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TECHNICAL NOTE

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Passport Examination by Polarized Infrared Spectra

ABSTRACT: In this study, a new nondestructive technique for passport examination is proposed. In this technique, linearly polarized light is used to measure Fourier transform infrared (FT-IR) reflectance spectra of films on the biographical data page. Thirty genuine and thirty-five counterfeit Japanese passports and five marketed films pasted on name cards were examined. The measured spectra were analyzed as follows. The absorption spectra were obtained by the Kramers–Kronig transformations of reflectance spectra. The peak ratios were then calculated from the absorption spectra by adding the peak areas at 1126 and 1263 cm^{-1} and dividing the result by the peak area at 1727 cm^{-1}. When nonpolarized light was used, the samples could not be distinguished by comparing the peak ratios. However, when polarized light was used, they were successfully distinguished by the comparison. Therefore, polarized light is useful for the forensic discrimination of passport films by the measurement of FT-IR spectra.

KEYWORDS: forensic science, passport examination, linearly polarized light, infrared spectra, films on paper

Passports are examined to accomplish three purposes. The first is the authentication of passports under scrutiny; this is important for forensic document examiners. However, forensic examiners from criminal investigation agencies examine passports for two additional purposes. The second purpose is the detailed examination of forged passports to establish associations. When similar features are detected in forged passports discovered in different places, it is suspected that they are produced by the same criminal group. Furthermore, when counterfeit passports contain materials that are difficult to obtain, it is useful to investigate the supply route of these materials so as to arrest the criminal group responsible. Therefore, criminal investigation agencies often maintain a database of the detailed features of forged passports. The third purpose of passport examination is to acquire proof of the crime. In other words, when a suspect is arrested, his or her crime must be proved by comparing the forged passport with his or her possessions.

The identification of the printing methods of portraits, letters, microtexts, marks, ground tint, etc., is a conventional method of passport examination. Another method involves the examination of anticounterfeit features such as fluorescent inks, metameric inks, fluorescent threads, infrared-absorbing inks, and infrared-reflecting inks. However, the conventional methods of passport examination do not provide sufficient information. For example, as ink-jet printers are used extensively around the world, the identification of the printing method alone does not provide sufficient information for passport examination. Therefore, it is important to develop new methods.

Films that are used on the biographical data page of forged passports usually differ from those of genuine passports because it is difficult to obtain genuine films. Therefore, a detailed examination of the characteristics of the film can prove to be very effective in passport examination. In this study, both genuine and counterfeit Japanese passports are examined by analyzing the films on the biographical data page. A comparative analysis of the chemical composition of the film by Fourier transform infrared (FT-IR) spectroscopy or Raman spectroscopy is also effective in passport examination. However, some counterfeit passports are covered with a film whose chemical components are the same as those of the films in genuine passports. Such counterfeit passports cannot be distinguished from genuine passports by conventional methods.

Cho et al. (1,2) have reported that a polarized FT-IR spectrum is useful for the forensic comparison of organic fibers because it provides information on the molecular orientation in elongated fibers. In this study, the application of the polarized FT-IR spectrum measurement to the examination of Japanese passports was investigated. It is assumed that this technique is also useful for the forensic examination of passports whose films are elongated during production (4). Although Cho et al. (1,2) measured the spectrum in the transmission mode, in this study it was measured in the reflecting mode so as to perform a nondestructive examination of the passports. In addition, the effectiveness of the information regarding the molecular orientation in the film in the identification of forged passports was examined.

Materials and Methods

Thirty genuine and thirty-five counterfeit Japanese passports and five name cards were examined. Table 1 describes the features of the samples. All the counterfeit passports were obtained from actual crime scenes and were verified as counterfeit by microscopic inspection. Samples of the name cards were prepared to determine the intersample standard deviation (ISD) of the measured values of the films from the same package. Five polyethylene terephthalate (PET) films with a thickness of 100 μm were selected from the same package and applied onto the same type of paper by the same method.

Polarized infrared spectra were measured in the reflection mode by using the FT-IR microspectrometer—Spectrum Spotlight 300 (Perkin Elmer Co., Waltham, MA; Table 2). An infrared polarizer was installed in the interferometer between the beam splitter and the sample in the optical path of the microscope (Fig. 1). The absorption spectra were obtained by the Kramers–Kronig transformations of the reflectance spectra using the software provided with the

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TABLE 1—*Features of the samples.*

		Type	Number of samples
Passport	Genuine	Machine-readable	27
		Non-machine-readable	3
	Counterfeit		35
Name card	Films from the same package		5

Film material—polyethylene terephthalate.

TABLE 2—*Operating conditions of Fourier transform infrared spectroscopy.*

Scan range	4000–650 cm^{-1}
Scan times or accumulations	64 times
Optical resolution	4 cm^{-1}
Aperture size	100×100 μm

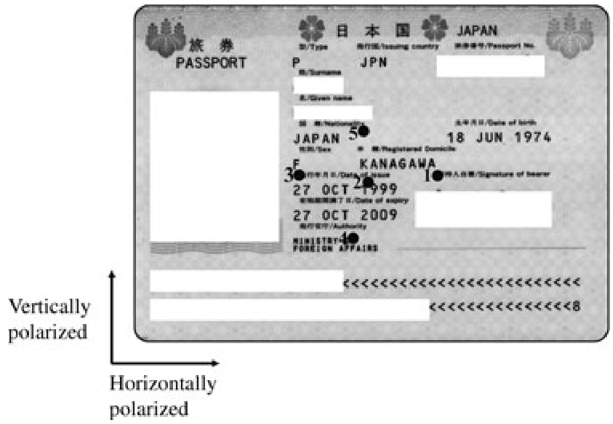

FIG. 2—*Definition of directions and measured points.*

instrument. Subsequently, the peak ratios were calculated from the absorption spectra by adding the peak areas at 1126 and 1263 cm^{-1} and dividing the result by the peak area at 1727 cm^{-1} (Eq. [1]). The calculations were performed using Matlab 6 (The MathWorks, Inc., Natick, MA).

intrasample variations of the peak ratios of the films. The intersample averages and SDs of the genuine passports and name cards were also calculated to consider the variations in the peak ratios of the passport films produced by the same tools and techniques.

$$B = \frac{\int_{1220}^{1320}\left\{A(x) - \frac{A(1320)-A(1220)}{1320-1220} - A(1220)\right\}dx + \int_{1060}^{1160}\left\{A(x) - \frac{A(1160)-A(1060)}{1160-1060} - A(1060)\right\}dx}{\int_{1700}^{1760}\left\{A(x) - \frac{A(1760)-A(1700)}{1760-1700} - A(1700)\right\}dx}, \tag{1}$$

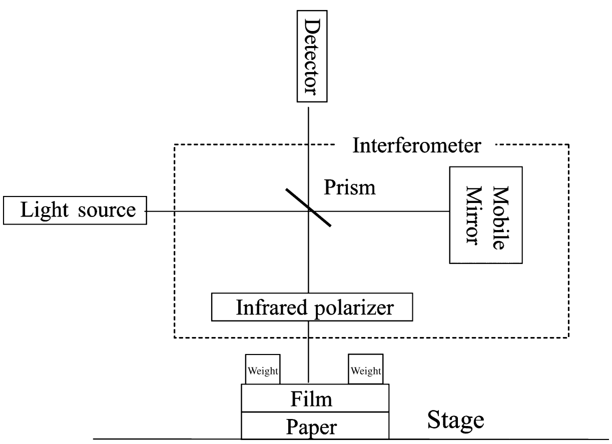

FIG. 1—*Optical system for measurement of polarized infrared spectra.*

where B is the peak ratio; $A(x)$, the spectrum; and x, the wavenumber (cm^{-1}).

Six weights of 45 g each were placed on the sample to reduce its warp. The words "horizontal" and "vertical" were defined as the directions parallel to the long and short sides of the sample, respectively. The spectra were measured at five different points on the sample, as shown in Fig. 2. Three spectra were measured at each point by using different light sources—nonpolarized light, horizontally polarized light, and vertically polarized light (Fig. 2). The intrasample averages and SDs for all samples were calculated to determine the repeatability of the measurements and the

Results

Figure 3 shows the spectra of a genuine sample that were normalized by the peak height at 1727 cm^{-1}. The peak heights at 1263 and 1126 cm^{-1} were affected by the polarization direction. Figures 4 and 5 show the peak ratios of the spectra measured using nonpolarized light and polarized light, respectively. The error bars indicate the intrasample SD of the peak ratios. A comparison of the intrasample SDs of five measured values revealed that, when nonpolarized light was used, the intersample dispersion of the peak ratios was relatively small. In contrast, when polarized light was used, the intersample dispersion was relatively large.

Furthermore, when polarized light was used, the intersample dispersions of genuine machine-readable passports and name cards were relatively smaller than those of the counterfeit passports. The peak ratio of the non-machine-readable passports differed from that of the machine-readable ones.

Discussion

The ratio of the peak areas at 1263 and 1126 cm^{-1} to the peak area at 1727 cm^{-1} changes because of a difference in the polarization direction. The peak at 1727 cm^{-1} is attributed to the C=O vibration, while the peaks at 1263 and 1126 cm^{-1} are attributed to the C(O)–O vibration (3). The former chemical band is vertical to the molecular axis of PET, while the latter is parallel (Fig. 6). The change in the peak ratio because of the difference in the polarization direction is explained by the orientation of the PET molecules in the film in a specific direction. The molecular orientation in PET is caused by elongation during the film manufacturing

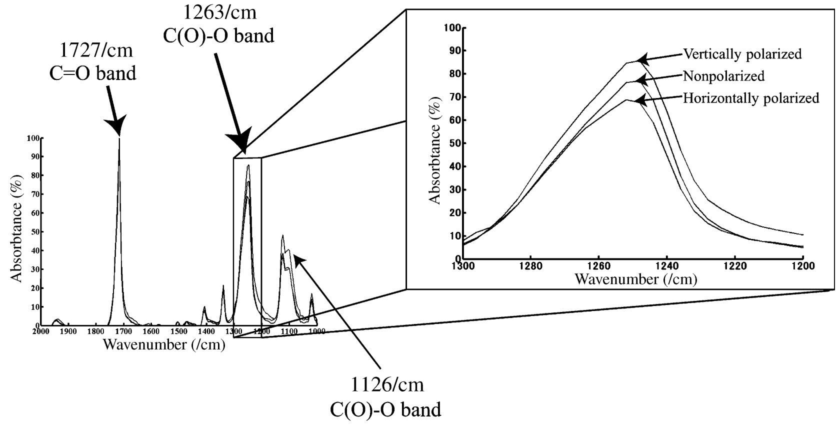

FIG. 3—*Spectra of a genuine sample.*

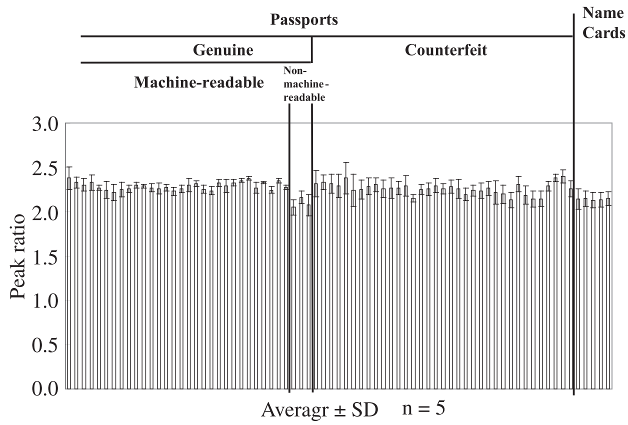

FIG. 4—*Peak ratios of spectra measured using nonpolarized light.*

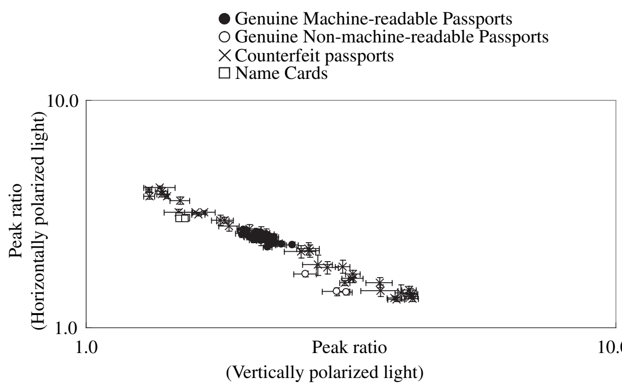

FIG. 5—*Peak ratios of spectra measured using horizontally polarized light and vertically polarized light.*

process; elongation is carried out to improve the mechanical property of the film (4). The difference in the elongation methods probably influences the polarized FT-IR spectra.

Cho et al. (1,2) measured the polarized spectra of PET fibers and observed a difference in the peak ratio in the spectra. Although they measured the transmission spectra, the reflectance spectra of PET were measured in this study so as to examine the films without peeling them off the base paper. The difference in the type of the spectra affects the selection of bands for sample examination.

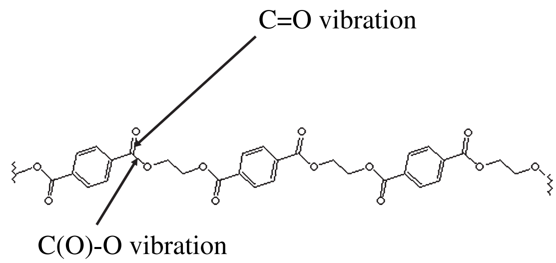

FIG. 6—*Structure of polyethylene terephthalate molecule.*

Here, the most strongly absorbing bands of PET (1126, 1263, and 1727 cm^{-1}) were used to examine the samples, although Cho et al. (1,2) used other bands. They could not use the most strongly absorbing bands because they measured the transmission spectra of thick fibers with saturated band heights. In contrast, the reflectance spectra with unsaturated band heights were measured in this study. It is preferable to use strongly absorbing bands for the analysis of the reflectance spectra because the influence of the underlying paper is effectively eliminated.

When polarized light was used, the intersample dispersions of the genuine machine-readable passports and name cards were relatively smaller than the intersample dispersion of the counterfeit passports. The results of only four counterfeit passports were the same as those of the genuine machine-readable passports. Therefore, with the exception of four forged passports, all passports were distinguished from the genuine machine-readable passports. This implies that all but four counterfeit passports were not covered by genuine films. This fact serves as a test in the investigation of criminal groups.

Although the results were obtained from a small number of samples, it appears that the films of the genuine non-machine-readable passports differ from those of the genuine machine-readable passports. Therefore, for passport examination, it is important to determine whether the passport is machine readable or not. This process is very simple. Machine-readable passports contain a printed portrait photograph and rows of numbers and alphabets on the lower side of the biographical data page. In contrast, non-machine-readable passports contain a pasted portrait photograph but do not contain the rows of numbers and alphabets.

The peak ratios of the films of the forged passports varied significantly. The ISD of the peak ratio of the five films pasted on the name cards by the same tools and techniques was relatively less than that of the peak ratio of the forged passports. The ISD of the peak ratio of the genuine machine-readable passports was also relatively less than that of the peak ratio of the forged passports. Therefore, it was assumed that a number of criminal groups forged the passports. If the values of the peak ratio detected for a number of passports are close, then there is a possibility that they must have been forged by the same criminal group. This fact also serves as a test in the investigation of criminal groups. Thus, the use of a polarizer for obtaining FT-IR spectra enhances the comparisons of passport films.

When nonpolarized light was used, the peak ratio analysis could not distinguish the passport samples. In contrast, when polarized light was used, the passport samples were successfully distinguished by comparing the peak ratios. Therefore, polarized light is useful for the forensic comparisons of passport films by the measurement of FT-IR spectra.

Conclusion

This study nondestructively measured the polarized FT-IR spectra of the films on passports. The peak ratio analysis could not distinguish the passport samples when nonpolarized light was used. In contrast, when polarized light was used, the passport samples were successfully distinguished by comparing the peak ratios. Therefore, polarized light is useful for the forensic comparisons of passport films by the measurement of FT-IR spectra.

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