Pb-Free Components

Active Devices

Component Plating

For all practical purposes, the component industry has identified two plating systems to choose from: Palladium (Pd)-based and tin (Sn)-based (matte Sn and, to a lesser extent, Sn-Bi).

Which is more popular?

Tin, by far. Most estimates indicate that palladium-based leadframes comprise only 5 to 15% of the component market. They tend to be most popular among Japanese component manufacturers and Texas Instruments.

Why is palladium not more popular, especially considering concerns regarding whiskering of pure tin (Sn)?

From an OEM standpoint, the only issue with palladium plating, solderability, has been primarily solved though the use of a final application of gold flash and a reduction in palladium plating thickness.

However, from the view of a component manufacturer, there are two primary issues: moisture sensitivity level (MSL) and cost.

- *Moisture Sensitivity Level:* The noble nature of palladium can reduce the adhesion between the leadframe and the encapsulant. This tends to reduce the MSL. There are avenues available to the contract packager to correct for this problem, but these techniques have the potential to add cost with regard to materials and the manufacturing process.
- *Cost:* This is a more subtle issue. The component manufacturing supply chain consists of the leadframe maker and the contract component assembler. Palladium-plated leadframes, supplied by the leadframe maker, are more expensive. However, Pd-plated leadframes eliminate the post-plating process, performed by the contract component assembler. Some cost analyses have suggested that this effectively eliminates any cost differential to the end user. However, if the contract component assembler is unable to charge back for post-plating equipment, they lose money. Therefore, there is a strong financial incentive for contract component assemblers to recommend tin-plated components.

HDPUG has just released a report, authored by Samsung and Texas Instruments, that attempts to address these issues. However, the final decision is still with the component manufacturer, not the OEM, and most component manufacturers seem to have decided on tin plating for now.

What is tin whiskering? How does it occur?

For an extensive background on tin whiskering, we recommend the NASA Goddard Tin Whisker Homepage or iNEMI Tin Whisker Group.

How is the industry dealing with the potential for tin whiskering?

There are currently three broad approaches: Testing, Mitigation, and Avoidance.

Testing

Testing is currently being driven by iNEMI, who has recommended three different life tests to confirm the absence of tin whiskering, which is now available as a JEDEC standard:

- Elevated: 60°C/93% RH for at least 4000 hours
- Ambient: ~25°C/~50% RH for at least 4000 hours
- Cyclic: -55 to +85°C for at least 1500 cycles

A recent article by Intel, using an acceleration approach that has not been independently validated, claims that these test conditions exceed typical lifetime requirements for desktop (5 yr), mobile (4 yr), server (11 yr), telecom-controlled (15 yr), and networking (10 yr) applications. Through the same analysis, however, it would seem to suggest that these test conditions are insufficient for automotive (10 yr), telecom-uncontrolled (15 yr), military (20 yr), and avionics (30 yr) life requirements.

The value of these test conditions has also been called into question based on recent testing, which seems to strongly suggest that ambient environment conditions, especially the type and concentration of corrosive gases, may be a greater driver for tin whiskering than temperature or humidity.

Regardless of the test condition being used, there is still disagreement in regard to the appropriate pass/fail criteria. Certain specifications are absolute, ranging from 25 microns to 75 microns, depending upon the industry and the particular customer. Other specifications are relative, usually specifying a length no greater than 1/3 to 1/2 the lead spacing.

Mitigation

Mitigation involves reducing the propensity for tin whiskering through plating chemistry, plating processes, and post-plating operations. There are two primary mitigation techniques being performed by contract component assemblers or required by OEMs:

- *Use of a nickel underplate:* Studies by IBM and more recently confirmed by iNEMI have found a pronounced reduction in tin whisker length and density when a nickel underplate is applied between the copper leadframe and the tin plating. The thickness of the nickel underplate is very important, but there is some confusion as to the minimum thickness (even iNEMI lists two minimums of 0.5 and 1.27 microns). DfR recommends a minimum of 1.2 microns, as field failures due to tin whiskering have been traced back to nickel underplate thickness dropping below 0.8 microns. In addition, OEMs should require, at minimum, certificates of compliance (CoC), and preferably statistical process control (SPC) data, demonstrating control of this process.

- *High temperature annealing:* 150°C for 1 hour within 24 hours of plating.

Additional mitigation techniques are available to the component manufacturer, including combined (nickel underplate with anneal), thicker tin platings (greater than 10 microns), and proprietary tin plating compositions. Combined has shown excellent mitigation properties in the past, but unfortunately few, if any, contract component assembler seem to be offering this option. Thicker tin platings also seem to show promise, but are also not widely offered.

The most popular offering seems to be patented or proprietary tin plating processes or compositions. Unfortunately, these types of mitigation techniques have had much smaller exposure to qualification testing and are therefore riskier in regard to ensuring a consistent mitigation capability.

NOTE: Conformal coating is not a true mitigation technique. Research on the effectiveness has been inconsistent and primarily tends to show that tin whiskers easily grow through the soft polymer coatings. In addition, conformal coating, except for paralyene, will tend to be extremely thin over the leads due to the effect of gravity. Conformal coating can prevent breakage. This eliminates the possibility of tin whiskers rolling around the surface of the board and intermittently causing shorts across exposed conductors.

Avoidance

A number of companies, primarily in the avionics and military markets, are attempting to *avoid* the presence of tin-plated components in their products. The extent of avoidance varies. NASA and the US Air Force have banned tin-plating from their systems. Other avionic manufacturers are focusing only on surface mount leaded devices with more than 3 leads, as other component packages have a coarse pitch (>2.5 mm) sufficient enough to greatly reduce the potential for bridging due to tin whiskers.

There are currently three approaches for avoidance: Procurement, Pd-Plating, Solder Dipping.

What is procurement avoidance?

The concept of procurement avoidance is for the design team to only select components that are definitively SnPb or Pd plated. This must be performed very early in the design process, as complex circuits are literally designed around the microprocessors and DSPs that are selected. This is the most cost-effective approach and is virtually never done, which proves that functionality always trumps reliability.

Can I request palladium plating if I am very concerned about tin whiskering?

Theoretically, no. Components are considered a commodity item and the most apt analogy would be asking for coconut-flavored corn.

However, this is an area where concerned companies, such as avionics, telecommunications, medical, and other high reliability applications, have truly failed to grasp their capability to influence the electronics market. What many of these companies have failed to realize is that while they are a minute portion of the market, *it is their business that provides the profit margins*. High volume customers are usually able to receive such a significant discount, that it is the low volume customers, with their higher margin purchases, that allow many component manufacturers to survive.

Rather than cooperation among themselves and communicate to component manufacturers, OEMs in high reliability applications are instead spending tens of millions of dollars to study tin whiskering, qualify components through excessively long-term testing, or perform inherently risky solder dipping (see below).

There is no reason why components cannot be offered in both Pd-plated and Sn-plated leadframes. Communication, cooperation, and negotiation can be difficult and time-consuming. However, by failing to recognize their bargaining position, OEMs spend enormous sums of money while still incurring an unreasonable level of risk and uncertainty.

Where can I find more information on solder dipping?

Solder dipping has been around for long time. The leader in this field seems to Corfin Industries, with its Robotic Lead Finish System. However, there are some serious concerns (ESD and thermal damage) and some limitations.

Moisture sensitivity

A presentation on the influence of Pb-free on moisture sensitivity level (MSL) is available here.

Robustness to higher reflow temperatures

As of May 2005, DfR Solutions has not heard of any active components experiencing failure due to exposure to elevated Pb-free reflow temperatures. This statement excludes packaging issues (such as popcorning) and devices that already had known temperature limitations (e.g., some RF devices).

Passive Devices

Ceramic Capacitors (Thermal Shock)

The temperature changes during solder assembly can result in the creation of thermal shock cracks in ceramic capacitors. Capacitor manufacturers are aware of this and provide two sets of specifications to prevent this failure mechanism.

- *Reflow:* Maximum heating and cooling rates of 2-3°C/sec;
- *Wave:* Maintain a sufficient preheat temperature and avoid wave soldering case sizes larger than 1210 (120 mils length x 100 mils width).

Avoiding thermal shock cracks requires assemblers to follow the basic premise of these specifications. Therefore, for Pb-free solder...

- *Pb-free Reflow:* Maximum heating and cooling rates of 2-3°C/sec (some reflow profiles in industry specifications allow for a 6°C/sec cooling rate, to increase throughput);
- *Pb-free Wave:* Maintain a sufficient preheat temperature (170 to 190°C) and avoid wave soldering case sizes larger than 0805 (80 mils length x 50 mils width).

Ceramic Capacitors (Flex Cracking)

Recent work by DfR has determined that moving to Pb-free will not increase the risk of flex cracking in ceramic chip capacitors. For a full report, please contact us at askdfr@dfrsolutions.com.

Tantalum/Polymeric Capacitors

Recent work performed by the staff at DfR Solutions consisted of subjecting several types of tantalum and polymeric capacitors to two Pb-free reflows with a peak temperature of 260°C. Since both these component types have self-healing mechanisms, the strongest indication of potential reliability issues can be assessed through the performance of a step stress surge test (SSST).

Capacitor performance under SSST was statistically equivalent to capacitors subjected to more benign reflow profiles and within the expectations of the capacitor manufacturers. For more details, please contact DfR Solutions at askdfr@dfrsolutions.com.

Of greater concern is the susceptibility of these components to popcorning, especially the traditional expectation of MSL 1. For more information, click here.

Other Passive Components (aluminum liquid electrolytic capacitors, resistors, thermistors, relays, inductors, etc.)

Information on the reliability of other passive components is still being gathered and reviewed.