Environmentally Friendly Electronics for High Reliability

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Abstract

In 2006 when the European Union's RoHS Regulation went into effect, a number of global firms who produce high-reliability products such as servers and telecommunication equipment had decided to take the exemption allowed for Pb containing solders in these applications. As a result they had not completed the tests necessary to prove the reliability of Tin Silver Copper (SAC) alloys in these applications. In 2007 it became apparent to many of these firms that they could no longer procure components with traditional SnPb surface finishes, and thus they faced an unknown reliability risk. In 2006 iNEMI had begun a study to evaluate the reliability of "Pb-Free BGAs in SnPb Assemblies." This paper will report on the results of this initial study and will then report on several studies currently under way to evaluate the reliability of new green-materials in high-reliability applications.

Introduction

Since 1998, iNEMI's collaborative agenda has been increasingly dominated by projects that address infrastructure gaps facing the electronics industry as it makes the transition to be compliant with materials restrictions and end-of-life regulations. While the original emphasis was on materials and process-related issues, the scope has broadened over time to include supply chain and business process issues. More recently, our efforts have been dominated by the issues faced by the high-reliability product sectors.

In 2006 when the European Union's RoHS Regulation went into effect, a number of global firms who produce high-reliability products such as servers and telecommunication equipment had decided to take the exemption allowed for Pb containing solders in these applications. The primary justification for these exemptions was that they had not completed the evaluations necessary to prove the reliability of Tin Silver Copper (SAC) alloys in these long life time/mission critical applications. In 2007 it became apparent to many of these firms that they could no longer procure components with traditional SnPb surface finishes, and thus they faced either an unknown reliability risk or a source of supply risk.

Many members of the high-reliability community now recognize that they quickly must follow the consumer market in evaluating new "green materials" if they are to take advantage of the high volume low-cost components produced for the consumer market. These same firms now recognize the cost and time required to evaluate the reliability of new materials in each of their applications. Consequently they are evaluating the feasibility of introducing Pb-free solders and surface finishes at the same time they introduce bromine flame retardant free (BFR-free) Printed Circuit Boards (PCBs). This paper will describe a number of projects that the iNEMI consortium has established to determine the reliability of Pb-free and BFR-free components in electronic assemblies.

High-Reliability Electronics

While Pb-free assembly is now well established in the consumer segment, a number of challenges remain before this technology can meet the stringent reliability requirements of mission-critical products such as medical electronics, telecommunication infrastructure equipment and high-end computer servers. Many of these products enjoy exemptions from, or are out of scope of, the European Union's RoHS; however, the long-term outlook indicates that conversion to Pb-free assembly is inevitable.

Many iNEMI members are designing and manufacturing high-reliability electronics. Many of these firms are taking advantage of Pb exemptions offered under the EU RoHS Directive and, therefore, expect to continue to use SnPb assembly for some time (i.e., several years). Over the longer term, however, most of these same companies are planning for Pb-free conversion. Due to the supply chain conversion to Pb-free, this posture is creating a number of challenges/risks:

- The vast majority of component suppliers are converting to tin finishes for I/O terminals. Tin whiskers remain a concern for high-reliability applications, although mitigation practices are now established that can substantially reduce the risk.
- Most Pb-free BGAs are not compatible with SnPb assembly processes.
- Either need to have ongoing availability of SnPb-compatible BGAs, or
- Need to develop a robust process for mixed assembly.

Many high-reliability applications make use of large, complex PWBs. Once this segment does convert to Pb-free, there will be several issues to resolve:

- Highly complex boards stress materials and processes used for Pb-free assembly (e.g., laminates).
- Component survivability due to higher processing temperatures (especially for wave solder).
- Greater temperature variability over these complex assemblies.
- Robust repair processes are still in development.

iNEMI High-Reliability RoHS Task Force

In order to address some of these issues, iNEMI formed the High-Reliability RoHS Task Force to work with the supply base to ensure that high-reliability product needs are met. The group has now completed four position papers and recommendations to help provide guidance for industry.

The first paper addressed the availability of SnPb-compatible BGAs for the high-reliability segment. It also

communicates clear requirements for tin whisker mitigation and testing practices. This position paper is available at: http://thor.inemi.org/webdownload/projects/ese/High-Rel_RoHS_recommends.pdf

The second document published by the group covered manufacturing issues associated with thermally complex assemblies. This document is available at: http://thor.inemi.org/webdownload/projects/ese/High-Reliability_RoHS/High_Rel_position_021606.pdf

The third document dealt with the qualification and use of RoHS 5 and RoHS 6 subassemblies in high-reliability products. It is available at: http://thor.inemi.org/webdownload/projects/ese/High-Reliability_RoHS/High_Rel_position_061206.pdf

The fourth document "Recommendations for Managing Pb-Free Alloy Alternatives," addressees the proliferation of alloy alternatives that are being created.

iNEMI's High-Reliability Task Force is working to develop an industry view and communicate results to the supply base. Proposed tasks include:

- Define list of key knowledge gaps for high-reliability Pb-free:
  - Reliability.
  - Manufacturing.
- Create matrix of work underway to close gaps:
  - Consider existing sources of data.
  - Consider all industry/university cooperative efforts.
- Create timeline for completion.
- Coordinate work and communicate results.

The BGA Challenge

For companies that participate in industries that require high-reliability/long-service-life products, the rationale for staying with SnPb assembly was very clear: in many cases Pb-free technology had not been able to demonstrate the required level of reliable performance for long-life, mission-critical applications. This was further compounded by the fact that in some cases the ability to move to Pb-free assembly was impeded by the non-availability of Pb-free parts for older, low-volume or out-of-production BGA components. While it is increasingly obvious that virtually all electronics products will be Pb-free over time, there are a number of knowledge gaps that must be closed before Pb-free reliability can be predicted with the same certainty that SnPb assembly can deliver. The risks and potential long-term costs associated with this uncertainty to users and producers of these products are too great to ignore.

High-reliability hardware companies were relieved to understand that exemptions would be granted for continued use of SnPb in their products; however, the rapid transition of the supply chain to meet the high-volume needs of consumer electronics is causing problems with the availability of critical components (new and existing) in their traditional surface finish configurations. Many suppliers have elected to convert all of their components over to Pb-free connection finishes. In a number of cases, this presents compatibility issues (especially with BGAs) for those users who are allowed to continue to use SnPb assembly processes.

The strategy of staying with SnPb assembly is starting to create supply continuity issues for those who thought that exemptions (or being out of scope) would temporarily insulate them from the movement to Pb-free material systems that industry has much less experience with.

iNEMI SnPb BGA Availability Task Group

iNEMI has formed the SnPb BGA Availability Task Group, made up of firms that are either taking the Pb exemption or are out of scope for EU RoHS. The efforts of this group are focusing on ways to work with the BGA component supply base (integrated circuit as well as packaging firms) to support SnPb-compatible BGAs, assist with questions of long-term reliability, and/or other solutions to address concerns. Activities to date include:

- Developed a list of critical BGA component families.
- Estimated Total Available Market (TAM) for these devices in a SnPb assembly version.
- Worked with the supply base to come up with alternatives that meet this critical market need.
- Organized a workshop with BGA supply base to help ensure balanced solutions. Event was held on March 1, 2007, at Hewlett-Packard in Cupertino, California.

Results from BGA Workshop

The following conclusions were reached from this workshop:

- So much emphasis has been put on RoHS conversion that the supply base still seems to be somewhat surprised/misinformed that there are significant ongoing needs for SnPb BGAs.
- More education is definitely needed on the unique characteristics of high-reliability product lifecycles (high development costs, long product availability window, decades of support, etc.) and how the RoHS transition has exacerbated the situation.
- More consensus and education is needed on remaining knowledge gaps and what must be done to reduce risk. It is clear that the supply base is somewhat skeptical of the level of risk/severity of gaps remaining.
- The high-reliability users have enjoyed the technology, availability, and low cost of consumer-driven components and would like to continue to do so. Staying with SnPb BGAs is moving them away from this paradigm (during the extended transition period).
- Suppliers are treating SnPb BGAs as custom parts with all the implications that this brings (limited competition, limited availability, less favorable pricing).
- Perhaps iNEMI should develop a business case for accelerated investment to close knowledge gaps (based on cost and availability issues of custom vs. standard parts).
- The proliferation of Pb-free metallurgies is becoming a significant issue for industry. While it is inevitable that change will occur as we learn more about Pb-free, it is counterproductive to diverge to so many

alloys. This could be a good opportunity to combine forces to drive convergence.

- The position being taken by military and aerospace (SnPb forever!) is especially problematic and would drive the re-establishment of dedicated military parts lines if it is to be achieved.

BGA Business Potential

While total unit volume is relatively small, the packaged semiconductor revenue generated from high-reliability products is significant (18% of BGA and 12% of CSP value). More importantly, these critical devices leverage over 25% of the total hardware revenues for electronics! It is believed that this analysis should help to justify the critical need for these components during this lengthy transition period.

Results from the iNEMI Pb-Free BGAs in SnPb Assemblies Project

iNEMI is in the process of completing a four-year project on this subject. Highlights from this effort will be presented at the ICEPT Conference.

New High-Reliability Projects

Based on recommendations from the iNEMI High-Reliability RoHS Task Force and Results from BGA Workshop, iNEMI has started a new round of projects addressing the needs of high-reliability applications. Included are three new projects:

- *Evaluation of Pb-Free Component & Board Finish Reliability.* This project will evaluate the effects of alternative surface finishes for circuit boards and package substrates on Pb-free solder joint reliability during mechanical and thermal stress testing.
- *Pb-Free Early Failure Project.* This new iNEMI effort will be working to determine whether a large sample size will reveal Pb-free early failures in accelerated thermal fatigue testing of Pb-free solder joints. All components for the test vehicle are on order and many have been received. The test vehicle board design is complete.
- *BFR-Free High-Reliability PCB.* This project is a follow-on to iNEMI's current BFR-Free PCB Project. Proposed project objectives include:
  - Build on industry knowledge and capability and on results of the iNEMI BFR-Free Project: Test Phase (Phase II).
  - Consider unique market segment requirements.
  - Identify technology readiness and gaps.
  - Stimulate supply capability.
  - Determine BFR-free board-level reliability for various components.

Conclusions

This paper highlights some of the collaborative work undertaken to address the specific needs of the high-reliability product segments as they continue to work towards the Pb-free transition. While this change is inevitable, there are still a number of risks that must be mitigated before mission-critical applications can again enjoy the benefits of full utilization of consumer-driven components in a Pb-free assembly environment. The Pb-free conversion experience has revealed that the high-reliability community must respond to material changes being introduced in consumer products if they wish to take full advantage of the cost reductions high volume manufacturing provides.

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