Options in Flip-Chip Cleaning

By Gary Caplinger, Product Engineer
Speedline ACCEL

It is no secret that the push in electronics towards greater connection density is a primary driving force in circuit package design today. While die sizes shrink, functionality continues to grow, and this creates major I/O challenges. For example, the tiny solder bumps used today for flip chip interconnections have typical pitch dimensions of only 250 microns, and standoff distances in the range of 50 to 100 microns.

Fortunately, flip-chip packaging can deliver substantial I/O resources – providing for potentially thousands of connections rather than only dozens available with perimeter lead designs. But the resulting close dimensions introduce a whole new realm of cleaning challenges. Nevertheless, assembled flip-chips must be absolutely free of contamination in order to meet performance and dependability standards.

As with other soldered packages, high-temperature reflow of flip chips can create charred and caramelized flux residues that are difficult to remove. In addition, any residual solvent, water, or other manufacturing byproducts left after flip chip cleaning will lead to ionic contamination and corrosion, and interfere with underfilling to create voids that promote moisture collection, overheating and part failure.

Manufacturers have three primary alternatives for cleaning flux residues from flip chips after solder reflow. These are: inline spray, ultrasonic bath, and centrifugal cleaning. Table 1 summarizes the primary characteristics of each of these cleaning methods.

Cleaning Method	Advantages	Disadvantages
Inline Spray	A continuous, integrated manufacturing process	Minimal cleaning penetration around die; large equipment footprint
Ultrasonic	Relatively effective cleaning	May damage delicate parts, long-term reliability concerns, typically off-line batch
Centrifugal	Very effective cleaning process in a small floor space footprint, short cycle times, complete cleaning, total drying	Batch, off-line process

Table 1 - Flip chip post-reflow cleaning options.

Inline spray cleaners are long, conveyorized systems that direct cleaning solvents against parts to be cleaned using vertically-oriented spray nozzles. Devices being cleaned pass through wash, pre-rinse, rinse and drying zones on a continuous conveyor. Inline systems are good for removing flux residues and oils on exposed surfaces in a continuous production setting, but are generally not effective in penetrating the close tolerance and hidden gaps of flip chip assemblies.

Batch style **ultrasonic cleaners** place parts to be cleaned in a solvent immersion bath, where ultrasonic energy aids in flux removal by agitating surfaces and contaminants. This process is superior to inline cleaning for cleaning complex parts. However, in the case of flip chip components, ultrasonic energy may not be able to fully penetrate the gap and reach hidden contaminants. Additionally, mechanical resonance induced during ultrasonic cleaning could cause micro-fracture of delicate parts and degrade long-term reliability.

Centrifugal cleaning, another batch process, offers an important performance advantage over other flip-chip cleaning methods - the ability to direct the solvent laterally around and between die terminations, under force. For example, the ACCEL MicroCel™ centrifugal cleaning system holds flip chips in fixtures so that component edges can be impinged directly by solvent. A robot arm assembly containing fixtured flip chips is lowered into a cleaning solvent bath in a sealed process chamber, and rotated alternately in clockwise and counter-clockwise directions at 100 to 200 rpm, causing the solvent to flow between and around interconnections.

Photo 1 – The Speedline ACCEL MicroCel ™ centrifugal cleaning system uses fixtures for flip chips that are mounted on a robot arm and rotated in the cleaning chamber.

This cleaning process combines soaking in an alcohol or terpene solvent, with agitation and solvent flow resulting from the centrifugal force of rotation. Because the chamber is sealed, the solvent temperature can be safely raised to a level near the flash point, and this reduces surface tension and lowers viscosity values to increase solvent action.

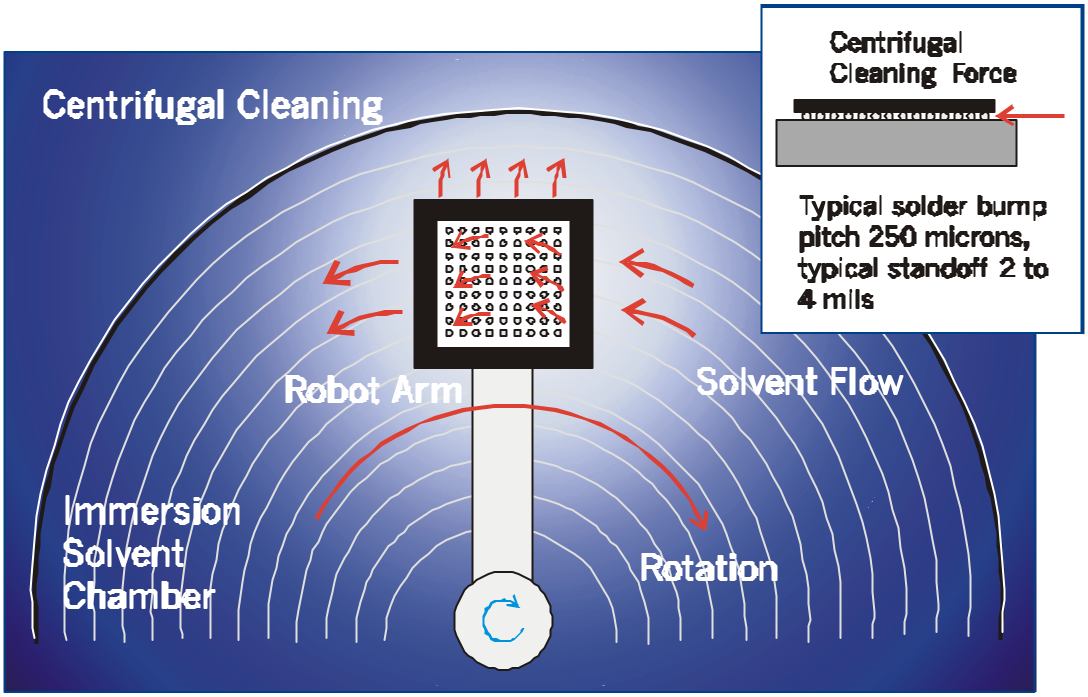

Figure 1 - Movement of fixtured flip chip assemblies through the solvent bath creates positive flow of solvent between interconnections. Full coverage is assured by alternating the direction of rotation during a cleaning cycle. Multiple flip chip components are mounted to the centrifugal system robot arm.

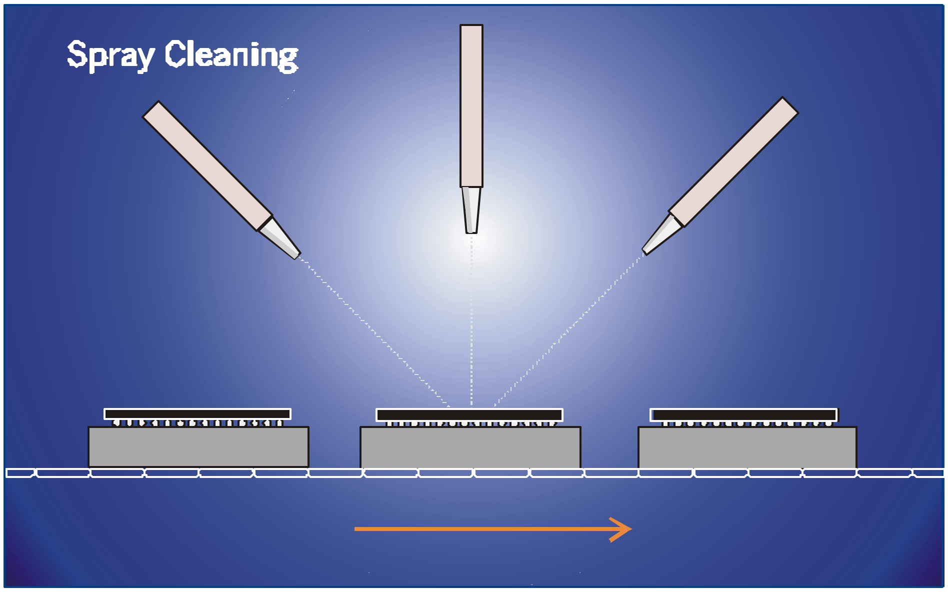

Figure 2 - A spray cleaning system is effective for conventional circuit assemblies, but may not be capable of removing flux residues and contaminants from flip chips.

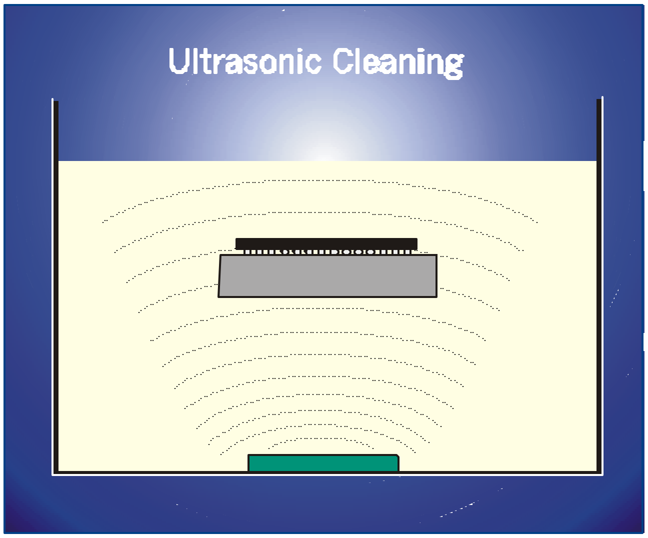

Figure 3 - The energy created by an ultrasonic cleaning system displaces surface contaminants effectively, but does not penetrate the hidden recesses that characterize flip chip devices.

After the solvent washing step, cleaning solution is drained from the sealed chamber, and a DI water rinse spray is introduced as the spin rate of the robot arm is increased to 300-500 rpm. Spray orientation is lateral so that the rinse water impinges on the edge of packages and flows between interconnects. This spray rinse step is carried out in an empty chamber so that cleaned parts are not re-contaminated with residue from the rinse water. When rinsing is complete, parts are dried by further centrifugal rotation in the presence of heated air or N_2.

Products cleaned in a centrifugal cleaner such as the ACCEL unit can be held in place and secured to the rotating robot arm head using universal adjustable fixtures, standard fixtures, or custom fixtures that are specific to a product. Fixtures are available for small circuit modules, wafers, singulated packages, Auer® boats, magazines, cassettes and JEDEC trays.

This centrifugal cleaning system incorporates an automatic, closed-loop and fully integrated waste-water treatment system. When using a solvent that can be separated from water, this system automatically extracts it from the rinse water and returns the solvent to the wash reservoir for reuse. Used rinse water is processed through a four-stage purification process that includes microbial control, filtration to 5 microns, carbon adsorption and mixed-bed deionizing to restore the water to its original level of purity. No drain or external water treatment is required, and the entire process takes place in the compact cleaning system housing.

Centrifugal cleaning parameters operation may require adjustment for optimum performance depending on part complexity, the solvent in use, and the nature of contaminants to be removed. These variables include centrifugal rotation speed, the radius of the rotating element, dwell times of the wash, rinse and dry cycles, and solvent temperature.

While centrifugal cleaning is a batch process, this method can keep pace with a conventional manufacturing line. For example, the ACCEL centrifugal cleaning system can process as many as 288 devices per cleaning/rinsing/drying cycle, which consumes approximately 15 minutes. This centrifugal system is compatible with semi-aqueous, aqueous, alcohol and traditional cleaning solvents.

A closed centrifugal cleaning process provides good odor containment because cleaning, rinsing and drying steps all take place in a sealed process chamber. With centrifugal cleaning, there is no aerosol phase as with a spray system, no solvent drag-out, and no objectionable odors because solvent is never exposed to the atmosphere.

Centrifugal cleaning produces results that meet or exceed those of other cleaning technologies for devices such as flip chips. For example, typical cleaning results measured with the ACCEL system include ionic contamination of 0.0 micrograms/in^2, surface insulation resistance greater than 10^{14} ohms/in.^{2}, and no visible residue at 30X magnification.

The primary solvent factors to be considered for flip chip cleaning are solvency for the flux/contaminants in question, and solvent surface tension, vapor pressure, flash point, safety/toxicity, and cost. Because of the sealed nature of centrifugal cleaning concerns related to flash point, safety/toxicity and waste disposal are minimized.

In controlled tests, it has been shown that with centrifugal cleaning, average levels of ionic contamination on cleaned flip chip parts can be reduced by one-half to one-third compared to the results achieved by the best-performing spray-type systems. These tests were conducted using a hydrocarbon cleaning compound in the centrifugal cleaning system, with processing 24 hours or less after reflow. These results were compared to spray cleaned parts that were processed within one-hour of reflow, minimizing consolidation of contaminants.

An evaluation of centrifugal cleaning by Texas Instruments illustrates the cleaning performance that can be achieved with centrifugal energy. This component manufacturer tested flux removal efficiency using square glass coupons sandwiched to glass plates, with clearances of 2, 5 and 10 mils. The test contaminant was Alpha 321 flux, dyed for visual inspection. This material was injected into the spaces between plate and coupon, then heated to a temperature that simulated reflow levels typical of flip chip manufacturing conditions.

Cleaning was performed the following day using an in-line system with DuPont HCFC 120 solvent. Results from this process are shown in the photo (Figure 1). Flux removal is apparent around the edges of all coupons, with results proportional to the clearance between glass surfaces.

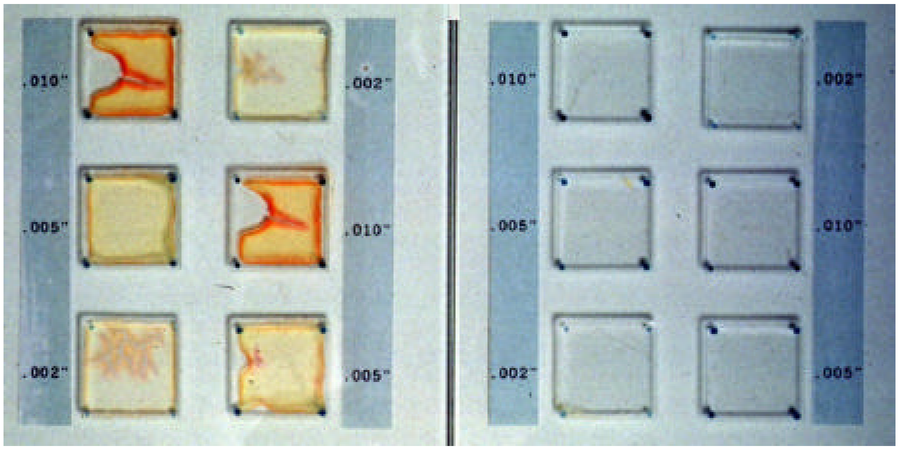

Figure 1 - Glass test plates cleaned with in-line (left) and centrifugal (right) cleaning systems.

The Inline Spray Test Plate (left hand side in the photo) illustrates the amount of flux remaining beneath closely spaced components following this traditional cleaning method, which relies on capillary force for solvent penetration. These tests made no attempt to simulate flow impediments such as the fine pitch leads and area array connections that could be expected on devices of this size.

Comparable glass plates were prepared for testing in an ACCEL MicroCel Centrifugal Cleaning System, using Alpha EC-7R semi-aqueous solvent. The samples on the right hand side of the illustration show the amount of flux remaining following this cleaning method.

These examples graphically illustrate the improved defluxing efficiency that can be accomplished using solvent penetration propelled by centrifugal force. Additionally, the centrifugal extraction of entrapped rinse water promotes rapid drying and contributes significantly to overall throughput in aqueous and semi-aqueous processes.

Flip chips present some of the most difficult cleaning challenges in electronics manufacturing. Fortunately, with an appropriate cleaning solvent and a properly designed and programmed centrifugal cleaning system, it is possible to deliver contamination-free flip-chip devices, ready for underfilling and subsequent assembly.

xxxxx