EUROPEAN SPACE AGENCY
CONTRACT REPORT

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EUROPEAN SPACE AGENCY CONTRACT REPORT

ESTEC Contract Number: 400135341/21/NL/GLC/ov
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Open Space Innovation Platform (OSIP) PROJECT:

Delamination in plastic package(DIPP)

Executive Summary

FINAL REPORT

Written by	***Responsibility*** + handwritten signature if no electronic workflow tool
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CHANGE RECORDS

ISSUE	DATE	§ CHANGE RECORDS	AUTHOR
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1. SUBJECT

This document is the final report of the OSIP study : delamination in plastic package. This document describes the scope of the project, the activities performed in this project and the results obtained.

2. CONTEXT

The various players in the space sector activities (equipment manufacturers, operators, and space agencies) believe that the future belongs to industrial components.

Industrial components (such as Automotive-quality and commercial-quality components) have already been selected and used for launcher-type or short duration satellite missions. Metallographic cross sections made on plastic packages industrial components, in the frame of these programs, revealed delamination between the chip and the encapsulation resin.

Delamination has generally been accepted for short-term missions because it "has not enough time" to worsen after application of mechanical vibration due to the launch phase and due to the short duration of the mission ; but this acceptation is questioned for long-term applications such as conventional satellites

We also know that these defects-delamination- are more likely to evolve during long term thermal cycling, where the length of delamination of all types will increase, sometimes reaching out to the external sides of the packages, allowing potential corrosion of the bonding and dice.

Long term space missions expose equipment to thermal stresses, especially repeated thermal cycles, which are present in all kind of satellites missions. These permanent thermal cycling combined with the operating phases of the equipment (ON-OFF), causes thermomechanical stresses in the components and affect the component (and equipment) reliability.

Today, we do not have enough experience to estimate what is the level of degradation of industrial plastic packaged parts (COTS) at the end of long term space mission.

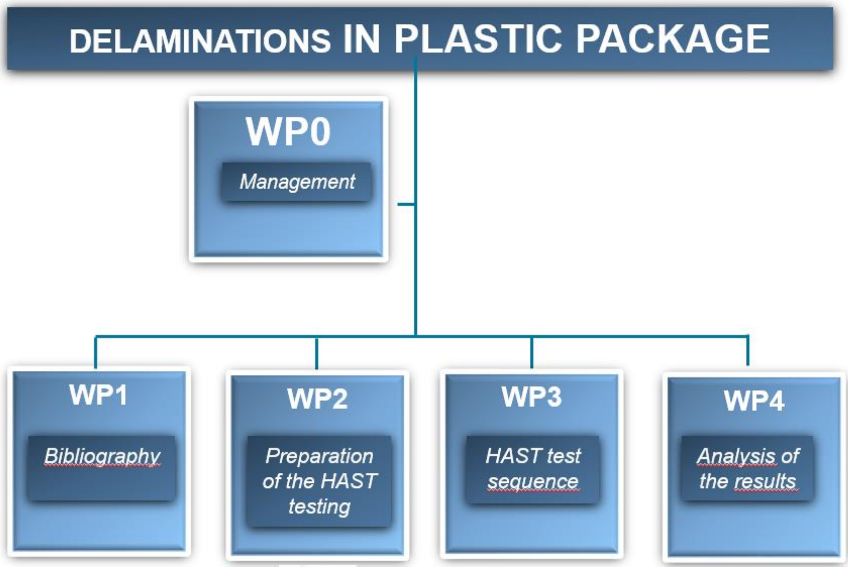
3. STUDY PLAN

3.1. Objectives of this study

- To study how delamination evolves over time and the thermomechanical stresses imposed by the equipment/satellite qualification sequences and the space environment.
- To determine what are the most critical stresses for such type of plastic body components in the space environment.
- To establish a basis of criteria to be used to characterize delamination and the level of acceptance.

4. PROJECT DESCRIPTION

The project is divided in 5 work packages.
The duration was initially 12 months but it has been delayed of 5 months.



4.1. WP1: bibliography

The aim of this task is to compile technical and normative documentation (from IEEE, conference, etc…) about delamination and voids in plastic packages components.

We were looking for information dedicated to :

- The description of types and localization of delamination in the parts
- The most appropriate methods and tools for delamination and voids detection , a.o the SAM (acoustic microscopy)
- Norms (ESA, MIL, …), for test methodology and defect descriptions.

4.2. WP2: Preparation of the HAST testing

The purpose of this task is to simulate the stresses imposed on the components throughout the space mission lifetime, we targeted :

- To select a large panel of different plastic packages that are representatives of the packages already used or ready to be used in space missions
- To submit them to the constrains of manufacturing operation (vapor phase assembly of packages on PCB)

- To define a test plan in order to simulate the thermomechanical and electrical constraints applied on packages.

HAST sequence (Highly Accelerated Stress Test) or THB (Temperature Humidity Bias Test) are different methods that can match with the simulation of long duration space missions. We studied these methods (literature/bibliography) in order to select the most appropriate one.

The bibliography step makes us choose the HAST sequence.

4.3. WP3: HAST test sequence

The aims of this task are :

- To manufacture the test vehicle: The selected parts will be assembled on PCB using the methods and machines (vapor phase reflow) used for standard space PCB production

- To operate and monitor the test sequence : the HAST has been run with parts biased ON, in order to be realistic.

- To perform non-destructive inspections with the scanning acoustic microscope (SAM) in order to detect the initial presence and evolution of delamination during the stress sequence. SAM inspections of the parts have been performed before and after each step of the test sequence.

The objective of this task is to measure the evolution of the (identified) defects along the test sequence, and make a classification of these defects (location, criticity etc…).

4.4. WP4: Analysis of the results

This last task aimed to try to perform a classification of the defects : the types if defects, their severity, their evolution.

The purpose is to make a proposition of criteria for the acceptation of delamination.

5. RESULTS

5.1. Bibliography

This bibliography we built, is constituted of two parts :

• Part 1: dedicated to a review of papers (mainly found in IEEE review) related to plastic packages commonly reported defects . These papers are mainly focused on delamination, testing sequences developed to create these defects in order to study them, and methods used to investigate these defects (such as Scanning Acoustic Microscopy).

• Part 2: dedicated to a collection of methods and norms dealing with selection, test, conditioning of plastic packages components for use in severe applications.

In each part of this bibliography, the papers/norms are presented with their titles, authors, and also summarized in order to focus the reader's attention to interest that the papers/norms may present for the present project.

This bibliography was very useful; it makes us learn that :

- the CSAM is the most relevant inspection method for delamination observation.
- the HAST sequence is the most appropriated way to age the plastic parts.

5.2. Packages selection

The parts have been selected based on the characteristics of the packages: we choose packages of different sizes, for discrete, integrated circuits (simple and more complex) and power components and from different manufacturers.
We choose 10 packages per part type. If 2 manufacturers are available, we choose 5 part of each.

5.3. Test vehicle

The configuration of the test vehicle initialy imagined required too many connections, and the number of connections is limited by the HAST device/chamber (30 channels / lines in the I/V matrix).

So, we had to imagine another way to perform the test. We needed to find an efficient way to bias the parts during HAST and then, to use the boards to test each type of component with an automatic set up.

We created the following test vehicle: it is composed of 1 ''mother board'' connected to ''daughter boards'' dedicated to each type of components, on both sides.

- **The mother board** size is 175 mm x 175 and it is populated with 16 ''daughter board'' (8 on each side).
- **The ''Daughter boards''** are dedicated to each type of components. The dimensions are 48mmx48mm. each daughter board is populated with 2 connectors (40 channels each) on each side to be biased.

  Every PBA is populated on both sides.

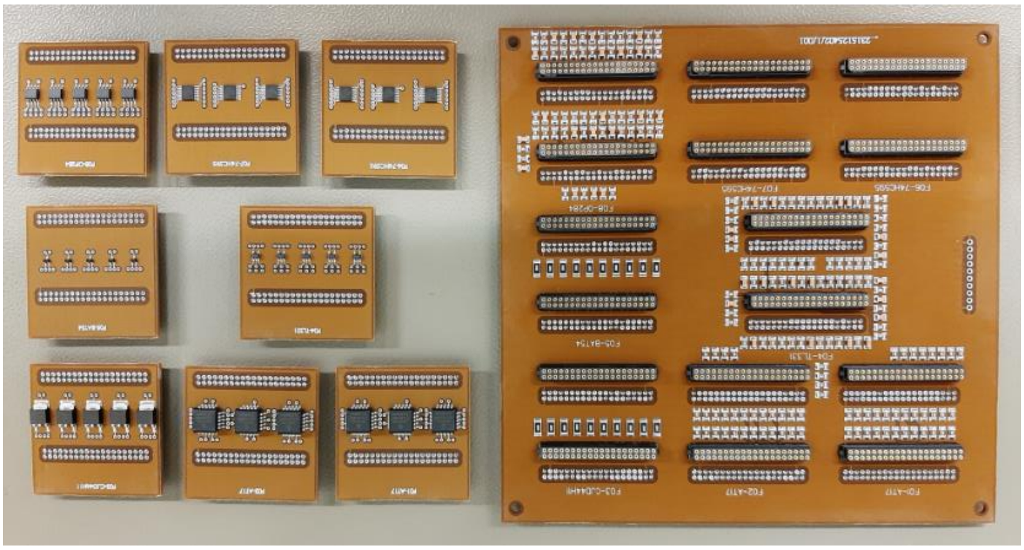


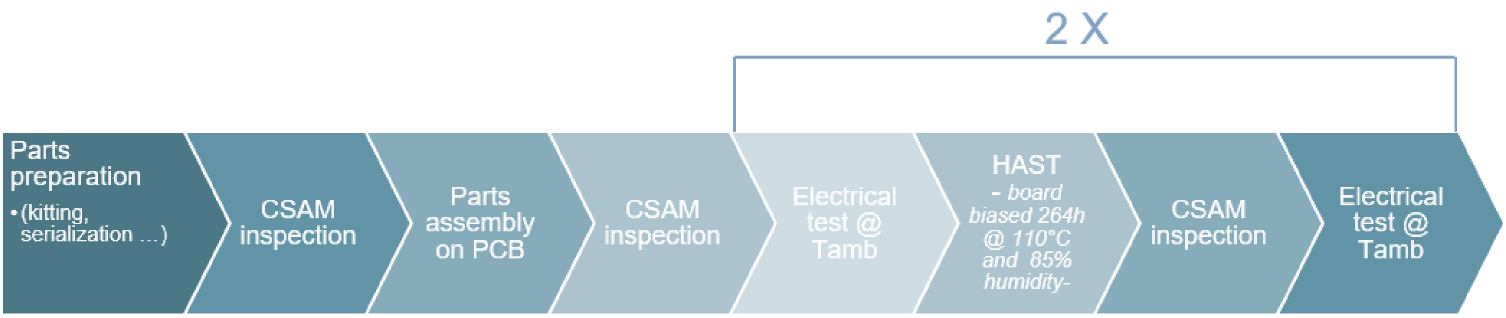
Figure 1 : Test vehicle.

N.B: The test vehicle is a multilayer PCB with a technology and quality similar to the one used for internal assembly qualification of new SMT packages.

100% of the components are biased. Depending on the complexity of the part, between 60% and 100% of the parts have been be electrical tested.

5.4. Test plan

The following test plan has been defined :



5.5. CSAM inspections

All CSAM inspections have been performed :

- At T0: on component alone (not brazed on PCB)
- After assembly/brazing on the PCB
- After the HAST – run #1
- After the HAST – run #2.

On the 100 parts tested, we can conclude that delamination occurs since the beginning (T0) or after assembly but not after HAST (1 run or 2 runs).

HAST seems to have a low impact in the creation or evolution of delamination.

5.6. Electrical test:

The aim is to detect leakage current variation or bonding lifting/breaking due to delamination.

I/V plots have been performed for each part by measuring the voltage with regards to a step by step increasing of the current.

The electrical test has been performed before and after the HAST runs. The parameters have been measured and compared between:T0 and HAST Run 1 and HAST Run1 and HAST Run 2.

No failure has been observed (no short circuit or open circuit) after the 2 runs of HAST.

Even parts with dramatic delamination (such as the one in DPAK-3) did not show any electrical parameters variations.

Electrical test seems not to be the appropriate test to detect delamination after parts ageing.

5.7. Conclusion

The test plan performed in this study makes us learned that:

- Delamination occurs since the beginning (T0) or after assembly but not after HAST (1 run or 2 runs) as expected.
- HAST seems to have a low impact in the creation or evolution of delamination.
- Electrical testing did not reveal major discrepancies or failure ; no short circuit or open circuit have been detected even on parts with severe delamination.

As HAST is a realistic simulation of space missions stresses, it is reassuring to observe that HAST ageing has a low impact on delamination’s creation and evolution.

It is interesting to see that delamination mainly occurs since the beginning or after assembly. It shows that CSAM inspection included in the manufacturing flow is relevant and will permit to detect these type of defects.

Nevertheless, every delamination is not necessarily a cause of rejection. Delamination that are located in a non-active area can be accepted.

In addition, it seems that adding more electrical testing is not relevant to check the integrity of the part and the lack of delamination.

6. ANALYSIS OF THE RESULTS

This study was a starting point to evaluate the impact of delamination but it did not bring enough elements/results yet to set up acceptance and rejection criteria. Nevertheless, this study highlighted several lessons learned that can be used as guidelines and recommendations.

6.1. Defect classification and guidelines

On the parts tested in this study, delamination occurred in 3 locations:

- The header (the tie bar)
- The die area
- The lead area

Depending on the type of component – means if the part is a power component or not – the consequence of the presence of delamination are not the same.

For ***power components***, the die attach is a very important issue. Because of the power dissipation, the contact between the die and the package shall not be degraded. So, for such parts, an important delamination between the die and the package is considered critical. As far as we know, based on our current knowledge, we do not accept power parts with delamination at die level. To set a (precise) criterion, additional test would be necessary, in particular the thermal resistance (R_{Th}) measurement.

The power parts need to use large bonding to carry the current. Those bonding are basically in aluminum and more robust than thin gold wires used generally for ‘’non power parts’’. Electrical test performed after the HAST ageing did not show discrepancies: none failure, none short circuit nor open circuit. So, this study gave us the feeling that we could accept until 50% of delamination at lead/bonding area level without risking electrical failure.

But, even if those bonding are more robust that thin gold wires, we do not know today if delamination around those bonding has an impact on the bonding strength and reliability for a long term space mission.

For ***‘’non power’’ parts***, delamination in the die area could be accepted depending on the part itself and its construction. But, for this type of parts, the bonding area is a sensitive location. The bonding robustness could be impacted by the presence of delamination if its size is important.

So, this study brought us elements to better define the criticality of the locations concerned by delamination but, to set acceptation and rejection criteria, we would need to quantify the defects.

Additional testing are necessary to make a clear status : a correlation between CSAM inspection and bond pull test - to do in frame of a DPA - has to be performed especially for ‘’non power parts’’ which use low diameter bonding (like integrated circuit for instance).

6.2. Recommendations

4 main conclusions can be drawn :

First, to select parts to be used in a design, we note that it is not worth wasting time and money in ageing tests in general (and HAST in particular). They are not really necessary to evaluate the parts. It is better to sort the parts at T0 after a CSAM inspection and to retain only the parts with no or few delamination.

Secondly, It seems also relevant to qualify the more typical defects/delamination : indeed, we recommend to perform a CSAM inspection after the components assembly on the (assembly) qualification test vehicle. If the assembly qualification is successful, it will be possible to compare the results of the construction analysis required on each new purchased lot with those from the construction analysis performed on the qualified lot. If the initial defects observed on the purchased lots are in the same range of magnitude as the ones observed on the lot used for qualification, we will have a good idea about the evaluation and the behavior of the defects/delamination.

Then, We note that the sample's size is very important to perform an evaluation or a qualification. 10 pieces is a minimum. With less parts, delamination could be by passed.

Finally, we realize that we do not have enough information in this study to be able to set an acceptation criteria about the size and the thickness of delamination. Additional studies are necessary.

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