Infrared Microspectroscopy in Forensic Science, Hair Fiber Analysis

Key Words
ATR Objective, Forensic Science, FT-IR, Hair Analysis, Microscope, Microspectroscopy

Introduction

Forensic science has benefited greatly from the advantages of infrared microspectroscopy. In particular, its non-destructive nature and ability to analyze with only a small amount of sample (as low as a picogram or less) makes it ideal for the limited-quantity sample evidence usually associated with forensic investigations. This application note will discuss the infrared microspectroscopic analysis of a particular type of forensic sample: hair fibers.

Problem

Hair fibers are a common evidence type found at crime scenes. Light microscopy is routinely used in forensics to determine if an unknown hair sample could have originated from a known source. If chemical information from the hair can also be included, the ability to match an unknown hair with a known source greatly increases; thus, infrared microspectroscopy is quickly becoming a necessary tool in most forensic laboratories.

By using infrared spectroscopy, more information about the sample can be obtained. For example, if a fiber has been degraded by burial or by time, the surface features needed to identify it may no longer be present. In this case, infrared microspectroscopy could identify the fiber as proteinaceous, cellulosic, or synthetic. Additionally, infrared can detect chemical treatments done on the hair (such as bleaching or permanent-waving). Infrared microspectroscopy can be used to detect the chemical damage along the length of individual hair fibers, which could be useful in determining the extent of natural weathering of the hair, or the frequency of chemical treatments. Finally, ATR microscopy enables discrete surface areas on individual hair fibers to be analyzed to detect residues left behind from styling aids, such as hair spray or conditioner.

Infrared supplies the investigator with the information needed to identify and determine the possible source of unknown fibers.

Solutions

A single hair fiber was cut to a length of approximately 100 microns and flattened with a roller knife on a clean glass slide. The flattened fiber was picked up with a tungsten probe and transferred to the bottom KBr salt plate in a micro-compression cell, along with a small crystal of KBr. A second KBr salt plate was placed on top of the bottom plate, and the micro-compression cell was tightened until optical contact was made between the fiber and the salt plates. The cell was placed on the microscope stage of a Thermo Scientific™ Nicolet™ Continuμm™ microscope, interfaced to a Nicolet FT-IR spectrometer. A background spectrum was obtained through the KBr crystal, and the sample spectrum was obtained through the fiber. Both spectra were collected with 4 cm^{-1} spectral resolution, and 64 scans were co-added for each. The sample size was 50 × 100 microns.

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Figure 1 shows the infrared spectra obtained from a normal, untreated hair and a hair that has been bleached and permanent-waved. The increase in absorbance of the bands at 1175 cm^{-1} and 1040 cm^{-1} is indicative of disulphide oxidation of cystine in keratin. This oxidation can be caused by treatment with alkaline hydrogen peroxide, or bleaching. The 1040 cm^{-1} band is due to the symmetric S=O stretch in cysteic acid, and the 1175 cm^{-1} band is due to the asymmetric S=O stretch. Table 1 shows the band positions indicative of different chemical treatments on hair fibers. Clearly, this information is useful in determining possible sources of unknown hair fibers.

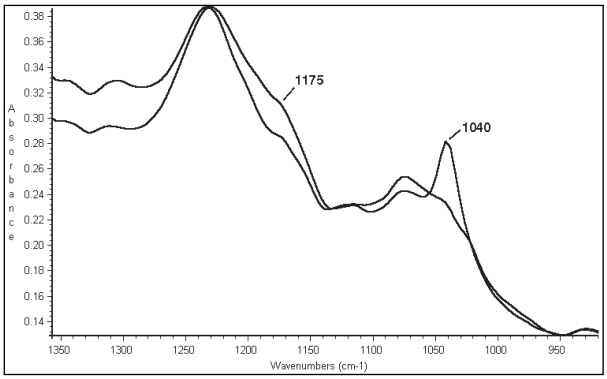

Figure 1: Infrared spectra of a normal, untreated hair fiber and a chemically damaged hair fiber

Hair Treatment	Oxidation Products
Alkaline Hydrogen Peroxide	Cysteic acid (1040 cm^{-1} and 1175 cm^{-1})
Metabisulfite Treatment	S-sulfonate (Bunte-salt) (1022 cm^{-1})
Natural Weathering	Cystine monoxide (1071 cm^{-1}), cysteic acid (1040 cm^{-1} and 1175 cm^{-1}), Bunte-salt (1022 cm^{-1})

Table 1: Oxidation products resulting from different hair treatments[1]

The second example involves the detection of cosmetic treatments found on hair fiber surfaces. Figure 2 shows a video image capture of a hair fiber with hair spray on the surface. If this sample were to be analyzed by a transmission method, as in the first example, the spectrum would predominantly show protein. Hair is a strong infrared absorber, and detecting something on its surface is difficult by traditional transmission techniques. However, by using ATR microscopy, a spectrum of predominantly the hair spray can easily be obtained. For this example, a hair fiber was mounted on a glass slide and held in place at both ends with double-sided sticky tape. By placing the sample on a glass slide, the illumination from below the sample can be used to aid in viewing the sample with the Survey Mode of the ATR objective. A ZnSe crystal (n = 2.4) was used in the ATR objective, which yields a sampling diameter of 42 µm when using the 2.5 mm diameter upper aperture (100/2.4 = 42 µm). The background spectrum was obtained through air (the crystal in contact with nothing), and 64 sample scans were co-added and ratioed against 64 background scans to obtain the infrared spectra at a resolution of 8 cm^{-1}.

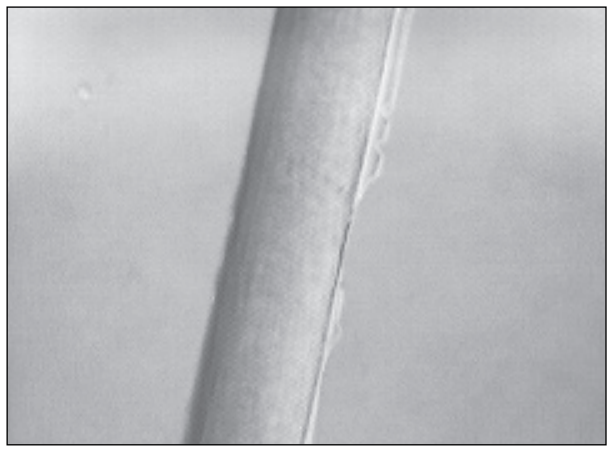

Figure 2: Video image capture of a hair fiber with hair spray visible on the surface

Figure 3 shows the infrared spectra obtained from a clean hair and a hair spray coated hair. Clearly, major differences exist between the spectra. By performing a spectral subtraction of the clean hair from the hair sprayed hair, the difference spectrum in Figure 4 results. The main resin in the hair spray, poly(vinylacetate) is easily identified.

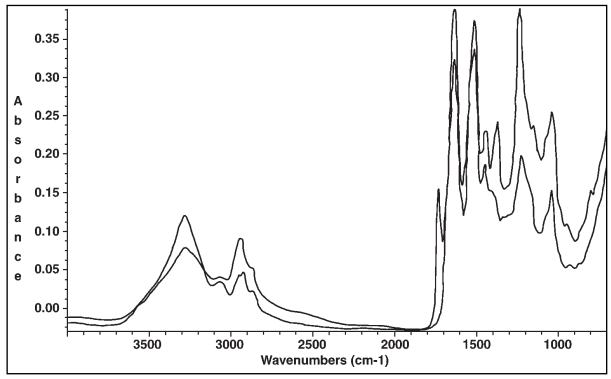

Figure 3: Infrared spectra of a clean hair fiber and a hair spray coated hair fiber

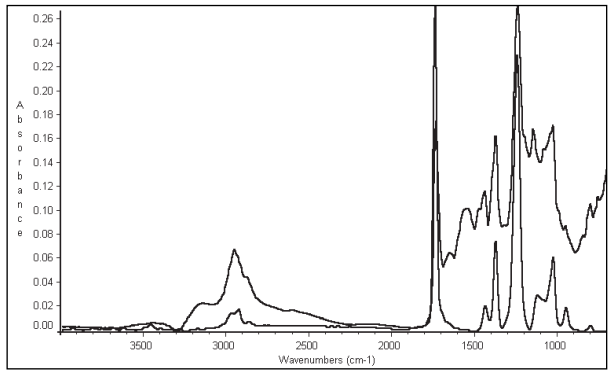

Figure 4: Infrared difference spectrum of the clean hair from the hair sprayed hair, and a reference spectrum of poly(vinylacetate)

Conclusion

Infrared microspectroscopy is an important technique for aiding forensic scientists in their investigations. Individual hair fibers can easily be analyzed, and differences due to chemical damage, natural weathering, and cosmetic treatments are readily apparent.

References

1. M. Joy and D. M. Lewis, *Int. J. Cosmet. Sci.*, 13, 1991.