COUNTERFEIT COMPONENTS
and
ACOUSTIC MICROSCOPY

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Abstract

The electronic component user community has now become aware of the immediate danger of counterfeit components although this is still most frequently experienced as the failure of a board to function when first switched on. There are, however more subtle dangers. At the International Conference of the Israel society for Quality 2005, IGG (now ALTER UK) presented a number of examples of counterfeit components, which included product where significant differences in the moulded plastic encapsulant had been observed. This white paper will develop this theme, considering how the encapsulants used by semiconductor manufacturers may be identified and changes or variations detected and will look in detail at encapsulants, and the potential hazards to system reliability.

The principle tool in these investigations has been the scanning acoustic microscope, commonly referred to as SAM or CSAM. This paper will explain the principles of CSAM and illustrate how these are applied in non-destructive testing, failure analysis and how the CSAM compliments radiographic or x-ray inspection. The limitations of CSAM will also be reviewed.

This paper will also describe the results of ALTER UK's research to date into plastic encapsulants and will suggest how this work may be taken forward in the fight against counterfeiters.

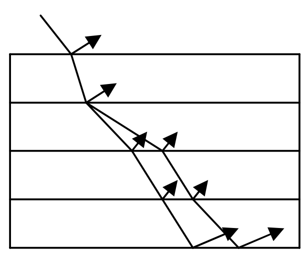
Introduction

Acoustic microscopy uses the same principles as SONAR (for submarine detection), medical body scanning and crack detection (in aircraft). If an ultrasound pulse, that is one above 20KHz, can be transmitted either through or into the subject and the exiting or reflected signal can be detected and processed, an image of the subject can be developed.

Acoustic microscopy relies on two principles: -

- The speed of sound through a material or the acoustic impedance of a material.
- Snell's Law of refraction. Snell, or Willebord Snellius, studied light refraction in 1621 and derived a mathematical formula used in the solving of optical problems. From the acoustic microscopist standpoint this can be simplified to "at any interface part of the acoustic signal will be refracted". The transition between materials of different acoustic impedance enables imaging of the interface between the materials.

An Acoustic Microscope



Snell's Law

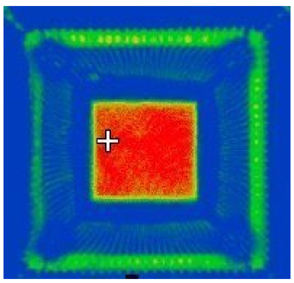
Acoustic microscopy needs a medium through which the ultrasound can be transmitted. It is normal to use de-ionised water so already contamination of the test sample has been avoided. With the application of suitable drying procedures acoustic microscopy may be considered to be a non-destructive test.

Applications of Acoustic Microscopy

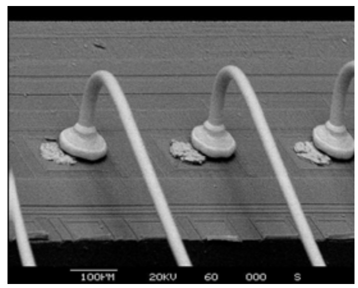
The bulk of the SAM work performed by ATG concerns the screening and failure analysis of plastic encapsulated microcircuits (PEMS) diodes and transistors (PEDS). SAM is able to look at the interfaces between the “plastic” encapsulant and both the die and the supporting lead frame. Poor adhesion of the plastic to the lead frame can allow ingress of moisture from the external environment, which in turn can result in: -

- Corrosion.
- Electromigration of volatile materials, particularly silver in the PEM.
- High leakage currents.

Poor adhesion of the plastic to the die can result in catastrophic failure of a PEM due to a mechanism popularly called “pop corning”. If a gap exists between the plastic and the die (delamination) when the component is soldered to a board massive expansion of air and or moisture in the gap will occur resulting in sufficient movement between encapsulant and die to break the 25um gold wires used to connect the die to the lead frame.



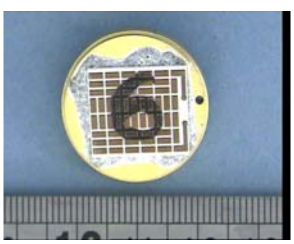
SAM Image of a Delaminated Die



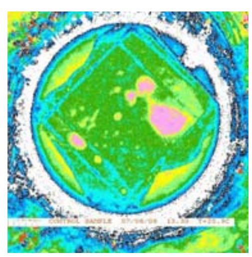
SEM Image of Broken Bond Wires (after Depotting)

The other common applications for SAM are: -

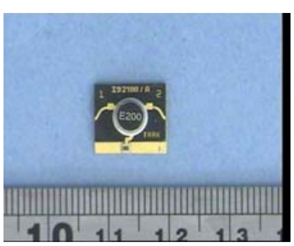
- Assessing semiconductor die attachment, particularly when the heat sink material is impervious to x-rays, eg copper tungsten alloys.
- Assessing microwave ferrite material for cracks. This application was first suggested by an Israeli company.
- Assessing multilayer ceramic capacitors, particularly those used in filter connectors.



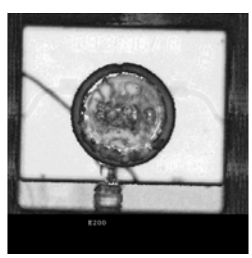
Detector die on a copper/tungsten heat sink



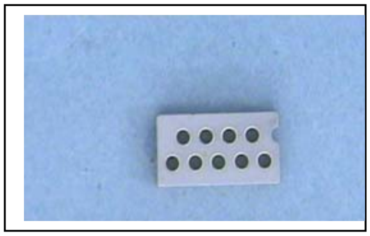
CSAM Image showing void in the solder die attach



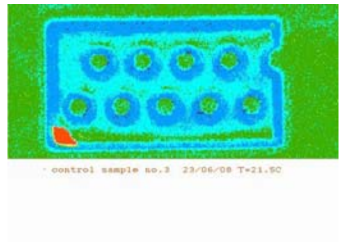
An RF Isolator



CSAM Image Cracks in the Isolator Ferrite



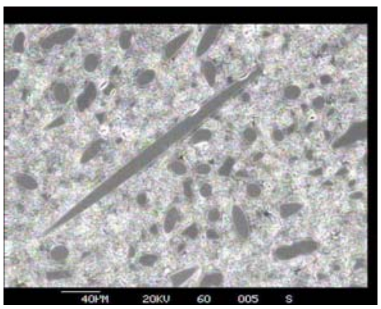
A ceramic capacitor from a filter connector



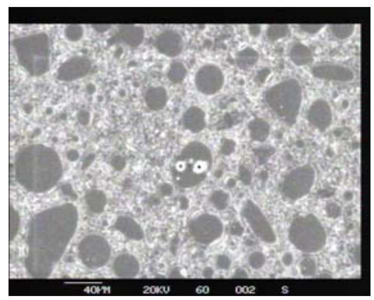
CSAM Image Delamination in the ceramic

Acoustic Microscopy and Counterfeit Components

The encapsulants used in PEMS and PEDS may vary considerably although all are commonly called “plastic”. Some of these variations are application driven, eg the automotive industry has very specific needs but most are cost driven. The component manufacturing industry is driven by the mobile telecoms and computer markets and lower materials costs and higher throughput are desirable goals. These may not be to the benefit of users in the MIL-Avionics-Space industries who need robustness, protection from the external environment and long life.



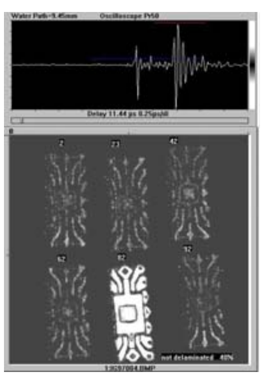
ACTEL



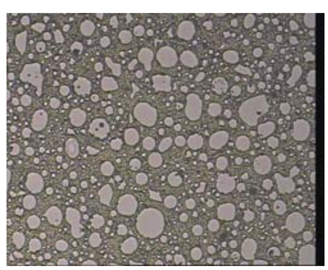
ZETEX

SEM Images of cross-sections through two good but very different “plastic” encapsulants.

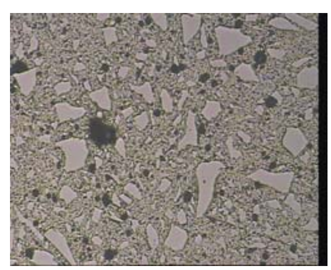
At the 2006 International Conference of the Israel Society for Quality, IGG Component Technology Ltd (now ATG) reported on the identification of significant differences in the acoustic microscopy of one batch of known counterfeits. Further work was performed on samples from this batch and other batches of the same part type and variations in the encapsulant were established.



The original CSAM Image



Encapsulant from the middle top CSAM Image

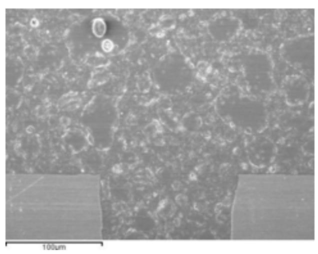


Encapsulant from the middle bottom CSAM Image

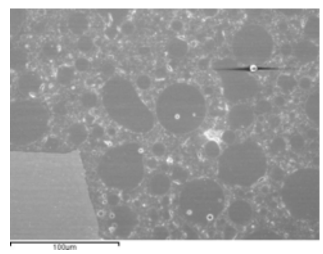
The obvious variation is the shape of the filler, in one case very regular and in the other very irregular. Analysis of the "plastic" was undertaken by X-ray Energy Dispersive Spectroscopy, which revealed that the good parts sampled contained antimony (Sb) a common fire retardant agent. The counterfeit parts showed only minute traces of a bromine based flame retardant. The conclusion must be that even if functional these parts were potentially a serious safety hazard.

It was considered that the limited data available justified continuing the research but to achieve this needed other counterfeit components. Whilst accidental procurement of counterfeit components is only too easy deliberate acquirement is almost impossible.

Some of the counterfeit lots subsequently identified were not available for financial and political reasons and the next parts to become available where an obsolete IDT product.
The parts were marked with a single date code but radiographic inspection had revealed that the die were of differing sizes. It was subsequently confirmed that the batch included two revisions of an IDT die and a CYPRESS die. When cross sectioned there was a difference in the encapsulant when the samples containing IDT & CYPRESS die were compared.



IDT Die



CYPRESS Die

SEM Images of cross-sections through the "IDT" encapsulant.

Both encapsulants had a similar chemical make-up and both contained an antimony based fire retardant.

It had not been possible to perform an acoustic microscope inspection of the batch only on a single sample of the IDT/CYPRESS product. This showed results in line with other IDT and similar product which had previously been analysed, the results of which are included in the ATG CSAM Database.

This database tends to show a similarity between the products of one manufacturer which would be expected but not the diversity which might be expected when comparing different manufacturers using similar packages. This of course may be because the manufacturers are outsourcing assembly to the same sub-contractors. It is however, suspected that the equipment may be limiting the investigation. There are many variables in acoustic microscopy: -

- Frequency of Operation.
- Water Temperature.
- Focussing/Gating.
- Acoustic Signal Power.

All of these may effect high resolution comparisons. At present water temperature is recognised as the most variable factor and it is intended to concentrate on improving the water temperature stability but first more counterfeit components are needed to continue the research.

Conclusion

The considered opinion is that SAM could be used to identify variations between component encapsulants but the technique requires more refinement.