Get SMART: Tin Whiskers Eliminated!

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Earlier I promised to bring you details of current trends of the various discussion groups in the industry. I had no idea at the time that one of the greatest breakthroughs in electronics manufacturing technology since the European introduction of RoHS would come from people on my own tin whisker mail forum that are actively involved in the research and "search for a cure" in the area of tin whiskers would be the major focus of my next article.

Since before the introduction of RoHS in 2006, the industry has been searching for answers on preventing tin whisker formation on electronics assemblies. There seemed to be no way to prevent them; the best that could be hoped for was to "mitigate" the risk with a variety of means, only a few of which were available to the actual users of the components.

The problem was around before the legislation was put into place, and NASA for years has had an excellent Web site up and running with many examples and case studies of the phenomenon. Tin plating of components had of course been around for many years before the RoHS legislation impacted the global electronics community, but the switch to tin as a solderable finish for over 85% of all components, particularly fine-pitch applications, raised the risk probability of failures due to tin whisker shorting.

The real impact on the high reliability electronics manufacturing industry was not fully realized until it became apparent that in the case of Sn/Pb terminated components, the entire component industry switched to alternate plating materials--mostly tin plating and halted production of the historic Sn/Pb terminated components. In retrospect this was bound to happen given that most electronics components are NOT used in high-reliability devices, and given the cost of running two lines of inventory for tin/lead and non-tin/lead product lines.

Since the switch from tin lead as a component termination finish, many companies have set up as new ventures or existing companies are seeing a much increased volume of business in the area of converting SAC alloy-terminated and tin-terminated components back to a tin/lead finish for reliability purposes in specific market areas.

Most telling in the area of reliability impact is the exemption in the original RoHS legislation for the use of tin/lead in telecommunications equipment which lead to the terminology RoHS5 and RoHS6 to distinguish between the assemblies using the telecommunications Pb exemption (RoHS5) and those not using it and complying to the RoHS Pb limits for homogenous compounds (RoHS6).
There have been many trials carried out on tin whisker mitigation. In all cases these have focused in either changing the plating of the component or covering the finished assembly in some form of conformal coating compound.

In the case of the component terminations, trials have been successfully carried out on a number of termination plating materials which successfully have shown NOT to exhibit tin whisker effects after five years of testing. The issues facing the manufacturers of the components has actually been one either of cost in the case of materials, such as Au or Pd, or of not being able to solder the resulting component as in the case of Ni plating.

In the area of conformal coating, the issue has been to develop a coating that will not allow the whiskers to penetrate and short to a whisker on an adjacent termination. The two most successful of these are based on ceramic in one case and polymer chemistry in the other.

In the case of the ceramic, it is not yet fully established what surface preparation is necessary to

ensure that the ceramic adheres adequately to the tin to prevent penetration and to every other surface such that it does not flake off. In the case of the polymer coating, a novel concept is being pursued to deflect, rather than to prevent puncture of, whiskers.

So what about elimination?

As outlined above--ongoing trials have proven that a coating of Ni, Au or Pd as a termination finish has not seen evidence of any whisker growth and were compared to a sample using tin finish as a control which did exhibit whisker growth [1].

A group of engineers heavily involved in the manufacturing industry decided to take this to the next level. They rationalized that if plating could be selectively applied to a finished circuit board--that this would effectively *eliminate* as opposed to merely *mitigate* reliability impacts of tin whiskers.

The problem was, of course, how to ensure that the process treated only the metal areas and not add reliability problems due to residues able to cause low resistance conditions on the finished assembly.

When you get right down to it, the issue here is similar to the one faced by the bare board industry--how to get a coating, such as ENIG, onto the surfaces that are required to be soldered without causing residues to remain on the board surface that would otherwise cause reliability issues.
The new process does, indeed, use similar chemistry to that found in the circuit board industry. The initial trials carried out in the process of testing this patent-applied-for process used an electroless nickel chemistry. In the testing carried out with nickel as a tin whisker elimination coating, it was found that a coating thickness of 0.2 microns is needed to eliminate the phenomena of whisker growth [1].

In the testing, a FULLY ASSEMBLED board was electroless nickel plated by placing the assembly into the plating bath. Once removed, the board was rinsed off and dried in a process similar to that already in use in both the bare board fab and assembly industries.

Before immersion in the chemistry the areas of the board not requiring plating such as gold connectors and edge contacts were masked off using standard masking materials. The result is shown in the photograph below. Every metal surface on the assembly is now coated with nickel, and tin whiskers will not be an issue--they have not been mitigated, but eliminated.

The board above works just fine after the treatment and, thanks to the nickel surfaces, will continue to work reliably without the doubt of a tin whisker induced failure. So far, not one assembly to which the process has been applied has failed to function after the process exactly as it did before.

The benefits of the process are many in the drive to eliminate whisker growth in a high-reliability electronics assembly; some of these are outlined below:

- Eliminates BOM scrubbing and testing components for Pb-free Sn at receiving.
- Solves termination finish whisker problem with COTS assemblies.
- Permanently suppresses whisker growth (Kim et al. > 5 yrs for 200 nm Ni [1]).
- Applicable to all electronic assemblies (mask, add a few components later if necessary).
- All tin is covered/no shadowing /hot aqueous immersion.
- Risk of damage to assembly function, reliability and legibility negligible.
- Fixed and maintenance costs negligible.
- Small equipment footprint.
- Process inherently safe--doesn't use exotic chemicals (i.e., not already in use in electronics industry). Long history, wide use of electroless Ni.
- Training of work force simple--expect broad process window.
- Quick, so no bottleneck: Time requirement $\ngtr$ 5 minutes/assembly.
- Process can be performed immediately after cleaning and before conformal coating; no additional cost for masking.
- Easy cleanup of assembly for next process step--water and steam, dry.
- No interference with rework; masking allows components to be added later.

The trials continue on this new process. The industry is currently carrying out many trials and hopes to work with a number of OEMs to run side-by-side trials with fielded units of both untreated and treated products.

Given the long history and current use of electroless nickel, both on circuit board bare fabs and components, along with the historic tin whisker testing on nickel coated components [1], it looks like the search for an effective, easily-reworkable, easily-implemented, cost-effective process for the elimination of tin whiskers is over.

The inventors of the proces--Bob Landman, Gordon Davy and Denny Fritz--have formed a company for the commercialization of the process and can be contacted at:

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I, for one, have to say: Great work guys.

References:

1. "Prevention of Sn whisker formation by surface treatment of Sn plating Part II," Keun-Soo Kim, Suk-Sik Kim, Seong-Jun Kim, Katusaki Suganuma, ISIR, Osaka University, Masanobu Tsujimoto, Isamu Yanad, C. Uyemura & Co., Ltd., 2008, TMS Annual Meeting.

*John Burke founded UK-based SMART (Surface Mounted and Related Technologies) Group actively helps people solve issues with soldering and other manufacturing process related topics--all while holding down a full time executive job for a company in the valley. Burke has headed the management team at three contract manufacturing companies, as well as managing manufacturing related sections of large multi-national companies, and has years of experience in electronics and system level manufacturing, design, and test--at bench, as well as at executive management levels--and takes an active role in all aspects of the process and process improvement. Burke has many patents issued for advanced manufacturing technology. To contact John, click **here**.*

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