



Automotive Failure Analysis by FT-IR Microscopy

Application Note M112

Introduction

FT-IR microscopy is essential for automotive industries, offering precise chemical analysis for failure detection and quality assurance. Fast and reliable defect identification on surfaces and challenging locations is crucial for maintaining high product standards and ensuring effective production processes.

This note focuses on FT-IR microscopy employing Attenuated Total Reflectance (ATR) for rapid identification of surface contaminants and defects in automotive components, showcasing its significant benefits in quality management and failure analysis.

Materials & Methods

The featured analyses utilized Bruker's LUMOS II FT-IR microscope with an integrated motorized ATR crystal. The built-in pressure sensor ensures reproducible and optimal sample contact through adjustable pressure settings. The narrow ATR crystal tip (100 μm) allows precise measurements on difficult-to-reach and irregular surfaces without extensive sample preparation, significantly enhancing analytical efficiency.

Results & Discussion

FT-IR microscopy and especially the ATR technique demonstrate significant practical advantages in automotive quality control and failure analysis, as the following examples will demonstrate.

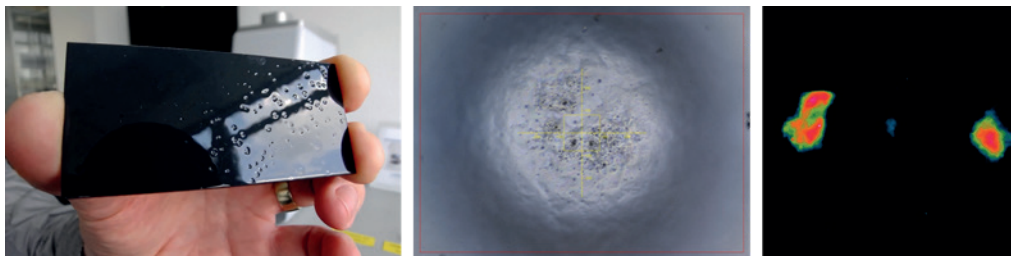


Fig. 1

Sheet metal exhibiting obvious cratering (left), the microscopic close-up of a crater, showing black droplets of an unknown residue (mid), and the IR image collected by using ATR, showing the chemical identity of the contaminant (right).

Surface contaminations significantly impact automotive applications, particularly in processes such as painting or applying functional coatings. Inadequate surface cleaning prior to coating can result in defects such as cratering and the formation of so-called „fish eyes.“ Figure 1 illustrates the analysis of a coated sheet metal sample provided by a German car manufacturer.

The microscopic image of a crater exhibits an unknown residue at its center. To investigate the contaminant, FT-IR ATR imaging was used to analyze the ROI inside the crater. The resulting IR image identified the substance as silicone oil—a common contaminant. This finding indicates that the metal surface was not properly cleaned prior to coating, leading to coating failure.

As mentioned before, similar problems can arise when dealing with functional coatings. In the next example (Fig. 2), a surface-damaged diesel engine piston was subjected to FT-IR analysis.

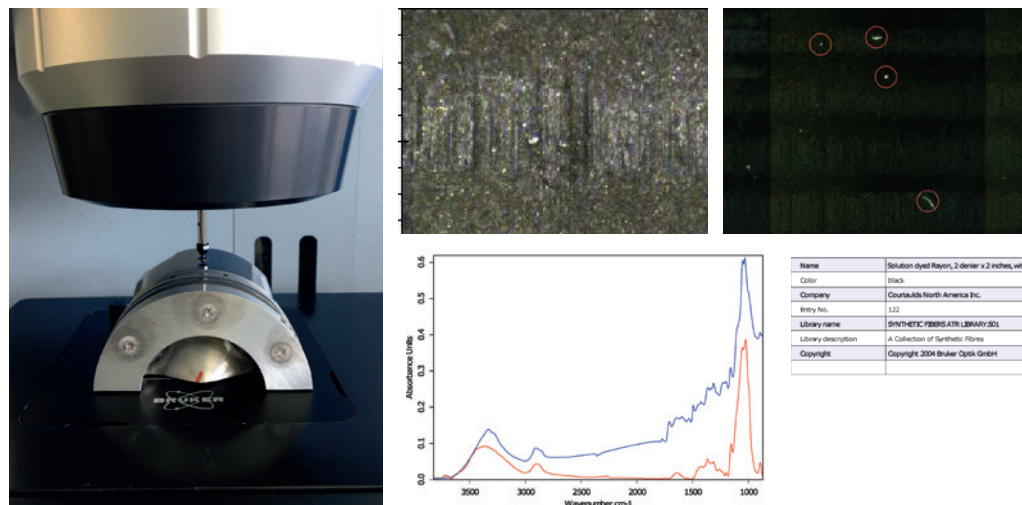


Fig. 1 Halved piston from a diesel combustion engine and microscopic visual images of the piston’s coated surface before and after applying polarizing filters, revealing fiber contamination. ATR-FT-IR spectral identification confirms the fibers as rayon, highlighting FT-IR microscopy’s ability to uncover and chemically identify otherwise hidden contaminants.

By using polarizing filters, small fibers were revealed in the groves of the coating.

Subsequent ATR analysis, aided by the LUMOS II microscope’s precise contact mechanism and pressure control, identified the contaminant as rayon. This directly facilitated the pinpointing of contamination origin, resolving the issue and protecting the piston coating’s integrity.

Overall, particulates and fibers are typical contaminations in automotive industries. Due to the compact design of automotive components, however, defects and contaminants often remain undetected until functional failure occurs. This electrical motor housing (Figure 2) is a perfect example for that.

The visual image showed a foreign particle on a metal spring. The integrated, motorized ATR crystal of the LUMOS II provided direct access to the internal structure of part of electrical motor housing without any sample preparation. The contaminant was conclusively identified as polyamide, enabling targeted corrective measures and highlighting the analytical capability of the ATR method in restricted spaces.

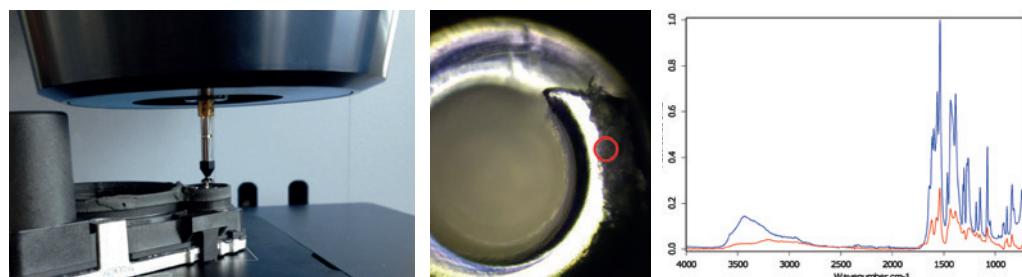
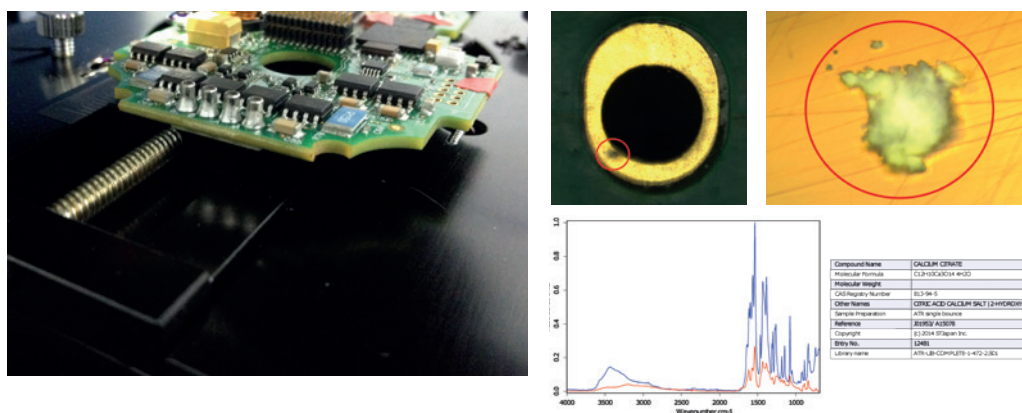


Fig. 2 ATR measurements were performed inside the spring retainer of an electric motor housing. Visual inspection (red circle) revealed surface contamination, which FT-IR spectra identified as polyamide (red), clearly distinct from the metal background (blue).

Fig. 3

ATR crystal positioned on a damaged automotive circuit board. The metal contact area shows a white contaminant particle (red circle). ATR-FT-IR spectral analysis identified the residue as calcium citrate, enabling root cause tracing and highlighting ATR microscopy's strength in analyzing delicate electronic components.



Another critical component in automotive industries are electronics. This circuit board (Figure 3) was dead on arrival, as a contamination on a gold contact hindered electrical connectivity. To clarify the origin of the residue for RMA purposes, ATR was used for chemical identification.

The precise crystal positioning allowed analysis without sample preparation on the structured surface. The white residue was identified as calcium citrate, likely introduced during the manufacturer's cleaning process, supporting the quality claim and RMA process.

Conclusion

Across these examples from the automotive industry, the LUMOS II and ATR-FT-IR microscopy proved essential by offering direct, non-destructive analysis with minimal sample preparation, high spatial resolution, and immediate chemical identification. By rapidly identifying contaminants and defects directly at their locations, ATR significantly enhances automotive quality control and streamlines failure analysis workflows.

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