A Survey on Electronic Corrosion and its Prevention

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Abstract : Corrosion of complex electronic equipment is an increasingly serious problem, causing expensive damage. Corrosion occurs throughout the entire life cycle during different stages of manufacturing, assembly, transport and storage of components and assemblies and during field operations of the equipment. Presence of moisture, chloride, sulphur dioxide, hydrogen sulphide and other airborne corrosives, meteorological parameters etc influence the occurrence of corrosion. The present review describes the current understanding mechanism of corrosion of electronic components and equipments in different environmental conditions. The various corrosion testing methods and methods of corrosion prevention in these electronic devices have also been elaborated.

***IndexTerms* – PCB, Electronic Waste, Corrosions.**

I. INTRODUCTION

Corrosion is the process of gradual deterioration of a metal from its surface due to the unwanted chemical or electrochemical interaction of metal with its environment. The corrosion of metal causes loss of metal, unpleasant appearance, high maintenance cost and finally service failure. Electronic industries are the major field of application in present scenario. Electronic devices have vast applications in various fields of medical, aerospace, automotive sector, telecommunication, defense as well as various house hold equipments like television, cell phone, electrical appliances with digital display etc. These devices are operated in varying climatic conditions. Several environmental factors play significant role in proper service of electronic equipments. Some of the common problems caused by corrosion in electronic components are: Destruction and loss of materials, Nasty appearance, Increase in contact resistance, Leakage current, Soldering detachment, rusting on steel part, Oxide layering, Short circuit and Operation failure The factors that affect corrosion in electronics are: Moisture and humidity, Corrosive gases, Accumulation of Dust particles, Microbes, Heat, Solar radiation, Interruption in power supply, Low or high voltage, Loose fitting of connections, Mechanical vibration, Dissimilar metals such as gold and aluminum (Au & Al) in contact, Presence of an electrolyte at the interface of two dissimilar metal contacts etc. Some of the main components of an electronic device which are prone to be corroded or damaged due to environmental impact resulting to an inadequate service or a system failure are Integrated Circuits (ICs), Printed Circuit Board (PCB), Transistors, Capacitors, Diodes, Switches, Cable connectors, Hard disc, Packaging and shielding parts etc

II. MATERIALS IN ELECTRONIC SYSTEMS

From the viewpoint of a corrosion specialist, corrosion in electronics is not a surprise due to the multiplicity of materials used simultaneously with several other factors conducive for corrosion. As the materials used are many and component designs are complicated, it is beneficial for the non-electronic reader to have knowledge on these prior to the discussion on corrosion issues. A detailed discussion on every component is beyond the scope of this view, therefore following are the important ones that experience significant corrosion problems.

Printed Circuit Board

Printed circuit boards can suffer from variety of problems if the surface is contaminated with electrically conducting materials. When combined with moisture, contamination results in lowering of resistance between tracks and pads that can lead to corrosion of metals. It can also result in the formation of metal filaments, which grow between pads or tracks on rigid or flexible circuits and between oppositely charged metal terminations of components or between the pins of connectors. The essential conditions required for this are a combination of ionic contamination, moisture and an applied voltage. Equipment used under very dry conditions should not suffer from these problems. Unless there are large temperature fluctuations that result in condensation occurring on the surface of the circuitry or if the contaminants are hygroscopic and adsorb enough moisture to provide a liquid layer on the surface. At high relative humidity values less than 100%RH a thin moisture layer will be present on the surface which is enough to decrease surface insulation resistance, cause corrosion or form metallic dendrites. The higher the humidity, the thicker is their moisture layer and faster the corrosion or dendrite growth. After copper electroplating, Water soluble copper salts, acid residues and plating additives if not removed from the panel can lead to ionic contamination of salts of tin and lead (during tin –lead plating), surfactants through urea and organic brighteners used if not removed by water rinse can be the cause for ionic contamination which is the source for corrosion. The unwanted copper foil removed by ammoniacal solution must also be removed in order to prevent the formation of ammonium complexes which will be formed during future fabrication process. The peroxide solution used for stripping tin-lead to prepare bare copper boards is a strong oxidizer that can attack laminate as well as the metal.

Hermetic Packages

Hermetic packages constitute a small part of total microelectronic packaging and generally provide extra protection from the environment. Well, hermetic seals are sometimes fragile and can crack to create leaks as a result of handling or while joining to circuit boards. Even devices in pin hole free hermetic packages can corrode. Moisture adsorbed on the inner walls of the package can desorb and initiate failure. Devitrifying glass is one type of sealing material with a high moisture content that is evolved upon vitrifying. Moisture trapped inside a sealed cavity can leach ions from the sealing glass or other sources to form a conductive electrolyte. Once an ionic path exist between conductors, corrosion and failure by any mechanism as like integrated circuit failure mechanism can occur. Corrosion behaviour of plastic – encapsulated devices have been found similar to unencapsulated devices. Nguyen and colleagues used in insitu capacitance monitor to study moisture permeation in plastic packages.

Computer hard disk

Inside of a computer hard disk drive consists of several components. The round disc platter is the magnetic recording media for hard disc. The platter is usually made of aluminium electroplated with nickel, and an over layer of 50 nm thick magnetically active cobalt alloy using PVD. Over the magnetic cobalt layer there is a thin layer of carbon, which is also coated using PVD. The arm like device that extends over the disc platter is known as the head arm, and is the device that reads the information out of the disc platter. The head arm is attached to the head actuator, which controls the head arm. Not shown is the chassis which encases and holds all the hard disk drive components.

Solder Corrosion

Tin-lead alloys ranging between various compositions of lead and tin (either Pb rich or Sn rich) are most common solders used in electronic applications. Pure Sn forms protective oxide film while lead oxides formed are not stable and easily react with chlorides, borates and sulphates. Frankenthal and siliconolfi [13] found that both tin and lead rich Pb and Sn alloys form SnO, most likely SnO, during the initial exposure of oxide free surfaces to oxygen. When metallic tin becomes totally depleted from the surface lead is oxidized on the surface Pb-Sn to yield mixed oxide. Lead forms unstable oxides which easily react with chlorides, borates, and sulphates. Contamination from assembly residues of low solids “no clean” fluxes is non-corrosive. Soldering is effectively carried out in a controlled atmosphere (N2) containing a trace of less than 1% formic acid. This acid reacts with oxides on metals and metallized ions to form metal formates, which vaporize or decompose at soldering temperature evolving water vapour, hydrogen and carbon monoxide.

III. TYPES OF CORROSIONS

The metal in your circuit boards can corrode in several ways, including:

- **Atmospheric:** This is the most standard type of corrosion. Metal is exposed to moisture, which contains oxygen, causing a reaction where the metal ions bond with the oxygen atoms and create an oxide. Copper experiences atmospheric corrosion very easily, which is not a problem for copper plumbing because corroded copper retains its mechanical properties. It does not, however, retain its electrical conductivity, so this is a big problem for circuit boards.

- **Galvanic:** Galvanic corrosion occurs when different types of metals are in the presence of an electrolyte. In these circumstances, the more resistant metal will actually corrode faster than the baser metal it’s in contact with, so when gold is in contact with tin, for example, the gold will corrode much faster than usual.

- **Electrolytic:** In this type of metal degradation, adjacent traces experience dendrite growth when ionic contaminated moisture infects the electrical voltage between them, creating metal slivers that result in a short circuit.

- **Fretting:** With fretting corrosion, the action of closing solder-plated switches creates a wiping action that removes the surface oxide layer, allowing the layer beneath to oxidize. Eventually, excessive rust builds up and prevents the switch from activating.

IV. CORROSION PREVENTION TECHNIQUES

There are several means to improve the tolerance for corrosion and the climate. When selecting the means, it would be important to recognise at first the basic principles, which can be used to curb environmental stresses. When these have been used, the concrete means for protecting the
component board, for example, or ensuring the functionality of the connector contacts should be studied.

Using of fault-resistant technique

Corrosion and climate cause changes to the properties of all components and materials. If the device could be designed to function including wide scale changes of component parameters, most devices would tolerate also corrosion quite well. Corrosion causes mostly small gradually progressing changes in electronics, which slowly deteriorate the properties of the device. If the electrical/mechanical functionality of the device requires very small tolerances in the signals, leakage currents or the size or quality of the impedances in the circuits (humidity affects the dielectric constant εr), the device will be sensitive to corrosion, since corrosion of the surfaces, contamination and humidity affect not only the metal surfaces but the electrical properties of the surfaces of the insulators as well. These changes in the serial resistances of the joints (connectors, solder joints, switches), leakage currents between the wires and insulation resistances caused by corrosion should be included in the sizing of the electric circuits in the designing of the device. Numerical tolerances for these should be calculated and these used for informing the corrosion experts and manufactures of the components in order to identify the correct level of protection measures. The most problematic areas with regard to the corrosion risk are usually the electromechanics: connectors, switches, relays and connections of other components and displays as well as the wiring pattern of the circuit board. In the most difficult conditions, which prevail for instance in a typical coating plant, faults in the electromechanics where corrosion plays a part include more than half of all the occurring faults. Minimising of the number of electromechanical connections, especially unprotected connections that can be opened, is a good means of reducing the corrosion risk. Practical reasons support the use of electric connections that can be opened in the devices, for example EMC seals, connector sockets of displays, keyboards and plug-in units and outside cable connectors. This means that the fault tolerance must be built on also developing the properties of these parts affecting corrosion resistance.

Minimisation of gas contacts

Gas contacts as referred to here mean the contact of substances in the air with the outer or inner surfaces of an electronic device. The contact of gas and dust particles with the surfaces becomes more frequent with faster airflows and higher contents of gases and dust in the air. To put it simply, this means that the probability of chemical reactions (corrosion, humidification) and contamination is higher if the surface is in constant contact with these undesirable particles. It has been observed in practical structures that even simple mechanical cover significantly reduces the contamination of the surfaces and therefore also corrosion and other surface phenomena. The inside of a device may reveal a completely contaminated circuit board on one side because of the airflow while the backside appears clean and flawless. In the same way, a two-part edge connector may look neat on the inside even though the outside has been contaminated. The explanation to this is simply the few gas contacts in a mechanically protected space. The reduction of polluted airflow inside the device is one of the best means to prevent corrosion if temperature of the device can be controlled by smaller or closed airflow. However, it should be remembered that humidity and condensation also cause problems in too tightly sealed. The basic general principle in designing electronics could be the reduction of the airflow for instance by using a double layered structure where the dense wiring of the electronics and small components are insulated against the external flow of air and only the parts necessary for cooling remain in contact with the strong flow of air. Taken further, this would mean casting the electronics in an inert mass, which does not absorb water. In such a case, the device would consist of small packages cooled with a relatively free choice of means.

Keeping the cases and electronics dry

The insides of the device cases and the electronics should be maintained as dry as possible in all situations since the presence of water always increases the risk for corrosion considerably and weakens the isolation of the surfaces. A relatively tight device case is the best solution. The problems in fact begin with the design of the case, what kind of case is the best? Since the cases usually let outside air in them the heat from the device itself should be used to minimise the harmful effects of humidity in order to keep the device dry and to ensure the removal of possible moisture inside the device. If the various pats of device could always be kept warmer than its surroundings it would be easy to keep it dry. The cooling air inside the device provides a natural help in the removal of moisture but if the flow is based only on weak natural convection or ventilation through cracks in the seals, precautions must be taken against long term effects of internal moisture and the inside surfaces must be better protected. It would be important to stop the dripping of water resulting from condensation onto the component boards or the connectors in indoor and outdoor conditions.

Compatibility of materials at the joints

There are various boundary surfaces of materials in electronics, for example on the circuit board, wiring patterns, connectors, switches and microcircuits. If the device is subjected to the corrosive substances present in air and to water and since water is always in contact with all the surfaces, at least to some extent, galvanic corrosion occurs always when two metals are in contact with one another. High temperature and humidity accelerate these reactions. The smallest risk for corrosion exists between two surfaces of the same metal. If the metals are different, the least corrosion occurs between surfaces where the electric surface potentials are as close to one another as possible. The electrochemical and galvanic voltage series of metals can be used to help in the choice of materials. If the materials differ much in this respect, the probability for corrosion is great, if there is water and if there are corrosive gases in the air and on the surfaces.

It is rather difficult in electronics devices to avoid contacts between different materials, such as contacts of the EMC seals with the circuit board and the outer case of the device. These are naturally in contact with various metals. The solution for this case also is to design the seams of the seals mechanically in such a way as to stop the penetration of moisture at least to the centre parts of the contact area of the seam, even if there is a zone sensitive to water and corrosion around the edges. When using tin-lead solder, it should be checked that the circuit board or the component wires do not carry excessively thick layers of gold which forms intermetallic alloys with tin. The mechanical strength of these alloys is weak and they corrode quickly in heat.

Isolating coatings

It is necessary to protect the wiring pattern against effects of contamination and moisture if the quality of the air flowing inside the device cannot be affected and the device case is relatively open. The coatings protect the boards also from mechanical stress in connection with assembly and service. In dry conditions the solder resist coating alone gives some protection against the harmful effects of temporary humidity even though it lowers the isolation resistance of the surface especially when wet.

V. CONCLUSION

Corrosion occurs throughout the entire life cycle during different stages of manufacturing, assembly, transport and storage of components and assemblies and during field operations of the equipment. Electronic devices can fail due to a number of failure modes depending on inherent factors related to materials, design, and cleanliness under exposure to humidity and other gaseous conditions. In this paper we discussed about various electronics product which undergone corrosion, various types of corrosions and way to prevent the corrosion

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