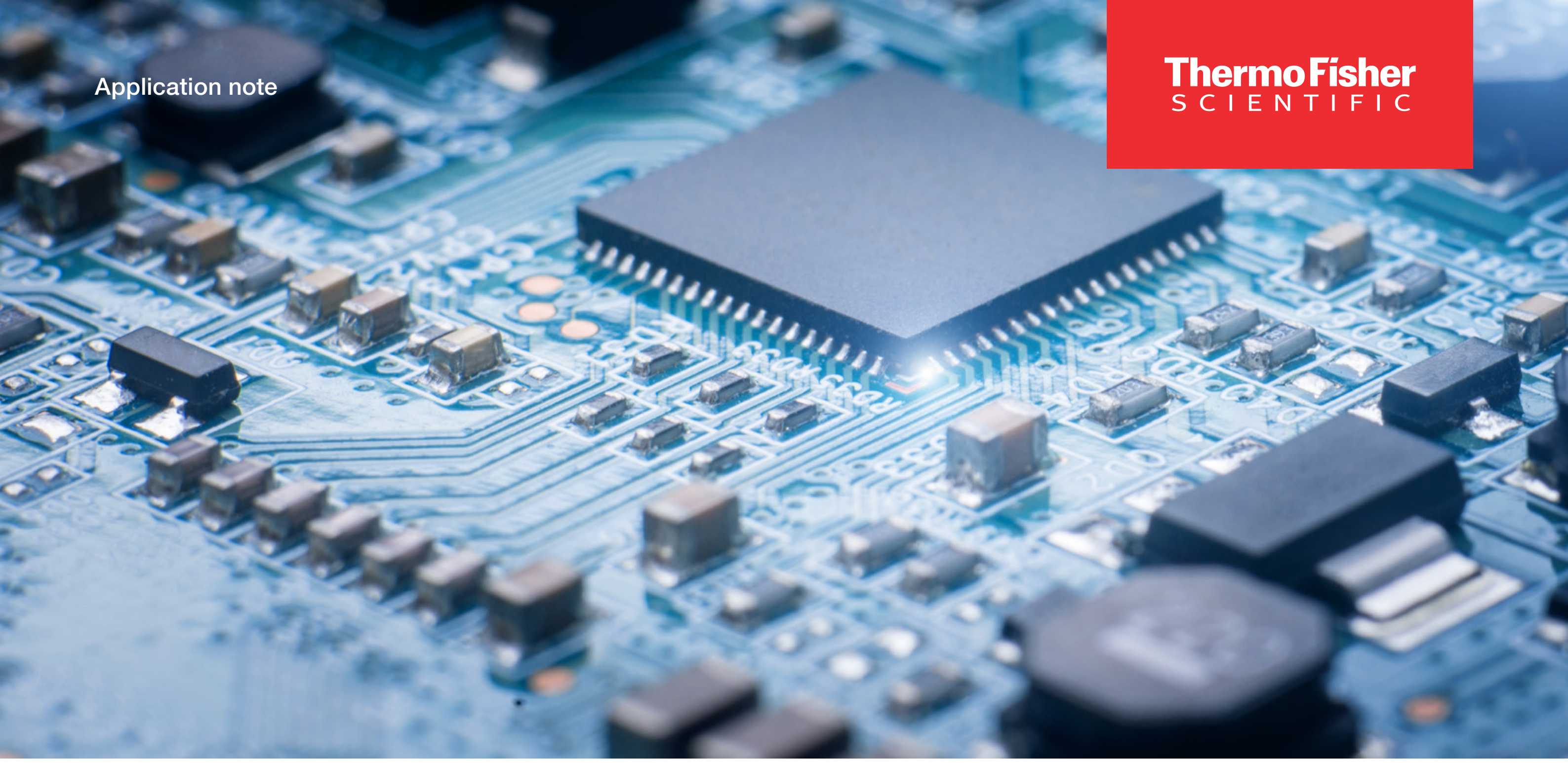
Application note



Failure Analysis of Printed Circuit Boards using FTIR Microscopy

Authors

Jaspreet Singh, PhD, and Rui Chen, PhD, Thermo Fisher Scientific

Introduction

Printed circuit boards (PCB's) are one of the most critical elements within modern electronics, enabling the support and electrical connection of components in a circuit. With the increasing drive towards miniaturization and the increased complexity of electronics, reliability of PCB's and PCB assemblies (PCBA's) is critical towards ensuring products function as intended.[1] The investigation of issues and root causes related to PCB production and failure, performed through a multidisciplinary approach, is known as failure analysis (FA).

Common PCB failure analyses include residue analysis, foreign material identification, and analysis of foreign features on the boards. Many analytical techniques are utilized for PCB failure analysis, including visual microscopy, molecular spectroscopy, scanning electron microscopy, X-ray fluorescence, and cross-section analysis, among others.[2–4] Each analytical technique provides different pieces of information about the sample. These analytical methods can be broadly classified into two groups, destructive and non-destructive. Destructive methods, such as micro-sectioning, involve physical alteration or damage to the sample; hence, such methods limit the number of analyses and ultimately the amount of information that can be discerned from a single sample. Non-destructive methods keep samples intact, thus allowing multiple analyses using different techniques to be performed. Non-destructive methods result in a more holistic understanding of the root causes for PCB failures and are therefore highly preferred.

Fourier-transform infrared (FTIR) microscopy is a non-destructive analytical technique that has been extensively applied in the analysis of PCB's.[5,6] FTIR microscopy can provide information about the chemical composition of the failure, help identify foreign material on assemblies, and map the chemical changes or distribution of materials across the surface of a PCB. In this application note, examples of root-cause failure analyses of PCB assemblies using FTIR microscopy are illustrated.

Experiment

PCBA's were acquired from commercially available products. Three PCB samples were analyzed: 1) a black PCB with an unknown feature; 2) a PCB with white residues; and 3) foreign material dispersed over a component. Sample 1 was analyzed "as-is" to identify the unique features. To mimic two commonly encountered failure scenarios, residues on assembly 2 were prepared through the addition of flux followed by cleaning. Foreign deposits on assembly 3 were prepared by dispersing excess flux on the final assembly.

A Thermo Scientific™ Nicolet™ RaptIR FTIR Microscope was used in this study, and Thermo Scientific™ OMNIC™ Paradigm software was used for all data acquisition and analysis. A 4X objective was used for visual image capture, with a 15X IR objective automatically rotating in for IR data capture. Single point measurements were collected with a germanium crystal micro-ATR (Ge-μATR) using an aperture of 100x100 μm, a spectral resolution of 8 cm^{-1}, and 16 scans co-addition for each spectrum. The motorized stage and built-in pressure sensor were used to automate data collection at the defined location and at the desired pressure. The mapping data was acquired in reflection mode with high-speed data collection at a spectral resolution of 16 cm^{-1} and 1 scan, with a 50 μm x 50 μm aperture and a 45 μm step size.

Results and Discussion

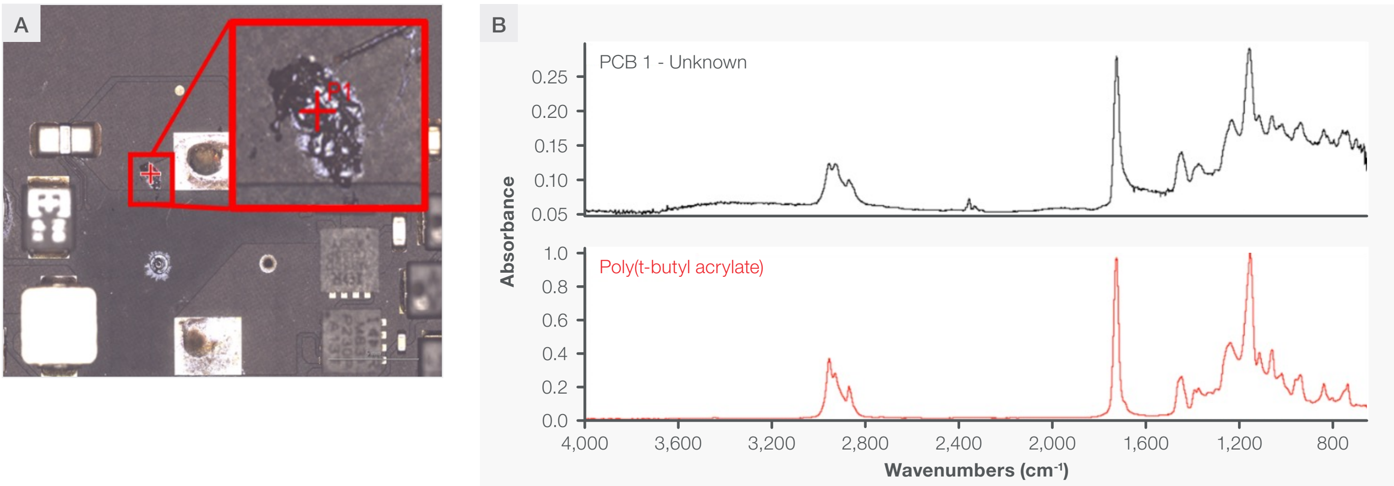


Figure 1. A) A visual image showing an unidentified feature and the sample point indicated and expanded in the inset image; and B) the resulting infrared spectrum (black) and library match (red).

Figure 1A shows the image of the PCBA with an unknown feature on the board, indicated by the red box. A single point measurement was made at the crosshair. The stacked spectra in Figure 1B show the sample spectrum (black) and the corresponding library match (red). The material was identified as a poly(t-butyl acrylate) with a match value of 87.43, a material commonly used in the formulation of binders, adhesives, and sealants, among others. This foreign material likely originates from some adhesives/binders which may be used in the manufacturing of the PCB assembly. In this case, the identification of the unknown feature provides an insightful clue about its origin and important guidance on future mitigation.

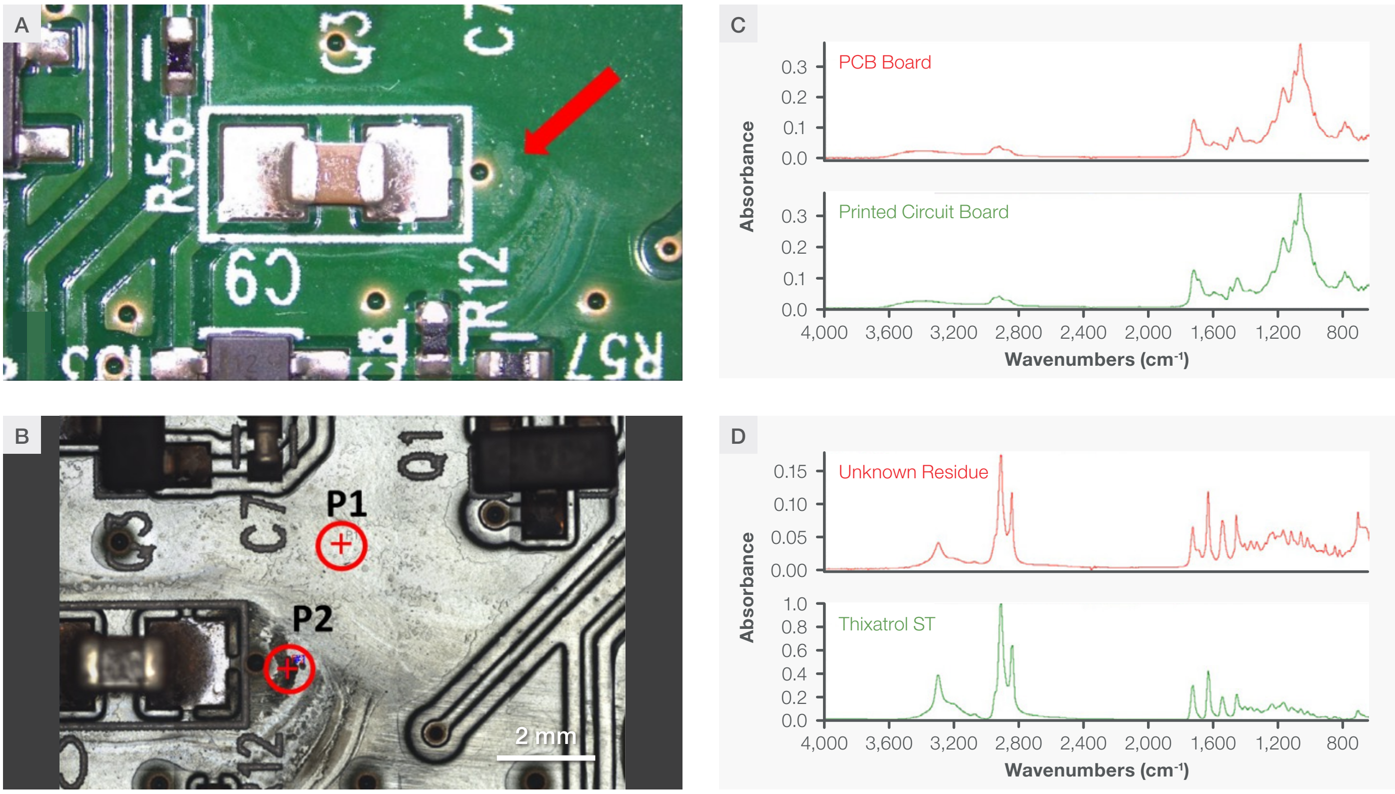
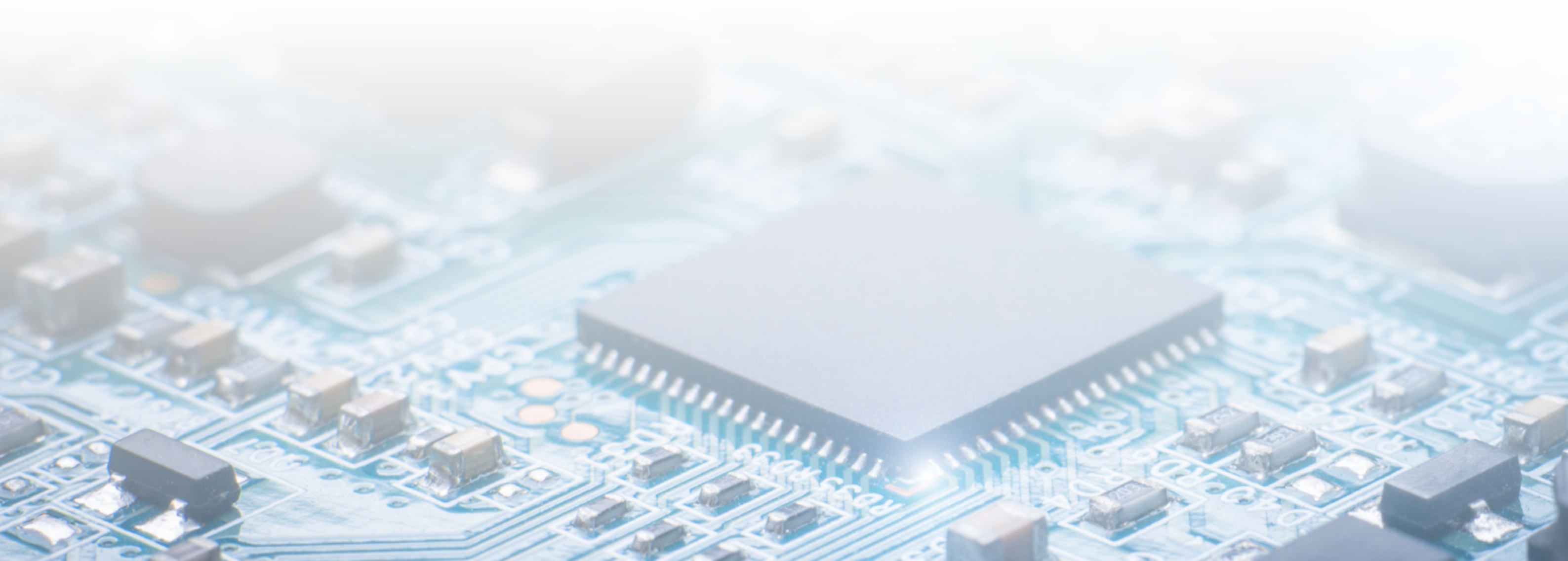


Figure 2. A) Visual image and B) RaptIR FTIR microscope visual image of residue. The resulting spectra and library matches are shown in C) for the clean PCB board (*P1*) and in D) for the residue (*P2*).

The second sample represents a common failure in PCBA's, where a residue is observed on the final assembly which results in a failed visual inspection. Figure 2A shows an image from a visual microscope, with a visually discernible white film dispersed on the board indicated by the arrow. Figure 2B shows a visual image of the same region using the RaptIR microscope. Two sample locations were analyzed in this sample, as indicated with the red circles: a clean PCB location (*P1*) as the reference and the residue (*P2*). Figure 2C shows the spectra of the bare PCB (top, red) and its library match (bottom, green). Figure 2D shows the residue spectrum (top, red) and the library match (bottom, teal). The clean PCB spectrum is significantly different from the residue spectrum. A library search of the clean PCB against a user-created library shows a good match to "clean PCB substrate" with a match value of >95. On the other hand, the residue provides a good match from a commercially available library to Thixatrol ST (match value >93), a rheological component often found in flux or coatings. Clearly, the residue originating from flux or coating was not completely removed by the cleaning procedures.



The final example is a PCBA analyzed by collecting area maps across two soldered regions. Distributions of materials can be visualized through chemical profiles generated based on spectral correlations, peak area, peak height, ratios, or multivariate curve resolution, among others. FTIR mapping yields information on the chemical distribution and/or chemical change across a sample, thereby offering valuable insight to the location and spread of possible contaminants. Figure 3A shows the reference spectrum (red, top) used for generating the infrared correlation image and its library match (yellow, bottom). The spectrum has a match value of >83 to rosin oil, a natural flux material used in soldering. Figure 3B shows the visual images of the two locations with visible non-conformities. Area maps were collected over two regions, A2 and A3, respectively. A2 represents an area of ~ 4 mm x 4 mm with >8300 spectra acquired in about 12 minutes and A3 an area of ~ 3.7 mm x 3 mm with >5800 spectra collected in under 9 minutes. Figure 3C shows the chemical maps created by correlating the spectra in the defined region with the reference spectrum. The colors in the chemical map represent the similarity between the collected spectra and the reference spectrum, with red indicating high correlation and blue low correlation. Figure 3C clearly shows that the rosin oil is spread around a large portion of the regions but with uneven distribution. Residual flux can lead to possible premature product failure and the understanding of its chemical origin and distribution provides important information on necessary countermeasures in production.

Conclusion

In this note, examples of common types of failure analysis of electronic components are demonstrated with the Nicolet RaptIR FTIR microscope. Foreign materials can be directly analyzed on the final assembly for rapid identification of failures or non-conformities. Micro-ATR was utilized for non-destructive, contact-based analysis to identify adhesive and rheological components. Automated mapping showed distribution of flux residue across the surface of a PCBA, enabling a comprehensive visual and chemical analysis.

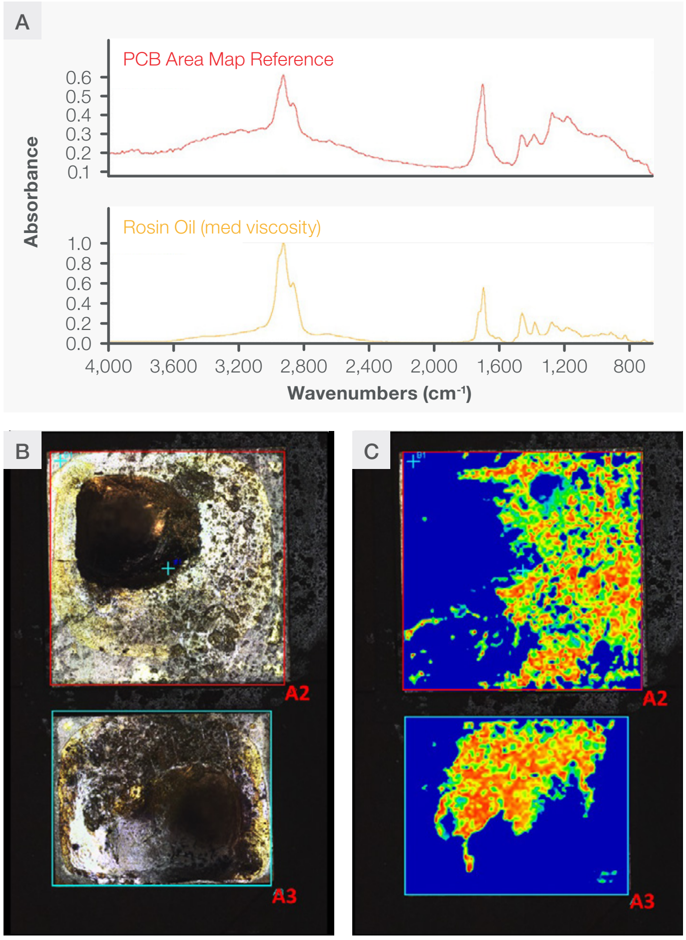


Figure 3. A) Reference spectrum (red, top) and its library match (green, bottom) for rosin oil; B) images of the two locations with visible non-conformities; and C) chemical maps representing the similarity between the collected spectra and the reference spectrum for rosin oil. (red high correlation and blue low correlation)

References

1. Fung, V. W.; Yung, K. C. An Intelligent Approach for Improving Printed Circuit Board Assembly Process Performance in Smart Manufacturing. *Int. J. Eng. Bus. Manag.* **2020**, *12*, 1847979020946189. https://doi.org/10.1177/1847979020946189.
2. Grosshardt, O.; Nagy, B. Á.; Laetsch, A. Applying Microscopic Analytic Techniques for Failure Analysis in Electronic Assemblies. *Appl. Microsc.* **2019**, *49* (1), 7. https://doi.org/10.1186/s42649-019-0009-1.
3. Huang, C.; Li, M.; Ku, C.; Hsieh, H.; Li, K. Chemical Characterization of Failures and Process Materials for Microelectronics Assembly. *Microelectron. Int.* **2009**, *26* (3), 41–48. https://doi.org/10.1108/13565360910981553.
4. Ji, L.-N.; Yang, Z.-G.; Liu, J.-S. Failure Analysis on Blind Vias of PCB for Novel Mobile Phones. *J. Fail. Anal. Prev.* **2008**, *8* (6), 524–532. https://doi.org/10.1007/s11668-008-9174-1.
5. Shrivastava, A.; Bangerth, S.; Azarian, M. H.; Morillo, C.; Pecht, M.; Levin, M.; Steinhardt, L.; Callini, A. Detection of Capacitor Electrolyte Residues with FTIR in Failure Analysis. *J. Mater. Sci. Mater. Electron.* **2014**, *25* (2), 635–644. https://doi.org/10.1007/s10854-013-1146-x.
6. Conseil, H.; Stendahl Jellesen, M.; Ambat, R. Contamination Profile on Typical Printed Circuit Board Assemblies vs Soldering Process. *Solder. Surf. Mt. Technol.* **2014**, *26* (4), 194–202. https://doi.org/10.1108/SSMT-03-2014-0007.

Learn more at **thermofisher.com/ftir**