

Fingerprint and Footwear Forensics Newsletter

February 2010 Publication No.6/10



Home Office
Scientific
Development Branch

SPECIAL EDITION: FOOTWEAR MARK RECOVERY AND IMAGING

Authors: Dr Helen Bandey, Dr Stephen Bleay

IN THIS ISSUE

- Introduction
- **PART 1: FOOTWEAR MARK RECOVERY**
 - Methodology
 - Recovery of Dry Origin Marks
 - Safe Use of Electrostatic Lifting Apparatus
 - Recovery of Wet Origin Marks
 - Blood at Crime Scenes
- **PART 2: FOOTWEAR MARK IMAGING**
 - Best Practice Guidelines for the Imaging of Footwear Marks
 - Appendix A: Optimum Imaging Techniques for Different Types of Mark
 - Appendix B: Estimating Capture Resolutions for Digital Cameras
 - Acknowledgements

CONTACTS

For Footwear Mark Recovery enquiries contact:

Helen Bandey

Tel: 01727 816385

Email: helen.bandey@homeoffice.gsi.gov.uk

For Footwear Imaging enquiries contact:

Stephen Bleay

Tel: 01727 816252

Email: stephen.bleay@homeoffice.gsi.gov.uk

ADDRESS

<http://scienceandresearch.homeoffice.gov.uk/hosdb/>

HOSDB, Woodcock Hill, Sandridge,
St Albans, Hertfordshire, AL4 9HQ, UK

INTRODUCTION

This is the second newsletter produced by the Fingerprint and Footwear Forensics (FFF) group at HOSDB with the aim of updating scientific support staff with information regarding the recovery and imaging of footwear marks. The first was published in May 2008¹ and contains information relating to footwear mark recovery; storage guidance for electrostatic and gelatine lifts, chemical enhancement of marks in a range of contaminants (blood, soil, greases etc), and sequential processing.

Since then, work has continued, in accordance with force priorities and with the support of the National Footwear Board. We are now able to issue further guidance in part 1 of this newsletter relating to recovery of footwear marks, from both volume and serious crime scenes.

HOSDB was also asked to look at the standards required for imaging of footwear marks at scenes of crime or in custody suites. This has been completed and forms part 2 of this newsletter.



Figure 1: Reverse footwear marks in dust recovered using electrostatic lifting apparatus

¹ H Bandey, *Fingerprint and Footwear Forensics Newsletter, Special Edition: Footwear Mark Recovery*, May 2008, 24/08, ISBN 978-1-84726-654-5

PART 1: FOOTWEAR MARK RECOVERY METHODOLOGY

FFF has been evaluating the relative effectiveness of fingerprint enhancement processes since the 1970s. Typical methodology involves processing thousands of marks so that variations due to the donor, substrate, mark age etc. can be taken into account in evaluating the effectiveness of a process. This methodology has been challenged and refined regularly at an international level, predominantly through the International Fingerprint Research Group (IFRG) making it a widely accepted and powerful comparison method. 'Standard' fingerprints do not exist in the real world so trials must represent a range of realistic marks if the results are to be transferred to successes on operational material. A small section of the methodology can be found in the Appendix to HOSDB newsletter (Pub. 08/06). FFF intends to publish the methodology, in full, in the near future.

A similar methodology was used for the comparison of footwear mark recovery processes in this newsletter, although the following problems were faced:

- (1) The physical size of a footwear mark compared to a fingerprint makes it impractical to conduct such large trials - the time taken to enhance one footwear mark is comparable to the time it would take to enhance a sheet of, say, sixty fingerprints.
- (2) Fingerprints taken from a donor at a moment in time are relatively consistent, making process comparison straightforward. Footwear marks can be difficult to reproduce partly due to the uneven distribution of contamination across the sole of the shoe.
- (3) Although the chemical constituents within fingerprints are variable, they generally contain a mixture of eccrine and sebaceous sweat and occasionally other external contaminants. The constituents within footwear marks could be anything that the wearer has walked over or stepped in.
- (4) Footwear marks are typically found on dirtier substrates than fingerprints, so there may be additional background contamination issues. This is evident by the number of reverse footwear marks recovered from scenes with powders/lifting.

A major consideration was to work with realistic marks likely to be encountered operationally. With the difficulties of the design of experiments explained above, it has been possible to produce guidelines to support current practice. The information is based on general trends observed during the study whilst taking account of the broad range of variables. The guidelines should therefore be used as supplementary information to current practice.

RECOVERY OF DRY ORIGIN MARKS

Background

Dry origin footwear marks are created when dry residue, such as dust, is transferred between the sole of a shoe and a surface as a result of contact between the two. Typically, this type of mark can be seen with an oblique white light source and photographed in-situ. However, the success of this method is very dependent upon the contrast difference between the mark and the substrate. This can be affected by the amount of residue material and the nature of the surface (cleanliness, texture etc).

Other methods, such as electrostatic lifting and gelatine lifting, can be very successful for recovering dry origin marks. Adhesive lifters were not studied in detail in this trial. It is generally accepted by scene examiners that they are ineffective at recovering marks in dust, and this was confirmed by a short study.

For electrostatic lifting, the film is placed or rolled out over the area of interest and a charge applied. This charge attracts dust or loose particulates from the surface. The fragile mark is not 'fixed' to the film, but instead held on by a residual charge. It was clear from an article in the previous footwear mark recovery newsletter¹ that storage of the film, both short and long term, can be problematic.

For gelatine lifters, the lift is placed or rolled over the mark and left for a short period of time before removal. Storage is less problematic than for electrostatic lifts, although early photography is still recommended¹. The use of gelatine lifts is not limited to recovering marks in dust, but can be used to lift a range of contaminants including wet origin marks and even fingerprints in certain situations. The main disadvantage is it is generally necessary to first see the footwear mark to be able to lift it, whereas electrostatic lifting can be used speculatively.

Objective

To determine the relative effectiveness and optimum sequential use of electrostatic lifting apparatus and gelatine lifting for the recovery of dry origin marks.

Experimental

A range of flooring materials and other surfaces were used during this trial including lino, laminate, smooth and textured tiles, wood, metal sheets, paper and carpet. Marks were deposited by walking through a dusty area and then onto one of the surfaces. Alternatively, reverse marks were planted by walking from a clean area through a dusty area. 84 marks were examined in total.

Half of each mark was lifted with ESLA². The full mark was then lifted with a black gelatine lifter³. This method was chosen so that (1) the ESLA lift and gel lift could be compared directly, after photography, and (2) the effect of ESLA prior to gel lifting could be investigated.

Electrostatic lifts were photographed using a Canon EOS 5D camera and oblique lighting. Gelatine lifts were imaged on the GLScan³ imaging equipment.

Grade	Comment
1	Gel significantly better than ESLA
2	Gel slightly better than ESLA
3	Gel very similar to ESLA
4	Gel slightly worse than ESLA
5	Gel significantly worse than ESLA

Table 1: Grading scheme for the relative comparison of half marks recovered using gel lifters and ESLA

Grade	Comment
1	Gel significantly better than ESLA/Gel
2	Gel slightly better than ESLA/Gel
3	Gel very similar to ESLA/Gel
4	Gel slightly worse than ESLA/Gel
5	Gel significantly worse than ESLA/Gel

Table 2: Grading scheme for the comparison of half marks lifted with gel lifter only or gel lifter with ESLA beforehand

For the direct comparison, the half marks were graded according to the relative quality of the marks using the scheme in Table 1. For the effect of ESLA on subsequent gel lifting, again a score that represents the relative quality of the two halves of gel lift was used and is described in Table 2.

Results and Discussion

Figure 2 shows the average score across each surface for the direct comparison of electrostatic and gel lifting. The average score across the whole trial is 2.5, indicating that gelatine lifting is marginally more effective at recovering dusty marks than electrostatic lifts, on average, and for this trial. Looking into more detail, on all but carpet, the average scores are ≤ 3 , although there were occasions where electrostatic lifting was the more effective process. Only on carpet is ESLA more effective on average than gels and, in practice, gels would not be used as the mark would not be visible.

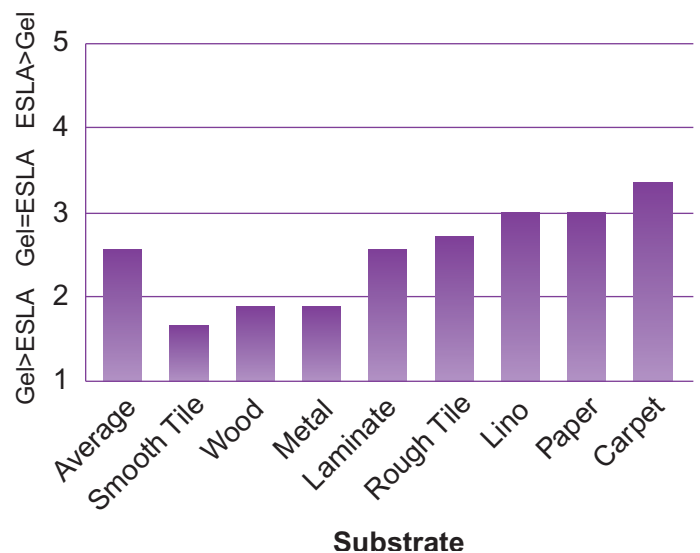


Figure 2: ESLA vs. Gel comparison on split marks in dust showing the substrate dependence

Figure 3 represents the same data in a slightly different way and shows the range of scores across the trial. 58% of the marks gave a better quality lift with a gel, although 40% were only slightly better; 23% gave a better quality lift with ESLA with 21% being only slightly better; and there was little difference between the processes for 19% of the marks. This data shows that, in general, although both processes are very effective, visible dusty marks should give better results if lifted with a gel lift in preference to an electrostatic lift.

² PathFinder (Model: SOC002), CSI Equipment Ltd, UK

³ BVDA International, The Netherlands

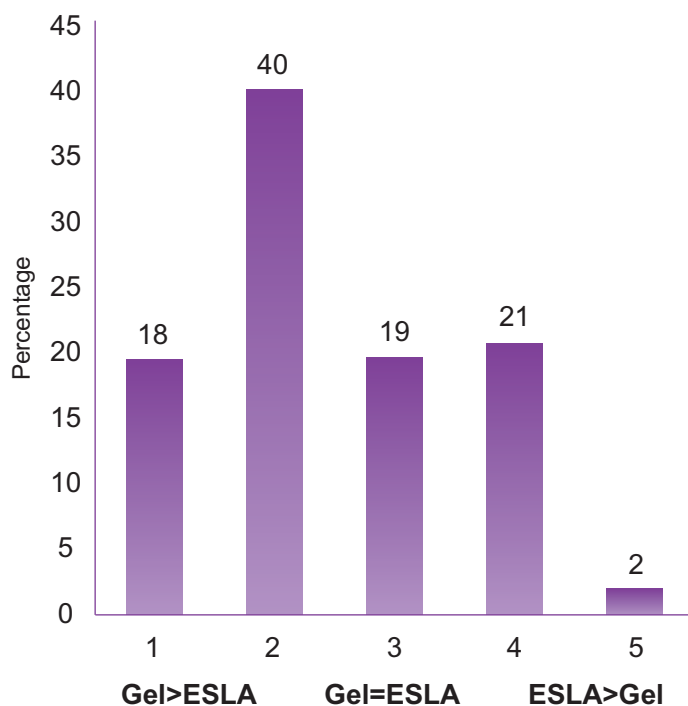


Figure 3: ESLA vs. Gel comparison on split marks in dust showing average grades across all surfaces

Figure 4 shows a typical example of the difference in quality between an electrostatic lift and a gel lift. The electrostatic lift is often grainy in appearance as the lift consists of only loose particles, making it difficult to see fine detail. Gel lifts, on the other hand, appear to have more continuous edges on the blocks within the mark, making fine detail more apparent.

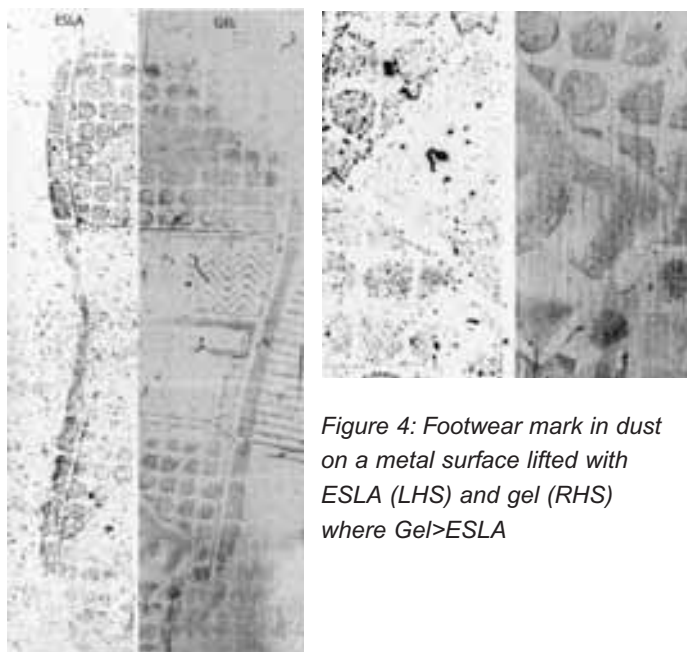


Figure 4: Footwear mark in dust on a metal surface lifted with ESLA (LHS) and gel (RHS) where Gel>ESLA

The second part of the study involved determining the effect of ESLA use prior to gel lifting on dry origin marks and the results are summarized in Figure 5. The graph shows that ESLA had no effect on 40% of the marks subsequently lifted with a gel; 39% of marks show ESLA to be detrimental to the subsequent gel; 21% improve subsequent gels. It is worth noting that 95% of the marks (grades 2-4) show no significant changes to the mark quality by using ESLA first.

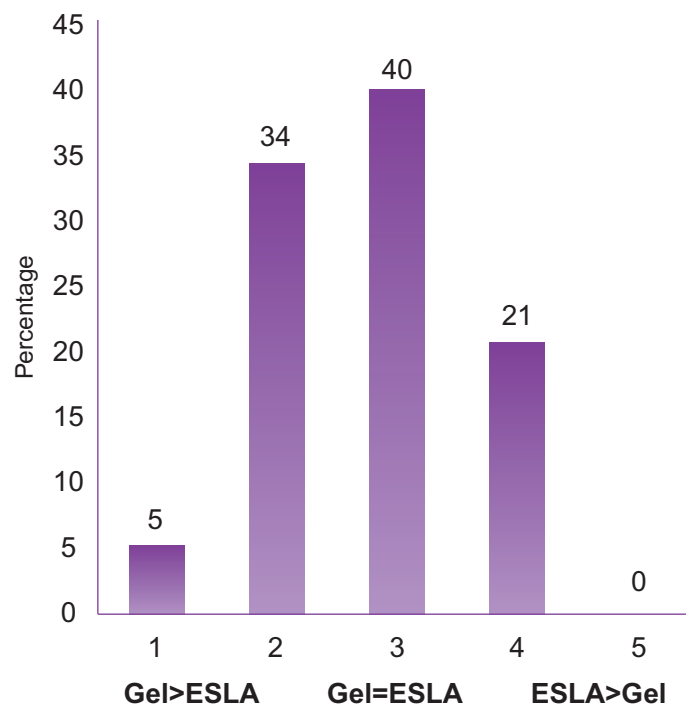


Figure 5: Gel vs.ESLA/Gel comparison on split marks in dust showing average grades across all surfaces

Figures 6 and 7 show typical example of types of marks recovered in this study. It is clear from both images that ESLA and gel lifting are both very effective processes and ESLA has little effect on subsequent gel lifting. They also show that ESLA can be useful for removing excess dust from the surface. This can be advantageous on very dusty surfaces where direct gel lifting may result in a very 'noisy' lift. In some cases the use of ESLA prior to gel can cause the mark on the gel to be slightly fainter. This is likely to be most evident for very weak dusty marks. Both of these effects were generally minor in terms of seeing fine detail within the footwear mark recovered with a gelatine lift.

The 'dry origin' marks recovered in this trial were made by simply walking into or out of dusty areas. When viewed with an oblique light source, there is no reason to believe that the marks have been made in anything but dust. The ability of gel lifting to remove more information from the surface suggests that the mark is composed of different components in addition to the ESLA-removable material. Although this can lead to a better quality mark, it can also be detrimental as surface texture, scratches etc can also leave an impression in the gel resulting in obscured footwear mark detail. In these cases electrostatic lifting may be more effective than gel lifting. This is demonstrated in Figure 7 where the gel has recorded detail from what looks to be wipe marks across the surface.

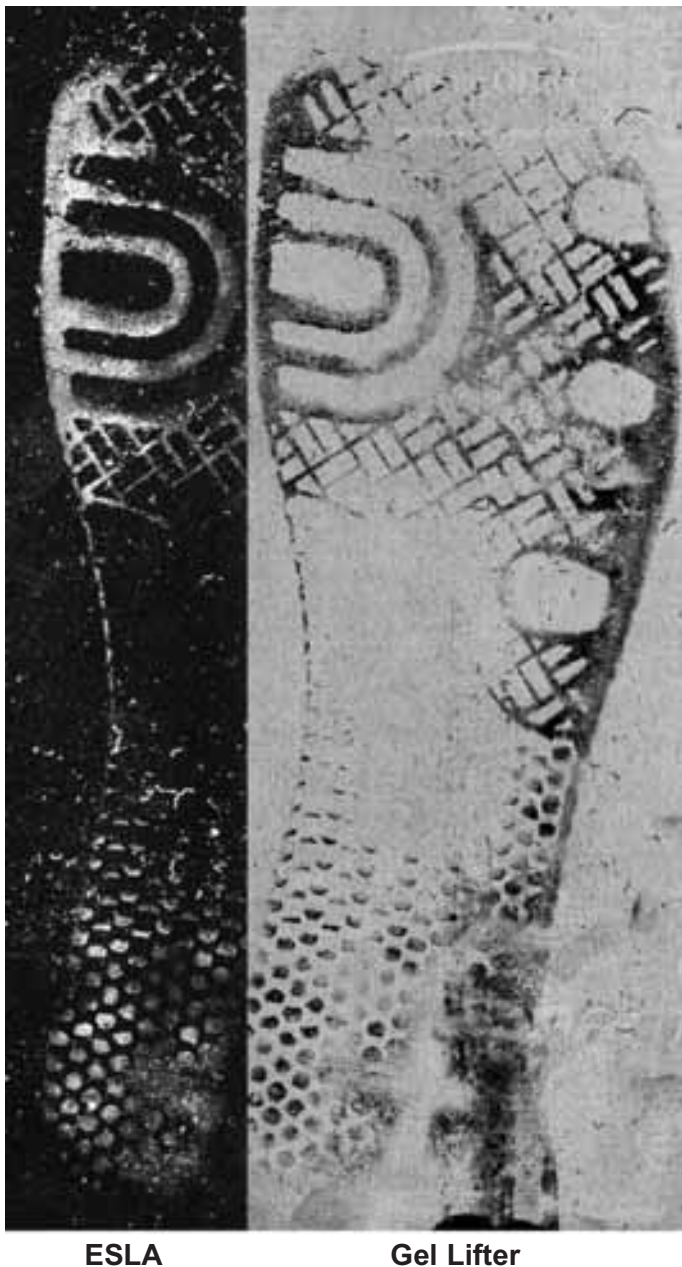


Figure 6: Typical example of ESLA and Gel lifter used sequentially on paper where half of the mark has been lifted with ESLA followed by a gel lift of the complete mark.



Gel Lifter

ESLA

Figure 7: Typical example of ESLA and Gel lifter used sequentially on a ceramic floor tile where half of the mark has been lifted with ESLA followed by a gel lift of the complete mark.

Guidelines

1. If footwear marks in dust are visible, best results are likely if the marks are recovered using gelatine lifters
2. If the mark or surface is heavily contaminated with dust, it can be "cleaned out" with ESLA
3. If the mark is extremely weak, ESLA should not be used prior to gelatine lifting
4. If footwear marks cannot be seen with an oblique light source, ESLA should be used to search speculatively

SAFE USE OF ELECTROSTATIC LIFTING APPARATUS

Electrostatic lifting apparatus (ESLA) is an effective method for recovering dry origin footwear marks, in particular marks in dust. Although most scene examiners in the UK have access to ESLA, other processes, such as gelatine lifts, are often used in preference. However, ESLA is particularly effective when used speculatively to search for marks; a procedure not routinely used with other lifting methods due to higher costs and/or practical issues.

Indications are that the reluctance to use ESLA is, in part, due to health and safety concerns - other issues include ease of use and used film storage. Storage issues were evaluated in the previous newsletter¹. The Health and Safety Laboratory (HSL), under contract to HOSDB, has carried out an assessment of commonly used ESLA equipment to determine the likelihood of an operator receiving an electric shock and whether or not they are hazardous to health. By evaluating these issues, we can publish guidance and provide scene examiners with the confidence to use these devices appropriately and safely in the field, although manufacturers' instructions must be followed at all times as equipment continually evolves.

The equipment operates by applying a high voltage electrostatic charge onto a lifting sheet which if touched can result in an electric shock. The severity of the shock is likely to be dependent upon how and where the equipment is used, yet there is little guidance for scene examiners on this.

The High Voltage Charger Unit

Unit	Product Name	Manufacturer	UK Supplier
1	PathFinder	CSI Equipment Ltd	CSI Equipment Ltd
2	ESP900	Sirchie	WA Products
3	Dustmark Lifter	Armor Forensics	Tetra SOC
4	-	Kjell Karlsson Innovations	-

Table 3: Manufacturers' information for electrostatic lifting apparatus tested in this evaluation

Table 3 lists the devices tested by HSL in this study. Units 1-3 are used most commonly by scenes of crime departments. Unit 4, as far as we are aware, it not currently used by UK forces, but was included in the study as it is an example of the older style of ESLA where external probes are used to charge a film rather than integrated contacts on the charger unit (see Figure 8).



Figure 8: Commercially available ESLA Charger Units

A hazard associated with charger units is the amount of current that could be delivered to a person accidentally contacting the output. If contact is made, there is a short transition period between the open circuit voltage decaying and the steady state current stabilising, when a short higher current pulse could occur. This is likely to result in an unpleasant shock. It should be noted that steady state values for all charger units were well below 1mA; values lower than this are generally accepted as being harmless but might be perceived as a slight tingling.

Units 1-3 are arranged to be used with integral contacts, two of which need to be earthed using the ground plate before the third becomes live, making accidental contact less likely in normal use. However, these safety features do not appear in unit 4 where it is a lot easier for the operator to accidentally receive an unpleasant shock from the external probes.

The Film and Surface

Film Parameters: Various parameters for a range of films sold by UK forensic suppliers were measured by HSL. There was a small range in film thickness (0.03-0.04 mm), surface resistivity (insulating side) (10^{13} - 10^{16} W), and breakdown voltage (10-15 kV) which may be within manufacturing tolerances rather than intentional differences.

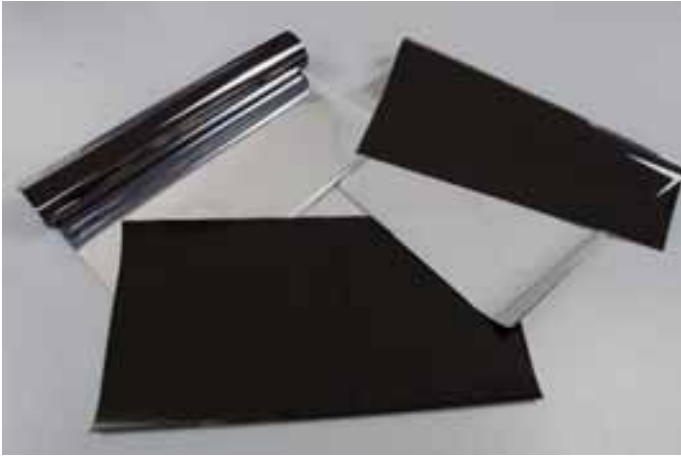


Figure 9: Different sizes of ESLA film

Surface Type: The potential to experience a shock from the film is highly dependent upon the surface on which it is used. Charge tends to dissipate at the film edges where the conducting top layer comes very close to the surface; the dissipation rate being dependent on how conducting the surface is. The result is that higher levels of charge can be drawn when the film is used on highly insulating surfaces, which dissipate the charge slowly. In other words, the more charge that the film holds, the greater the shock received if touched. As far as this study is concerned, the worst-case scenario would be on highly insulating surfaces such as most plastic materials.

Use of equipment on conducting surfaces poses less of a hazard in terms of electric shocks. The amount of charge that a film can hold is considerably less than on an insulating surface. This is because the film breaks down at the edges even with a voltage as low as 2 kV. In the HSL tests, when used on a good conducting floor, the voltage had to be reduced from the maximum to avoid similar problems. In most operating instructions, it is suggested that an insulating plate is placed underneath the earth plate so that a higher voltage (thus more charge) can be applied before arcing happens.

Film Size: On a highly insulating surface, the energy transfer from touching the film increased proportionally to the rolled out film area. In these tests, the highest value obtained was ~ 1 J from a 3.3 m² film (or 0.4 m x 8.3 m where 0.4 m is the width of a typical roll). HSL have likened the nature of the discharge to the type of shock obtained from an electric fence. To qualify the pathological effect of the shock that might be obtained from the film by a person, it seems reasonable to refer to the allowable energy levels in the standard BS EN 60335-2-76: 1999 for electric fences. This allows a

maximum energy level of 5 J applied to a 500 W load. Assuming linearity, the user would need to roll out a 0.4 m wide roll of foil by 41 m before failing to meet the standard. In practice, not only are large films difficult to manage, but it is unlikely that the batteries within the charger unit would have sufficient power to charge this size film.

Surprisingly a rolled up film gave comparable results to the smaller sheet; this is likely to be caused by charge leakage at the film edges.

Worst Case Scenario

A worst case situation could arise if the operator were kneeling down at a large charged sheet placed upon an insulating surface, and then overbalanced and put their weight on the charged sheet for several seconds, completely discharging it. In this case, it is possible to make contact with the charger unit via the charged sheet resulting in the maximum amount of discharge when touched. In order to test this theory, results were obtained with the charger unit left operating and connected to the sheet during this discharge, and also with the charger removed prior to the discharge. The data showed little difference between the two readings, demonstrating that there is no 'added hazard' when the film and charger are both live.

Secondary Effects

We have shown that the shock received from using ESLA is not directly hazardous to health but people's perceptions of shocks vary as skin resistance varies – what might be unpleasant to some may affect others more severely. This could lead to secondary effects due to surprise that may cause a hazard (dropping things etc).

The HSL study did not identify whether the equipment would have a more severe effect on those with pacemakers or other heart conditions. As a precautionary measure forces may wish to limit the equipment's use to those with no pre-existing heart conditions. However, some kits state in their manufacturers' instructions that they are safe to use in this case. Forces may wish to investigate this further.

The charge transfers measured from the spark discharges are likely to have enough energy to ignite flammable gases and vapours, and possibly some dusts. The amount of charge measured is high from an ignition point of view, but the spark length is short, which may reduce the likelihood of ignition. In this context, this study did not determine if this is a significant hazard in normal operational

use. As a precaution, ESLA should not be used in areas where flammable gases or vapours may be present. The amount of airborne dust would need to be considerable for this to be a hazard – in such extreme environments it is unlikely that that ESLA would be effective.

It is possible for people close to the sheet or charger to become charged themselves if they are isolated from earth, resulting in a non-hazardous, but unpleasant shock, upon contacting an earthed object. To avoid this, users should wear antistatic footwear, and avoid standing on highly insulating surfaces. If standing on a highly insulating surface is unavoidable, maintaining skin contact with earth, via a wire or other suitable object, will prevent them becoming charged.

Health and Safety Summary

1. The three commercially available ESLAs tested in this study are safe to use in normal operational applications provided manufacturers' operating instructions are followed at all times.
2. ESLA should not be used in damp or wet conditions.
3. The earth plate or mylar film must not be touched when the ESLA is switched on.
4. The severity of a shock increases with film size from a tingling effect to becoming quite unpleasant and users are encouraged not to use large, unmanageable lengths of film unless absolutely necessary and with increased precautions.
5. ESLA must not be used in areas where flammable vapours may be present.
6. In order to speed charge dissipation from the film (especially on insulating surfaces and/or large areas) an earth bonding lead can be placed on the film at one end and either the earth plate or other earth source (radiators etc) at the other.
7. Any minor shocks received could lead to secondary effects, such as dropping things, due to surprise.
8. Wear antistatic footwear, or maintain earth contact by other means when this is ineffective.

RECOVERY OF WET ORIGIN MARKS

Wet origin footwear marks are created when wet or damp residue is transferred between the sole of a shoe and a surface as a result of contact between the two. One method of leaving such marks is by walking from an outside, wet/damp area (encountered during or after rainfall) into a dry property. Depending upon the heaviness of the mark, wet origin marks are often dried out by the time the scene examiner is on site.

The ability to locate dried wet origin marks using a white light search will depend upon three principal factors: the constituents and 'heaviness' of the mark; the substrate; and the optimum use of white light so that highest contrast between the surface and mark can be achieved.

In addition to a white light examination, wet origin marks are typically enhanced/recovered with either black gelatine lifters or powders followed by subsequent lifting. The aim of this study was to determine the relative effectiveness of these recovery processes and, if possible, produce supplementary guidance to the information already given the Footwear Mark Recovery Manual⁴.

The constituents of wet origin marks vary considerably, so it is not unreasonable to expect recovery/enhancement processes to perform differently depending upon the mark constituents, in addition to the substrate that it is on. As it is unlikely that the scene examiner will know the constituents of the marks, general guidelines are most appropriate. In order to produce general guidelines a representative sample set of contaminants must be studied. For this study footwear marks were deposited onto typical indoor flooring materials (laminated, tiles, wood) after walking across a range of contaminants (mud, puddles, wet roads/pavements and wet grass). They were then either lifted directly with a gel lift, or powdered before lifting. Aluminium flake, magnetite flake, black granular and black magnetic were the powders used in this study. Although hundreds of footwear marks were deposited and enhanced, it was believed that the sample set was too small and localised to give specific guidelines. For this reason, general guidelines have been produced based upon the results from a year long study of locally obtained marks from around HOSDB. Some examples are given in Figures 10-12.

⁴ NPIA Footwear Mark Recovery Manual, 2007

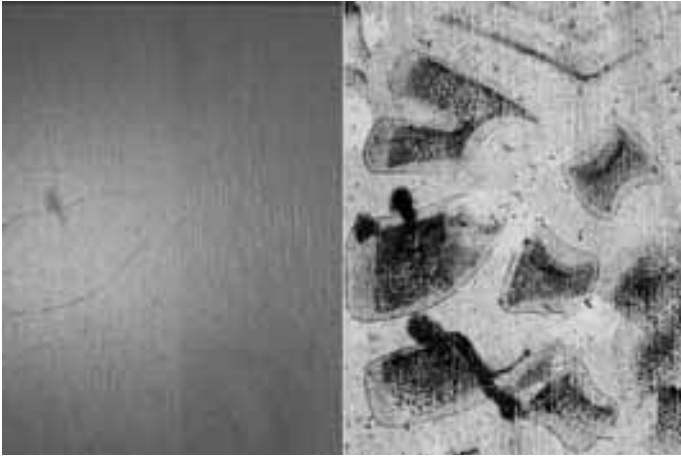


Figure 10: Barely visible wet origin footwear mark (left) recovered from laminate flooring with a gel lifter (right). The gel lift shows not only the 'water mark' but also the tread pattern. Typically, powders would only target the water marks.



Figure 11: Barely visible wet origin footwear mark (left) on laminate flooring powdered with Black Magnetic (right). The powdered mark predominately enhances the water mark. Note the non-visible mark enhanced with powder at the top of the image.

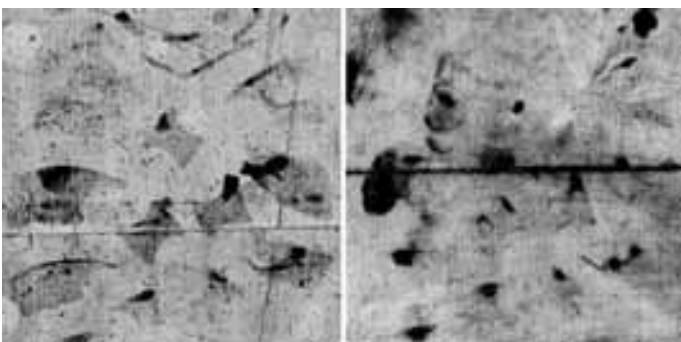


Figure 12: Footwear marks left on laminate flooring after walking through a puddle. The LHS image is a straight gelatine lift of a mark; the RHS image is a gelatine lift of a similar mark that had been powdered with aluminium.

General Guidelines

1. Where appropriate, visible marks should be photographed prior to lifting or powdering.
2. For wet origin marks only, loose particulate matter can be removed from a mark using ESLA, or a very light brushing with a clean, soft brush, so that there is good contact between subsequent lifting materials and the substrate.
3. Gel lifting of the latent mark can result in a mark of higher quality than a powdered mark, BUT gel lifting of a latent mark prior to powdering can reduce the quality of the subsequent powdered mark.
4. Gel lifts of weak latent marks can be difficult to visualise and subsequently image using conventional photography. If specialized imaging equipment, such as a GLScan³, is not available it may be more appropriate to powder the mark, although fine detail may be lost.
5. Powdered marks can generally be lifted successfully with gelatine lifters. If marks are over-powdered or the surface is heavily contaminated, a second lift may give additional detail.
6. Adhesive lifters should not be used to recover latent marks.
7. Adhesive lifters can be used to recover aluminium powdered marks although gelatine lifters will give a better result.
8. If possible, black granular powdered marks should be photographed on the surface.

BLOOD AT CRIME SCENES

In the previous newsletter¹ guidance was given on how to enhance footwear marks in blood on non-porous surfaces using protein stains. Since then, work has focussed on determining best practice for the enhancement of footwear marks in blood on carpet. For this type of substrate, protein stains are typically not practical to use and reactive reagents, such as luminol, are used in preference by forensic service providers and some police forces in the UK. These reagents can be very effective for speculative searching for blood where only small traces may be present. Therefore, although our original brief was to evaluate the use of luminol for the recovery of footwear marks, the study was expanded to cover the general use of these types of blood reagents at scenes.

As part of a scoping study, HOSDB have hosted two workshops (March 09 and January 10). Participants were from a range of backgrounds with expertise including forensic biology, footwear enhancement and comparison, chemical enhancement of marks, blood pattern analysis and training. Forensic service providers, police forces and training centres were represented.

The aim of the first workshop was to discuss current practices, including training, and then

identify gaps and inconsistencies in procedures. It was clear from the discussions that there are many areas of blood enhancement that would benefit from further research and/or guidelines. In particular, it was felt that the police service would benefit from best practice guidelines for the use of luminol at scenes. However, although luminol can be a very effective process, it must be used appropriately by those who are fully trained and competent as it is all too easy to misinterpret or destroy evidence.

Since the first workshop, HOSDB have conducted in-house research on the effectiveness of luminol, including formulation comparisons, application methods, photography and the importance of dark adaptation. A second workshop was organised to discuss if and how our findings should be published taking into account the concerns expressed over user competency. It was agreed that guidelines for the police service should not be issued until further work is completed and training courses are in place, including maintenance of competency after the initial training. Instead we intend to publish our data in a peer reviewed scientific journal.

In the mean time, it is suggested that forces contact Helen Bandey (details on the front cover) if interested in including luminol in their forensic strategy.



Figure 13: Item of blood contaminated clothing where the LHS has been treated with a luminol reagent and the RHS treated with Acid Black 1

PART 2: FOOTWEAR MARK IMAGING

BEST PRACTICE GUIDELINES FOR THE IMAGING OF FOOTWEAR MARKS

Purpose

The purpose of this report is to provide guidelines for the imaging of footwear marks recovered in custody suites, at crime scenes, in photographic units and in chemical treatment laboratories. It provides guidance on how to achieve images of resolution appropriate to the end use of the mark, including intelligence, identification and database storage purposes.

Main Recommendations

1. Imaging of footwear marks should be carried out with the imaging equipment level and perpendicular to the plane of the footwear mark.
2. The image of the footwear mark must contain a reference scale.
3. The imaging equipment and corresponding lighting conditions used for capture of the footwear mark should be appropriate for the type of mark being captured.
4. If photography is used for capturing the footwear mark, the mark should fill as much of the frame as possible.
5. If the image is required for identification purposes, it should be captured at a resolution of 300 pixels per inch (ppi) or greater.

Capturing Footwear Images

In the context of footwear marks, capture is the process of recording a still image of the mark. Prior to image capture the following steps should be taken, in accordance with the NPIA Practice Advice 'Police Use of Digital Images', 2007:

- Obtaining relevant authorisation or displaying fair processing notices, as necessary;
- For digital images, checking image meta data or embedded data (this may include time and date, camera number and location, software version, operator's name, user defined fields, information provided by manufacturer);
- Starting an audit trail before capture or as soon as possible afterwards (ensuring either the equipment/software used records this automatically, or starting a manual audit trail);
- Checking equipment (e.g. ensuring battery is charged and date is correct).

There are several locations where footwear images may be collected, including custody suites where footwear will be taken from suspects, crime scenes where marks will be imaged in situ and laboratories where marks may be developed on exhibits. Each of these locations will impose different constraints on image capture.

Capture Locations

Custody Suites: The requirement in custody suites is to capture a high resolution image of an impression from the sole of the shoe and in some cases an image of the sole of the shoe itself. These images should be capable of being used for intelligence (i.e. pattern recognition) and for identification (i.e. direct matching of features on the suspect's shoe with those in marks recovered from crime scenes).

Crime Scenes: The requirement for crime scene imaging will be to some extent dependent on the detail visible in the mark recovered. In theory, a high resolution image capable of being used for both intelligence and identification should be captured. In practice, a large proportion of marks will only contain sufficient detail for intelligence purposes and a lower resolution image may be acceptable.

Photographic Units/Laboratories: This situation is similar to that at crime scenes, however greater control over image capture conditions should be achievable. It also covers the situation where lifted marks (gel lifts, tape lifts, ESLA lifts) are brought back to a laboratory for imaging.

Capture Requirements

The principal issue for the capture of footwear images is to ensure that there is sufficient detail in the image for it to be fit for purpose. The two main purposes for which footwear evidence may be required are:

Intelligence: This includes a range of applications where the only information required is the general pattern of the shoe making the mark. These may include matching the pattern of the footwear mark recovered from the scene to a known shoe type or linking crime scenes by the occurrence of marks from the same type of footwear.

- For digital images captured for intelligence purposes, a capture resolution as high as is practicable should be selected wherever possible to allow the possibility of subsequent use for identification. Images of as low as 50ppi may contain useful information, but higher resolution should be used if at all possible.

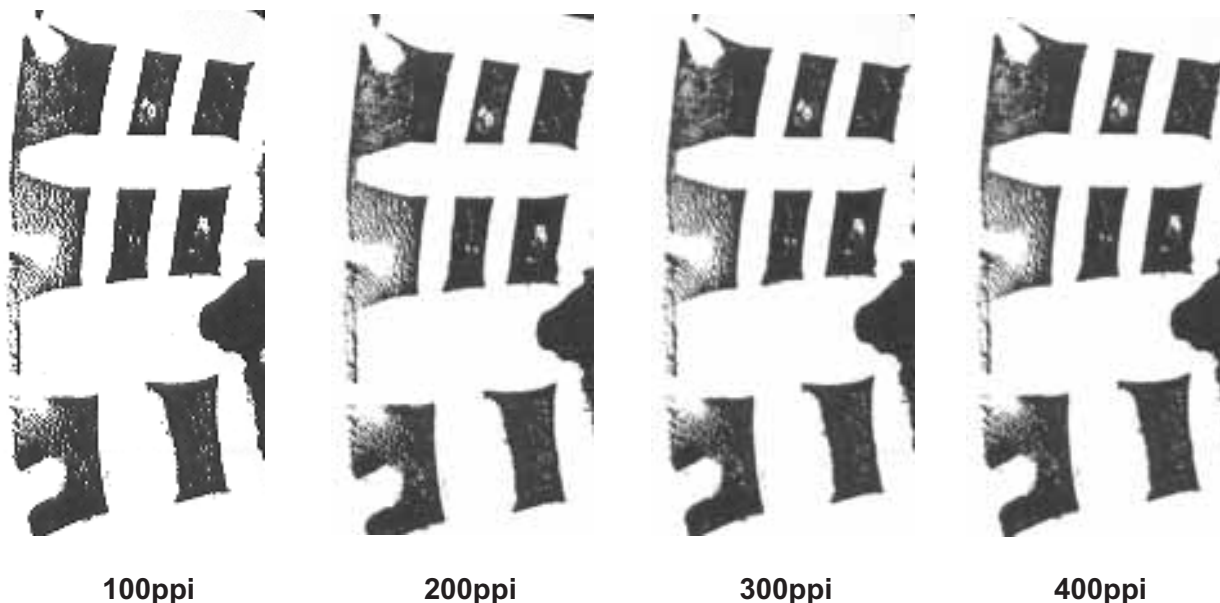


Figure 14: Series of images captured at different resolutions

Identification: This is the positive matching of a crime scene mark to an individual shoe or impression made from a shoe. This is likely to require higher quality, higher resolution images than those used for intelligence alone.

- For digital images captured for identification purposes, a capture resolution of 300ppi or greater should be used.

In general, fine detail of the type required to make identifications from wear features can be resolved in images of 300ppi and above. This is illustrated in the series of images shown in Figure 14.

In addition to these purposes, images may also be stored on databases. The requirements for stored images will be dependent on the functionality of the particular database on which it is stored, and should take in to account the storage capacity available on the police force network. The NFRC database administered by NPIA suggests that images of tread prints (e.g. from PrintScan) are scanned at 200ppi.

The capture resolution requirements outlined above cannot be considered in isolation. To ensure that all pertinent information is captured in the image it is also essential that the mark is appropriately lit and that suitable capture equipment is used. Some guidance on equipment is given in SWGIT guidelines⁵, more specific advice on imaging equipment and lighting for particular types of mark is given in this document.

A wide range of techniques can be used to capture footwear images, including:

- Conventional photography (SLR or medium format)
- Digital photography (SLR or medium format)
- Scanning using 'off the shelf' flatbed scanners
- Scanning using high performance scanners based on linescan cameras (eg GLScan³)
- 3D scanners
- Photocopying
- Chemical pads in custody suites

Not all of these imaging techniques are appropriate for use with the full range of footwear marks likely to be encountered. The selection of the optimum equipment to use should take into consideration both the image quality and resolution required and the type of mark being captured.

Types of Footwear Mark

In general there are five types of footwear mark that may be recovered from a scene or surface:

- Deposition of dry dusty material
- Deposition of a wet material which subsequently dries
- Removal of material already present to leave a negative impression
- Leaving an indented impression in a surface such as soil
- Bruise marks left on skin by contact

⁵ Scientific Working Group on Imaging Technology (SWGIT), Section 10: General guidelines for Photographing Footwear Impressions v1.1, 05/06/2003

In addition to marks recovered from a scene there are the impressions taken from shoes recovered from suspects. These are made in a variety of ways including inked impressions, powdering followed by lifting or commercial products such as Printscan, which uses a chemical pad.

Optimum imaging techniques

Table 4 is provided as a guide to the various imaging techniques that can be considered for different types of mark, together with an indication of those regarded as most appropriate for each scenario.

Further details on the selection of optimum imaging techniques for different types of mark are provided in Appendix A.

Because of the large physical size of footwear marks, it may not be possible to obtain a high resolution

image using some of the items of equipment identified in Table 10. Whereas some capture techniques such as scanners capture at fixed resolutions that may be controlled by the operator, other techniques such as digital photography will rely on the operator setting up the imaging conditions to achieve the required resolution. If possible, a macro lens should be used, and RAW, TIFF (or highest quality JPEG) files should be captured. Further guidance on capture resolutions achievable with different types of digital camera is given in Appendix B.

With the assumption that most footwear marks are of approximate length 300mm, it is possible to calculate maximum capture resolutions for digital cameras of different chip size assuming that the footwear mark fills the frame. This approach gives the approximation shown in Table 5.

Type of Mark	Development/recovery technique	Imaging technique					
		Convention Photo*	Digital Photo*	Flatbed Scanner	Line scan camera	3D scanner	Photo copy
Dry, dusty	ESLA	XX	XX	X	XX	-	-
	Black gel lift	XX	XX	X	XX	-	-
	ESDA	XX	XX	XX	-	-	X
	Direct imaging	XX	XX	-	-	-	-
Dried contaminant	ESLA	XX	XX	X	XX	-	-
	Black gel lift	XX	XX	X	XX	-	-
	ESDA	XX	XX	XX	-	-	X
	Direct imaging	XX	XX	-	-	-	-
	Powdered tape lift	X	X	XX	-	-	X
	Chemical development	XX	XX	-	-	-	-
	Light sources	XX	XX	-	-	-	-
'Negative' marks	ESLA	XX	XX	X	XX	-	-
	Black gel lift	XX	XX	X	XX	-	-
	Direct imaging	XX	XX	-	-	-	-
Indented marks	Casting	XX	XX	-	-	XX	-
	Direct imaging	XX	XX	-	-	XX	-
Bruises	Direct imaging	XX	XX	-	-	-	-
Custody suite marks	Inked impressions	X	X	XX	-	-	X
	Powdered impressions	X	X	XX	-	-	X
	Direct imaging	XX	XX	X	-	-	-

Table 4: Guide to the various imaging techniques that can be considered for different types of mark, together with an indication of those regarded as most appropriate for each scenario. XX - Technique is suited to imaging this type of mark; X - Technique can be used for imaging this type of mark, but is not optimum; - Technique not suited to imaging this type of mark. * For photographic techniques correct choice of lighting, lens and filters will be essential in achieving optimum results – macro lenses are preferable to zoom lenses to avoid image distortion effects

Camera Megapixels	Maximum footwear capture resolution
6.1	250
8.2	300
10.2	330
12.8	370
16.7	425
39	610

Table 5: Effect of chip size on maximum capture resolution

These capture resolutions can be compared to those achievable with the other imaging techniques (Table 6).

Capture equipment	Maximum achievable resolution for 1:1 image
Conventional photography	Equivalent to 8 (SLR) – 30 (medium format) megapixel camera (i.e. >300ppi)
Digital SLR	425ppi
Digital medium format	610ppi
GLScan (based on linescan camera)	1000ppi
Flatbed scanner	1600ppi*
3D scanner	Not known
Photocopiers	600 – 1200ppi*

Table 6: Maximum capture resolution for a range of imaging techniques. *It should be noted that for resolutions much in excess of 600ppi, most scanners and photocopiers will begin to apply interpolation techniques to achieve the stated resolution. Systems using interpolation should only be used at resolutions below the point at which interpolation begins to be applied.

Enhancement/Processing

Captured images of footwear marks may require enhancement or processing to produce an image acceptable for intelligence or identification purposes. This enhancement and/or processing may be carried out by using digital techniques, or by conventional darkroom techniques in locations where these are still in use.

The types of digital processing that may be carried out may be divided into 'Basic' processes that are effectively analogues of conventional darkroom techniques, and 'Advanced' processes that have no conventional analogue. More detailed descriptions of the techniques and their division between 'Basic' and 'Advanced' can be found in the Home Office Digital Imaging Procedure⁶ and in the SWGIT Guidelines on Image Processing⁷.

Examples of 'Basic' processes that may be applied to footwear images include:

- Contrast/brightness adjustment
- Invert
- Mirror
- Rescaling (when an image is to be rescaled to 1:1 at a particular resolution it is important to capture the initial image at a higher resolution so that extrapolation of data does not occur during rescaling).

Examples of 'Advanced' processes that may be applied to footwear images include:

- Greyscale conversion
- Linear filtering (e.g. sharpening)
- Perspective correction (research⁸ indicates that this technique should not be applied to images of footwear taken at angles of greater than 40° off axis)
- Geometric restoration (e.g. correction of effects such as barrel distortion)
- Pattern noise reduction (e.g. removal of patterned backgrounds using Fast Fourier Transforms).

⁶ Home Office/ACPO Digital Imaging Procedure v2.1, November 2007, Publication 58/07

⁷ Scientific Working Group on Imaging Technology, Section 5: Recommendations and Guidelines for the Use of Digital Image Processing in the Criminal Justice System v2.0, 09/01/2006

⁸ Y Shor, A Chaikovsky, T Tsach, 'The evidential value of distorted and rectified digital images in footwear imprint examination', *Forens. Sci. Int.* 160 (2006) 59-65

Guidance from the NPIA⁹ recommends that although 'Basic' processing techniques can be applied by Generalists, 'Advanced' processing techniques should only be used by Specialists with training in image processing and an understanding of the potential effects of the processing techniques on the image⁹. Several commercial programs such as Photoshop and Image ProPlus are available for performing such processing functions. Maintaining an audit trail of any enhancement and processing carried out is essential.

Output

The output media used should be taken into consideration when producing footwear images. Digital printers (whether desk-top printers or mini-labs) typically output images at resolutions in the range 250ppi – 400ppi. This may be less than the original capture resolution of the image and degradation in the image quality may occur during output.

It is therefore recommended that printers with output resolution of at least 300ppi be used for printing of digital footwear images for identification.

APPENDIX A: OPTIMUM IMAGING TECHNIQUES FOR DIFFERENT TYPES OF MARK

ESLA

ESLA marks consist of dust particles attracted electrostatically to a black gloss substrate. The dust particles are lighter than the background and this provides contrast between the mark and background. However, this contrast can be improved by selection of the correct lighting and imaging techniques.

In the case of ESLA marks, the best contrast is obtained by very low level oblique white lighting (custom made LEDs and linear lighting attachments for white light sources are commercially available) and an imaging system perpendicular to the surface, as shown in Figure A1.

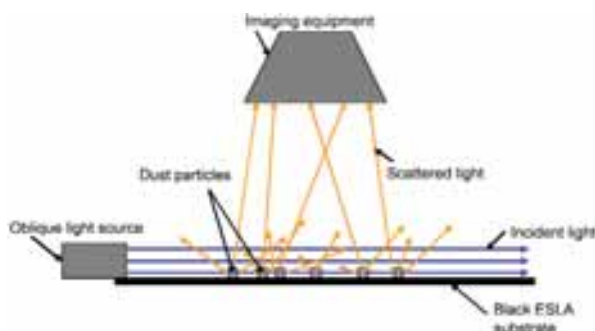


Figure 15: Schematic diagram showing the light scattered from particles on an ESLA film whilst illuminating with an oblique light source

The oblique lighting is angled such that if no particles are present on the surface, no light is reflected towards the imaging system and the black surface of the lift is seen. However, if particles are present on the surface they scatter the oblique light in all directions and some will be reflected into the imaging system, thus appearing white and giving high contrast with the background.

As a consequence, the optimum technique for imaging ESLA lifts is usually by digital or conventional photography with low level oblique lighting. Similar results can be obtained using specular lighting using digital or conventional photography, or using specialist scanning systems such as GLScan. Experimentation with a range of light sources and angles is recommended before image capture.

Flatbed scanners should not be used for imaging ESLA marks because the light source and imaging lens are too close to the dust deposits and the angle of illumination relative to the lens is not optimised to provide contrast in the image.

Similar lighting conditions can be used when imaging dust marks in-situ, prior to lifting using ESLA.

Black gel lifts

Black gel lifts are a very effective means of lifting several different types of deposit from surfaces. They consist of tacky sheets of black gelatine which are placed over marks and smoothed in place. When the gel layer is lifted, the surface may be modified in several ways according to the material originally present. The following effects may be observed, either singly or in combination:

- Loose dust particles from the surface may adhere to the gel
- Layers of grease or contaminant may be picked up by the surface of the gel
- Firmly attached surface particles or features may leave indentations in the gel
- Indentations in the surface will not make contact with the gel but the texture of the surrounding surface may be seen, leaving a negative impression
- Particles of powder used to develop and visualise the mark may adhere to the gel.

⁹ NPIA Practice Advice, 'Police Use of Digital Images', 2007



Figure 16: Schematic diagram showing the types of modification made to the gel surface on contact with a substrate

Black gel lifts are best imaged using high angle, specular lighting conditions with the imaging equipment perpendicular to the exhibit. The lighting should be set such that with no surface features on the gel, the light is reflected specularly from the gel surface and does not reach the imaging equipment, thus the gel appears black. When features are present on the surface they scatter the incident light in several directions or produce a more diffuse reflection, depending on the nature of the surface feature. Some of this reflected light will reach the imaging equipment, thus producing contrast between the black gel surface and the surface features (Figure 17).

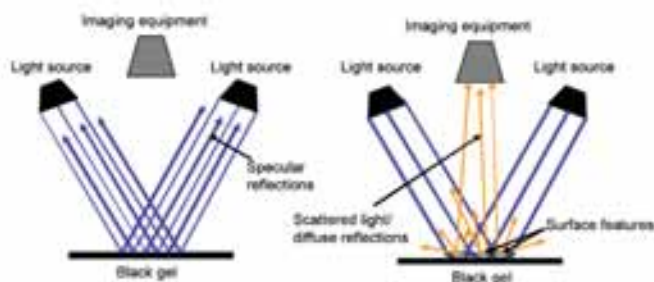


Figure 17: Schematic diagram showing the light scattered from particles on a black gel lift whilst illuminating with high angle light sources

These conditions are best achieved using digital or conventional photography with high angle white lights (e.g. a slide projector or white LED), or using specialist equipment based on line-scan cameras where the lighting has already been optimised and enclosed in a light-tight system (e.g. GLScan).

However, gel lifts should not be imaged using specular lighting alone, they should also be examined in oblique lighting as for ESLA lifts. This is because gel lifts may pick up more than one type of contaminant from a surface and the scattering from one type of feature may obscure that from another. Experimentation with a range of light sources and angles is recommended before image capture.

Flatbed scanners should not generally be used for imaging of black gel lifts, although they are capable of capturing reasonable images when there is high contrast between mark and background, for example gel lifts of powdered marks. In these cases it is necessary to replace the acetate cover layer to prevent the gel lift adhering to the glass plate of the scanner.

ESDA

ESDA is a technique usually applied in the detection of indented writing, but may also be used to detect indentations left by footwear on thin, porous surfaces such as documents and envelopes. The marks are developed by covering the article with a thin layer of clear plastic and applying an electrostatic charge. The charged surface is then cascaded with beads containing black toner particles, which may be preferentially attracted to the indented regions of the mark. The result is a two-tone black and white mark which may be laminated to preserve the features.

Such images can easily be captured by conventional or digital photography, ensuring that the lighting is set to be even across the entire region of interest. Alternatively, flatbed scanners may be used for the capture of marks of this type. They are well suited to the scanning of two-tone images and the close contact between the surface of the ESDA mark and the glass top plate will eliminate any potential reflections from either the laminating layer or the clear plastic layer from the ESDA lift.

Tape lifts

In many cases, footwear marks can be enhanced using powders in a similar manner to the development of latent fingerprints. Both black granular and aluminium powders have been shown to be effective for these purposes. Powdered footmark impressions can be lifted using black gel lifts and imaged using the techniques outlined above. However, powdered footmarks can also be lifted using clear tapes in the same way as powdered fingerprints.

Clear tape lifts can again be imaged using digital or conventional photography. In these cases good results can be obtained using a 'black box' arrangement with incident lighting at 45° to the mark and the imaging system perpendicular to it (Figure 18). The 'black box' is a cavity painted black or lined with a light absorbing material such as black velvet. The principle is that the incident light passes through the clear plastic of the lift and is absorbed within the box, preventing any light reaching the imaging system. If the incident light

encounters any particles of powder it is scattered, and some scattered light will be reflected back to the imaging system, thus providing contrast between powdered mark and background. Note that this scattering will be more effective for aluminium powder compared to black granular.

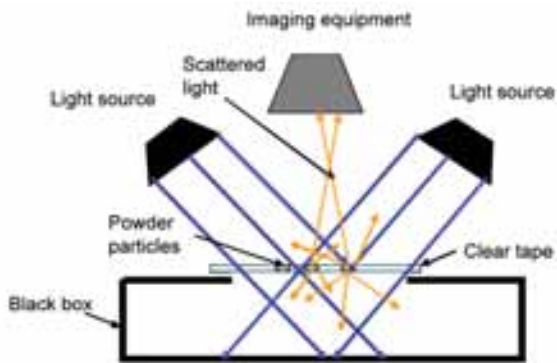


Figure 18: Schematic diagram showing the light scattered from a powder lift on a black box whilst illuminating with 45° angle light sources

Flatbed scanners have also proved to be highly effective in the imaging of tape lifts. By placing a backing of high contrast behind the lift, the scanner can capture the entire image under even lighting conditions. Because the lift is in intimate contact with the glass top plate, there are no reflections from the clear plastic tape.

For aluminium powder lifts, a black gloss paper backing sheet should be used.

For black granular powder lifts, a white gloss paper backing sheet should be used.

Chemically developed marks

Many of the footwear marks developed at crime scenes or in laboratories are developed using equivalent chemical processes to those used for fingerprints. Some of these techniques require the use of specialist light sources and/or filters to optimise visualisation of the mark. Best practices for chemical development and for imaging may be found within the HOSDB Manual of Fingerprint Development Techniques and Fingerprint Detection by Fluorescence Examination.

There are some exceptions to this general guidance, for example chemiluminescent dyes such as luminol-based reagents. It is hoped to provide more comprehensive guidance for imaging marks developed using these chemicals in the future.

Indented marks

When marks are deposited in soft surfaces, the captured image must show the pattern present. This again is best achieved using digital or conventional photography combined with off-axis lighting to reveal the features in the pattern. Preferentially

lighting the impression from one side creates shadows within the mark which may show the pattern in sharp relief. It is good practice to take images with the mark lit from at least two sides so that none of the features present will be obscured by shadow in the combined image (Figure 19).

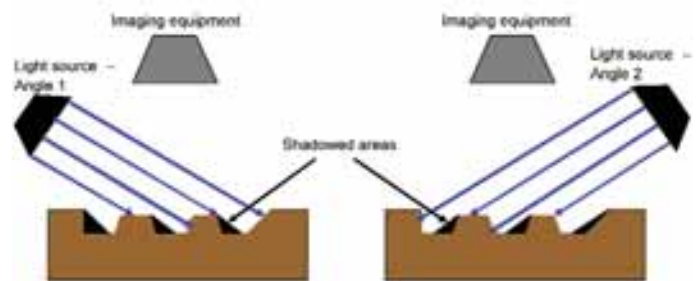


Figure 19: Schematic diagram showing shadows created from indented marks whilst illuminated with off-axis lighting

In some circumstances the impression may be in a very light surface (e.g. snow) or a very dark material. In these situations it may not be possible to image the detail in the mark using lighting alone and it may be necessary to use a coloured spray to reveal the pattern.

3D scanning is a technology that has much potential for the capture of this type of mark, but it has not yet been fully evaluated for these purposes within the UK. It is hoped to provide guidance on the use of 3D scanning techniques in future.

Bruises

The optimum technique for the imaging of bruise marks is conventional or digital photography. Optimum lighting conditions will be dependent on the particular location of the mark and it is not possible to provide general guidelines.

Visualisation of bruise marks may require specialist imaging techniques such as polarised lights, ultra-violet or infra-red photography. It is hoped to provide more detailed guidance on this subject in the future.

Latent marks

Latent marks may be imaged in-situ prior to any chemical development or lifting. Imaging of this type of mark must be treated on a case by case basis according to the conditions at the scene. In general, digital and conventional photography will be the optimum techniques for this type of mark because of the flexibility they provide in terms of light sources and imaging angles. In some cases, use of a diffuse light source at a specular angle from the imaging equipment can reveal marks because of differences in the reflectivity of the deposits in the footwear mark and that of the surface it is deposited on (Figure 20).

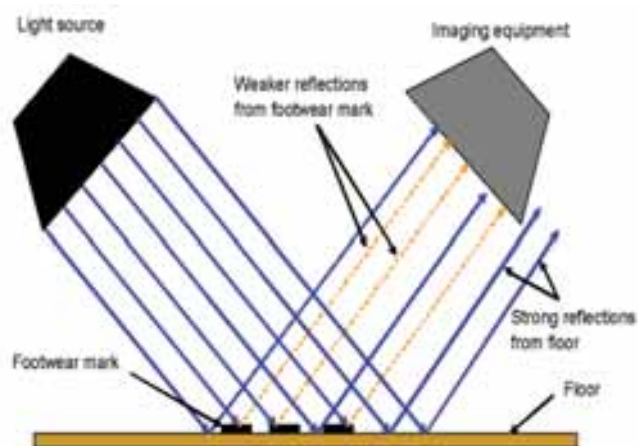


Figure 20: Schematic diagram showing specular reflections from a surface to reveal marks

Specialist photographic equipment such as tilt/shift lenses and 5x4 cameras may be of use in capturing such marks on shiny surfaces or inside exhibits without introducing image distortion.

Custody suite marks

The majority of custody suite marks are either powdered impressions taken from the sole of the shoe, or two-tone black and white images developed using chemical pads such as Printscan. Both these types of mark are well suited to capture by a flatbed scanner or a photocopier, although digital or conventional photography could also be used.

General comments

For most types of footwear mark, black and white photography is preferable because it will provide the best contrast between the footwear mark and the background. Unlike fingerprint images, there is no requirement to utilise a greyscale image for transmission onto a national database and therefore colour photography/imaging should also be used if it is of benefit for the expert carrying out interpretation of the mark. Examples of where colour images may be useful are where coloured marks produced using a chemical process have been developed against a highly patterned background. In these situations being able to follow the single colour of the footwear mark as it crosses different colour boundaries will be easier than trying to distinguish it on a greyscale image.

APPENDIX B: ESTIMATING CAPTURE RESOLUTIONS FOR DIGITAL CAMERAS



Figure 21: 10 Megapixel camera, length of scale along bottom of the image ~330 mm. Equivalent capture resolution ~ 300ppi

For digital photography, it is possible to give an estimate for capture resolution with a knowledge of chip size and by placing a scale along the bottom of the image, as illustrated below.

This value can be calculated for any camera using the equation below:

$$CR = 25.14 \times (P / D)$$

Where

CR = capture resolution in pixels per inch (ppi)

P = the number of pixels on the sensor along the horizontal (long) axis

D = the distance in millimetres of the scale visible along the horizontal (long) axis of the image

ACKNOWLEDGEMENTS

We would like to acknowledge student contributions from Adam Michalik (University of Bradford), Emma Newton (University of Kent) and Jessica Sharpe (University of Bath) for their work on the recovery of dry and wet origin footwear marks; Tom Ciuksza for his contribution to blood enhancement; and Andrew Gibson for his contribution to imaging standards.

Newsletter publications can be downloaded from:

<http://scienceandresearch.homeoffice.gov.uk/hosdb/>

For further information contact: **hosdb@homeoffice.gsi.gov.uk**

ISBN 978-1-84987-168-6