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TECH 2 TECH Technical Article

Does Water Do the Job On Its Own?

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INTRODUCTION:

Water-soluble fluxes are widely used for modern advanced packaging devices. While electronic components keep moving toward to fine-pitch and miniaturization, an observation shows that some electronic assemblies have also started to adopt water-soluble fluxes for soldering processes because modern electronic devices create more problems while using conventional No-Clean fluxes. As water-soluble fluxes are designed to be cleaned by DI-water, IC packaging houses and electronic assemblers tend to clean water-soluble flux residues by DI-water only and reduce cost of cleaning agent.

However, numerous cleaning and electrical defects have been reported on those devices that cleaned by DI-water only in the field. Studies have revealed that certain amount of flux residues were commonly observed under flip chip dies or Bottom Termination Components. To achieve DI-water only cleaning process, there are many factors need to be considered and evaluated before implementing DI-water cleaning process. The purpose of this technical paper is to demonstrate the key barriers of cleaning modern electronic devices by DI-water including (1) product miniaturization, (2) soldering reflow temperature, (3) variety of water-soluble flux formula.

KEY WORDS:

Advanced Packaging, Electronic Assembly, Miniaturization, Standoff Gap Height, Surface Tension, Heat Exposure

PRODUCT MINIATURIZATION:

The market demand has driven most of electronic devices to be miniaturized with more functionalities. Product designers must advance product designs with more compact circuits to achieve market needs, particularly smart phones, smart watches and others handheld devices. By looking at newly semiconductors and electronic assembly technologies, chip designers create more functionalities and efficiency on chips by utilizing 7nm to 5nm wafer foundry technologies to create more I/Os. Downstream product assemblers adopt advanced technologies such as TSV 3D ICs, Cu pillar flip chip, SiP, PoP to packaging components and HDI with many leadless components to assembly circuit boards. All these advanced technologies have features of smaller bump size, fine-pitch and low standoff gap height (distance from the board surface to the bottom gap of the component) (Figure 1). With these features, water-soluble flux residue normally gets trapped under bottom termination components and bridges conductors (Figure 2) after the soldering process in which it creates high risk product reliability.

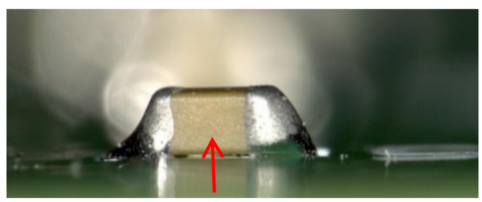

Figure 1: Standoff gap height between board and component

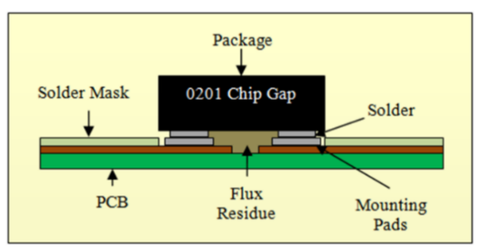

Figure 2: Flux Residue Bridges Conductors

Comparing with no-clean flux, water-soluble flux is easier to clean but contains high levels of ionic content left behind after the soldering process. Without the ideal post cleaning process to remove those corrosive ions completely, ionic residues will corrode metallization and create electrochemical migration which leads to electrical leakage or electrical shorts in the near future and result in product reliability failure. To remove water-soluble flux residues under those flip chip dies or bottom termination components, cleaning fluid needs to penetrate very low standoff gap height between components and substrates so that cleaning fluid can create flow channels to remove flux residues.

While standoff gap height has been commonly narrowing down to 1-2 mils (25um-50um) or even smaller on modern components including Cu flip chip packaging, QFNs, and chip resistors, it requires higher mechanical energy to deliver cleaning fluid into those tiny gaps and longer wash time to achieve ideal cleanliness. Besides these two cleaning parameters, one of the key factors is that cleaning fluid also needs to have low surface tension which generates better wetting performance that allows cleaning fluid to get into gaps easily. The surface tension of DI-water is 72 dynes/cm and forms large droplet itself (Figure 3). A previous study has also shown that DI-water alone has difficulty to get into gaps that less than 2 mils in common cleaning recipe. A PCB assembler has claimed that they could not achieve ideal cleanliness by DI-water only even though they maximized the process window for mechanical energy and wash time that accepted their operation. As for this case, a side-by-side cleaning trial was performed to compare with the cleanliness between cleaned by DI-water only and cleaned by aqueous cleaning agent. The detail cleaning parameters and result is shown as follows:

Figure 3: DI water (on the right) forms large droplet

CLEANING COMPARISON BETWEEN DI-WATER AND KYZEN CLEANING AGENT:

DI-Water Cleaning

Cleaning Agent	Wash Temp	Belt Speed
DI Water	145°F/62.8°C	2ft/min

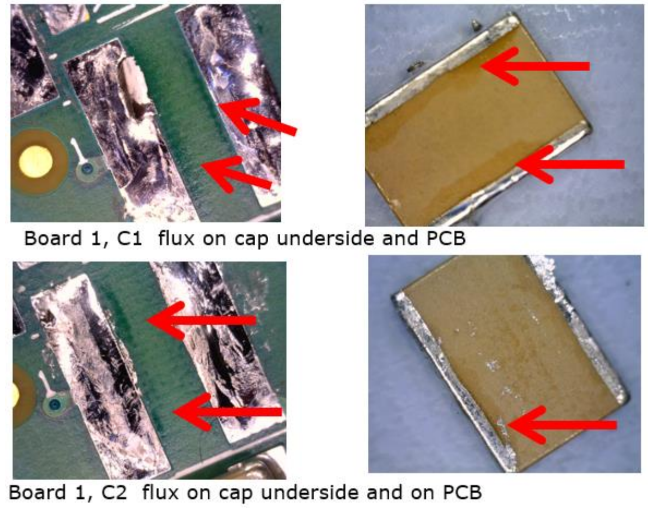

Figure 4: Test board 1 cleaned by DI-Water

KYZEN Chemistry Cleaning

Cleaning Agent	Wash Temp	Belt Speed
A-xxxx@3%	140°F/60°C	2ft/min

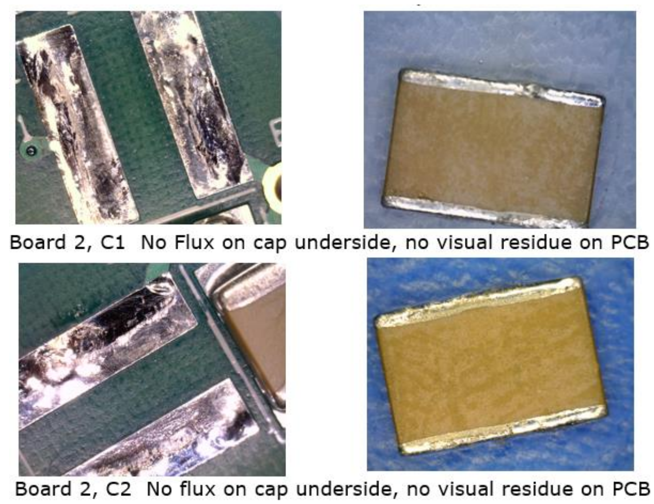

Figure 5: Test board 2 cleaned by KYZEN Cleaning Agent

The cleaning trial was followed by an existing cleaning recipe. The trial result has clearly shown that there was flux residue left behind on the bottom side of the chip capacitor and PCB after cleaned by DI-water. No flux residue was observed on test board 2 that was cleaned by KYZEN aqueous cleaning agent under microscope inspection. The data findings also show that with 3% cleaning agent, it can not only improve the cleanliness but lower the cleaning temperature, saving some operation cost. Ideal cleaning parameters could be further achieved and verified by future evaluation and optimization.

SOLDERING REFLOW TEMPERATURE:

Modern electronic devices commonly use No-Clean and water-soluble (organic acid or OA) fluxes for soldering process. As most of the applications move towards to miniaturization, No-Clean flux residues become more problematic and bring higher risk to product reliability because weak organic acids are difficult to completely activate. No-Clean flux residue is also harder to remove than water-soluble flux residue, especially under small standoff gap, and may create electrochemical migration as well. Thus, water-soluble fluxes now become the mainstream materials for soldering process on those miniaturization devices in terms of the consideration of cleaning requirement.

Lead-free process has driven many changes to the electronic manufacturing process including soldering materials. The elevated soldering temperature and changing flux compositions often cause hard to clean flux residues. Excess heat or overheating during the soldering process can result in flux polymerization, char, or even burnt out (Figure 6, 7). What happens next is that the properties of flux residues can be changed and unmatched to cleaning agents. For example, when water-soluble flux is polymerized due to excess heat, DI-water is not able to remove non-ionic polymer materials and result in partial cleaning which normally cause negative side effects called residue. Another common case is that when water-soluble fluxes get burnt out, those residues can never be removed, even using cleaning agents.

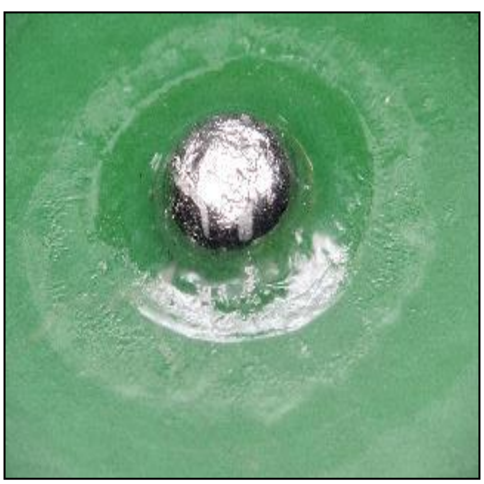

Figure 6: Polymerized Flux

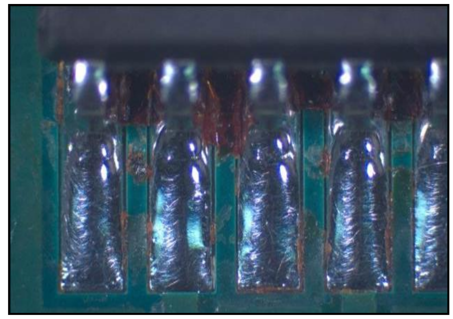

Figure 7: Burnt Flux Residue

Some advanced packaging and electronic assemblies may require multiple reflow processes and users tend to clean flux residues after all soldering process is done to save time and cleaning cost. In this way, some of the flux residues may get much harder than the others on the same product. With this approach, users may encounter poor cleanliness on certain areas when using DI-water since the flux residue properties changed during the second reflow process and not well matched to DI-water. To implement DI-water only cleaning process, proper control of upstream soldering temperature is the important key to open cleaning process window to achieve ideal cleanliness. However, when users see the difficulties to optimize heat exposure during upstream process, the best approach to overcome the barriers and improve cleanliness will be applying a cleaning agent into the cleaning process.

WATER-SOLUBLE FLUX VARIETY:

Water-soluble flux typically contains (1) Resin, (2) Activator, (3) Solvent, and (4) Rheology modifiers. Water-soluble flux residues always leave high levels of ionic materials behind with high potential of dendrite growth, so they are always required to remove completely after the soldering process. By its formula, water-soluble flux is designed to be cleaned by DI-water only. However, flux suppliers have continued modifying the water-soluble flux formula in order to meet application requirements, particularly for miniaturization, since the distance between soldering pads and pitch keeps decreasing.

With the features of miniaturization and lead-free process, flux suppliers need to formula more polar functional materials, higher oxygen barriers and higher level of WOA (weak organic acid) to increase water-soluble capacity of wetting and oxidation removal. Due to the distance of soldering pads reduces, solder paste after printing or dispensing process needs to sit on pads with proper thixotropy index to avoid soldering bridging issues. Thus, higher molecular weight vehicle and non-ionic materials are added to prevent solder paste slump issues. All these changes cause the water-soluble flux residue properties to be created unequally since each supplier has different materials selection that will surely impact post cleaning process. Figure 8 and 9 show the different cleaning capabilities by DI-water between two water-soluble fluxes. Both water-soluble flux residues were cleaned under spray nozzles for 30 seconds by DI-water. Figure 10 and 11 show the improved cleaning rate by applying KYZEN cleaning agent at 5% for 30 seconds between the two flux residues. The comparison result indicates that water-soluble fluxes in the market are not equal and may bring different challenges during cleaning processes. DI-water is a good cleaner for ionic residue. However, it may not be sufficient to meet today's manufacturing requirements since water-soluble flux may also contain some of non-ionic materials together because of the requirements mentioned earlier.

Figure 8: WS A by DIW

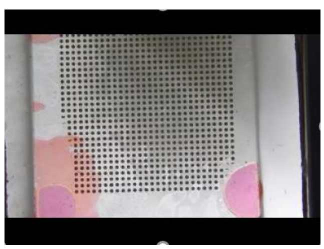

Figure 9: WS B by DIW

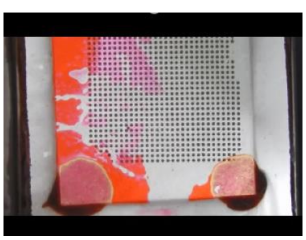

Figure 10: WS A by KYZEN CA@5%

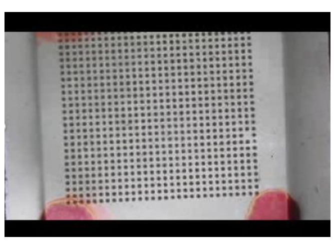

Figure 11: WS B by KYZEN CA@5%

CONCLUSION:

All solder paste flux compositions are not created equally. A specific cleaning solution may fit on one manufacturing but may not fit the others. The combination of water-soluble flux vs DI-water cleaning may not always work out in the field due to overall limitation of product manufacturing. Low levels of ionic residue can lead to product reliability failure soon because of the features of miniaturization. To design an ideal cleaning process, there are many considerations and factors to review. One of the key factors of ideal cleaning process designs is to match the cleaning agent to soil. This includes affinities and kinetic surface energies for the soil. The soil must be miscible in order to dissolve in the cleaning agent. When users see the challenges to optimize upstream process for DI-water cleaning, the best approach is to adopt cleaning agents that improve cleanliness and cleaning efficiency.

- Component selection
- Solder mask definition
- PCB circuit trace width
- Bump size, Bump pitch
- Standoff gap height
- Solder Paste/flux Selection
- Package Placement
- Solder Paste Reflow (Heat Exposure)
- Cleaning Agent
- Cleaning Machine Impingement Energy
- Wash Time
- Wash Temperature

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