Application Information

Chemical Exposure of Devices

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Introduction

Allegro™ MicroSystems manufactures semiconductor devices with standard internal aluminum interconnects, and with external copper terminations plated with tin. The silicon-based device is molded in a standard non-hermetically sealed epoxy package. Customers may wish to use Allegro devices in a wide array of configurations, applications, and situations where exposure of the Allegro device to environmental elements and humidity, chemical solutions, motor oil, transmission fluid, road salts, and so forth, may occur. These different types of chemical exposures of the Allegro device may result in corrosion and failure of the device under some circumstances.

This application note discusses the types of situations and applications that can give rise to failure of the device from corrosion. Please refer the Allegro website, www.allegromicro.com, in the Design Center section, for additional information that may be relevant on soldering and encapsulating, including the application notes *Soldering Methods for Allegro Products (SMD and Through-Hole)*, AN26009; *Guidelines for Designing Subassemblies Using Hall-Effect Devices,* AN27703.1; and *Guidelines for Leadforming Using Back-Biased Hall-Effect Devices*, AN296080.

Non-Hermetic Epoxy Packages

A hermetic package in the semiconductor industry is a ceramic package that seals the active silicon device completely from any and all chemical entry. A non-hermetic package in the semiconductor industry is a plastic package (filled epoxy) that covers, but does not seal, the active silicon device from chemical entry. For example, dye penetration test exposure results show that penetrating dye can be found inside all non-hermetic packages, but not inside hermetic packages. This is because the bond of the epoxy to the external terminations (copper leads) is not entirely intimate and can leave a micro-capillary void at the interface that is enough to allow chemical penetration.

The possibility of chemical penetration to the silicon active device means that no warranty or guarantee is possible from Allegro for corrosion failure of the device. It is therefore the responsibility of the customer to use the device in such a way as to minimize or prevent exposure of the device to corrosive chemicals. Chemicals which have been found to be corrosive to the internal silicon active device are (but not limited to): chlorides, phosphates, strong acids, strong bases, automobile exhaust gases, motor oils, transmission oils, ice melting salts, human contamination, and other automotive fluids. Because of the numerous varieties of chemicals, constantly changing commercial formulations, and unknown environments in which the device may operate, Allegro does not and cannot test or qualify chemicals for corrosion potential. It is therefore the responsibility of the customer or end user to qualify the final configuration of the device in the actual application environment or simulation.

In figure 1, aluminum interconnects on the silicon device are seen to have been corroded away, thus electrically disconnecting the circuits, after exposure in the field to a vehicle transmission oil. The device was confirmed by FTIR analysis to have the transmission oil on the surface of the silicon device, proving that penetration of the oil was complete. The package containing the device was not overmolded or conformal coated.

Reducing the Potential of Corrosion

The Allegro device may be protected from exposure to corrosive chemicals by eliminating the use of such chemicals and substituting non-corrosive chemicals in the application or assembly of our device. For example, if the device is to be soldered onto a circuit board or other soldering operation, the solder flux employed should be a non-halide-containing flux. Any chemicals used to remove flux residues should also be halide- and phosphate-free (this includes many organic solvents and organic compounds).

Using protective coatings over the package containing the device can also provide protection of the device from chemical exposure. Conformal coatings can be very helpful to prevent chemical entry into the package. Typically, conformal coatings are applied after the device package is soldered onto the circuit board, or wired or welded onto terminals, or mounted in an assembly. The conformal coatings can be sprayed, dipped, applied with a roller, potted, or injected onto and around the device. Note that a sprayed-on coating does not seal all surfaces completely because it is unidirectional and the underside of the device may not be sealed. Dipped or potted conformal coatings provide a better guarantee of complete sealing. There are hundreds of types and varieties of conformal coatings to choose from, the most common being silicone, urethane, and epoxy. These coatings can be heat cured, air cured, or UV cured.

Further protection can be used to protect the device package in harsh environments by potting or overmolding with a plastic. This is typically done for Hall sensor ICs used in ABS, transmission, cam timing, or other automotive applications. The device package should be fully encapsulated in the overmold plastic to provide a better seal from chemical entry. The raw material for the overmold should be of such a purity grade as to have low-ppm content of chloride and phosphate. A nylon (PA) type of overmold can present problems because it easily absorbs moisture which can accelerate corrosion. Specifically, a nylon 6 or 66 type is known to have severe problems with moisture absorption, while nylon 612 less so. A polyphenylene sulfide (PPS) does not absorb moisture much at all and can be a best choice for some types of applications. Any leads or terminations or wires emanating from the assembly should also be overmolded or sealed with secondary sealers, potting compounds or conformal coatings. In general it should be noted that plastics do not seal perfectly to other plastics. Also note that superglues (cyanoacrylics) are not recommended.

The accelerating factors and other conditions involved in producing corrosion failures are time, temperature, humidity, concentration of corrosive chemicals, quantity of corrosive chemical penetration into the electronic package, type of chemicals, and moisture. Human contamination from handling directly the devices during assembly by the customer can also lead to corrosion and the use of gloves and face masks are necessary to avoid this source of corrosion during subassembly or board mounting. Allegro takes great steps to ensure that every stage of its manufacture and assembly prevents contamination by the use of gloves, face masks, and full head-to-toe clean room gowns.

In general, the more layers of sealing material that are used (providing a more tortuous path for any chemical trying to enter),

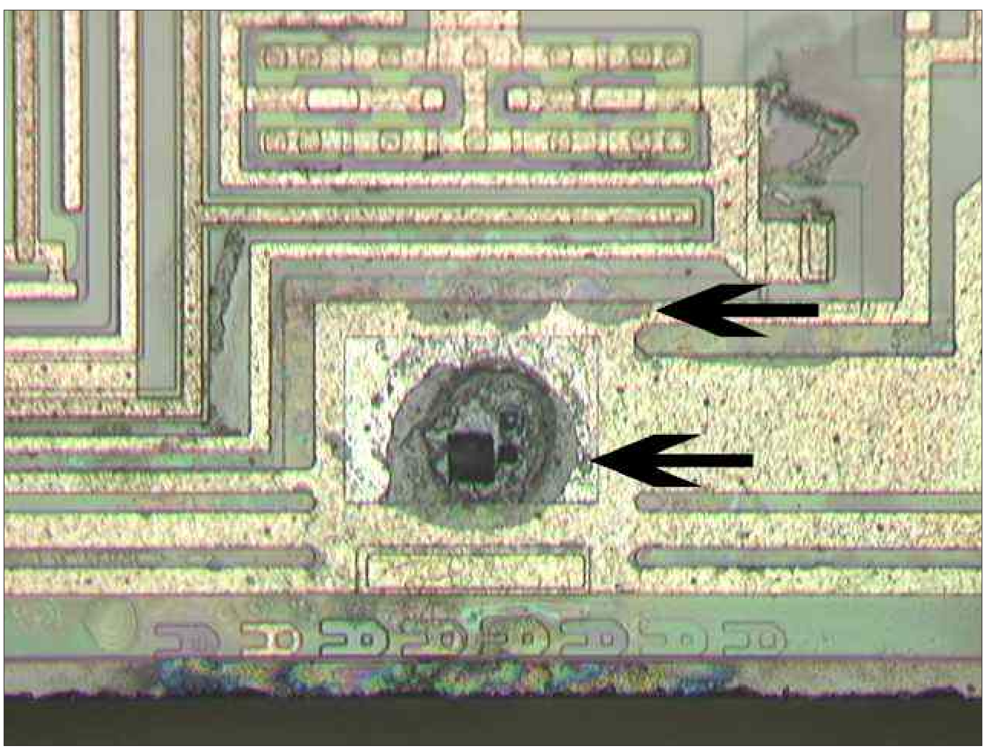

Figure 1. The arrows point to the corroded and missing aluminum metal on the device. Note that the gold wire bond to the pad (circular area) was corroded open and caused an electrical disconnect in this location causing the device to fail.

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the more the device is protected and the long term reliability increased. Thus the use of a conformal coating over the device followed by an overmold of plastic would provide far greater reliability from chemical corrosion than either a conformal coating or an overmold alone. The customer must choose the appropriate configuration for the expected application, exposure to corrosive chemicals and level of reliability needed.

Corrosive Contaminants

Leaching of various contaminates by water can occur over time, even in overmolded applications. During assembly processes, the high processing temperatures can accelerate leaching, but more significant are the long-term effects. This can lead to the formation of corrosive compounds after the end product has been sent to the field. Major contributors to corrosion are halide and phosphate compounds. Materials containing halides (chloride) and phosphates should be strictly avoided in the assembly process. This applies not only to fluxes, but also to solders and solder pastes, and to overmolding compounds. Of particular concern are nylon (PA) overmolding compounds, which can be highly susceptible to moisture absorption. The best defense against such corrosion is to eliminate halides from all materials used in the manufacturing process. For example, higher-grade nylons typically have minimal halide content. Such efforts should be supplemented by regular vetting of all process stages to ensure that no sources of contamination have been introduced. Sources can include not only materials consumed in manufacturing, but also substances that can be conveyed on the persons of production workers. Face masks, gloves, and suitable gowning should be in use at all times. The customer's assembly operations should also take precautions to prevent the contact of the devices with bare fingers and similar contamination. Note that finger prints contain salt (sodium chloride) which can be particularly corrosive.

Protecting Terminations from Corrosion

The terminations (leads) of the device are copper based with tin plating and are also subject to corrosion. Copper can be corroded by acids, salt, phosphates, and other corrosive chemicals. Similar chemicals can also corrode tin. If there is enough chemical exposure, the copper leads and plating can be attacked and dissolved, creating an open circuit, or the residues of a milder corrosion can provide a leakage path between leads that is conductive or produce a short from dendritic growth and this can cause an electrical failure of the device. Corrosive solder flux can be a problem if it contains chlorides or if active fluxes are not thoroughly washed off after soldering. The commercial designations for solder flux types are "aqueous clean flux" or "no clean flux." Both of these types of fluxes should be cleaned off the board to prevent any residues from either directly causing corrosion or preventing a good seal of a conformal coat or overmold material. The environment of the application could expose the leads to salt, automotive fluids such as automatic transmission fluid (ATF), engine oil, exhaust, or other chemicals, all of which over time could attack and destroy the integrity of the terminations. Therefore, attention should be paid to conformal coating, potting, or encapsulating with overmold compound the terminations as well as the entire package body.

Automotive Applications

The use of Hall cell devices in automotive applications where exposure to road salt, ATF, manual transmission fluid, engine oil, other automotive fluids and lubricants, and exhaust gases is one of the most potentially corrosive environments. Experience in the field (with hundreds of millions of devices) has resulted in few corrosion failures over the years, with overall corrosion levels in the ppb (parts per billion). Great care should be taken to design, engineer and manufacture automotive assemblies so as to minimize the chance for corrosive elements to enter the device and destroy it. Allegro recommends that protective coverings such as conformal coatings, overmolds, potting, and others be used to help provide layers of protection in these corrosive environments. Of the conformal coatings available such as silicones, urethane acrylics, and epoxies, the customer must select a coating and means of applying it that gives the best reliability. Note that overmolding with nylons does not provide the best protection by itself because nylons soak up moisture and contaminants readily. That is why potting compounds may be a better choice, or if nylons must be used (nylon 612 is the best of the nylons), they should be used with a good conformal coating over the Allegro package and leads prior to overmolding. Or PPS may be used, which does not have the moisture problems that nylons have.

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There are papers and articles in the literature clearly stating that ATF and other automotive fluids can corrode electronic devices. One such article is: "Improving Sensor Reliability", J. Titus, Test & Measurement World, 3/1/2005. Another is: "Corrosion Studies of Copper and Aluminum Interconnects Exposed to Automotive Oils," Toshiaki Ishii, Nobutake Tsuyuno, Toshiya Sato, and Mitsuhiro Masuda, IEEE Transactions on Components and Packaging Technologies, Vol. 29, No. 1, March 2006.

Conclusion

The cited papers show that the active silicon circuit is very susceptible to corrosion. The epoxy molding compound that Allegro uses to encapsulate the device offers a larger degree of protection than a bare silicon circuit, but it is not absolute. Further protection can be afforded by the use of additional overmolding (such as nylon or preferably PPS), potting (epoxy), or a properly applied conformal coating (sealing 100% of the surface area). Such protection can take the reliability toward the 0 ppm level goal that the industry is seeking, but cannot guarantee 0 ppm. In addition, extra protection could help reach the automotive industry goals of 10–15 years reliability. However, achieving a given reliability goal of the customer's assembly is the customer's responsibility, therefore Allegro assumes no liability for corrosion of its device in the customer's assembly from corrosive chemical exposure while in the application.

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Revision History

Number	Date	Description
–	September 8, 2017	Initial release
1	September 12, 2018	Minor editorial updates
2	September 18, 2019	Minor editorial updates

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