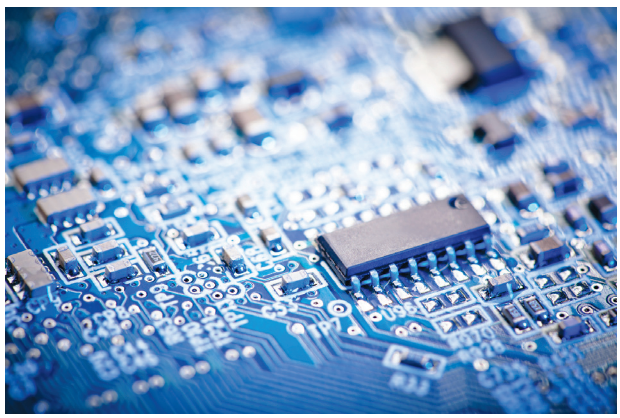
Damage-free failure/defect analysis in electronics and semiconductor industries using micro-ATR FTIR imaging

Application note

Electronics and Semiconductor



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Introduction

The electronics and semiconductor industries rely heavily on failure and defect analysis to maximize productivity and minimize expensive downtime. As technology improves, manufactured devices get smaller and the processes used to make them become more intricate. Costly downtime associated with the presence of particulate and chemical contamination becomes more critical to a successful manufacturing operation. Any contamination requires the manufacturing process to stop while the defect is accurately and reliably characterized, the source identified, and the problem remedied. Minimizing the time needed to complete this process can quite literally save millions of dollars.

Fourier Transform Infrared Spectroscopy (FTIR) is a non-destructive analytical technique that helps identify and monitor the chemical makeup of almost any material. The technique yields a characteristic chemical fingerprint of the sample by measuring the absorption of infrared radiation and a range of FTIR instruments are now available, each with particular analytical capabilities. The Agilent Cary 620 chemical imaging system uses an FPA (a two-dimensional matrix of detector elements which yield both rows and columns of pixels) to collect true compositional images of the surfaces of delicate components. Minimal or no sample preparation is required and the entire, non-destructive, analytical process can be performed by non-specialists in a matter minutes. Data, which is collected with unrivalled spatial resolution, can be extracted from each and every pixel on the chemical image. Heterogeneities as small as 2 µm are readily distinguished from the matrix, and a molecular signature of every square micron of the sample is easily identified by automatically searching through commercially available reference libraries.

Methodology

Sample acquisition

An LCD color filter and a printed circuit board (PCB) were received from two manufacturers. Both manufacturers had used traditional analytical techniques to unsuccessfully identify the presence of unexpected particles on their components and needed to increase their knowledge about the composition and origins of these defects so that their impact on the manufacturing process could be assessed.

Sample preparation

Both samples received from the manufacturers were analyzed by simply placing them onto the motorized microscope sample stage, ready for micro-ATR contact and data collection. No further sample preparation was required and in both cases, the components were mounted onto the microscope, analyzed, removed from the sample stage, repackaged and then returned to the manufacturers after analysis without any damage or evidence of the analytical process.

Instrumentation

High spatial resolution chemical images were obtained using an Agilent Cary 620 FTIR microscope with a 64 × 64 Focal Plane Array (FPA) detector coupled to an Agilent Cary 660 FTIR spectrometer. Data was collected at 1.1 µm per pixel resolution using a micro Germanium Attenuated Total Reflection (ATR) accessory and processed using Agilent Resolutions Pro software. Instrument operating parameters are summarized in Table 1.

Table 1. Agilent Cary 660 FTIR and 620 FTIR microscope collection parameters

Parameter	Value
Spectral resolution	8 cm^{-1}
Scans	128
Spectrum range	4000–900 cm^{-1}
Spatial resolution	1.1 µm/pixel
Field of View (FOV)	70x70 µm
Total number of spectra	4096
Total collection time	4 minutes

Identifying submicroscopic foreign particles on LCD screen components

Microscopic specks of "dust" appeared to contaminate the surface of a fragile LCD color filter. The customer was extremely concerned about the source of the particles and asked that they be quickly and reliably identified so the origin could be established and the problem remedied. The filter was simply placed onto the motorized microscope stage and measured as received. Measurements were performed in micro-ATR mode using Agilent's unique live FPA imaging technique, which, by providing real-time feedback, ensures that the correct amount of pressure is applied by the ATR and allows the most delicate components to be analyzed without damage. A 70 × 70 µm micro-ATR FTIR chemical image of the area was collected at a pixel resolution of 1.1 µm/pixel and the molecular composition of the defects and the matrix characterized. Resolutions Pro software was used to process the spectra (4096 spectra of the matrix and the defects were simultaneously collected in 4 minutes) and generate false color images of the relative intensities of a strong absorbance peak at 1017 cm^{-1} that characterized the contaminant (Figure 1). In-house spectral libraries were used to identify the contaminants as spacers which are normally used to keep the layers apart, but had become dislodged post-manufacture.

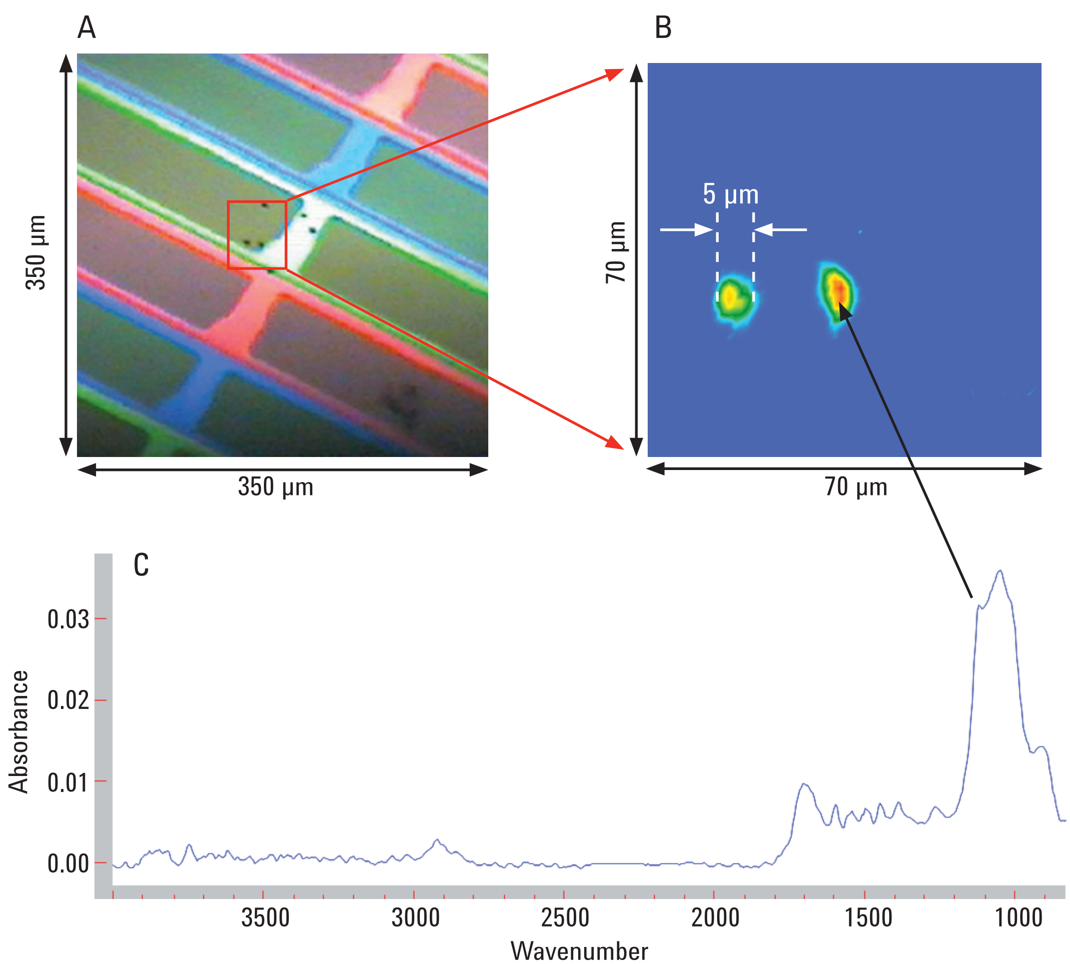

Figure 1. Particulate contamination in a LCD color filter. A) Visible image capture of region of interest containing defects, B) FTIR chemical image, based on absorbance at 1017 cm^{-1}, C) Single pixel spectral extraction from one of the defects.

Identifying and characterizing contamination on a printed circuit board (PCB)

Printed circuit boards (PCB) support and connect electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. PCBs are ubiquitous in modern life but since components must be cleanly insulated or connected to ensure correction functioning of the board, any minor contamination can easily prove problematic. The customer, who supplied the PCB shown in Figure 2, had previously tried to troubleshoot the PCB using a micro-ATR imaging system from another vendor, but without using Agilent's unique live ATR imaging technique. The large, white area in the center of the board is the result of the significant damage caused by excessive ATR pressure. Subsequent analysis using the Cary 620 FTIR employing the real-time ATR imaging technique ensured that the correct amount of pressure was applied by the ATR on this delicate sample. Once acquisition conditions had been determined, a chemical image was collected (Figure 2) and processed using Resolutions Pro software. Regions of anomalous molecular composition became readily evident as soon as the image had been collected and

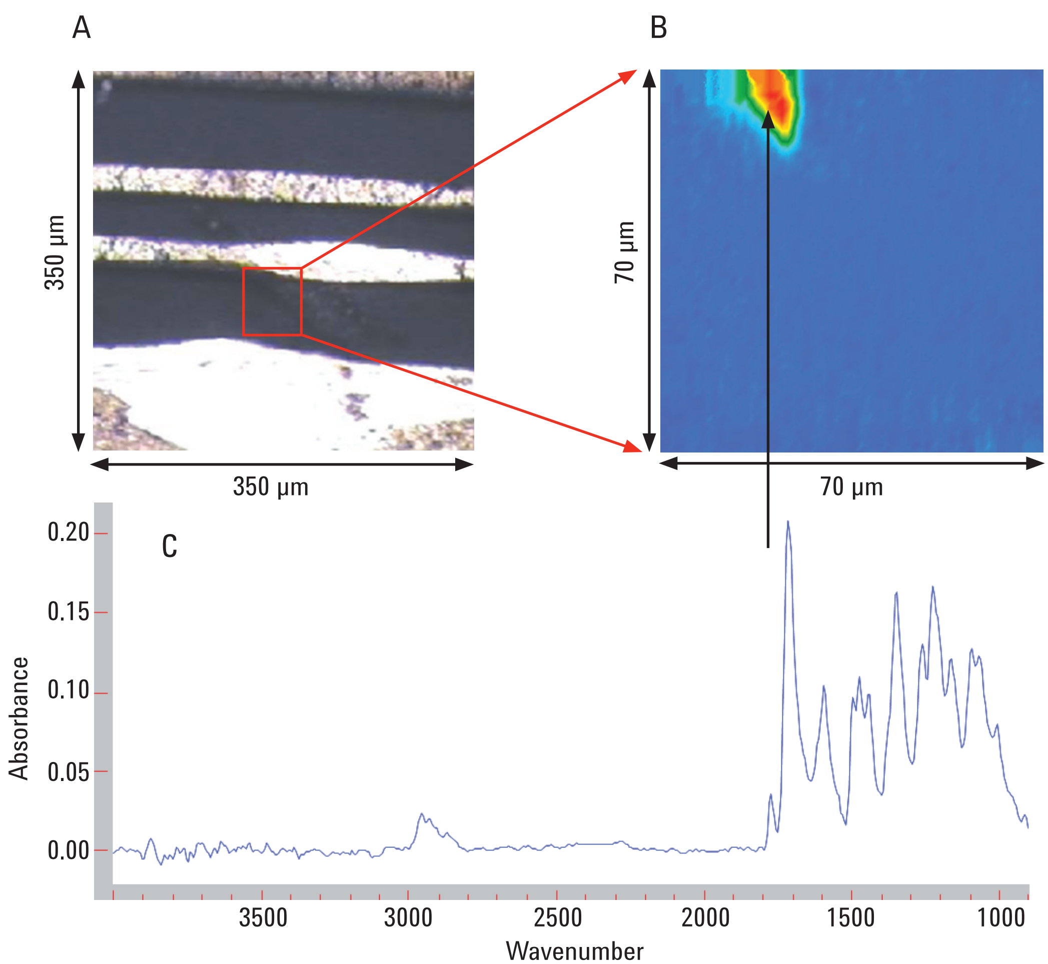

Figure 2. Visible light image (A), micro-ATR FTIR chemical image at 1720 cm^{-1} (B) and extracted single pixel spectrum of a defect location on PCB (C). The large white area on the visible image is damage during a previous, failed attempt to identify the defect using a non-Agilent ATR FPA imaging system.

it took only a quick spectral search to identify the contaminant specks to be polyetherimide which had not been correctly cleaned after manufacture.

This analytical approach demonstrates how quickly identification of contaminates by ATR imaging can help rectify the problem, reducing downtime and product non-conformance costs.

Conclusions

The Agilent Cary 620 FTIR chemical imaging system has been successfully used to quickly, easily and non-destructively characterize contaminant species on delicate electronic components down to a few microns without causing any damage or leaving any indentations — all within a few minutes. In such situations, where analysis of particles as small as a few microns is required, the live FPA on Agilent's Cary 620 FTIR imaging system with enhanced chemical contrast is the only analytical technique capable of providing spatially resolved chemical information to reliably and non-destructively characterize materials such as dirt, dust, skin, solder particles, oil or clipped wires. FTIR chemical imaging provided essential, spatially resolved, chemical information within a few minutes and, by quickly helping resolve the chemical makeup and therefore also the source of the defects, significantly reduced manufacturing downtime, and increased both the efficiency and productivity of the manufacturing operations.

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