High Performance Fabric and Fiber Characterization

The MicromATR Vision™ Advantage

Introduction

High performance fabrics and fibers perform critical functions in modern aerospace, military, energy, first responder, and consumer applications. Synthetic fabrics are engineered to perform under extreme heat or stress applications. Aramid polymers include several varieties such as Nomex® (meta-aramid) and Kevlar® (para-aramid). Meta-aramids are known for their high heat resistance in applications such as firefighting gear, whereas para-aramids have better tensile strength in high impact applications such as bullet proof body armor. Other advanced fabrics, such as carbon fibers, are weak until they are combined with epoxy resin to make carbon fiber reinforced polymers (CFRP) which are replacing metal components in aerospace, military, and automotive vehicle applications.

Polyphenylene sulfide (PPS) and polyimides (PI) are additional classes of polymers capable of withstanding high temperatures without failure. The increased use of high performance fabrics emphasizes the need for rigorous chemical analysis and characterization techniques. Fourier transform infrared (FT-IR) spectroscopy provides a "finger print" chemical characterization method for analysis of fibers and fabrics. The unique advantages of the MicromATR Vision diamond attenuated total reflection (ATR) accessory as an characterization tool will be discussed in this application note.

Results and Discussion

FT-IR fiber and fabric analysis is commonly performed with complex, expensive FT-1R microscope systems. The MicromATR Vision, which integrates video microscopy with easy-to-use diamond ATR, provides a less complex solution to characterize fibers and fabrics. ATR analysis is preferred over other infrared (IR) techniques since it requires virtually no sample preparation. The combination of visual image and IR spectral data provides morphology and orientation information that can improve accuracy of results. Aramid fabrics, shown in Fig 1, exhibit fiber orientation as imaged by the MicromATR Vision camera. The top image (Fig 1, a) is from a typical Kevlar® fabric, showing randomly oriented fibers. The third image (Fig 1, c) has fibers with a similar appearance. However, highly oriented linear fibers are observed in a second type of Kevlar® material (Fig 1, b).

a b c

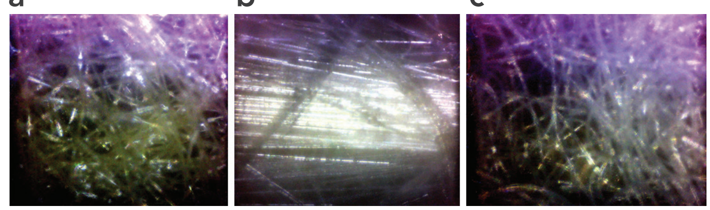

Figure 1: The MicromATR Vision captured images of two different types of Kevlar® (a and b) and Nomex® (c). The visible images indicate the second type of Kevlar® (b), has a very linear and straight orientation, whereas the other two fabrics (a and c) have a random orientation.

The eSpot software controls the camera including adjustment of brightness, contrast, and level of magnification. In addition, eSpot facilitates live viewing of the sample, image capture, saving images independently from the FT-IR software, and image annotation/documentation.

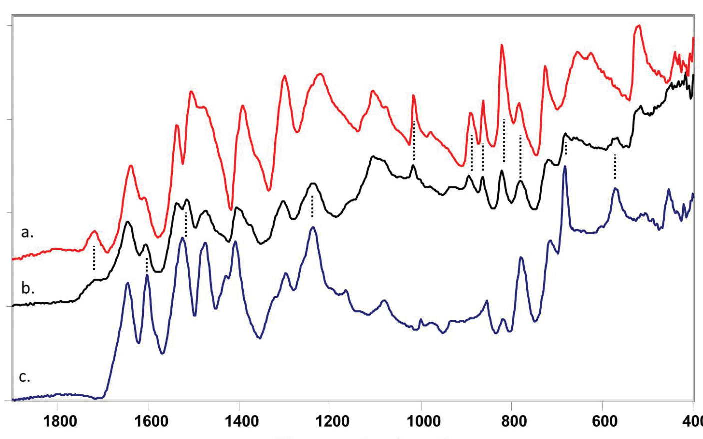

Figure 2: The overlaid FT-IR ATR spectra of the Figure 1 aramid polymers, Kevlar® type 1 (a, maroon), Kevlar® type 2 (b, blue) and Nomex® (c, red).

The corresponding FT-IR ATR spectra are shown in Fig 2, which compares and contrasts the three fabrics. The spectrum of the first fabric (Fig 2, a) is consistent with Kevlar®, and matches reference IR spectra of Kevlar®. The bottom IR spectrum (Fig 2, c) indicates pure Nomex®. Interestingly, the middle spectrum in Fig 2 (b) indicates a mixture of both Kevlar® and Nomex®, with matching bands indicated by dashed lines to the pure fiber spectra. Some of the differentiating bands for Kevlar® are observed at 890cm-1, 862cm-1 and 820cm-1. Examples of additional bands in Fig 2 (b) for Nomex® are observed at 778cm-1, 682cm-1 and 571cm-1.

a b

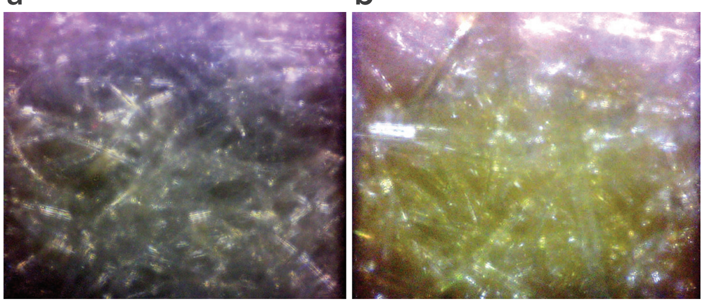

Figure 3: The MicromATR Vision captured images of PET (a) and PI (b). The visible images indicate mostly random directional fiber orientation in both samples, but a yellow color is observed in the PI fibers.

Polyimides are a special class of polymers used in extreme heat applications. Polyimides are expensive polymers and their use is limited to applications that require demanding specifications. Polyethylene terephthalate (PET) is a very common and inexpensive polymer that can be added to more expensive fabric polymers to reduce costs. PET fabric often has similar visible appearance to other polymers, however, the IR spectrum of PET is easily distinguished from PI as shown in Fig 4. The visible image of PI and PET are shown in Fig 3, in which the PI (Fig 3b)

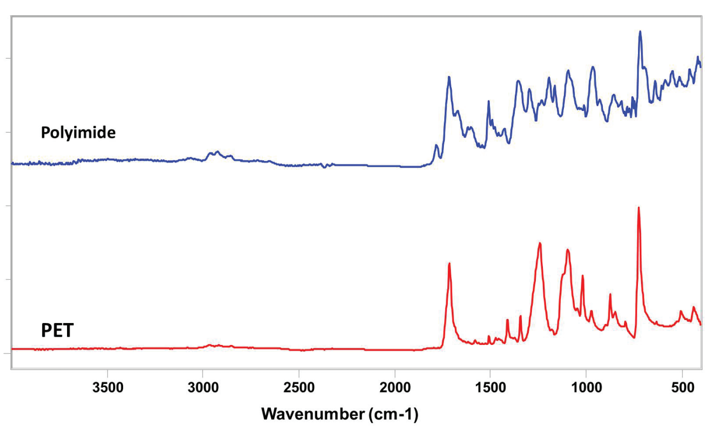

Figure 4: The stacked FT-IR ATR spectra of PET fabric (red), and polyimide fabric (blue).

has a more yellow appearance, however, the fabric fibers have similar morphology. FT-IR ATR libraries are available in most FT-IR software packages and can be searched to correctly identify and distinguish these fabric polymers measured on the MicromATR Vision accessory. The FT-IR library search algorithms can determine how well the IR bands from the unknown match the library spectrum.

Another type of fabric used in high temperature applications is made from polyphenylene sulfide (PPS) fibers. PPS fabrics and other fabric materials can be coated with polytetrafluoroethylene (PTFE) to improve filtration capability or to improve resistance to chemical attack. The spectra shown in Fig 5 indicate PPS fabric with and without a PTFE coating (Fig 5 blue and red respectively). The PTFE (Teflon®) has strong IR absorbance bands at 1205cm-1 and 1148cm-1 with weaker bands at 640cm-1 and 502cm-1. In addition to the PTFE coating on PPS, hydrocarbon bands are observed at 2921cm-1 and 2851cm-1, consistent with a wax or oil. The high quality of the spectra measured on MicromATR Vision accessory also allow the thickness of the PTFE and hydrocarbons on the PPS fabric to be compared by measuring the peak heights of their respective bands.

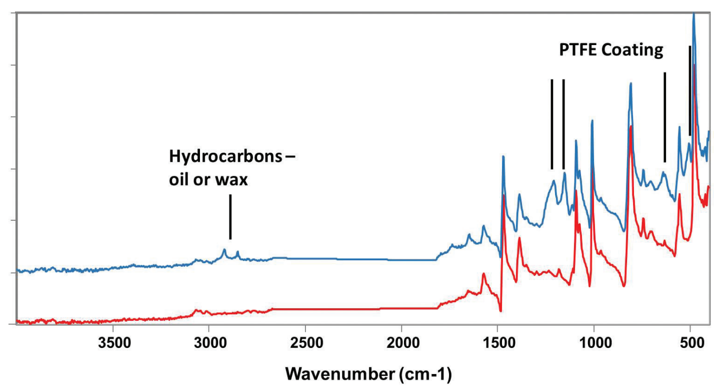

Figure 5: The overlaid FT-IR ATR spectra of PPS fabric (red) and PPS fabric coated with PTFE (blue).

Conclusion

The MicromATR Vision ATR sampling accessory's built in camera capability provides additional visible information about a sample. This is especially useful in the analysis of fabrics and fibers, which can have orientation and morphology differences. The viewing capability also aids in finding and positioning small fiber bundles for ATR analysis. Differences, such as fiber color, can be captured, annotated, and saved using the eSpot imaging software. Small differences in coatings and residues on fabrics can be measured, identified, and compared qualitatively using the diamond ATR. These capabilities make the MicromATR Vision a valuable tool for the analysis and characterization of today's high performance fabrics and fibers.