

Role and Selection of Polymer Activities for Aerospace Boards

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Abstract: Polymer activities encompassing masking, potting, staking, bonding, coating, dam and fill operations are important for reliable package realization. The selection of the material is important for the card as well as subsystem level as the performance can be compromised eventually leading to failure of the system. In aerospace and defense systems compared to other general electronic boards considerations of temperature and radiation are the key parameters for the selection of the material. This article details the overview of the standard material, selection of various polymer materials, material characterization aspect taken into consideration before implementation in the high reliability boards.

Keywords: polymer material, characterization, electronic board, outgassing.

1. Introduction

Electronic systems constitute major part in the electronic system for high reliability electronic boards for aerospace and defense. As the environments are different from terrestrial environments so the electronic systems and associated circuits are having different requirements than the traditional systems. Due to harsh environment and vacuum conditions, various electronic boards, components and materials can degrade

eventually leading to failure. Identification of the materials and associated processes for long life, reliability to be ensured so as to avoid degraded performance¹. This necessitates the requirement of proper materials and process identification. One of the key processes which are different in aero space applications is the implementation of the polymer activities both at card and package level. General polymer activities are classified as per below:

- (i) Conformal coating and potting
- (ii) Radiation Shielding
- (iii) Bonding activities
- (iv) Dam and filling, Staking activities

Other activities which are carried out are absorber bonding, fastners, ecobonding, harness potting which are carried out as part of polymer activities.

Shock, vibration, temperature variations are the key factors responsible for the degradation or failure of electrical boards. Specific aerospace mission encounter various radiation sources such as earth radiation belts, solar energetic particles, galactic cosmic rays which affects the circuits and can trigger failures. Various other parameters such as out gassing from the materials and components inside the package and byproduct of the chemical reaction of outgases species within the package are detrimental towards the reliability of the packages. In the present article various materials employed in the polymer activities for high reliability board applications are presented.

2. Material Selection

Material selection is an important consideration as degraded components or circuits cannot be repaired in the space and the main considerations are reproducibility, reliability, re-workability and inspectability. The selection depends upon the various constraints which is determined by the orbit selection, inclination and associated environment which is defined on the basis of temperature exposure, electro-magnetic radiation, thermal shock, meteoroids, debris, solar wind etc. Selection of various materials are based on thermal considerations, minimal stress, ease of fabrication, minimal outgassing, stability, compatibility, matched coefficient of thermal expansion etc. Materials employed in the realization of the packages are polymer potting compounds, films, tapes, insulations, adhesives, coatings, tie cords, lubricants etc. In the case of interplanetary mission extreme temperatures are encountered apart from radiation effects,

solar winds and cosmic rays. Some materials like silicones when cured release acetic acid which may corrode electrical wiring. Also polymeric material are prone to change characteristics after exposing to space environment such as PTFE and polyimide can become brittle after exposing to radiation in vacuum. Also wire insulation can become brittle and crack due to high temperature heating. Many coatings may degrade or damaged due to radiation or solar flares and susceptibility increases in vacuum when exposed to UV radiation. Materials possessing conductive particles can cause flaking or emission and preventive mechanisms to be taken for avoidance. Bias, moisture and ionic contamination are the main source of failure in spacecraft systems. The main considerations for the material selection² are

- (a) Mechanical and physical properties
- (b) Corrosion and compatibility
- (c) Environmental considerations
- (d) Out gassing Evaluation
- (e) Testing and properties evaluation

Fig 1 (a) shows the basic flow of the polymer activities carried out in the fabrication line. The main consideration is related with the ultrasonic cleaning and baking of bare PCB. After population of the cards, cleaning is carried out using vapour degreaser using IPA and DI water (3:1). Another aspect is masking of glass body component prior to conformal coating. In the cards having active devices, radiation shielding of active components such as FPGA, Zener diodes, HMC etc are carried out. Eco-bonding of the fasteners, thermistors, PRT, feed through, power transistor both at PCB level as well as package level are carried out.

Material testing is carried out either as received or by preparation of the measurable sample. Out gassing properties are the important criteria in the selection of the material and considered as surface evaporation combined with bulk contaminant species. These species can be initially present or decompose products. Initial present outgassing species species are water, solvents, additives, lubricants whereas decomposition products are due to thermal, solar radiation, electromagnetic particles, atomic oxygen, debris, electrical discharges and arcing. Outgassing of volatile silicones can cause contamination which can be responsible for electrostatic discharge phenomena. Limiting collected volatile condensable materials (CVCMM) and total mass loss (TML) are important as condensation reacts adversely with radiation whereas high mass loss indicate loss of properties and functionality. The weight loss per unit area through evaporation at a

temperature T can be described by zero order reaction as shown in equation (3.1).

$$(2.1) \quad \frac{dm}{dt} = 0.04375 \cdot P_s \cdot \left(\frac{M}{T} \right)^{1/2},$$

$$(2.1) \quad \begin{cases} \%CVC M = \left(\frac{C_0}{S_e} \right) \times 100 \\ \%WVR = \frac{S'_F - S_F}{S_L} \times 100, \end{cases}$$

where M is molecular mass, T in K, P_s is vapor pressure, C_0 is mass of condensation, S_L initial specimen mass.

In case of lower IC geometries with thinner oxides TID tolerance is enhanced but SEE increases with IC scaling. SEE described in terms of random failure rate whereas TID is described in terms of mean time to failure. At higher frequency, SETs can be turned into SEU and mitigation techniques for the same to be evolved. Polymer activities such as radiation shielding, potting apart from components packaging and design techniques are the main considerations to avoid the radiation damages.

3. Process Qualification

The main bottleneck for implementation of the new material stems from the surface roughness which leads to the contamination due to re-work operations. Various other phenomena such as air bubbles trapping resulting in corona, bubbles at solder joints or air trapping beneath components which can trap moisture resulting in shorts or arcing. Multiple steps are carried out for the qualification of the proposed material. The process is initiated by preparing the sample employing the proposed material and physically evaluating. Subsequently various qualification steps are carried out on the bare sample as well as dummy boards for validating the performance. The polymer material classification is carried out in various domain such as conformal coating, potting, eco-bonding, lacing thread for tying, chotherm for thermal management of components.

Another aspect is to avoid moisture penetration so as to maintain the properties and shelf life of the material.

Various operations carried out are shown in Fig 1(c) related with the polymer activities such as conformal coating, Dam and fill along with potting operations.

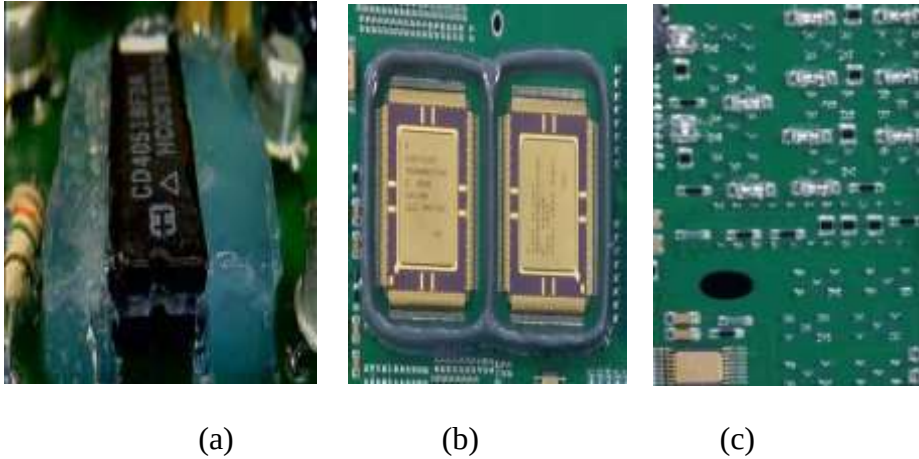


Figure 3. Polymer activities (a) Potting (b) Dam & Fill (c) Conformal coating

Material verification can also be carried out using the THB model which is based on temperature and humidity as shown⁵ in equation (3.1)

$$(3.1) \quad t_s = t_{amb} \cdot \exp(-X \cdot \rho - Y \cdot \tau); \rho = RH_S^N - RH_{amb}^N; \tau = \frac{1}{T_{amb}} - \frac{1}{T_S}.$$

4. Discussions

Polymer is the important activities as long term reliability of the cards are associated with the components and materials employed during the realization of the boards. Selections of materials along with the analysis of its properties for specific mission requirements are the major factor for consideration. Polymer activities ranging from conformal coating, potting, stacking, radiation shielding, eco-bonding, dam and filling are carried out both at the card as well as package level employing various materials. The change of material also requires handling and dispensing mechanism to be evolved. In the case of electronic boards for aerospace and defense applications apart from shock other aspects such as extreme temperatures, radiation are the prime cause which can potentially damage circuit or can cause short due to outgassing and associated phenomena introducing contamination. In this article the materials are explored and qualified for

the polymer activities. Various tests both at material as well as sample level are carried out to qualify the same for space mission. The selection of material is based on the criteria such as dependability, reproducibility, stability, minimal outgassing, and compatibility with other materials, well characterized and should not undergo phase transformation due to extreme environment conditions.

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