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Detection of Pretreated Fingerprint Fluorescence Using an LED-based Excitation System

ABSTRACT: Optimization of a light emitting diode (LED)-based excitation system for the detection of pretreated fingerprint fluorescence is described. Fluorescent ridges can usually be excited by irradiation with forensic light sources such as xenon arc lamps or quartz-halogen lamps with high-power output and suitable filters. However, they are too expensive for many crime laboratories in smaller organizations. We concentrated on LEDs which have advantages over conventional light sources in that they are simpler and of lower cost, but the power output and quality of each individual LED unit is not sufficient for the detection of weak fluorescent ridges. To resolve this subject, blue and green LED arrays composed of ninety LED units were adopted and suitable low pass filters for them were designed. An experimental system, consisting of blue and green LED arrays with the suitable low pass filters for illumination, high pass filters for viewing, a digital camera and a computer, was tested. The fluorescent images of cyanoacrylate ester fumed/rhodamine 6G stained fingerprint on white polyethylene sheet and weak fluorescent ridges of ninhydrin/indium chloride treated fingerprint on white paper were successfully detected and photographed. It was shown that the improvement of LED beam in intensity and quality can compensate the disadvantages, resulting in well-contrasted images.

KEYWORDS: forensic science, fingerprint fluorescence, LEDs array excitation, low pass filter, cyanoacrylate ester/rhodamine 6G, ninhydrin/indium chloride

Fingerprint detection still holds the most important place in crime investigation and attempts to develop new methods for visualization of latent fingerprints have been continued throughout the world.

In daily fingerprint work, weak fingerprints have often been resolved by utilizing fluorescent enhancement methods (1) such as fluorescent compound dusting, fluorescent dye staining employed together with cyanoacrylate ester fuming, and zinc chloride ($ZnC1_2$) treatment of Ruhemann's Purple (RP) fingerprints developed with ninhydrin. The other reagents such as o-phthalaldehyde (2,3), 7-benzylamino-4-nitrobenz-2-oxa-1,3-diazole (BBD) (4), 1,8-diaza-9-fluorenone (DFO) (5) were also reported to be applied to untreated latent fingerprints mainly on porous substrates resulting in fluorescent compounds on the fingerprint ridge.

These fluorescent dyes and fluorescent compounds on the fingerprint ridge can be excited by irradiation with forensic light sources. In many cases, a xenon arc lamp or a quartz-halogen lamp with high-power output and suitable filters, and sometimes an appropriate laser, are used as the light source. These light systems do work quite well but are expensive for many crime laboratories in smaller organizations, especially for many identification sections in police departments. In addition to this, photographing of weak fluorescence has been rather avoided in Japan owing to its complicated operation. So an inexpensive, simplified, and reasonably efficient light system has been in great demand.

For the development of a simplified system for exciting and photographing the fingerprint fluorescence, we focused on light emitting diodes (LEDs) which have recently made a marked advance. In fluorescence analysis, LEDs have been used mainly for portable instrument use (6). To construct a compact device, the LED should be the most suitable light source as far as size and cost. Moreover, blue and green LEDs have suitable emission bands to excite the fluorescent dyes or the fluorescent compounds on the treated fingerprint ridge. We made a new compact system utilizing blue and green LEDs experimentally and tested it.

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Materials and Methods

Optical Design

Blue and green LEDs should have suitable emission bands for excitation of some fluorescent dyes such as well-known rhodamine 6G. Figure 1 shows the LED emission spectra overlapping with the absorption spectra of two kinds of treated fingerprint ridge, ethyl cyanoacrylate fumed/rhodamine 6G stained fingerprint ridge and ninhydrin/indium chloride ($InCl_3 \cdot 4H_2O$) treated fingerprint ridge. The measurement was achieved using LEICA MPV SP microscope photometer. By the way, both fingerprint ridges can be excited by use of blue or green LED to a greater or less extent because their absorption spectra are broad. The enhancement effect of indium chloride to ninhydrin developed RP fingerprint was found to be over twice larger than that of zinc chloride, as reported in previous papers (7,8). Absorption maximum of ninhydrin RP/indium chloride complex is 510 nm shifting from 496 nm of ninhydrin RP/zinc chloride complex, so green LED should be preferable for the RP/indium chloride complex excitation rather than blue LED from a point of view of absorption efficiency. So we used green LED for indium chloride treated fingerprint in this paper.

The output power of a individual LED unit is not strong enough to excite fingerprint fluorescence still now. So we adopted an array of LEDs (50 mm × 60 mm) available commercially from IMAC

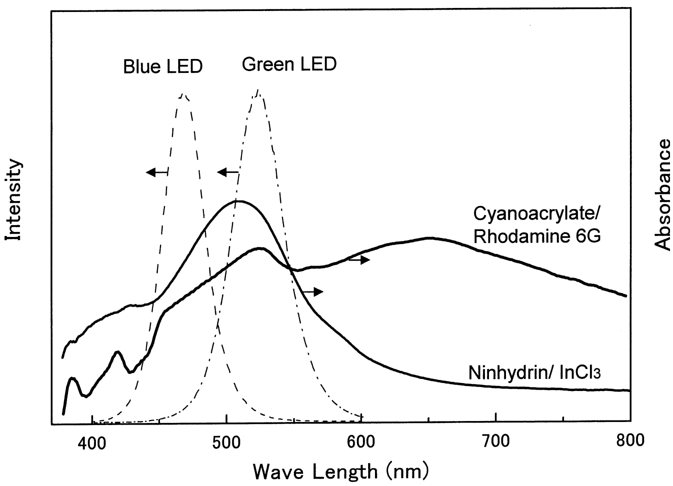

FIG. 1—*Emission spectra of blue and green LED and absorption spectra of fingerprint ridges after pretreating by two methods: (a) ethyl cyanoacrylate fuming/rhodamine 6G staining on white polyethylene sheet; (b) ninhydrin/indium chloride treatment on paper.*

Co., Ltd. (Japan). It is composed with 90 LED units (9×10 units) made by Nichia Corporation. Nakamura et al. (9) of which a research worker has developed a practical blue LED for the first time in the world. By using aggregation of 90 LEDs, electric power consumption of the LEDs attainable for excitation was increased to 7.2 W. Simultaneously the LEDs array gave a wide and uniform lighting area where even a large palm print could be exposed.

A high pass filter has to be inserted between a substrate and a camera because the emission of LED reflects on the surface of substrates and interferes with the observation of weak fingerprint fluorescence. A filter changer mounting several high pass filters was made and used for quick choice of the most suitable filter by a trial and error method while considering fluorescent specificity of the substrates. By the way, emission wavelength ranges of LEDs are too wide to give well-contrasted fingerprints. Especially, as shown in Fig. 2, a small part (a) of the emission overlaps with the fluorescence observation region and interferes with the observation, as reported in tissue fluorescence analysis (10). It is not sensible to eliminate the interference emission part by a selection of high pass

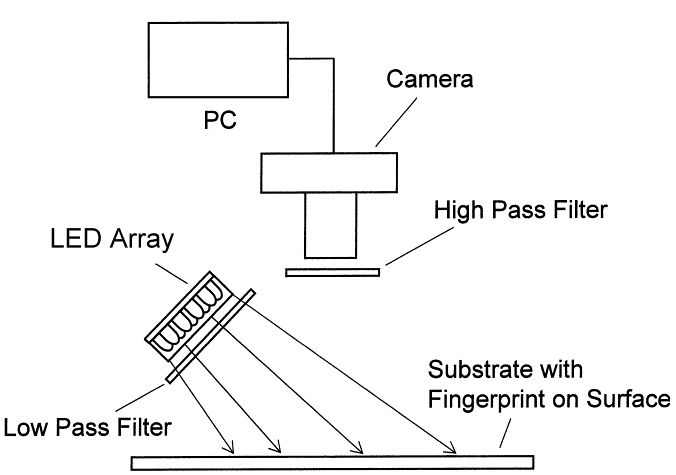

FIG. 2—*Diagram of LED-based excitation system.*

filter 2, since the large part of fluorescence (b) should be lost and consequently only a small part (c) is observed. The other choice is a selection of high pass filter 1. In this choice, the small part (a) of the emission leaks into a camera and interferes with the observation of fingerprint fluorescence. The most sensible way to solve this problem must be use of a low pass filter. The low pass filter set in the LED emission cuts off the part (a), resulting in high quality light suitable for the high contrasted fluorescence observation even using high pass filter 1. In weak fingerprint detections, the choice of filter 1 accompanied by a suitable low pass filter should give better contrast than the choice of filter 1 or filter 2 alone. On the basis of this view, two types of interference film low pass filter, 490 nm type for the blue LED and 540 nm type for the green LED, were designed.

Illumination intensities of emission beams from the blue LEDs array (7.5 W) and the green LEDs array (7.5 W) were compared with those of blue and green beam from POLILIGHT® (Rofin, Australia; a versatile light source used in forensic science, 300 W), composing a xenon arc lamp and a collection of band pass filters. TOPCON IM-5 illumination meter was used for the measurement. The illumination intensities at 5 cm away from the LEDs arrays, with attachment of the low pass filter, were 6150 luxes (blue LEDs array) and 12,700 luxes (green LEDs array). Otherwise illumination intensities at 5 cm away from the tip of POLILIGHT® cable without an attaching output lens were 54,800 luxes (450 nm mode) and 83,300 luxes (530 nm mode). Thus the illumination intensities of LEDs arrays were improved but still weaker by one-seventh (green) to one-ninth (blue) compared to those of POLILIGHT®.

On the basis of these points mentioned above, the prototype LED-based excitation system, illustrated in Fig. 3, for the detection of treated fingerprint fluorescence was assembled with blue and green LEDs arrays, several high pass filters installed in a changer, low pass filters, a digital camera, and a notebook-type personal computer.

Signal Processing

Fluorescent fingerprint pictures taken by the digital camera can be directly sent to the personal computer. As known, a digital RGB picture consists of three color components, blue, green, and red. Image processings, including extraction of color components and white/black conversion, can be done to get more contrasted fingerprint fluorescence images by use of digital image editing software such as Adobe Photoshop®. Like this, more high-contrast images can be acquired by the digital processings from the original fluorescence pictures.

Specimen Preparation

Two types of fluorescent fingerprints were made for the performance tests of the developed system. First, a latent fingerprint deposited normally on a white polyethylene sheet was fixed by ethyl cyanoacrylate fuming and subsequently stained by dipping it into dilute methanol solution of rhodamine 6G. The fluorescent image obtained had medium intensity. Second, a latent fingerprint deposited weakly on a white paper was dipped into 0.5% acetone/ligroin (2/5) solution of ninhydrin and was heated at 70°C for 5 h in an incubator. The visualized RP fingerprint was so weak that it was unrecognizable. The RP fingerprint was subsequently sprayed finely with 2% methanol solution of indium chloride ($InCl_3 \cdot 4H_2O$). Orange fluorescent complex was formed immediately. By the way, one must note the fact that indium chloride is not stable even in a solid state. In most of our experiments, fresh

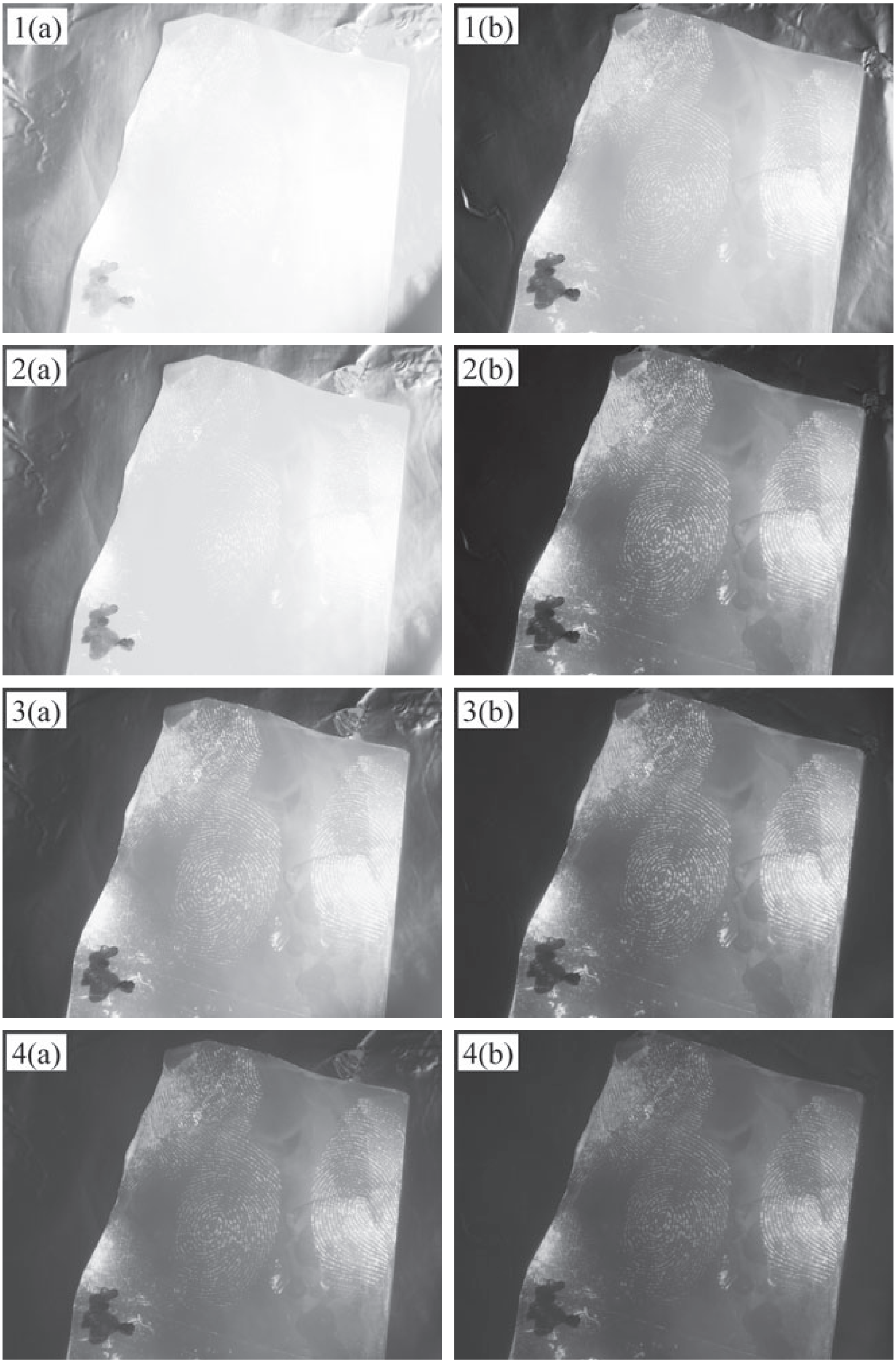

FIG. 3—*Changes of fluorescence contrast between fingerprint ridge and background by changing low pass filter and high pass filter: the fingerprint was deposited on white polyethylene sheet and treated with cyanoacrylate ester/rhodamine 6G and excited by blue LEDs array with attaching 490 nm low pass filter (1b–4b) and without attaching low pass filter (1a–4a); four kinds of high pass filter (1a,1b: 500 nm, 2a,2b: 520 nm, 3a,3b: 540 nm, 4a,4b: 560 nm) were used.*

products direct from the maker (Shinko Chemical Co., Ltd., Japan) were used. Indium chloride older than about 6 months in a sealed bottle changed purple RP-print color to orange but did not give fluorescence. Unfortunately its appearance after the deterioration is unchanged. So one should use a fresh indium chloride product for preparing the spraying solution.

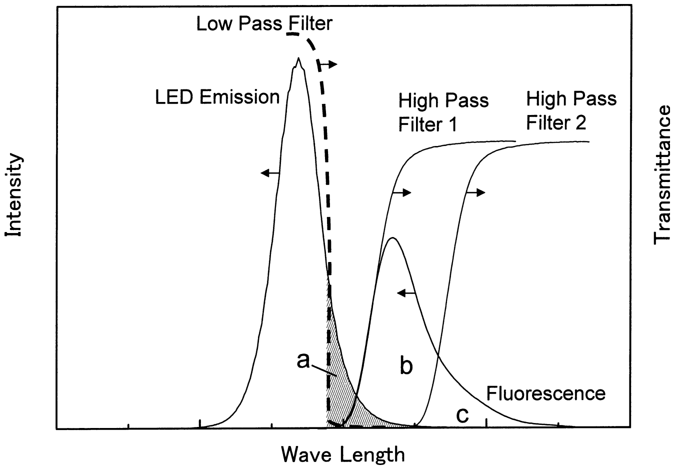

FIG. 4—*Relationship between spectral properties of LED emission, fingerprint fluorescence, high pass filter, and low pass filter: (a) LED emission disturbing fingerprint fluorescence observation (shadow part); (b and c) fingerprint fluorescence observed using high pass filter 1; (c) fingerprint fluorescence observed using high pass filter 2.*

Results and Discussion

Effect of Low Pass Filter and High Pass Filter (Cyanoacrylate Ester/Rhodamine 6G)

Figure 3 shows the effect of use of a low pass filter and high pass filters. The fingerprint on a white polyethylene sheet treated with cyanoacrylate ester and rhodamine 6G was examined. The right four images (1b, 2b, 3b, 4b) in Fig. 3 were photographed using a blue LEDs array with attaching the low pass filter (490 nm) and digital camera with attaching selectable high pass filters.

The right four images show better contrast than the corresponding left four images (1a, 2a, 3a, 4a). These improvements in contrast have to be given by the employment of the low pass filter which cut away the small part (a) of LED emission shown in Fig. 2. Furthermore the most suitable high pass filter can be chosen by a trial-and-error method. In the situation of the sample in Fig. 3, 520 nm (2b) and 540 nm (3b) high pass filters are fit to use. The 500 nm high pass filter (1b) gave a low contrast image and the 560 nm high pass filter (4b) gave a weak image.

As a result, high-performance low pass filter and high pass filters are necessary when LEDs are used as the light source to get high contrasted fluorescent ridges.

Enhancement of Weak Fingerprint (Ninhydrin/Indium Chloride)

Ninhydrin and its analogs are the most efficient reagent to detect latent fingerprints on papers. Ninhydrin reacts with the amino acids in fingerprint deposits to produce a blue-purple dye (RP). A weakly deposited fingerprint results in a low-contrast image because the quality of the image is directly related to the amount in the deposited fingerprint. If the RP fingerprint image developed with ninhydrin is visually weak, it can be improved by fluorescent complex formation with zinc chloride, which is a great methology found by Herod and Menzel (11) in the first place and subsequently established by Menzel et al. (12). We used indium chloride for the enhancement as mentioned above.

Figure 4*a* shows a weak RP fingerprint which was developed with ninhydrin on white paper. It is too weak to see by naked eye. Figure 4*b* shows a clear fluorescent image which was obtained by treating Fig. 4*a* with indium chloride and by photographing the fluorescence using the green LEDs array with the low pass filter (540 nm) and digital camera with the high pass filter (560 nm). Furthermore, digital processing by using Adobe Photoshop® gave an impressive image shown in Fig. 4*c*, which was obtained by extracting the red color component from Fig. 4*b* and subsequent white/black conversion of the red color component. Similarly, weak fingerprints treated with widely used ninhydrin/zinc chloride could be enhanced well by using the blue or green LED array of the developed system (Fig. 5).

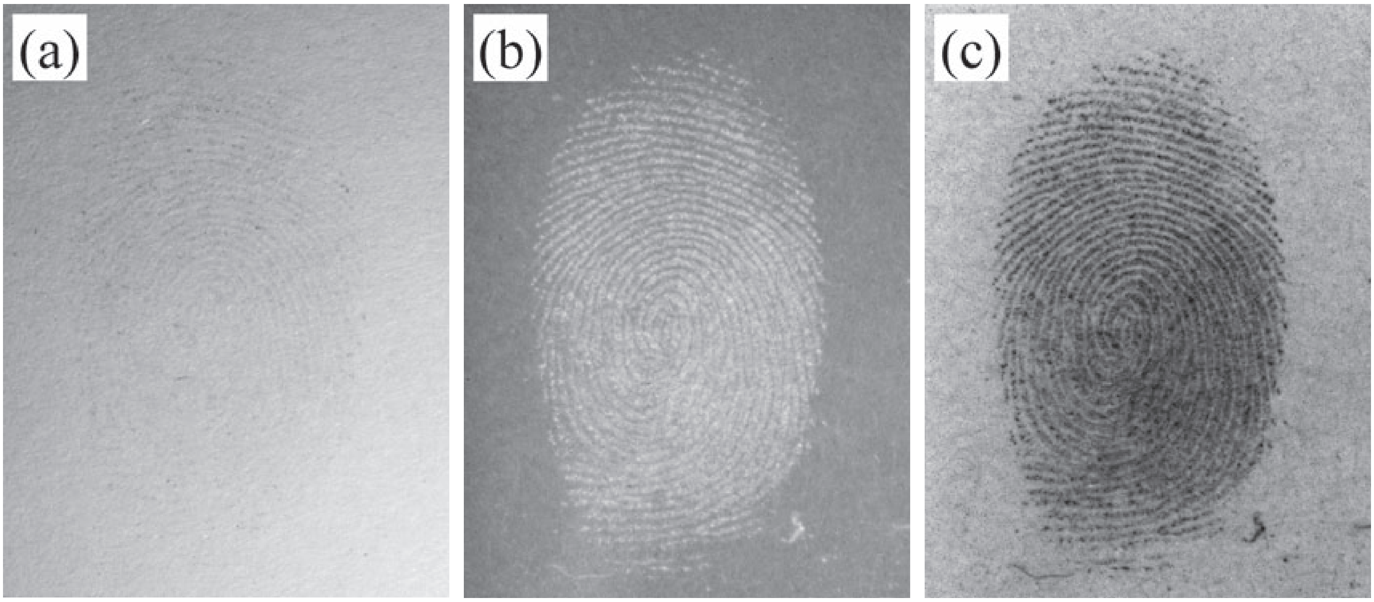

FIG. 5—*Enhancement of weak fingerprint ridge using the LED-based excitation system: (a) A weak fingerprint developed with ninhydrin on white paper; (b) fluorescent image photographed at room temperature after indium chloride treating (green LEDs array with low pass filter [540 nm] and high pass filter [560 nm] were used); (c) black image of the red component extracted from RGB image (b) using digital processing software (Adobe Photoshop®).*

Conclusion

The novel prototype LED-based excitation system achieved good contrast when imaging both cyanoacrylate ester/rhodamin 6G treated fingerprint and ninhydrin/indium chloride treated fingerprint. The merits of the LED-based system are low cost in manufacturing, simplicity, and easy maintenance. Compared to conventional light sources, the emission intensity of individual LED units is still weaker. However, it was shown that the improvement of the LED beam in intensity and quality can compensate the significant disadvantage, resulting in well-contrasted images. In the future, LED-based excitation systems should be more important in many crime laboratories according to the advance of LED technology.

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