International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Fingerprints of Epoxy Bleed-out on Porous Ceramic Surface

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Abstract— *Epoxy bleed-out (EBO) is a potentially deleterious failure mode emanating from the separation of epoxy glue components and their spread in the substrate. Herein, the fingerprints of a 'disappearing' EBO after cure were explored via surface analytical techniques such as the Fourier transform infrared spectroscopy (FTIR), Scanning electron microscopy – energy dispersive X-ray spectroscopy (SEM-EDS) and Time-of-flight Secondary ion mass spectroscopy (TOF-SIMS). Results indicate the presence of organic residues similar in composition with glue components, and are not reaching the bonding area, and the absence of Ag traces that could induce electrical shorting leading to functional failures.*

Keywords— *Resin bleed out, surface, TOF-SIMS, FTIR, SEM-EDS.*

I. Introduction

Epoxy bleed-out (EBO) is the separation of adhesive components and their spread across a substrate surface [1]. The EBO occurrence can interfere with close packed components and subsequent assembly processes such as wire bonding [2]. Of particular challenge is the use of ceramic substrates where the oxide or nitride surfaces are highly conducive for epoxy component wetting, aggravated by the often porous nature which provides larger surface area for wetting [3]. Moreover, the surface treatments such as plasma cleaning, which are necessary to promote good wirebonding and stronger encapsulant adhesion to prevent delamination, aggravates the EBO occurrence [4]. Technical resolutions such as the use of no-bleed epoxy adhesive [5-6], and the application of anti-EBO coatings [7] on the substrate surface are implemented.

Herein, we encountered EBO after the application and staging of a conductive die attach glue on ceramic interposer surface. The EBO presence posed criticality in the wirebonding process if and when the EBO layer reaches the bonding area, and if conductive traces cause electrical shorting leading to functional failures. Systematic surface analyses were performed via FTIR, SEM-EDS and TOF-SIMS to determine the fingerprints of the EBO residues on critical areas on the ceramic surface.

II. Experimental Details

Samples showing EBO traces after attach process and staging were analysed. Surface analyses were done using Bruker Hyperion Tensor II Fourier Transform Infrared (FTIR) Spectrometer, IONTOF TOF.SIMS[5] in the positive and negative polarities using Bi^+ primary beam, and FEI Dual Beam Helios Nanolab 600i FIB-SEM-EDS system.

III. Results and Discussion

EBO was detected after the die attach process and staging during the assembly process. The bleed-out is visible in a scope surrounding the periphery of the glue mound as indicated in Fig. 1. The bleed-out mark disappears after oven curing. FTIR, SEM-EDS and TOF-SIMS analyses were performed to elucidate the fingerprints of the EBO on the porous ceramic surface.

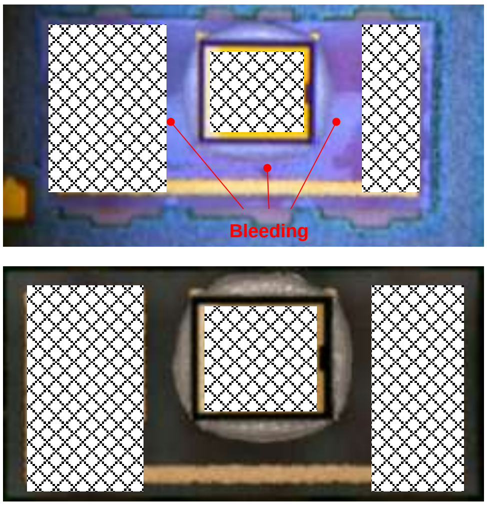

Fig. 1. EBO marks after the glue attach process and staging (top) and after the oven curing (bottom). Portions not crucial to the analysis were redacted due to the proprietary nature of the product.

A. FTIR Analyses

FTIR analysis is designed to analyze organic compounds but cannot identify the exact structure of an unknown compound. At best, it can suggest possible structures based on similarity analysis in reference to a database. An in-house library of spectra, generated from the scanning of direct and indirect materials used in the product, is used as a reference. The Bruker matching algorithm suggests spectra with their corresponding hit rate (% similarity). Matching is limited to formulations; it does not discriminate between or among individual components of the formulations.

Fig. 2 shows the stacked spectra of two processed samples, one fresh surface, and the reference glue material. PT1 & PT2 in Samples 1 & 2 correlate with the glue material (71-76%). PT3 does not match with the glue but matches with the fresh surface, indicating that PT1 & 2 are within the bleed-out area.

Ian Harvey Arellano, "Fingerprints of Epoxy Bleed-out on Porous Ceramic Surface," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 3, pp. 198-201, 2019.

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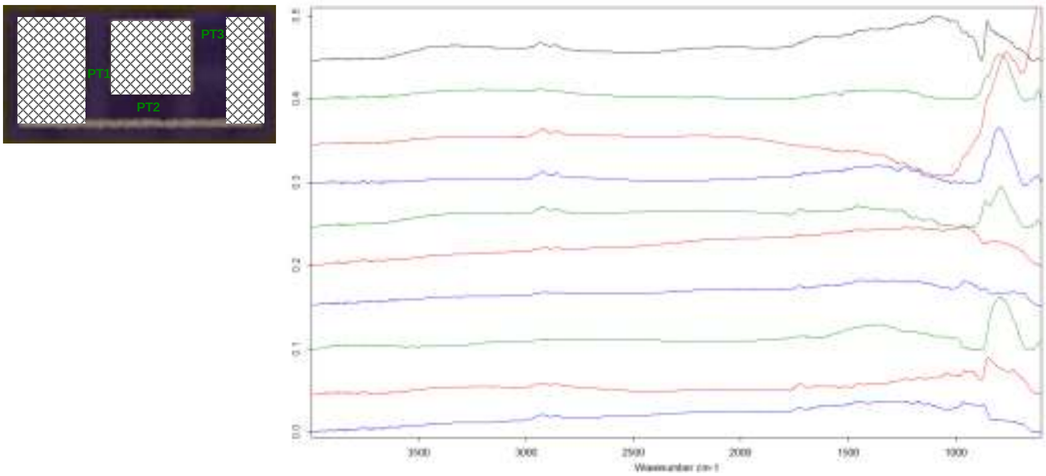

Fig. 2. FTIR spectra of samples and references. From top to bottom of the stack: glue, PT3 – fresh, Sample 2 & 1, PT2 – fresh, Sample 2 & 1, and PT1 – fresh, Sample 2 & 1. Reference image indicating PT1, 2 & 3 is included in the upper left side of the image.

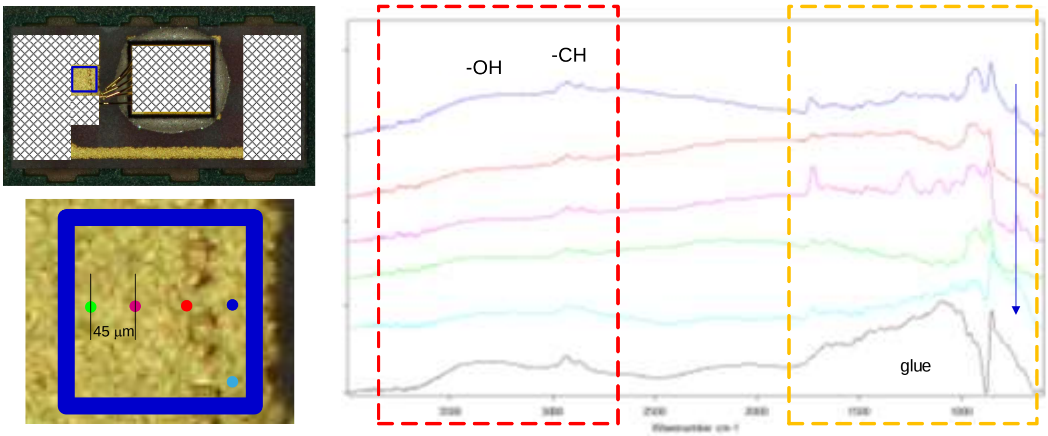

Fig. 3. FTIR spectra of the bonding area.

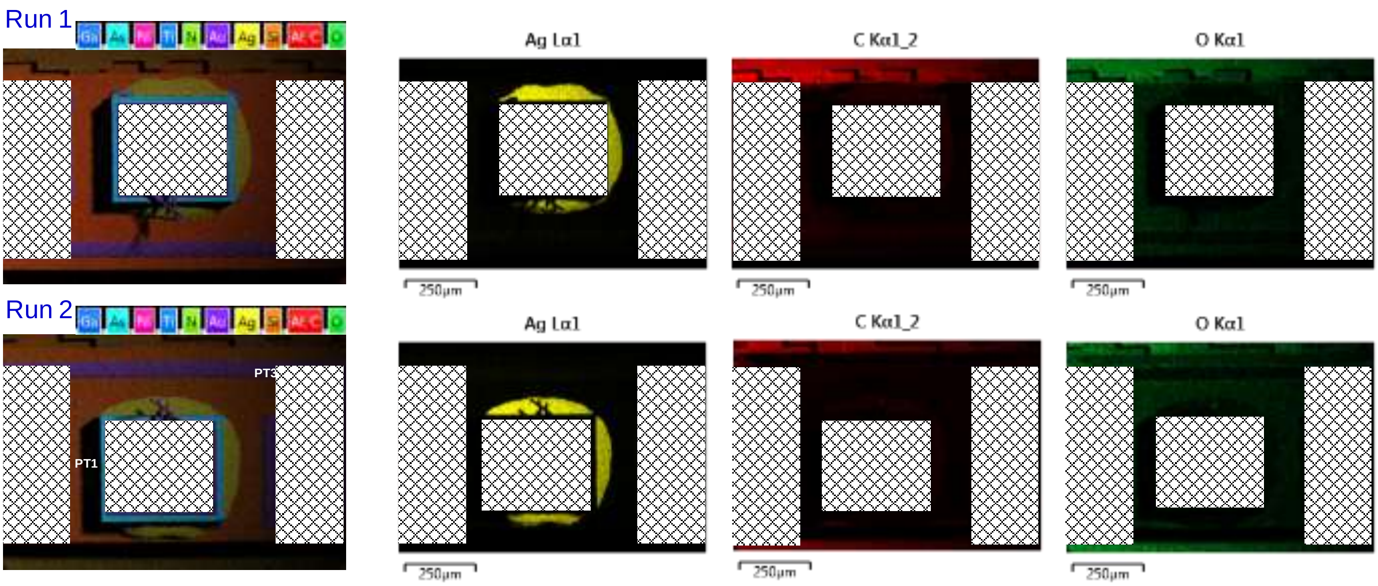

Fig. 4. EDS elemental maps.

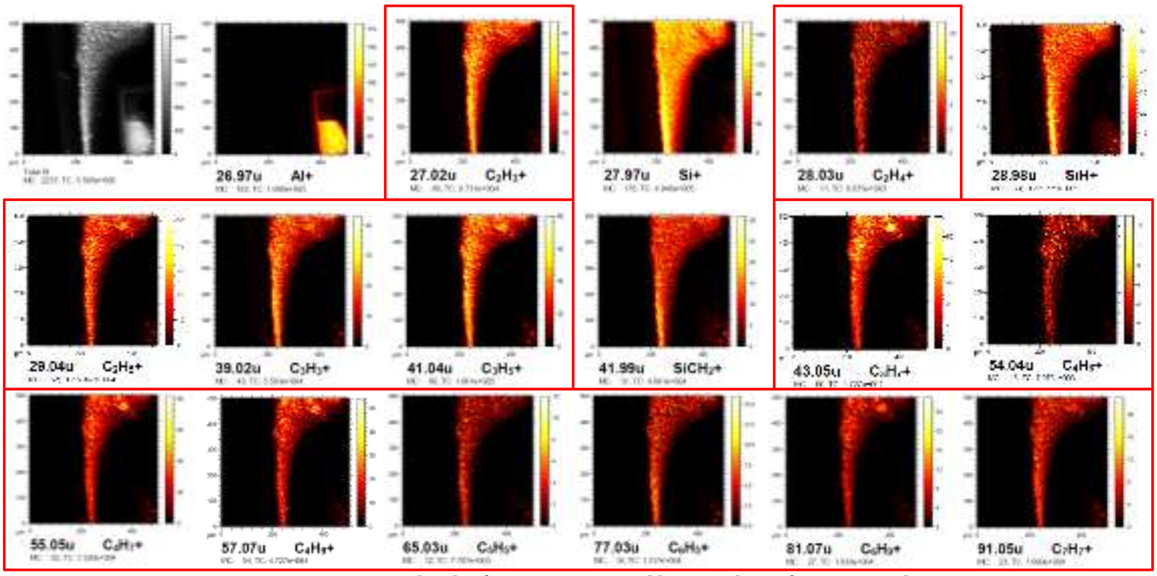

Fig. 5. Positive scan TOF-SIMS molecular fragment maps. Red boxes indicate fragments with organic origin.

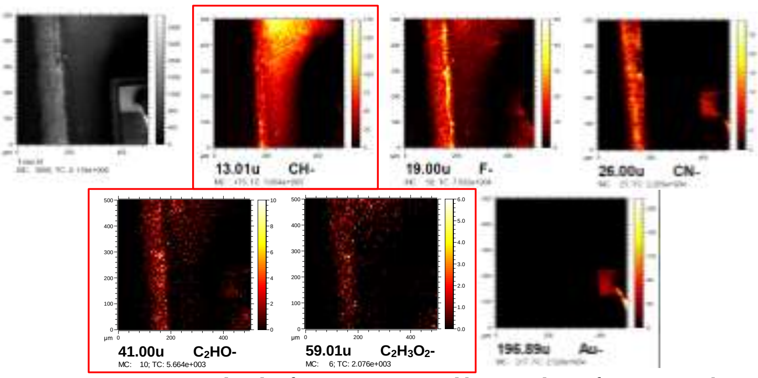

Fig. 6. Negative scan TOF-SIMS molecular fragment maps. Red boxes indicate fragments with organic origin.

To assess the potential effect on the wirebonding process, the bonding area was analyzed. Spectra from the bond pad does not match spectrum of the glue (Fig. 3). Spectral region between 2800 and 3200 cm^{-1} could not discriminate among the organics, hence is seldom used to understand differences between materials. The region between 3200 and 3500 cm^{-1} corresponds to –OH stretch, which can come from the adsorbed H_2O and is not usually used as basis for determining differences between materials. The fingerprint region (<1000 cm^{-1}) is the more significant area for comparison. The peaks present in this region does not match peak profile of the reference glue, suggesting that the EBO did not reach the bonding area.

B. SEM-EDS Analyses

FTIR analysis suggested the presence of glue on the ceramic surface, but not on the bonding area. To assess if conductive traces (Ag) dissipated from the glue mound, SEM-EDS analysis was done. The presence of conductive traces on the ceramic surface could potentially lead to electrical shorting, a product functional failure. Possible organic remnants (C, O) were observed on the ceramic area even after oven cure. TOF-SIMS analysis is suggested to check if C, O is organic or just part of the ceramic ($Al_xO_yN_z$). No indication of Ag, C and O on the bond pad validating the results of the FTIR analysis that the EBO did not reach the bonding area.

C. TOF-SIMS Analyses

There is a pronounced elevation difference of the bond pad area, the ceramic area, the glue and the die, posing a geometric constraint and limiting accessibility. The sample was tilted to maximize the signal, making the ROI accessible despite the geometric constraint. The bond pad area was excluded due to the loss of signal from the ceramic area when bond pad is part of the ROI. The loss of signal is due to the geometric constraint. The positive and negative scans confirm the presence of organic residues on the EBO area. Organic fragments (C_xH_y and $C_xH_yO_z$) on top of the ceramic substrate indicate the presence of the glue resin component. These results are consistent with the FTIR & FESEM-EDS results.

IV. Conclusion

EBO encountered after glue attach process and staging during assembly poses possible device functional failure. Systematic analyses of the EBO fingerprints on the surface of the porous ceramic substrate using FTIR, SEM-EDS and TOF-SIMS indicate that EBO area is positive for traces of the glue material. However, the bonding area does not contain glue residues. Possible organic remnants (C, O) were observed on the ceramic area even after oven cure but no indication of Ag, C and O on the bonding area and the die. Moreover, the positive and negative scans confirm the presence of organic residues (C_xH_y and $C_xH_yO_z$) on the EBO area. These results indicate a low risk for the EBO to affect the device functionality.

ACKNOWLEDGMENT

The author acknowledges the support of the Failure Analysis and Process Engineering Groups of STMicroelectronics, and the service of the Department of Science and Technology - Advanced Devices and Materials Testing Laboratory (DOST-ADMATEL).

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