SOLVENT SUBSTITUTION FOR ELECTRONIC ASSEMBLY CLEANING

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ABSTRACT

The Department of Energy (DOE) is striving to eliminate the use of chlorofluorocarbon and chlorinated hydrocarbon solvents from weapons production. A major use of these materials is in the cleaning of electronic assemblies during production. In seeking to eliminate these materials, a screening study has been completed to identify alternate materials/processes. This screening study involved parallel investigations into: 1) the use of alternate cleaners for removing the rosin-based flux and mold release material currently being used, and 2) the use of water soluble fluxes in place of the rosin-based flux. The evaluation criteria used in this screening study were: the environmental, safety and health impact upon production operations, cleaning efficacy, corrosion potential, and, the bondability and high voltage breakdown resistance of cleaned surfaces. Upon completion of the screening evaluation, oxo-decyl acetate and a terpene cleaner have been selected for further study.

INTRODUCTION

Like industry in general, the DoE weapons complex utilizes chlorofluorocarbon and chlorinated hydrocarbon solvents for most cleaning and degreasing operations. However, environmental, safety, and health (ES&H) concerns and regulations, now dictate that the use of these materials must be minimized and eventually eliminated. Since electronic assembly cleaning processes account for a large percentage of total halogenated solvent usage within the weapons production complex, Sandia National Laboratories (SNL) and Allied Signal/Kansas City Division (AS/KCD) have established a joint program to identify, qualify and implement alternative materials and processes that would eliminate halogenated solvents from electronic assembly cleaning processes at AS/KCD. This program is presently focussed on a major electronic system. The fabrication of this system, which contains eight major electronics assembly modules and numerous secondary components, requires 49 separate solvent cleaning steps using trichloroethylene (TCE). These cleaning steps are primarily for the removal of rosin solder flux residues after soldering, cleaning of completed subassembly and assembly modules prior to foam encapsulation, and post-encapsulation cleaning of silicone mold release from encapsulated units.

HALOGENATED SOLVENT ELIMINATION OPTIONS

In seeking to eliminate halogenated solvents from electronic assembly cleaning processes, two separate options were investigated. The first of these options is the use of alternate cleaning materials in lieu of the halogenated solvents now being used for the removal of the rosin mildly activated (RMA) solder flux and silicone mold release residues. The second option involves alternative processing using water soluble soldering fluxes rather than the RMA solder flux now being used. Water soluble fluxes have the advantage that they can be cleaned with water, thus eliminating the need to use halogenated solvents for flux residue removal. Since mold release cleaning studies had indicated that the silicone mold release agent can be removed with isopropyl alcohol (IPA), it was hypothesized that a two step cleaning process, hot deionized (DI) water followed by IPA, would effectively remove residues from both the water soluble solder flux and the silicone mold release agent. Additionally, using IPA as the second cleaning step would remove any water remaining from the first step and rapidly evaporate to leave dry assemblies.

ELECTRONIC ASSEMBLY CLEANING PROGRAM

A three phase program was designed to carry out the studies necessary to identify, qualify, and implement alternative cleaning processes for electronic assembly cleaning. Phase 1 is an initial screening study, involving a limited number of alternative cleaning agents and water soluble solder fluxes, to identify a single cleaner or flux for further evaluation. Phase 2 involves more extensive testing and evaluation of the alternative cleaner or water soluble flux that was identified in Phase 1. Finally, given a successful outcome of the Phase 2 testing and evaluation, Phase 3 will be the implementation of the alternative cleaner or water soluble flux into production operations.

At this time, the Phase 1 screening studies have been completed. In these studies five substitute cleaning materials were evaluated as potential replacements for halogenated solvents: a terpene, oxo-decyl acetate, two proprietary aqueous cleaners, and isopropyl alcohol. Additionally, two water soluble soldering fluxes, Kester 2120 and Kester 2224, were evaluated as possible substitutes for the Kester 197 RMA solder flux now in use. A two step cleaning process, hot DI water followed by IPA, was used in the water soluble flux evaluation studies. Evaluation criteria that were used in the Phase 1 screening studies were: ES&H impact at AS/KCD, cleaning efficacy, cleaner corrosivity, bondability of cleaned surfaces, and high voltage breakdown resistance of high voltage assemblies after cleaning. The bondability and high voltage breakdown resistance testing were necessary due to specific issues related to the production and function of this particular system.

ES&H IMPACT ASSESSMENT

An ES&H impact assessment was done by environmental, fire safety, and industrial hygiene personnel at AS/KCD. As a result of this assessment it was determined that, properly used, none of the alternative cleaners or water soluble fluxes would present a significant ES&H problem with either current or anticipated future regulations.

CLEANING EFFICACY STUDIES

Cleaning studies were carried out at both SNL and AS/KCD. The SNL studies were primarily focussed on the removal of solder flux and silicone mold release agent from four substrate materials common to the electronics system under study. These materials were bare copper, bare copper which had been fluxed and Sn/Pb solder dipped, 17-4 PH stainless steel, and E-glass/polyimide printed wiring board material. The bare copper and solder dipped copper substrates were used to simulate electronics materials before and after soldering. The 17-4 PH stainless steel is used as the structural housing material for the electronics assemblies and the E-glass/polyimide printed wiring board material is used in all of the electronics assemblies in the system.

For the alternate cleaner studies, coupons of the four substrate materials were contaminated with each of the two contaminants: the Kester 197 RMA solder flux and the silicone mold release agent. These coupons were then cleaned using TCE or one of the five substitute cleaning materials. The TCE-cleaned samples were necessary to provide a basis for comparison between the current cleaner and the alternative cleaners. After cleaning, the coupons were analyzed to determine cleaner efficacy for each combination of substrate, contaminant, and cleaner.

In the water soluble flux studies, coupons of the four substrate materials were contaminated with each of the two water soluble fluxes and then cleaned using the two-step cleaning process. As in the alternate cleaner studies, the cleaned coupons were then analyzed to determine cleanliness levels for each combination of substrate material and water soluble flux.

The solder-flux contaminated coupons from both the alternate cleaner and water soluble flux studies were analyzed visually and with either Auger electron spectroscopy (AES) or x-ray photoelectron spectroscopy (XPS) to identify and quantify surface contaminants. An additional set of solder dipped copper coupons was analyzed using an Omegameter to measure residual ionic contamination levels.

All silicone mold release-contaminated coupons from the alternate cleaner studies were analyzed visually and also with either AES or XPS. Silicone mold release cleaning efficacy for the alternate cleaners was also determined using contact angle goniometer measurements. For these measurements, copper coupons were contaminated with silicone mold release agent and then cleaned with TCE or one of the five alternate cleaners. After cleaning, water drop contact angle measurements were made to determine relative surface cleanliness levels.

In addition to the above SNL cleaning study, cleaning studies were also carried out at both AS/KCD and SNL to determine the effectiveness of TCE, the five alternative cleaners, and the two step DI water/IPA cleaning process in removing a number of general contaminants that are present in the production area. These studies were necessary because experience has shown that these materials occasionally end up on production units and must be removed. These studies were performed on bare copper, bare aluminum, and solder dipped copper substrates using various oils, greases, mold releases and body oils. Cleaning efficacy in these studies was determined visually, by weight loss measurements, MESERAN (Measurement and Evaluation of Surfaces by Evaporative Rate ANalysis) values, water drop contact angle measurements, and Grazing Angle Reflectance-Fourier Transform Infrared Spectroscopy.

Analysis of data from all the SNL and AS/KCD cleaning studies indicated that, of the five substitute cleaners, the oxo-decyl acetate and terpene cleaner were the most effective in removing the RMA solder flux, silicone mold release agent and general contaminants that were studied. These data also showed that the oxo-decyl acetate and terpene cleaner both cleaned as well as TCE in these studies. Data from the water soluble flux and silicone mold release cleaning studies indicated that the two water soluble fluxes and silicone mold release agent can be effectively removed using a two step DI water/IPA cleaning process. However, the general contaminant studies found that this cleaning process would be less effective for removing some of the production area contaminants.

CLEANER CORROSIVITY STUDIES

Two types of tests were conducted at SNL to evaluate the relative corrosivity of the substitute cleaners and TCE. The first of these tests was an immersion test to determine dissolution rates in each of the cleaning solutions. In this test, preweighed coupons of copper and Sn/Pb solder were immersed in each of the cleaners for one week, at ambient temperature. At the end of this time, the coupons were removed, rinsed, dried, and reweighed. These weight loss measurements provided an indication of the relative corrosiveness of each cleaner. As expected, the two aqueous cleaners exhibited greater dissolution rates than the organic cleaners (TCE, IPA, oxo-decyl acetate and the terpene).

The second part of the corrosion evaluation testing was designed to assess potential long-term corrosion problems due to cleaner residues left from incomplete rinsing after cleaning. In this test, bare copper and Sn/Pb solder coupons were prepared under no rinse, partial rinse, and full rinse conditions for each of the cleaners. These coupons were then placed in an environmental chamber and aged for 30 days at 40°C, 70% relative humidity. At the end of this time, the coupons were removed and a visual assessment was made of the relative amounts of corrosion present. Results of the immersion and cleaner residue tests indicated that all five substitute materials were acceptable.

BONDABILITY TESTING

Post-cleaning bondability of materials was investigated at SNL. These tests were necessary due to the large number of bonding and encapsulation processes which occur during production of the system. In these studies coupons of 17-4 PH stainless steel, and E-glass/polyimide wiring board were contaminated with the RMA flux and the two water soluble fluxes. An additional set of Sn/Pb solder-dipped copper coupons was prepared by dip soldering bare copper coupons that had been fluxed with the RMA flux and the two water soluble fluxes. Coupons prepared using the RMA flux were cleaned using TCE or one of the five alternate cleaners while coupons prepared with the water soluble fluxes were cleaned using the two step DI water/IPA cleaning process. After cleaning, thin-wall steel cylinders were bonded to the cleaned substrates with an encapsulating resin and torqued to failure to determine the short-term adhesive shear strength between the resin and coupon. Within experimental scatter, all coupons yielded the same short-term adhesive shear strength.

HIGH VOLTAGE BREAKDOWN TESTING

The final evaluation testing in Phase 1 involved high voltage breakdown testing at AS/KCD. High voltages are present in several modules of the electronic system under study and previous experience had shown that high voltage breakdown problems are often the first indication of incomplete cleaning and/or contamination of these modules. High voltage breakdown testing was done using a specially designed high voltage test assembly. Three separate groups of test assemblies were fabricated using the RMA flux and the two water soluble fluxes. After fabrication, the RMA fluxed assemblies were cleaned with TCE or one of the five alternate cleaners while the water soluble fluxed assemblies were cleaned with the two step DI water/IPA cleaning process. After cleaning, each test assembly underwent high voltage stress testing to determine breakdown behavior. Results of this testing indicated no significant high voltage breakdown failures due to the use of any of the cleaners or water soluble fluxes.

CONCLUSIONS

At the completion of Phase 1 testing, both the oxo-decyl acetate and terpene cleaner were selected for further evaluation in Phase 2 of this program. This selection was based upon cleaner performance and systems-level concerns associated with the use of aqueous or semi-aqueous cleaning processes.

As has been previously discussed, the oxo-decyl acetate and terpene cleaner were found to be as effective as TCE in removing the RMA flux, silicone mold release agent, and general production area contaminants. Additionally, in contrast to the proprietary aqueous cleaners and water soluble solder fluxes, these cleaners neither contain nor require water for their use. Although the use of aqueous processing was not a concern when these investigations were started, during these studies a systems level decision was made that, if possible, no moisture should be introduced into the weapon system as a result of aqueous processing methods. This decision hindered any possible use of the proprietary aqueous cleaners and water soluble solder fluxes.

At this time, Phase 2 studies are underway. Among the issues being addressed in these studies are: materials compatibility, electronic functionality of cleaned assemblies, and the long-term reliability of cleaned assemblies.

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