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SMALL-CORE MATERIAL COMPATIBILITY STUDY

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Abstract

A Small-Core Material Compatibility Study was conducted in support of a weapon system upgrade. The purpose of this study was to provide high-level materials compatibility information on a specific material set consisting of all the main materials of construction used within a selected subsystem (and its components). For example, materials included circuit boards, metals, silicone compression pads, desiccant and removable foam encapsulants. The Small-Core Study addressed material compatibility from the aspects of exposure time, temperature, presence of a potential foam depotting agent, and internal gas environment. While most samples were aged in a standard inert gas backfill environment, other environments were also used to determine possible material interactions if the internal environment deviated from ideal. To achieve this wide range of parameters, the test matrix consisted of 11 different exposure conditions. No incompatibilities were identified among the materials used in this study. The use of the non-standard environments, however, did provide insight into possible materials interactions. Selected results from the gas analysis, desiccant analysis and adhesion tests are presented.

Introduction

The goal of the Small-Core Materials Compatibility Study was to detect gross physical and chemical changes in a representative set of subsystem materials under slightly accelerated thermal aging conditions. The intent of this study was not to provide the necessary data for predicting system life, but to produce information on any potential interactions (compatibility) of the entire material set. This information supports component design to ensure long system life and is intended to bridge a gap between fundamental mechanistic aging studies and function-based full sub-system level aging studies (e.g. AAT-1).

Of note, the subsystem being studied incorporates a removable foam encapsulant. This material was selected because of a beneficial impact on long-term surveillance and to enable more effective rework of printed-wiring assemblies (if desired). While aging information was obtained for all canisters in the test matrix, this paper will highlight findings for the non-standard internal environments (non-hermetic and foam depotting solvent vapor). Specifically, the gas analysis, desiccant analysis and selected adhesion tests will be addressed.

Experimental

The Small-Core study matrix was defined to bound most of the possible STS conditions while still providing some level of aging acceleration. Attention was given up front to ensure that any material interactions could be observed and where possible quantified. In this study, selected material samples were aged in 11 hermetic stainless steel canisters for 6, 9 or 12 months under either ambient, thermal cycle or isothermal conditions (Table 1). Regular gas samples were taken throughout the test period. The effect of depotting was investigated by including clean and reworked samples in each material set, as well as creating an environment that had excess of a foam depotting solution vapor (can 7). A non-hermetic environment was also created (can 8) to simulate a possible internal environment if a cracked weld developed in a sealed subsystem. Thermal cycling over long periods of time was used to accelerate any adverse chemical incompatibilities. The thermal cycle ranges from -35°C to 55°C, with a soak at 40°C, as shown in Figure 1. Isothermal exposures were intended to meet (50°C) or exceed (64°C) material property limits, especially with respect to foams, in an attempt to discover possible failure modes. For thermal exposures, intermediate termination times (6 and 9 months) were used in order to identify general initiation times and modes for any identified interactions.

Table 1. Small-Core Study Matrix

Exposure Conditions	Can #	Termination Time (months)	Internal Environment vol%
Baseline	-	-	-
Ambient	1	12	inert gas
Thermal cycling	2	6	inert gas
	3	9	inert gas
	4	12	inert gas
	5	12	inert gas
	6	12	inert gas
	7	12	inert gas with depotting solution vapors
	8	12	air, (~60% RH)
Isothermal_1, 50°C	9	12	inert gas
Isothermal_2, 64°C	10	6	inert gas
Isothermal_2, 64°C	11	12	inert gas

*inert gas - 95vol% N_2 – 5vol% He

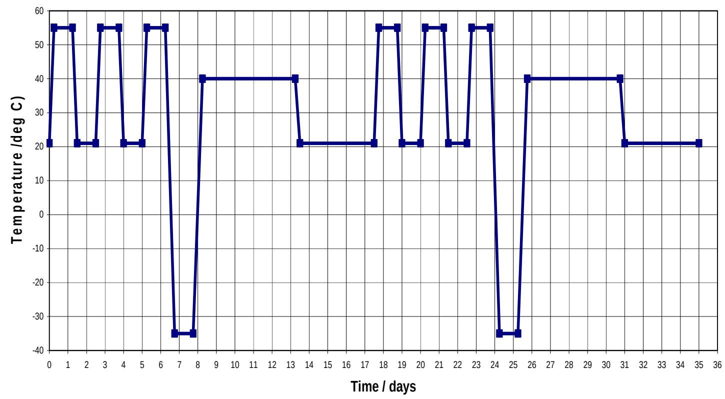

Figure 1. Small-Core Temperature Cycling Profile.

Results and Discussion

The outgassing of volatile species from the removable foams was found to be a key issue. The levels of Fluorinert™ outgassing as a function of gas sample for the 12 month aged canisters are shown in Figure 1A. These data represents the intensity of the mass 69 peak of the MS analysis. The plot shows that aging at ambient temperature (can 1) resulted in the lowest outgassing levels, while isothermal aging at 64°C (can 11) resulted in highest levels of outgassing, as would be expected. For the thermally cycled (TC) canisters, there are two deviations in the outgassing trends. First, the depotting solution vapor appears to facilitate outgassing (can 7 compared to cans 4,5 and 6). Second, the presence of air and water vapor appears to decrease outgassing or interfere with Fluorinert™ detection (can 8 compared to cans 4, 5 and 6).

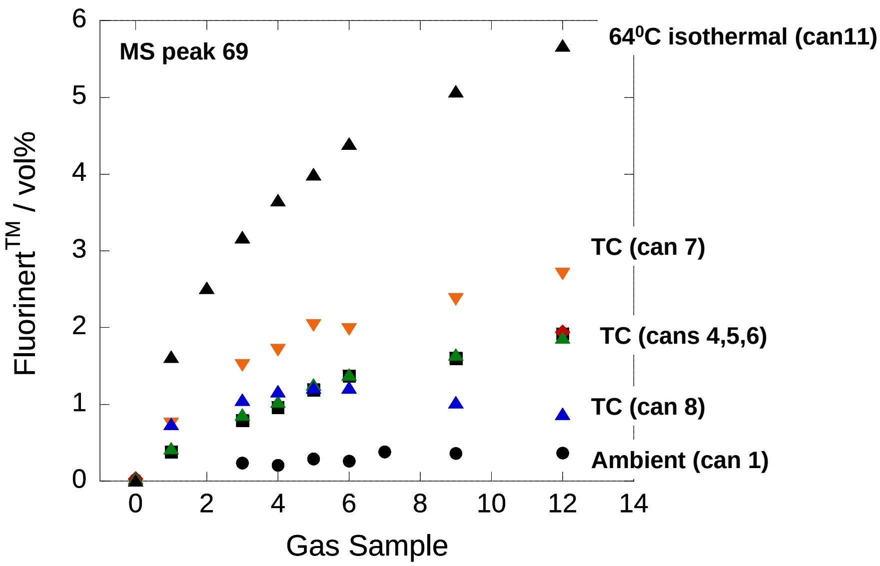

Figure 1A. Volume % of Fluorinert™ as a function of gas sample for 12 month aged canisters.

Desiccant Analysis. Aging of the desiccant material in an environment containing removable foams resulted in a significant finding. Water uptake tests on selected samples showed that amount of water adsorbed was equal to the amount desorbed, indicating that no detectable degradation of the active desiccant component had occurred. TG-IR analysis of the desiccant material showed that all aged desiccant pucks had absorbed varying amounts of siloxane. The IR spectrum of the desorbed siloxane was highly consistent with octamethyl-tetracyclosiloxane (Figure 2), a contaminant from the removable resin (subsequent to this study reduced by a quality control procedure on volatiles). In a finding with significance to surveillance activities, volume measurements were found to correlate with the estimated percent siloxane absorbed rather than with percent water absorbed (Figure 3).

Reference spectrum of octamethyl-tetracylcosiloxane

Measured spectra of can 1 desiccant

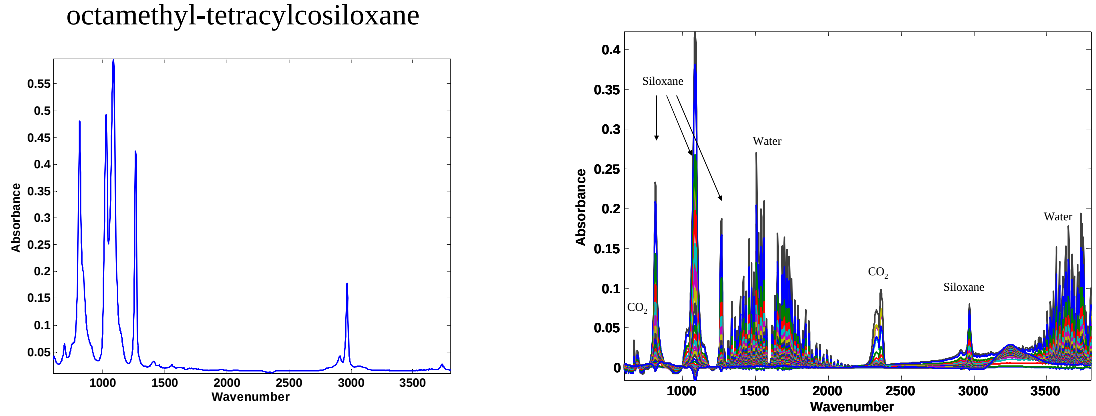

Figure 2. TG-IR analysis of desiccant/binder pucks.

a) % siloxane gained

b) % water gained

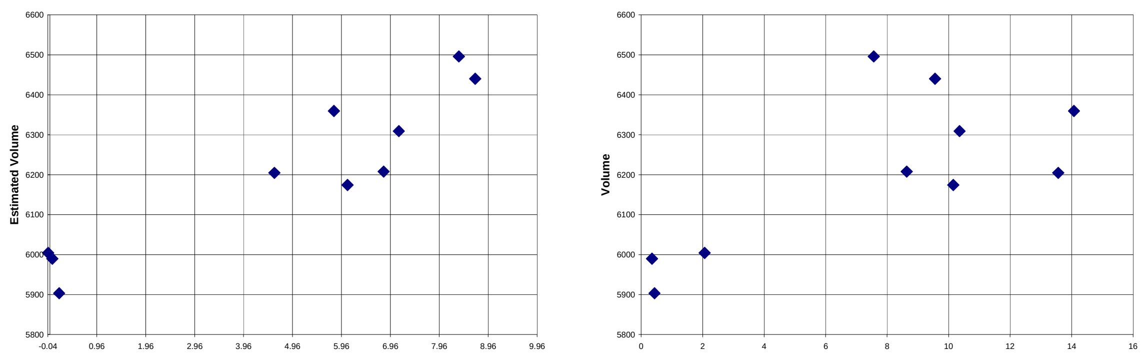

Figure 3. Estimated volume for desiccant puck as a function of a) % siloxane gained and b) % water gained.

As previously mentioned, non-ideal environments were used to probe possible material interactions that would not be manifested under normal circumstances. These environments included 1) the presence of excess depotting solution (1-butanol/toluene) vapors (can 7) and 2) the presence of oxygen and 60% RH (can 8). While no effect of exposure to the non-ideal environments was found for the large majority of the material samples in the Small-Core study, in a small minority of samples there was a noticeable and deleterious effect. For example, aged can 7 and can 8 RCC200 removable conformal coating / polyimide glass samples had the lowest adhesion strength of all the samples in the matrix. The cause of the decreased adhesion for these samples is not known. It should be noted that since the Small-Core study, the solvent used for depotting has been changed from 1-butanol/toluene to furfuryl alcohol. Additional work on the RCC200 / PWB interface with the new depotting solution (furfuryl alcohol) is planned.

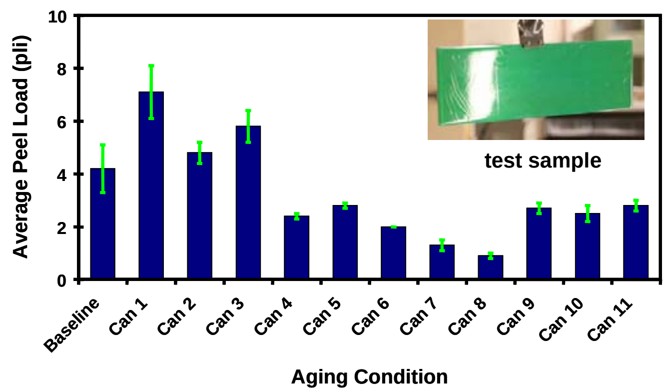

Figure 4. Peel test data summary for RCC200 coated polyimide glass PWB.

Conclusions

Overall, no material incompatibilities were identified among the materials included in the Small-Core Material study. The outgassing of volatile species (Fluorinert and siloxanes) from the removable foams was found to be the primary concern. Specifically, the presence of Fluorinert and/or siloxane gaseous species resulted in complications for the gas and desiccant analyses. In addition, aging in the non-ideal environments resulted in some unexpected material interactions occurred, many of which are not understood at this time.

Acknowledgement

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References

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