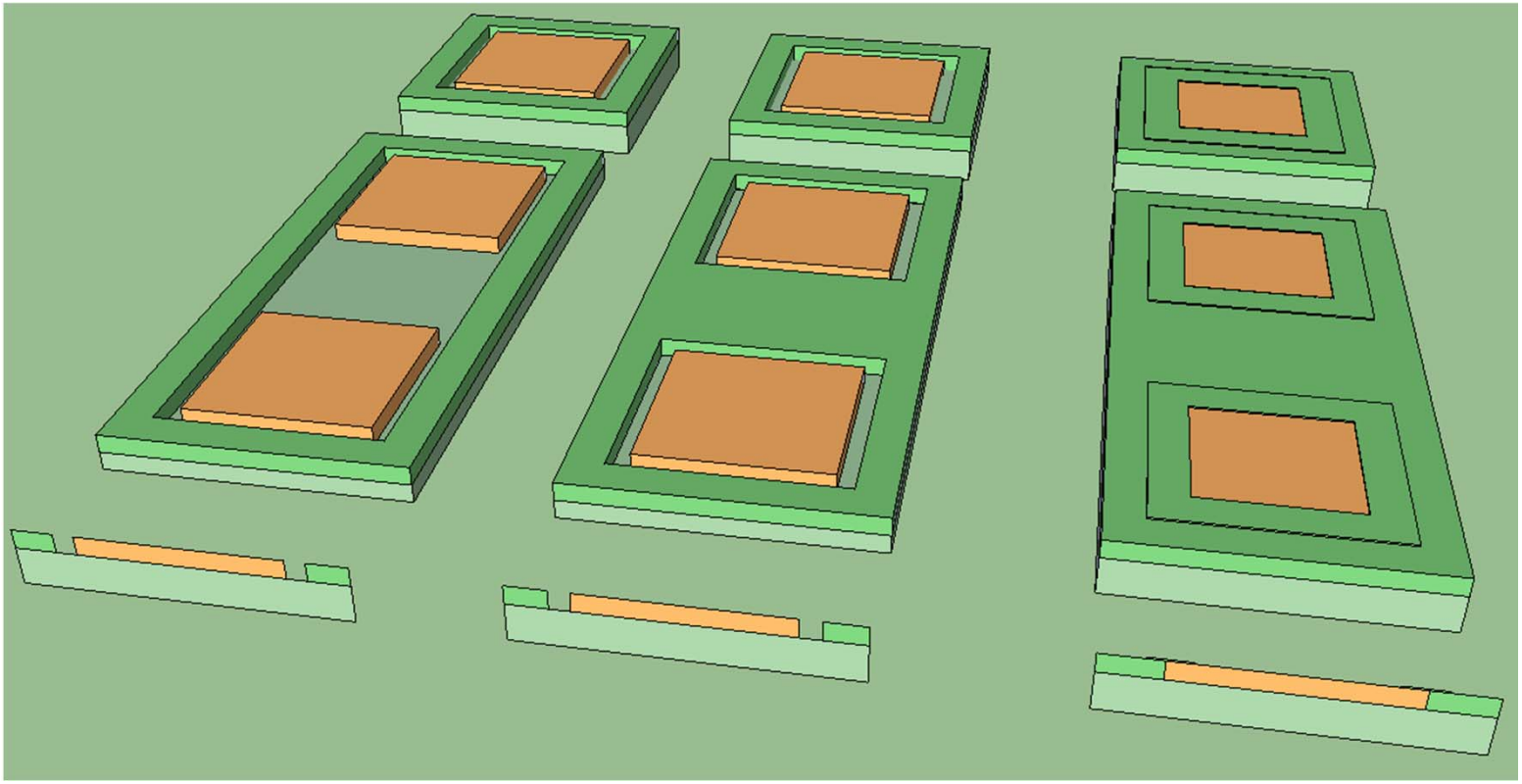
Wide Pitch

No Solder Mask

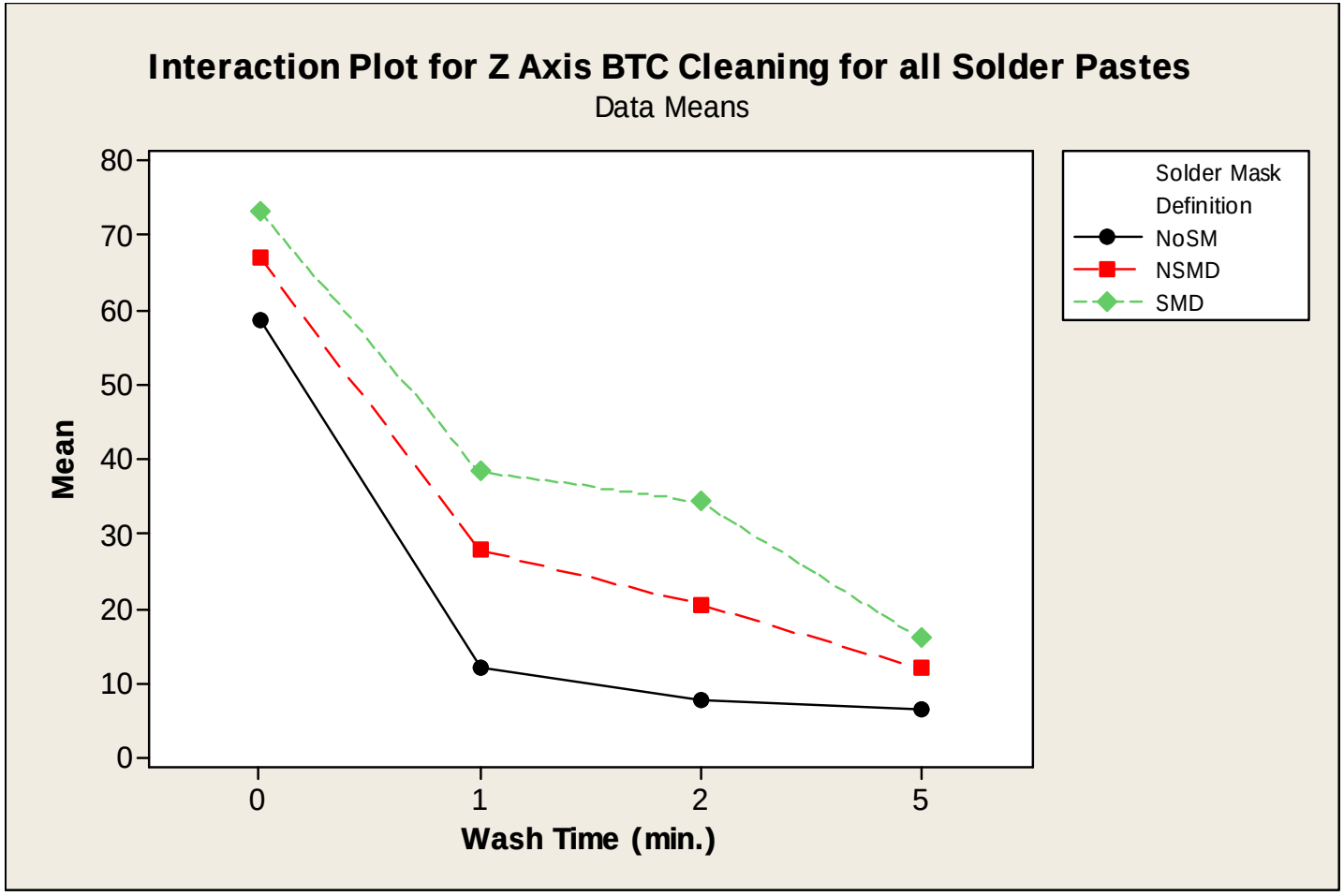


Narrow Pitch

SM Comparison



Cleaning Comparison Data



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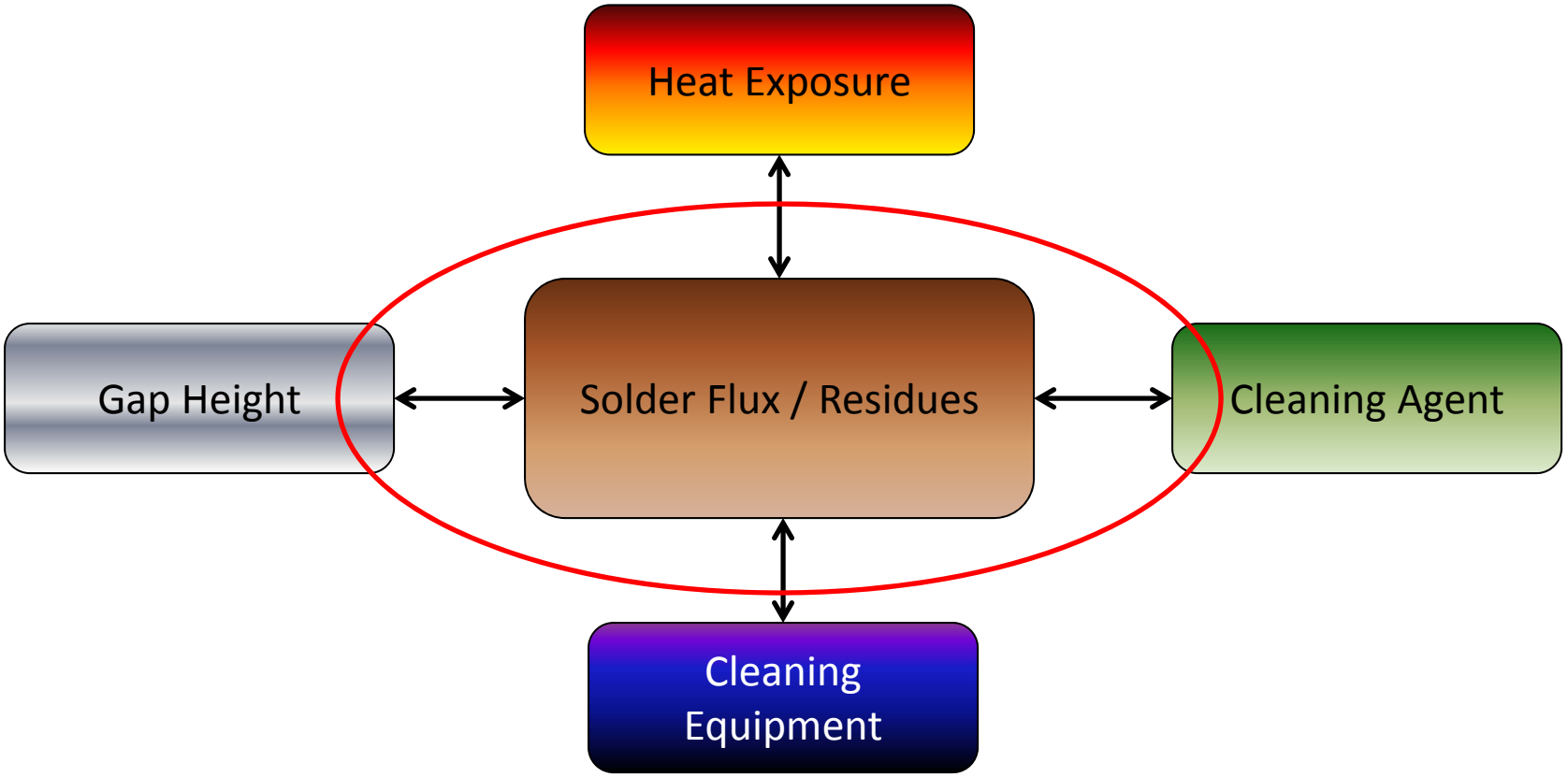
FACTORS AFFECTING CLEANING

Cleaning BGAs

- To clean under component gaps with tight Z-Axis
  - Understand the nature of the soil
  - Optimize the soldering step
  - Increase gap height if possible
  - Select cleaning agent that matches up to the soil
  - Mechanical system to deliver cleaning agent to soil
  - Rinse step to remove soil and ionic contamination
  - Cleaning process that does not damage the part

Factors Affecting Cleaning



Soil

Alloys

- Eutectic tin/lead
- Lead free
- High lead

Flux Vehicles

- RA (rosin activated)
- RMA (rosin mildly activated)
- WS (water soluble)
- NC (No clean)

Each of these impact the nature of the residue

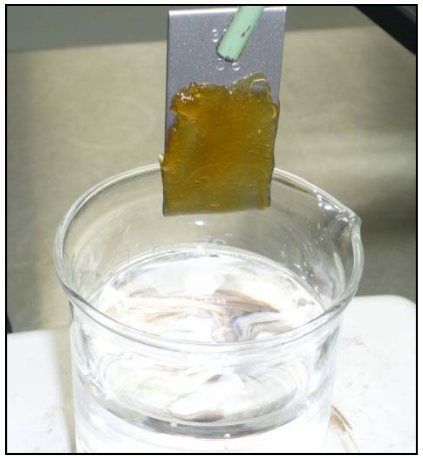
And what is required to clean it

Flux technology can impact alloy appearance

Soil Characterization

- What is the nature of the soil?
  - No Clean, Pb-free, Water Soluble, etc.
- What processing conditions can change the soil's cleaning properties?
  - Reflow, time before cleaning, etc.
- What tests are available to predict cleaning properties?
  - Solubility Parameters
  - Matching Cleaning Agent to Soil

Cleaning Rate

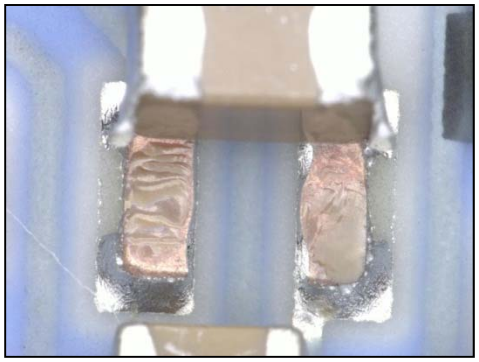


Static Cleaning Rate

+

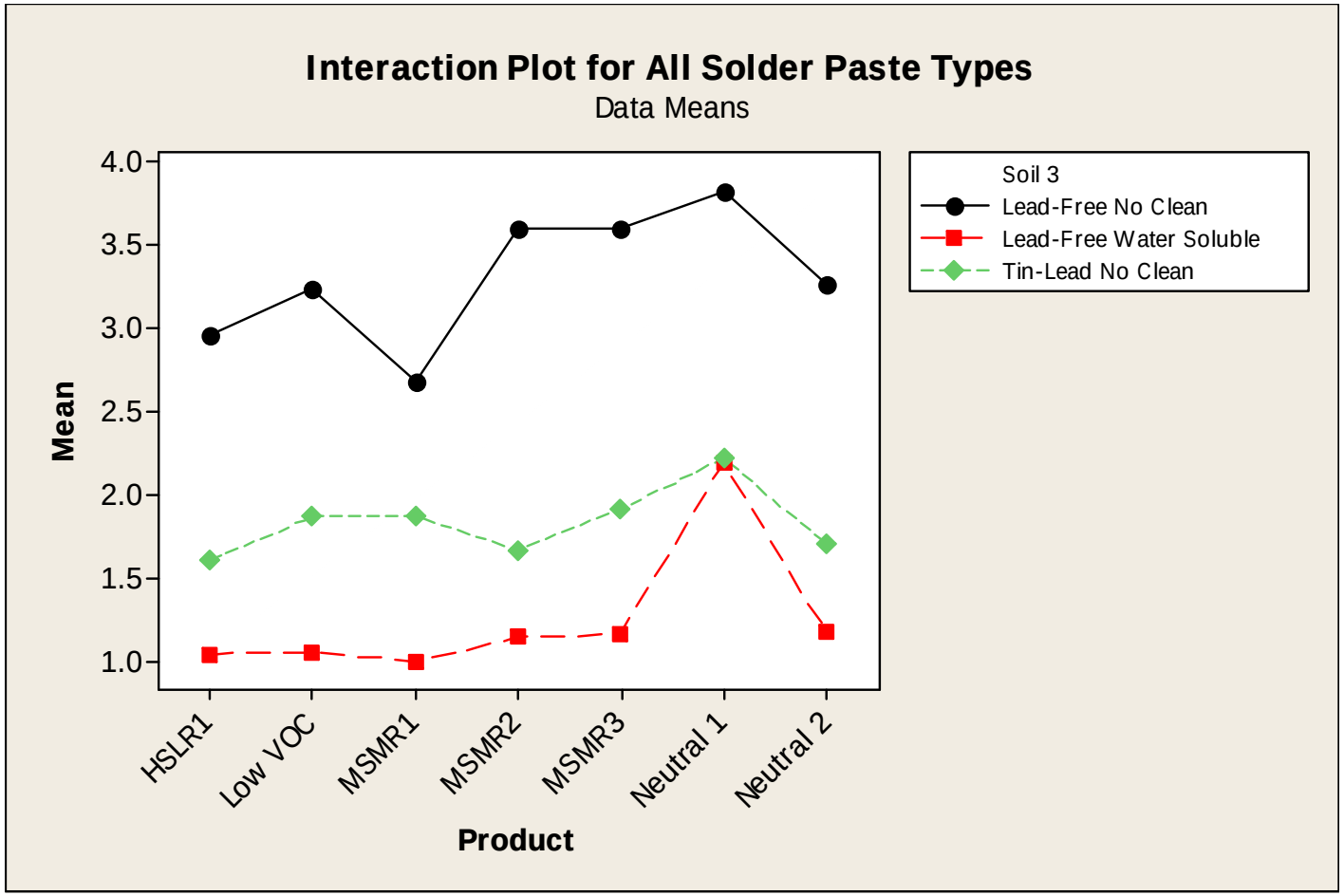
Dynamic Cleaning Rate

=

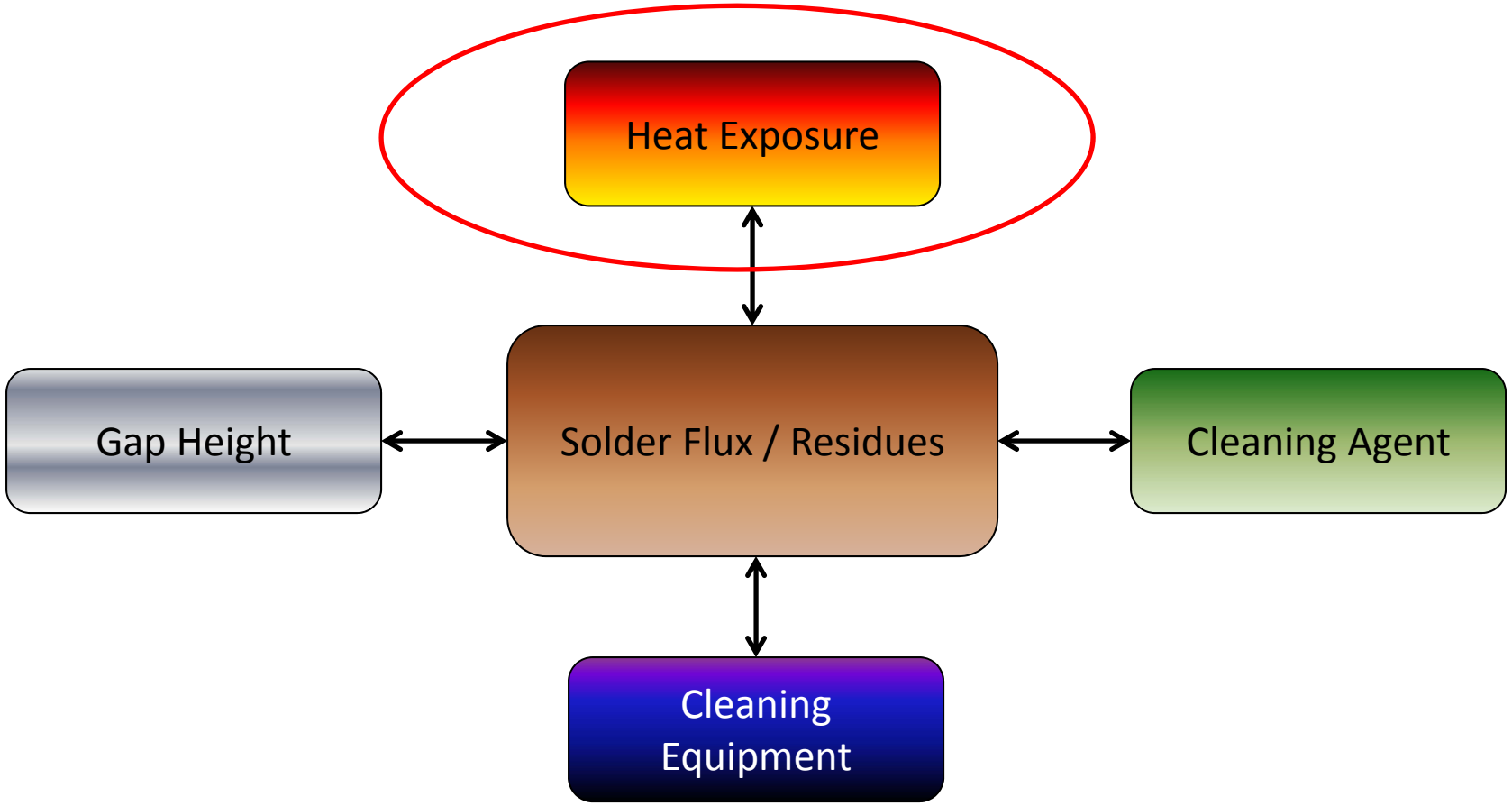


Actual Cleaning Rate

Static Cleaning Rate Comparisons



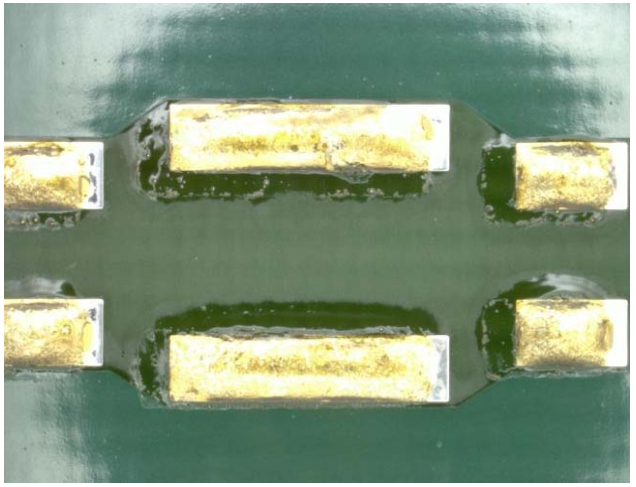
Factors Affecting Cleaning



Soil

- Critical to manage thermal exposure
  - Hard to remove flux residues result from
    - Long soak reflow profiles
    - Multiple reflow exposures
    - Bake cycles

Optimized Reflow



Overheating Reflow

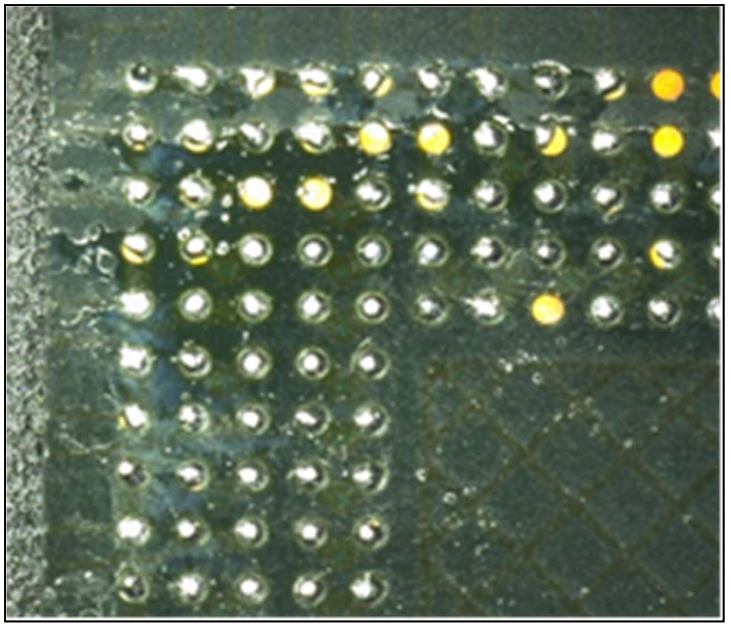
Heat per Alloy

Flux	Alloy	Melting Temp (°C)	Peak Reflow (°C)	Cleaning Influence
RA	Sn 63.5/Ag 3.5	~180	~210	Easy
RA	SAC 305	221	~251	Typical
RA	Sn 5 / Pb 85 / Sb 10	245 - 255	~275 – 285	**Difficult**
RMA	Sn 63 / Pb 37	183	~213	Easy
WS	Sn 63 / Pb 37	183	~213	Easy
“HMP” RA	Sn 5 / 93.5 / 1.5	305 – 306	~335 – 336	**Very Difficult**
NC	Sn 96.5 / Ag 3.5	221	~251	**Difficult**

“HMP” = High Melting Point

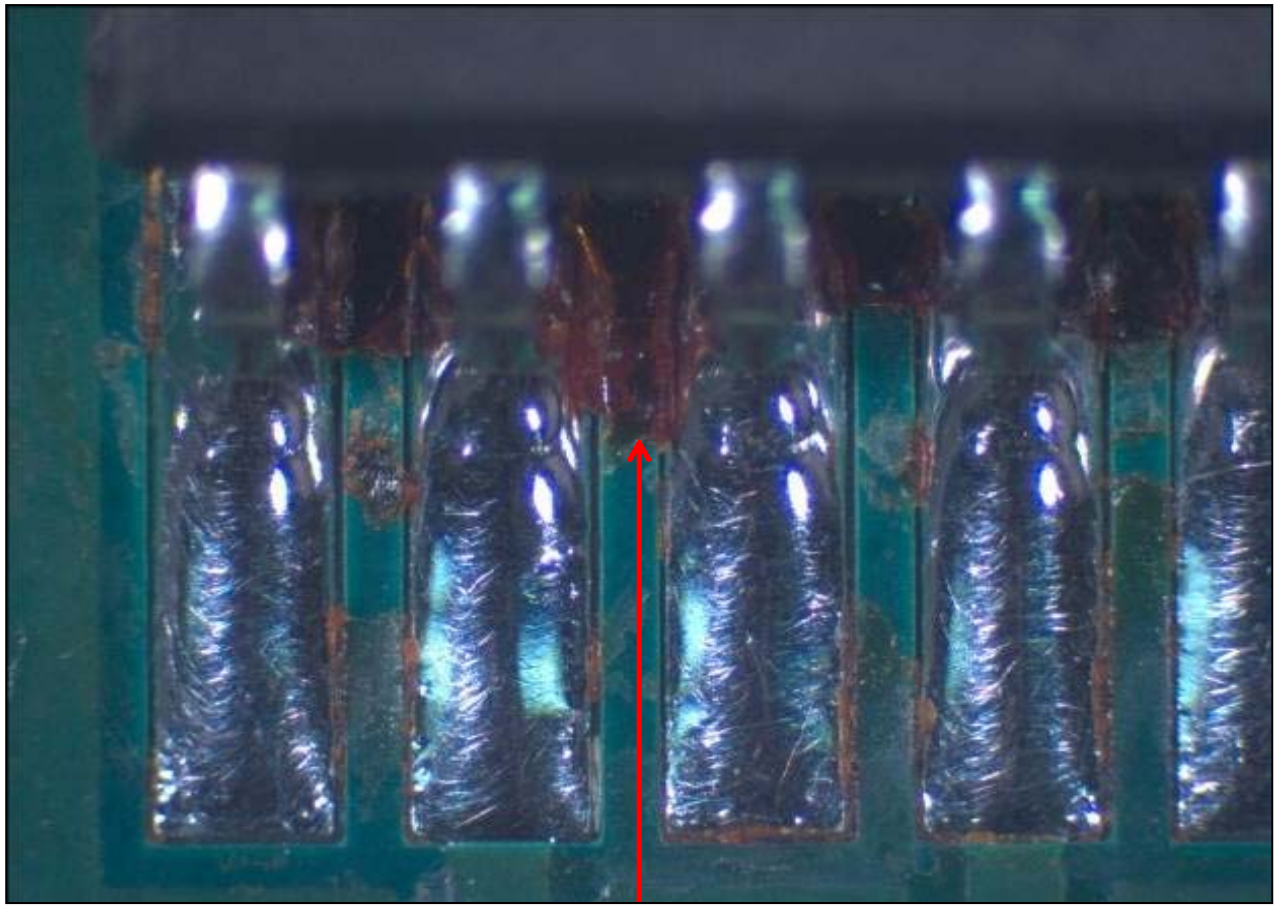
Elevated Reflow Temperatures

- Fluxes with higher molecular weight oxygen barrier
  - Withstand hotter temperatures
  - More difficult to clean
- Reduced Volatiles
  - Minimize voiding
  - Greater amount of residue
- More Oxidation Resistant
  - Reduce charring / burn off
  - Requires greater solvency & activity



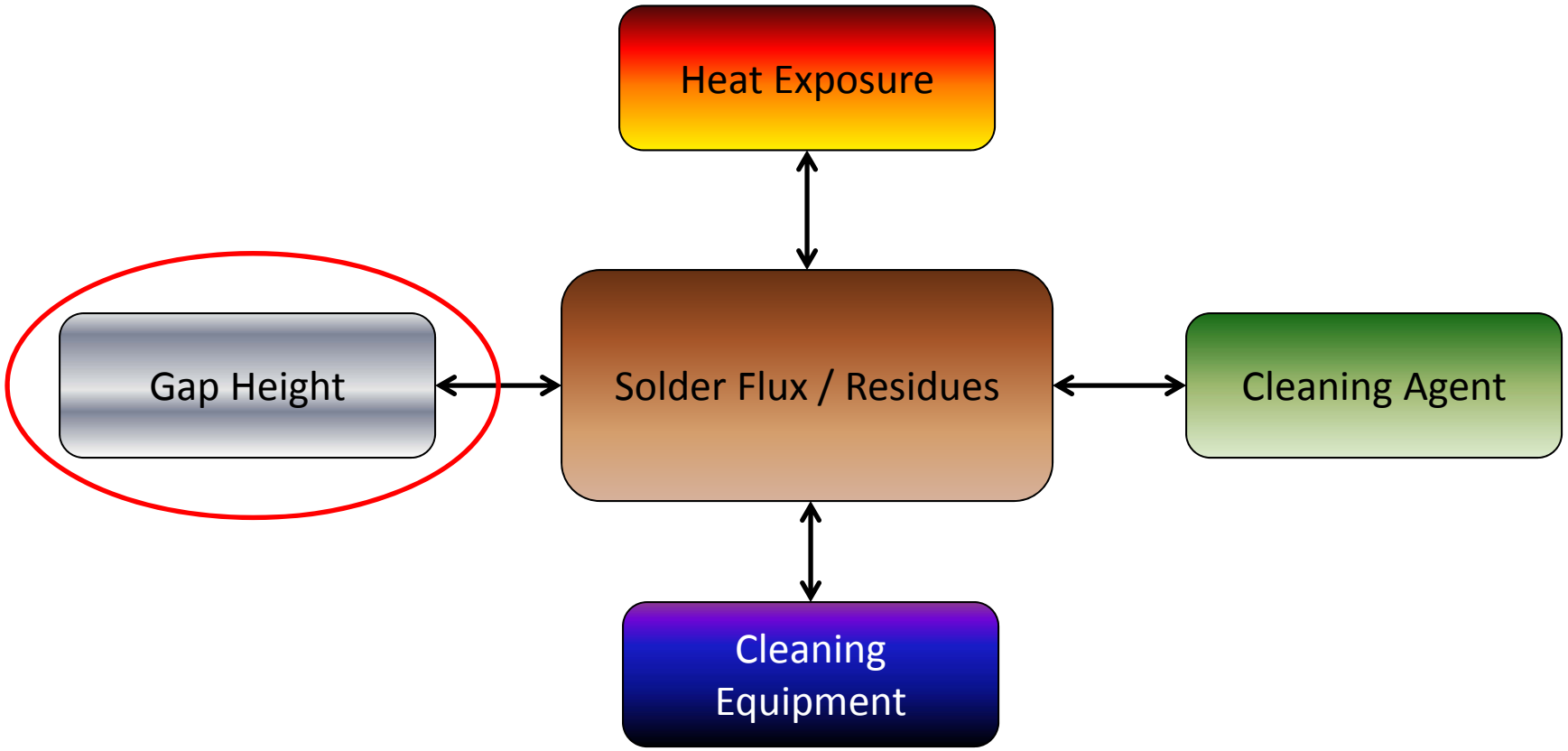
µBGA with 0.40 mm pitch

Char / Oxidize Residue



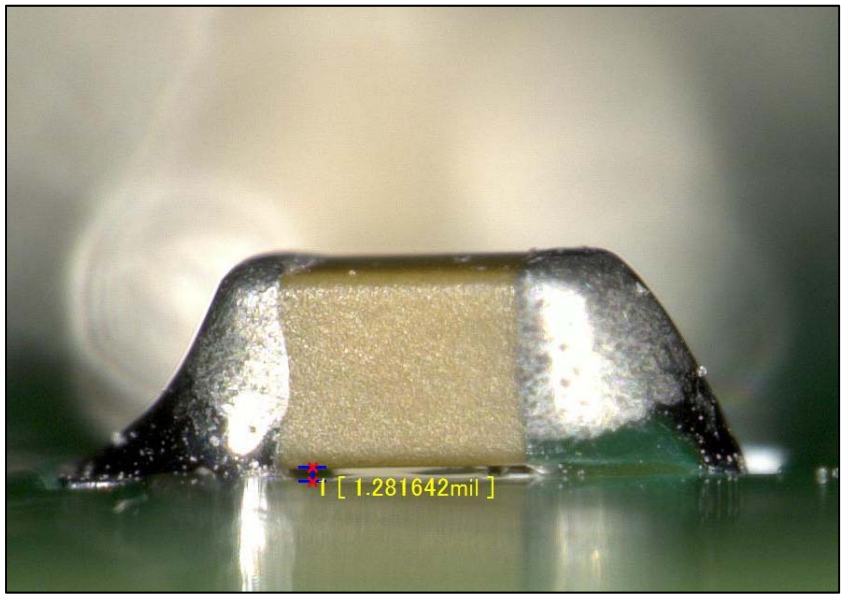
Burnt Flux Residue

Factors Affecting Cleaning

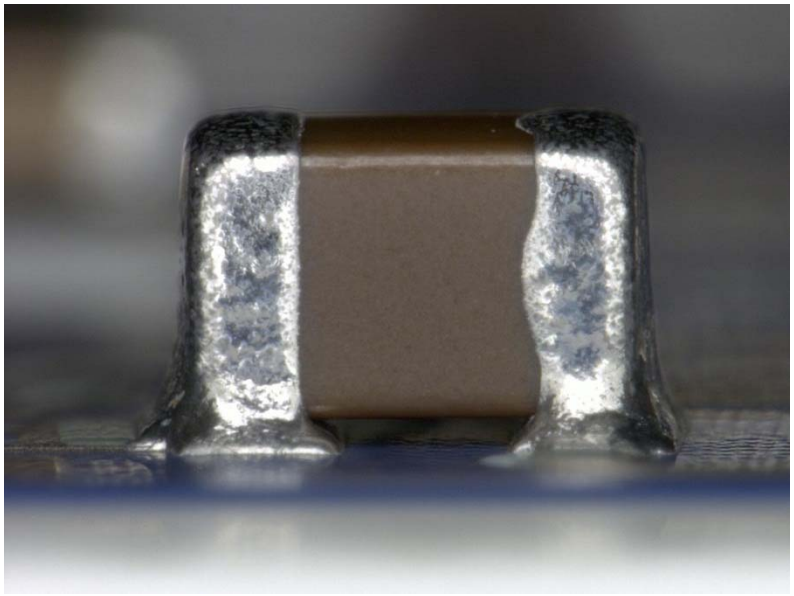


Chip Caps

- Gap Heights under 2 mils
- Flux bridges conductors

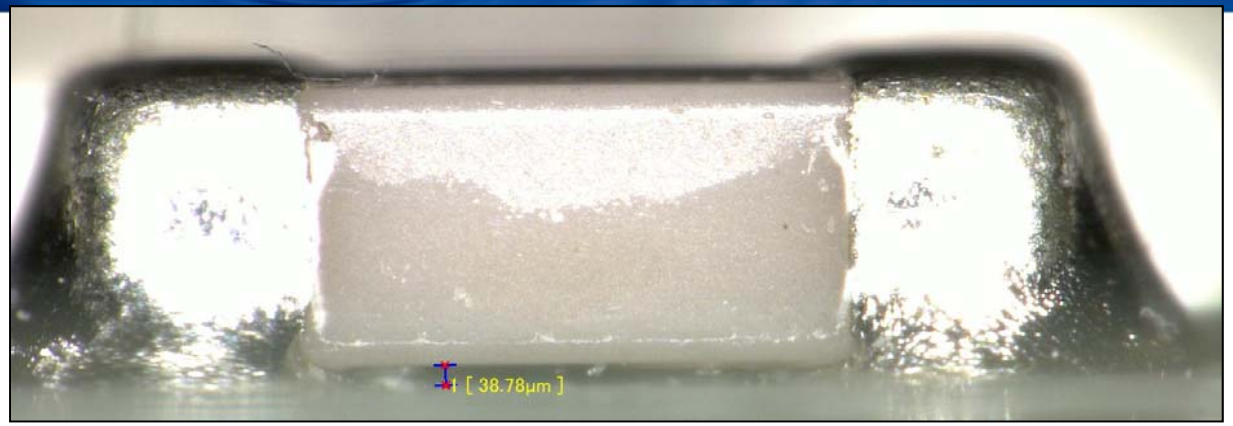


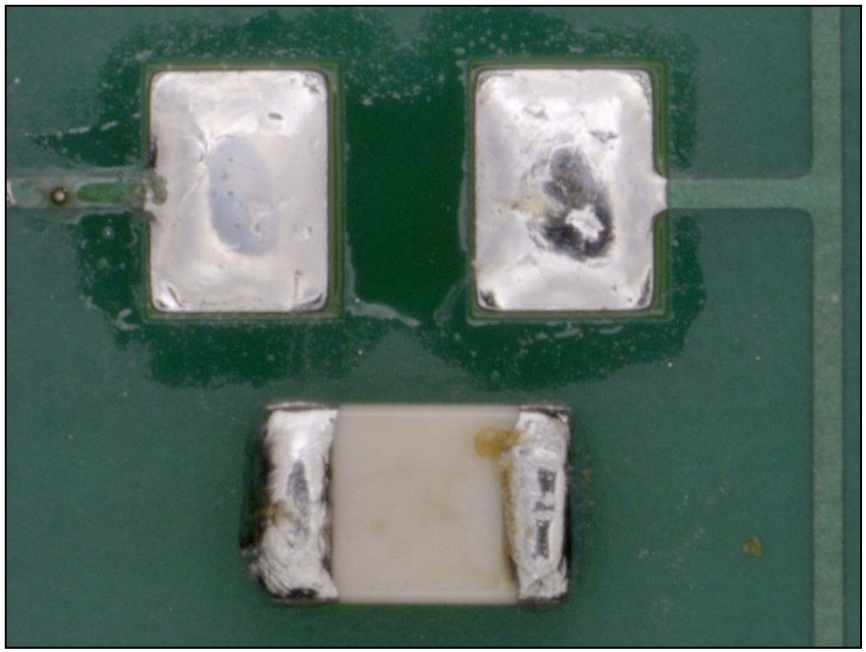
Low Gaps Require More Cleaning Time



High Gaps Require Less Cleaning Time

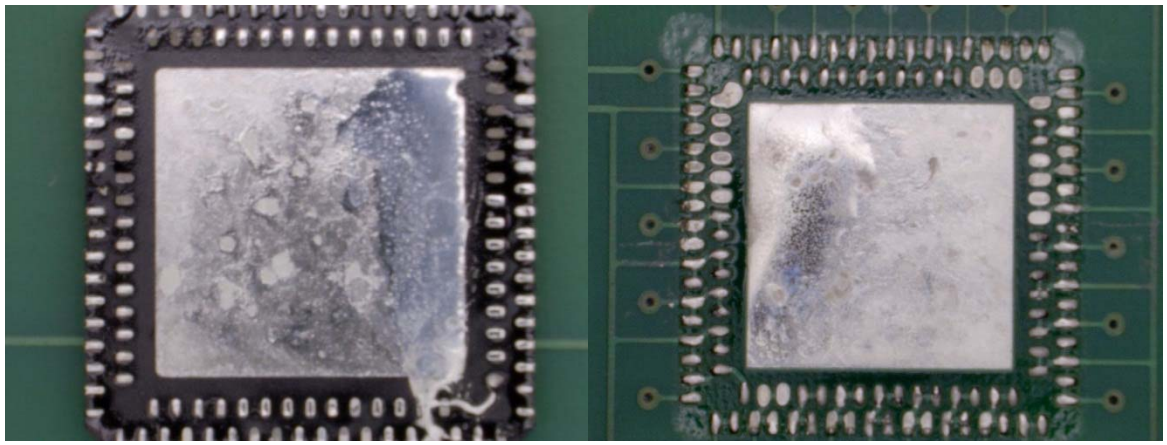
Flux Bridging / Underfill





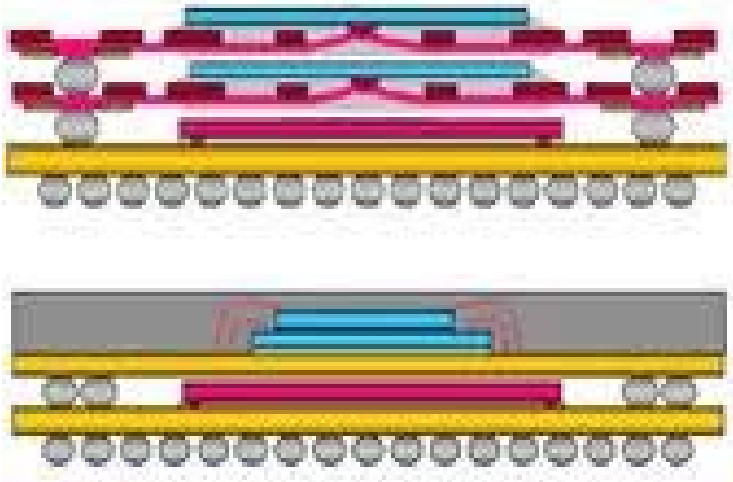
QFN / MLF Components

- Trapped flux under QFNs
  - No-clean flux residues are a risk due to
    - Non-activated weak organic acids
    - Partial cleaning exposes ionic residues
  - Water soluble flux residues
    - High levels of ionic residues



Advanced Packages

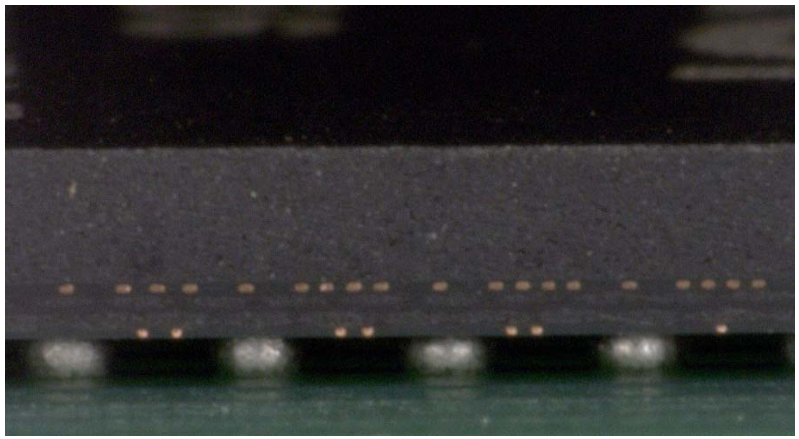
- BGAs, CSPs, WLPs and Flip Chip are under
  - Constant pressure to miniaturize
  - Lower cost
  - Put more packages or modules on the device

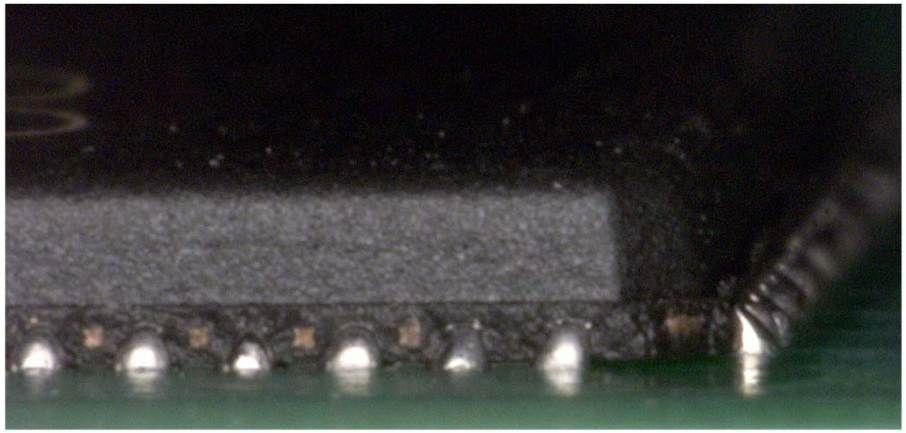


Package on Package

Z-Axis Comparison

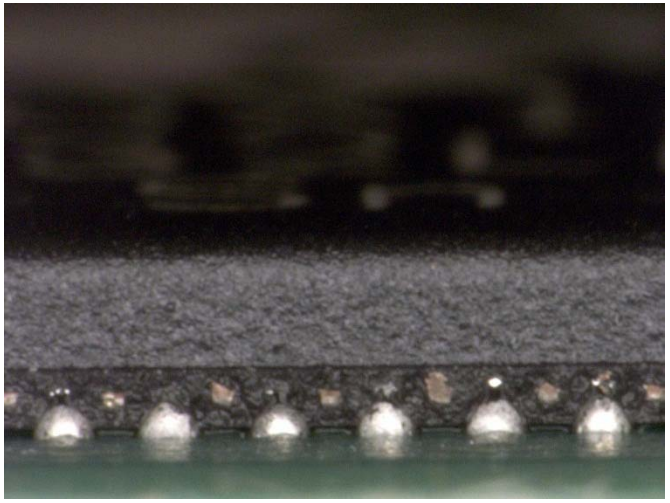
- BGA Components
  - 7-15 mil – good for cleaning
- Leadless Components
  - 1-5 mil – bad for cleaning





Z-Axis Concerns

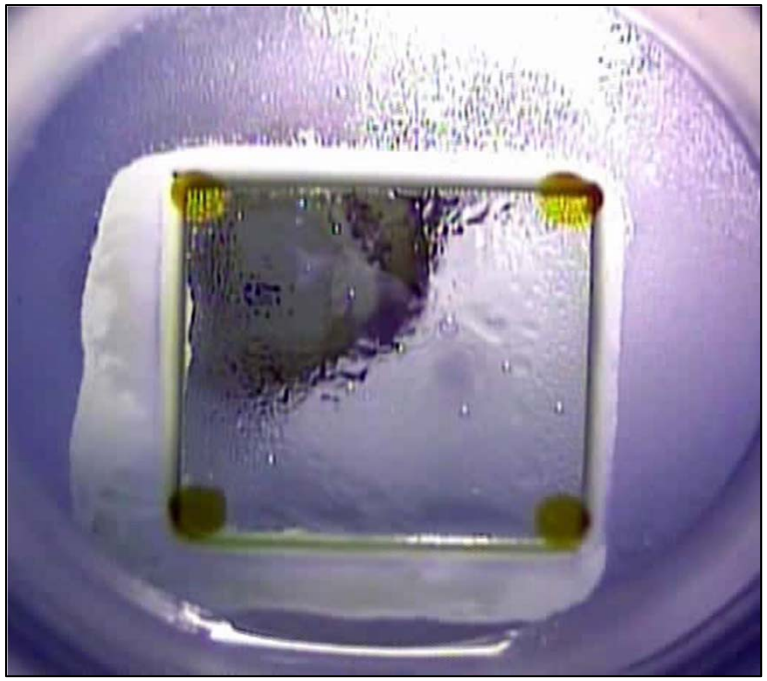
- Electric Field = Voltage/Distance
  - Electric field increases
    - Digital technology as high as 0.5 volts/mil
    - Analog/power technology as high as 1.6 volt/mil
    - QFN as high as 3.5 volts/mil



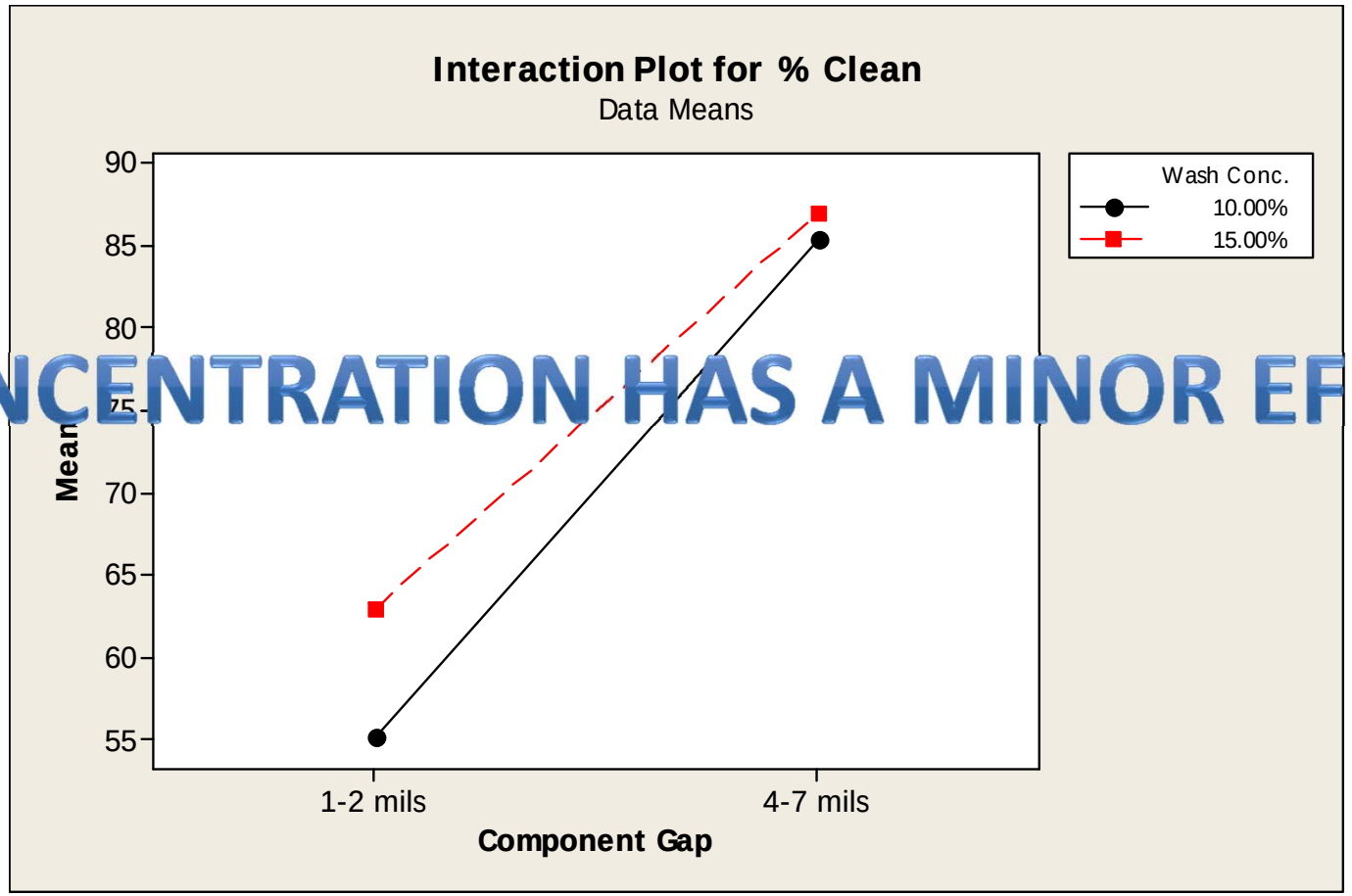
Trapped Residue Between Leads and Ground Pad

Gap Heights Magnify Cleaning Issues

- Flux underfills bottom termination devices
- To clean
  1. Wet soil +
  2. Dissolve soil +
  3. Break through soil +
  4. Create a flow channel =
  5. **Clean**

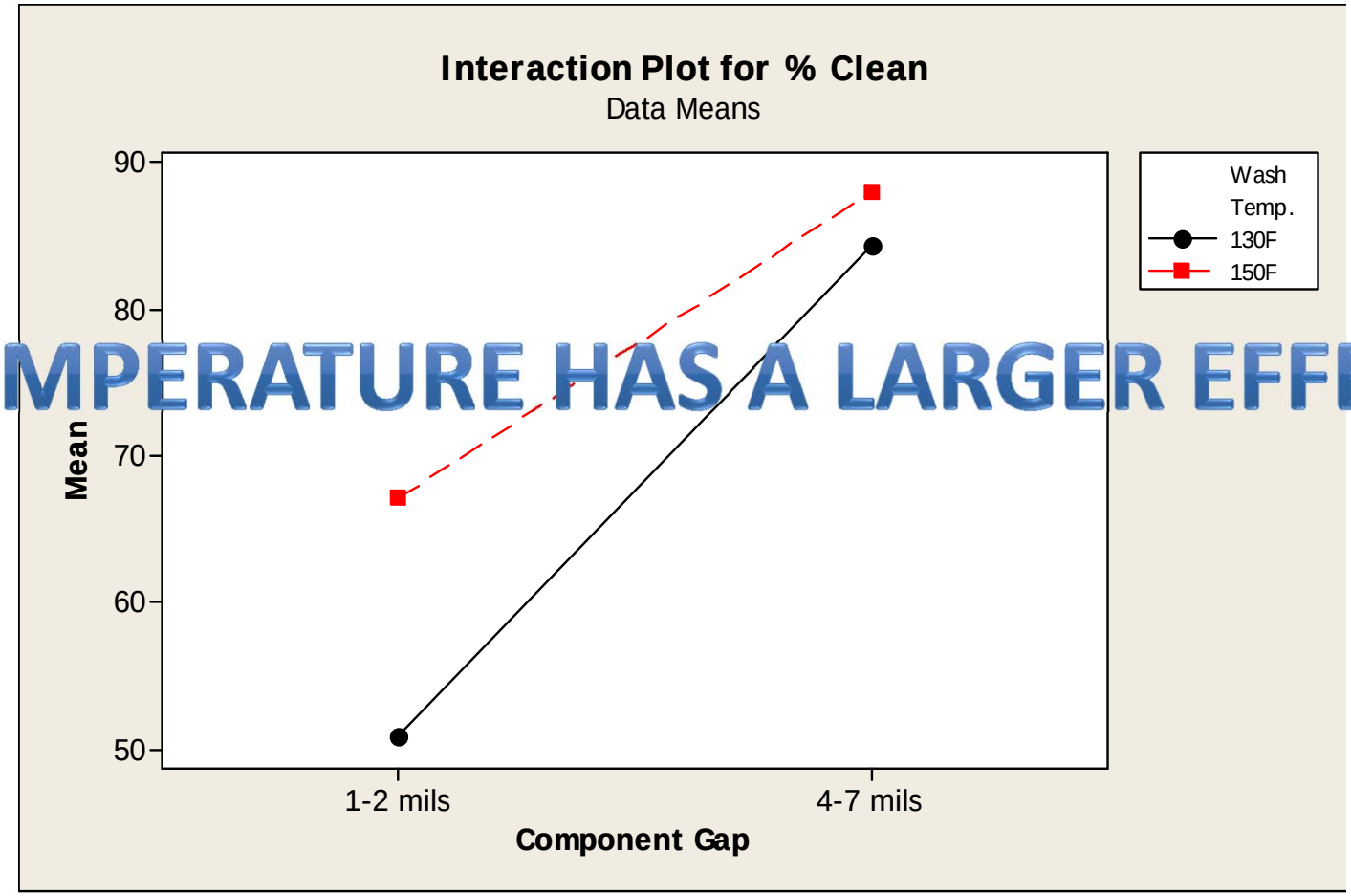


Wash Concentration



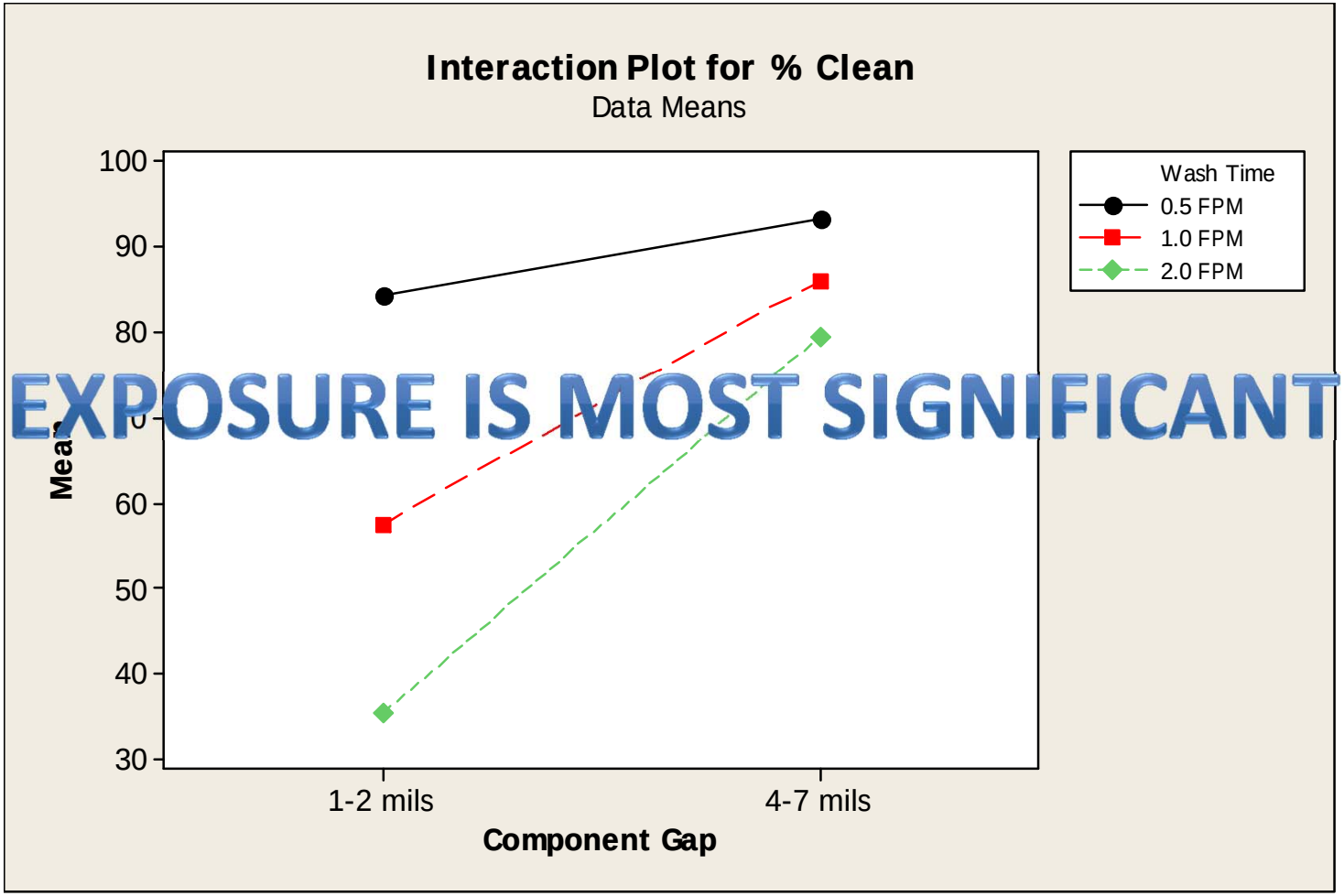
CONCENTRATION HAS A MINOR EFFECT

Wash Temperatures



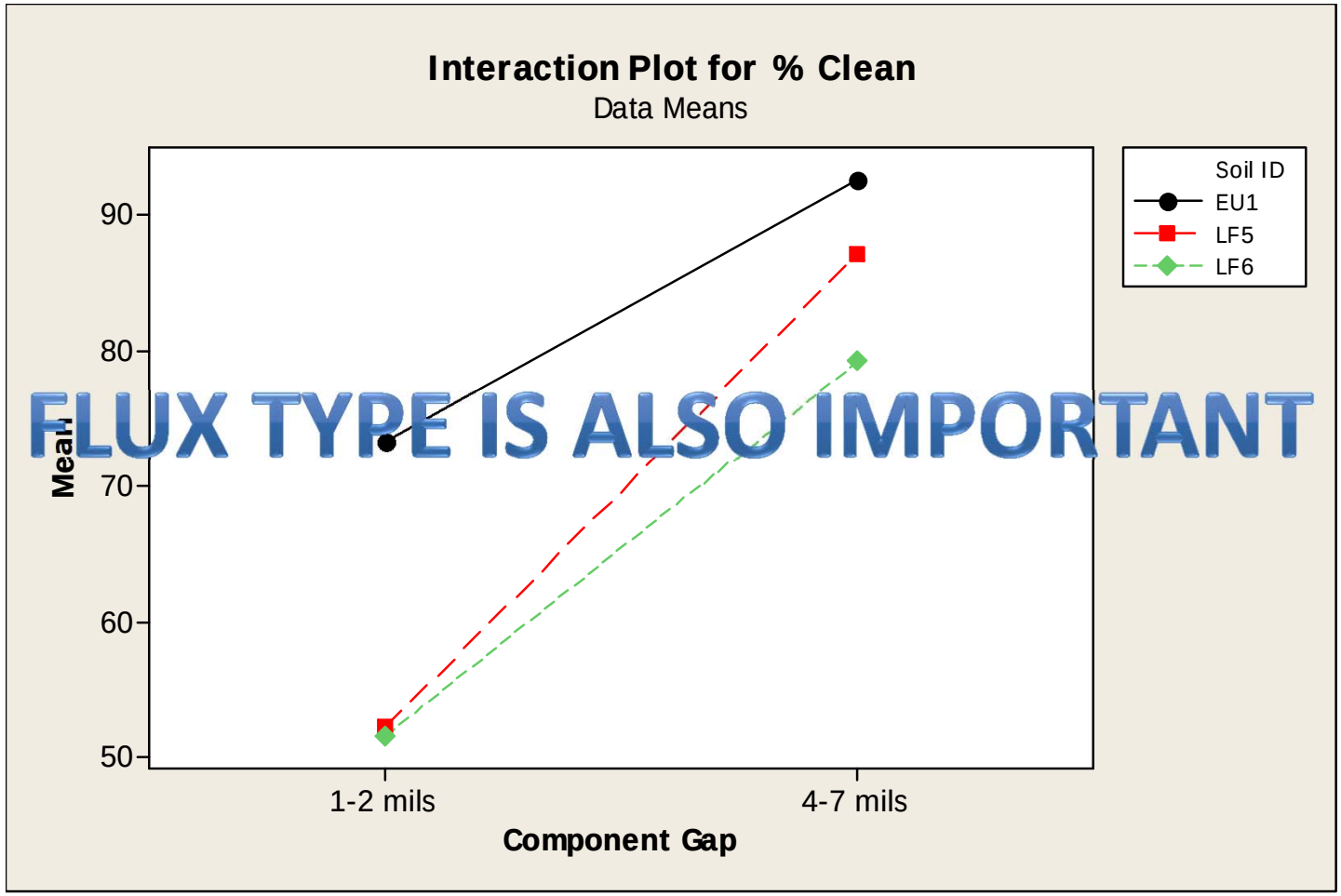
TEMPERATURE HAS A LARGER EFFECT

Wash Exposure Time



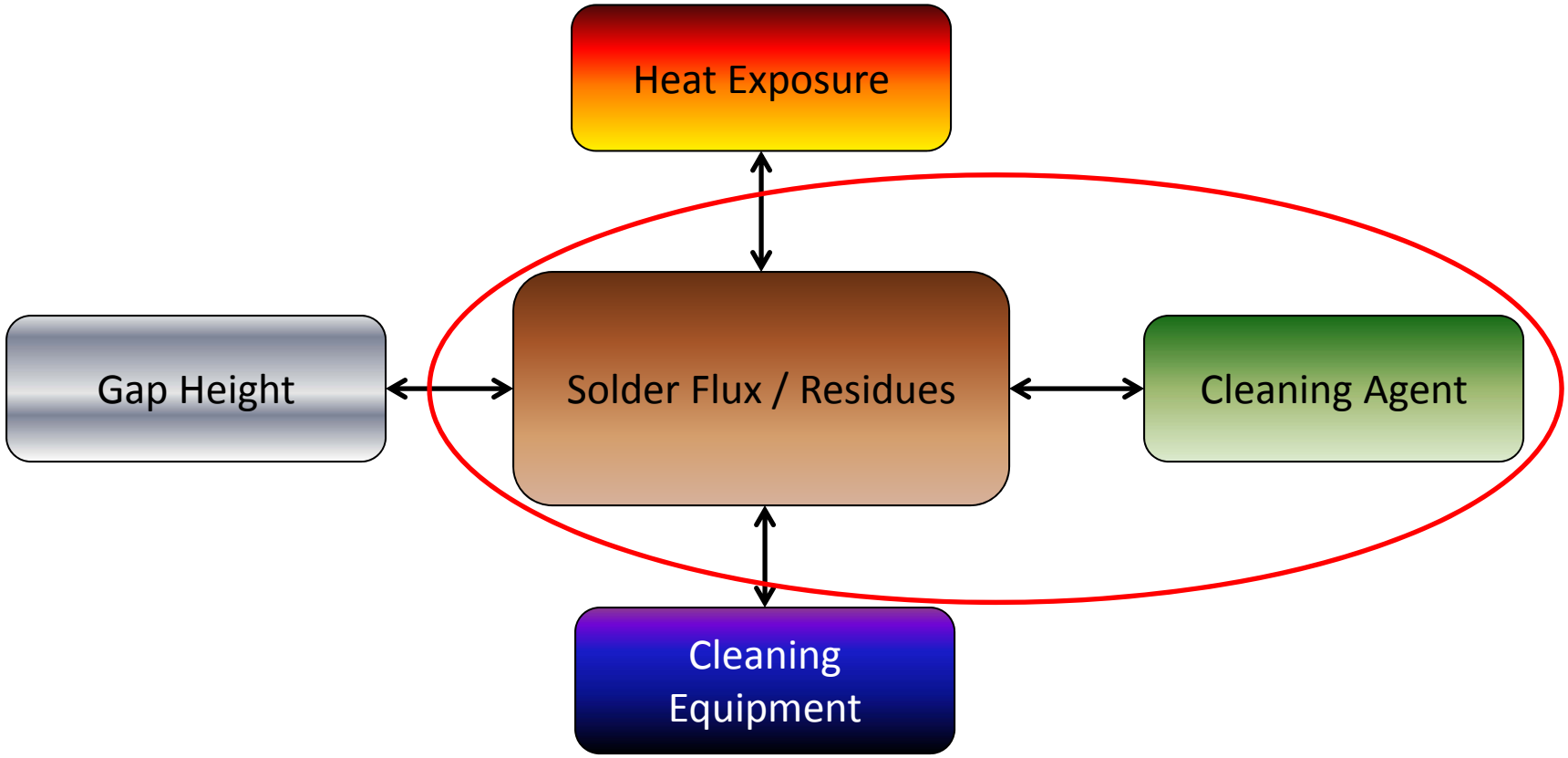
EXPOSURE IS MOST SIGNIFICANT

Solder Pastes



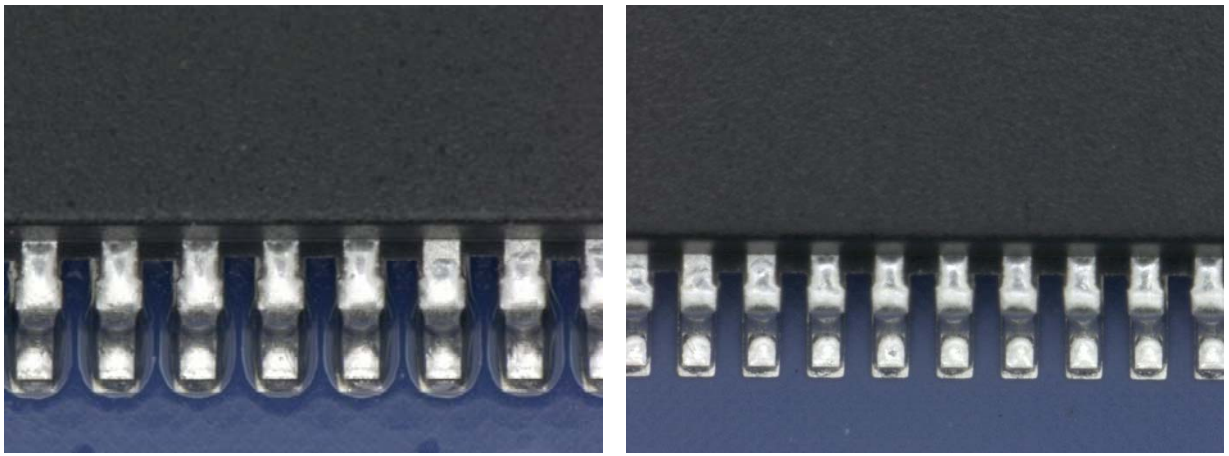
FLUX TYPE IS ALSO IMPORTANT

Factors Affecting Cleaning



Cleaning Agent

- Must be matched to the flux residue/ soil
- Functional cleaning agents are
  - Engineered to the soil and cleaning equipment
  - Hydrophobic in nature to clean resinous soils
  - Hydrophilic in nature to clean polar soils



Before Cleaning

After Cleaning

Cleaning Agent Matched to Soil

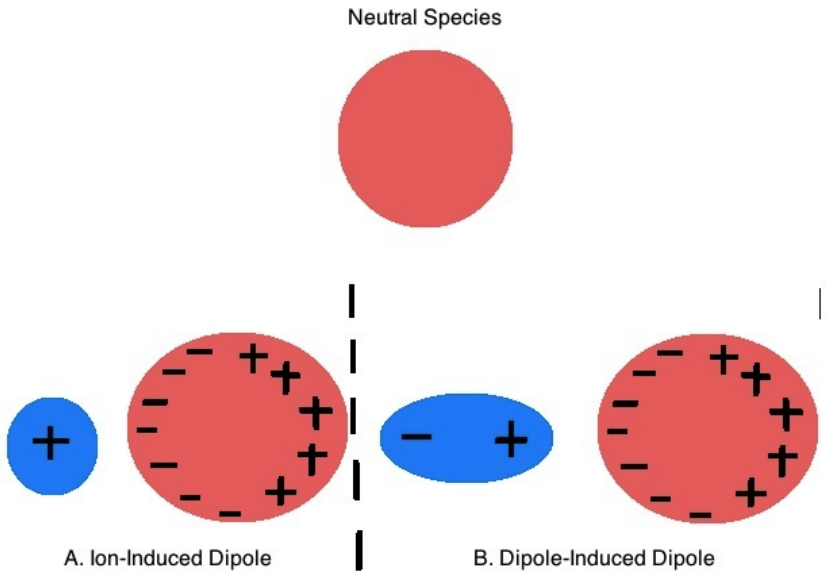
Which will clean better?

Maximizing Static Rate

- Cleaning agent that dissolve the soil will be
  - Miscible / Dissolve in the cleaning agent
  - The basic principle ~ *Like Seeks Like*
- Key cleaning factors
  - Cleaning agent affinities (polar / ionic, covalent / non-ionic)
  - Kinetic surface energies

Cleaning No-Clean Flux

- Soils are made up of covalent resin structures
  - Polar covalent
  - Non-polar bond dipole
- Activators induce a dipole on flux resin
  - Improves dissolution
  - Removes harden residues



Significant Factors

- Process parameters
  - Cleaning agent
  - Wash concentration
  - Wash temperature
  - Wash time
  - Impingement energy

Wash Concentration

- Aqueous cleaning agents
  - Run at different dilution rates
  - Soil make-up influences concentration
  - Two phase cleaning fluids
    - Improves Hydrophobic /Hydrophilic balance
    - Lower concentration levels
    - Effective on covalent no-clean flux residues

Wash Temperature

- Rosin and resin flux residues
  - Soften at higher wash temperatures
  - As a general rule
    - The rate doubles for each 10°C (18°F) rise in temperature
    - On some residues, solubility is inverse to temperature
    - The chemical characteristics of the soil determine the actual wash temperature process window

Wash Time

- Wash time dependent on
  - Density of the assembly
    - BTC's require longer time to penetrate and clean
    - Gap Height ~ Lower takes longer time to clean
    - Flux residues ~ Harder residues increase cleaning time
    - Cleaning agent ~ Closer match reduces cleaning time
    - Impingement energy ~ Targeted energy reduces time

Impingement Energy

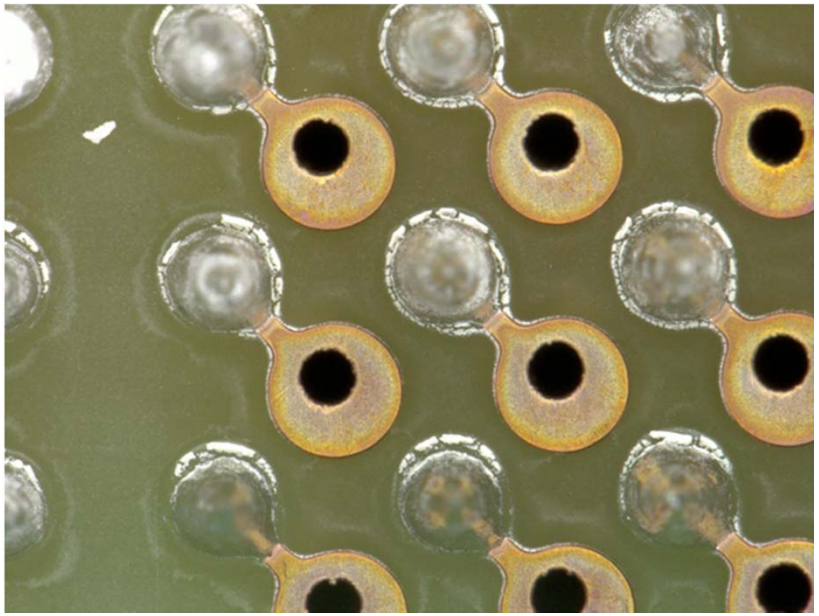
- Cleaning Agent + Impingement Energy = Clean
  - Low energy machines require longer cleaning time
  - Low energy may be insufficient to penetrate gaps
  - Strong impingement energy reduces cleaning time
    - Spray-in-air using tighter spray patters
    - Ultrasonic cleaning energy

ONE CLEANING AGENT FOR ALL APPLICATIONS IS MORE CHALLENGING

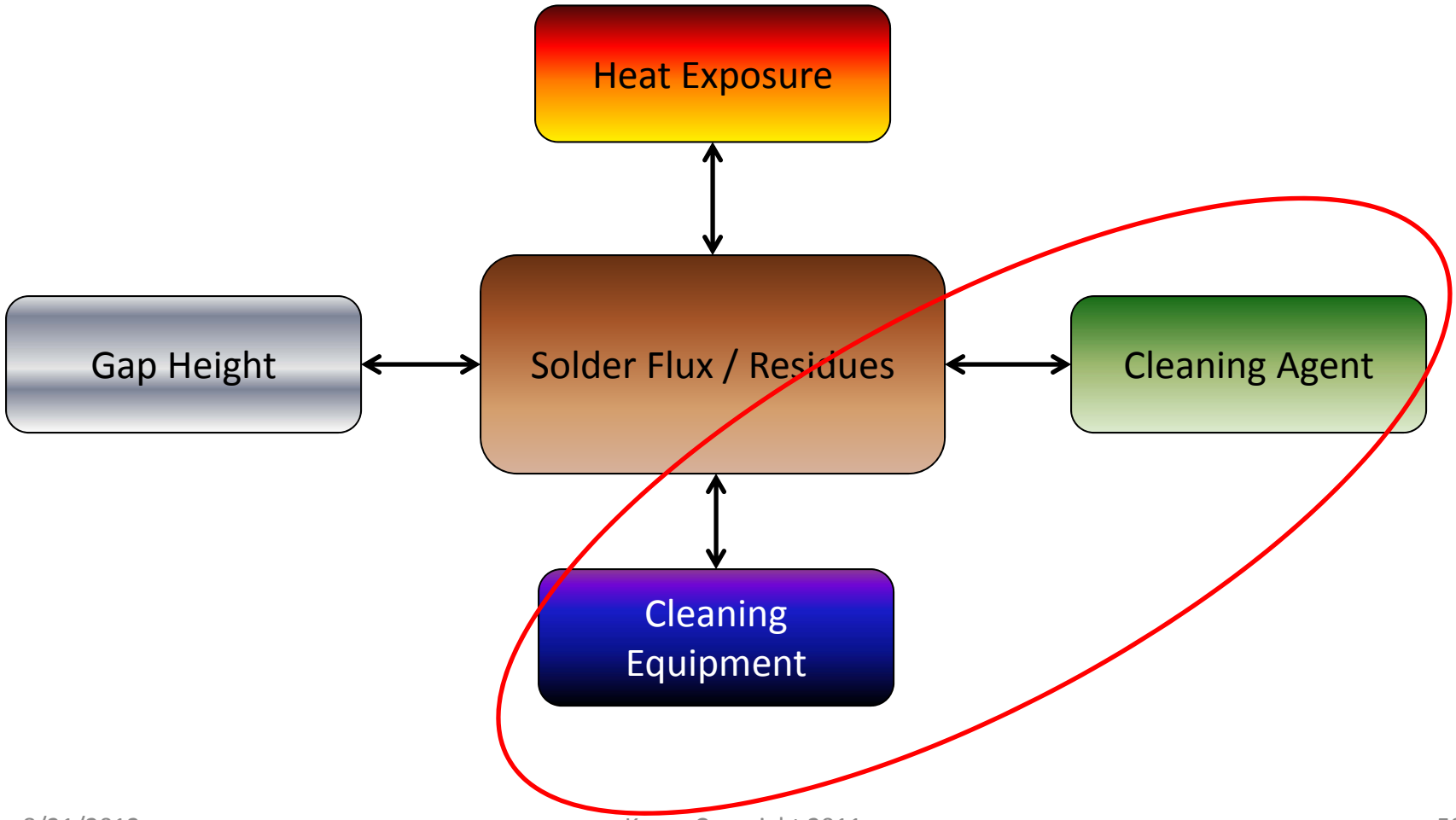
- Cleaning agent #1
  - Cleans fast, impacted sensitive high-lead alloys
- Cleaning agent #2
  - Didn't clean as well, but solder joints were better
- Cleaning agent #3
  - Cleaned better than #2, still affected solder after longer / multiple exposures
- Cleaning agent #4
  - Best looking solder, slowest to clean
  - Especially on the high temp alloys

Poorly Match Cleaning Agent

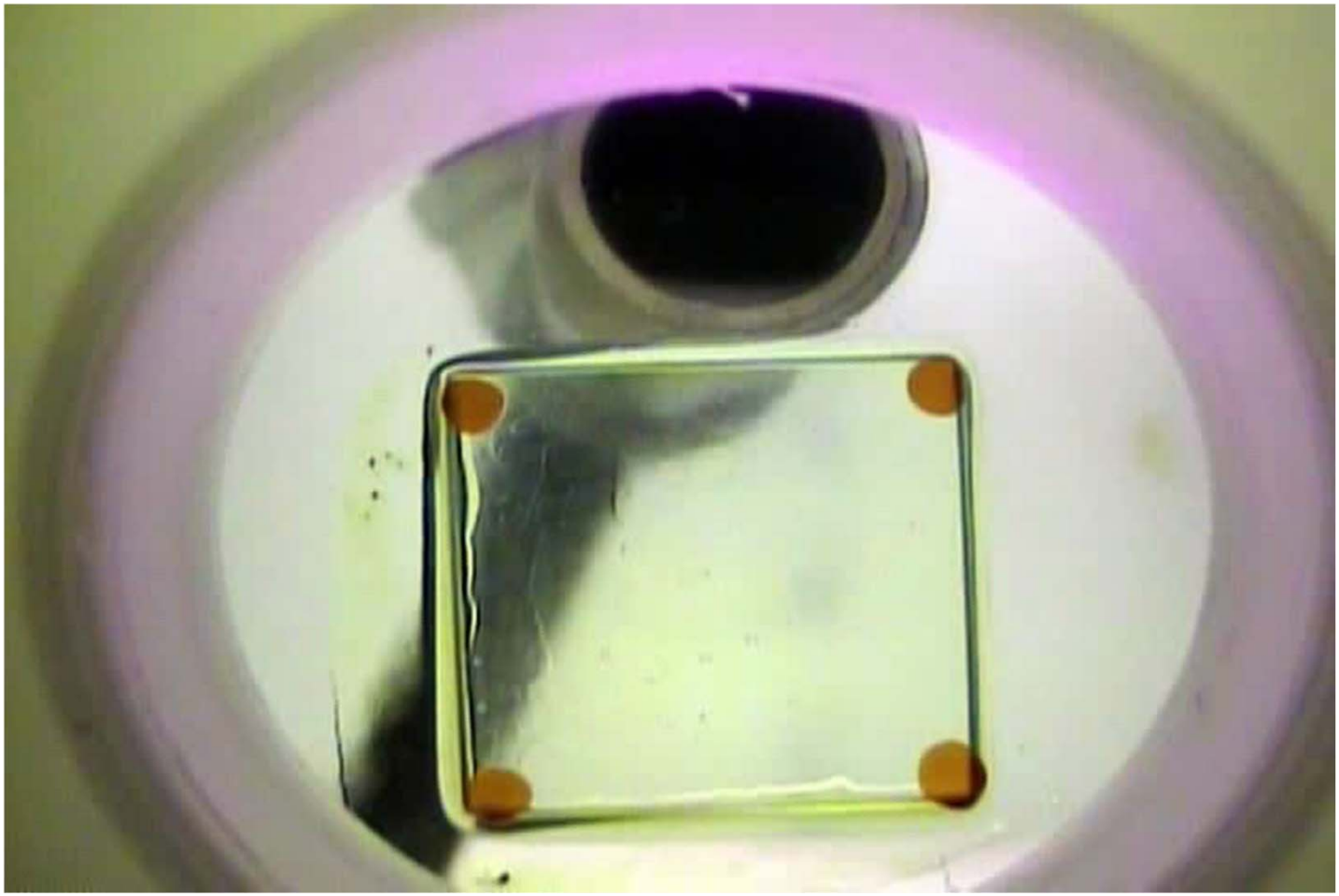
- A poorly matched cleaning agent will not
  - Remove the residue
  - Even in the presence of mechanical energy
  - Remove partials levels of the flux residue
    - White residue
    - Expose activators and metallic salts



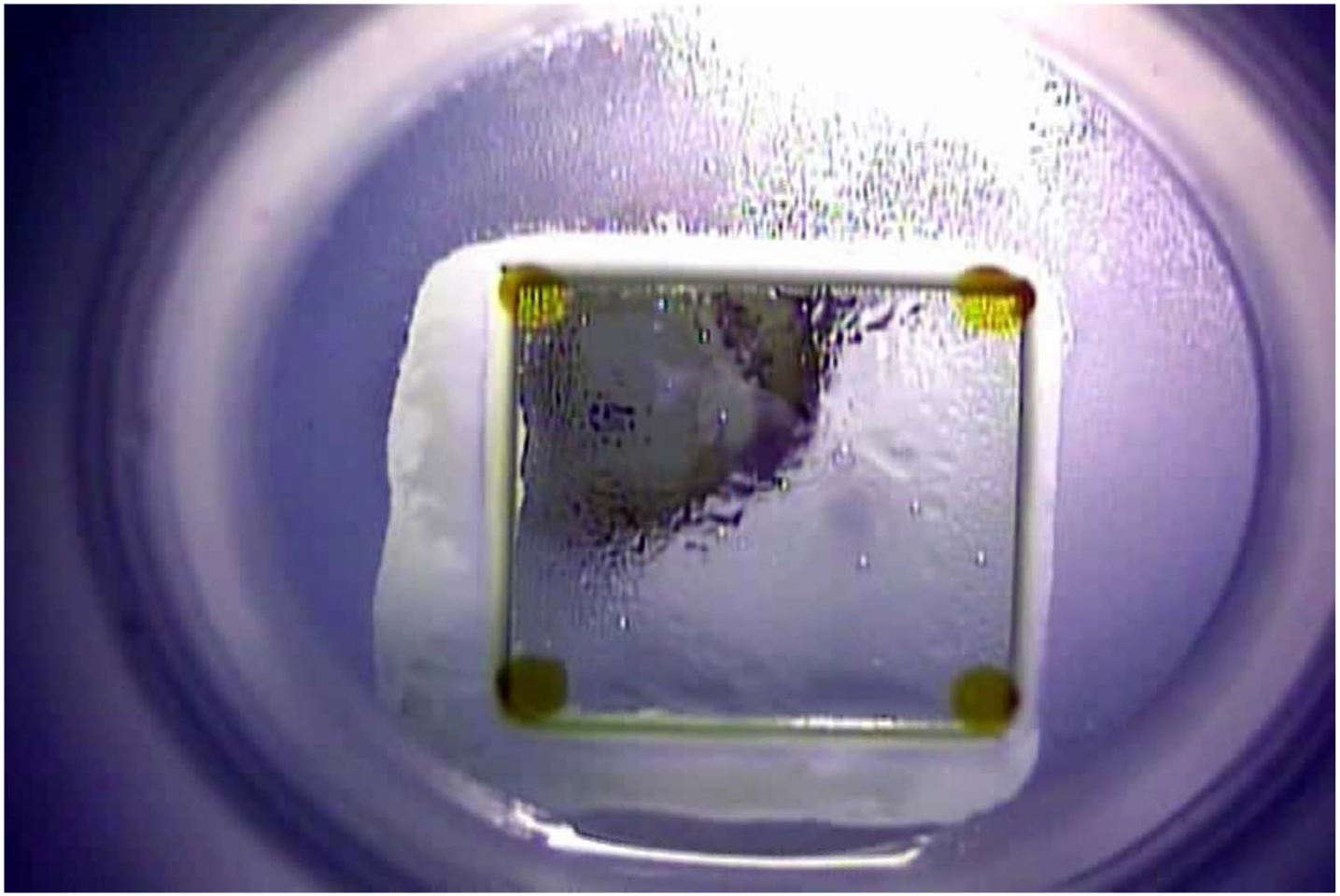
Factors Affecting Cleaning



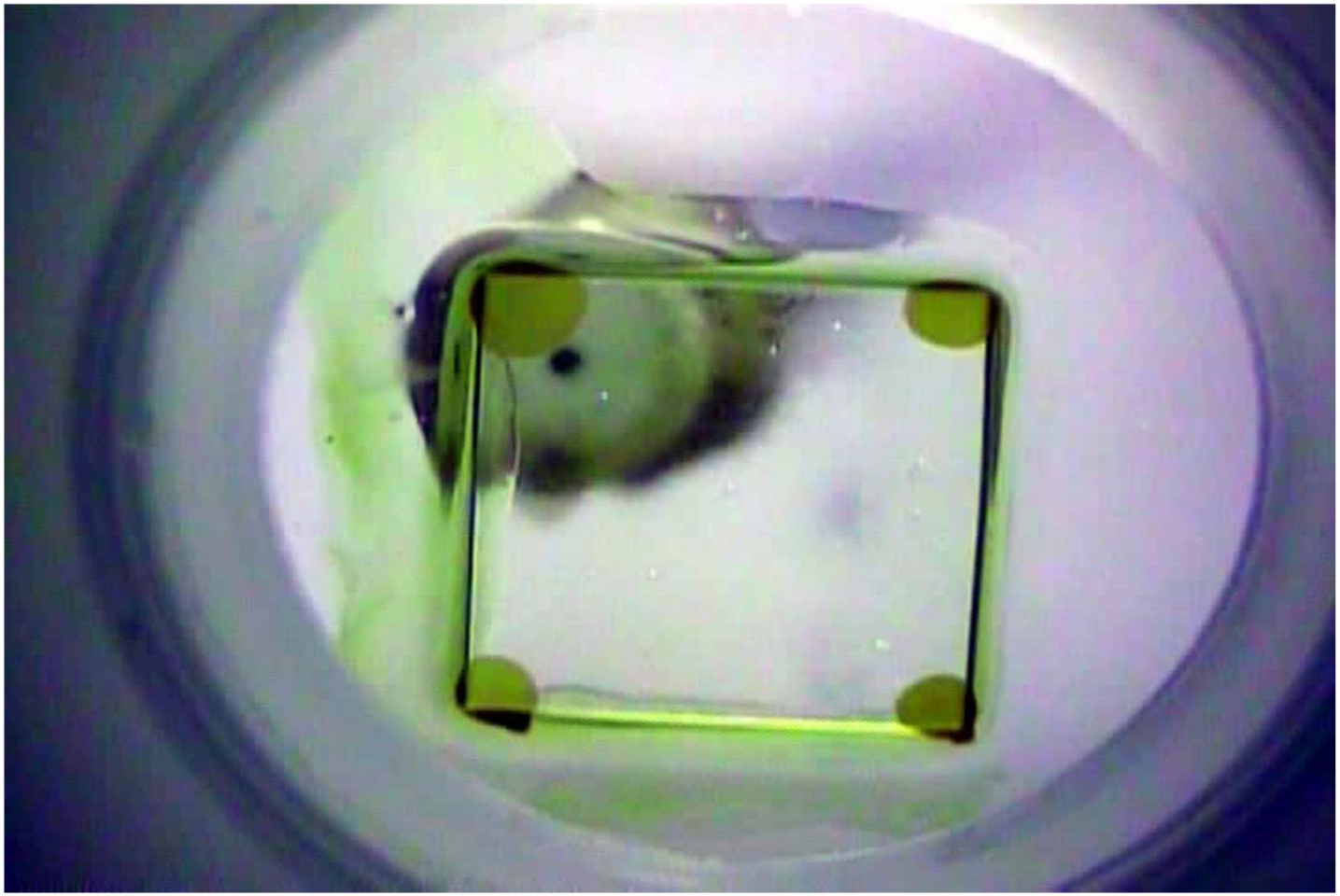
Low Pressure



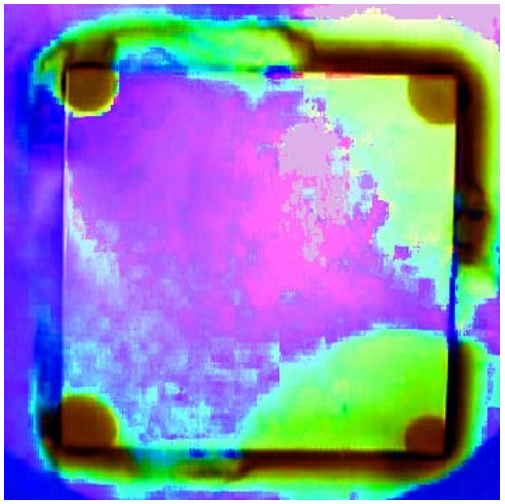
Soft Residue

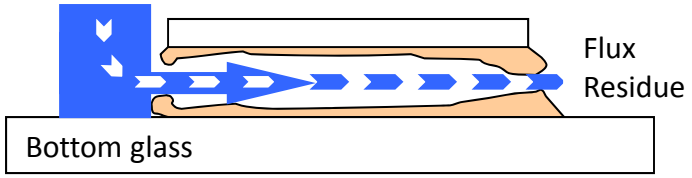


Hard Residue



Observed Cleaning Propagation





- Cleaning Channels develop in "solvent rich" out gassing channels

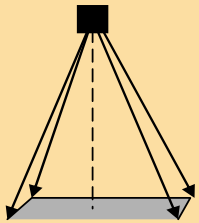
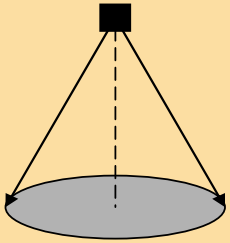
Fluid Delivery

- Flow Rate
  - Direct effect on droplet size
  - Increased flow rate increases droplet rate
- Pressure
  - Has an inverse effect on droplet size
  - An increase in pressure will reduce droplet size
- Spray Angle
  - Has an inverse effect on droplet size
  - An increase in spray angle reduces droplet size

Spray System Nozzle Design

- Four variables determine Impact pressure
  - Nozzle type
  - Distance
  - Manifold pressure
  - Fluid Density

Source: Stach & Bixenman (2005). SMTAI.

Spray Type	Typical pressure @ 2",50psi man. /Pressure loss/in	Indicated use
Fan/Delta 	2 psi / ~50% drop/inch	Wide coverage, overlap for high impingement or close work distance
Conical 	0.4 psi / ~75% drop/inch	Widest coverage area, lowest kinetic energy, flooding applications
Coherent 	10 psi / ~10% drop/inch	Smallest coverage, highest energy density over longest distance

Spray Nozzle Pressure Measured at Board Surface

Manifold Pressure	Flow: (gpm)	Impingement (psi) @			Coverage width (in)@	
0.075"Coherent Jet		**1"**	**2"**	**4"**	**1.5"**	**4.0"**
30 psig	0.69	15	10	6.5	0.6	0.7
40 psig	0.82	17	12	8	0.6	0.7
50 psig	0.89	19	13	9.5	0.6	0.8
60 psig	0.97	20	15	11	0.6	0.8
F40-1.0 Fan Nozzle						
30 psig	0.89	3.2	1.6	0.2	1.5	3.25
40 psig	1.06	4.4	1.8	0.3	1.7	3.60
50 psig	1.20	6.0	2.3	0.5	1.7	4.0
60 psig	1.30	7.2	2.5	0.5	1.8	4.0

Source: Stach & Bixenman (2005). SMTAI.

F40-1.0 Fan Nozzle

60 PSI

100 PSI

0.75 Coherent Jet

60 PSI

100 PSI

KYZEN

CONCLUSIONS

Cleaning BGAs

- Pose new challenges
- Requires
  - Tighter process controls
  - More rigorous attention to process design
  - Developing process control windows
  - Implement the process using proper test methods

Inadequate Cleaning Practices

- Can cause severe failures
  - Products that fail in the field
- Lead-free soldering is
  - More challenging to clean
  - Fluxes are more difficult to remove
    - Higher molecular weight
    - Polymers
    - Increased temperature
    - Miniaturization
- Plan for these changes during process design

Circuit Board Design

- Plays an important role for cleaning
- Key considerations
  - Density of components
  - Component layout
  - Thermal heat requirements
- From a cleanability perspective
  - Bottom termination component selection
  - Solder mask definition
  - Placement and layout influence the clearance gaps
  - Higher standoff gaps improve cleaning and reduce time

Contact Information

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Thank You!