

Failure Diagnosis in RF Boards and Mitigation Techniques

S. S. Besra, M. Sathisha, Kamaljeet Singh and A.V. Nirmal

System Engineering Group
U R Rao Satellite Centre, Bangalore
Email: ssbesra@ursc.gov.in

(Received December 10, 2020)

Abstract: Surface mount technology is preferably employed for higher throughput and better circuit reliability. PCB board for radio frequencies imposes certain challenges due to incompatible material as well as non-uniform material height. Other requirements such as PCB size, ESD sensitivity, warpage, thermal profile also plays important role for having the higher process yield. Critical devices such as VCO, PLL, Amplifiers chips are having body grounding and are also prone to ESD failures. The requirements for RF boards are different from the standard digital circuits for SMT process. Various boards populated with miniature and special devices are also employed for RF boards and this requirement impose restrictions on the process line. This article details the challenges imposed by the RF boards and the mitigation techniques employed to overcome the same using the SMT line. X-ray and optical inspection are the main characterization tools in the SMT line. X-ray has been effective in detecting defects in non-destructive way and hence enhanced the product quality. The inspection system ensures there are no defects such as solder shorts; Wire breaks, PTH damages, Loose particle/conductive debris inside the packages, Micro-D connector assemblies etc. The system is continuously used to inspect solder joints of QFNs, BGA & CCGAs which cannot be inspected with visual methods. This article details various failures observed using X-ray inspection system and corrective methodology adopted to avoid the future occurrence of the phenomena.

Keywords: Radio-frequency, X-ray, PCB, failure analysis

1. Introduction

Analysis techniques for sub micron semiconductor devices are broadly classified into three categories namely: Electrical Failure Analysis (EFA),

Physical Failure Analysis (PFA) and Fault Isolation. Physical failure analysis using non-destructive technique is the preferred technique due to ease of analysis and safeguarding the component. Radiographic analysis is non-destructive (NDT) which allows inspection of PCB without causing permanent damage. In this direction, X-ray technique is the powerful tool to diagnose the fault and analysis of the component as well as packages which can be simultaneously analyzed¹. Quality oriented PCB needs inspection to find out hidden features mostly solder joints of objects. Traditional method such as optical, ultrasonic and thermal imaging may impose challenge in diagnosis of hidden solder joints, buried and blind holes. X-ray inspection can penetrate into packaging without causing damage to the component/board.

RF boards for aerospace applications need high end reliability to meet the stringent requirements. The various options such as multiple cards, vertical and horizontal stacking, body grounding, enhanced usage of ICs and high density boards necessitated to have proper mechanism for checking various failure modes in package. The prominent modes encountered are the loose jumper in as well as in between cards, proper connector mating, cracks, delamination which effects long term reliability of the circuit performance². In RF boards, gap between the connector and pad, loose contact, mating incompatibility, foreign elements, improper grounding leads to various performance issues most prominently reflected in the losses and oscillatory behavior. X-ray is the effective tool for the diagnosis of the various issues encountered in the RF cards. The effects become more prominent after package undergone various test and evaluation cycles such as shock, vibration and thermal cycling. The X-Ray inspection is useful to find out any metallic loose particles in the package which can be lead to catastrophic failure later on. This article details various failure diagnosed by X-ray inspection and the possible reasons to mitigate the same for future systems.

2. X-Ray Equipment and Capability

Materials absorb X-ray proportional to the atomic weight and it depends upon the density, atomic number and thickness. The X-Ray tube emits an X-Ray beam which hits the image detector beneath the sample manipulator. The X-ray image is converted by the detector into a format that can be displayed on screen^{2,3} and the sample can be manually clamped into the PCB holder or kept on a CFRP plate. After closing the sliding door the control is used to position the manipulator until the sample is in the

appropriate position to be penetrated by the X-ray beam at the desired points. The control console comprises the following:

- (a) Keyboard
- (b) Trackball for operating the system PC and X-ray control software
- (c) Rocker switches
- (d) Joystick for controlling the sample manipulator, detector and rotation/tilt axis
- (e) Rotation axis

General X-ray parameters are voltage, current, filters and software algorithm. The main parameters settings related with voltage and current which are kept around 100-120kV and filament current around 35-40 μA . The parameters of the X-ray is chosen based on the the components attached to the device as radiation sensitive devices can degrade due to prolonged X-ray radiation. The usages of the system are:

- (a) Solder joint inspection
- (b) Package inspection
- (c) Connector inspection
- (d) 3D –CT inspection



Figure 1. X-ray equipment

The machine consists of X-ray tube, platform and detector for proper imaging as shown in Fig 1. Prolonged exposure to X-ray radiation may

cause degradation of the radiation sensitive devices which can be avoided by proper parameters selection.

3. Failure Diagnosis and Corrective Methodology

Various failures encountered after stacking of the package is difficult to diagnose due to inaccessibility of the various points. The X-ray inspection of various points related with connector mating, body grounding, component configuration etc are carried out and various faults noticed are as below

1. Connectors: mating not proper
2. Body grounding: improper grounding leading to oscillations
3. Inductor: batch to batch variations in number of turns
4. Improper Lead: lead cut

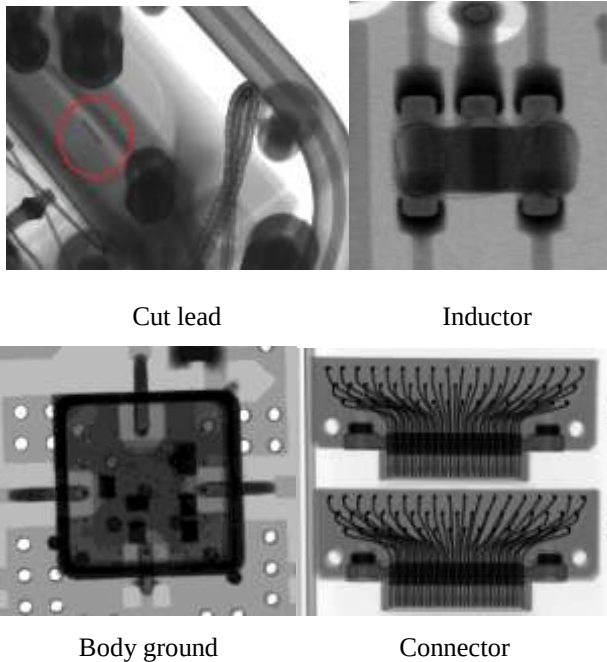


Figure 2. X-ray inspection

The dark and white contrast image as shown in Fig 2 corresponds to metal and glass/plastic/ceramic portion. The failure of SMD components also can be detected using the X-ray imagery. Fig 3 shows the crack observed and the subsequent image clearly validate the crack resulting in open mode.

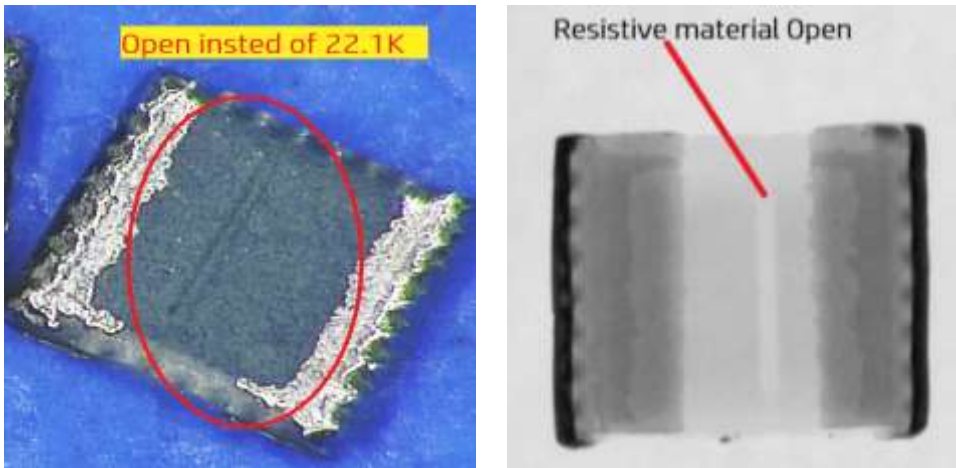


Figure 3. Resistor open mode failure and X-ray image

4. Corrective Methodology

Following are some corrective methods

1. Jack post screw is replaced with more length
2. Broken pin is taken out
3. Solder splash is removed and cleared for next process
4. Cut lead is taken out and cleared for next process
5. Solder short is removed
6. Wire strands is taken out and cleared for mounting

The inspection system ensures there are no defects such as solder shorts; wire breaks, PTH damages, loose particle/conductive debris inside the packages, Micro-D connector assemblies etc. This system can inspect hidden defects such as open, shorts, misalignment, missing components etc. Another important aspect of X-ray imaging is related with the analysis of voids which are important in the case of QFN devices. Voiding image provide the insight of attachment which can be easily distinguishable using the contrast showing the solder area and void area (Fig 4.0). The voids larger than 20 % of the overall area rendered the process failure and re-attachment to be carried out.

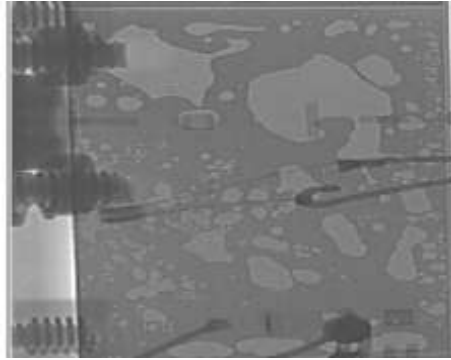


Figure 4. Voids observed after substrate attachment

X-ray facility with computed tomography (CT) images provides 3-D view which can provide the dimension of the voids.

5. Discussion

The X-ray inspection system is indispensable part of the package realization to find out various anomalies which leads to timely intervention saving time and effort. X-ray and optical inspection are the main characterization tools in the SMT line. X-ray has been effective in detecting defects and hence enhanced the product quality. The inspection system ensures there are no defects such as solder shorts; Wire breaks, PTH damages, Loose particle/conductive debris inside the packages, Micro-D connector assemblies etc. The system is continuously used to inspect solder joints of QFNs, BGA & CCGAs which cannot be inspected with visual methods. Body grounding is inspected for voids, contamination, intermixing compounds using the X-ray image

The inspection system ensures there are no defects such as solder shorts, Wire breaks, PTH damages, loose particle/conductive debris inside the packages, micro-D connector assemblies etc. The system is used to inspect and acquire images of the system is also used to detect solder shorts in 3DD memory module after soldering activity. Continual miniaturization and enhanced heat and power requirement demands reliable system and X-ray has been effective in detecting defects and hence enhanced the product quality

6. Conclusion

This article is targeted to diagnose and to carry out the analysis of the defects occurred on RF/microwave boards, components, due to fabrication

process. In this study, X-ray imaging is carried out and various types of defects and various causes of the same are deduced. The finding of the study is successfully applied in all the ongoing fabrication activities.

Acknowledgement: Authors gratefully acknowledge the support provided by Director and Deputy Director, URSC. Also gratefully acknowledge the support of our colleagues at SEG.

References

1. *Flight Electronics Hardware assembly X-ray Inspection*, SEG-CEFD-SMTS-DC 04, 2020.
2. C. Ramanchandra, S. K. Das, M. Ravindra, A. M. Khan, B. M. Sweety, U. G. Chandan and D. Jaypal, In -Situ Polyimide Removal using Modified Dual Acid Decapsulator, *IEEE 17th International Symposium on Physical and Failure Analysis of Integrated Circuits (IPFA)*, (2010), 1-3.
3. Equipment Application, *E nanomax*, 180.
4. L. Solymar, *Modern Physical Electronics*, Champane & Hall, 3, 1975.
5. Howard H. Manko, *Solders and Soldering* McGraw- Hill Professional.