Combating the military's tin whisker threat: no-lead strategies for power products

BY KEITH NARDONE

Global transition to lead-free material has raised concerns regarding reliability of electronic interconnects, especially for the military and aerospace community. One of the concerns with tin-rich lead-free materials is the formation of tin whiskers. Tin whiskers are a concern because they are conductive and can, as a consequence, cause short circuits that can cause catastrophic failures. The problem, recognized many years ago, was previously minimized by adding lead, which is now identified as a hazardous substance and banned.

The banning of lead in electronic equipment is especially troublesome for the military. The requirements for long lifetimes and assured reliable performance are only the first of it. Although military electronic equipment is exempt from the law, the unfortunate reality is that fewer manufacturers will be making leaded parts. A further dangerous possibility, perhaps, is the risk that pure tin parts could find their way into even military equipment where reliability—a crucial attribute—could be compromised.

Early on, the tin-whisker problem was recognized as a threat to our military and aerospace business and drove a proactive effort to initiate the Vicor tin whisker mitigation program at power electronics manufacturer Vicor Corp. in Andover, Mass. Vicor undertook research and testing to accommodate the no-lead requirement, and engaged with key military and aerospace contractors to leverage their expertise to develop internal procedures.

This work resulted in the adoption of strategies that mitigate the impact of the tin-whisker phenomenon when tin finishes are used. The strategies are: (1) use matte tin finishes, (2) use a nickel barrier layer under non-bright tin plating, (3) ban use of immersion-tin type plating on PCBs, and (4) subject tin-plated SMT components to lead-free reflow. Vicor will, of course, comply with iNEMI and JEDEC recommendations and continue to monitor and comply with the latest proven practices.

Tin whisker mitigation strategies

Tin plating grain size has an impact on whisker growth. All Vicor products, and MIL-COTS products in particular, have a large grain size, which results in a matte tin finish and a smaller number of grain boundaries. Bright tin plating is the result of a small grain size and a greater number of grain boundaries. The greater the number of grain boundaries, the faster the diffusion rate and the faster the rate of whisker growth. Bright tin plating is not an acceptable plating scheme due to the grain-size issue.

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Post-plating treatments, including annealing processes, can also reduce or eliminate tin whisker growth. Tin plating is annealed after plating for one hour at 150 degrees Celsius to promote controlled intermetallic compound formation and reduced tin whisker formation.

Simple scanning electron microscope (SEM) images taken at 4000X, show that bright tin plating is the result of submicron grains that are virtually featureless, while the preferred matte finish grains (greater than 6 microns) are clearly visible.

Nickel/tin intermetallic compound formation produces a tensile stress and reduces the compressive stress on the tin plating. Tensile stresses are less conducive to whisker growth, while compressive stresses are more conducive. For this reason, a nickel barrier plating layer is required to mitigate tin whisker growth.

RoHS-compliant printed circuit boards (PCB) will not use a tin finish, not even immersion tin, because they are prone to whisker growth, especially with fine lines and spaces. Also, a copper/tin intermetallic forms during deposition and continues to grow, thus limiting the useful shelf life of the stored parts, which is unacceptable for military or aerospace applications.

PCBs that are currently finished with electroless nickel immersion gold (ENIG) will continue to be processed using ENIG. PCBs that were previously hot air solder leveled (HASL) SnPb will be finished with either ENIG, or HASL (tin/silver/copper Alloy) as the application demands. Organic Solderability Preservative (OSP) may be used if the application permits.

Matte tin terminations are subjected to lead-free reflow during surface-mount operations, relieving stress and further reducing the risk of whiskering.

The use of lead-free reflow processes, which act like an annealing process, helps to mitigate the growth of tin whiskers. All Vicor manufacturing processes have transitioned to RoHS compliance, meaning that all solder used on the production-floor manufacturing lines is tin/silver/copper (SnAgCu) or tin/silver (SnAg). All reflow temperatures are set at the lead-free temperature.

Finally, for military and aerospace applications, tin-whisker risk assessment algorithms developed by larger electronic equipment are available as needed or desired.

Tin whisker experience

Vicor personnel have been using components with 100 percent tin plating for more than four years without tin-whisker-related field returns. In addition, Vicor has been shipping RoHS-compliant products over a similar time frame with no field returns related to tin whiskers.

Initial tests were conducted on 100 percent matte tin during 2003, before extensive data was available. In that testing, large-grained, 100 percent matte tin plated on copper/lead frames resisted whiskering even when the plating was put in compression and in elevated and humid environments. Bright tin was unacceptable, with resultant tin whisker growth reaching 700 microns on samples stored at ambient temperature.

Our tin plating suppliers also use barrier layers. Vicor requires, where possible, a nickel barrier on all tin-plated components. A minimum of 2 microns is required based on iNEMI and plating supplier recommendations. Vicor has conducted extensive thermal cycling (-55 to 125 C) for 1000 cycles, THB testing, high temperature storage (125 C, 150 C, 175 C) for 1000 hours, and autoclave testing, and hasn't found any failures related to tin whiskering. Even exposed J-leads and J-lead connections to V-I Chip components have not shown any failures due to tin whiskers. V-I Chip components have been reflowed at higher reflow temperatures at 245 C and have not shown any tin whiskering.

Conformal coatings or epoxies have been suggested as a way to reduce whisker risks. Vicor already uses a type of thick conformal coating spin fill in its brick products as part of its thermal-management strategy. This silicone-based polymer is 90 to 92 percent filled with ceramic particles adding additional resistance to whisker growth. This fill material encapsulates all components, wets leads, and fills the space between package leads, components, and traces.

V-I Chips are underfilled and molded as a mitigation strategy against tin whiskers. Underfill material encapsulates all components, wets leads, and fills the space between package leads, components, and traces. This is a standard process technology for V-I Chip. Overmolding encapsulates any exposed surfaces on the internal components, further reducing the possibility for tin whiskers.

Exposed areas include J-lead terminations and the J-lead termination attachment to the V-I Chip. J-lead terminations are coated with nickel-palladium-gold (Ni-Pd-Au), which is tin whisker-resistant plating. J-leads are attached to the V-I Chip with solder balls composed of tin-silver-copper (Sn-Ag-Cu) alloy, which is resistant to tin whiskering. Further mitigation is achieved as these solder balls undergo several reflows and thermal exposures which relieve the stress and mitigate whisker formation.

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