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TECHNICAL NOTE

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Forensic Applications of Infrared Imaging for the Detection and Recording of Latent Evidence

ABSTRACT: We report on a simple method to record infrared (IR) reflected images in a forensic science context. Light sources using ultraviolet light have been used previously in the detection of latent prints, but the use of infrared light has been subjected to less investigation. IR light sources were used to search for latent evidence and the images were captured by either video or using a digital camera with a CCD array sensitive to IR wavelength. Bloodstains invisible to the eye, inks, tire prints, gunshot residue, and charred document on dark background are selected as typical matters that may be identified during a forensic investigation. All the evidence types could be detected and identified using a range of photographic techniques. In this study, a one in eight times dilution of blood could be detected on 10 different samples of black cloth. When using 81 black writing inks, the observation rates were 95%, 88% and 42% for permanent markers, fountain pens and ball-point pens, respectively, on the three kinds of dark cloth. The black particles of gunshot residue scattering around the entrance hole under IR light were still observed at a distance of 60 cm from three different shooting ranges. A requirement of IR reflectivity is that there is a contrast between the latent evidence and the background. In the absence of this contrast no latent image will be detected, which is similar to all light sources. The use of a video camera allows the recording of images either at a scene or in the laboratory. This report highlights and demonstrates the robustness of IR to detect and record the presence of latent evidence.

KEYWORDS: forensic science, infrared (IR), bloodstains, tire prints, gunshot residue (GSR), burned documents, writing inks

The detection of latent evidence at a crime scene is a challenge to crime scene investigators. Such latent physical evidence can often give valuable information in relation to the reconstruction of the scene. Hence, a scientific, methodical and systematic program should be set up for evidence examination to prevent loss of potential evidence.

Infrared light (IR), between 760 and 1500 nm (which lies within what is called the near infrared region), is a very powerful tool for forensic science but is also an underused means of detecting latent evidence. IR has been used previously to examine questioned documents (1–5), bloodstain patterns (6), the age of bite mark and patterned injury on skin (7,8). The operation of the traditional photographic IR method is inconvenient and unable to obtain results quickly, since there are issues with focusing and film development. It is for these reasons that IR has been underused in the forensic field.

Alternative light sources (ALS) and ultraviolet (UV) light have found favor in forensic investigations as they are both nondestructive means of searching items for evidential material. A contrast in the absorption between the background substrate and the latent evidence is required to enable visualization of the latent evidence. IR light sources offer a similar benefit to ALS and UV methods and we report on the use of IR to examine a number of different substrates for latent evidence. The experiments were designed for the detection of serial dilutions of bloodstains, writing inks, gunshot residues, burned documents, and the other application in this study.

Materials and Methods

Sample Preparations

Bloodstains were made in 20 μL serial dilution with 1/2, 1/4, 1/8, and 1/16 times dilutions, respectively. The solutions were pipetted onto 10 pieces of different material black clothe samples including 35% rayon and 65% polyester, 35% cotton and 65% polyester, 100% cotton, 35% polyester and 65% cotton, 100% velvet, 50% acrylic and 50% wool, 5% lycra and 95% cotton, 5% spandex and 95% polyester, 30% polyester and 70% rayon, and 30% acrylic and 70% wool.

Three kinds of black writing inks were collected as follows: 31 different permanent markers, 23 different fountain pens (roller-ball), and 27 different brand ball-point pens. Here "fountain pens" are those containing aqueous-based fluid inks in a reservoir as in the classical fountain pens, popular in the pre-1960 era. Each pen was used to write one word or phrase on the three kinds of different material black clothe samples.

Gunshot residue was collected after discharging a weapon at known distance from dark clothe sample. The ranges included 15, 30, and 60 cm and in all cases a 9 mm pistol (Smith & Wesson) with 9 mm bullets (NPA 01 3) was used.

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IR Examination

A Sony F717 or F828 digital camera (Sony Corporation, Tokyo, Japan) or Sony DCR-DVD803 digital video camera (Sony Corporation) was used to capture the images under illumination. The 2/3 in. HAD CCD sensor was used in the Sony F717 and F828 digital cameras. The 1/3 in. HAD CCD sensor was used in the Sony DCR-DVD803 digital video camera. The B + W 093 IR pass filter (B + W filter Company, Bad Kreuznach, Germany) was employed to filter the visible light. The "093 pass filter" blocks wavelengths <930 nm.

The digital camera should be programmed for IR photography. The "nightshot" mode allowed for a longer shutter speed suitable for IR photography. The program auto mode (P model) was used so that the camera will automatically focus and provide the value of f stop, shutter speed times, and ISO. An aperture of between f 2.0 and 2.2, with shutter speed times from 1/60 to 8 sec, ISO of 100–800, and an IR pass filter was used. The exact conditions used depended upon the available light and the subject being photographed.

In this paper, the IR device on the digital camera or video were used to detect the four kinds of blood dilution times on ten pieces of different material black clothe samples, detect the absorb situation of 81 different pens on the three kinds of black clothe, detect the distribution of gunshot residue particles in the three different shooting distance.

Results and Discussion

Identifying the Presence of Bloodstains on Black Fabric Samples

To determine whether bloodstains absorb the near IR wavelength, spots of blood were deposited on ten different pieces of black fabric samples. Bloodstains were shown to absorb near to the IR and could be visualized on different substrates if there was sufficient contrast (9). The detection limit of bloodstains when using white light was at 1/4 times dilution. When using IR light the limit of detection was increased to 1/8 times dilution. From Table 1, the bloodstains on the 2 items, 35% rayon and 65% polyester (item 1) and 5% lycra and 95% cotton (item 7), were barely observed even for undiluted preparations. A possible reason for explaining the lack of detection of the bloodstains is that the dyes on the clothe samples have similar absorbance and reflection of IR as bloodstains.

The method of utilizing IR to search for bloodstains was applied in case 1. No bloodstain was visualized on a pair of black trousers using visible light. Suspect stains could be seen clearly when searched using IR light (Fig. 1).

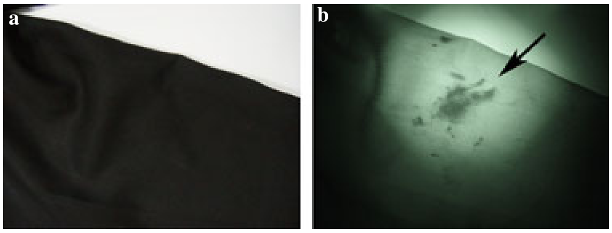

FIG. 1—*Searching a pair of black trousers for the presence of bloodstains in a car accident. (a) No evident pattern is observed using white light. (b) The presence of bloodstains is clearly visible under IR illumination.*

Detection of Writing on Fabric Using IR

This study examines the effectiveness of detecting writing made by a range of inks on different fabric samples. Both the fabric samples and the writing inks were black in color so the writing could not be seen with the naked eyes. The clothe samples were made from three different compositions including: 35% polyester and 65% cotton (item A), 100% cotton (item B), and 100% polyester (item C). The results of using IR light to detect the writing inks are shown in Table 2. Fountain pen ink could be visualized using IR light less effectively than the permanent inks but was recorded on considerably more occasions (88%) than the ball point pen (42%).

The nibs of ball-point pens are the smallest tested and therefore there is less quantity of writing inks that is deposited on the fabric samples. Most of writing inks used in these ball-point pens do not absorb IR. The relatively poor results for the ball point pens may be a reflection of the amount of ink deposited when the mark is made.

In case 2, there was an undiscovered name found on the dark shirt. A young male committed suicide using gasoline in a park and his unburned dark clothe sample was examined to find any clue related to the identity of the male. IR examination of his shirt revealed a name written on the inside of the collar (Fig. 2).

IR light can be employed on burned document examination but most equipment used is not portable and therefore can not be used at a scene. An example where a piece of paper upon which printing could not be observed but it can be deciphered under IR illustration is shown in Fig. 3. The difference of IR reflection on different writing inks or dyes can also be used in the identification of counterfeit paintings, if the IR images of the genuine articles were recorded previously.

TABLE 1—*Screening results of bloodstains on 10 pieces of different black fabric.*

Item	Composition	Neat	1/2	1/4	1/8	1/16
1	35% rayon and 65% polyester	1	0	0	0	0
2	35% cotton and 65% polyester	4	3	2	1	0
3	100% cotton	4	3	2	1	0
4	35% polyester and 65% cotton	4	4	2	1	0
5	100% velvet	4	3	2	1	0
6	50% acrylic and 50% wool	4	4	2	0	0
7	5% lycra and 95% cotton	1	0	0	0	0
8	5% spandex and 95% polyester	4	3	2	1	0
9	30% polyester and 70% rayon	4	4	3	2	0
10	30% acrylic and 70% wool	4	3	2	1	0

The numbers represent: not visible, barely visible, visible, good and excellent of 0, 1, 2, 3, and 4, respectively.

TABLE 2—*The results of various intensities were shown using three kinds of different black pens on three different black materials.*

	The intensities of 31 permanent markers					The intensities of 23 fountain pens					The intensities of 27 ball-point pens				
Item	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
A	2	1	1	11	16	4	2	3	14	0	19	3	1	4	0
B	2	0	1	11	17	1	4	5	13	0	11	6	5	5	0
C	2	0	1	11	17	3	1	5	14	0	17	3	5	2	0

The material of item A is made of 65% cotton and 35% polyester, sample B is made of 100% cotton and sample C is made of 100% polyester. The numbers represent: not visible, barely visible, visible, good, and excellent of 0, 1, 2, 3, and 4, respectively.

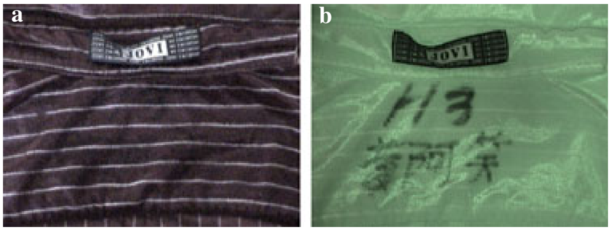

FIG. 2—*Identification of writing on the clothe samples. (a) No clear pattern could be detected by white light but (b) IR illumination of the clothes identified a name written on the inside of the collar.*

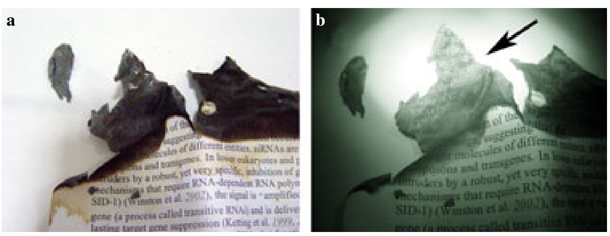

FIG. 3—*Examination of a burned document. The printing could not be seen using white light (a), but it could be seen clearly using IR (b).*

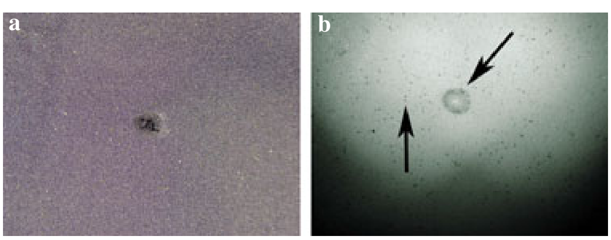

FIG. 4—*GSR on the clothe sample. The presence and extent of GSR made from 15 cm shooting distance on clothe sample may be difficult to detect when using white light (a), but they can be seen on the same fabric sample when using IR (b) on the edge of entrance hole and around the entrance hole.*

Detection of Gunshot Residue (GSR) from Different Shooting Distances

Presumptive tests for the presence of GSR are available (10) but these tests can be destructive. Certain components of GSR absorb IR and this absorption can be recorded relative to the background absorption (Fig. 4). The number of black particles observed using IR was approximately 418, 317 and 63 within a 10 cm radius around the entrance hole when the firearm was discharged at distance of 15, 30 and 60 cm distance of shooting, respectively. Such data can be used in determining the distance between the point of discharge and the clothes. In addition to recording distribution of the particles IR light sources are a non-destructive presumptive test for GSR.

Other Application in Forensic Science

Trace impression evidence such as tire prints on a dark background may be invisible to the naked eye but may be visible using IR light. In case 3, IR light detected the latent tire print of a bus on the clothe samples of a victim of a traffic accident (Fig. 5). Two tire patterns on the clothe samples were matched to those of two right rear tires of the suspected bus.

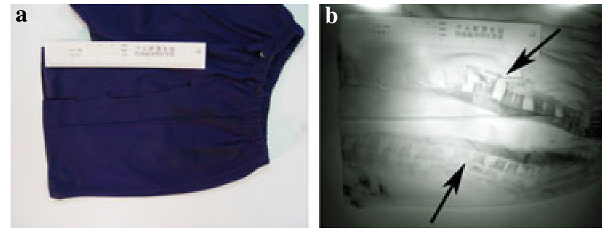

FIG. 5—*Identification of the tire prints on blue clothe sample. No mark was visible under white light illumination (a), but two clear marks can be seen using IR (b).*

Conclusions

We have demonstrated that IR can be a simple but effective means of searching items both at a scene and in the laboratory for the presence of latent trace evidence. The process is non-destructive allowing further testing to be performed if required. In this study, the IR can be used to search the patterns of the bloodstains, writing inks, GSR, tire prints on dark clothe samples and burned documents. The only perceived disadvantage of the use of IR light occurs when the background substrate and the evidence type absorb IR light to the same extent. This would be the same for all light based search methods, but using a range of light sources including IR can increase the chance of detecting latent evidence.

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