Molex will contact customers to notify them of the changes as each product converts to lead-free. Contact your local Molex sales representative for more information on the Product Change Notification (PCN) process.

Impact on Connectors

Molex has been actively engaged in investigations concerning the impact that the lead-free initiative will have on our connector products. In general, the elimination of lead will affect our products in two areas – the terminal plating finish and the plastic housing.

The predominant source of lead in connector products can be found in the terminal plating finish. Because many of our terminals are currently plated with tin-lead, a finish without the lead content will need to be adopted for future products. Tin-lead is currently used for connector applications as a solderable surface, as a contact interface and as a solderless interface (e.g. press-fit application, crimp, wire wrap). The requirements of these applications must be considered in the selection of an appropriate lead-free finish. As a solderable coating, the selected lead-free finish must provide acceptable solderability and reliability. For contact interface and solderless applications, the lead-free plating must provide an acceptable level of electrical performance (contact resistance) without undue degradation due to mating/unmating wear, fretting wear or fretting corrosion. The contact interface coating (and some specific solderless applications) must also exhibit a coefficient of friction that is sufficiently low to permit mating forces similar to tin-lead finishes. In high density applications, the selected lead-free finish must also provide an acceptable level of resistance to tin whisker formation. Tin whiskers are pure tin filaments that can grow spontaneously out of tin-rich coatings. There is a concern that in certain situations, the whisker can be long enough to cause a short between adjacent conductors. Because the lead in tin-lead materials is effective in suppressing tin whisker formation, this phenomenon has received considerable attention in recent years due to the requirement to eliminate lead from electrical and electronic assemblies.

Although the plastic housing materials used in our products do not contain lead they will still be impacted by the lead-free initiative. Significantly higher soldering process temperatures (240^{o}C – 260^{o}C) are expected for lead-free soldering processes and the plastic housing must be able to withstand those exposures. Many thermoplastic materials are used for surface mount connector products, but their ability to survive the lead-free soldering process can only be determined on a part-by-part basis. A “blanket” qualification of plastic housing materials is not possible because a product’s size, shape and configuration (e.g. wall thickness) greatly influence its ability to withstand the higher temperatures without blistering, deforming or discoloring.

Lead-free Solutions

Terminal Finish

In order to facilitate our customers’ lead-free implementation, Molex has decided to adopt a single, worldwide lead-free terminal finish. The best candidate for a replacement finish for connector terminals is pure tin. Molex (and the rest of the connector industry) has been reliably using pure tin finishes on connector products for over twenty years. In addition, recent internal and external studies have validated the reliable performance of pure tin for connector applications.

In the search to find a replacement for tin-lead plating for connectors, a number of candidates have been considered. They include tin (Sn), tin-bismuth (SnBi), tin-copper (SnCu), tin-silver (SnAg), gold flashed palladium-nickel (Au flash/PdNi) and gold flashed palladium (Au flash/Pd). The evaluation of these candidates require comparing them to tin-lead with respect to various criteria including:

- Solderability
- Solder Joint Reliability
- Tin Whisker Susceptibility

- Tin-Lead and Lead-free Process Compatibility
- Contact Resistance
- Fretting Resistance
- Coefficient of Friction
- Plating Process
- Scrap Value
- Cost

Molex connectors currently utilize a 90% tin, 10% lead (nominally, by weight) composition as the predominant solderable plating finish. The following Table compares each of the lead-free candidates to 90/10 SnPb with respect to the criteria listed above:

Criteria	**Sn**	**SnBi**	**SnCu**	**SnAg**	**Au flash/PdNi**	**Au flash/Pd**
Solderability	OK	OK	OK	OK	OK	OK
Solder Joint Reliability	OK	SnPbBi potential[3]	OK	Not tested	OK	OK
Tin Whisker Susceptibility	Slightly higher risk[1]	Slightly higher risk[1]	Significant Risk[2]	Slightly higher risk[1]	No whisker risk	No whisker risk
SnPb and Pb-free Process	OK	SnPbBi potential[3]	OK	Not tested	OK	OK
Contact Resistance	OK	OK	OK	Not tested	OK	OK
Fretting Resistance	OK	OK	OK	Not tested	Better than SnPb	Better than SnPb
Coefficient of Friction	OK	OK	OK	Not tested	OK	OK
Plating Process	Easier than SnPb	Difficult[4]	Difficult[4]	Very Difficult[5]	OK	OK
Scrap Value	OK	Bismuth content[6]	OK	OK	OK	OK
Cost	OK	OK	OK	Expensive	Very Expensive	Very Expensive

Footnotes:

1. Pure tin, tin-bismuth and tin-silver have all shown a slightly higher susceptibility to tin whiskering than tin-lead in published studies. The use of a nickel barrier layer has been found to minimize the risk of whisker formation. Molex typical uses a 1.25 micron (minimum) thick coating of nickel as a barrier layer.
2. Investigations have indicated that tin-copper finishes grow tin whiskers more readily than pure tin.
3. When tin-bismuth finishes are used in conjunction with tin-lead solders, a ternary alloy of tin, lead and bismuth can form that melts at 96ºC. This ternary alloy can collect in the solder joint and cause decreased reliability in applications that approach or exceed the melting temperature. However, an ample amount of bismuth must be present to form this alloy. Most tin-bismuth platings on connector terminals use from 1% to 4% bismuth and thermodynamically, this will not lead to the formation of the alloy.

4. For both tin-bismuth and tin-copper plating, it is very difficult to control the composition of the alloy. In the case of tin-bismuth plating, the bismuth content can drop rapidly, causing significant composition control issues.
5. Tin-silver plating chemistries require complexing agents that allow the tin and silver to deposit simultaneously. Process control for the chemistry is very difficult and the complexing agents cause significant problems for waste treatment systems.
6. The scrap value of terminals plated with tin-bismuth is substantially less than tin-lead, tin and tin-copper. The scrap material is often recycled by copper alloy producers. Bismuth is a severe contaminant in the copper alloy production process and therefore is restricted from their operations.

As can be seen from the Table above, the best candidate for replacing tin-lead as a plating finish is pure tin. If not for the tin whisker risk, tin would be a drop-in replacement for tin-lead.

Note: Due to a direction set within the Japanese component supplier industry, tin-bismuth plating was selected as the lead-free finish for a specific family of connectors (FFC/FPC). Due to business, rather than technical reasons, Molex was forced to comply with this direction. Although not our first choice, this finish was adopted in response to customer requirements.

The choice of pure tin as the preferred finish for connectors has also been recently endorsed by other connector manufacturers. In a joint position paper, Molex, Tyco Electronics, FCI and Amphenol have collectively published the rationale behind the use of pure tin as the lead-free finish of choice for connectors.

Plastic Housing

There are a number of engineering thermoplastic materials used for connector housings. Some have demonstrated resilience to surface mount hot air reflow processes using traditional tin-lead solders. However, the predominant lead-free solder alloy candidates require significantly higher temperatures in order to ensure proper soldering. In general, it is expected that the lead-free solder alloys will require peak soldering temperatures of approximately 260°C. A typical lead-free soldering profile may require surface mount components to be able to withstand a temperature exposure between 255°C and 260°C for up to 120 seconds.

Two of the thermoplastic materials' properties can provide an indication as to the ability to withstand the expected increase in lead-free soldering temperatures - melting point and heat deflection temperature (HDT). The melting point is the temperature at which the plastic changes from liquid to solid and is important because the material must be liquid for use in the molding process. The heat deflection temperature is the relative measure of a plastic material's ability to perform for a short period of time at elevated temperatures while supporting a load. In general, for a material to perform adequately in a lead-free surface mount connector application, it first must have a melting point above the expected 260°C peak temperature. To be reasonably assured of compatibility with lead-free surface mount soldering, its HDT should also exceed 260°C. However, there is a "gray area" in which a material may have a melting point above 260°C, but a HDT at or just below 260°C. In these cases, the particular product application must be considered and specific engineering tests may be required. Products that fall under this condition will be tested according to a test standard that Molex has adopted for qualifying products to the higher lead-free reflow soldering temperature. A copy of the test standard can be found here.

The following chart shows melting points and heat deflection temperatures for common plastic materials used in connectors today.

Material	Heat Deflection Temperature	Melting Point
PBT	205°C	220°C
SPS	245°C	300°C
PA 6/6	250°C	255°C
PCT	255°C	310°C
PPS	265°C	320°C
PPA	285°C	330°C
PA 46	290°C	300°C
LCP	270°C	335°C

As can be seen, there are materials currently used today that will withstand the higher lead-free surface mount soldering process temperatures (PPA, PA46 and LCP) and some that will need to be evaluated according to their specific application (PCT and PPS). In general, the materials with higher temperature compatibility are also more costly. As a result, any products that require material replacement for higher temperature compatibility will also have a concurrent cost increase.

Conversion Strategy

Molex's conversion strategy and associated material selection is based on customer feedback that indicates the industry will use a mix of lead-free and lead-bearing products as lead is phased out of electrical and electronic products. During this transition, lot number/production dates and special labeling will be used to differentiate products.

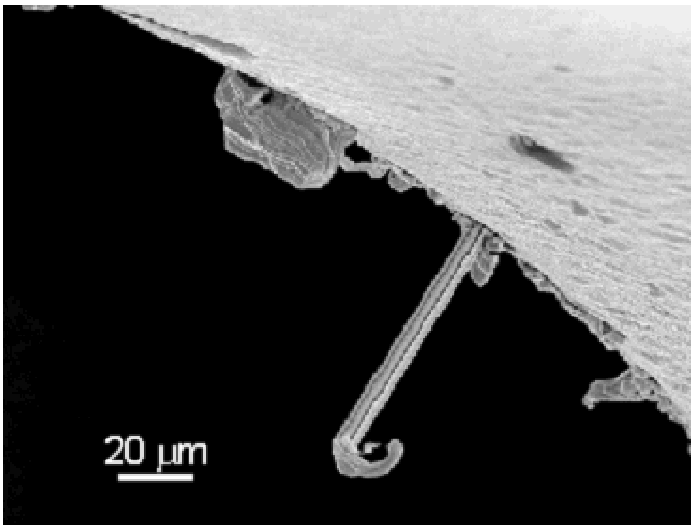
A two-phase lead-free conversion approach addresses the concern over the proliferation of new part numbers. The first phase of the approach is focused solely on the removal of lead from products, in this case the tin-lead plating. It purposely does not address the temperature compatibility of plastic housings. In this first phase, current tin-lead plated terminals would be converted to pure tin plated terminals. Because of the experience we have in using a pure tin finish and its compatibility with both the proposed lead-free assembly processes and the current tin-lead soldering process, there is a minimal risk in switching to pure tin. As such, a broad blanket conversion will be possible as customers will see no change in performance.

The second phase of the strategy will involve testing of our products’ plastic housing materials at the higher reflow soldering temperatures associated with lead-free assembly processes. For those products that require a change in the plastic housing material due to incompatibility with the higher temperatures, a new part number will be assigned. These parts would be defined as lead-free process compatible. Product from the first phase of the strategy would be defined as lead-free.

Technical Information

Tin Whiskers

Pure tin or high tin content alloy plating finishes have received significant scrutiny of late because of the fear that they may grow tin whiskers. Tin whiskers are hair-like crystals that can grow spontaneously from the surface of tin and high tin content alloys and, in some cases, can potentially cause electrical shorts. They appear to be driven by the release of stress that has been induced in the plating finish.



Photomicrograph of a tin whisker

Despite a significant amount of effort within the electronics industry, the fundamental mechanisms that cause whisker formation are not yet fully understood. In addition, numerous studies have attempted to identify accelerated tests for longer-term validation of the absence of whiskers. While no acceleration factors have been established correlating these tests to actual field performance, the predominant accelerated test methods that have evolved from these studies appear to have converged on the application of one or more of the following conditions:

- Compressive stress
- Heat
- Humidity
- Thermal Cycling

Molex initiated tin whisker studies in 1999 and they continue today. The results of an initial study are summarized in a document entitled Tin Whisker Test Report.

Based on the results of this testing and studies conducted by various groups and individuals in the electronics industry, a test standard for qualifying lead-free finishes with respect to tin whiskering has been adopted. A copy can be downloaded here.

For more information, contact leadfree@molex.com.