MATERIAL CONTROL FOR LEAD-FREE MANUFACTURING

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ABSTRACT

The upcoming transition to Lead-Free electronics assembly has been a subject of much research and discussion lately. To manage this important transition requires a significant effort in many areas. The challenge does not stop when the new process and materials have been selected and qualified. The key issue that remain is that of managing the material logistics.

A successful transition will require a significant collaborative effort between production, engineering, procurement, and a large number of component suppliers and distributors. During this process one area that should not be overlooked is the actual production floor. After all this is where all the different materials come together to make the finished product. The assembly line is where the largest number of people are involved and the complexity of their task translates in the highest risk of errors.

This paper focuses on the practical considerations of managing the materials on the production floor during the transition to Pb-free.

STRATEGIES FOR MANAGING THE TRANSITION

Ultimately every OEM that designs and distributes electronics products must define its own strategy and action plan for Pb-free. This is based of course on legislation, international markets and other considerations.

Many companies will continue to assemble Pb-based products. This includes products that are exempt from the new legislation. Other OEMs will convert all their products to Pb-Free to minimize the cost and complexity of managing two different versions of the same product. As a result the majority of EMS and ODM assemblers will have to manage two different sets of materials and run two different processes side-by-side for a significant period of time. Depending on the strategy being used by the assembler this transition can range from a few months to many years in manufacturing, rework and field repairs. In most cases this will create a logistical nightmare that exceeds the capabilities of current systems and procedures.

The timeline of that transition is also much sooner than some anticipated. One leading cell phone manufacturer has already been producing millions of Pb-free products in North America over the past two years. Leading producers of PCs have also implemented very aggressive schedules with their suppliers to introduce new products in a Pb-free version as soon as the end of 2004. They are doing this up to 18 months ahead of the legislative deadline to avoid the additional costs and complexity of running two different versions of the same product or converting these products in mid-life.

It is important to realize that these high volume applications are really driving the supply chain. This may turn into a problem for companies that have decided not to convert to Pb-free because their existing parts may be no longer available over the next few years. In the end they may have to convert their products to Pb-free even if they are exempt from the legislation because some components will be only offered in Pb-Free version.

KEY PB-FREE MATERIAL ISSUES

- Material Compatibility Issues
- Identify and segregate Sn/Pb and Pb-Free Materials
- Line Setup Validation
- Tighter process window
- Impact on Moisture Sensitive Devices
- Pb-free Material Declarations

MATERIAL COMPATIBILITY ISSUES

Because of material and process compatibility issues it is critical to avoid mixup of Pb-based and Pb-Free components and other materials.

Many papers and articles have been published about the technical issues associated with forward and backward compatibility, i.e. assembling Sn/Pb components with Pb-free alloys and using Pb-free components with a Sn/Pb process.

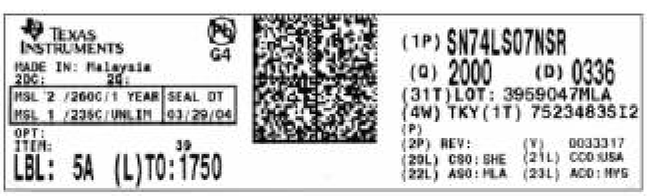
On the supplier side most of the major component vendors have developed their own roadmap to manage the transition, taking into account the requirements from their various customers. Intel for example does not recommend forward or backward compatible assemblies with their components.

MATERIAL IDENTIFICATION

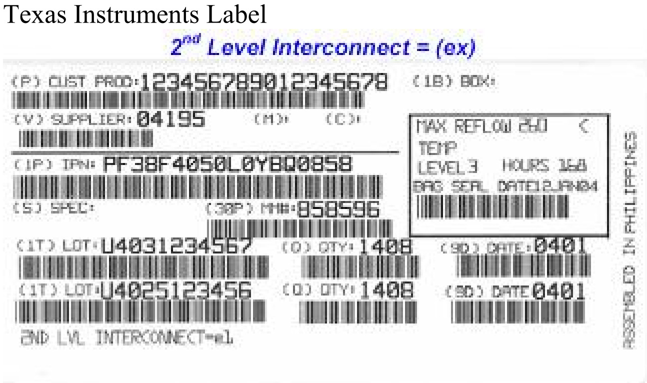
The first challenge is to clearly identify and segregate Pb-based and Pb-Free materials. This includes components and PBCs of course, but it also includes solder pastes, solder bars, solder wires, etc. It may also include special tooling that can have subtle differences for both processes, like stencils, etc.

Until now, the major focus has been placed on releasing an industry standard to identify Pb-Free components and finished assemblies. The NEMI RoHS Transition Task Group worked closely with JEDEC to define a new industry standard : JESD97 “Marking, Symbols, and Labels for Identification of Lead (Pb) Free Assemblies, Components, and Devices,” released in May 2004. This document is very important as it provides a standard set of symbols and guidelines for component vendors and assemblers. This will not however eliminate all confusion because the actual format and content of each label will continue to vary significantly from one supplier to another.

Examples of supplier Pb-Free labels :



Texas Instruments Label



Intel Label

PART NUMBERING

Since most of the procurement and manufacturing systems rely strictly on part numbers this is clearly a main area of concern for material identification.

The main problem right now is a lack of agreement on the methodology to manage part numbering for Pb-Free components in the supply chain. On the user side, NEMI and other groups are recommending that Pb-free components be identified with new part numbers and many vendors have agreed to take this approach. In some cases this will take the form of a prefix or suffix added to the existing part number.

Many other vendors have refused to accommodate this request because it will effectively double the number of part numbers that they have to manage, in some cases exceeding the capability of existing systems. In this case the transition will be managed by production date or lot codes.

In any case the actual method being used to identify Pb-free components should be clearly defined and communicated to the assemblers via the standard PCN process (Process Change Notice). Once again the ultimate responsibility of managing this variability will reside with the assembler.

AUTOMATING MATERIAL CONTROL

Unfortunately there is no general industry standard on component and material labelling. This means that every vendor has its own internal format of label containing different elements of information. This typically includes as a minimum the part number, lot number or date code and quantity. The information is generally printed in a readable form with certain fields also available in barcode or 2D matrix formats.

This poses a great challenge when the assembler is trying to automate the control of materials in the warehouse and on the production floor. A limited number of large OEMs have enough leverage to specify their own formats of barcode labels to all their suppliers but the vast majority of assemblers must generate their own barcode label for each batch of material upon receiving or kitting, before it gets released to production.

Since we are now dealing with a closed system and a uniform labelling scheme, the most effective approach is to assign a unique serial number to each individual item. Then all the material and process information assigned to this specific item can be maintained an updated in a central database. The unique serial number gets generated when the material is received or just before it gets released to production. This unique number can be printed in a simple barcode format or it can be assigned to a unique RFID tag temporarily attached to the material container.

This identifier can be quickly scanned as the material moves from one location to another in the factory, on and off production equipment or in and out of a storage location. To make this process faster, the individual machine and storage locations can also be identified with their own unique barcode labels. The operator simply scans the material and its location to perform a transaction in the material control system. This data acquisition process can be automated even further by using RFID tags and RF antennas integrated inside production equipment and storage locations. This approach has several benefits, one of which is a very accurate real-time inventory of all materials on and off the assembly line. It also provides the foundation for other material control applications like line setup validation MSD Control and traceability.

Manual Scanning of Barcode Label

RFID Smart Feeders on placement machine

MOISTURE-SENSITIVE COMPONENTS

Even prior to Pb-free, there is a subset of electronic components that creates a significant logistical challenge for assemblers. The majority of active components that are packaged with plastic and other organic materials are categorized as moisture-sensitive. This means that they must be packaged and shipped in sealed dry bags, with special labels indicating that these components have a limited floor life once the bags are opened for production. The actual floor life varies from a few hours to a year and it changes based on the complete history of exposure time in various environments, including dry bags, dry cabinets, bake ovens, and ambient conditions. This requires a very high level of component tracking on the shop floor.

The introduction of Pb-Free has created a major impact on the moisture-sensitive parts. The higher reflow temperature translates in higher internal pressure, thereby reducing the allowable floor life. This means that all components have to be re-tested and re-classified by the manufacturer. Studies have shown that this can result in downgrading components by 1 to 3 levels of moisture-sensitivity.

Other components that were not previously considered as moisture-sensitive must now be handled with similar precautions. This includes certain types of passives, connectors and PC boards that can suffer damage through a combination of exposure to moisture followed by high temperature reflow. In addition to the traditional cracks and internal delaminations, new failure modes have also been reported for PBGAs. Excessive warpage of large body components has been shown to be greatly influenced by moisture. This failure mode will be included in the upcoming release of the MSD industry standards.

Since the same parts can be used by different customers in Sn/Pb and Pb-free assemblies, some component vendors, including Texas Instruments and Philips have decided to indicate the two different MS levels at the two different reflow temperatures. This dual classification method is technically justified but once again it increases the complexity of the information on the label and the risk of human errors during assembly.

The issue of MSD control is still frequently compared to that of ESD Control 10 years ago. Even without considering Pb-free most assembly operations do not yet fully comply with the industry standard and routinely expose their ICs to excessive stresses during reflow. The transition to Pb-free will compound that issue by significantly reducing the process window and increasing the rate of field failures due to internal component damage.

The same type of automated material control systems that have been used by leading assemblers to control Moisture-Sensitive components are now becoming a necessity for anyone who is assembling Pb-free products. Existing systems and procedures must be upgraded to deal with the new elements associated with Pb-free reflow temperatures.

LINE SETUP VALIDATION

Another common production task that will be impacted by Pb-free is that of validating the setup of each machine on the assembly line. In the past this seemingly simple task has created major headaches for most assemblers. The fact is that production operators have to deal with a very large number of different elements and it becomes very easy to make mistakes and load a material in the wrong location.

With the high rate of production on modern assembly lines, loading the wrong reel of components on a placement machine can result in hundreds or thousands of defective assemblies. In many cases the impact will be limited to the cost and delay of reworking the boards but in some cases the problem may escape to the field resulting in a serious customer satisfaction issue.

Many part numbers have multiple digits and they can be very similar, further increasing the risk of human errors. With the introduction of Pb-free, the level of complexity and the risk of human errors will increase significantly, making this validation process a critical success factor for maintaining cost and quality on a similar level to existing Sn/Pb products.

One major ODM went through this experience recently when it started running Pb-free prototypes for one of its major customers. The initial plan was to use the same SMT line for Sn/Pb and Pb/free production but it was eventually decided to run a dedicated line after finding out the total line setup time went from an average of two hours to eight hours because of all the additional verification involved when switching from a Sn/Pb to a Pb-free process.

Manual Setup Validation

In the past different methods and systems have been used to reduce the risk of human errors during line setup. First, clear written instructions and setup sheets are a must. These procedures are frequently combined with an additional verification process. This can take the form of a complete first article inspection and test. Another common method involves having a second operator or a QC inspector verify the setup of every machine before starting production. In both cases this translates in significant downtime on the assembly line. Even then, this type of manual verification is still prone to human errors.

In order to make this validation process faster and more efficient, many assemblers have implemented various types of automated systems for setup validation.

Semi-Automatic Setup Validation

The most common method of automated setup validation is using barcode labels on the material containers. A typical solution for placement machines will consist of scanning a barcode label on the reel of components and then scanning another barcode label on the feeder and/or feeder slot on the placement machine. This information is then automatically compared with the specified machine setup and discrepancies are identified to the operator.

This type of system is significantly better than a manual procedure but it still involves human intervention in the scanning process. Some errors can still be made when scanning the wrong material or the wrong location.

Closed-Loop Setup Validation

The highest level of validation can be accomplished by what is called closed-loop setup validation system. This involves some kind of intelligent tooling like a smart feeder for example. In this case a reel is first associated with a smart feeder during an offline feeder setup process. When the feeder is loaded on the machine, the system automatically detects and validates that the right feeder and component is loaded in the right location.

Traditionally the above systems have been limited to validate the setup of components in reels and tape feeders on placement machines. Newer technologies provide a similar level of automation for any other kind of material on any kind of equipment or process. This includes validating other types of components in JEDEC trays, tubes, etc. and also validating other types of materials like a jar of solder paste or a stencil on a screen printer for example.

A robust system requires more than standard barcode readers and application software. Experience has shown that simple warnings and alarms are not always sufficient to have operators react and take corrective actions. In this case it becomes necessary to implement completely error-proof systems. This means physically stopping the production equipment until the setup is validated. This can be accomplished by physically controlling the operation of a machine or by preventing the movement of boards into a process until it is completely validated.

Screen Printer with Closed-Loop Hardware


RF Antenna for Jar of Solder Paste

Using RFID to replace barcode labels provides a means to obtain fully closed-loop setup validation on any type of material on any type of equipment. As an example, closed-loop validation can be easily retrofitted on an existing screen printer. In this case a low cost re-usable RFID tag is attached to each stencil and jar of solder paste and a set of RF antennas are mounted inside the equipment to automatically detect the identity of the stencil and solder paste jar when they are loaded in place. The system requires no intervention from the operator unless a setup error is detected. It is not possible for the operator to bypass the system or to run production until all the right elements are in the right location.

Of course this higher level of automation requires a higher investment in terms of hardware but this cost can be offset by the elimination of manual scanning and the associated errors. The cost justification will vary from one type of material to another and from one type of equipment to another. Many factors come into play in this analysis and every application is different. Ultimately a complete line setup validation system should be flexible enough to support all types of materials and equipment, with a combination of semi-automatic and closed-loop hardware. This insures that the most effective level of automation is implemented where it makes economical sense.

TRACEABILITY AND MATERIAL DECLARATIONS

Manufacturing and material traceability has been the subject of increased attention in our industry over the past few years also. Many OEMs have been requesting their suppliers to provide component lot traceability data for every product, and even for every board. In many cases the individual boards are serialized to provide a finer level of traceability. The main drivers for this request have been the need to precisely identify the root cause of a specific defect in the field and to enable selective recalls of other products that may have the same problem.

The transition to Pb-free brings an increased focus towards material and process traceability. First because of the increased level of complexity already mentioned, there will be a greater risk of problems on the production line, during and after the transition. In addition, Pb-free legislation and customer requirements will mandate the assembler to provide documented evidence that a specific product was built with Pb-free materials.

As a result of this and other factors, component lot traceability is no longer sufficient for many customers. Some leading OEMs are already starting to request complete process traceability for each and every board being assembled by their suppliers. This can include the actual lot of solder paste that was used to build the product or even the actual temperature in a specific oven zone when the board was being processed. To support the Pb-free compliance this traceability data should also include the part number, lot number or date code and any other relevant information to identify that all materials were classified as Pb-free by their respective suppliers.

There is no set method of monitoring or enforcing the Pb-free legislation at this point in time. However there is clearly a responsibility that exists at each level in the supply chain to verify the status of incoming materials and guarantee the compliance of the finished product or sub-assembly.

Efforts are underway to standardize the process for gathering and reporting material content. A Joint Industry Material Composition Declaration Guide is being developed by a group of industry associations. For the assemblers this will translate into a significant effort to obtain from their suppliers the material content of each component on the bill of materials for every product. Then the assembler must generate the Material declarations for the finished product.

There is a significant aspect of liability associated with Pb-free legislation and material traceability. Although there is real cost involved in capturing and storing this much data, the alternative can be much worse. A recent example involves Sony, who was forced to replace peripheral cables for 1.3 million PlayStation 1 game consoles after the Dutch government raised health and environmental concerns. Shipment of the consoles was blocked because the cables contained too much cadmium.

The good news with material traceability is that the same material control system that is used to manage inventory on the shop floor, prevent setup errors and to provide MSD Control can also be used to record and associate all materials with the finished product. This provides a whole new level of information, well beyond the traditional component lot traceability. And the system can be cost-justified on the basis of actual improvements in setup time and reduced scrap and rework. It does not have to be seen as an additional expense required only to gather data for the customer. It becomes part of an integral material control system, focused on reducing waste by insuring that all the right materials are at the right place at the right time. This is very much in line with the current trends in Lean Manufacturing and Environmental responsibility.

CONCLUSION

Once the Pb-free materials have been selected and the process has been qualified the major manufacturing issue that remains is that of managing the material logistics. There are many critical aspects of controlling materials on the production floor. The key issues include :

- Identify and segregate Sn/Pb and Pb-free materials
- Validate Line Setup
- Control Moisture-sensitive components
- Provide complete material and process traceability

These issues can all be addressed with proven and cost-effective material control systems, using a combination of barcode and RFID technology.

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