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Microreflectance FTIR Techniques Applied to Materials Encountered in Forensic Examination of Documents

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ABSTRACT: Microreflectance Fourier transform infrared spectrometry (FTIR) has been applied to the forensic examination of documents. The materials examined were black printing inks, paper, plastics, photocopy toners, and transfer letters (Letra set). Good discrimination was achieved between different samples of these materials. Euclidean distances were calculated on the bases of first derivatives of measured FTIR reflectance spectra. Some results were compared with those obtained by diffuse reflectance FTIR. Microreflectance FTIR is nondestructive to the materials and may be used as a complement to optical techniques for examination of documents.

KEYWORDS: forensic science, questioned documents, microreflectance Fourier transform infrared spectroscopy, diffuse reflectance Fourier transform infrared spectrometry, Fourier transform infrared microscopy

During the last few years, various Fourier transform infrared spectrometry (FTIR) microtechniques have been introduced into forensic science laboratories. In addition to diffuse reflectance FTIR (DRIFTS), which has been the subject of several forensic science applications (1–5), particular interest has focused on FTIR microspectrophotometry in transmission mode (6,7).

FTIR microspectrophotometry is very useful, since it can be applied to the small sample sizes often encountered in forensic science laboratories. The reflectance techniques are particularly valuable because they are generally nondestructive to the material examined. Recently, a FTIR microreflectance techniques was used to analyze photocopy toners (8), and internal reflection (IRE) FTIR microspectrophotometry was applied to the examination of various forensic science materials (9).

In this study, specular microreflectance FTIR was applied to various materials encountered in document examination. However, this technique is not as sensitive as the internal reflection FTIR, but is normally available at laboratories having an FTIR microscope. The results were in some cases compared with those obtained by DRIFTS. The materials examined were black printing inks, paper, plastic materials used in documents, transfer letters (Letra set), and photocopy toners. Microreflectance FTIR is nondestructive to the sample and is not limited by the size of the document. The aim of this method was to increase the possibility of nondestructive optical techniques to distinguish between genuine and counterfeit samples. To evaluate the discrimination power of FTIR reflectance techniques, Euclidean distances were calculated for some of the materials examined. Also, the so-called similarity factors were calculated. All these calculations were based on the first derivatives of the observed FTIR spectra.

Experimental Procedure

FTIR spectra were recorded with a Perkin-Elmer, Model 1725 X, FTIR spectrophotometer.

Diffuse Reflectance FTIR

A Perkin-Elmer diffuse reflectance accessory (PEDR) was used to obtain DRIFTS spectra. This device was placed in the sample slide holder of the FTIR instrument. A micro-sample cup was filled with KBr powder, and the resulting reflectance spectrum was used as the background spectrum. The samples (paper and plastics) were simply placed on the top of the sample cup. The sample height was adjusted to give maximum reflectance by means of a single focus adjustment knob. The sample size was limited to about 4 cm^2 because larger samples reduce the amount of the FTIR radiation. Normally, 50 scans were averaged for background samples and 200 scans for the samples investigated. The resolution was 8 cm^{-1}, and the gain was 2.

Microreflectance FTIR

The measurements of specular microreflectance FTIR spectra was performed on a Spectra-Tech IR-Plan™ microscope attached to the FTIR spectrophotometer. The microscope objective was Reflachromate™ (15 by 0.58 N.A.) and the detector was a narrow band 0.25 by 0.25 mm of mercury-cadmium-telluride (MCT). The reflectance spectra were normally collected from a 1- by 1-mm surface area. The resolution was 8 cm^{-1}, and the gain was 4. Two hundred scans were averaged for each sample. This required 2 min of instrument time. The reflection from the clean surface of the KBr pellet was used as reference spectrum. Photocopy toners were thermally transferred to metallic stubs and studied by microreflectance FTIR from these surfaces (8). The reflectance spectra from the clean surface of the stubs were used as reference spectra for these measurements. Smaller areas (0.5 by 0.3 mm or even less) of transferred toner material were sufficient for making the measurements.

Data Acquisition and Handling

A Perkin Elmer software IRDM was used for data acquisition and handling. The first derivatives of the observed FTIR spectra

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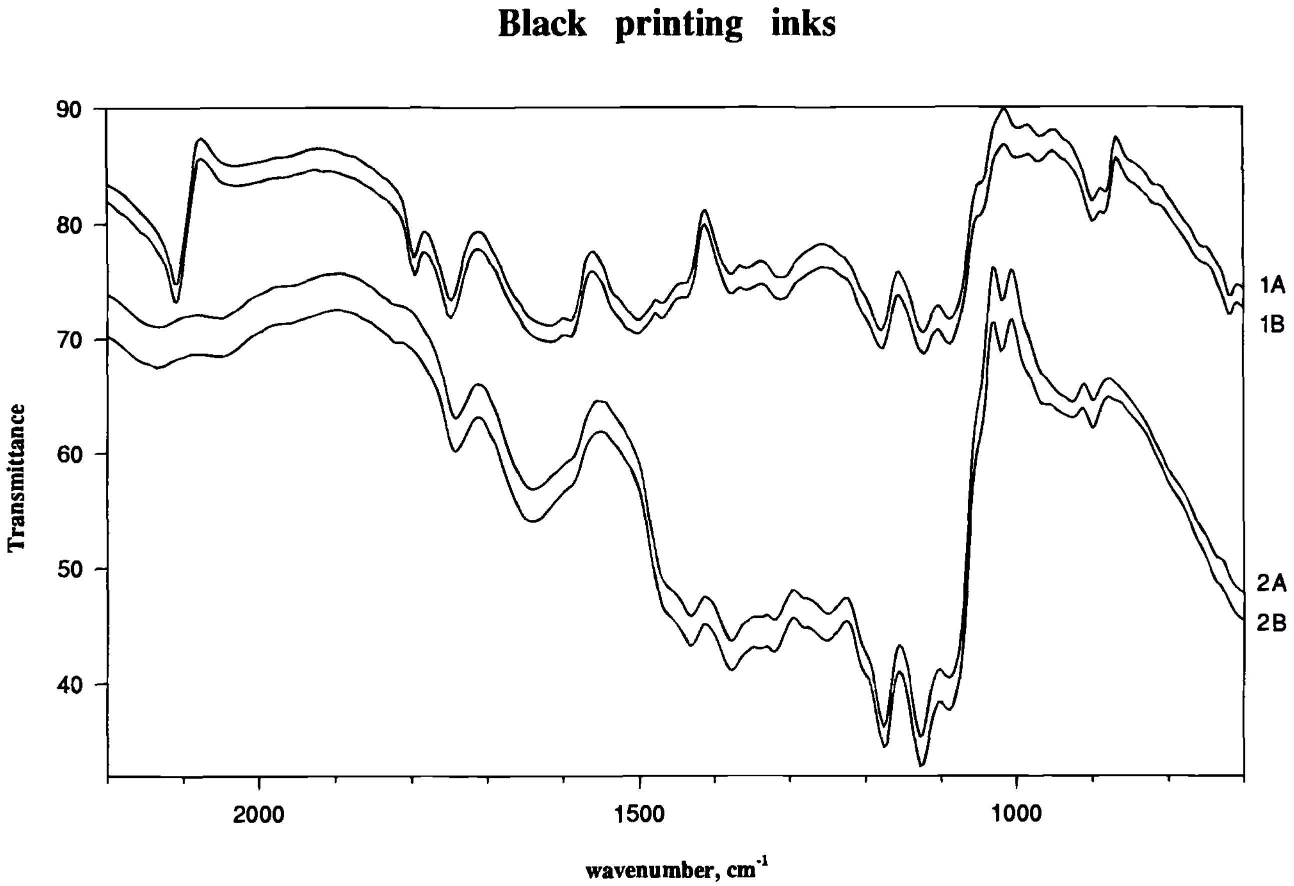

FIG. 1—*DRIFTS spectra (transmittance mode) obtained for two different black printing inks. Two measurements (A,B) on different areas of each of the samples were performed.*

were calculated to compare spectra by calculating Euclidean distances between them. The spectra derivatives were then normalized. Using the JCAMP utility of the IRDM software, the spectra files were converted to DX-files, which contained the measured data in the form of string variables. We have written our own Basic program to convert these DX-files to ordinary data files. The Euclidean distances were calculated using the wavenumber range from 800 to 2200 cm^{-1}, the range with the most pronounced differences between the spectra.

The Euclidean distances between two FTIR spectra were calculated according:

$$ED_{AB} = SQRT[\sum_{i=800}^{i=2200} (A_i - B_i)^2]/(2200 - 800)$$

where A_i and B_i are the normalized values of first derivatives of the FTIR spectra obtained for Samples A and B, respectively, and i represents for the wavenumbers used for the calculations.

The choice of the wavenumber range from 800 to 2200 nm for the calculations was based on rather subjective aspects, but this part of FTIR spectra includes the fingerprint region as well as absorption bands of many functional groups. No peaks were observed in the regions of 2200 to 2800 cm^{-1}, and only few weak bands appeared in the regions above 3000 cm^{-1} in the materials examined. The choice of limited range of the FTIR spectra also simplified the calculations of Euclidean distances as the dimension of the mathematical matrices involved in the comparison between many samples (like the examples in Tables 1 and 2) was decreased.

"Similarity factors" were calculated in the following way. The values of first derivatives of FTIR spectra were compared for each wavenumber recorded. A threshold value was chosen (typically about 0.4). The sum of wavenumbers for which the differences between two spectra to be compared were less than the threshold value was called the "similarity factor." The factors was expressed in percent. Thus, a similarity factor of 100 means that the differences were lower than the threshold for each wavenumber compared—the spectra matched perfectly. Also, here the wavenumber range from 800 to 2200 cm^{-1} was used for the calculations. This method of comparison corresponds to visually comparing (matching) each of two spectra.

Results and Discussion

Several types of materials encountered in document examination were investigated. The results are reported for each of the material types separately.

Black Printing Inks

Both DRIFTS and microreflectance FTIR were measured on small pieces of paper (approximately 1 cm^2) containing various types of black printing inks. Inks on leaflets and various documents were examined. Only black inks were chosen, since inks of other color shades are easier to examine by other optical techniques. The areas covered by inks were at least 1 mm^2, although smaller

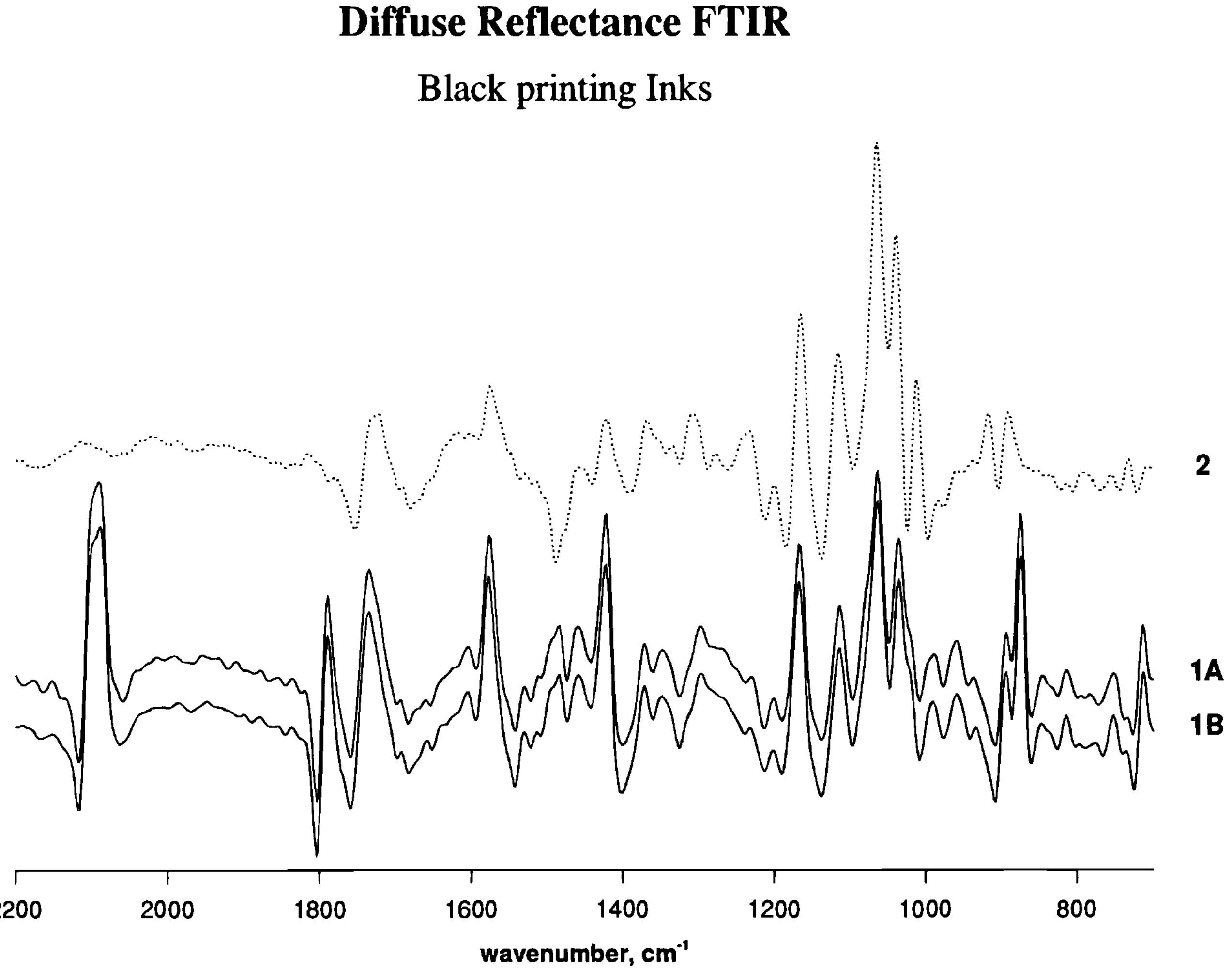

FIG. 2—*The first derivatives of the spectra shown in Fig. 1. For easier comparison, the spectra, which are in reality overlapping, were shifted in y direction. Two repetitive measurements on the same sample (1A, 1B) matched almost completely, whereas Sample 2 (dotted line) shows clearly different details.*

areas might also be examined, particularly by microreflectance FTIR. Background from the paper did not seem to contribute to the FTIR spectra, and corrections for this were not made.

The reproducibility of measurements was very good, particularly for DRIFTS Figure 1 shows spectra obtained for two of the inks investigated with two separate measurements being made on each sample. Only that part of the FTIR spectra, which was most useful for comparison, is depicted. Most of the black inks examined (totally 15 different samples) gave absorption looking spectra, and only a few samples showed significant contribution from specular reflectance. Figure 1 shows that FTIR spectra recorded by repetitive measurements on the same sample (different areas) were often shifted in parallel. This depends presumably on some differences in surface topography and changes in geometry between these repetitive measurements. Such parallel shifts do not influence spectra derivatives. The first derivatives calculated for the spectra in Fig. 1 matched almost exactly (Fig. 2). For easier comparison, the derivative spectra in Fig. 2, which are in reality overlapping, were moved in the *y* direction. Euclidean distances calculated for ten of the samples investigated are shown in Table 1. A minimum of two measurements was made on each sample. The rows in Table 1 represent single measurements, whereas the columns are average spectra, calculated from two to four repetitive measurements on the same sample. To simplify the orientation in the table, the shortest distances are in boldface type and underlined.

The DRIFTS measurements are generally influences by the factors like sample thickness and concentration. Kubelka and Munk developed the most widely used model that describes the process of diffuse reflectance quantitatively. This model is described in detail by Suzuki (1, Paper 1). In this work, the reflectance measurements are only used to find differences between samples of different origin. The thickness of ink layers on the same kind of document should be the same; differences in this parameter would indicate different origin.

All the different inks in Table 1 could be distinguished on the basis of Euclidean distances and also from similarity factors. The latter were lower and the distances larger for repetitive measurements on samples with large contributions from specular reflectance (Samples 3 and 10 in Table 1).

The reproducibility of microreflectance FTIR measurements on black printing inks was lower compared to DRIFTS. This is mainly caused by lower signal-to-noise ratio. By measuring two different areas on the same sample and calculating the average spectrum, discrimination between different samples was almost as good as for single measurements using DRIFTS. Table 2 shows the Euclidean distances calculated from microreflectance FTIR measurements

TABLE 1—*Diffuse reflectance FTIR of black printing inks.*

Sample	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5	Mean 6	Mean 7	Mean 8	Mean 9	Mean 10
Euclidean Distances Between Various Samples										
1a	**1.56**	26.51	38.15	19.45	35.50	40.01	28.62	39.46	20.76	22.26
1b	**1.56**	26.35	38.14	19.46	34.80	40.00	28.23	38.88	20.75	22.02
2a	26.47	**1.51**	27.37	22.51	34.01	30.30	15.17	46.99	21.28	21.23
2b	26.39	**1.51**	28.98	21.77	34.85	31.70	15.83	47.46	20.58	20.46
3a	38.03	28.11	**2.20**	37.56	39.40	9.84	28.75	49.83	36.15	36.24
3b	38.32	28.35	**2.20**	37.79	39.28	12.09	29.71	50.57	36.46	36.57
4a	19.59	22.25	37.80	**1.41**	36.57	39.64	26.07	41.69	11.41	10.09
4b	19.33	22.04	37.54	**0.70**	36.18	39.56	26.28	41.38	10.69	9.85
4c	19.12	22.45	37.68	**0.94**	36.03	39.34	26.50	41.17	10.76	9.98
5a	35.07	34.34	39.25	36.26	**0.36**	43.51	36.86	28.16	36.04	33.88
5b	35.17	34.47	39.31	36.33	**0.36**	43.54	36.93	28.13	36.16	33.96
6a	39.91	30.89	10.48	39.53	43.42	**0.42**	30.48	52.03	38.10	38.62
6b	40.04	31.05	11.13	39.63	43.62	**0.42**	30.53	52.11	38.19	38.72
7a	28.40	15.40	29.27	26.21	37.10	30.60	**0.62**	46.73	27.71	26.27
7b	28.58	16.03	29.25	26.47	36.79	30.59	**1.16**	46.31	28.03	26.43
7c	28.22	14.93	28.97	25.93	36.81	30.36	**0.93**	46.63	27.32	25.90
8a	39.23	47.30	50.27	41.58	28.26	52.14	46.63	**0.78**	40.72	40.41
8b	38.72	46.79	49.79	41.06	27.74	51.72	46.16	**1.01**	40.22	39.94
8c	39.28	47.35	50.29	41.61	28.30	52.22	46.69	**0.69**	40.74	40.46
8d	39.37	47.39	50.29	41.68	28.32	52.22	46.74	**0.92**	40.79	40.48
9a	20.25	20.65	35.91	10.59	35.66	37.86	27.15	40.20	**1.63**	10.43
9b	21.32	21.40	36.89	11.56	36.88	38.69	28.46	41.09	**1.65**	11.18
9c	20.67	20.74	36.00	10.81	35.84	37.96	27.51	40.62	**1.25**	10.37
10a	21.93	20.60	36.12	9.66	33.74	38.32	25.19	40.22	11.50	**2.14**
10b	22.46	21.19	36.69	10.55	34.23	39.13	27.32	40.52	9.98	**2.14**
Similarity Values Threshold 0.4										
1a	**100**	34	24	31	29	27	26	27	39	35
1b	**100**	37	27	32	30	28	28	29	40	35
2a	36	**100**	45	53	38	37	55	32	48	49
2b	35	**100**	41	53	35	31	51	32	49	53
3a	26	42	**97**	32	47	78	35	43	37	28
3b	27	41	**97**	31	49	76	34	43	36	29
4a	31	54	30	**100**	30	28	42	31	53	60
4b	32	53	34	**100**	34	31	42	34	56	59
4c	32	54	33	**100**	35	30	42	32	54	59
5a	30	37	48	33	**100**	47	34	52	34	31
5b	31	37	47	32	**100**	47	31	52	34	31
6a	27	33	77	30	48	**100**	31	43	38	25
6b	27	33	76	30	47	**100**	34	43	37	26
7a	26	55	34	43	34	34	**100**	30	39	45
7b	27	53	32	41	31	31	**98**	27	35	47
7c	25	54	36	43	34	32	**100**	30	39	44
8a	28	34	44	33	51	43	30	**100**	36	28
8b	28	32	43	32	52	44	30	**100**	37	29
8c	28	32	41	31	53	43	30	**100**	36	29
8d	27	32	42	32	52	42	29	**100**	34	30
9a	42	49	38	55	36	33	38	37	**99**	61
9b	41	47	35	55	35	34	37	35	**98**	57
9c	39	50	37	55	34	39	40	35	**99**	59
10a	32	51	29	58	31	25	46	26	54	**96**
10b	35	52	29	59	31	28	45	31	61	**96**

TABLE 2—*Microscopy reflectance FTIR of black printing inks.*

Sample	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5	Mean 6	Mean 7	Mean 8	Mean 9	Mean 10
					Euclidean Distances Between Various Samples					
1a	**0.85**	9.43	70.28	6.34	25.11	78.05	12.91	41.91	7.27	7.69
1b	**0.85**	10.08	70.88	6.85	24.90	78.42	13.60	41.98	7.46	7.74
2a	9.97	**0.73**	66.16	8.61	25.77	72.11	9.68	43.61	10.72	11.56
2b	9.53	**0.73**	66.63	8.25	25.87	72.65	9.57	43.91	10.22	11.07
3a	70.17	66.03	**4.45**	68.23	78.38	65.98	67.19	85.01	70.64	71.96
3b	71.26	67.04	**4.45**	69.16	78.95	65.29	68.75	86.09	71.66	72.93
4a	6.51	8.33	68.59	**0.97**	26.63	77.58	13.02	42.74	5.90	6.94
4b	6.72	8.58	68.53	**0.97**	26.47	77.63	13.79	42.39	6.42	7.30
5a	23.62	24.61	78.04	25.21	**1.73**	78.55	27.95	32.12	23.74	23.02
5b	26.40	27.06	79.07	27.90	**1.73**	78.59	30.41	32.47	26.44	25.82
6a	81.76	75.89	67.49	81.10	81.80	**3.97**	75.19	96.91	82.09	82.96
6b	74.74	68.91	63.66	74.14	75.36	**3.97**	68.02	90.80	75.12	75.98
7a	13.56	9.56	67.51	13.55	29.39	71.21	**0.99**	47.05	13.64	14.59
7b	12.96	9.75	68.15	13.28	28.95	71.97	**0.99**	46.73	12.94	13.79
8a	43.33	45.08	86.17	43.95	33.46	95.00	48.29	**2.47**	44.24	43.38
8b	40.66	42.55	84.77	41.27	31.18	92.70	45.56	**2.47**	41.44	40.65
9a	7.30	10.30	70.83	5.90	25.13	78.41	13.13	42.73	**0.76**	3.41
9b	7.41	10.64	71.20	6.36	25.03	78.76	13.42	42.87	**0.76**	3.28
10a	7.73	11.46	72.35	7.03	24.56	79.59	14.31	41.95	3.47	**0.78**
10b	7.68	11.18	72.27	7.17	24.27	79.31	14.05	42.00	3.23	**0.78**
					Similarity Values Threshold 0.3					
1a	**100**	45	12	58	43	20	37	17	48	47
1b	**100**	46	11	60	45	26	35	16	48	47
2a	44	**100**	15	62	40	32	43	18	48	49
2b	48	**100**	15	64	41	33	44	19	50	50
3a	12	16	**88**	15	13	32	12	30	12	11
3b	12	16	**88**	14	11	27	10	32	11	11
4a	61	64	14	**100**	41	24	40	13	56	60
4b	58	62	16	**100**	44	30	38	14	53	58
5a	45	41	12	41	**95**	26	30	21	41	39
5b	41	40	11	42	**95**	27	30	18	40	39
6a	21	29	30	23	23	**86**	19	31	19	19
6b	25	35	27	32	29	**86**	23	22	21	22
7a	37	45	14	38	30	22	**98**	15	47	45
7b	36	42	11	39	29	20	**98**	14	47	41
8a	16	17	28	14	18	24	14	**89**	16	18
8b	17	17	29	13	20	24	14	**89**	11	13
9a	51	48	12	56	42	20	48	13	**99**	80
9b	48	48	12	53	38	18	47	12	**99**	81
10a	49	50	13	58	38	19	42	13	79	**99**
10b	47	49	11	61	39	20	45	15	81	**99**

on the samples of black printing inks examined previously by DRIFTS. Each row in Table 2 represents an average of two independent measurements. Each column represents mean spectra, calculated from four measurements on each sample. All ten samples could be distinguished by this technique, as well. Figure 3 compares DRIFTS and microreflectance FTIR when applied to the same sample. Both techniques often gave absorption-looking spectra.

Paper

Paper is another material suitable for examination by reflectance FTIR techniques. Ten samples of white paper from different manufacturers were examined by DRIFTS and microreflectance FTIR, and all of them could be distinguished in a manner similar to that described for black printing inks. DRIFTS spectra for two of the samples (1—printer paper, 2—ordinary photocopy paper) are shown in Fig. 4. The spectra exhibit contributions from both cellulose and inorganic constituents of paper.

Plastics

Various types of plastic materials encountered in forensic examinations of documents were analyzed by microreflectance FTIR. These included identification cards, driving licenses, and plastic materials appearing in passports. Because of the sample size and a requirement of nondestructive examination, DRIFTS could not be used. To obtain microreflectance spectra, the plastic cards with smooth surfaces were simply laid on the microscope board.

FTIR reflectance spectra of plastics exhibit distortion caused by the specular reflectance component. This specular reflectance results in an anomalous dispersion feature, and the spectral bands are derivative-shaped. It is known that the application of the Kramers-Kronig dispersion relations to such spectra yield transmission-like spectra. The transmission spectrum obtained by the Kramers-Kronig transformation is quite good if the reflectance spectrum contains only the specular component (10).

The plastic cards mentioned above generally contain several plastic layers. The base material, e.g., polycarbonate, is embedded

FTIR of Black Printing Inks

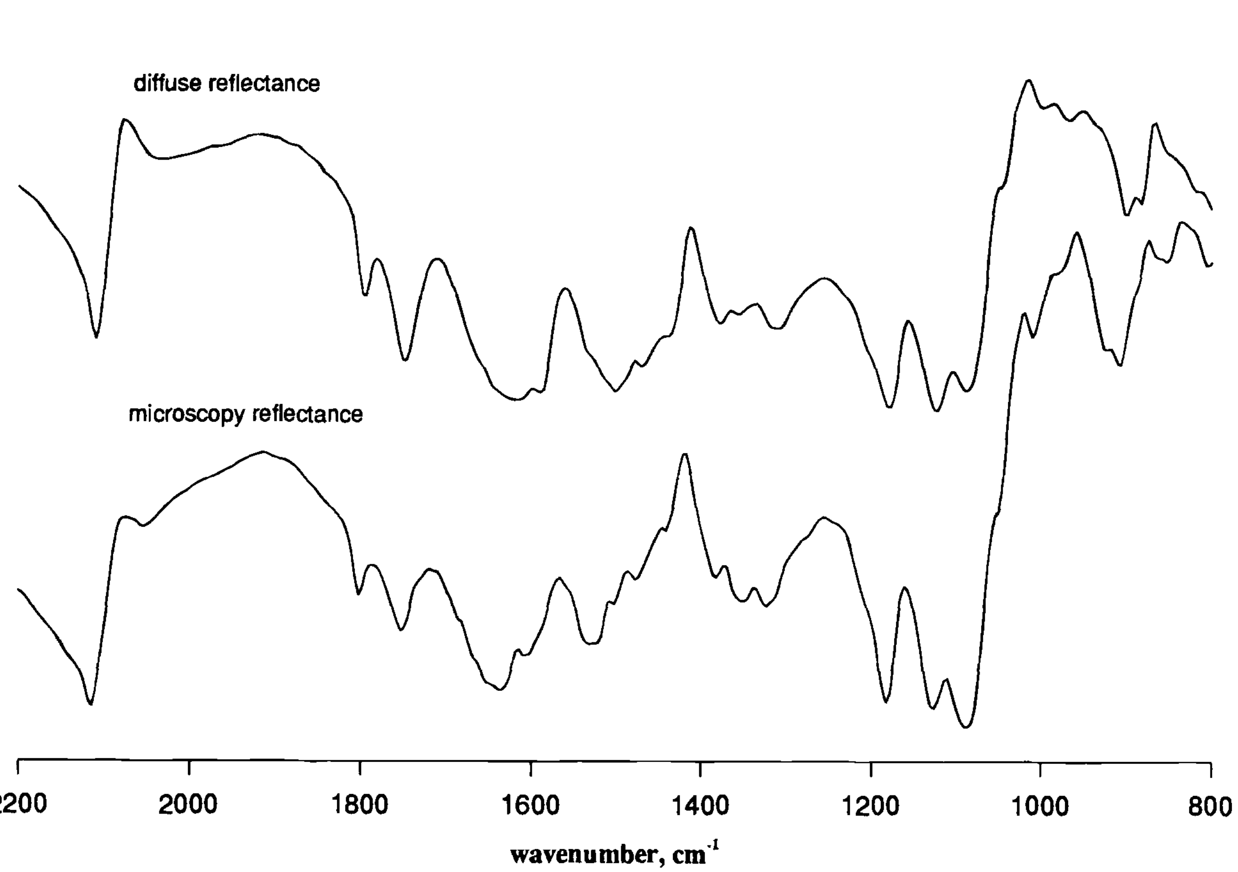

FIG. 3—*A comparison of DRIFTS (upper trace) and microreflectance FTIR (lower trace) performed on the same sample (black printing ink, Sample 1). Both spectra are absorption looking with similarities in most of the spectral details.*

in double-layered polymer material. The inner layer is usually polyethylene and the outer layer polyester. The thickness of the two embedding plastic layers may influence the appearance of the FTIR spectra but, the extent of this influence was not further investigated here.

Despite the spectral distortion, the reproducibility of the analysis is very good, and the genuine origin of plastic materials may be established by this nondestructive analysis. Figure 5 shows the comparison of spectra obtained for Finish, Swedish, and Bulgarian driving licenses.

Transfer Letters Type Letra Set

Transfer letters are occasionally encountered in document examination. These may be investigated by destructive methods like scanning electron microscopy. We made efforts to examine them by microreflectance FTIR directly on the document.

Black-colored transfer letters of eight different manufacturers were investigated. Since transfer letters are made from plastic material, the FTIR spectra showed a spectral band with an anomalous dispersion feature. Figure 6 shows microreflectance FTIR spectra from three different types of transfer letters (LETRASET, STIK IK, MECANORMA). All of the eight manufacturers investigated produced transfer letters of similar chemical composition. Nevertheless, all the types of letters except three could be distinguished.

Photocopy Toners

Internal reflection FTIR in a microscope equipped with an ATR objective was suitable for investigation of black photocopy toners according to Bartick et al. (9). The technique used in this study, the microscopy reflectance FTIR, gave generally poor quality spectra for black photocopy toners. Satisfactory results were achieved for toners from color photocopiers. The background material (paper) showed some influence on the FTIR spectra. The correction for paper background was done by displaying the FTIR spectra for toners and subtracting the spectra for background multiplied by a continuously variable factor. This factor was varied starting from one and decreasing until the resulting spectrum corrected for background did not exhibit any negative part in the region of 3000 to 4000 cm^{-1}. Generally, this factor varied between 0.2 and 0.4.

This technique could distinguish between color copiers using different toners. As a result of low signal-to-noise ratio of this reflectance method, it was generally not possible to investigate pure colors (e.g., magenta), since the area necessary for good quality FTIR spectra was quite large. Therefore, a partially destructive technique was used (8). This technique involves transferring the toner to a metallic stub for direct examination by microreflectance FTIR. Since metals are good FTIR reflectors, "transflectance" FTIR spectra are obtained for toner material transferred to the aluminum surface. The method is very sensitive and can be used for both black and colored photocopy toners. Some results

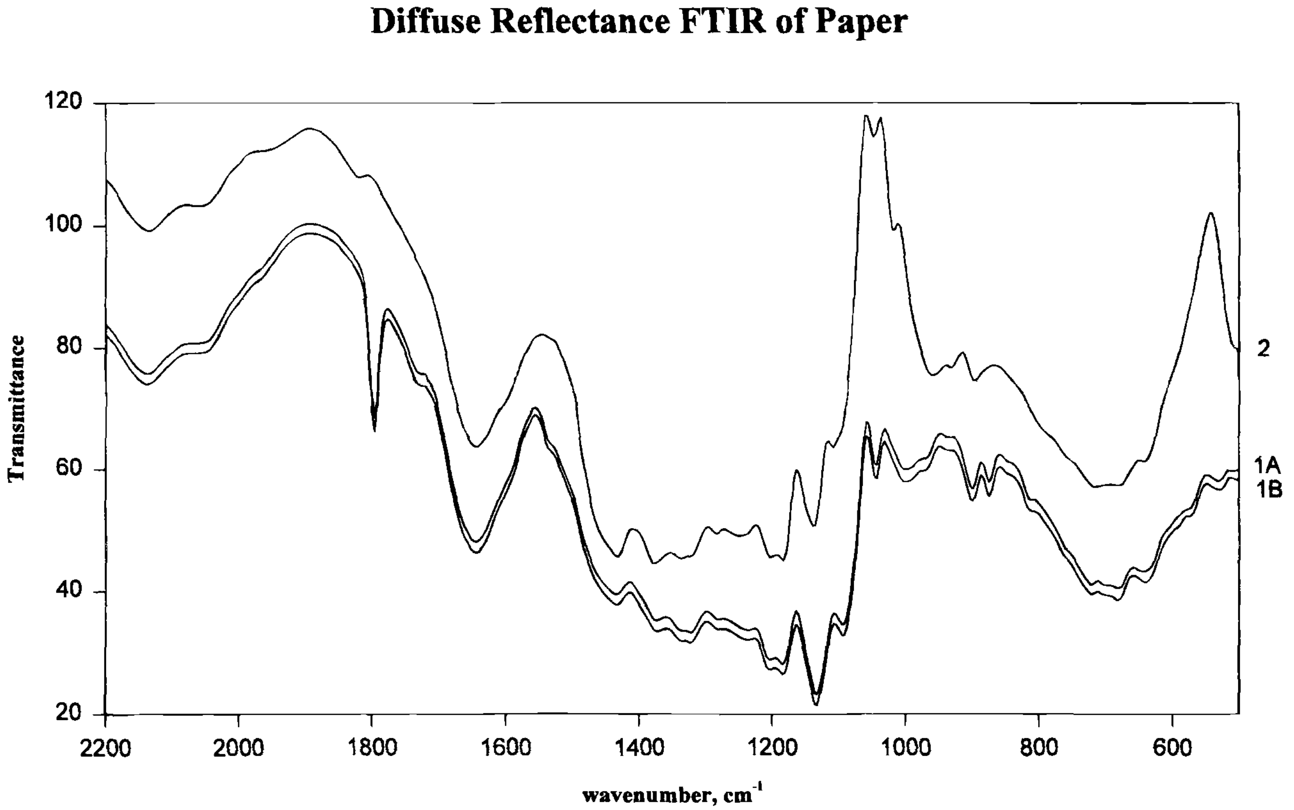

FIG. 4—*DRIFTS spectra (transmittance mode) obtained for two different samples of white paper (1—ordinary photocopy paper, 2—printer paper). The good reproducibility of the method is illustrated by two separate measurements of Sample 1 (1A, 1B).*

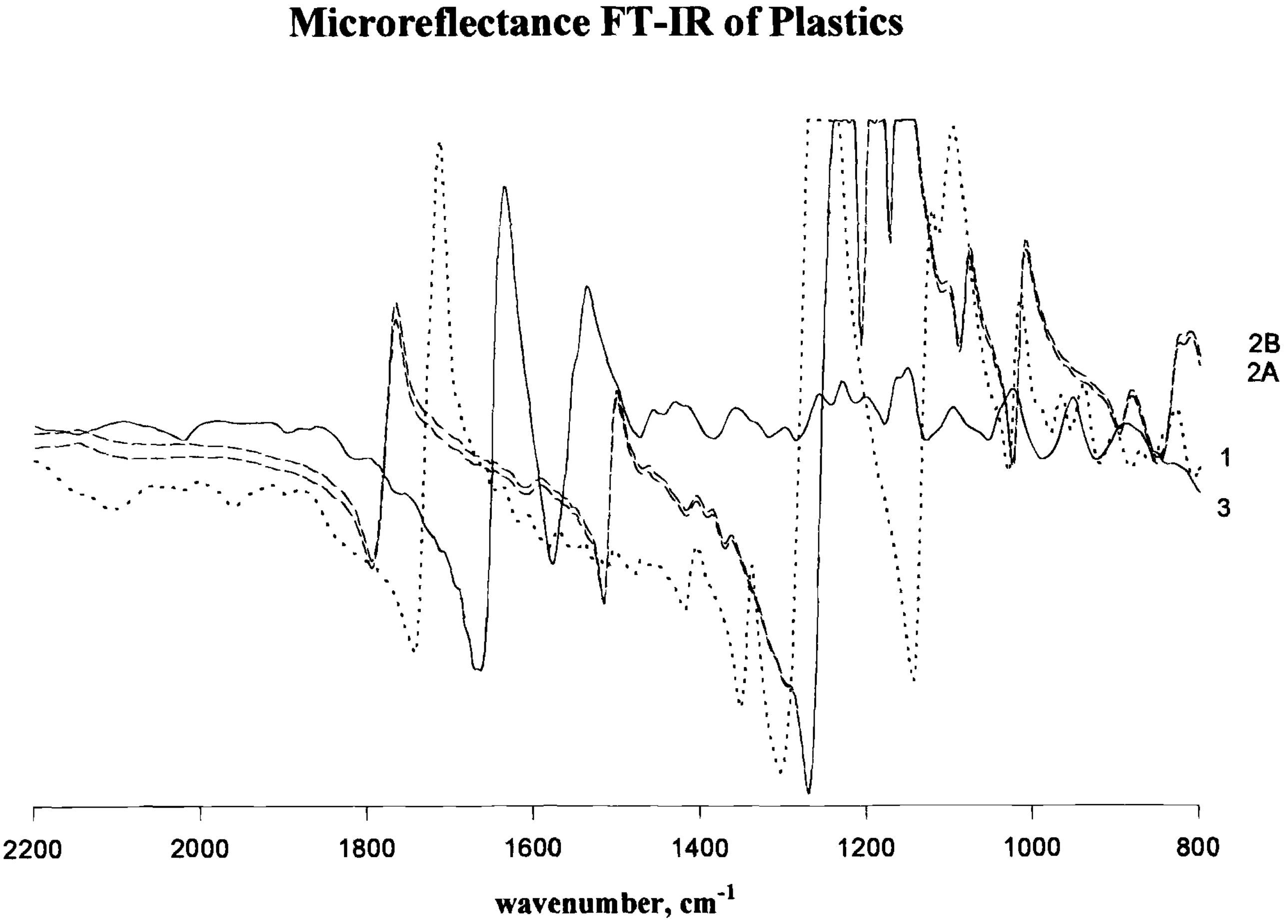

FIG. 5—*Microreflectance FTIR of plastic surface on Swedish* (dotted line), *Finish* (dashed line), *and Bulgarian* (connected line) *driving licenses. The spectra exhibit large contribution from specular reflectance. The reproducibility of the measurement is, however, good (see 2A and 2B) and the differences between the spectra obtained for different samples are significant.*

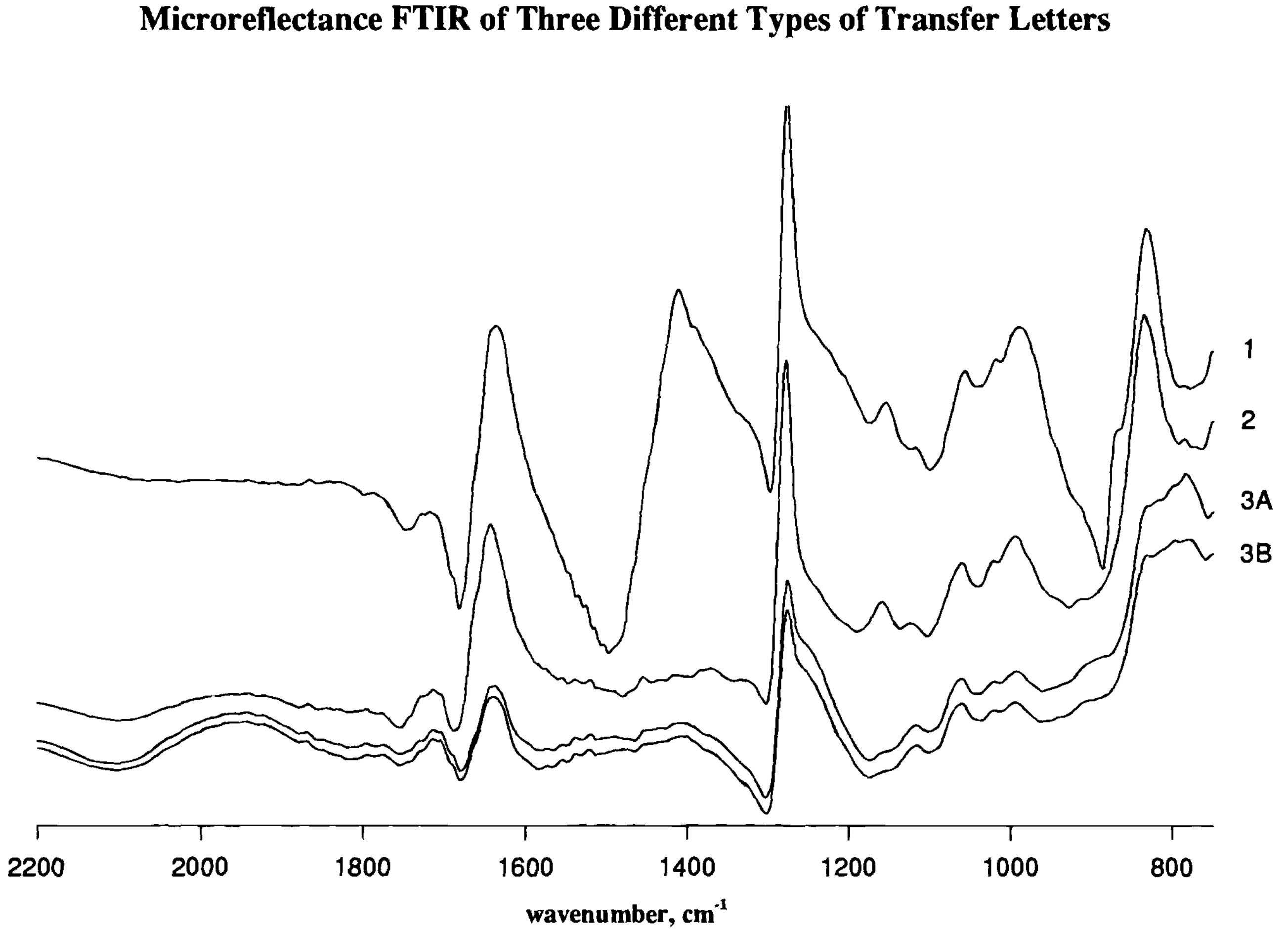

FIG. 6—*Microreflectance FTIR spectra obtained for samples of transfer letters from three different manufacturers—LETRASET (1), STIK IK (2), and MECANORMA (3). The reproducibility is shown on Sample 3.*

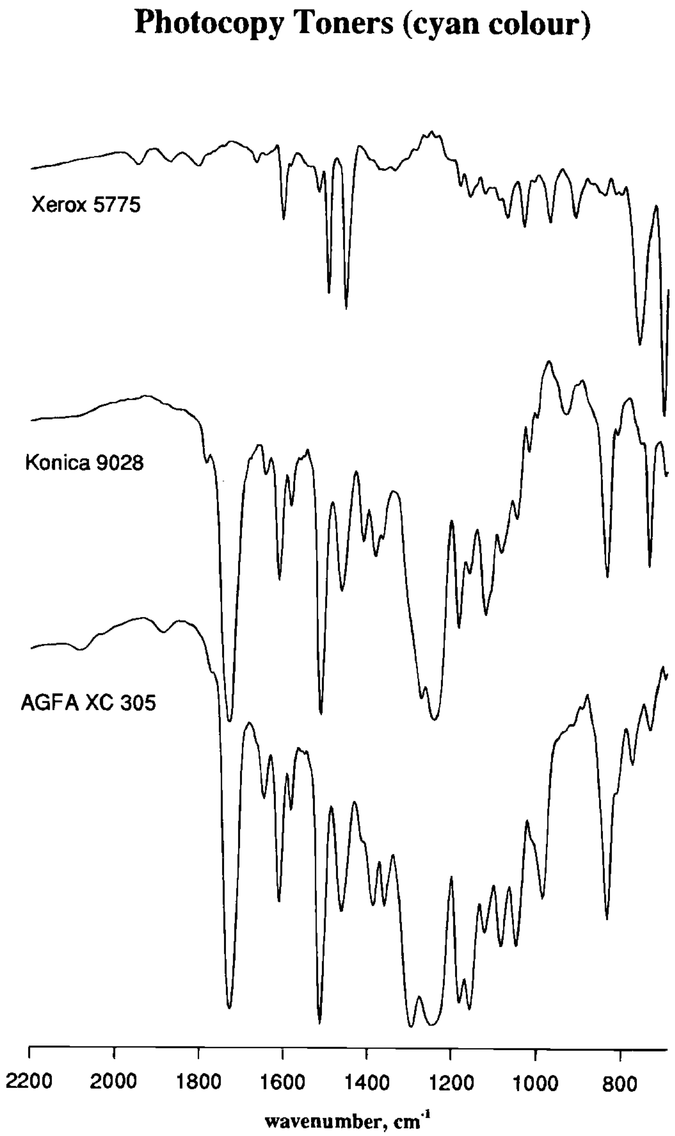

FIG. 7—*FTIR spectra for samples of cyan toners from three different manufacturers of photocopy machines (Xerox, Konica, and Agfa). The samples were thermally transferred to aluminum stubs before analysis by microreflectance FTIR. The spectra shown were obtained from areas of about 0.3 by 0.3 mm.*

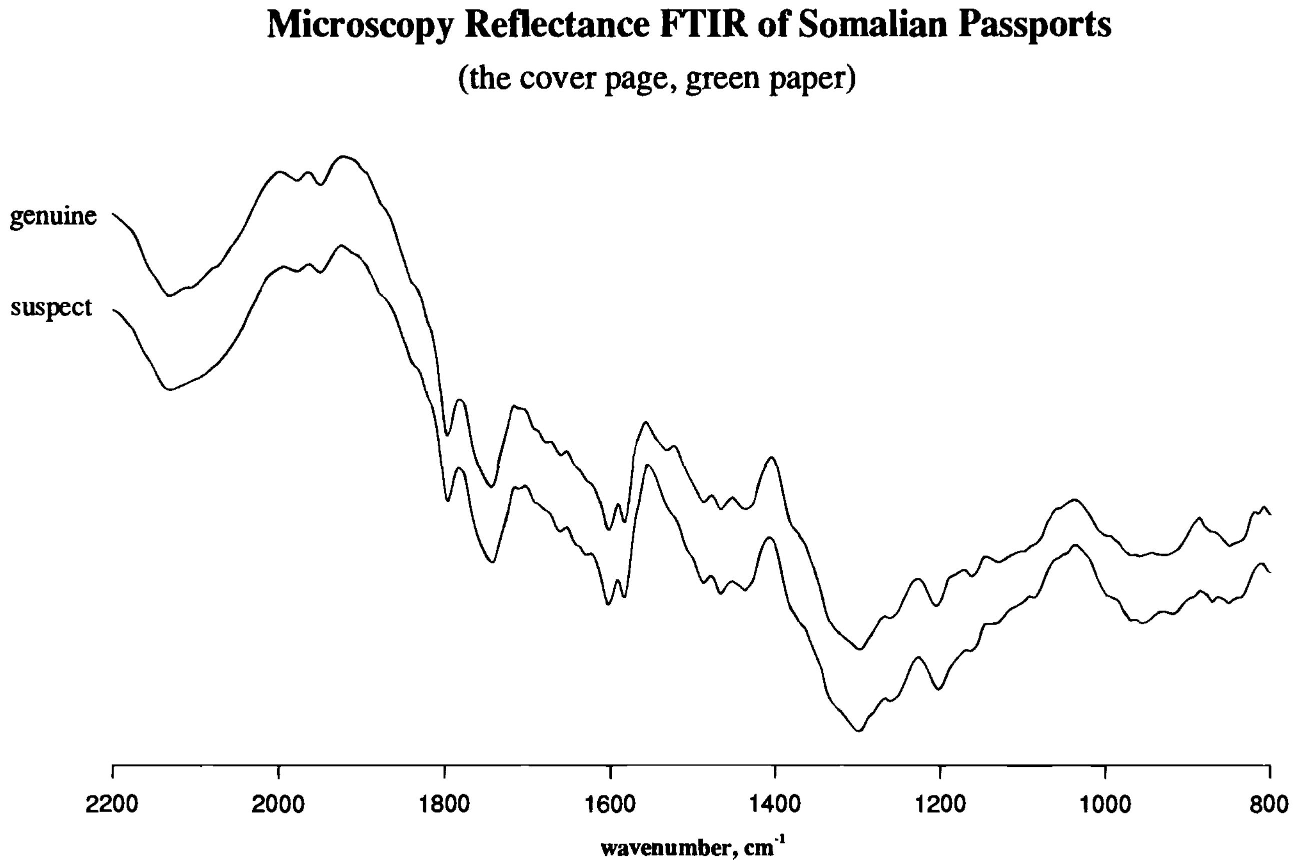

FIG. 8a—*Microreflectance FTIR recorded from various materials in genuine and suspect Somalian passports with green cover page (paper). The examination could not detect any differences in these materials between genuine and suspect passports.*

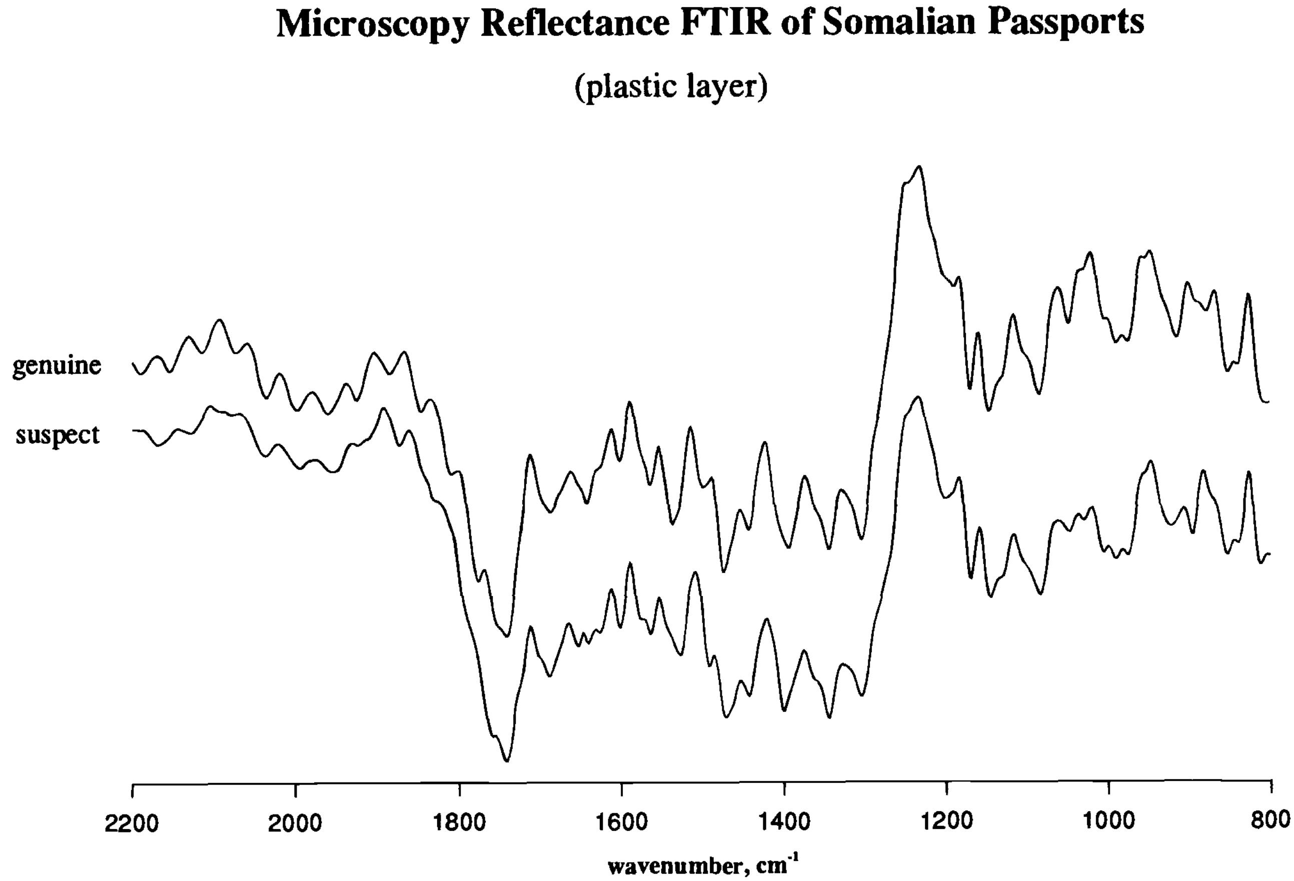

FIG. 8b—*Microreflectance FTIR recorded from various materials in genuine and suspect Somalian passports with plastic layer in the inside page covering photo etc. The examination could not detect any differences in these materials between genuine and suspect passports.*

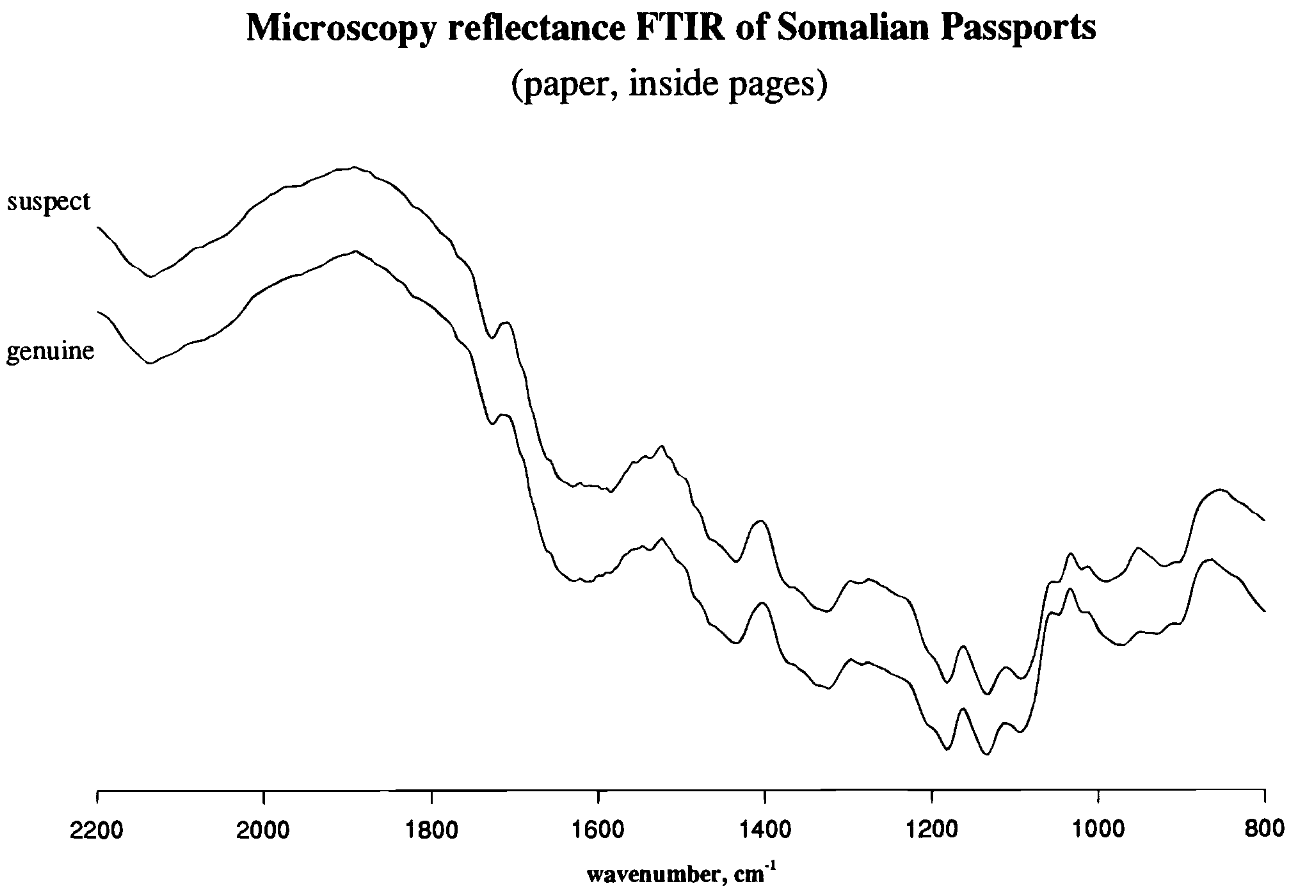

FIG. 8c—*Microreflectance FTIR recorded from various materials in genuine and suspect Somalian passports with paper in inside pages. The examination could not detect any differences in these materials between genuine and suspect passports.*

achieved for black toners were reported (8). For toner from color photocopiers, measurements can be applied to small areas (under 0.1 by 0.1 mm), and the method has a good potential to measure separate colors in a photocopy. We found some differences between FTIR spectra for magenta and cyan toner from the same photocopier, although the nature of the plastic material was the dominating factor for appearance of the spectra.

Test copies from ten different color photocopiers were investigated. The measurements were performed on magenta and cyan toners separately. Euclidean distances were calculated from the first derivatives of FTIR spectra in the manner described above. The copiers could be divided into six groups with one copier and one group with four indistinguishable copiers. In this last group, there were two Canon (CLC 300 and CLC 500), one Agfa (XC 305), and one Kodak copier (Color Edge 1550). These photocopiers use the same kind of toners (according to the information we have received) produced by the same manufacturer. Figure 7 compares cyan toners from three photocopiers: Xerox, Konica, and Agfa. The spectra are similar to conventional FTIR spectra obtained for extracts from the same toner material. Any contribution of specular reflectance from the specimen surface to the spectra seems small.

Casework

The techniques described in this study are frequently used for document examination in our laboratory. One example, in which various materials on the same document were examined, is presented. This concerned a Somalian passport, suspected of being counterfeit and made in nongenuine material. We examined the cover page material, paper on inside pages, plastic layer covering the photo page, and black printing ink on inside pages by FTIR microreflectance. The FTIR spectra were compared with those obtained for genuine materials in passports from our reference collection. The agreement between spectra recorded for the suspect and genuine materials was very good. Figure 8 illustrates the results of this examination.

Conclusions

Nondestructive microreflectance FTIR technique was applied to various materials encountered in document examination, including black printing inks, paper, plastics, transfer letters (Letra set), and photocopy toners. Unlike another reflectance technique, DRIFTS, microreflectance FTIR is nondestructive even for large-sized samples.

The nondestructive techniques may be applied to many different materials without the necessity of obtaining good results because additional techniques may also be used. Microreflectance FTIR is a valuable complement to other optical methods for forensic examination of documents for many different materials and for materials of similar shade color but of different chemical composition.

References

(1) Suzuki EM. Forensic science applications of diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS). V. direct analysis of metallic paints—screening of panels. J Forensic Sci 1989;34(1):180–96, and references therein.

(2) Mazzella, WD, Lennard CJ, Margot PA. Classification and identification of photocopy toners by diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS): II. Final report. J Forensic Sci 1991;36(2):449–65.
(3) Mazzella WD, Lennard, CJ, Margot PA. Classification and identification of photocopy toners by diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS): I. Preliminary results. J Forensic Sci 1991;36(3):820–37.
(4) Mazzella WD, Lennard CA. Use of silicon carbide sampling accessory for the diffuse reflectance infrared Fourier transform analysis of samples of interest to forensic science. J Forensic Sci 1991;36(2):556–64.
(5) Merrill RA, Bartick EG. Analysis of ballpoint pen inks by diffuse reflectance infrared spectrometry. J Forensic Sci 1992;37(2): 528–41.
(6) Wilkinson JW, Locke J, Laing DI. The examination of paints as thin sections using visible microspectrophotometry and Fourier transform infrared microscopy. Forensic Sci Int 1988;28:43.
(7) Tungol MW, Bartick EG, Montaser A. Analysis of single polymer fibres by Fourier transform infrared microscopy: the results of case studies. J Forensic Sci 1991;36(6):1027.
(8) Andrasko J. A simple method for sampling photocopy toners for examination by microreflectance Fourier transform infrared spectrophotometry. J Forensic Sci 1994;39(1):226–30.
(9) Bartick EG, Tungol MW, Reffner JA. A new approach to forensic analysis with infrared microscopy: internal reflection spectroscopy. Anal Chim Acta 1994;288:35–42.
(10) Katon JE, Sommer AJ, Lang PL. Infrared microscopy. Appl Spectrosc Rev 1989–1990;25(3&4):173–211.

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