

Visualization of Latent Sweat Fingerprints Deposit on Paper by Infrared Radiation and Blue Light

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Abstract—A simple device termed infrared radiation (IR) was developed for rapid visualization of sweat fingerprints deposit on paper with blue light (450 nm, 11 W). In this approach, IR serves as the pretreatment device before the sweat fingerprints was illuminated by blue light. An annular blue light source was adopted for visualizing latent sweat fingerprints. Sample fingerprints were examined under various conditions after deposition, and experimental results indicate that the recovery rate of the latent sweat fingerprints is in the range of 50%-100% without chemical treatments. A mechanism for the observed visibility is proposed based on transportation and re-impregnation of fluorescer in paper at the region of water. And further exploratory experimental results gave the full support to the visible mechanism. Therefore, such a method as IR-pretreated in detecting latent fingerprints may be better for examination in the case where biological information of samples is needed for consequent testing.

Keywords—Forensic science, visualization, infrared radiation, blue light, latent sweat fingerprints, detection.

I. INTRODUCTION

MATERIAL on the protuberant ridges will be transferred to the surface and leaving a fingerprint when a finger touches an object [1]. Detection of latent fingerprints on paper items is a difficult problem in crime investigations. At present, a variety of techniques have been developed to visualize latent fingerprint, including Raman spectroscopy [2], [3], nanoparticle reagents [4], [5], infrared spectroscopy [6], electrochemical/electrochemiluminescence methods [7], [8]. Among them, the reactive detection method using chemical reagents has been most widely used. Laser technology in the application of forensic science has been studied since the late 1970s and has become one of leading techniques for nondestructive fingerprint detection [9]-[11]. Cai [12] has visualized latent fingermarks through long-wave ultraviolet fluorescence by shortwave UV laser excitation. Bond [13] has described a method of visualizing latent fingerprint deposits on thermal paper, but these techniques could not be applied to nonthermal paper, and mechanism of the method is not clear. Moreover, previous studies were mainly concentrated on the investigation of the visualization through materials [14]-[19]. On the other hand, the fingerprints on paper have been widely

used to discriminate suspect.

The visualization of fingerprint on paper is the main issue in the forensic research. First, rough surface of the paper causes diffuse reflection of the light. Second, sweat contains 98-99% water, a number of inorganic salts (such as sodium chloride and phosphorus), and organic materials (such as amino acids, fatty acids, urea, and polypeptides) [20], [21]. However, because of the low sample concentration, the identification of latent sweat fingerprint is still limited. Direct fluorescent probes of latent fingerprint are weak and usually suffer from interference from background fluorescence. It is well known that fluorescer is added to paper during the manufacturing process to enhance the appearance of the finished product. The fluorescer typically absorbs blue wavelength and then re-emits at visible wavelength [22]. The fluorescer of the paper can be solubilised and transferred by hot water. Owing to this unique characteristic of fluorescer, we examined the latent sweat fingerprints on paper with an additional heat treatment by IR and blue light and proposed a protocol to handle the evidence, and what seems to be the first reported operational of this technique. The visualized mechanism was demonstrated.

II. METHODS AND EXPERIMENTS

A. Instruments

The system comprises an annular blue light, an IR instrument and the related picture is given in Fig. 1 (a), and an imaging camera system (Canon), a 580-nm band-pass filter.

Before the visualization, sweat fingerprints on the paper items were placed into IR instrument when the temperature reached 200 °C and it was heated for 2 min. The treated paper items were illuminated by annular UV light. As the excitation source, blue range matches with the absorption region of eccrine sweat (main organic component of latent fingermarks) and fluorescer of the papers. A 580-nm band-pass filter is placed in front of the imaging system, the image is recorded by the camera. The diagram of the visualization is shown in Fig. 1 (b).

B. Samples

Latent sweat fingerprints were collected from 10 volunteers after washing their hands, keeping them clean for 30 min and stamping on various paper items. The substrates included A4 paper, newspaper, kraft paper, napkin paper, POS ticket, and invoice paper.

III. RESULTS AND DISCUSSION

The experimental results are shown in Table I. 24 fingerprints, each having seven features or more ("Good"

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results), were revealed in the 60 samples. Among others are 19 fingerprints with less features ("Weak" results), and 17 irretrievable (Negative results). The recovery rate (the ratio of positive results to total samples) is thus estimated to be in the range of 50%-100%.

TABLE I
RESULTS OF LATENT SWEAT FINGERPRINTS IMAGING

Items bearing latent sweat fingerprints	Results distribution		
	Good	Weak	No
A4 paper	9	1	0
Invoice paper	4	4	2
Napkin	2	4	4
Kraft paper	2	3	5
POS ticket	4	4	2
Newspaper	3	3	4

Fig. 2 shows the scheme of latent sweat fingerprints visualization on (a) A4 paper (b) invoice paper (c) kraft paper (d) POS ticket (e) newspaper (f) napkin. The results were obtained by the homemade IR instrument and annular blue light. Apparently, from each image, we can successfully identify the ridge details with bare eyes. These experimental

results were judged by professional fingerprint technicians. The successful visualization on paper items using IR pretreatment could be explained by the hypothesis that fluorescer of the paper was soluble in sweat, and then redistributed and concentrated in the region of fingerprint while heating. The weak visualization on kraft paper is probably due to the low amount of fluorescer.

The images of latent sweat fingerprints on newspaper under different treated temperature for 2 min are presented in Fig. 3 (a) 50 °C (b) 75 °C (c) 100 °C (d) 125 °C (e) 175 °C (f) 200 °C (g) 225 °C (h) 240 °C. Sweat fingerprints are unable to detect while the temperature ranging from 50 °C to 175 °C. Clearly, the temperature above 200 °C is suitable for sweat fingerprint visualization on newspaper. With the increase of the temperature, the latent sweat fingerprints image clearly showed the typical fingerprint ridge pattern with sufficient details that would enable an individual to be identified. The effects observed here for the visibility of fingerprints when newspaper is heated above 200 °C are possibly due to low concentration of fluorescer and higher treated temperature is needed for its impregnation into sweat region to achieve the detect limitation.

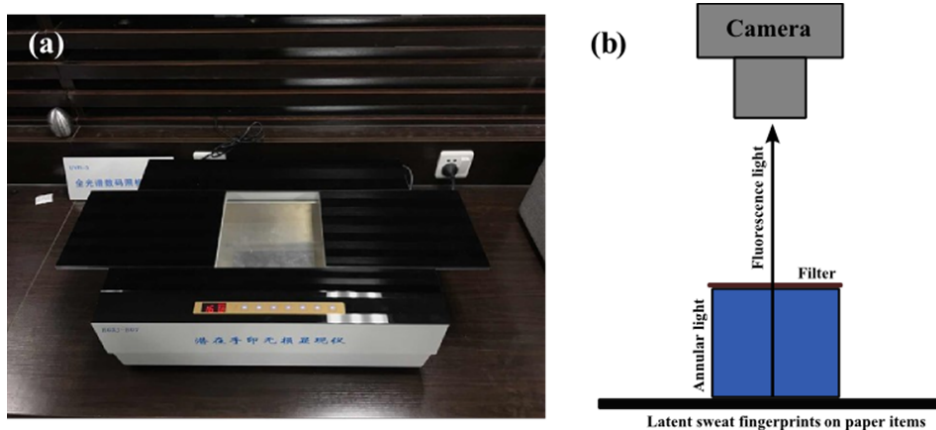


Fig. 1 (a) Device of the IR (b) Diagram of latent sweat fingerprints visualization

The optical images of sweat fingerprints deposited on kraft paper are displayed in Figs. 4 (a) and (b). The visibility temperature is relatively higher than ordinary paper because of the thickness of kraft paper, low amount of fluorescer and high detect limitation.

Similar imaging of the latent sweat fingerprints on A4 paper was obtained as exhibited in Figs. 5 (a)-(c). The pattern and details of the fingerprint could be clearly identified. And the exposure temperature is relatively low on account of high amount of fluorescer in A4 paper. The sweat fingerprint of (c) is dark relative to image (b), because coking of the A4 paper arises when the temperature was adjusted to 220 °C. The mechanism of visibility was further demonstrated by detecting latent sweat fingerprints collected on other substrate surfaces besides paper. But, the results showed that all the visibilities have come to nothing.

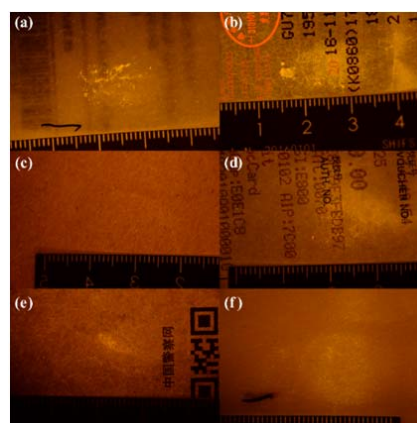


Fig. 2 Latent sweat fingerprints on (a) A4 paper (b) Invoice paper (c) Kraft paper (d) POS ticket (e) Newspaper (f) Napkin



Fig. 3 The images of latent sweat fingerprints on newspaper under different temperature for 2 min (a) 50 °C (b) 75 °C (c) 100 °C (d) 125 °C (e) 175 °C (f) 200 °C (g) 225 °C (h) 240 °C



Fig. 4 The images of latent sweat fingerprints on kraft paper under different temperature for 2 min (a) 220 °C (h) 240 °C

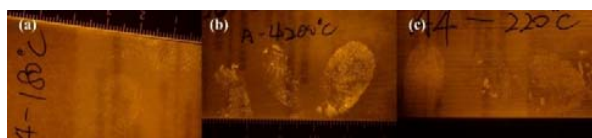


Fig. 5 The images of latent sweat fingerprints on A4 paper under different temperature for 2 min (a) 180 °C (b) 200 °C (c) 220 °C

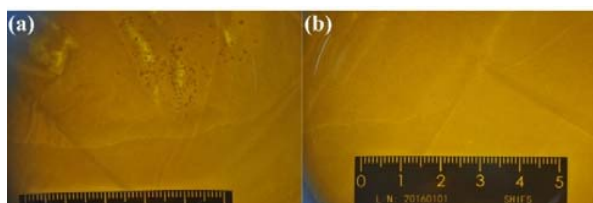


Fig. 6 The images after heating by IR device and illuminated with blue light (a) salt and its solution on the napkin (b) ultrapure grade water obtained from a Milli-Q Integral system on the napkin

Salt, its solution and ultrapure grade water were adopted as samples in demonstrated experiments. The images from demonstrated experiments are given in Figs. 6 (a) and (b). These results assist our proposed mechanism. In the region of wrinkles and boundaries of the napkin, the bright ridges are obvious in both images. Moreover, the salt particles give out no light. Therefore, we excluded the salt and microelements in the sweat lead to the visualization. The mechanism is transportation and re-impregnation of fluorescer in paper at the region of water.

As stated above, the application of IR heating device has been shown to develop latent sweat fingerprints at fixed temperatures. The preheated imaging of the latent sweat fingerprints using IR device and blue light can be easily recognized with the bare eyes, which would provide clear evidence for individual identification. We believe that this imaging of latent sweat fingerprints will find widespread use in forensic investigations and medical diagnostics.

IV. CONCLUSION

In summary, we reported a method using IR heating instrument and blue light for the visualization of latent sweat fingerprints, and investigated the applicability of the proposed IR device which is vital for the detection of latent fingerprints on paper items. Sample fingerprints from male and female donors showed that identifiable fingerprints could be detected by this method with recovery of 50%-100%. A mechanism for the observed visibility has been demonstrated based on further experiments. This is suggested to be as a result of transportation and re-impregnation of fluorescer in paper at the region of water. In comparison to conventional methods, such a method as UV-excited visible fluorescence in detecting latent sweat fingermarks may be better for examination in cases where biological information of samples is needed for consequent testing.

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REFERENCES

- [1] C. Champod, "Fingerprints and other ridge skin impressions," CRC, Boca Raton, Florida, 2004.
- [2] P. Hazarika, "Advance in fingerprint analysis," *Angew. Chem. J.*, vol. 51, pp. 3524-3531, 2012.
- [3] X. Tang, "Chemical imaging of latent fingerprints by mass spectrometry based on laser activated electron tunneling," *Anal. Chem. J.*, vol. 87, pp. 2693-2701, 2015.
- [4] O. S. Wolfbeis, "Nanoparticle-enhanced fluorescence imaging of latent

- fingerprints reveals drug abuse," *Angew. Chem. J.*, vol. 48, pp. 2268-2269, 2009.
- [5] M. J. Choi, "McDonagh AM, Maynard P, Roux C. Metal Containing nanoparticles and nano-structured particles in fingermark detection," *Forensic Sci. Int. J.*, vol. 179, pp. 87-97, 2008.
 - [6] T. Chen, "Infrared spectroscopic imaging of latent fingerprints and associated forensic evidence," *Analyst J.*, vol. 134, pp. 1902-1904, 2009.
 - [7] L. R. Xu, "Imaging latent fingerprints by electrochemiluminescence," *Angew. Chem. J.*, vol. 51, pp. 8068-8072, 2012.
 - [8] Y. Li, "Enhancing the visualization of latent fingerprints by electrochemiluminescence of rubrene," *Electrochem. Commun. J.*, vol.33, pp. 92-95, 2013.
 - [9] V. R. Salares, "On the detection of fingerprints by laser excited luminescence," *Forensic Sci. Int. J.*, vol. 14, no. 3, pp. 229-37, 1979.
 - [10] K. E. Creer, "Operational experience in the detection and photography of latent fingerprints by argon-ion laser," *Forensic Sci. Int. J.*, vol. 23, no. 2-3, pp. 149-60, 1983.
 - [11] E. R. Menzel, "Comparison of argon-ion, copper-vapour and frequency-doubled Neodymium Yttrium Aluminum Garnet (Nd:YAG) laser for latent fingerprint development," *J. Forensic Sci. J.*, vol. 30, no. 2, pp. 383-397, 1985.
 - [12] N. B. Cai, "Inherent fluorescence detection of latent fingermarks by homemade shortwave ultraviolet laser," *J. Forensic Sci. J.*, vol. 62, no. 1, pp. 209-212, 2017.
 - [13] J. W. Bond, "A noninvasive and speculative method of visualizing latent fingerprint deposits on thermal paper," *J. Forensic Sci. J.*, vol. 60, no. 4, pp. 1034-1039, 2015.
 - [14] M. Wang, "Fluorescent nanomaterials for the development of latent fingerprints in forensic sciences," *Adv. Funct. Mater. J.*, vol. 27, pp. 1606243(1-16), 2017.
 - [15] C. C. Chen, "Latent fingerprint development on thermal paper using traditional ninhydrin and 1,2-indanedione," *J. Forensic Sci. J.*, vol. 61, no. 1, pp. 219-225, 2016.
 - [16] J. H. Yoon, "Visualization of sweat fingerprints on various surface using a conjugated polyelectrolyte," *Appl. Mater. Interfaces J.*, vol. 8, pp. 24025-24029, 2016.
 - [17] K. Song, "Photoacoustic and colorimetric visualization of latent fingerprints," *ACS Nano J.*, vol. 9, no. 12, pp. 12344-12348, 2015.
 - [18] C. Ricci, "Chemical imaging of latent fingerprint residues," *Appl. Spectroscopy J.*, vol. 61, no. 5, pp. 514-522, 2007.
 - [19] J. J. Zhao, "High-resolution and universal visualization of latent fingerprints based on aptamer-functionalized core-shell nanoparticles with embedded SERS reporters," *Appl. Mater. Interfaces J.*, vol. 8, pp. 14389-14395, 2016.
 - [20] P. J. Wood, "Understanding immunology," 2nd ed Pearson Education, Upper Saddle River, New Jersey, 2006.
 - [21] A. Girod, "Composition of fingermark residue: a qualitative and quantitative review," *Forensic Sci. Int. J.*, vol. 223, pp. 10-24, 2012.
 - [22] V. Causin, "The discrimination potential of diffuse-reflectance ultraviolet-visible-near infrared spectrophotometry for the forensic analysis of paper," *Forensic Sci. Int. J.*, vol. 216, pp. 163-167, 2012.

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