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Classification and Identification of Photocopying Toners by Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS): II. Final Report

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ABSTRACT: A diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) technique has been employed to record the IR spectra of 152 different black and color toners used in photocopiers and laser printers. Based on characteristic absorption bands in the infrared (IR) spectra, 149 of these toners were classified into 36 distinct groups. A small sample of toner was removed from the surface of a questioned document (produced on a photocopier or laser printer), the IR spectrum was recorded using the diffuse reflectance technique, and the class of toner was determined by comparison with a collection of standard spectra. A knowledge of the compatibility of each type of toner can then be employed to provide a list of photocopying machines (or laser printers) that could have produced the questioned document. The technique does not appear to be affected by the age of the photocopy, the batch or toner, or the prior treatment of the questioned document with a fingerprint development reagent such as ninhydrin.

KEYWORDS: questioned documents, toners, photocopiers, photocopies, printers, laser printers, DRIFTS, diffuse reflectance, infrared spectroscopy, infrared Fourier transform (FTIR), classification, identification, documents, criminalistics, database

A significant increase in the number of questioned document cases involving photocopies has lead to the development of several analytical procedures for the classification and identification of photocopying toners [*1*]. In a previous article [*2*], a diffuse reflectance infrared Fourier transform spectroscopy (DRIFTS) technique was described for the infrared analysis of raw photocopying toners and small samples of toner removed from the surface of photocopied documents. From the results of this preliminary evaluation, it was possible to conclude the following:

1. The DRIFTS technique can be successfully, simply, and rapidly applied to the analysis of both raw toner powders and toners extracted from photocopied documents—the IR spectra obtained can, in some cases, differentiate photocopies produced on different machines (photocopies produced on different machines that use the same toner cannot be differentiated by this method).

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2. The spectrum of a toner extracted from a photocopy and measured by DRIFTS is identical to the spectrum of the raw toner powder.
3. Toners may be classified into a number of groups according to characteristic absorption bands in their diffuse reflectance infrared spectra.
4. A database of infrared spectra of toners available on the market could be used to obtain a list of likely machines used to produce a questioned photocopy. If a particular case involves copies produced on a number of different machines, the list of suspects can be restricted to those having access to such a combination of photocopiers (in a certain office or department, for example).

The purpose of this second article is to present the completed DRIFTS database for a wide range of toners available on the Swiss market and to answer the following questions posed in our first report [*2*]:

1. Are there significant variations between batches of the same brand of photocopying toner that can be detected by the DRIFTS technique?
2. Do toner samples from photocopies produced over an extended period of time on the same machine give identical infrared spectra?
3. Is the toner analysis affected by prior treatment of the document with reagents used for the chemical development of latent fingerprints (ninhydrin, for example)?

Experimental Procedure

The apparatus, sample preparation, and instrumental parameters for the DRIFTS analysis of raw toner powders and toner extracted from photocopies were as described previously [*2*].

Toner Samples

Samples of 119 black photocopying toners, with information on the compatibility of each toner, were provided by relevant company representatives in Switzerland (Table 1). A number of color toners (for color photocopiers), toners for use in laser printers, and several photocopies (in cases where the bulk toner powder was not available), were also obtained (Table 2). In total, 152 different toners were received for analysis. These toners represent a large percentage of the toners currently available on the Swiss market.

Photocopies produced on the same machine over an extended period of time and photocopies produced on different machines of the same brand and model were analyzed by the DRIFTS technique in order to evaluate any variation due to time or toner batch employed. In addition, photocopies were treated with a number of fingerprint development reagents—notably ninhydrin, secondary treatment with zinc or cadmium nitrate [*3*], 1,8-diaza-9-fluorenone (DFO) [*4*], and physical developer [*5*]—before recording the infrared spectrum of the toner. The resulting spectra were compared with the toner spectra obtained from the same documents before treatment with the fingerprint reagent.

Results

The toner samples taken from the photocopied documents and the raw toner powders were classified into 36 distinct groups according to their infrared spectra. The classification scheme is based on the presence or absence of certain infrared absorption bands (Table 3). Sample spectra from Groups 1 through 16 were published in our previous article [*2*]. Figures 1 through 10 show typical spectra for each of the remaining 20 groups (Groups 17 to 36) with important absorption bands indicated. (Only the "fingerprint" region between 2100 and 700 cm^{-1} is shown in these spectra, as this is where most of the

TABLE 1—*List of the 119 black photocopying toners (raw powders) analyzed in this study together with the respective photocopying machines that use these toners.*[a]

Bulk Toner	Compatibility
Agfa CB-742	Agfa X-20, 22
Agfa CB-745	Agfa X-12
Agfa CB-746	Agfa X-30, 31
Agfa CB-749	Agfa X-29, 40, 41
Agfa CB-750	Agfa X-2
Agfa CB-752	Agfa X-55, 88
Agfa CB-755	Agfa X-35, 45
Agfa CB-757	Agfa X-25
Canon NP-150	Canon NP-150, 155
Canon NP-200	Canon NP-200
Canon NP-210	Canon NP-210, 270, 271, 300, 305, 400, 500
Canon NP-1015	Canon NP-1015, 1215
Canon NP-2215	Canon NP-215
Canon NP-3025	Canon NP-3025, 3225, 3525, 3725
Canon NP-3325	Canon NP-3325, 3825
Canon NP-4035	Canon NP-4035, 4040, 4540
Canon NP-4335	Canon NP-4335, 4835
Canon NP-6000	Canon NP-6000, 7000, 8000 series
Canon NP-9030	Canon NP-9030
Canon NP-9330	Canon NP-9330
Elfotec Canon NP-3000	Canon NP-3000 series
Elfotec Canon NP-120	Canon NP-120, 125
Elfotec Canon NP-150	Canon NP-150
Elfotec Minolta EP-310	Minolta EP-310
Elfotec Minolta EP-450	Minolta EP-450, 450Z
Elfotec Minolta EP-470Z	Minolta EP-470Z, 490Z, 50, 415
Elfotec Minolta EP-650	Minolta EP-650
Elfotec Mita DC-111	Mita DC-111, 112, 152
Elfotec Mita DC-131	Mita DC-131, 161, 181
Elfotec Mita DC-211	Mita DC-211, 4055
Elfotec Olivetti Copia 1000	Olivetti 1000, 1050
Elfotec Panasonic FP-1300	Panasonic FP-1300, 1520
Elfotec Sharp SF-750	Sharp SF-750, 770
Elfotec Toshiba BD-5511	Toshiba BD-5511, 7811
Harris 3M 6020	Harris 3M 6020, 6030, 6130
Harris 3M 6110	Harris 3M 6110
Harris 3M 6113	Harris 3M 6113, 6213
Harris 3M 6115	Harris 3M 6115, 6215
Harris 3M 6242	Harris 3M 6242
Harris 3M 6260	Harris 3M 6260
Kodak EK-85	Kodak EK-85
Kodak EK-235	Kodak EK-150, 200, 235
Kodak EK-300	Kodak EK-300
Kodak IM-40	Kodak IM-40
Kodak K-90	Kodak K-90
Konika 100	Konika 100
Konika 112N	Konika 112, 112Z
Konika 150	Konika 150, 250Z
Konika 160	Konika 160, 250N
Konika 170	Konika 170, 500, 550
Konika 180	Konika 180, 220, 280, 320
Konika 225	Konika 225
Konika 400	Konika 400
Konika 404	Konika 404
Konika 420	Konika 420, 700, 760
Minolta EP-30	Minolta EP-30
Minolta EP-270	Minolta EP-270, 370, 370Z
Minolta EP-350Z	Minolta EP-350Z
Minolta EP-410Z	Minolta EP-410Z, 415Z, 425Z

TABLE 1—*Continued.*

Bulk Toner	Compatibility
Minolta EP-450Z	Minolta EP-450, 450Z
Minolta EP-470Z	Minolta EP-470Z, 490Z, 4230
Minolta EP-550Z	Minolta EP-550Z
Minolta EP-570Z	Minolta EP-570Z
Minolta EP-650Z	Minolta EP-650Z
Minolta EP-2100	Minolta EP-2100, 3120
Minolta EP-4300	Minolta EP-4300
Mita DC-1205	Mita DC-1205, 1255
Mita DC-1656	Mita DC-1656
Mita DC-2285	Mita DC-2285
Mita DC-3285	Mita DC-3285
Mita DC-5585	Mita DC-5585
Oce 1900	Oce 1700–1900
Pelikan Canon NP-120	Canon NP-120, 122, 125
Pelikan Canon NP-150	Canon NP-150, 155; Selex 60AZ; Olivetti Copia 7045; Roto Copy 315
Pelikan Canon NP-270	Canon NP-201, 210, 211, 250, 270, 271, 300, 305, 350, 400, 401, 402, 500; Copyer Selex 303
Pelikan Canon NP-3000	Canon NP-3000 series
Pelikan Fujitsu 7300	Fujitsu 7300; Develop 2300
Pelikan Konika 100	Konika 100
Pelikan Konika 90	Konika 90
Pelikan Minolta EP-50	Minolta EP-50; Agfa X-15; Develop 200
Pelikan Minolta EP-310	Minolta EP-310; IBM 102
Pelikan Minolta EP-450Z	Minolta EP-450, 450Z
Pelikan Mita DC-131	CPF Apollo; Gemini; Planet A3; Vega; Develop 77.1; Gestetner 2000, 2001, 2002, 2003, 2004, 2006; GSF 121, 131, 132, 133, 161, 232; Kardex DC-121, 122, 131, 132, 133, 161, 232, 435, 535S; Mita 121, 122, 131, 132, 133, 232; Monroe RL-612, 614; Oce 1525, 1625, 2625; Olivetti Copia 1300, 1350; Olympia Omega 1210, 1330; Rex Rotary 7040R; Roneo VR 23.30; Utax C-160, 161, 166, 168, 170, 260, 266, 288
Pelikan Mita DC-211	Copystat DC-213, 313; CPF Tritron: Develop 71, 75, 78; Gestetner 2007, 2130; Kardex DC-211, 213, 313, Mita DC-211, 213, 313, 2105; Monroe 725, 735, RL-725, RL-735; Oce 1630; Olympia Omega 2130 RE; Rem Orion; Renker Safir 234 RE, 244, 264, 313; Rex Rotary 7020, 7075, 7130, 7230; Triumph Adler 220, 220 RE; Utax C-220, 225, 230, 233
Pelikan Mita DC-111	CPF Copilot; Gestetner 2110; Kardex DC-111; Monroe RL-710; Oce 1530; Olympia Omega 1110; Rex Rotary 7110; Triumph Adler 210; Utax C-110
Pelikan Mita DC-152Z	Develop 76Z; Gestetner 2115; Kardex DC-152; Mita DC-152 Z; Oce 1540; Renker Safir 254; Rex Rotary 7315 RE; Triumph Adler 215 RE; Utax C-116, 216
Pelikan Mita DC-1205	Gestetner 2201; Mita DC-1205; Nashua 8112; Oce 2025; Triumph Adler 2012
Pelikan Panasonic FP-1520	A.B. Dick Delta 2000; Olympia 3015; Panasonic 1520, 2520, 2625
Pelikan Ricoh 5010	Infotec 9026, 9032, 9040; Ricoh 5010
Pelikan Ricoh FT-4030	Infotec 9018, 9020, 9025, 9035, 9046; Ricoh 4030, 4060
Pelikan Ricoh M5	
Pelikan Sanyo 1100	Apeco 350 ZE; Decimo Fax 1100; Geha Variocopy; Sanyo 1100, 1102, 1150, 1152; Uchida 350S
Pelikan Sharp 740	Olivetti Copia 1400, 1450; Sharp SF-740
Pelikan Sharp 760	Copy-Mat 2050; Olivetti Copia 7030; Sharp SF-760
Pelikan Sharp 850	Copy-Mat 5050; Sharp SF-850
Pelikan Toner	Alcatel 1005; Baumatic 540; Cybernet CP-55; Copystat; Royal 2110; Decimo; Copywrite; Facit 2350; Olympia 001; Precisa 6006; Radio Shack PC-200; Saxon SX-10; Sears SX-10; Xerox 2000

TABLE 1—*Continued.*

Bulk Toner	Compatibility
Pelikan Toshiba 4511	Harris 3M 526, 545, 546, 565, 595, 596; Lumoprint Rapid; Roto Rapid; Toshiba BD-3503, 3504, 3701, 3702, 4501, 4502, 4510, 4511, 4515, 7501, 7511, 8101, 8102, T-44, TP-44
Pelikan Toshiba 7811	Harris 3M 516, 570, 576, 583, 586, 596; Toshiba BD-3301, 5511, 7801, 7811, 7812, 7813, 7815, 7816, 8811, 8812, TP-50
Ricoh 4000	Ricoh FT-7770, 7060, 6620, 5590, 5580, 5570, 5520, 5560, 5000, 5010, 4480, 4430, 3320
Ricoh M-Serie	Ricoh LR-1, FT-2260, M-100, 10, 5
Utax C-110	Utax C-105, 110
Utax C-220	Utax C-220, 221, 222, 225, 230, 233
Xerox 1025	Xerox 1025, 1038, 2510
Xerox 3700	Xerox 3700
Xerox 4000	Xerox 2080, 4000F
Xerox 4045	Xerox 4045
Xerox 4075	Xerox 4075
Xerox 5046	Xerox 1065, 5046
Xerox 5080	Xerox 5080
Xerox 5090	Xerox 5090
Xerox B (= Y)	Xerox 3600F, 660F
Xerox F (= N, U, X)	Xerox 1055, 2080, 4000F, 7080
Xerox G (=J, M)	Xerox 5400F, 8200–9500F
Xerox H (= L, P)	Xerox 3100F, 3400F
Xerox R	Xerox 1040, 1045, 1048, 1050, 5052
Xerox T	Xerox 1075
Xerox V	Xerox 1030, 1035
Xerox W	Xerox 1020
Xerox Z	Xerox 2700F

[a]The information regarding the compatibility of each toner is given as received from each company representative and has not been otherwise checked for accuracy or completeness.

TABLE 2—*List of the 9 color photocopying toners, 12 black laser printing toners, and 12 photocopies that were analyzed in addition to the 119 black photocopying toners.*

Color Toners		Laser Printing Toners	Photocopies
Canon CLC-1	(yellow)	Farbax EP	Canon PC-5
Canon CLC-200	(yellow)	Farbax EP/S	Canon PC-20
Canon CLC-200	(black)	Farbax PC/FC	Gestetner ZDF-2355
Canon CLC-500	(cyan)	Farbax Ricoh 4080	Harris 3M 566
Canon CLC-500	(yellow)	Pelikan Canon CX LBP-8	IBM 3-20
Kodak Coloredge	(yellow)	Pelikan Canon SX II LBP-8	Kodak 150
Konika 225	(red)	Pelikan Dataproduct 1200	Monroe RL-9162
Panasonic FP-C1	(yellow)	Pelikan Dataproduct 2600	Nashua 4550Z
Xerox 1005	(yellow)	Pelikan Kyocera F-1010	Panasonic FP-2520
		Pelikan Ricoh 4080	Sharp SF-8200
		Pelikan Ricoh 6000	Toshiba 5110
		Pelikan Xerox 4045	Xerox 1065

TABLE 3—*The classification scheme, according to characteristic absorption bands in the diffuse reflectance infrared spectra, for 149 of the toners analyzed.*[a]

Group	Toner		Characteristic IR Bands, cm^{-1}
1	Agfa CB-750		1783, 1246, 843
	Canon NP-150		
	Canon NP-200		
	Canon NP-210		
	Canon PC-20	(P)	
	Canon PC-5	(P)	
	Farbax EP/S	(L)	
	Farbax PC/FC	(L)	
	Kodak IM-40		
2	Pelikan Konika 100		1495, 1000, 970, 910
3	Agfa CB-752		1410, 1273, 1110, 1085, 1019, 934, 875, 734
	Canon NP-6000		
	Kodak EK-90E		
	Kodak EK-85		
	Minolta EP-550Z		
	Minolta EP-570Z		
	Pelikan Fujitsu 7300		
4	Agfa CB-745		2973, 1649, 1297, 1159, 985, 775
	Canon CLC 1	(C)	
	Canon CLC 200 (black)	(C)	
	Canon CLC 200 (yellow)	(C)	
	Canon CLC 500 (cyan)	(C)	
	Canon CLC 500 (yellow)	(C)	
	Konika 225	(C)	
	Pelikan Xerox 4045	(L)	
	Oce 1900		
	Xerox 4045		
	Xerox 3700		
	Xerox H		
	Xerox Z		
5	Konika 100		3030, 1456, 1274, 1074, 1019, 999, 760, 734
6	Canon NP-1015		2928, 1161
	Canon NP-2215		
	Canon NP-3025		
	Canon NP-3325		
	Canon NP-4035		
	Canon NP-4335		
	Canon NP-9030		
	Canon NP-9330		
	Elfotec Minolta EP-470Z		
	Elfotec Mita DC-111		
	Elfotec Mita DC-211		
	Elfotec Sharp SF-750		
	Harris 3M 566	(P)	
	Kodak EK-300		
	Mita DC-1205		
	Panasonic FP-C1	(C)	
	Pelikan Canon NP-150		
	Pelikan Canon NP-3000		
	Pelikan Panasonic FP-1520		
	Pelikan Ricoh M5		
	Ricoh M-Serie		
	Utax C-110		

TABLE 3—*Continued.*

Group	Toner		Characteristic IR Bands, cm^{-1}
7	Agfa CB-755 Agfa CB-757 Elfotec Minolta EP-450 Minolta EP-30 Minolta EP-270 Minolta EP-410Z Minolta EP-450Z Minolta EP-470Z Minolta EP-2100 Minolta EP-4300 Pelikan Minolta EP-50		1704, 1180
8	Minolta EP-350Z Minolta EP-650Z		1546, 1318, 1272, 1202
9	Nashua 4550Z	(P)	1327, 1267, 1179, 799
10	Ricoh 4000		1272, 1202, 1180
11	Elfotec Minolta EP-650 Harris 3M 6113 Panasonic FP-2520 Pelikan Canon NP-270 Pelikan Mita DC-152Z Pelikan Ricoh 6000 Pelikan Toshiba 7811 Sharp SF-8200	 (P) (L) (P)	1271, 1162, 1070
12	Harris 3M 6020 Toshiba 5110	 (P)	2094, 1183
13	Mita 1656 Mita 2285 Mita 3285 Monroe RL-9162 Pelikan Minolta EP-450Z Pelikan Mita DC-211 Pelikan Mita DC-1205 Utax C-220	 (P)	1185, 1158, 1116
14	Agfa 742 Elfotec Minolta EP-310 Pelikan Ricoh 4080 Farbax Ricoh 4080 Pelikan Minolta EP-310 Pelikan Sharp 760 Xerox B Xerox G Xerox F Xerox M Xerox R Xerox T Xerox V Xerox W Xerox 1005 Xerox 1025 Xerox 4000 Xerox 5080	 (L) (L) (C)	2935, 1272, 1184, 1004
15	Gestetner ZDF-2355 Harris 3M 6110 Harris 3M 6260 Mita DC-5585	(P)	1327, 1258, 1200, 1164

TABLE 3—*Continued.*

Group	Toner		Characteristic IR Bands, cm^{-1}
16	Agfa CB-749		2928, 1328, 1294, 1201, 1180, 1161
	Harris 3M 6242		
	Pelikan Dataproduct 1200	(L)	
	Pelikan Dataproduct 2600	(L)	
	Pelikan Sharp 850		
17	Pelikan Sharp 740		1298, 1110, 1042, 831
18	Pelikan Toshiba 4511		1694, 1514, 1223
19	Pelikan Mita DC-131		1694, 1514, 1467, 817
20	Kodak Coloredge	(C)	1613, 1454, 1018, 875
21	Agfa CB-746		1865, 1787, 1605, 1494, 1225, 753
22	Elfotec Panasonic FP-1300		2929, 1163, 923
23	Elfotec Canon NP-150		2928, 1700, 1163
	Elfotec Canon NP-3000		
24	Xerox 5090		1316, 1115, 844
25	Farbax EP	(L)	1466, 1418, 1347, 1191
	Pelikan Canon CX LBP-8	(L)	
	Pelikan Canon SX II LBP-8	(L)	
26	Harris 3M 6115		1201, 1164, 1071
27	Xerox 4075		1649, 1363, 1294, 1155, 977, 823
28	Elfotec Toshiba BD-5511		2876, 1496, 1363, 763
	Elfotec Mita DC-131		
29	Pelikan Canon NP-120		2921, 2852, 1743, 1465, 1114
30	Pelikan Mita DC-111		1381, 1327, 1158, 760
	Pelikan Ricoh FT-4030		
	Pelikan Ricoh 5010		
	Pelikan Sanyo 1100		
31	Pelikan Konika 90		1455, 1196, 1135
32	IBM 3-20	(P)	1152, 1067, 752
33	Pelikan Kyocera F-1010	(L)	3257, 858
34	Xerox 1065	(P)	1695, 1263
35	Konika 112N		1583, 1151, 1071
	Konika 150		
	Konika 160		
	Konika 170		
	Konika 180		
	Konika 225		
	Konika 400		
	Konika 404		
	Konika 420		
36	Kodak EK-235		1545, 1199, 1134
	Kodak 150	(P)	

[a](C) indicates a color photocopying toner, (L) a black laser printer toner, and (P) the toner from a photocopy. The remaining toners are bulk powders for use on conventional photocopying machines. The toners Elfotec Canon NP-120, Elfotec Olivetti Copia 1000, and Pelikan Toner were not classified due to poor quality and irreproducible spectra.

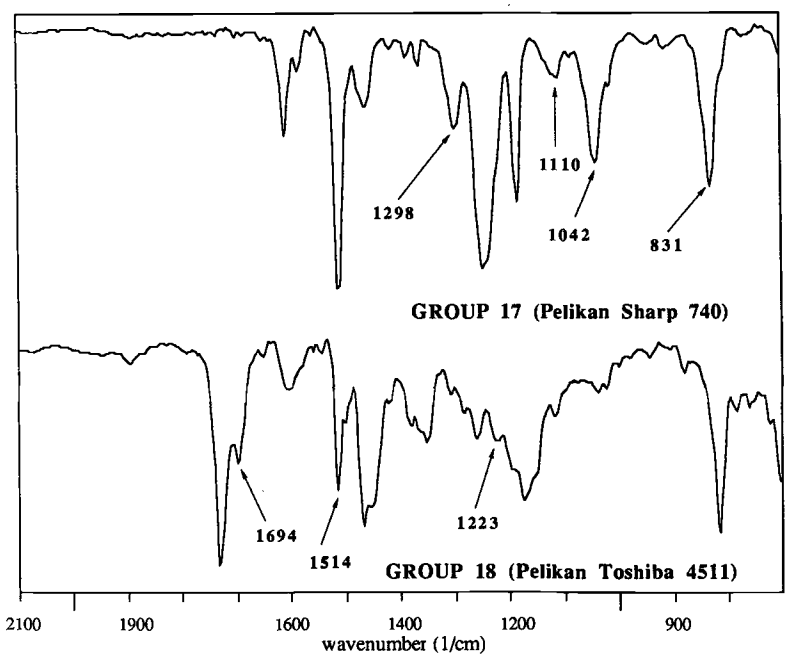

FIG. 1—*Examples of spectra from Group 17 (Pelikan Sharp 740) and Group 18 (Pelikan Toshiba BD-4511) showing characteristic absorption bands.*

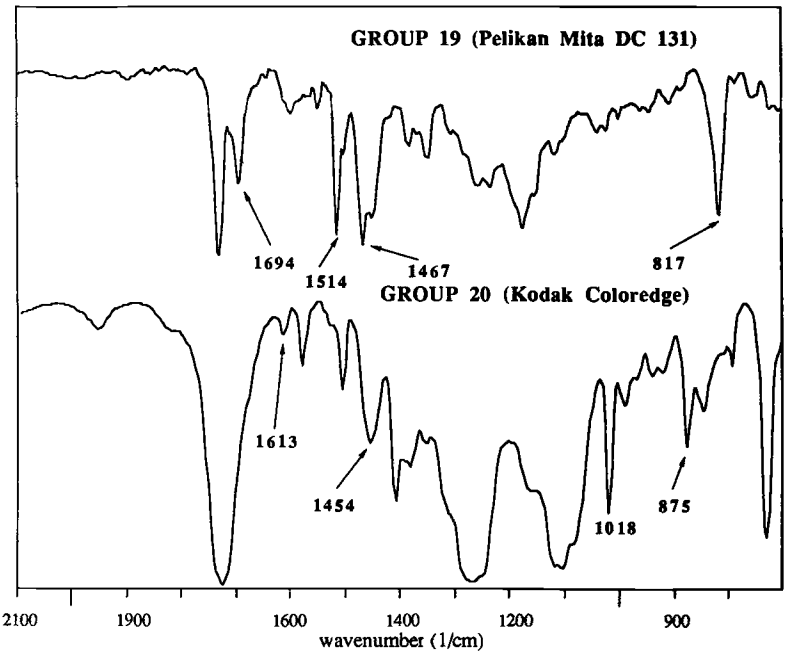

FIG. 2—*Examples of spectra from Group 19 (Pelikan Mita DC-131) and Group 20 (Kodak Coloredge) showing characteristic absorption bands.*

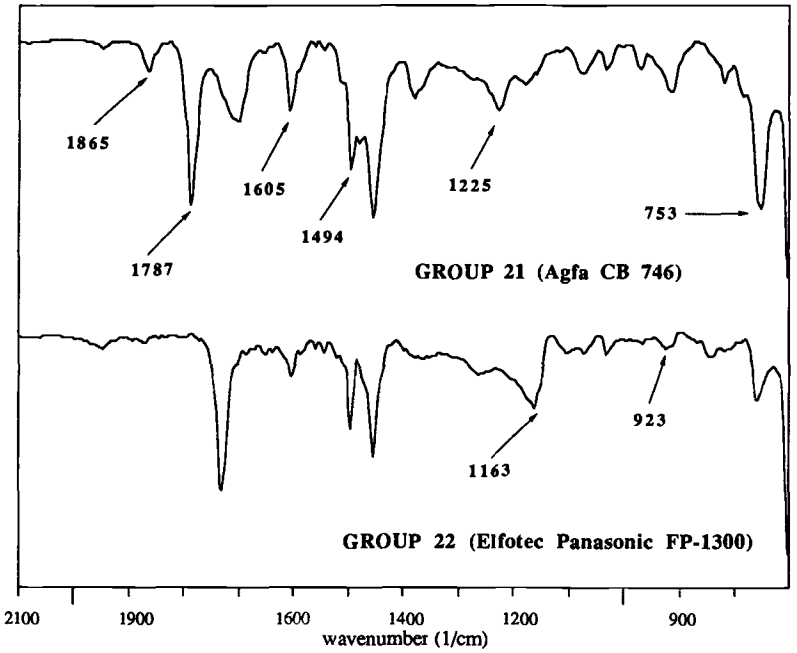

FIG. 3—*Examples of spectra from Group 21 (Agfa CB-746) and Group 22 (Elfotec Panasonic FP-1300) showing characteristic absorption bands.*

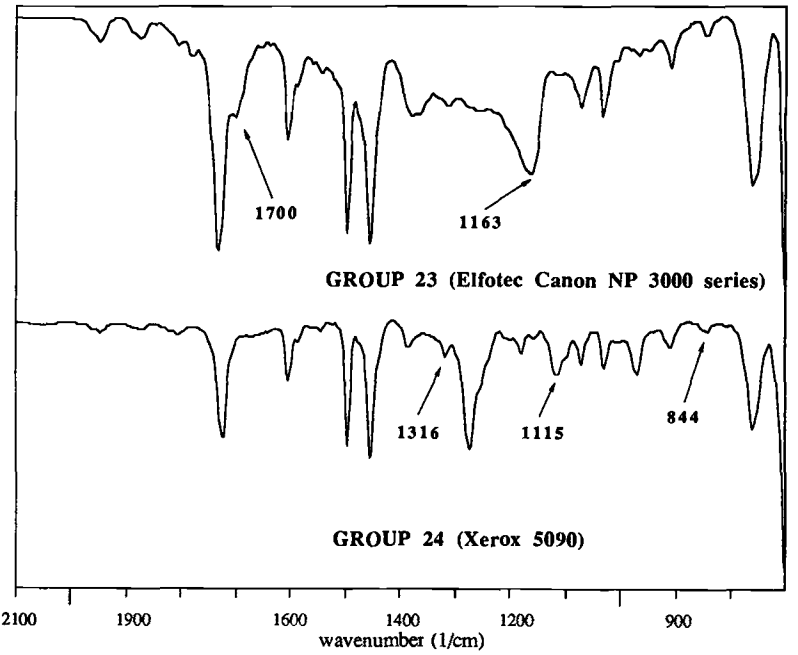

FIG. 4—*Examples of spectra from Group 23 (Elfotec Canon NP-3000) and Group 24 (Xerox 5090) showing characteristic absorption bands.*

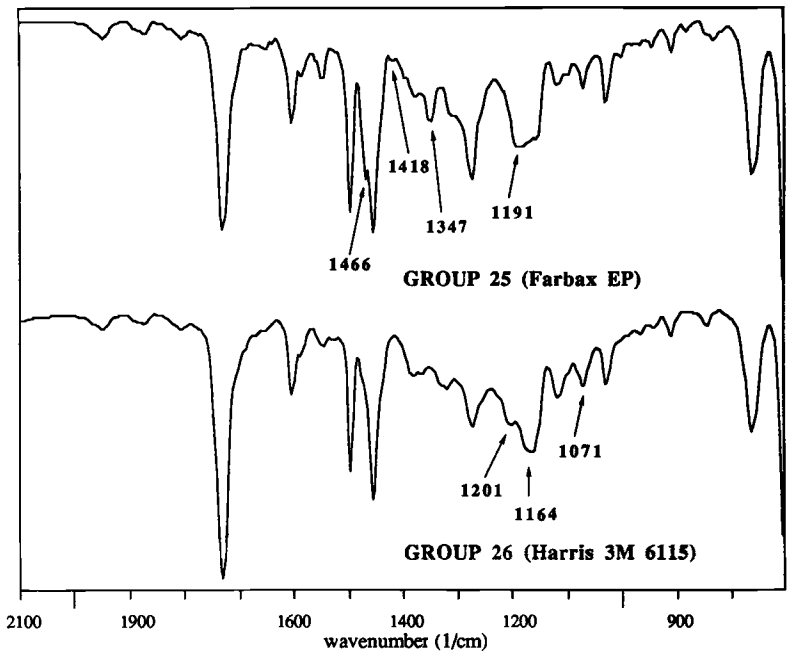

FIG. 5—*Examples of spectra from Group 25 (Farbax FP) and Group 26 (Harris 3M 6115) showing characteristic absorption bands.*

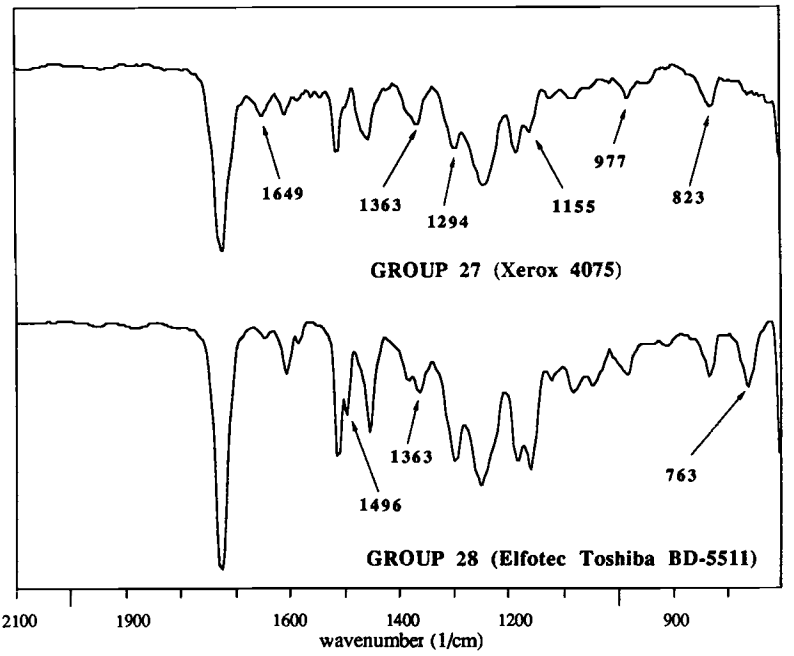

FIG. 6—*Examples of spectra from Group 27 (Xerox 4075) and Group 28 (Elfotec Toshiba BD-5511) showing characteristic absorption bands.*

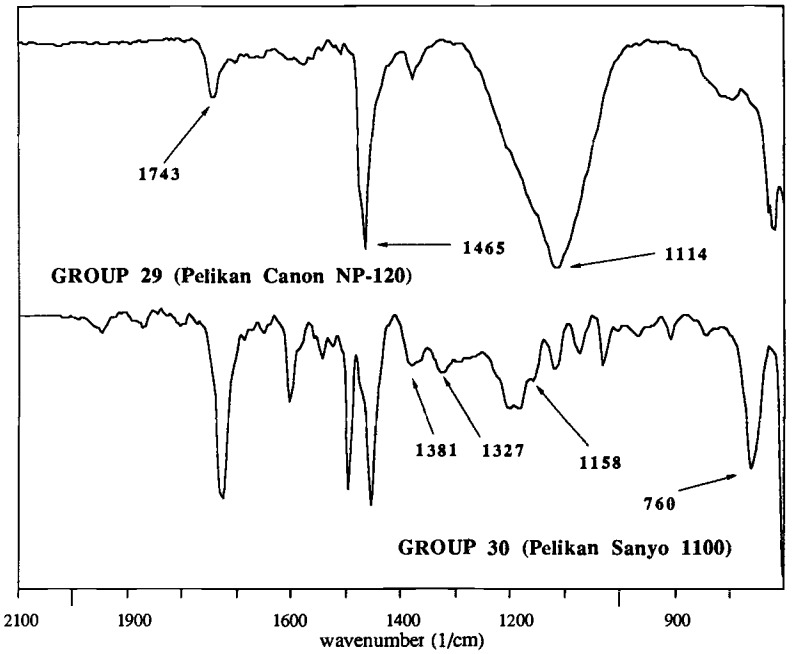

FIG. 7—*Examples of spectra from Group 29 (Pelikan Canon NP-120) and Group 30 (Pelikan Sanyo 1100) showing characteristic absorption bands.*

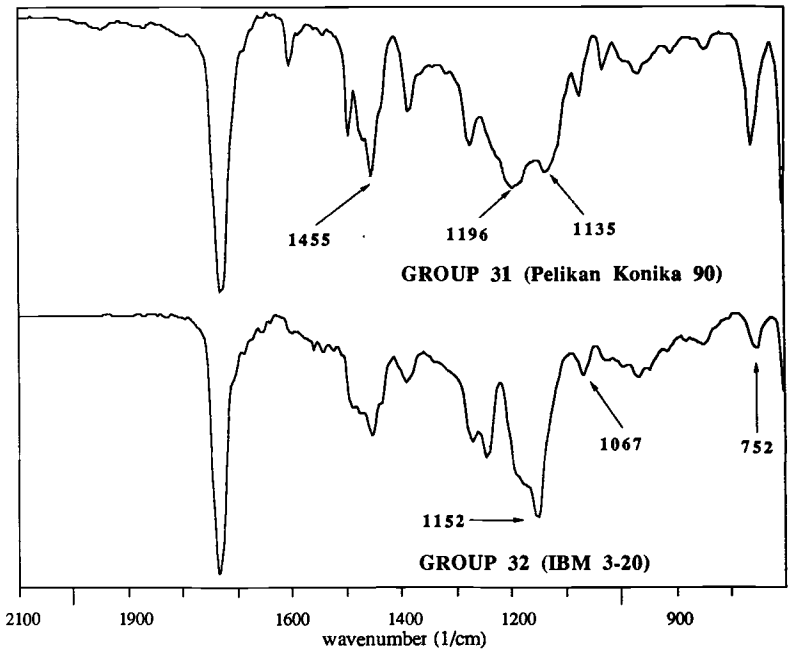

FIG. 8—*Examples of spectra from Group 31 (Pelikan Konika 90) and Group 32 (IBM 3-20) showing characteristic absorption bands.*

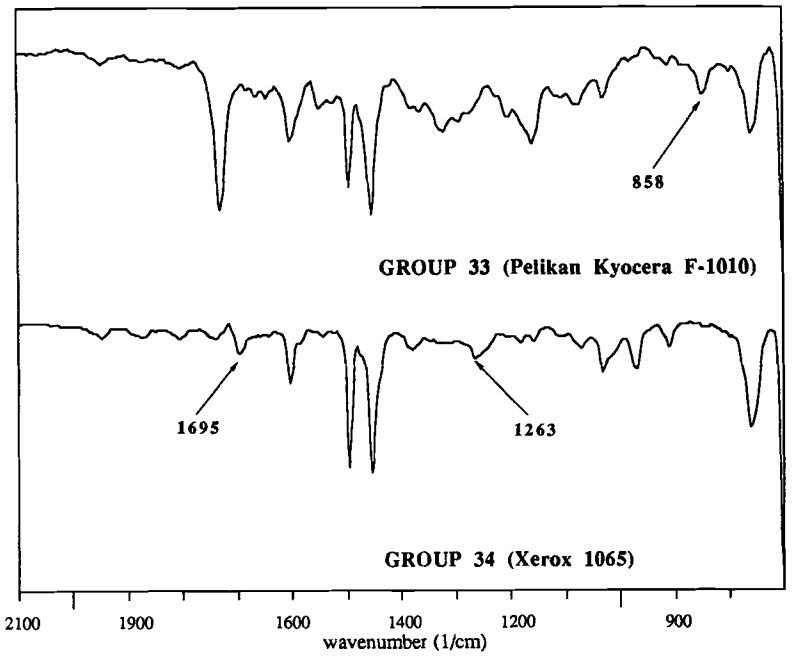

FIG. 9—*Examples of spectra from Group 33 (Pelikan Kyocera F-1010) and Group 34 (Xerox 1065) showing characteristic absorption bands.*

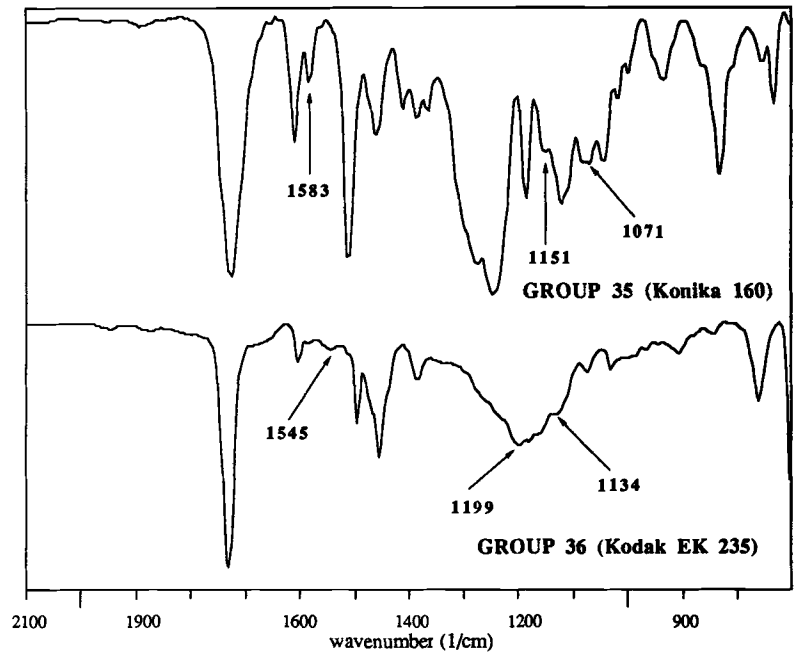

FIG. 10—*Examples of spectra from Group 35 (Konika 160) and Group 36 (Kodak EK-235) showing characteristic absorption bands.*

characteristic absorption bands are found.) Three of the 152 toners analyzed (Elfotec Canon NP-120, Elfotec Olivetti Copia 1000, and Pelikan Toner) were not classified in this scheme because of poor quality and irreproducible spectra.

The date of production of a photocopy on a particular machine does not appear to affect the results obtained by the DRIFTS analysis of the toner. Figure 11 shows an example where the infrared spectrum from a recent photocopy is compared with that from a photocopy produced on the same machine 12 months earlier and with the corresponding raw toner powder used in the machine. No significant difference can be observed between the three infrared spectra.

Photocopies produced on different machines of the same brand and model also gave equivalent toner spectra. For example, the toner on a photocopy produced on a machine located in the Swiss canton of Ticino gave the same infrared spectrum as the toner produced 12 months later on a machine of the same make and model but located in the canton of Vaud (Fig. 12). In addition, equivalent toner spectra are obtained for photocopies produced on different models of machine that use the same toner. This was illustrated in a proficiency test received from the Collaborative Testing Services, Inc.,

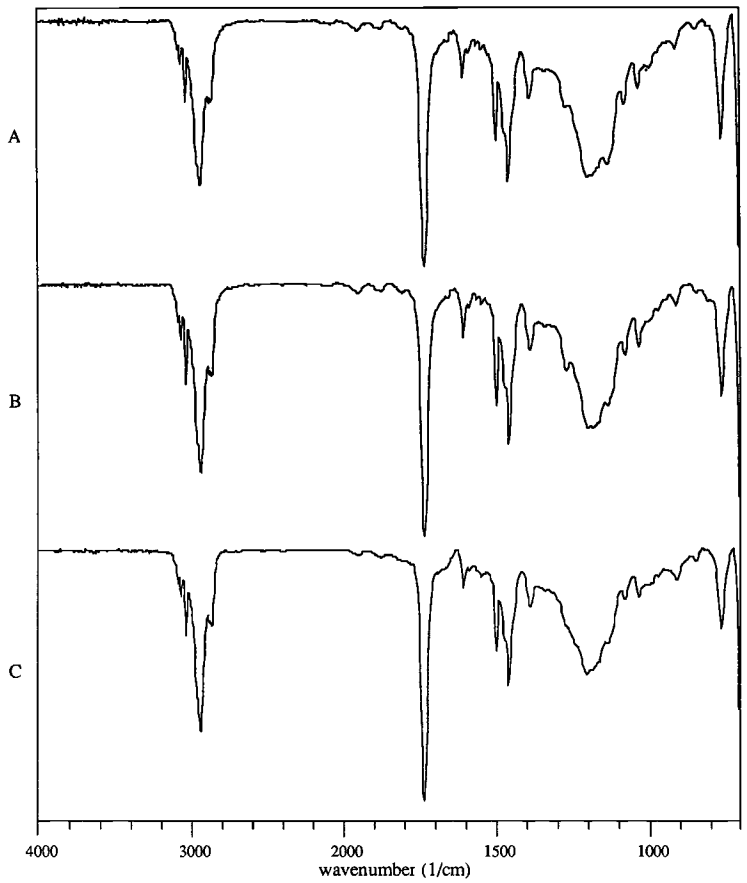

FIG. 11—*Comparison between the diffuse reflectance spectra of toner samples from a Kodak EK-200 photocopier:* (A) *the toner extracted from a copy produced in July 1989,* (B) *the toner extracted from a copy produced in July 1990 on the same machine, and* (C) *the raw toner powder Kodak EK-235 compatible with this machine.*

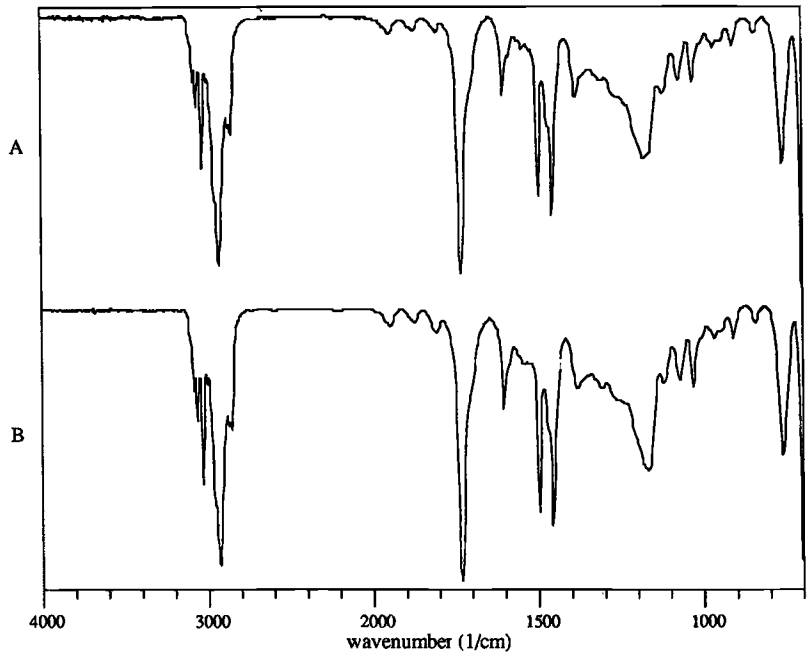

FIG. 12—*Comparison between the diffuse reflectance spectra of toner extracted from* (A) *a photocopy produced in the Swiss canton of Ticino on a Minolta EP-450Z and* (B) *a photocopy produced 12 months later in the canton of Vaud on a machine of the same make and model.*

Herndon, VA (Test No. 90-5, Questioned Documents), in which a photocopy, provided with the test and produced on a Canon PC-5 copier, gave the same toner spectrum as a comparison photocopy produced in Switzerland on a Canon PC-20 copier (Fig. 13). The results, therefore, do not appear to be affected by the particular machine in question but only by the brand and model of machine (which dictates the type of toner that is employed).

Analysis of toner samples on photocopies before and after treatment with fingerprint reagents did not indicate any significant influence from these reagents. For example, the infrared spectrum of the toner, obtained after treatment of a document with DFO, did not differ from that obtained before the application of the reactive agent (Fig. 14). Similar results were observed when ninhydrin was used as the fingerprint reagent both with and without secondary treatment with metal salts such as zinc nitrate or cadmium nitrate. The infrared toner analysis on documents treated with physical developer (Fig. 15) was equally unaffected by the fingerprint treatment. These results confirm that the research for latent fingerprints on questioned photocopies, using the techniques currently employed, can precede the infrared analysis of the photocopying toner without any adverse effect on the latter. This is an important consideration as the removal of toner samples before the fingerprint treatment may be undesirable in some cases.

Discussion and Conclusions

Our results confirm the suitability of diffuse reflectance infrared Fourier transform spectrometry (DRIFTS) for the analysis of raw toner powders and toners extracted from documents produced on photocopiers (black and white and color copiers) and on laser printers. Consideration of characteristic absorption bands in the infrared spectra produced

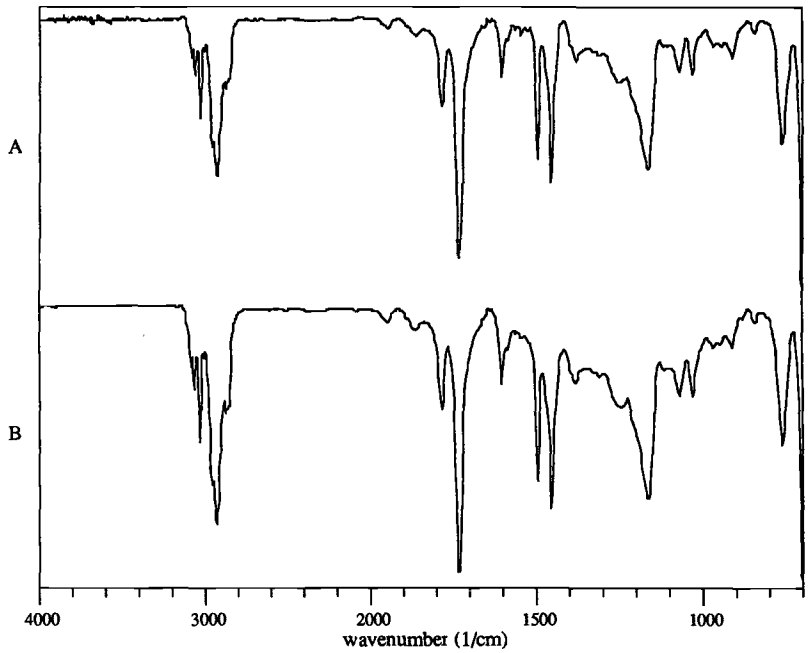

FIG. 13—*Comparison between the diffuse reflectance spectra of toner extracted from* (A) *a photocopy produced in the USA on a Canon PC-5 (Collaborative Testing Services, Inc.) and* (B) *a photocopy produced in Switzerland on a Canon PC-20. These two desk-top machines probably use the same toner.*

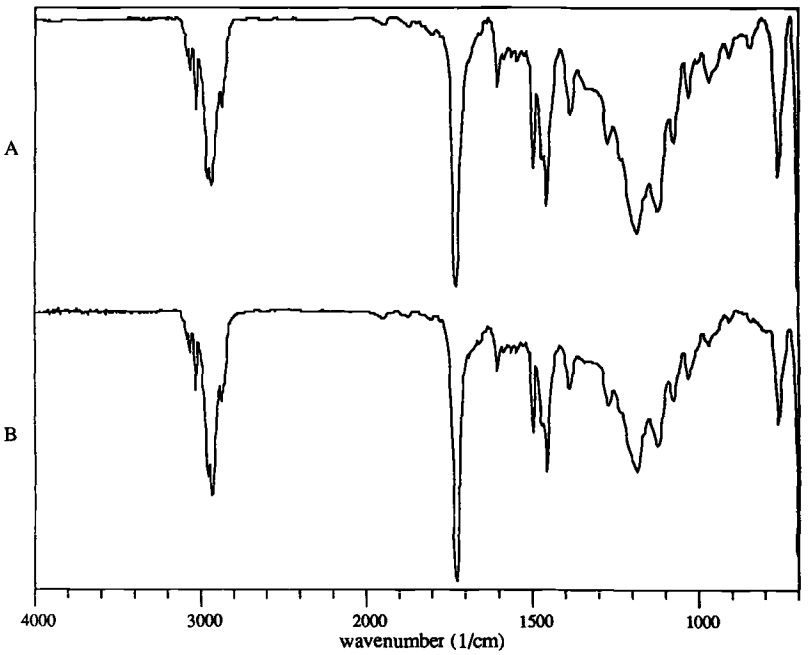

FIG. 14—*Diffuse reflectance spectra of toner samples extracted from a photocopy produced on a Xerox 5052:* (A) *before treatment and* (B) *after treatment with the fingerprint development reagent DFO.*

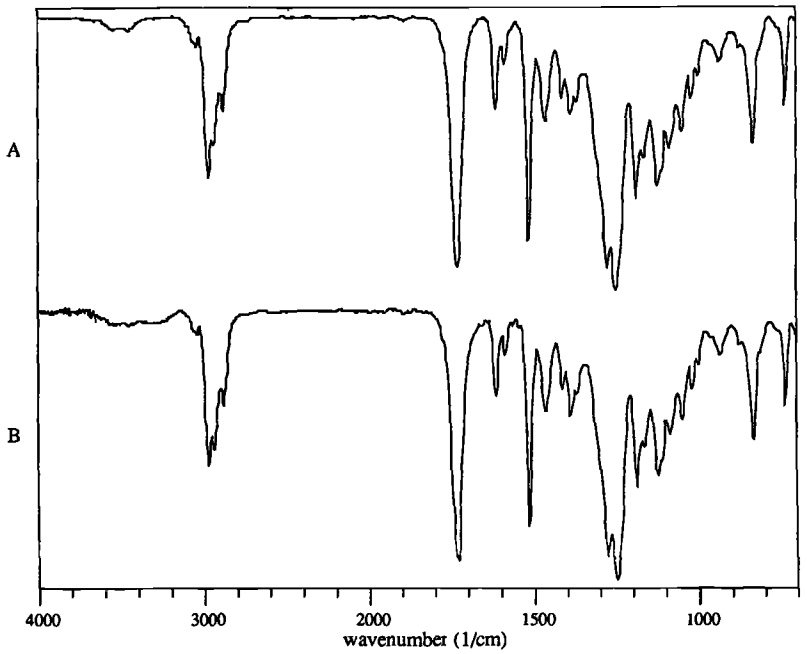

FIG. 15—*Diffuse reflectance spectra of toner samples extracted from a photocopy produced on a Canon NP-6550:* (A) *before treatment and* (B) *after treatment with physical developer.*

by this method has allowed the classification of 149 different toners into 36 distinct groups. This indicates a high discriminating power for the technique. It is possible, however, that the application of a complementary technique, such as pyrolysis gas chromatography, may further subdivide toners located within the same group [*6*]. The pyrolysis gas chromatography of a number of the toners analyzed in this present study has confirmed this possibility; however, a full evaluation has not yet been conducted.

In addition to the remarks contained in our previous article [*2*], we are able to confirm the following:

1. There does not appear to be any significant differences between batches of the same brand of photocopying toner that can be detected by the DRIFTS technique. This conclusion is justified in that no differences were detected between photocopies produced over an extended period of time on the same machine or between copies produced on different machines of the same brand and model or different machines which use the same toner (different batches of toner would have been involved in these cases). Of course, if the manufacturer introduces a significant variation in the composition of a particular toner between batches, this will be detected by infrared spectroscopy. No example of such a variation has yet been detected.

2. Toner samples from photocopies produced over an extended period of time on the same machine give identical infrared spectra. This is true, of course, only if the recommended toner is continually used in a particular machine. If the brand of toner is changed, differences may be expected in the corresponding infrared spectra. As stated above, a change in the batch of toner does not seem to have an effect.

3. The application of fingerprint development reagents to a photocopy does not significantly affect the infrared spectrum of the toner. It appears that the reagent residue that remains on the document is not in sufficient quantity to influence the infrared analysis of the toner.

It has been possible to show that toners used in laser printers (where the process is essentially the same as in a photocopier) can be analyzed in the same manner as conventional photocopying toners. This was also found to be the case for toners designed for use in color copiers. Indeed, the infrared spectrum of a color toner does not seem to depend on the actual color of the toner but on the organic resin base, which is usually the same for a particular application. [It is for this reason, for example, that the cyan and yellow Canon CLC-500 toners are classified together in the same group (Group 4) as a black laser printer toner (Pelikan Xerox 4045) and a number of black photocopying toners.] The analysis of color photocopies is of particular interest due to the increasing use of color copiers in the production of counterfeit bank notes [7].

The analysis of 152 different toners has allowed the construction of an infrared database representing the majority of photocopying toners available on the Swiss market. This collection of spectra, and a knowledge of the compatibility of each toner, has already proved useful in a number of questioned document cases treated in this laboratory.

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