RECOVERY OF LATENT FINGERPRINT ON FIRED AND UNFIRED CARTRIDGE CASE USING CYANOACRYLATE FUMING FOLLOWED BY FINGERPRINT POWDER AND DYE STAINING

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by

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for the degree of
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CERTIFICATE

This is to certify that the dissertation entitled recovery of latent fingerprint on fired and unfired cartridge case using cyanoacrylate fuming techniques research work done by Malarvili A/P Murugason during the period from February 2020 to August 2020 under my supervision. I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted as partial fulfilment for the degree of Master of Science (Forensic Science).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledge. I also declare that it has not been previously for concurrently submitted as a whole for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research and promotional purposes.

....

(MALARVILI A/P MURUGASON)

Date: 9/9/2020

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LIST OF SYMBOLS

ºC	Degree Celsius
±	Plus-minus sign

LIST OF ABBREVIATIONS

CSI	Crime Scene Investigation
CA	Cyanoacrylate
UV	Ultra violet
BY40	Basic Yellow 40
IFRG	International Fingerprint Research Guidelines
LPE	Latent Print Examiner
AFIS	Automated Fingerprint Identification System
ALS	Alternate Light Sources
VMD	Vacuum Metal Deposition
HREC	Human Research Ethics Committee

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ABSTRAK

Cap jari pada kelongsong peluru adalah bukti yang penting untuk menghubungkait pelaku dengan bahan bukti berkaitan dengan senjata api dan tempat kejadian. Walau bagaimanapun, bahan bukti forensik seperti ini sering diabaikan oleh penyiasat forensik. Berikutan itu, satu kajian telah dijalankan untuk menimbulkan cap jari pendam pada peluru dan kelongsong peluru dengan menggunakan teknik penimbulan cap jari kombinasi pengwasapan sianoakrilat dengan serbuk cap jari hitam , serbuk magnet cap jari dan pewarna pendarfluor *Basic Yellow 40* (BY 40). Dalam kajian ini, keberkesanan teknik penimbulan cap jari dikaji pada permukaan peluru dan kelongsong peluru untuk dua jangka masa yang berbeza iaitu 24 jam dan 7 hari. Sebanyak 540 peluru telah digunakan dalam kajian ini. Cap jari pendam yang berkualiti dapat ditimbulkan dengan menggunakan kombinasi teknik penimbulan pengwasapan sianoakrilat dan pewarna pendarfluor (BY 40). Hasilnya juga dapat dilihat dengan jelas dengan bantuan pencahayaan ultraviolet (UV). Cap jari jenis ekrin sukar ditimbulkan menggunakan teknik penimbulan cap jari berbanding dengan cap jari jenis sebum dan semula jadi/ asli. Cap jari yang ditimbulkan pada kelongsong peluru menghasilkan cap jari kualiti yang rendah akibat daripada proses menembak yang menghasilkan haba yang tinggi dan telah menjejaskan jalur cap jari pada kelongsong peluru. Jangka masa yang panjang antara waktu pemendapan cap jari dan waktu penimbulan juga telah menjejaskan kualiti cap jari yang ditimbulkan. Ini menjelaskan kepentingan penimbulan cap jari pada bahan bukti

dalam lingkungan jangka masa yang pendek. Kesimpulanya, kombinasi sianoakrilat dengan *Basic Yellow 40* (BY40) didapati berjaya menimbulkan cap jari yang berkualiti pada peluru hidup tetapi cap jari yang ditimbulkan pada kelongsong peluru tidak menunjukkan kualiti yang baik. Kajian ini telah membuktikan bahawa cap jari pada peluru hidup dan kelongsong peluru adalah satu bukti yang lebih penting dan harus diberi fokus ketika menjalankan siasatan forensik dalam kes-kes yang melibatkan senjata api.

RECOVERY OF LATENT FINGERPRINT ON FIRED AND UNFIRED CARTRIDGE CASE USING CYANOACRYLATE FUMING FOLLOWED BY FINGERPRINT POWDER AND DYE STAINING

ABSTRACT

Fingerprint on a cartridge case is a crucial evidence to link the perpetrator to firearm related evidence and the crime scene. However, such forensic evidence is often overlooked by the forensic investigator. A study was undertaken aiming to recover fingerprints using combination of cyanoacrylate fuming fingerprint enhancement technique with magnetic and regular powder dusting, as well as the basic yellow 40 (BY 40) florescent dying. In this study, the effectiveness of fingerprint enhancement technique on recovering fingerprints from the surface of unfired and fired cartridge cases at two different time duration between deposition of fingerprints and application of enhancement techniques was evaluated. From a total of 540 unfired and fired cartridge cases tested in this study, the best outcomes for enhancement of fingerprints was obtained through a combination of cyanoacrylate with basic yellow 40 technique. The usage of compatible lighting source would further increase the chances of obtaining the better marks. No significant difference was observed on the developed fingerprints on latent sebaceous and natural fingerprints, but eccrine fingerprints were found more difficult to develop using the enhancement technique. Upon firing, the fingerprints deposited on the cartridge cases were also less likely to be developed through enhancement technique, indicating the firing process had introduced damage on the ridge details. With extended time elapsed of fingerprint deposition, the chance of successfully development of fingerprints were also slightly reduced, suggesting the importance of fingerprint development within the shortest

duration. To conclude, a combination of cyanoacrylate with basic yellow 40 was found successful in recovering fingerprints from unfired cartridge cases but lower chance of successfully development was reported with fired cartridge cases. It is hoped that this study had provided important clue on the presence of such important evidence in the crime scene, particularly forensic cases involving firearm.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Fingerprint is a crucial evidence to link the perpetrator to evidence and crime scene. Since the unique ridge pattern of a fingerprint can be used for individualisation, fingerprints are vital piece of evidence. Conviction of a forensic cases is highly dependent upon proving beyond reasonable doubt whether a fingerprint was deposited when a crime was committed or from previous legitimate visit as it is often claimed by defendant team (Cadd et al., 2015).

Fingerprint can be potentially deposited on any substrate in crime scenes. These fingerprints are largely invisible and require optical, physical, chemical or combination of these techniques to enhance or differentiate from the substrate material. The surface where the fingerprint deposited can generally be divided to two categories, namely porous and non-porous surfaces. Typical non-porous surfaces include metal, plastic, glass, and glossy painted surfaces. Metallic surfaces are commonly found in crime scene such as car doors, cabinet door, tools made of steels, weapon and handles. Guns are generally made of steel, while cartridge casings may be made of any number of metals and alloys (mixtures of metals) including brass, copper, nickel, steel, or aluminum (Kulnides, 2014).

Visualisation of latent fingerprints on discharged cartridge casings could provide good forensic evidence, especially if the casing is recovered at the crime scene after a firearm has been discharged. In these conditions, a fingerprint can link an individual to the casing before it was loaded into the firearm and hence, potentially, provide a link to the perpetrator of the crime.

1.2 Problem Statement

In Malaysia, crime scene investigations are mainly handled by the Royal Malaysia Police personnel. Fingerprint is the unique and important evidence where crime scene investigator mainly searches for during almost all the crime scene investigation. In most shooting cases, spent cartridge cases are frequently found in the crime scene. In such cases, fingerprints could also be potentially found on the surface of spent cartridge cases due to the action when a live ammunition is introduced into a magazine.

This study mainly focused on whether a deposited fingerprint can still be recoverable upon combustion of an ammunition in certain time frame. The heat and combustion from firing process could potentially damage or disrupt the fingerprint composition on a firearm or ammunition. Before a bullet is loaded into a firearm, it is presumably handled and left with fingerprints. After a firing activity, the spent casing will be ejected from the firearm, and it could be found in the crime scene in most instances. As a result, the fingerprints left on casings found at a crime scene could be an important evidence to introduce or help convict a suspect.

To the author’s knowledge, there are few studies about the methods to develop fingerprints on brass cartridge casings. Fingerprints are rarely recovered from fired cartridge casings due to some factors during the firing process. One factor affecting the likelihood of developing a fingerprint from a casing is the friction between the casing and the firearm through the firing process.

Friction occurs between the magazine and casing when the casing is loaded into the magazine. Friction also occurs when the casing enters the chamber before firing and when the casing is ejected from the chamber after firing. Furthermore, exposure to high temperatures and combustion gases during the firing process may change the composition of oils and sweat from a fingerprint on a casing that are useful in the development and recovery of forensic evidence (Champod et al., 2005).

Therefore, the enhancement of fingerprint evidence from firearm and ammunition recovered from crime scene can be critical in identifying, charging, and ultimately convicting suspected criminals. For this reason, latent fingerprint evidence potentially found on the firearm and ammunition should be enhanced and recovered similarly as other evidence such as gunshot residue and tool mark evidence.

1.3 Objective

1.3.1 General Objective

This study aims to investigate the effectiveness of fingerprint enhancement technique on fingerprints found on fired and unfired cartridge case.

1.3.2 Specific Objective

i. To recover latent fingerprint using cyanoacrylate fuming followed by fingerprint powder and dye staining.

ii. To investigate the possibility to recover fingerprint from fired cartridge cases upon shooting.

iii. To analyse and evaluate the fingerprint using the U.K Home Office's Grading System.

1.4 Significance of Study

This research is designed to provide better understanding and as a guidance, especially for Forensic Division, Crime Investigation Department of Royal Malaysia Police. RMP, as a law enforcement agency, conducts crime scene investigation on forensic cases involving firearm and ammunition. The study on the effectiveness on utilising existing latent fingerprint enhancement method to detect and recover fingerprints could provide important hint on the presence of such important evidence in the crime scene. This research can also be used to aid in investigating unsolved firearm related cases throughout the past years in RMP crime data.

CHAPTER 2

LITREATURE REVIEW

2.1 Fingerprint Background

A fingerprint, or fingermark, is an elevated area of minutiae ridges found on the surface of the skin of every finger of human. These structures are referred to as friction ridges. Friction ridges are found not only on the fingers but also on the palms of the hand and on the soles of feet. The word “palmer” refers to the hand, namely the palms of hands, finger joints, and fingertips. The word “plantar” refers to the bottoms of the feet and toes.

Friction ridges are almost like curve on mountain. They are very similar to mountains which had been pushed up through the earth’s crust to the surface. In other words, friction ridges are pushed up through the layers of epidermis to the surface of the skin. Though friction ridges all seem to be of constant width and height when observed under low magnification, however, they are varying in terms of their width, height, and contour.

Friction ridges are also punctuated with sweat pores of varying size and contour. Friction ridges create a rough, textured surface that gives resistance between our hands and anything we touch. Each fingerprint consists of a special pattern of friction ridges and dozens of minutiae characteristics. Fingerprint analysts determine whether impressions of unknown origin and impressions of known origin may come from a similar source by utilizing these patterns, locations, types of characteristics, and other information from the friction ridges (Daluz, 2019).

2.2 Formation of Fingerprint

Initial contact involves an interaction between the finger and a substrate. The characteristic of an initial contact determines whether a possibly identifiable fingerprint is made on the surface. The contact result is often weakened into three stages as follows:

a. Application of the finger to the surface
b. Transfer of material between the finger and the surface
c. Removal of the finger from the surface

During the application of finger onto the surface, positive pressure is applied by the finger until both finger and the surface have deformed to their full extent. Transfer of material could also occur during the contact. Whether material is transferred from the finger to the surface or vice versa depends upon what substances are present and their relative affinities between the finger and surface.

2.3 Types of Fingerprint

Fingerprints could be found on any solid surface, including on the human body. Forensic analysts generally classify fingerprints into three categories consistent with the types of surfaces on which they are found and whether they are visible. In additionally to two dimensional fingerprints, such evidence is also likely to be appeared in three-dimensional plastic prints.

Those on hard surfaces can be found either patent or latent prints. Patent prints could be formed when blood, dirt, ink, or paint is successfully transferred from a finger to a surface, and they are readily found on a wide kind of smooth, rough, porous, and non-porous surfaces. On the other hand, latent prints are formed when natural oils and sweat from the skin are deposited onto another surface.

These prints are often found on various surfaces; however, they are not readily visible. Therefore, their detection frequently requires the application of an optical, physical or chemical treatment in order to visualize a latent fingerprint (Lennard, 2007). In term of the types of surfaces where fingerprint deposited on, the manufacturing processes, raw material and also the respective end use might display different physical and chemical properties, affecting the recovery and enhancement of fingerprints (IFRG, 2014). Generally, the smoother and less porous a surface, the greater the potential to develop latent fingerprints from the surface.

2.3.1 Positive Marks

Positive fingerprints form when residues are transferred from finger to the surface (Daluz, 2019). The fingerprint could be either visible or invisible to the naked eye depending upon the contaminants with a colour substance (e.g.: blood, ink, paint), reflectivity of the surface and composition of the residue (Figure 2.1). Positive marks are mainly found on the crime scene which may lead to the suspect. Figure 2.1 shows the schematic diagram showing the deposition of a positive mark.

Based on the visibility of the fingerprints, 'patent' marks are those which could be seen by naked eye because of the contaminant that contrasts in colour with the background, such as blood or dirt. Figure 2.2 shows an example of patent mark deposited with mud on white-painted chipboard. On the other hand, 'latent' marks are those are invisible for naked eye and need enhancement technique.

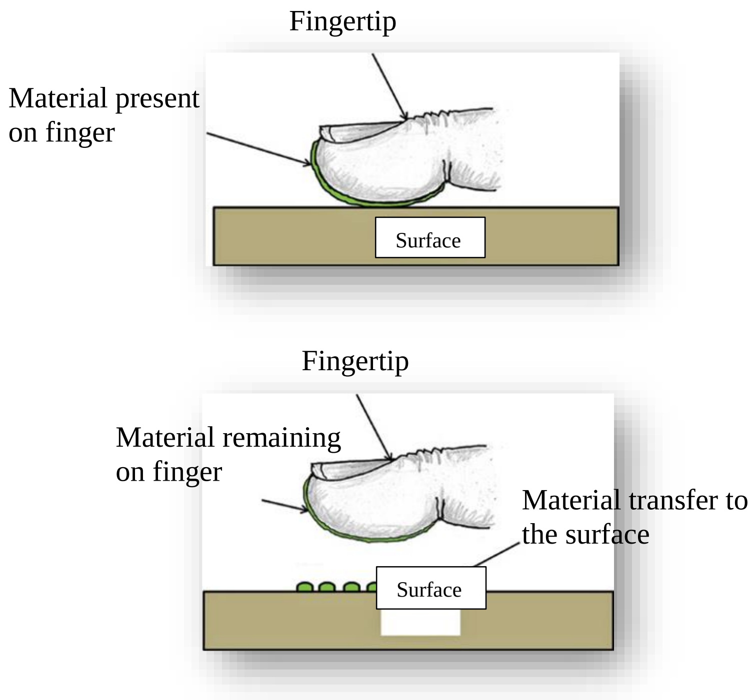

Figure 2.1: Schematic diagram showing the deposition of a positive mark (Bleay et al., 2018)

Figure 2.2: A patent mark deposited with mud on white-painted chipboard (Bleay et al., 2018)

2.3.2 Negative Marks

The surface covered with loose residues, such as dust or dirt, or thin layer of contaminants could produce negative marks (Daluz, 2019). Upon the finger contact on a surface, some of these residues or contaminant might be adhered to the finger, thus leaving negative impression of the ridge detail in the material leftover on the surface. Figures 2.3 and 2.4 show the schematic diagram showing the formation of a negative mark and an example of negative mark. Negative marks extremely fragile and less common than positive marks.

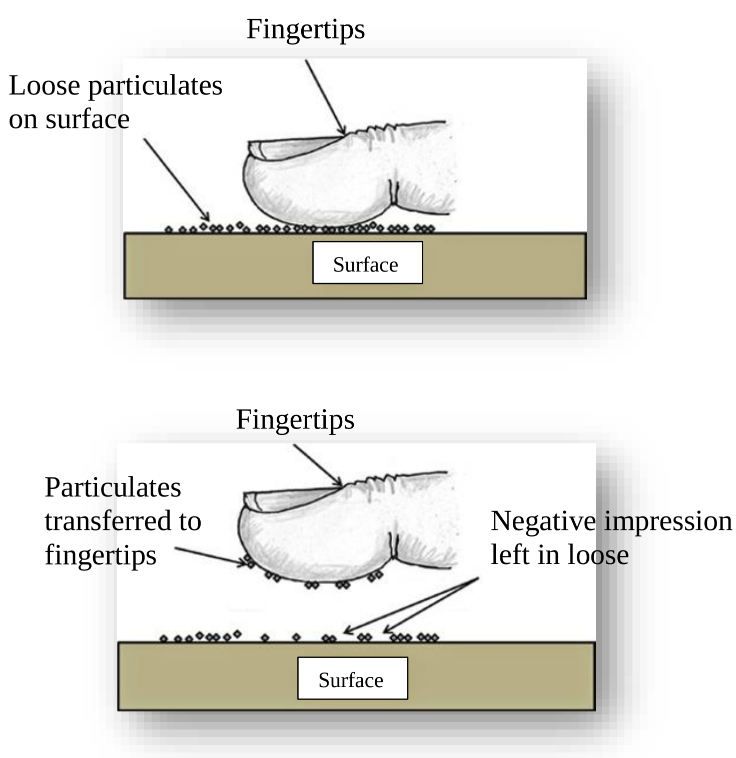

Figure 2.3: Schematic diagram showing the formation of negative mark. (Bleay et al.,2018)

Figure 2.4: Example of a negative mark left by contact with a dusty surface and enhances with oblique lighting. (Bleay et al., 2018)

2.3.3 Impression

Impressions may be formed in cases where the surface can melt or deform during contact. Surfaces made of soft substances (e.g. putty, wet paint) may permanently deform, leaving an impression of the ridge detail in the surface. Figure 2.5 illustrates the schematic diagram showing the formation of an impression in a soft surface. Such fingerprints deposition was also noted as ‘plastic’ fingerprints, because the deformation caused by the interaction of the finger with the surface is plastic. The deposition is also irreversible in nature. Impressions are encountered much less often than positive marks on operational material.

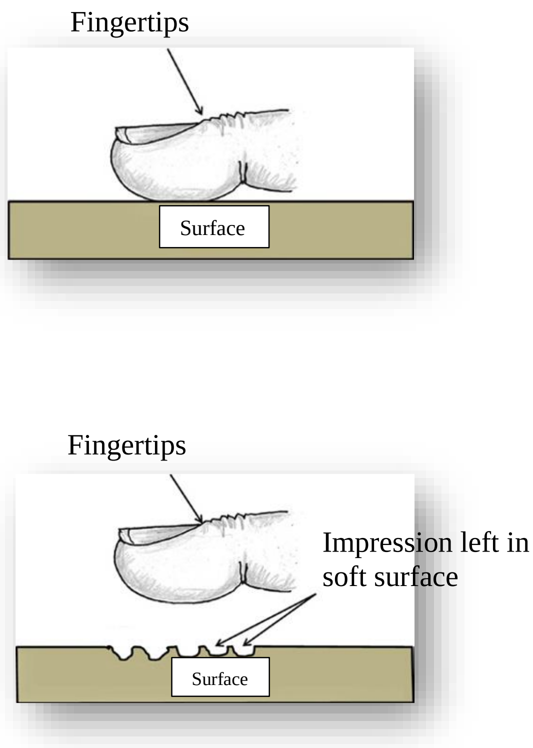

Figure 2.5: Schematic diagram showing the formation of an impression in a soft surface. (Bleay et al., 2018)

2.4 Natural Sweat

Fingerprint are complex mixture of natural secretions of glands within the skin. The essential constituents of a fingerprint are comprised of 95-99% water, as well as organic and inorganic compounds, forming a complex blend in some three-dimensional matrices (Cadd et al., 2015). Three primary glands contribute to the production of sweat, namely the sudoriferous glands (eccrine and apocrine), and sebaceous glands. Each gland contributes a unique mixture of chemical compounds. These compounds are often exuded from pores onto the friction ridges or are transferred to the friction ridges through touching a surface (Alcaraz et al., 2013).

Latent fingerprint deposits are made from varying combination of exudations from these two types of gland and while one form of secretion may predominate, either no pure eccrine or purely sebaceous deposit. As fingers contacts with the surface it’s quite common, fingerprints should have been present in a crime scene. Forensic investigators should correctly determine the combination of fingerprint recovery techniques to obtain important information on the identity of the fingerprint owner (Lennard, 2007) .

2.5 Eccrine Sweat

Eccrine glands are present all over a body with no exception, playing a crucial role in fingerprint composition. It is basically a tubular shaped structure with a duct portion that coils in helical fashion down deep into the dermis layer. The function of distal half of the sweat gland tubule is to re-absorb sodium, chloride, bicarbonate, glucose, and several other small solutes into our body system.

Under normal conditions, they allow water to be evaporated from the skin surface without the loss of essential solutes. Eccrine glands typically contain excessive water up to 98%. Additionally, such glands also contain numerous organic and inorganic constituents. The glands contribute amino acids which are primary compounds of a latent fingerprint. Serine, glycine, and alanine are the foremost abundant amino acids. Threonine, leucine, tyrosine, isoleucine, lysine, phenylalanine, methionine and cystine are present in lower amounts (Cadd et al., 2015).

2.6 Sebaceous Sweat

Sebaceous glands are small sac-like organs and may be found within the dermis layer of skin. They can be found throughout the body and are related to body hair except on the hands and feet. These glands secrete sebum, making major component of fingerprint composition. However, it was also noted that sebum can also present on the palm and hands after contact with other part of the body (Cadd et al., 2015). Sebum composition is very complex, including fatty acids, wax esters, triacylglycerol, cholesterol and squalene.

2.7 Fingerprint Pattern

In general, fingerprint patterns could also be divided into three large groups, namely an arch, a loop, or a whorl, each of which bears an equivalent general characteristics or family similarity. Figure 2.6 illustrates the three basic fingerprint patterns. The patterns may be further divided into sub-groups due to the smaller differences existing between the patterns within the same general group as described in Table 2.1.

Table 2.1: Fingerprint pattern groups

Fingerprint Pattern Group			
General Groups	Arches	Loops	Whorls
Sub Groups	• Plain Arch • Tented Arch	• Radial Loop • Ulnar Loop • Nutant Loop	• Spiral • Concentric • Lateral Pocket • Central Pocket • Twin Loop • Composite • Almond

Source: (Central Criminal Registry of Malaysia and Singapore, 2005)

Figure 2.6: The three basic fingerprint pattern types: arches, loops and whorls. (Daluz, 2019)

Ridge flow is an illustrative method of describing how the friction ridges form the patterns. Most fingerprint pattern types have one or more of the subsequent features formed as a results of ridge flow, referring to core and delta. The core of a fingerprint, like the core of an apple, is the center of the pattern (Figure 2.7). It is the important point around which the ridges flow. The second feature of most fingerprints is the delta (Figure 2.8). A delta is a region of friction ridge skin where ridge paths flowing in three different directions create a triangular pattern. These patterns appear almost like lake or river deltas, *i.e.* areas where the flow diverges.

Figure 2.7: The core of a loop pattern. (Daluz, 2019)

Figure 2.8: The delta of a loop pattern. (Daluz, 2019)

2.8 Triangle of Interaction

As described in the previous sections, a fingerprint originated from fingers can probable be deposited on a substrate. In other words, the residues from the fingers are successfully transferred onto the substrates forming positive fingerprints, whether latent or patent in nature. Upon deposition of fingerprints, the residues will interact with the substrate, and as well as the surroundings.

In most instances, the recovery of fingerprint is not carried out instantly after its deposition; therefore, it could be subsequently subjected to ageing and exposure to any environmental insults simultaneously. Persistency of fingerprint depends on the age of fingerprint which is operationally rare that the fingerprint of interest was freshly deposited. Like all materials, fingerprint undergoes changes over time. The aged composition of fingerprints could be resulted from the chemical, biological and physical processes occurring over time on the initial composition of fingerprints (Girod, 2012). After such interval, whether the fingerprint continues to be present on the substrate and viable for recovery is questionable.

A concept of the “triangle of interaction” was proposed, in which the composition of fingerprint, the nature of the substrate, as well as external conditions of the deposited fingerprints are respectively located at each corner. Time elapsed between the deposition and recovery procedure is also of importance, as it might affect the extent of interaction among these three parameters. Interactions after deposition of fingerprints can occur and these determine whether a fingerprint evidence on a surface can survive the surrounding at a certain time interval.

Note also that the interaction could occur between the surface and the surrounding restricting the forensic procedure, but a substrate is usually more resistant than fingerprint towards the effects of the surrounding. Upon exposure, the fingerprint on any surface may survive completely or remain only with certain constituents of fingerprint. This is, therefore, crucial to select the most appropriate fingerprint recovery and enhancement procedures.

2.8.1 The Fingerprints

Friction ridge impressions recovered from crime scenes or evidentiary items are known as latent prints. The word “latent” is extracted from the Latin word meaning “hidden.” Latent prints are invisible friction ridge impressions of unknown origin. Chemical composition of residues would affect the possibility to recover the latent fingerprints.

Formation of latent fingerprints is affected by many factors, including age, sex, stress, metabolism, diet, health, occupation, as well as the quantity and quality of finger contamination. In fact, the quality of fingerprint was also highly dependent on the instant when a fingerprint was deposited on a substrate. The conditions refer to the pressure, the contact duration, the time of day during deposition (*i.e.* morning, afternoon, and night), the dimension of the fingertip area in contact with substrate, the finger itself and the washing of hands.

Pressure and contact duration between finger and substrate affect the initial composition of fingerprint. Influence of time of the day was not a significant influence over the initial chemical composition of fingerprints. However, it could affect the fingerprint residues due to certain metabolism aspects (Girod, 2012). In literature, more robust conclusion and result should involve more subjects and samples as every single finger in each hand might carry different angle and pressure during deposition of fingerprint ((IFRG), 2014).

Fieldhouse (2011) studied on the consistency and reproducibility in fingerprint deposition through a fingerprint sampler designed and constructed to facilitate the deposition of fingerprint under controlled condition. A comparison of fingerprints demonstrated that a fingerprint sampler had facilitated the deposition of fingerprints with statistical significantly higher quality than fingerprints deposited without its use.

Merkel et al. (2011) also investigated on how contact, pressure, contact time, smearing and oil/skin lotion could influence the aging of latent fingerprint traces using optical, non-invasive image sensory in combination with an aging feature called "Binary Pixel'.

The parameters of approximated aging curves from the study suggested that the application of fingerprints with different contact time, contact pressure, smearing of fingerprint or contamination of oil seems to have no significant influence on the ageing process, except contamination with substances containing water that could increase the speed of aging (Merkel et al., 2011).

2.8.2 The Substrates

A substrate could determine the formation of fingerprints during initial contact and decide the subsequent phenomenon of fingerprints once they are transferred onto the substrate. Two properties play the important roles, namely the substrate porosity and substrate chemistry. After deposition, whether a fingerprint will remain on a substrate or migrate into the substrate to certain extent are highly dependent on the substrate porosity (Bleay, 2018).

Influence of the surface on the fingerprint composition depends upon porosity of the substrate and its capacity to retain compounds. This will be dependent upon its texture physio-chemical structure, curvature, temperature, electrostatic forces, and surface free energy that related to surface tension (Girod, 2012). Different types of surfaces and their respective absorption characteristics on the formation of fingerprints are summarized in Table 2.2.

Referring to Table 2.2, a fingerprint deposited remains on top of the non-porous substrate without any penetration. On non-porous substrate, fingerprints spread across the surface determined by wettability of the surface as well as the pressure of application. After application, the physical profile of fingerprint gradually shrinks as it dries out with the loss of water content (Champod et al., 2004).

Table 2.2: Summary of the different types of surface and their fingerprint residue absorption characteristics

Surface nature	Characteristics	Examples
Porous	Eccrine compounds are rapidly absorbed.	Paper, Cotton, Wood
Semi Porous	Eccrine compounds can be absorbed but need much more time than on porous surface. Sebaceous compounds are absorbed slowly and need more time than eccrine compounds.	Varnished wood, waxy surfaces, plastics, glossy papers

Table 2.2: Continued

Non-porous	All fingerprints compounds (*i.e.* eccrine and sebaceous) stay on the surface of the surface.	Glass, metal, paint, plastics

Source: (Girod, 2012)

The composition of the fingerprints will also be changed. On the other hand, the fingerprint residues can migrate into porous substrate, depending the substances that made the substrate. On porous surfaces, a fingerprint wets a substrate and most of the constituents from the fingerprint are absorbed into the substrate. A small proportion of insoluble constituents might remain on the substrate while the water in the residues carries the water-soluble constituents are migrated into the interior of the substrate. Intermediates between porous and non-porous substrates are semi-porous substrates that exhibit mixed properties.

On such substrates, certain amount of fingerprint residues remains on the surfaces while another limited proportion diffuse into it. Surface chemistry covers the water affinity (hydrophobic or hydrophilic), chemical reactivity or inertness, and the degree of difference in term of chemical behaviors between the fingerprint and substrate. Surface characteristic is an important consideration when selecting a technique, or sequence of techniques, for fingerprint detection. Properties of an unknown substrate must be considered before any attempt is made to develop latent fingerprints. Therefore, varying substrates would have different fingerprint outputs, leading to different selection of subsequent recovery and enhancement procedures.

2.8.3 The Environment

After deposition of fingerprint onto the surface, both were exposed to the environment conditions such as humidity, light exposure, temperature, rain, condensation, dust, air circulation, friction and contaminants present in atmosphere. These environment variations can significantly affect how the fingerprint composition degraded over time. Based on research it found out that main component of fingerprint residue such as lipid changes over time under different environmental conditions and fatty acids loss les rapidly in dark environment. Some studies have explored that increasing in temperature can lead to water loss and amino acids compared aging at room temperature (Cadd et al., 2015).

2.9 Latent Fingerprint

There are enhancement techniques to recover latent friction ridge impressions from objects of evidence or from surfaces at crime scenes. These techniques include the use of various powders, powder suspensions, and chemical reagents. The Latent Print Examiner (LPE) is a forensic scientist who compares evidentiary prints with record prints to determine whether they may have originated from the same source. LPEs may also recover evidentiary fingerprints from crime scenes and/or from items of evidence in a laboratory. If the suspect is unknown, an LPE may choose to search the evidentiary friction ridge impression in the Automated Fingerprint Identification System (AFIS).

2.10 Latent Print Development

Evidentiary fingerprints are often referred as latent, whether or not they are truly invisible. Evidence supports that latent fingerprints have only 20% water immediately after deposition (Hagan & Green, 2018). Latent prints are made visible using a variety of optical, chemical, and physical development procedures. Various choices of powders and chemical reagents are available for processing latent fingerprints, depending on the porous, semi porous, and nonporous surfaces. There are also chemical reagents available for enhancing patent (visible) prints, which may consist of a bloody or oily matrix.

The type of processing method chosen will depend on the condition and type of substrate; the composition of the latent fingerprint; the regional location and its unique atmospheric conditions; as well as the availability of powders, suspensions, and chemical reagents in the laboratory. Usually, the resulting visible fingerprint may appear to be a specific color, or it may be fluorescent and therefore more readily visible with alternate light sources (ALSs) or lasers. Fingerprint development techniques are also often broken down into physical processing methods and chemical processing methods. Physical processing implies that fingerprint is physically enhanced using various fingerprint powders and brushes. Chemical processing refers to the use of chemical reagents to achieve the same purpose.

Accurately determining the type of substrate predicted to have a fingerprint is an important step for successfully recovery and enhancement. Enhancement of latent fingerprints requires the application of an appropriate sequence of methods, depending on the nature of the surface, the circumstances of forensic case under investigation, and the resources available to the fingerprint analysts. Such sequences, consisting of complementary detection methods from the least destructive to more destructive, need to be optimised and validated under local conditions before casework implementation (Marriott et al., 2014). In general, after a surface is identified, a systematic search for latent fingerprint evidence can be carried out by:

- visual inspection with appropriate forensic light source.
- sequential latent fingerprints processing.
- documentation of developed fingerprints at each step.

Various fingerprint detection techniques had been developed and investigated throughout the years, as demonstrated in Table 2.3 (Bleay et al., 2018). Based on the different scene of crime, strategies to be adopted for the development of fingerprints will be different, which could be decided by:

- nature of evidence (porous, semi-porous or non-porous)
- circumstances of a forensic case (indoors or outdoors, dry or wet substrate, clean or dirty substrate, hot or cold surroundings etc.)
- ability to transport the items with fingerprints to the laboratory (whether a fingerprint can be enhanced on-site or requires use of special instrument or apparatus)
- potential detrimental effect of the technique against the evidence (whether the evidence requires any subsequent analysis) (Chadwick, et al., 2018)

Table 2.3: Fingerprint detection techniques

Techniques	Substrates	Types	Reaction
Forensic light Source	Porous and Non-porous	• Ultra-violet light • Visible light • Infrared light	- Initial process before any enhancement method. - Oblique lighting: light is shone at a shallow angle to create contrast with light and shadow. - Non-destructive process.
Fingerprint powder	Non-porous	• Granular powder (black, white, and bi-chromatic) • Magnetic powder (black, bi-chromatic, and/or fluorescent) • Fluorescent powder (many colors available • Metallic flake powder (aluminum, copper) • Nanopowders • Infrared powders	- Powder particles adhere to the oil and water constituents of latent print residue. - Fast, effective, and low-cost. - Used on dry, non-porous surfaces. - More effective on fresh fingerprints.

Table 2.3: Continued

Chemical	Porous	Ninhydrin	- Reacts with amino acids and other amine-containing compounds in fingerprint residues. - Ninhydrin is applied by dipping, painting, or spraying the aqueous solution. - The chemical reacts with proteins and amino acids to form a purple color, known as Ruhemann purple.
		1,8-diazafluoren9-one (DFO)	- Highly fluorescent fingerprint reagent. - Reacts with amino acids in fingerprint residues. - A superior fingerprint reagent as compared with ninhydrin. - DFO is applied to the substrate by dipping, spraying, or painting. - Produces a strong fluorescent reaction that is not readily seen with naked eyes.
		Indanedione (1,2-indanedione) (indanedione–zinc)	- Reacts with the amino acids in fingerprint residues, although it reacts with different amino acids from ninhydrin. - Visible fingerprints are pink in colour and lighter than Ruhemann's purple
		Physical developer	- Amino acid reagents are relatively fast, easy, and sensitive processes for developing fingerprints on porous items - Can be used in sequence with the amino acid reagents, but it must be used after treatment with amino acid reagents.
	Non-porous	Cyanoacrylate Ester: Superglue® Fuming	- The result is white, 3D friction ridge impressions. - The process effectively "glues" fingerprints to the surface of an object, making them more durable. - CA fuming, a monomer of CA is attracted to the latent print residue. - Two most popular methods are fuming chamber method and vacuum chamber method.

Table 2.3: Continued

	Cyanoacrylate Dye Stains	- After CA fuming, dye stain is then applied to the item. - This process is known as dye staining. - Luminescent (glowing) dye stains selectively adhere to CA polymer deposited along the friction ridges. - Dye stains are easy to use - The common dye stains used in forensic laboratories are: a) Rhodamine 6G (R6G) b) Ardrox c) 7-(p-methoxybenzylamino)-4-nitrobenzene-2-oxa-1,3-diazole (MBD) d) Basic yellow 40 (BY 40).
	One-Step Fluorescent Cyanoacrylate	- CA dye complexes are mixtures of dye and CA. - Resulting compound is a one-step fuming process that both fumes the print and dye stains it. - It saves time since the analyst does not have to treat the item with a separate dye stain.
	Vacuum Metal deposition	- The process of VMD utilises small amounts of metals vapourised in a vacuum chamber. - The vapourised metals adhere to the surface of an evidentiary item everywhere except along the friction ridges. - VMD was shown to be five times more effective at processing latent prints on fabrics than CA fuming.

Source: (Bleay et al., 2018)

2.11 Forensic Light Source

Light is used throughout latent print development to visualise latent prints. If a thorough visual examination of the surface reveals a latent print, the print is photographed. After fingerprint analyst proceeds with physical and chemical processing methods. There are several phases of latent print processing when the fingerprint analyst uses light as a