# RoHS: 10 Years Later – IT Equipment Corrosion Issues Remain

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**Abstract**
The European Union RoHS directive took effect in 2006, and of the 6 restricted materials, the elimination of lead from electronic devices took the most development effort and had the worst degrading effect on hardware reliability. One negative impact was the brittleness of the lead-free solder alloys that replaced the industry favorite, ductile Sn-Pb eutectic alloy. Another was the unexpected occurrence of creep corrosion on printed circuit boards using alternative PCB surface finishes. Along with the implementation of RoHS, the miniaturization of circuits, the expansion of IT markets in developing countries with high-levels of sulfur-bearing gaseous pollution, and the trend towards energy saving by resorting to free-air cooling, have all led to increased rates of corrosion-related hardware failures associated with particulate and gaseous contamination. The IT industry has taken a two-pronged approach to mitigating these failures: (1) by making the products more robust against contamination and high humidity levels; and (2) by gaining better understanding of the allowable levels of contamination, temperature and humidity under which IT equipment can operate reliably.

Additionally, many points along the supply chain have been identified where corrosion can form, and the additive effects may or may not be detected by testing or manifest themselves before delivery to the end-user. Failures at this point may be due to the cumulative effect of numerous "micro-failures" generated throughout the supply chain. However, what remains most frequent are product failures resulting from exposure to elevated pollutant levels and inadequate environmental controls at manufacturing locations. The result is an operating environment that does not meet current manufacturers' warranty requirements – requirements that have been put into place since the implementation of RoHS. This paper will describe the common modes of corrosion-related hardware failures in the past 10 years, the actions taken to make the products more robust, the understanding of the role played by contamination, and the means of negating their detrimental effects. The case will also be presented for environmental monitoring at various points along the supply chain and the addition of enhanced air cleaning for those locations that do not meet the air quality requirements of the finished devices. Data will be presented that highlight the need for air quality assessments of manufacturing facilities, where enhanced air cleaning is indicated, and the benefit of establishing an ongoing real-time air monitoring program to assure compliance with air quality specifications and warranty requirements.

## Introduction

The physical environment surrounding a printed circuit board (PCB) is defined by the temperature, humidity and gaseous and particulate contamination in the air. Environmental factors can cause PCBs to fail in two ways: First, electrical open circuits can result from corrosion, such as the corrosion of silver terminations in surface mount components. Second, electrical short circuits can be caused by (a) copper creep corrosion, (b) electrochemical reactions such as ion migration and cathodic-anodic filamentation or (c) settled, hygroscopic particulate matter contamination reducing the surface insulation resistance between closely spaced features on PCBs [1].

In 2006, the European Union's RoHS directive [2] banning the use of lead in solders led to changes in PCB finishes and the elimination of lead from solders, however, these changes dramatically increased the PCB failure rates due to sulfur creep corrosion. In the past decade, IT and datacom equipment manufacturers have learned to make their hardware more robust against these two failure modes, which occurred predominantly in geographies with elevated levels of sulfur bearing gaseous contamination [3].Still, even as these manufacturing changes were being widely implemented, the failure rates continue to be higher than in the pre-RoHS era. Printed circuit boards (PCBs) continue to suffer corrosion-related failures from a number of mechanisms that include open circuits due to corrosion of the metal terminations on surface-mount components; short circuits due to cathodic anodic filamentation and ion migration; and short circuits due to creep corrosion.

Changes in the design and operational practices in data centers have presented new concerns with regards to equipment reliability and uptime. These concerns center around 1) the use of elevated temperatures and humidity levels inside data centers for energy conservation and 2) the use of 100% outside air in place of mechanical cooling (i.e., free cooling). With data center administrators resorting to ever more use of direct evaporative air cooling to reduce energy usage, PCBs are increasingly suffering intermittent failures due to the deliquescence of dust coming off the cooling water.

Although failures of finished commercial and industrial products have had higher visibility, the contribution of failures from corrosion accumulated throughout the supply chain is only beginning to be examined as a likely route of electronic hardware failures. This includes all points along the manufacturing path from semiconductor manufacturing to final device assembly. It is suspected that many products, e.g., servers and hard drives used in IT / datacom equipment, may already be predisposed to corrosive failure due to poor manufacturing environments which will be discussed later in this paper.

**Creep Corrosion**

Amongst the various failure modes, creep corrosion has been the dominant corrosion-related failure mechanism since the implementation of ROHS in 2006.The restriction of lead metal in PCBs has forced the use of surface finishes, such as organic solderability preservative (OSP), immersion silver (ImAg), electroless nickel immersion gold (ENIG), immersion tin (ImSn) and various other finishes to enhance PCB solderability. Some of these finishes have made the PCBs susceptible to creep corrosion failures in corrosive environments high in sulfur-bearing contaminations [4-7].Creep corrosion, shown in Figure 1, is a mass transport phenomenon in which solid corrosion products (typically sulfides and chlorides) migrate over a surface without the influence of an electric field and short circuit neighboring features on PCBs. Creep corrosion is highly surface sensitive and only occurs on surfaces when two prerequisites are met: a site for generating corrosion product and a surface for supporting the creep of the generated corrosion product [8-10].

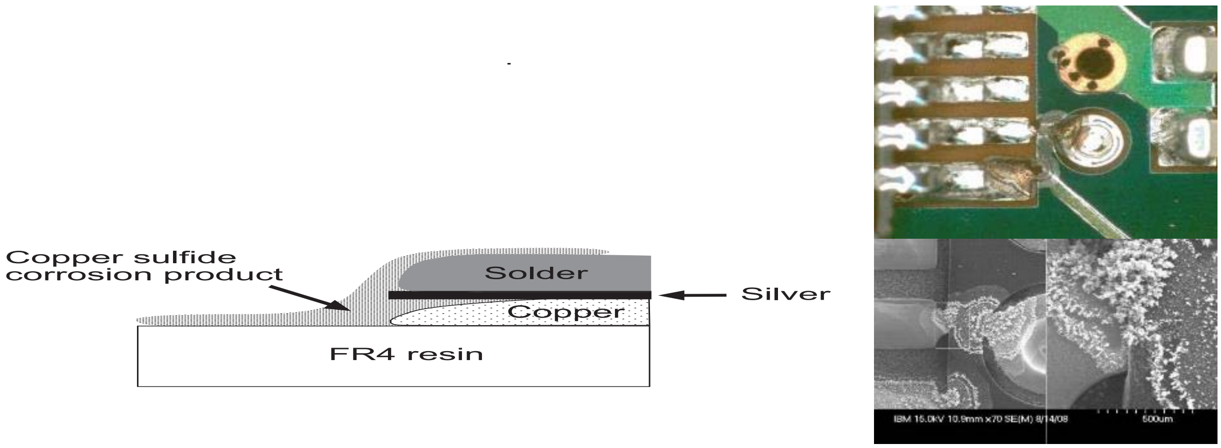


**Figure 1: Schematic showing creep corrosion in cross section. Creep corrosion picture in color is at top right and a scanning electron micrograph is at the bottom right [11].**

For instance, for PCBs with ImAg finish, both Cu and Ag will corrode readily to form sulfides on ImAg plated Cu pads. However, if the surrounding surface (such as clean FR-4 and solder mask surface) does not support creep of sulfides, the corrosion product will stay on the pad where it was generated. No creep corrosion will occur. On the other hand, if the surrounding surface is contaminated solder mask, creep corrosion may occur. It was generally believed that high relative humidity will increase the propensity to creep corrosion just as it increases corrosion of most metals. But the iNEMI task force on creep corrosion on PCBs conducted tests on the effect of relative humidity and showed that creep corrosion can occur at relative humidity levels as low as 15% for some ImAg finished PCBs. On the other hand, in these test runs, ENIG finished PCBs suffered creep corrosion at high humidity in the 74-80% range and OSP finished boards suffered no creep corrosion at any humidity [11,12]. Data center administrators cannot just simply lower the relative humidity to alleviate creep corrosion without having to take the costly step of gas-phase filtering the air in the data center to remove the sulfur-bearing gaseous contamination. So, the solution to the creep corrosion problem is to use a finish that is resistant to creep corrosion such as OSP and ImSn (immersion tin), and to ensure that the data center air falls within the G1 severity level of ANSI/ISA 71.04-2013 [13]. Acceptable air quality must be such that the copper and silver corrosion rates are less than 300Å and 200Å/month, respectively.

**Surface-Mount Resistor Corrosion [14]**

Another failure mechanism dominant in the last decade was the electrical open circuiting of surface-mount resistors due to the corrosion of the silver terminations in environments high in sulfur-bearing gaseous contamination. Surface mount resistors, shown in Figure 2, are bonded assemblies of materials with very differing temperature coefficients of expansions (TCE). Temperature changes mechanically stress the resistors weakening and cracking open the assemblies at the material boundaries through which sulfur-bearing gases can ingress and attack the silver terminations. The silver sulfide thus formed has higher volume than the silver it came from. The resulting internal mechanical stress further stresses and opens the cracks between materials increasing the rate of ingress of sulfur bearing gases. Thus, a corrosion positive feedback takes effect leading to the localized consumption of the silver termination resulting in an electrical open. Failures can be avoided using resistors that have multiple passivation layers protecting the underlying silver metallization at the terminals. In addition, data center air quality can be kept with the G1 severity level of the ANSI/ISA 71.04-2013 standard.

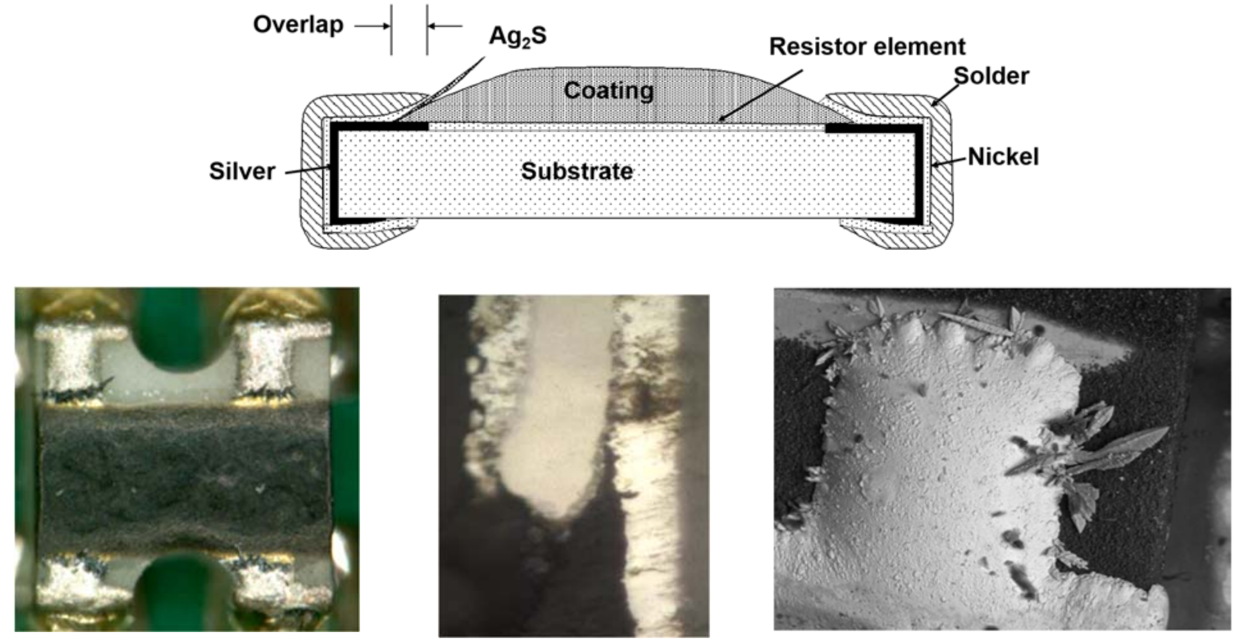


**Figure 2: (Top) Schematic of a surface mount resistor in cross section. (Bottom left) Top view of a corroded resistor pack; (Bottom middle) Corroded surface mount resistor in cross section; (Bottom right) Corroded resistor showing the silver sulfide needles growing out of the resistor.**

**Direct Evaporative Air Cooling and Air-Side Economizers**

With the increasing use of airside economizers and of direct evaporative air cooling, the relative humidity control in data centers is becoming lax and prone to excursion well above the ASHRAE recommended 60% relative humidity limit [13]. Air side economizers allow outside air to be blown into data centers when the outdoor air is cool, saving on the compressor energy used for room air conditioning. Direct evaporative air coolers blow air through a curtain of water mist, cooling the air due to the latent heat of evaporation of the water. Both these methods of air management in data centers expose the hardware to high humidity which can result in increased corrosion incidents. A common mode of failure that can occur in high humidity conditions are electrical short circuits due to (silver) ion migration.

**Ion Migration [14,15].** Under high relative humidity condition, well above the ASHRAE recommended 60%, moisture can be adsorbed on PCB surfaces forming electrolytic bridges between closely spaced silver metallization on PCBs. Silver from the positive pad of the PCB can form ions which can drift under the influence of an electric field and deposit on the negative pad. The deposits can take on a dendritic morphology bridging and thus short circuiting the gap between the two silver-plated pads. Figure 3 shows an example of silver dendrites growing between pads. The dendrites also contain sulfur-bearing contamination that probably aided in the silver migration hastening the phenomenon.

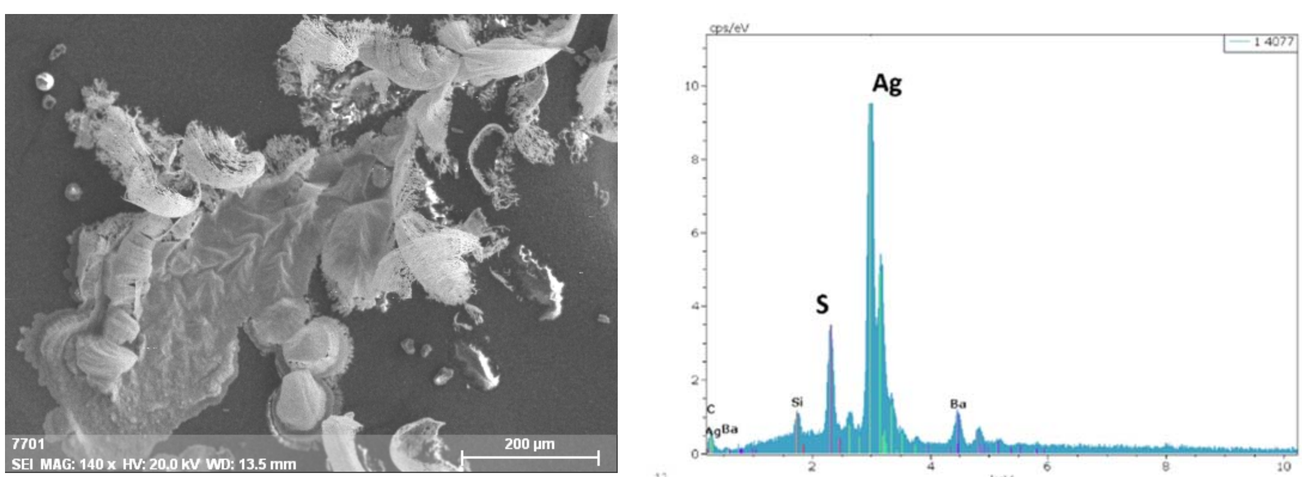


**Figure 3: Silver dendrites growing between silver pads on a PCB. The X-ray elemental dispersive analysis to the right shows that the silver dendrites are growing in the presence of a sulfur-containing contamination.**

**Corrosion in The Supply Chain**
RoHS applies all the way up and down the IT and datacom equipment supply chain; from semiconductor device manufacturers, all the way up to companies selling finished products such as servers, switches, routers, hard disk drives, etc. However, even with companies being diligent in requiring RoHS-compliant product certification throughout their supply chains, this does not mean that the materials being provided are not susceptible to corrosion.

In the early days of RoHS compliance, one failure mechanism caused by the lead-free transition that was not foreseen by the industry was that products produced with an immersion silver (ImmAg) surface finish will creep corrode in what some electronic equipment manufacturers considered to be high sulfur environments. i.e., ISA Class G2 or higher. And due to inherent processing difficulties with other surface finishes, ImmAg boards quickly became one of the standard printed circuit board finishes in the electronics industry [4]. It was not just circuit boards that were affected as RoHS compliance included items such as:

- Printed wiring boards
- Connector materials
- Pin connectors
- Plated-through-hole devices
- Leadframes
- Ball grid arrays
- Server and storage products
- Multi-layer ceramic capacitors
- Other common electrical components

While IT and datacom equipment manufacturers knew that there would be some reliability concerns with the switch to lead-free materials even before RoHS took effect, they did not anticipate that the use of ImmAg and other materials would have caused such a huge increase in failure rates. Previous experience had not prepared them for corrosion-related failures – even in urban areas with elevated levels of corrosive contaminants such as sulfur and nitrogen oxides, ozone, chlorine, and hydrogen sulfide. And with economics being what they are in this industry and many others, a great deal of manufacturing had been moved to regions with historically poor air quality – China, India, and SE Asia. This includes everything from basic semiconductor devices to final product assembly.

Because much of the supply chain for IT / datacom equipment are in areas where pollution levels present a high potential for corrosion and these suppliers do not have the same environmental requirements regarding corrosion as for IT / datacom equipment (i.e., ISA Class G1), high volume components may already have corrosion damage before they get to the next link in the supply chain. Without 100% inspection of each device, component, and/or assembly, these "micro-failures" could predispose the final products to corrosive failure if the proper environmental controls have not been put in place.

The following sections will present environmental monitoring information collected from four component manufacturers within the supply chain for one major IT equipment manufacturer, with emphasis on the presence and distribution of corrosive chemicals within the manufacturing environment and the effectiveness of contamination control strategies.

**Leadframe Manufacturer.** This firm is a global non-memory semiconductor supplier with a manufacturing facility in Dongguan, China that provides wire frame products. This company provides services from customized integrated circuit leadframe design to a wide range of standard products, including heatsinks and stiffeners, SOIC (small outline integrated circuit), QFP (Quad Flat Package), TQFP (thin quad flat package), PDIP (plastic dual in to package), PLCC (plastic leaded chip carrier) and TSOP (thin small outline package).

This facility is in an industrial park with significant vehicular traffic and is across the street from a recycling plant. Production personnel had reported evidence of corrosion based on visual discoloration of the silver on leadframes they were producing. Internal inspection and QC testing showed increased failure rates caused by what was identified as a "black oxide."

Several samples were sent for further analysis using scanning electron microscopy with energy-dispersive x-ray spectroscopy (SEM-EDS) to look at several areas on the leadframes. Where the leads end at the center of each pattern was a slight yellow color (Figure4, as seen with unaided eye). Trace amounts of sulfur were found to be associated with the silver layer. The source or type of sulfur contamination observed could not be determined nor could a quantitative analysis be performed. Sulfur was not detected on the copper or the iron-nickel region. This is consistent with our experience on corrosion forming in a temperature and humidity-controlled environment. At these levels of $H_2S$ and/or $SO_2$, it would be expected to see corrosion forming on the silver due to low humidity attenuation of corrosion on the copper.

The leadframe substrate appeared to be an iron-nickel (FeNi) alloy. Figure 5 shows a reflected light darkfield image showing the iron-nickel substrate as a dark grey. The lead ends are coated with a fine-grained silver with a thin copper layer beneath (probably to promote adhesion of the silver to the FeNi substrate).

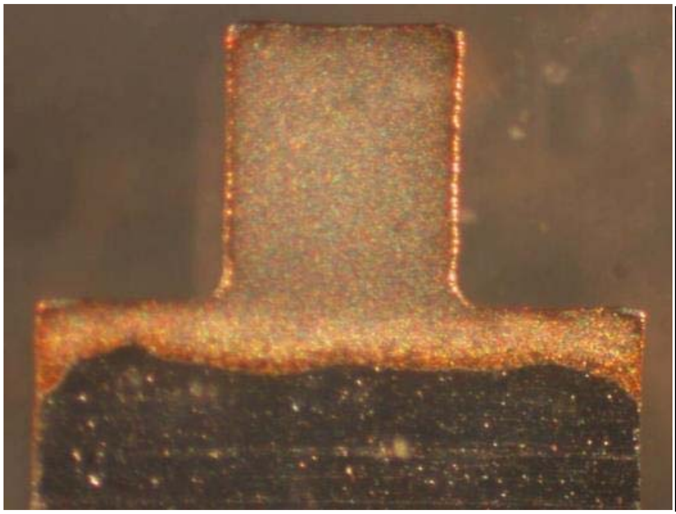

**Figure 4. Leadframe connector showing visible corrosion on the copper-silver junction.**

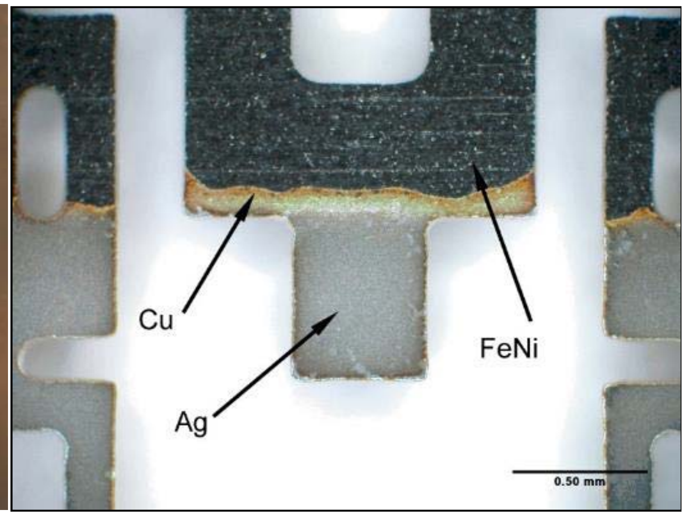


**Figure5. Magnified view of leadframe connector showing different metal layers.**

An environmental analysis was performed using corrosion classification coupons (CCCs) and the results indicated that the outdoor air and air in the production areas would be classified as ISA Class GX and G3, respectively, which greatly exceeds the general reactivity monitoring acceptance criteria of Class G1. Active sulfur compounds, sulfur oxides, and inorganic chlorine were detected – all of which can cause corrosion and process-related problems.

The company contracted a local environmental firm to provide additional air quality monitoring. They had installed wet scrubbers in the makeup air handlers and wanted to check the effectiveness against those contaminants of concern. The results from outside and inside the manufacturing areas (Table 1) confirmed the types of chemical contaminants identified by the CCC analysis and the effectiveness of the wet scrubbers.

***Table 1***. *Air Monitoring Data*

| | **Contaminant Gas Concentrations, (ppb)** | | | | |
|---|---|---|---|---|---|
| Outdoor Air | **$Cl_2$** | **$H_2S$** | **$SO_2$** | **$NO_2$** | **HCl** |
| | 345 | 717 | 382 | 531 | 670 |
| Manufacturing Area, ppb | | | | | |
| 1st Floor | 5.52 | 12.19 | 10.7 | 21.24 | 33.5 |
| 3rd Floor | 4.49 | 7.89 | 34 | 23.36 | 34.84 |
| After Wet scrubber, ppb | | | | | |
| 1st Floor | 2.07 | 11.47 | 7.64 | 13.28 | 26.8 |
| 3rd Floor | 3.11 | 0.72 | 8.79 | 8.5 | 25.46 |
| Wet Scrubber Efficiency, % | | | | | |
| 1st Floor | 62.50% | 5.91% | 28.60% | 37.48% | 20.00% |
| 3rd Floor | 30.73% | 90.87% | 74.15% | 63.61% | 26.92% |

Although the wet scrubbers showed some effectiveness against most of the contaminants, these systems required constant maintenance (maintaining proper pH in the system using a liquid caustic solution) and spent scrubbing solution had to be disposed of using a certified waste hauler. Further, the concentrations of chlorine and hydrogen sulfide being delivered to the manufacturing areas did not bring the corrosion level down to the desired ISA Class G1.

New air cleaning systems employing dry-scrubbing, gas-phase air filtration media in 25 mm deep beds in V-bank modules were installed in the makeup air handlers and the results of CCC monitoring showed air quality in all manufacturing areas to be ISA Class G1, with no evidence of active sulfur or chlorine contamination. Continued CCC monitoring in the production areas, and especially the silver plating areas, confirmed that the proper use and maintenance of these air cleaning systems could significantly reduce corrosion-related failures.

**Semiconductor Assembly and Test Company**. This company, also located in Dongguan, China, provides semiconductor package design, assembly, and test services. It manufactures chipscale packages (CSPs) that include fine pitch ball grid array (BGA), leadless plastic chip carriers, and thin array plastic packaging which provides metallic contacts to the circuit board allowing high density circuitry in a small footprint package. The company also provides Non-CSP laminate packages comprising Plastic BGA packages; Tape BGA packages that offer thermal management and enhanced electrical performance using a flexible circuit substrate bonded to a copper plate; and flip chip packages that use solder balls to connect to the printed circuit board. In addition, it offers Non-CSP leadframe packages are used in electronics applications, including automobiles, household appliances, desktop and notebook computers, and telecommunications products. Further, the company provides test services for digital logic, analog, mixed signal, and RF products.

This is a sister company of the leadframe manufacturer described above and who purchases essentially all that plant's production for their ICs and circuit boards. RoHS compliance was evident on many signs and posters and the Facility Manager was up-to-date on compliance, but not on the IT / datacom equipment manufacturers' ISA warranty compliance requirements relative to corrosion.

Because they were in the same general area as the leadframe manufacturer, they were very interested performing an environmental assessment using CCCs. As above, the results of the CCCs used for outdoor air indicated an ISA GX severity level with evidence of active sulfur, sulfur oxides, and inorganic chlorine. Inside the facility, monitoring indicated a G2/G3 environment. When asked, staff was not aware of any corrosion-related issues although they did report that they often rejected entire lots of leadframes from their sister company due to higher than acceptable failure rates. This causes internal problems with production scheduling and the requirement for increased inspections – both with in-production materials and finished products. This resulted in added costs, slowed production, and having to reschedule customer shipments.

This company was already using chemical filters but did not have a media life testing program in place. CCCs were placed upstream and downstream of the chemical filters and results indicated that (on average) the copper and silver corrosion rates were reduced by ~65%, with all the active sulfur and chlorine contamination being completely removed by the system. However, this testing showed that even with this reduction in corrosion rates, the air being delivered to the production areas would still be classified as ISA Class G2.

**Semiconductor Manufacturer**. This firm located in Bangkok, Thailand is a semiconductor facility for assembly and testing of integrated circuits (IC). With a production area of 55,220 $m^2$ on a 63,000 $m^2$ site, this facility is dedicated to assembly and testing of standard products, microcontrollers, and mixed signal integrated circuits.

This facility was built in 1974 and the cleanroom production areas are served by makeup air handlers not originally designed for the current cooling requirements. Because of this, temperatures are higher than in comparable cleanrooms and the humidity levels can vary significantly (±15%) during a work day. This, coupled with the poor air quality in Bangkok, presented an unacceptably high corrosion risk potential.

The Facility Manager discussed that they continually experienced silver corrosion problems on leadframes and legs of ICs. In fact, workers routinely discard 1-2 layers of leadframes from a roll before starting production because the silver had "turned black" overnight (Figure 6) and using those leadframes could have resulted in failure of finished devices that may not be discovered during final inspection.

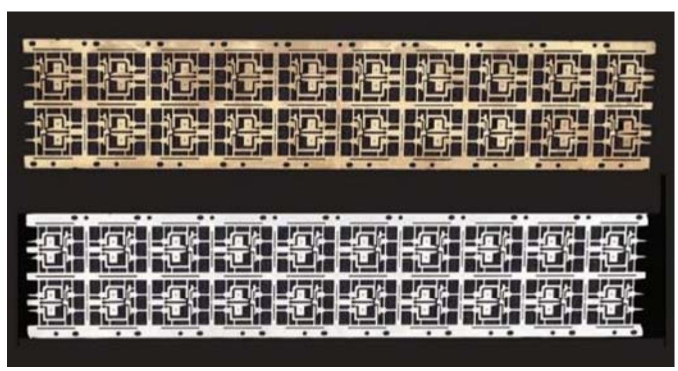

**Figure 6. Leadframes taken from in-production material exhibiting corrosion (top) and without corrosion (bottom).**

The lack of proper environmental control resulted in higher contamination and corrosion rates inside the production areas. CCC monitoring indicated average copper and silver corrosion rates at more than 10-15x higher than the prescribed ISA G1 severity level, with evidence of both sulfur oxide and inorganic chlorine contamination.

This facility purchased 6 ACMs to provide real-time monitoring in the production areas and the results confirmed the initial CCC assessment. The data indicates generally higher than acceptable (silver) corrosion rates, with some areas generally meeting

ISA Class G1 (Figure 7). The company is having internal discussions to determine whether ISA Class G1 should be their acceptance criteria or whether Class G2 would be acceptable with their production requirements.

**Hard Disk Drive Component Manufacturer**. This company specializes in designing, developing and manufacturing suspension assemblies for the hard disk drive (HDD) industry. Suspension assemblies are a critical component to position the read/write heads above the data on the surface of the spinning disks in the HDD. They are critical components to the reliability and performance of HDDs.

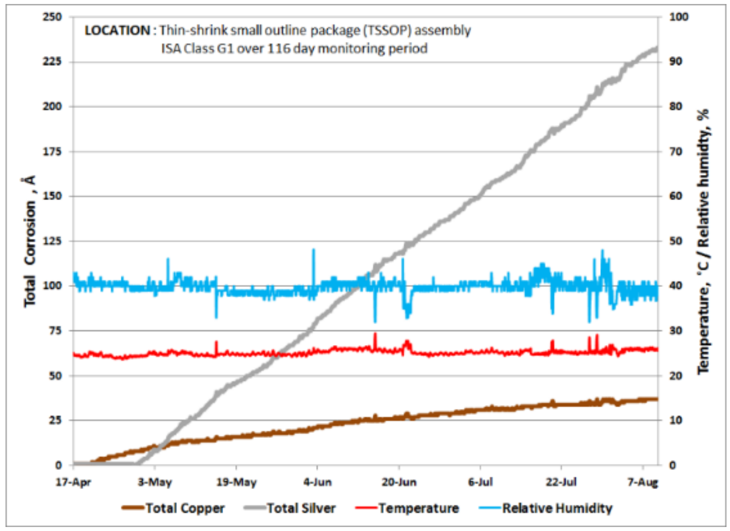


**Figure 7. ACM monitoring data from TSSOP production area.**

Since the implementation of RoHS, this firm was experiencing a higher than expected failure rate of head stack assemblies (HSAs) due to corrosion. Even for those HSAs that did not fail, more than 60% of these showed some evidence of corrosion (Figures 8, 9). Almost all the corrosion identified by failure analysis was due to sulfur creep corrosion. It was suspected that this contamination was being introduced into the manufacturing areas by the makeup (outdoor) air handling systems.

An environmental assessment was performed using both copper-silver CCCs and real-time ACMs. CCCs were placed in the makeup and recirculation air handlers and the ACMs in those production areas having the highest failure rates. Results of this assessment indicated an average ISA severity level of a mid-to-high Class G2 with evidence of sulfur oxide and inorganic chlorine contamination in all makeup air handlers and almost all the production areas monitored.

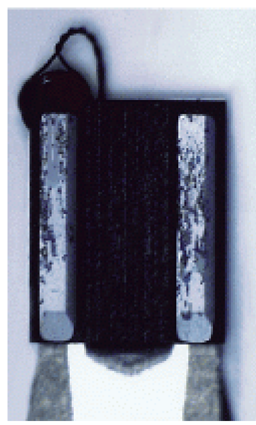

**Figure 8. Hard disk read/write head showing corrosion.**

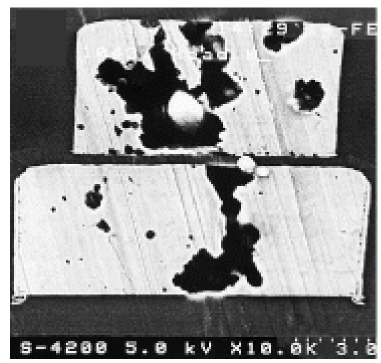


**Figure 9. Hard disk head slider showing corrosion.**

To address these contamination issues, an air quality specification was developed and stated that air quality in the manufacturing areas shall meet a severity level of ISA Class G1 for both copper and silver with no indication of chlorine contamination.

Gas-phase air filters were installed in each of the makeup air handlers to remove the sulfur oxide and chlorine contaminants and in the recirculation air handlers to provide an additional level of air cleaning. These filters employed an extruded carbon composite media with enhanced capacity for acid gases. Within a few days after installation, data from the ACM indicated that the contamination had been effectively removed and the corrosion rate dropped to the specified ISA Class G1 (Figure10).

**Summary and Conclusions**

From 2006 to 2008, the number of corrosion-related failures of IT/datacom equipment directly attributable to lead-free manufacturing regulations – by conservative estimates – increased by upwards of 250%. This was primarily due to failures caused by silver sulfide creep corrosion on devices using an ImmAg surface finish, corrosion of silver metal on the legs of ICs, and corrosion of silver finish component leads.

Between 2009 and 2011, as manufacturers began to replace silver with other materials, the failure rate stabilized and showed a slight decline, but failures were still above pre-RoHS levels.

In 2011, when ASHRAE TC 9.9 published their updated Thermal Guidelines, there was another increase in failure rates due to data centers starting to operate at higher temperatures for energy conservation. This combined with highly variable humidity levels inside many of these facilities, were enough to increase the rate of corrosive attack. Data centers that would have otherwise shown an ISA Class G1 severity level were now ISA Class G2 / G3. Now, any components already showing corrosion were more likely to fail sooner rather than later.

Some might argue that primary concerns with regards to corrosion-related product failures remain at the end-user level which have put IT/datacom equipment manufacturers in an uncomfortable position of having to defend their product quality – even 10+ years after RoHS was implemented. Failures at the macro level erode customer loyalty and satisfaction, not to mention erode the bottom line due to warranty replacement costs.

A few manufacturers have become very aggressive by placing the onus on their customers to provide proof that they are meeting all their product warranty requirements, including meeting and maintaining an ISA Class G1 environment. This protects the manufacturer but still does not necessarily get to the root of corrosion-related failures.

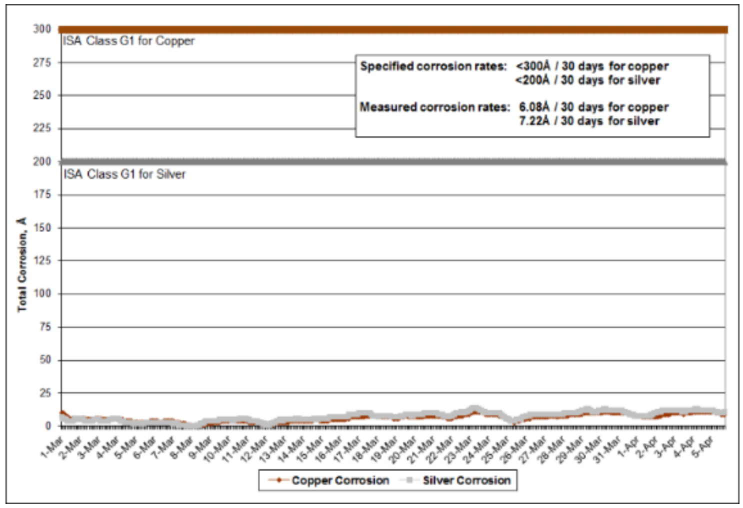


**Figure 10. Reactivity monitoring data from ACM showing reduction in corrosion rates after installation of chemical filters. Acceptable ISA Class G1 levels for copper and silver are shown as solid bars at 300Å and 200Å, respectively.**

Lead-free products will corrode in high sulfur environments (≥ISA Class G2) and corrosion failures have increased dramatically over pre-RoHS levels. Even though a server failure gets the attention, the most common failures are with the most common components: capacitors, transistors, DIMMs, graphic cards, motherboards, HDDs, etc.

These components have their start far upstream of the final product and it has been shown that corrosion can start at the semiconductor level. Micro-failures that may cause signal degradation or short circuits may not be problematic by themselves. However, if micro-failures accumulate at each step in the supply chain, it might not take much in terms of contamination and/or high/variable temperature and humidity where the finished product is installed to push it over the edge towards corrosion failure. Information from several electrical component manufacturers in the supply chain of a large multinational IT equipment manufacturer has been provided. Elevated corrosion levels were detected inside the manufacturing areas at all locations, and the results of environmental assessments, the contaminant control strategies put in place, and the results of ongoing air quality monitoring have been presented. This has highlighted the potential, if not the actual cause, of failures experienced at end-user locations.

The rapid expansion of the IT and datacom equipment market in certain polluted geographies of Asia that have elevated levels of gaseous contaminants in the ambient air and the increasing use of "free cooling" for energy conservation has resulted in an uptick in corrosion-related IT/datacom equipment failure rates that had been declining in previous years. This may not be entirely the fault of the IT/datacom equipment manufacturers – especially if they are too focused on keeping their downstream clients happy instead of looking back upstream at their component vendors.

Miniaturization of electronic components combined with reductions in feature spacing on PCBs and the loosening of the data center temperature and humidity envelope to save energy is making electronic hardware more prone to failure due to exposure to ambient pollutants. In this paper, the case has been made for the requirement for electrical component manufacturers up and down the supply chain to develop and implement, at the very minimum, an air quality monitoring program to establish a baseline for corrosive contaminants relative to ISA Standard 71.04-2013. Severity levels of Class G2 or higher should indicate the potential for corrosion-related product damage and/or failures. Steps should be taken to bring the environment down to ISA Class G1, with no evidence of active sulfur or inorganic chlorine contamination.

This will require better temperature and humidity control but, most likely, means the addition of chemical filtration to clean outdoor air before it is brought into and distributed throughout the facility by the makeup air handling units. There are many options available for air cleaning for corrosion control, from combination particulate-chemical filters for use in computer room air conditioning (CRAC) units, to flat panel extruded carbon composite filters or "V-bank" media modules for existing air handling units, to standalone recirculating air cleaning systems for use inside manufacturing areas. All of this helps to work towards the goal of eliminating corrosion as the cause for electrical component and electronic product failures.

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