Materials Tip

Materials Engineering Branch

Chemical Corrosion of Aluminum by Cleaning Solvents			
No. 121		Date revised: (First issued:)	17 January 2001 (March 1997)
Author(s):	Roamer Predmore	Point of Contact:	Roamer Predmore

An alert "describes a mechanism for the chemical corrosion of aluminum, aluminum wires, and aluminum bond pads employed in electronic parts and components involving a combination of water and 1,1,1-trichloroethane (TCE) cleaning solvents", (see Reference). As these solvents are among the more popular ones used for cleaning space flight hardware, the information contained in the alert is summarized below to provide guidance in their use.

TCE is an organic solvent commonly used to clean electronic parts and components. TCE, however, has a tendency to decompose, producing hydrogen chloride HCl as one product of chemical decomposition. To prevent this, a chemical additive or "inhibitor" is incorporated into the TCE. The function of the inhibitor is to suppress the chemical decomposition reaction, and render the TCE chemically stable for use as a cleaning solvent. A typical inhibitor is 1,4-dioxane and is present in the TCE at a concentration of about 3 wt %.

On occasion, corrosion of metallic components in electronic parts, such as aluminum, is encountered, and chemical analysis typically finds chlorine at the corrosion sites. TCE always becomes suspect if it was used as a cleaning solvent. However, efforts to actually corrode metallic components of electronic parts in JPL's failure analysis group, using inhibited TCE, historically have been unsuccessful.

Recently, it was learned that inhibitors such as 1, 4-dioxane are readily soluble in water. In turn, water and TCE are immiscible; they will not mix. In a laboratory experiment combining water and TCE in a common glass vessel, it was discovered that the 1, 4- dioxane inhibitor can be easily and readily extracted out of the TCE, preferring to be dissolved in water rather than in TCE. This leaves the TCE without an inhibitor, and thus begins decomposition to produce HCl. In turn, HCl now dissolves into water, producing hydrochloric acid, which actually causes the metallic corrosion. Thus, it was found that combining inhibited TCE and water can cause aluminum corrosion, leaving chlorine as a residue at the corrosion sites. Neither inhibited TCE or water, when used separately, cause this same corrosive behavior.

This work was carried out during an investigation of internal corrosion of aluminum wires and bond pads on a 1K memory RAM. A peculiarity of this part was the existence of a hole in the lid, permitting contaminants and/or cleaning solvents to enter. The hole was discovered during a hermeticity test. A review of what solvents were used on this failed part revealed that both inhibited TCE and water were employed. In a laboratory test, a delidded 1K memory RAM, used as a control, was immersed in the water phase of the combination water/inhibited TCE, and heated overnight at the boiling point of TCE (74°C). On inspection, it was found that the aluminum wires and bond pads were severely corroded, several of the aluminum wires were totally missing, and chlorine was chemically detected at the corrosion sites. Visual comparison of the corrosive damage on the control part was strikingly similar to the corrosive damage on the failed part.

This effort does not conclusively prove that the corrosion of this particular failed part was caused by the combination of water and inhibited TCE, but a strong indication is suggested. What the effort does prove is that the seemingly innocent combination of water and inhibited TCE can cause corrosion of aluminum (and perhaps other metals) used in electronic parts, and a caution for future use is strongly advised.

"Do not mix water and TCE. Use them separately on electronic parts and components, and take care that the parts and components are dried of one, before using the other. This also applies to alcohols, which generally contain water.

Reference: Safe-Alert No. E4-A-89-02, May 10, 1989, E.F. Cuddihy, Jet Propulsion Laboratory.