Component failure analysis of vehicle spark plugs using FTIR spectroscopy with a micro-ATR large sample objective

Application note

Polymer and materials

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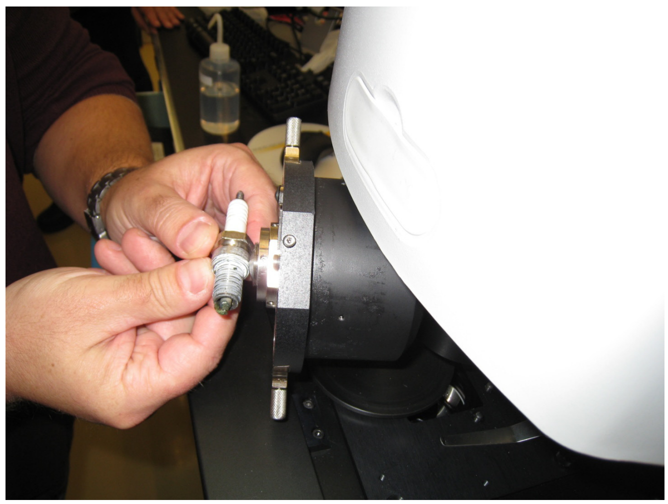
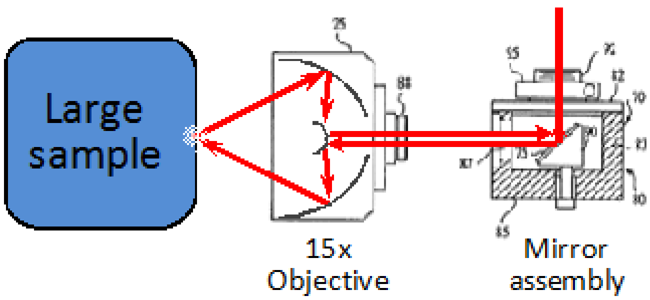


Introduction

Preventing failure of components or identifying the cause of any failure quickly and reliably is vital across all industries in order to minimize downtime and save money. In this example, the spark plugs of a very large fleet of commercial vehicles began to fail at an unacceptable rate soon after installation. Through simple visual observation, it was apparent that excessive deposits were accumulating on the spark plugs even after low mileage necessitating premature servicing and costly repairs. Clearly corrective measures needed to be implemented.

FTIR is widely used to identify the chemical composition of impurities present in materials, and the traditional approach to this application would be to scrape the surface of the spark plug to try to isolate a small portion from the area of interest. The materials would then be placed under the microscope and spectra would be collected. However, a simpler and completely nondestructive solution uses a micro-ATR FTIR with a large sample objective accessory (see Figure 1). The benefit of this arrangement is that the spark plug samples can be analyzed 'as is', with no intricate sample preparation required.



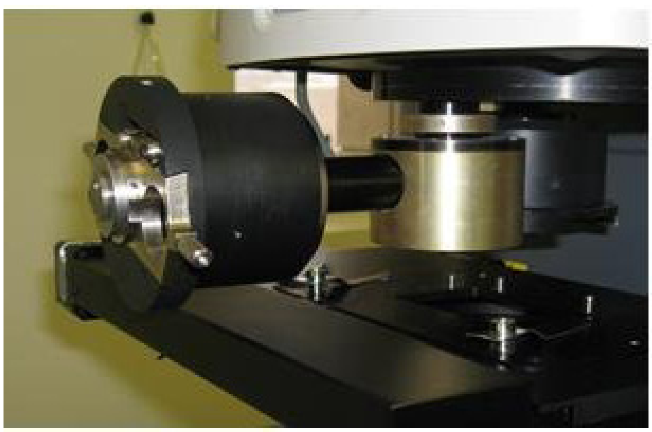


Figure 1. Top: Schematic of the patented Agilent Large Sample Microscope Objective accessory. Bottom: Photograph of the Large Sample Microscope Objective accessory.

Experimental

Instrumentation

An Agilent Cary 610 FTIR microscope fitted with a slide-on micro ATR and a Large Sample (LS) Objective accessory was interfaced to an Agilent Cary 660 FTIR spectrometer. The patented large sample microscope objective allows the measurement of unlimited sized samples in reflection or ATR single-point or imaging mode. In this study, the slide-on micro Ge ATR was mounted onto the objective, which points the infrared light out towards the front of the microscope, as indicated in Figure 1.

Sample analysis

Minimal sample preparation was required for the analysis. The spark plug was simply placed against the 90 degree objective of the Cary 610 FTIR microscope. The system was configured with standard mid-IR components (mid-IR source, KBr beamsplitter, 250 micron narrow band MCT microscope detector) with data collected at 4 cm^{-1} spectral resolution with 16 co-added scans (5 seconds).

Results and discussion

It was clear from zooming in on this spark plug that there were three areas of interest (Figure 2). These included the white lubricant, a potential contaminant (black speck) and the electrode tip with excess deposits.

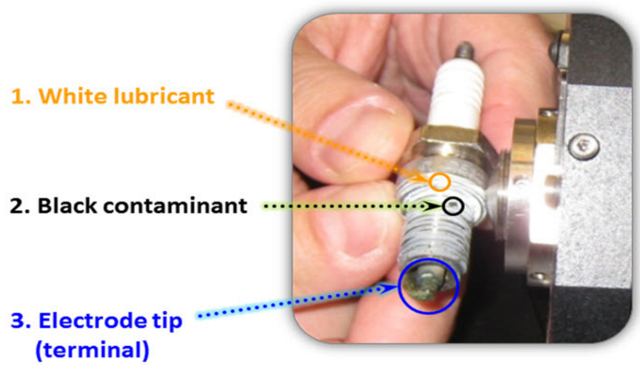


Figure 2. Side view during ATR analysis of three distinct sampling locations on a defective spark plug using the Agilent Large Sample Objective

Spectra were collected from each location in 5 seconds each. The spectra were overlaid using the Agilent Resolutions Pro software so that the data could be investigated visually, as shown in Figure 3.

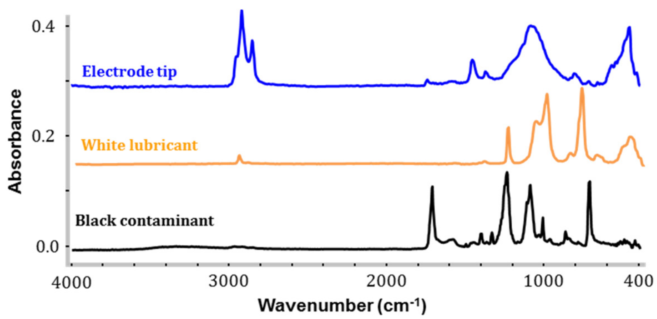


Figure 3. FTIR spectra acquired from three sampling locations of a spark plug overlaid using Agilent Resolutions Pro software. Each data set was acquired in 5 seconds.

All three spectra of interest were searched against a large commercial spectral database. The Resolutions Pro software provides direct access to the largest commercially available FTIR libraries, including a significant number of databases that are dedicated to polymer and materials applications. Alternatively, custom-made libraries can be searched.

The results of the search indicated conclusively that the white lubricant was of a silicon polymer based material. The black contaminant was identified as poly(ethylene terephthalate) (PET) with the desposits on the electrode likely to consist of silicone containing oily material.

In this case study, it was likely that the electrode tip deposits were derived from oil and fuel additives, which suggested that fuel and oil were leaking past worn valve guides and piston rings into the combustion chamber, causing hard starting and misfiring. This information enabled corrective action to be taken to prevent further costly repairs and downtime due to damaged vehicle components.

Conclusion

The Agilent 660 FTIR interfaced to a micro-ATR 610 FTIR microscope with Large Sample Objective accessory is capable of analyzing unlimited sized samples that are difficult to measure using conventional FTIR whilst being nondestructive, hence enabling further analysis via other methods if required. This enabled the direct and rapid analysis of faulty spark plugs that had visible deposits encrusted on the side and center electrodes of the terminal. The use of a commercial spectral library for the identification of unknown contaminants revealed that the deposits were derived from oil and fuel additives. Overall, the method is suitable to resolve component failure issues quickly and efficiently, increasing productivity.

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