Corrosion in Electronic Devices

The desire for increased performance and reliability from electronic systems has led to the use of new materials and technologies [1] and the drive for increased speed and reduced weight. Miniaturization support the delivery of the attributes of speed and weight. New materials and new technologies and miniaturization all contribute to the corrosion of those electronics systems. NASA recognizes that corrosion of complex electronic systems is a growing and expensive concern [2].

Putting that into context, the spacing between integrated circuits is the order of a couple of hundred nanometers. The distance between components on a printed circuit board is around five microns and has seen a twenty-fold reduction in the past two decades [1]. As miniaturization of electronic circuits increases (size decrease), the tolerance for corrosion loss reduces and is in the order of picograms (10^{-12}g) [2]. Corrosion loss is analogous to a fault in an electronic circuit.

Contaminants maybe introduced into the electronic system during production [2]. These maybe residues from passivation, etching and plating processes or from soldering fluxes. While production environments and procedures strive for cleanliness, it has been found that minute remnants of these contaminants are sufficient to accelerate the corrosion process [1].

Contaminants may be introduced during service. For example, the presence of chloride, nitrate and sulfate ions as well as dust can entrap moisture [1]. A tiny water droplet can bridge two dissimilar metals and form a galvanic cell enabling electrochemical corrosion, problematic for miniaturized electronic circuits [2]. Furthermore, it is known that large voltage gradients on printed circuit boards accelerates corrosion [1].

Low electrical resistant inert materials are sought for electronic circuits. Contrary to the normal perception of gold as a stable material, gold can corrode over a range of potentials and pH in chloride solution forming $AuCl_3$ [1].

Electronic circuits manufactured with lead, tin, copper, gold or silver are susceptible to electrolytic metal migration. The key characteristic of electrolytic metal migration is the formation of dendrites, starting at the cathode and growing toward the anode as seen in Figure 1. Dendrite growth continues *until there is an electrical short and system failure*. Blistering of electronic pins are shown in Figure 2.

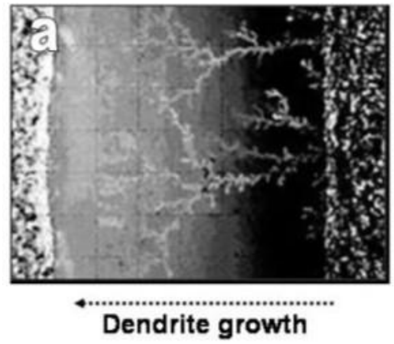

Figure 1. Silver dendrite formation on a printed circuit board due to migration [1].

Ambat [1] believes that electrolytic metal migration will become one of the most severe corrosion problems in electronics for two reasons:

1. Electrolytic metal migration is known to exacerbated under the presence of high electric fields. At constant voltage, the electric field between the conductors rises inversely with the conductor spacing.
2. The long-term reliability of circuitry fabricated with low residue fluxes and so-called no-clean fluxes has not been established.

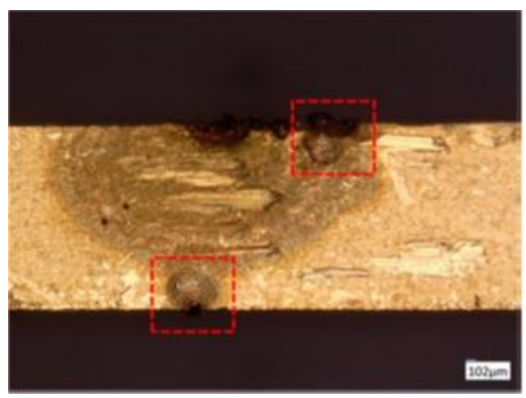

Figure 2. Optical microscopy image of an electrical pin showing blisters impregnated with corrosion products outlined in red [2]

Galvanic corrosion of switches and connectors results in an increase in circuit resistance which can in the short term to a loss of performance and in the long-term system failure.

References

[1] Ambat, R., A review of Corrosion and environmental effects on electronics, https://smtnet.com/library/files/upload/A-review-of-Corrosion-and-environmental-effects-on-electronics.pdf

[2] Pierre, M. S., Montgomery, E. L., Corrosion Failure in Electronic Devices for Aerospace Application, NASA Technical Report, KSC-E-DAA-TN55180, Jul 10, 2018

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