Electronics Manufacture-Common processes-To clean, or not to clean

The root of the dilemma

Rosin flux residues were generally perceived, especially by military users, as requiring cleaning, especially with activated fluxes. Using solvents for this caused problems since:

- organic solvents present fire hazards
- chlorinated solvents can be too aggressive
- both can be health hazards and have low threshold limit values (TLVs).

Fluorocarbon solvents, based on trichloro-trifluoroethane (CFC-113), were developed during the 1960s. Often known by the trade-names 'Freon' (DuPont) and 'Arklone' (ICI) they are inherently non-toxic and non-flammable, and can be mixed with other solvents to provide a range of cleaning properties. As a result, they rapidly became the preferred means of cleaning, despite the higher material cost.

However, during the 1980s, it was discovered that 'holes' were appearing in the ozone layer high in the earth's atmosphere, with potentially disastrous consequences for the environment. A number of materials were discovered to have been contributing to this and, as a result, a world-wide agreement to the 1987 Montreal Protocol put quickly-reducing limits on their production and set early targets for phasing them out totally.

The list of these materials included more than just the CFCs (chlorofluorocarbons) of common parlance, widely used as refrigerants, aerosol propellants and plastic 'foamers'. The electronics industry was deprived of two major solvents, CFC-113 and one of the more effective chlorinated solvents, trichloroethane (often known by its ICI trade-name, 'Genklene').

Alternatives to CFCs

The search for direct 'drop-in' replacements1 for CFC-113 was intense, and effective substitutes have proved elusive. In the late 1990s, chlorobromomethane and n-propyl bromide were suggested as alternatives. Although their performance appeared promising, concerns about their environmental impact have prevented any uptake. There will be more about these topics in the environmental section of Design for eXcellence.

1 http://www.protonique.com/ is a useful site for those interested in exploring cleaning issues.

There have been three main alternative cleaning approaches to deal with the withdrawal of CFCs.

Use a volatile organic solvent in a process similar to CFC vapour cleaning, using either non-flammable HCFC solvents or flammable solvents with a lower global warming potential (Figure 1).

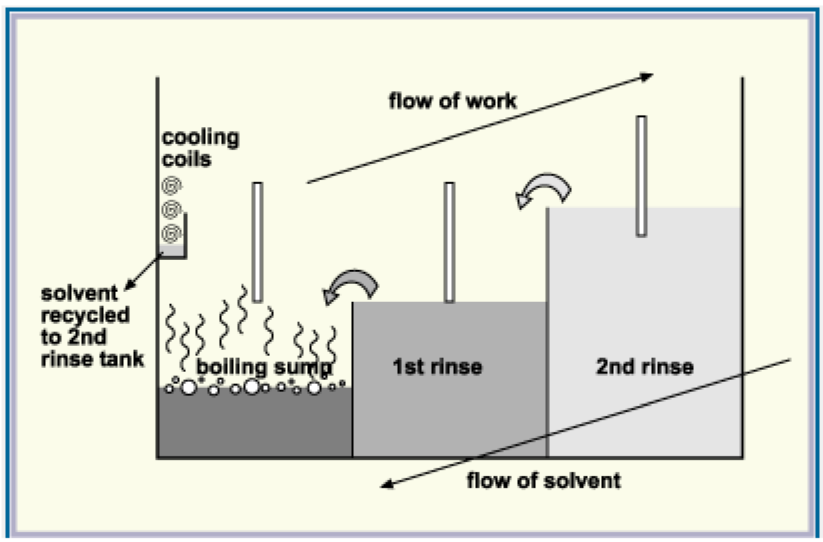

Figure 1: Schematic of a three-tank reflux cleaner as used for solvent cleaning processes

Use an organic solvent with a high boiling point, either evaporating the solvent at elevated temperature or choosing a water-miscible material which can be rinsed with water and dried once the solvent has completed its task of removing the ‘soil’ – this is referred to as a ‘semi-aqueous’ process (Figure 2).

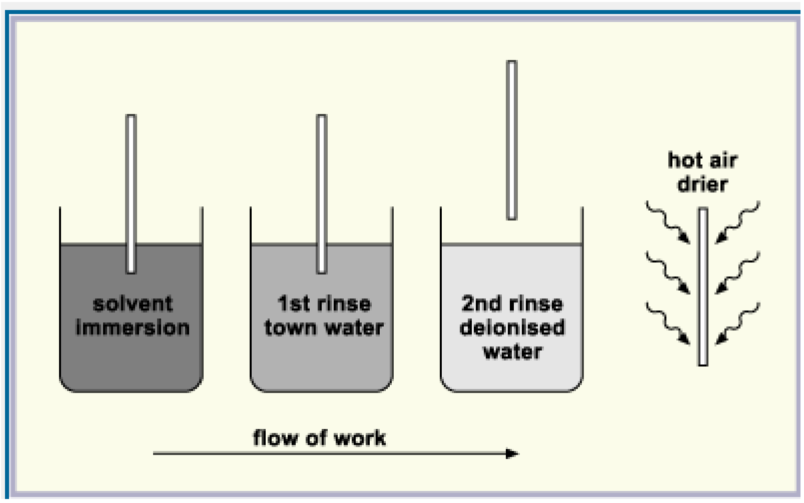

Figure 2: Schematic of a typical semi-aqueous cleaning process

Use water as a solvent, either in combination with detergent to remove rosin flux residues or in conjunction with water soluble fluxes. Some components are not compatible with water or are difficult to clean because of fluid entrapment in small crevices. Water-soluble fluxes are more active than rosin fluxes, providing a larger process window, but even traces need to be removed because they are acid.

There is a fair degree of overlap between these last two categories. What they have in common is:

- the need for expensive in-line plant for volume use
- a requirement either for a closed-loop water system or the monitoring and treatment of effluent.

A somewhat unexpected problem with a number of the processes, especially those based on water/saponifier combinations, is that the lead from solder will actually dissolve in the solvent, whereas this was not a problem with CFCs. This highlights the need to consider every aspect of the process when evaluating a proposed change!

Although the diagram appears in a number of places, the information in Figure 3 came from a study commissioned by Nortel. It shows the comparative difficulties and costs of a number of cleaning options. Such analyses normally show that the 'no-clean' option is the most attractive, provided that the finished boards meet all their functional requirements.

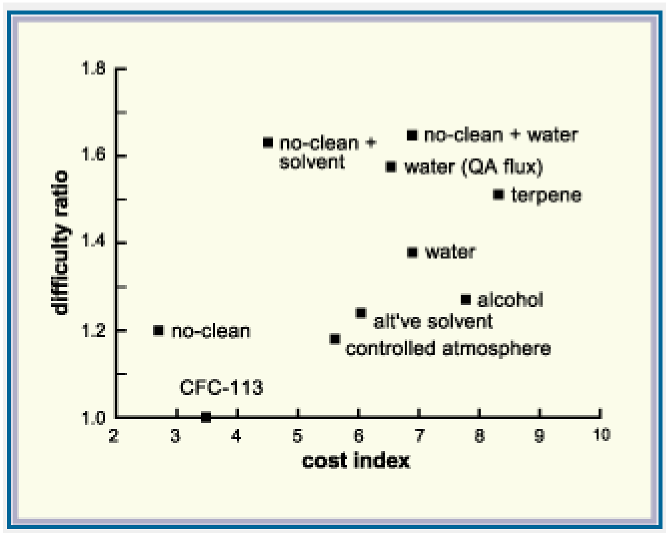

Figure 3: Difficulty:cost ratio for different cleaning methods

No-clean processes

The aim with ‘no-clean’ is to be able to use less flux, and make the residues less potentially harmful to the reliability of the assembly, as a way of making it unnecessary to clean the circuit after soldering. The term does not mean that there is nothing left on the board! There will still be flux residues, and they may or may not be deleterious to the long term reliability of the end product. A no-clean process involves selecting flux materials which will be effective in use but whose residues are:

- electrically insulating
- ‘pin testable’ (in other words, the pins on test fixtures are easily able to penetrate the coating on test lands and solderable areas)
- chemically inert, and will not react with any of the materials on the assembly during extended life (which may include elevated temperature and humidity)
- cosmetically acceptable; this is particularly important where a non-technical end-user gets sight of a board which is less than critically clean. Would you want to eat with dirty cutlery, even if the deposits were shown to be sterile?!

Each of these will have different priorities for different users. For many, the overriding need is for a robust process with low defect rates: in such cases, relatively high rosin-content products are still used, typically with 8–15% rosin content, but even for this market the trend is to reduced rosin, due at least in part to the reduced equipment maintenance and cleaning required.

The current major issues are associated with pin testability and cosmetic acceptability. Upcoming process improvements relate to eliminating solder balling and maximising the process window: all no-clean processes require tight process control, so that solderability is achieved and the joint satisfactorily wetted, before the protective qualities of the flux are dissipated.

No-clean fluxes

No-clean systems have been formulated for both wave soldering and reflow soldering. The basis for both is a flux which has a higher proportion of either solvent (for wave soldering) or rheology modifiers (for reflow soldering) and a lower concentration of both flux base and activator.

The route to reducing the residue level for a rosin flux is progressively to eliminate the rosin content while maintaining the activator level. However, this can 'only go so far' without fundamental flux redesign, because the rosin is an important and effective part of the formulation. These considerations put a number of constraints on the design of low residue fluxes, in particular on the type of activator.

Both flux base and activators have to be chosen so that:

- activators and reaction products are soluble in resin
- reaction products do not hydrolyse
- reaction products and activators are electrically non-conductive
- their decomposition products are not harmful.

It is generally accepted that halide should be eliminated from low-residue liquid fluxes, although this affects performance. There is also some evidence that solvents can be absorbed into the surface of a PCB and the result can be a reduction in SIR, while careful choice of solvents can enhance performance.

No-residue fluxes

'Low solids fluxes', with extremely low solids content can be used to prepare track surfaces by removing oxides and be 'spent' in the process. These are made by substituting synthetic resin for natural rosin by a careful selection of materials:

- that will decompose during the soldering process to yield extra activators which are dissipated and leave virtually no residues
- that include high boiling solvents which stay around long enough to influence the wetting behaviour, in the same way that rosin does.

However, if the flux becomes totally exhausted, or flows away during soldering, re-oxidation may take place, changing the wetting conditions. Trying to maintain flux viability throughout the process, yet have nothing at all left at the end of it, is like planning to have just enough fuel in your car that the engine will cut out as you arrive at the next petrol pump! In addition, small amounts of residues will always exist, although these amounts can be low enough for assemblies to meet specifications which call for low residuals, even without cleaning. Most significantly, there is generally a reduction in the ease with which the process may be set up and operated, and the available process window is very small.

Inert atmosphere soldering

We may need to use inert solder processes to be compatible with no-clean fluxes and, regardless of flux type, soldering in an inert atmosphere has been reported to give benefits, which include:

- improved soldering performance of complex or marginal joints leading to higher first pass yields and the ability to assemble more complex soldering designs, including double-sided surface mount
- the ability to solder to bare copper or tin-lead coatings
- preventing oxides from reforming once they have been removed by flux, which ensures a higher level of joint solderability, and considerably fewer defects
- in wave soldering, considerable reduction in maintenance due to reduced dross formation.
- Other advantages claimed by some users are improved plated through-hole wetting, a general reduction in shadowing, and the reduced possibility of solder balling. This last issue is particularly important because unremoved solder balls could create short circuits.

The key to inert atmosphere soldering is really the ability to solder in the absence of oxygen. Heating solder with any oxygen present will produce surface oxides, which are generally non-solderable. In the past, fluxes were aggressive enough to remove oxides during the wave or reflow process: for some time, manufacturers have been moving towards no-clean fluxes, which are very weak, and do not have an aggressive oxide cleaning action. No-clean soldering in particular requires that all the components and boards should be highly solderable and the soldering process must not add any significant oxidation, particularly in the case of solder reflow, where the assembly is at a high temperature for extended periods.

Oxidation is a function of the metals involved, their temperatures and exposed surface area, and the amount of oxygen present. With the finer particles used in pastes for fine-pitch devices, the surface area of the particles in a given volume of paste increases. With more available surface area, there is a greater tendency towards oxidation, and the only controllable variable is the amount of oxygen present.

Some conclusions for EDR

To a large extent the choice of flux will be determined by the preferences of the end user, supported by the technology range offered by the assembly house:

No-clean processes, fluxes and pastes will most likely be chosen for all applications, except those which demand flux removal for cosmetic purposes or to enhance the adhesion of subsequent conformal coats

A decision on whether to clean may also be affected by whether or not the components would withstand cleaning.

Most assembly houses would prefer a complete free hand in the selection of materials. This allows economies of scale and cuts changeover times, as well as giving them the best chance of high yields. There will usually be some debate (and the consequent cost) if an end user insists on a non-preferred flux and cleaning regime.

As more and more companies are becoming environmentally aware, other environmental stakeholders may be involved in the eventual decision. There will be more information about this in Design for eXcellence.

Whilst no-clean materials present no particular design challenges, you need to be vigilant in case cleaning is specified. If it is, then the components must withstand the cleaning regime. If aqueous cleaning systems are chosen, then your component positioning should seek to minimise water entrapment, so that the board may be cleaned effectively. This is almost certainly an area where an understanding of the exact processes used would help.

The choice of flux may also influence the board finish, because some finishes are more solderable than others – HASL is predictably solderable, even if quite old, whereas ENIG may present more of a challenge if the process is less carefully controlled. Some of the Organic Solderability Preservatives we shall be considering in Board finishes require specific precautions, and possibly a more active flux.

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Source: http://www.ami.ac.uk/courses/topics/0249_conc/index.html