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Recent Developments in MSD Control
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Introduction

This paper discusses some of the new challenges associated with MSD Control in PCB assembly plants and offers a solution to reduce manufacturing costs and improve quality by automating this critical aspect of quality control.

Significant trends

Electronics OEMs continue to experience increased pressure to reduce manufacturing costs while increasing product density and reliability. These two requirements are often working against each other, resulting in major headaches for the manufacturing engineers who must upgrade and maintain the complex equipment, systems and procedures used in the PCB assembly process. These requirements eventually exceed the abilities of humans to keep up with the sheer complexity and the tight process window associated with smaller and more sophisticated components. When this occurs, the only option is to further automate the process and remove the dependence of operator skills and training level on manufacturing costs and final product quality.

Some of the most significant technology and business trends affecting material control have a direct impact on the prevention of latent defects for Moisture Sensitive Devices (MSDs). Since the early days of SMT technology, one of the key requirements to build quality products has been to diligently follow the guidelines provided by the component suppliers for ESD and Moisture sensitivity. Excessive moisture in the plastic encapsulant can result in internal cracks and delaminations during solder reflow. This level of sensitivity is expressed by the Moisture Sensitivity Level (MSL) which defines the maximum exposure time to ambient conditions (at 30C/60%RH) prior to reflow, once the MSDs are removed from their protective dry bags.

The shorter life cycle of advanced electronic packaging is working against the suppliers who continually struggle to qualify and optimize the design and assembly process in order to achieve the lowest possible Moisture Sensitivity Level (MSL). This must be achieved while keeping up with shrinking package size, larger dies and finer pitch, all factors that tend to make components less robust to the assembly process. As a result the PCB assemblers must manage an increasing variety of highly sensitive components with shorter floor life.

In addition, many of these MSDs are now assembled on both sides of the PCB, resulting in a further reduction in the allowable floor life prior to placement and increasing the complexity associated with tracking components already assembled between the first and second reflow pass.

To make matters worse, the strong push to move assembly facilities to lower cost countries in an effort to further reduce manufacturing costs also means that the ambient conditions also reduce the allowable floor life due to the higher temperature and humidity levels in the assembly process.

Last but not least, the push to lead-free technology will have a direct and major impact on MSDs since the higher reflow temperature results in higher levels of moisture sensitivity. As a result existing components must be re-qualified and typically downgraded by one or more levels.

New revision of industry guidelines J-STD-033A

Clearly the challenge of properly controlling MSDs is constantly increasing. Existing MSD Control procedures and systems must be regularly updated to keep up with changes in product mix and the most recent industry guidelines.

Since 1999, a joint industry standard, published by IPC and JEDEC provides the guidelines that must be followed by assemblers to prevent moisture induced defects. This standard has recently been revised and it includes many significant changes and improvements. On one hand many of these changes increase the complexity of the resulting procedures and systems. On the other hand, automated systems can handle the new rules and tables and make them transparent to production operators, resulting in a wider process window. As a result assemblers can insure that they only bake components when absolutely necessary and for the shortest possible duration while ensuring zero moisture-related defects.

The latest revision of J-STD-033A was released in July 2002. Some of the most significant changes include the following :

- New bake table with 90 different bake cycles. The optimal duration varies ranges from 3 hours to 79 days based on the component MSL, body thickness, temperature, and saturation factor. (ref: J-STD-033A, table 4-1)
- There is no longer a limit to the number of bake cycles at 40C and 90C. The limit at 125C is now set at a cumulative duration of 48 hours.
- Limited shelf life for dry storage. The standard now specifies that previously dry components that are placed in dry cabinets at 10% RH may have a limited shelf life. This limit varies from 2 days to unlimited based on the MSL, body thickness and RH level. (Ref : J-STD-033A, Table 7-1)
- Parts returning to dry storage. There is a new set of rules to account for the desiccating effect of dry storage for components that were exposed to ambient conditions for more than one hour prior to be returned to dry storage.
 - o For levels 2, 2a and 3, the floor life clock can be temporarily stopped/paused during dry storage at less than 10% RH.
 - o For levels 2, 2a, 3 and 4, the floor life clock can be reset for components that have been exposed less than 12 hours, followed by 5 times the duration in dry storage at less than 10%RH.

- For levels 5 and 5a, the floor life clock can be reset for components that have been exposed less than 8 hours, followed by 10 times the duration in dry storage at less than 5%RH.

De-rating for ambient conditions

The de-rating table for ambient conditions has also been modified in J-STD-033A. This table is used to increase or decrease the allowable floor life based on the actual ambient conditions. The standard floor life that is defined by the MS level and that is normally identified on the MS label on the dry bag is based on experimental data at conditions of 30C/60% RH. This is why the specified floor life is no longer valid when ambient conditions on the assembly floor exceed 60%RH. Surprisingly this is often that case in some climates like Southeast Asia, China and some parts of Mexico for example. In this case Table 7.1 must be used to figure out the de-rated maximum floor life. This factor cannot be ignored since it can be very significant. For example, the most common category of components is a MSL 3 with thin body (less than 2.1 mm). This includes many SOIC, all TQFPs and TSOPs and many BGAs. This type of package will be de-rated from 7 days down to only 24 hours when conditions range between 60% and 70%RH. This is equivalent to a reduction by 3 levels of moisture sensitivity, down to a level 5a.

One of the significant changes in the de-rating table is a new definition of how the BGA packages are categorized. Unlike conventional leadframe packages, plastic BGAs are constructed with a base laminate and overmold. This changes the behavior of moisture diffusion and as a result the de-rating factor is also different. To take this into account, all BGAs are now categorized in one of two categories based on body thickness. BGAs with body thickness more than 1 mm are now considered thick components (like standard packages more than 3.1mm) and BGAs with body thickness less than 1 mm are considered thin components (like standard packages less than 2.1 mm).

From the standpoint of automation this means that the database of MSDs must now include the package type (BGA or standard leadframe), in addition to the body thickness and MS level. All these parameters must be taken into account in order to apply the proper de-rating factor.

Existing automated systems provide different methods to account for ambient conditions. In its simplest form, a process engineer can simply type in the seasonal worse case conditions of temperature and humidity in the configuration panel of the system. This data is used to automatically de-rate the floor life of each MSD when it is removed from its dry bag, based on table 7-1 of J-STD-033A. A further level of automation includes automatic sensors for temperature and humidity, coupled with a smart algorithm that will update the current conditions on a specified frequency. Of course, in any case it is also important that the automated system be able to adjust the remaining floor life or all components already exposed when a significant change occurs in ambient conditions.

Double-side reflow

A common misconception is that the tracking of MSDs can stop when the components are placed on the board, just prior to reflow. This is no longer true when MSDs are placed on both sides of the board in a double-side reflow process. The standard specifies clearly that once MSDs are removed from their dry bags, they must all reflow processing prior to the stated floor life. This is based on the fact that the first reflow does not have any significant drying effect since it is too short to allow any significant diffusion to take place. In other words, the clock keeps ticking after first reflow and it is necessary to continue tracking the remaining floor life of the components already assembled between the first and second reflow.

The tracking described above is clearly impossible to achieve with traditional manual procedures. An automated system can solve this challenge by associating the remaining floor life of all components placed on the first side with the unique serial number of that specific board. The system can provide real-time display of the remaining floor life for all partially assembled boards between the first and second reflow. The same system can also be used to define the shortest possible duration when the board needs to be baked at 90C prior to the second reflow. Ideally this system can also include a user-specified buffer to insure that all components have a sufficient remaining floor life prior to the first reflow cycle, in order to allow sufficient processing for the second side.

Rework

For similar reasons to the double-side reflow consideration above, boards must be baked prior to localized hot air reflow in order to avoid moisture-induced defects. Since most populated boards include some components that cannot withstand the 125C bake cycle, it is generally recommended to use the 90C bake cycle, which can range between 11 hours to 10 days, based on the properties of the specific component that must be reworked.

In this case, the automated system can be used to define the remaining floor life of each MSD once the board is assembled. This data can be used to determine if a board needs to be baked prior to reworking a specific component. When a bake cycle is required, the system can also specify what is the shortest bake duration.

A new diagnostic tool for MSD Control

Considering that MSD Control is such a complex issue, many engineers faced with implementing manufacturing procedures and systems wonder where to start. The fact that existing procedures are typically based on manual logs of exposure time, make it nearly impossible to use accurate data to make an informed decision. In most cases, important simplifications to the guidelines are made in order to provide a usable procedure for production operators. Too often these decisions are made without proper data to evaluate the risk and cost involved. This has a significant impact since most users will want to simplify on the safe side, resulting in a large number of unnecessary bake cycles. This creates non-value added cycle time and costs, while reducing the solderability of

components. It is also a major obstacle to achieve efficient material flow and on-time deliveries.

Concerned OEMs and CEMs have recently started to use automated MSD tracking systems as a diagnostic tool to properly evaluate and quantify the risks and costs associated with their specific production lines. In this case an automated system can be installed for a short period of time on a pilot line in order to gather detailed statistics of MSD usage. Since the automated system maintains a historical database of all material movements, it is possible to generate a report after a few weeks of production. This report includes the number of MSDs by MS level and body thickness, average and maximum exposure time, average time in dry storage, number and duration of bake cycles, de-rating for ambient conditions, etc. This data allows the assembler to precisely quantify the risk and costs associated with any simplified manual procedure. When applicable, this same data can be used to justify the capital expenditure associated with the automated system.

A global approach to material control

The automation of MSD Control should be considered a short term opportunity for cost reduction and quality improvement. Such a system can be installed quickly and painlessly since it only affects a small percentage of all materials and does not require any integration to existing systems. It also replaces very cumbersome manual procedures, yielding a fast return on investment.

On the other hand, a well-designed material tracking system should be modular and scalable such that it can be expanded to support future process and technology developments. In many cases it might be advantageous to use the same basic infrastructure to keep track of the real-time physical location of other materials on the production floor.

The MSD Control system can be combined with an existing feeder verification system to avoid redundant scanning operations and to further reduce the risk of human errors. Once the infrastructure is in place to control MSD on double-side reflow boards, it is also a small incremental step to gather component lot traceability data. Ultimately the same system can be used to control all materials and tooling on the production floor, insuring that all boards are built according to specifications and keeping a complete historical database for future reference.

Conclusion

Automated MSD Control is fast becoming a pre-requisite to build quality PCBs. These systems must be modular and scalable to keep up with ongoing changes in component technology, product mix, assembly process, material flow and to stay in line with the most recognized industry standard. Overall this is one of the most significant opportunities that exist to reduce manufacturing costs while improving customer satisfaction.