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TECHNICAL NOTE

CRIMINALISTICS

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Visualizing Latent Fingerprints on Color-Printed Papers Using Ultraviolet Fluorescence

ABSTRACT: Laser detection of latent fingerprints on a white paper has been performed, previously. Ultraviolet fluorescence from various kinds of printer toner and ink used for home printers were measured to study fluorescence imaging of fingerprints on a color-printed white paper. The experimental system consisted of a nanosecond pulsed tunable laser and a cooled CCD camera. Excitation wavelengths are 230 and 280 nm. Fourteen printers consisting of three color laser printers, three color inkjet printers, five monochrome laser printers, two monochrome copy machines, and a color copy machine were tested. Toner and ink of most printers exhibited fluorescence in the region from 360 to 550 nm. In most cases, clear fluorescence images were obtained by time-resolved imaging with a band-pass filter and 280-nm excitation. However for toners from laser color printers that showed strong fluorescence, better results were obtained with 230-nm excitation. Latent fingerprints on a photograph page and a black-character page of a newspaper were also imaged.

KEYWORDS: forensic science, fingerprint, fluorescence, laser, ultraviolet, time-resolved spectroscopy, tunable laser, toner, ink

Visualizing of fingerprints using fluorescence with a laser was begun by Dalrymple et al (1). Many reports on laser detection of fingerprints have been published, however, most have focused on experiments using chemicals (2,3). In previous publications (4–6), we reported the ultraviolet (UV) fluorescence spectra of fingerprints and demonstrated that fluorescence images of latent fingerprints on high grade white paper can be obtained using a pulsed Nd-YAG laser and the appropriate band-pass filter. In these experiments, we imaged latent fingerprints on white paper. However in actual cases, fingerprints are often found on paper covered with printed text or images.

Latent fingerprints on paper are usually developed with ninhydrin. However, in some cases detecting with ninhydrin is not effective. For example, because fingerprints become purple after reacting with ninhydrin, detection of latent fingerprints on black toner or a surface carrying black-printed text is difficult if using the conventional ninhydrin method due to the similar color property. To solve this problem, Takatsu et al. (7) proposed using indium chloride ($InCl_3$) with blue-green laser excitation. They also reported that cooling using liquid nitrogen is effective for visualizing latent fingerprints on black surfaces. However, their method requires processing with chemicals before laser excitation.

In the current study, we apply our method to fingerprints on white paper with color printing and demonstrate that imaging fingerprints is possible using UV fluorescence. For this purpose, we study the fluorescence spectra of various kinds of printer toner or ink and then image latent fingerprints on paper carrying text printed with these toners or inks.

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Experiment

The experimental system consisted of a pulsed Nd-YAG laser to excite the fluorescence and a cooled CCD camera with an image intensifier (ICCD camera) to acquire the images. The details are described in a previous publication (5). Since the fluorescence intensity of fingerprints is maximum when excited at *c.* 280 and 230 nm (5,6), we selected these as the excitation wavelengths for the current experiment. The pulsed laser beam was expanded using a convex lens before irradiating the samples. With this system, time-resolved fluorescence spectra and images can be obtained using the fast gated image intensifier. The gating control that determines the exposure time of the ICCD camera and the observation delay time is done using a programmed timing generator and a computer.

Before pressing fingerprints onto a printed paper, the fingers were washed with soap and dried in air. A fingerprint was pressed after wiping the nose. The examination was done just after being pressed. The fluorescence was collected using a UV lens and detected using a cooled CCD camera with an image intensifier. The CCD camera has 1024×1024 pixels, and each pixel is $13 \times 13\ \mu m^2$, and the images obtained were digitized in 16 bit. To suppress noise, the CCD was cooled to −20°C. In addition, a background image was subtracted from each measurement.

High grade white papers with a weight of 64 g/m^2 were used, which means that lignin in the pulp is 100% removed from the paper. Hereinafter, we denote this paper as HG64. Fingerprints were pressed on this paper after printing on it using a printer or a photocopier. Fourteen printers including monochrome or color laser printers, inkjet printers, and photocopiers were used (details are given in Table 1), and the high quality printing mode was used instead of the high speed mode. When printing black with color printers, the printers were set to the monochrome mode.

The fluorescence spectra with a 10 nsec delay were measured so that the laser pulse did not appear in the spectral profile. The florescence wavelength range was from 300 to 550 nm. The fluorescence spectra of toner and ink for each printer or copy machine and the fluorescence spectrum of HG64 are shown in the figures. In case of the examination of fingerprint images, fluorescence images were filtered through a 255- to 425-nm band-pass filter. The CCD gate width was set to 10 μsec and 1000 measurements were accumulated.

Results and Discussions

In Fig. 1, the fluorescence spectra of black-printed HG64 for all printers are shown along with that of nonprinted HG64 for 230-nm excitation. The peak at 460 nm is the second harmonic of 230 nm examination. Among the 14 black-printed papers, four samples show strong fluorescence. These four samples are printed with three color laser printers and one inkjet printer. Among these four printers, B-ColorLaser3 emits the strongest fluorescence, even stronger than that of HG64. Although the peak position is located at *c.* 440 nm and the spectrum appears to be almost a scaled version of the HG64 spectrum, B-ColorLaser3 spectrum is not just the fluorescence from HG64 white paper because the spectral profiles are in fact different from each other. For the other two color laser printers, their fluorescence spectra are less intense than that of the B-ColorLaser3, but have almost the same spectral profile. In the case of A-Inkjet1, the spectral profile and its peak position are different from those of HG64. Since laser toner and ink absorb UV light, we consider that the laser toner or ink of these printers emit their inherent fluorescence.

TABLE 1—*Fourteen printers tested in this study.*

Type	Manufacturer	Notation
Color laser printer	A	ColorLaser1
		ColorLaser2
	B	ColorLaser3
Color inkjet or bubblejet printer	A	Inkjet1
	C	Inkjet2
	B	Inkjet3
Monochrome laser printer	A	MonoLaser1
		MonoLaser2
		MonoLaser3
		MonoLaser4
		MonoLaser5
Color photocopy machine	D	ColorCopy
Monochrome photocopy machine	D	MonoCopy1
		MonoCopy2

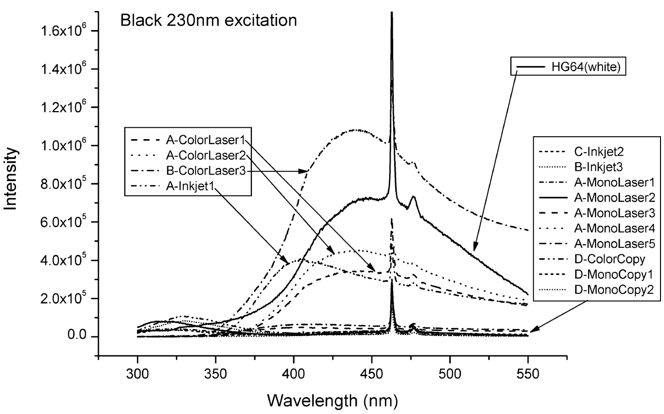

FIG. 1—*Fluorescence spectra of black-printed HG64 excited with 230-nm laser light.*

Figure 2 shows separate plots of the fluorescence spectra of inkjet printers, monochrome laser printers, and photocopiers. In the case of inkjet printers, only A-Inkjet1 shows strong fluorescence; the other two show weak fluorescence (Fig. 2*a*). For the five monochrome laser printers, three exhibit a peak at *c.* 320 nm, but the remaining two exhibit a broad peak at *c.* 400 nm and no features below 350 nm (Fig. 2*b*). For the photocopiers (Fig. 2*c*), all spectra exhibit a peak at *c.* 320 nm, which is similar to that observed in Fig. 2*b* for the monochrome laser printers. Since this

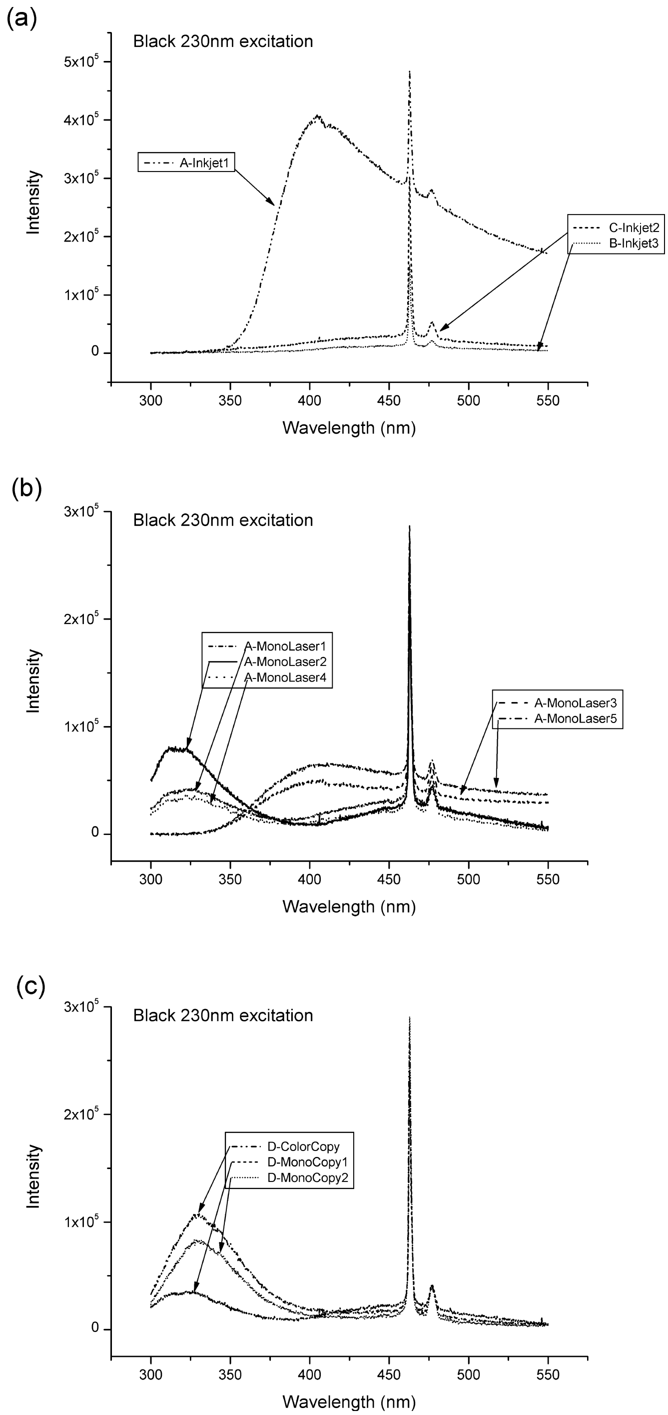

FIG. 2—*Fluorescence spectra of black-printed HG64 (230-nm excitation): (a) for all three inkjet printers; (b) for all five monochrome laser printers; and (c) for all three copy machines.*

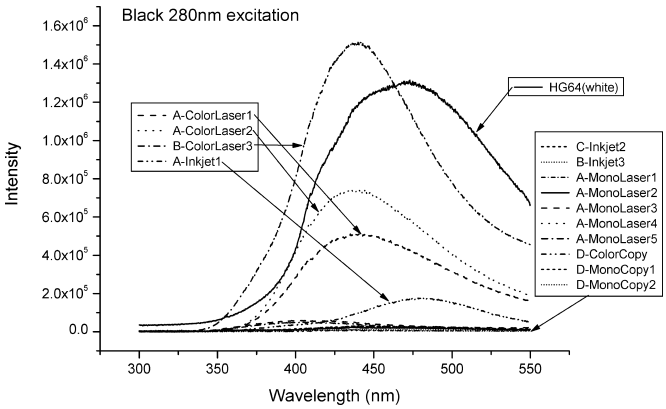

FIG. 3—*Fluorescence spectra of black-printed HG64 excited with 280-nm laser light.*

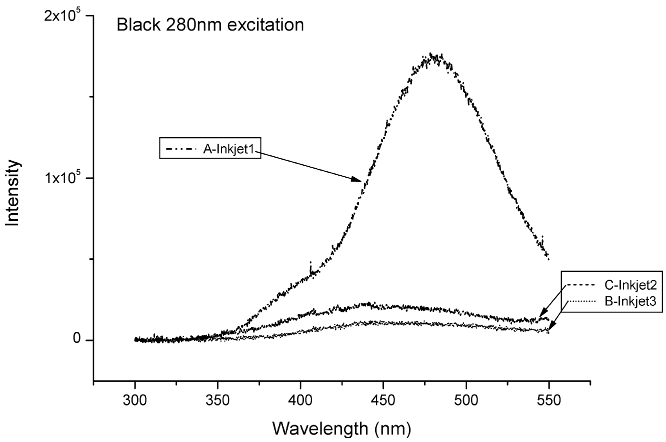

FIG. 4—*Fluorescence spectra of black-printed HG64 for inkjet printers (280-nm excitation).*

lower peak overlaps with peak A of the fingerprint fluorescence of Saitoh and Akiba (4), it complicates the visualizing of latent fingerprints with 230-nm excitation.

Figure 3 shows the results for 280-nm excitation. The same four samples as for the case of 230-nm excitation show strong fluorescence, but the fluorescence intensity for the other 10 samples is very weak and no peak is evident near 320 nm for any laser printer or photocopier. Except for A-Inkjet1, no clear difference is apparent between the fluorescence spectra excited at 230 and 280 nm. A-Inkjet1 shows clear fluorescence for both 230-nm and 280-nm excitation, but the peak position moves from 400 (230-nm excitation) to 480 nm (280-nm excitation). Two other inkjet printers show weak fluorescence (see Fig. 4). For monochrome laser printers and photocopiers, the spectra are too weak to be shown. From these results, we conclude that, in general, 280-nm excitation is better for fingerprint imaging than 230-nm excitation because there is no fluorescence of toner or ink below 350 nm.

From the measured fluorescence spectra, we see that the HG64 fluorescence is reduced due to absorption of the incident laser light by the toner or ink. Therefore, in many cases the fluorescence of black-printed HG64 is very weak. However, for the three color laser printers and the A-Inkjet1 printer, toner or ink emits strong inherent fluorescence with both 230- and 280-nm excitation and their spectra range from *c.* 350 to over 550 nm.

In a previous work (4,5), we showed that two broad peaks exist around 330 and 440 nm (peaks A and B, respectively, in Ref. [4]) in the fluorescence spectra of fingerprints and it is appropriate to visualize fluorescence using peak A. Therefore, fluorescence of fingerprints can be visualized with both 230- and 280-nm excitation when no fluorescence exists around 330 nm. However, most laser toners emit fluorescence near 330 nm when excited at 230 nm, but not when excited at 280 nm. Therefore, it is appropriate in general to excite at 280 nm.

Fluorescence images of all samples are shown in Fig. 5. We recognize that latent fingerprints on black surfaces (toner or ink) can be visualized clearly with our imaging system. It is possible to

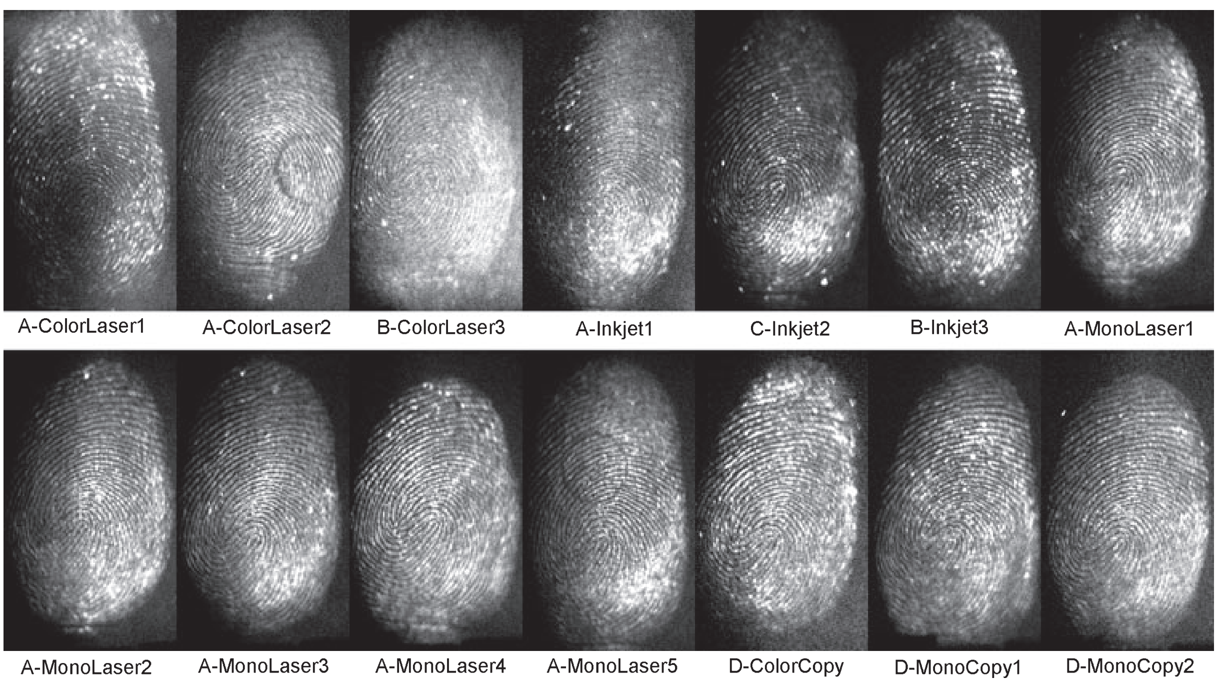

FIG. 5—*Fluorescence images of fingerprints on black-printed HG64 (280-nm excitation).*

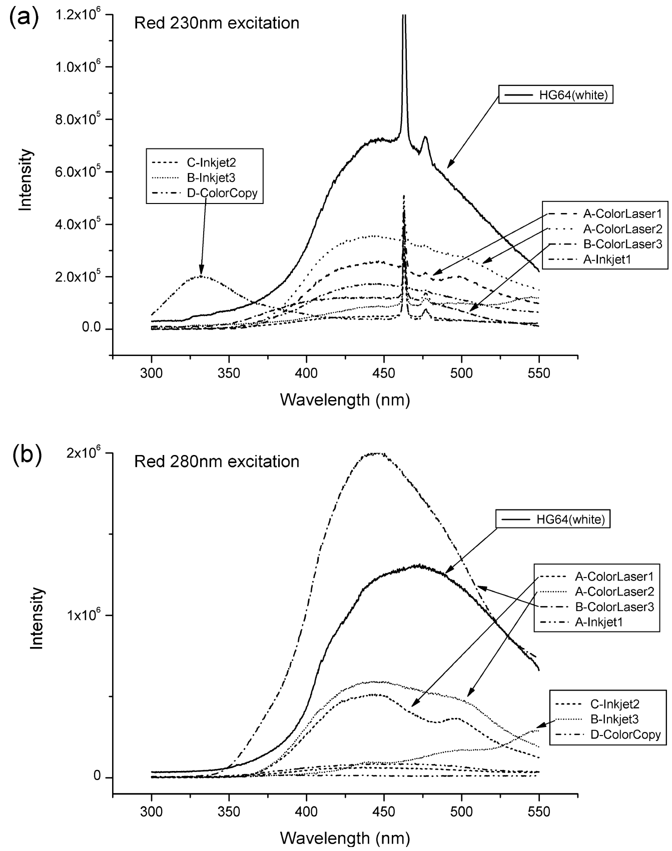

FIG. 6—*Fluorescence spectra of red-printed HG64 for all seven color machines: (a) 230-nm excitation; and (b) 280-nm excitation.*

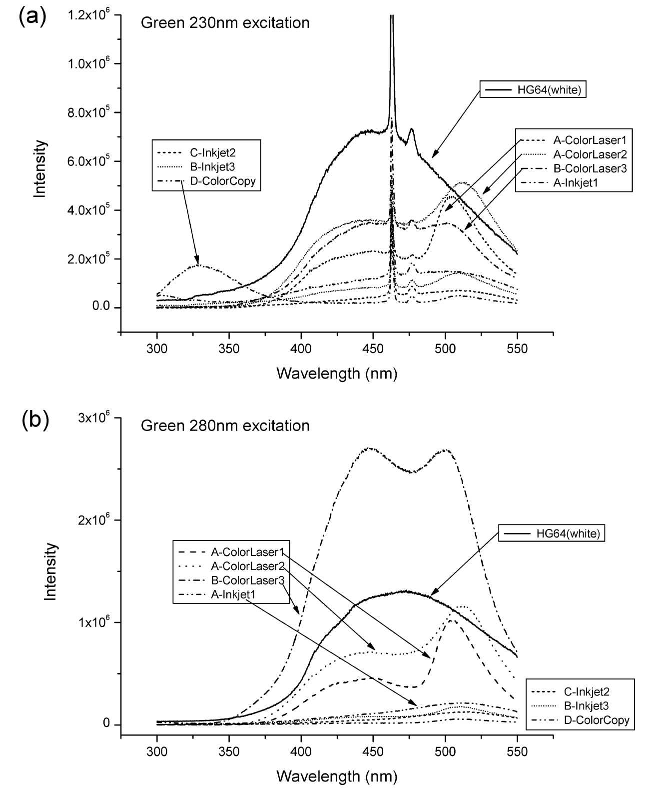

FIG. 7—*Fluorescence spectra of green-printed HG64 for all seven color machines: (a) 230-nm excitation; and (b) 280-nm excitation.*

visualize fluorescence without a band-pass filter when background fluorescence is weak; consider, for example, the situation for monochrome laser printers and photocopiers. However, since the fluorescence is relatively weak, the spectra need to be integrated for longer periods to obtain fingerprint fluorescence images, so that the intensity of the background fluorescence becomes significant. Better results with a high signal to noise ratio can be obtained with a band-pass filter.

In Figs 6–8, fluorescence spectra of color (RGB)-printed HG64 for all color printers are shown along with those of nonprinted HG64. For printing color on HG64, we used MS-Word or Photoshop with the color set in the RGB color space as follows: red as (R = 255, G = 0, B = 0), green as (R = 0, G = 255, B = 0), and blue as (R = 0, G = 0, B = 255). For 280-nm excitation, three color laser printers show strong fluorescence (see Fig. 6*b*). The fluorescence intensity for B-ColorLaser3 exceeds that of HG64. The intensity of the other two laser color printers is roughly comparable to that of HG64, and their spectra range from 350 to over 550 nm. The profile and the peak position are different depending on the ink color. For inkjet printers, fluorescence is weak except for the case of red of B-Inkjet3 printer that exhibits fluorescence above 450 nm (Fig. 6*b*). For 230-nm excitation, the fluorescence intensity of three color laser printers is comparable to that of HG64 in the blue, but elsewhere it is weaker than that of HG64. In this case, the difference in fluorescence intensity between laser printers and inkjet printers is small. For color photocopiers, D-ColorCopy exhibits its fluorescence around 325 nm, similar to what is observed for the black case. This means that 230-nm excitation is not appropriate for D-ColorCopy.

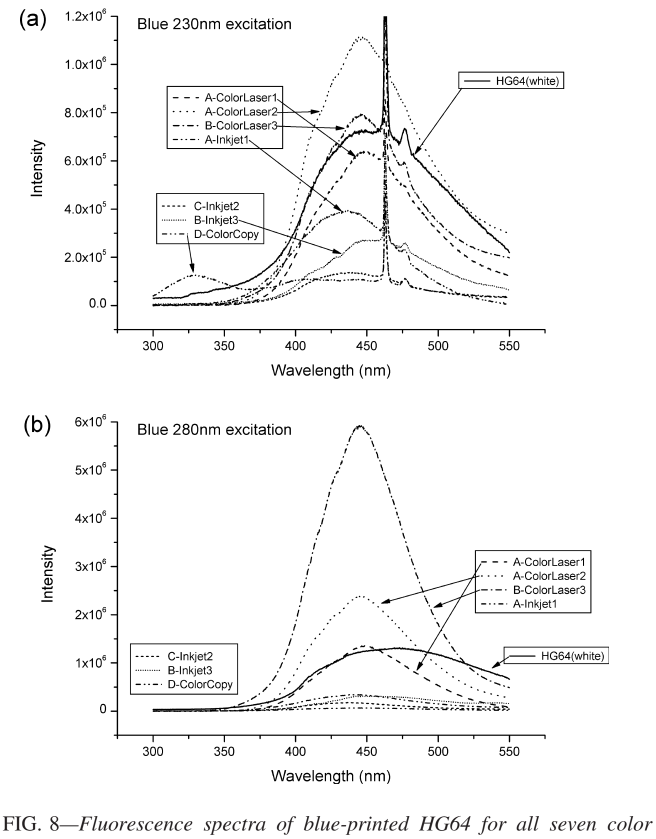

FIG. 8—*Fluorescence spectra of blue-printed HG64 for all seven color machines: and (a) 230-nm excitation; (b) 280-nm excitation.*

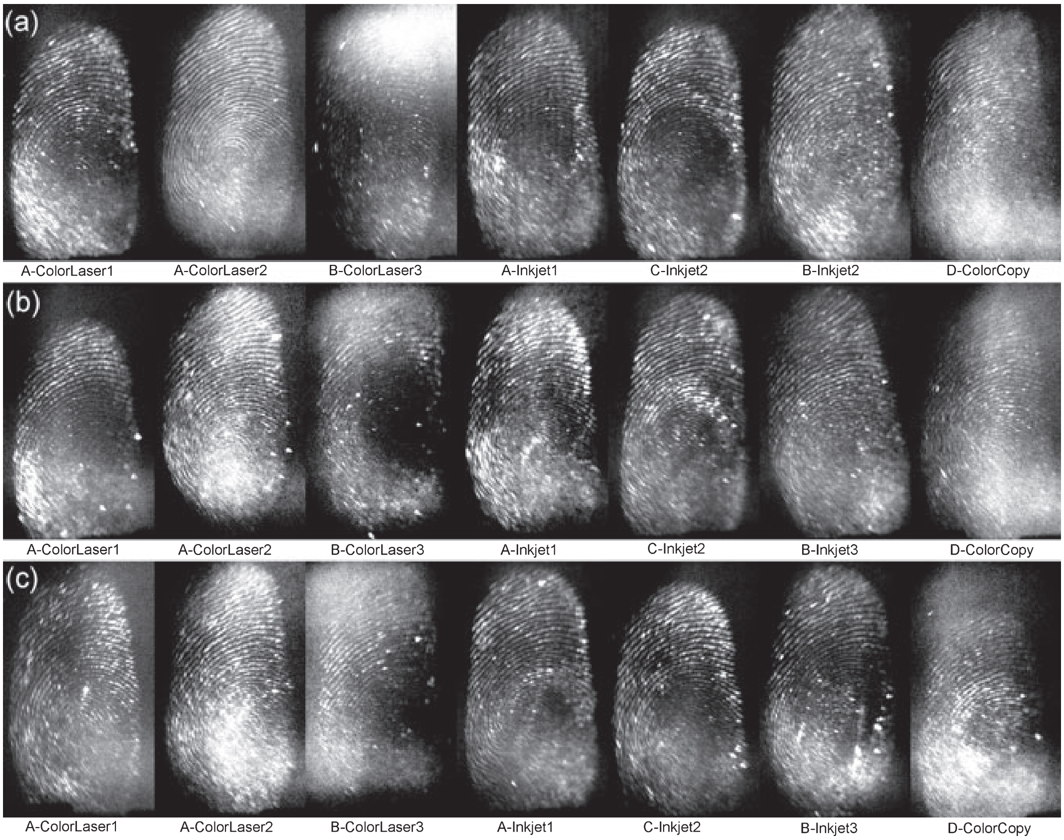

FIG. 9—*Fluorescence images of fingerprints for all six color machines (280-nm excitation): (a) on red-printed HG64; (b) on green-printed HG64; and (c) on blue-printed HG64.*

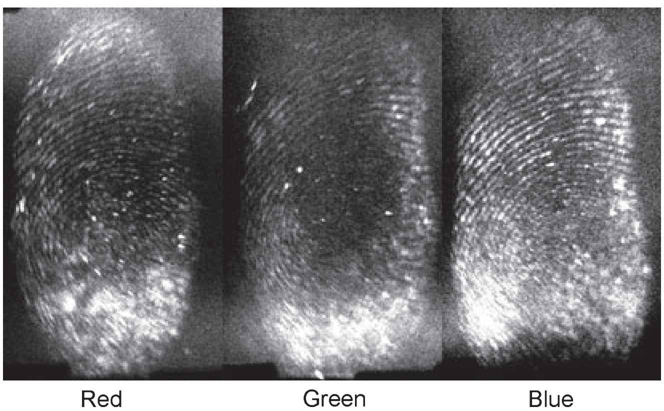

FIG. 10—*Fluorescence images of fingerprints on color (RGB)-printed HG64 for B-ColorLaser3 (230-nm excitation).*

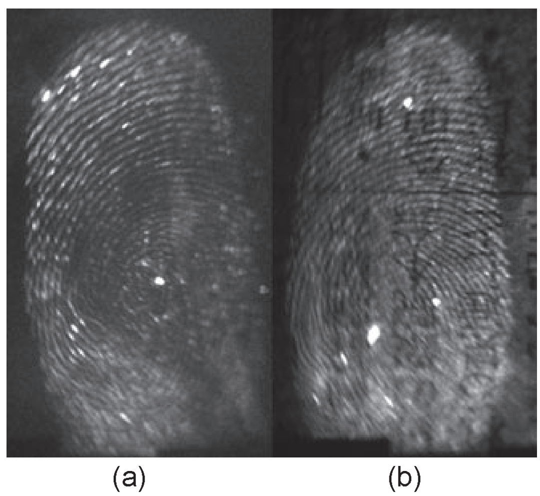

FIG. 11—*Fluorescence images of fingerprints on a newspaper. (a) For color photograph page (280-nm excitation). (b) For black character page (230-nm excitation).*

Fluorescence images of latent fingerprints on color (RGB)-printed HG64 are shown in Fig. 9. These images were obtained with 10-nsec delay and 280-nm excitation. Except for B-ColorLaser3, the images are of good quality so that the ridge structures are clearly recognized. Since the fluorescence spectrum of B-ColorLaser3 extends to around 350 nm, clear images were not obtained. In this case, better results were obtained with 230-nm excitation (see Fig. 10). For B-ColorLaser3, however, the fluorescence image is not very clear because its fluorescence intensity is quite strong.

We measured the UV fluorescence spectra of various kinds of ink and toner for home printers and photocopiers, and imaged latent fingerprints on color-printed papers with 280-nm excitation using the time-resolved imaging method. Since printer toner and ink absorbs UV light, the paper fluorescence is reduced to a low intensity. However, some types of ink or toner emit UV fluorescence; especially color laser toner, which emits strong fluorescence. Since the spectral range of most inks or toners ranges from *c.* 400 to above 500 nm, latent fingerprints were visualized like fingerprints on white paper. When the fluorescence spectra of ink or toner overlap in part with those of fingerprints, as happens, for example, with B-ColorLaser3, it is better to give excitation at 230 nm.

The fingerprints in Figs 5, 9, and 10 were pressed on single-color printed HG64. In actual cases, however, fingerprints are pressed on various print surfaces; that is, many colors are used to print the characters or images. Figure 11 shows images of latent fingerprints on newspapers. Figure 11*a* is an image of a fingerprint on a color photograph page and Fig. 11*b* is an image of a fingerprint on a page with printed text. In both cases, fingerprints were imaged clearly. For these examples, we used 280-nm excitation for the fingerprint on the color photograph page and 230 nm for the fingerprint on the text page. This choice of excitation wavelength is not important because both wavelengths are effective for these cases.

Fingerprints include many chemical components such as various amino acids and fatty acids, and it is not clear which component(s) contribute to the UV fluorescence. We are now investigating the origin of the fluorescence of fingerprints.

Summary

We have measured the UV fluorescence of various kinds of printer-toner and printer-ink printed on high grade white paper. The fluorescence intensity of most printed paper is weak, because ink or toner absorbs the fluorescence of the paper. Latent fingerprints on paper have been visualized using the inherent fluorescence of fingerprints in the deep UV region using a time-resolved method and optical filters. In most cases, clear fluorescence images are obtained with 280-nm excitation. Latent fingerprints on a newspaper were also imaged using this method.

References

1. Dalrymple BE, Duff JM, Menzel ER. Inherent fingerprint luminescence detection by laser. J Forensic Sci 1977;22:106–15.
2. Menzel ER. Fingerprint detection with lasers, 2nd edn. New York, NY: Marcel Dekker, 1999.
3. Lee HC, Gaensslen RE. Advances in fingerprint technology, 2nd edn. Boca Raton, FL: CRC Press, 2001.
4. Saitoh N, Akiba N. Ultraviolet fluorescence spectra of fingerprint. Sci World J 2005;5:355–66.
5. Saitoh N, Akiba N. Ultraviolet fluorescence spectra of fingerprint. Sci World J 2006;6:691–9.
6. Akiba N, Saitoh N, Kuroki K. Fluorescence spectra and images of latent fingerprints excited with a tunable laser in the ultraviolet region. J Forensic Sci 2007;52:1103–6.
7. Takatsu M, Sumida N, Shimoda O, Tateishi Y, Nakada Y, Hirayanagi S, et al. Detection of latent fingerprints on colored papers by fluorescence using Ninhydrin/InCl3 treatment followed by pulsed green laser excitation. Jpn J Sci Tech Iden 2002;7:45–52. [in Japanese].

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