EVALUATING THE EFFICIENCY AND SENSITIVITY OF ONE-STEP CYANOACRYLATE FUMING METHODS IN THE DETECTION AND VISUALISATION OF LATENT FINGERPRINTS ON THE ADHESIVE SIDE OF TAPE

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DECLARATION

I declare that this manuscript does not contain any material submitted previously for the award of any other degree or diploma at any university or other tertiary institution. Furthermore, to the best of my knowledge, it does not contain any material previously published or written by another individual, except where due references have been made in the text. Finally, I declare that all reported experimentations performed in this research were carried out by myself, except that any contribution by others, with whom I have worked is explicitly acknowledged.

Signed: Krystal Van Der Spil

28/06/2019

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Part One

Literature Review

EVALUATING THE EFFICIENCY AND SENSITIVITY OF ONE-STEP CYANOACRYLATE FUMING METHODS IN THE DETECTION AND VISUALISATION OF LATENT FINGERPRINTS ON THE ADHESIVE SIDE OF TAPE

Abstract

The evidential value of adhesive tape recovered from a crime scene plays a critical role in the criminal investigation as it could potentially contain things such as fibres, hair, DNA evidence, or fingerprints. Adhesive tape is a ubiquitous material that can be used in crimes that involve kidnapping and murder, as well as used to house cables in acts of terrorism. With regards to the adhesive side of tape, the sticky nature of this surface not only increases the likelihood of latent fingerprint deposits but has routinely proved to be a problematic substrate to work with. As latent fingerprints are generally invisible to the eye, enhancement methods are required to conduct adequate analysis on the fingerprint details. Despite several methods of fingerprint enhancement available, common issues including high background staining and low selectivity of fingerprint deposits create a difficult problem for forensic investigators to solve. Studies have shown that these issues can be overcome by utilising aqueous solutions of fingerprint powders, as well as traditional dye methods like gentian violet. Fluorescent dyes have also been explored and shown to be very effective when used on darker-coloured adhesive tapes. With regards to aged latent fingerprints, sticky-side powder and phase transfer catalysts have proven to be viable methods of detection and development. Traditional cyanoacrylate fuming was observed to be the best method of development in all reviewed cases, but the requirement of subsequent dye staining poses potential health issues to the user and the environment. One-step cyanoacrylate fuming has been proposed as a method incorporating the staining step into the cyanoacrylate fuming step, thus completing both steps simultaneously. As one-step cyanoacrylate fuming is a relatively new method of development, its potential application to the development of latent fingerprints on the adhesive side of tape has not been explored to its full extent and should be researched more extensively.

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LIST OF ABBREVIATIONS

BPS	Black Powder Suspension
BY40/BR28	Basic Yellow-40/Basic Red-28
CA	Cyanoacrylate
CdSe	Cadmium-selenide
FRS	Friction Ridge Skin
GV-E	Gentian Violet in Ethanol
GV-P	Gentian Violet in Ethanol + Phenol
PTC	Phase Transfer Catalyst
R6G	Rhodamine 6G
RAY	Rhodamine 6G/Ardrox/Basic Yellow-40
SPR	Small Particle Reagent
TiO_2	Titanium Dioxide
UV	Ultraviolet
WPS	White Powder Suspension

1. INTRODUCTION

Fingerprints are one of the most discriminatory types of evidence encountered at a crime scene.[1] Since 221 B.C. fingerprints have been used as a means of identification and its current use to aid criminal investigations is still proven to be an invaluable tool.[1] Fingerprints recovered from a crime scene play a significant role in the three aspects of forensic investigations; demonstration of whether a crime had been committed, identification of the individuals involved and their association to each other, and assisting in reconstruction of the sequence of events.[1, 2] The evidential value of a fingerprint enables the identification of an individual based on the papillary ridge patterns present on the pads of the fingers.[3, 4] Latent fingerprints, specifically, can be deposited onto a range of substrates, which ultimately denotes the method of enhancement, be it optical, physical or chemical.[5] Crimes such as kidnapping, terrorism, rape, and murder often involve the use of adhesive tape, which frequently presents latent fingerprints on the adhesive side.[6, 7] Due to its sticky nature, and difficulties in handling while wearing gloves, preferred handling is carried out by bare hands, which significantly increases the likelihood of latent fingerprint deposition.[4] As the development of latent fingerprints generally relies on the interaction between the chemical residue of the fingerprint and the method of enhancement, the adhesive properties of tape need to be taken into consideration when choosing an appropriate development method.[8]

The general process of developing latent fingerprints, or any evidential fingerprint, always begins with the least destructive method of analysis, so as to preserve any potential detail that may be recovered from the print.[5] In addition to this, by using the least destructive method first, it allows for subsequent analysis if needed. An analysis is done using three

detection methods; optical, physical or chemical.[1] Optical or visual detection involves simple observation and photography of the fingerprint, sometimes accompanied by the use of white light.[9] This detection method is generally non-destructive, but if exposed to high-powered lasers, which utilises lights of extreme intensities, the process can be harmful.[10] Optical detection is always carried out before physical or chemical examination as these methods are commonly destructive.[1] The use of physical or chemical enhancements for the detection of latent fingerprints is strongly dependent on the substrate that the fingerprint is deposited onto.

Some porous substrates, like fabrics, paper, or wood, can absorb the fingerprint deposits, thus changing the composition.[9] Additionally, these surfaces can absorb and react with the physical or chemical method of development applied, causing high background staining and issues in the visualisation of the print.[11] Processes, such as physical developer and Ninhydrin have been found successful for the use on porous surfaces.[12, 13] Non-porous substrates tend to be easier to develop latent fingerprints on as there is less interference from the background; however, fingerprints deposited onto these surfaces tend to be more fragile, thus requiring them to be preserved as soon as possible.[14] Physical development methods for use on non-porous substrates include fingerprint powders, such as fluorescent powders and carbon black, whereas chemical methods include vacuum metal deposition or cyanoacrylate (CA) fuming. Though most substrates can be classed into porous or non-porous, there are some surfaces that do not fall under these categories, such as waxy surfaces or adhesive tape.

While adhesive tape is a potential type of physical evidence recovered from a crime scene, the sticky nature of the adhesive side proves to be problematic with current methods of

latent fingerprint development.[15] As a result of its adhesive properties, the sticky side of tape increases the likelihood of a fingerprint to be deposited.[4] Various studies have been conducted in order to create a method that will effectively develop latent fingerprints on this problematic surface, but as there are multiple brands, colours and compositions of adhesive tape, there has been no single technique suitable for all cases.[16]

CA fuming has previously been found to be one of the most successful practices in developing latent fingerprints on the adhesive side of tape, but requires additional dye steps for fingerprints on dark surfaces.[17] This extra step is not only time consuming, but can also present carcinogenic properties as a result of using the dyes.[18] An alternative method, proposed as the one-step CA fuming method, incorporates a fluorescent powder into the CA fuming process, primarily developing and staining the fingerprint in one step.[19] Currently, various brands of one-step CA fuming have become commercially available, but limited research has been performed to evaluate their use for developing latent fingerprints on the adhesive side of tape.

This literature review focuses on evaluating the current methods of latent fingerprint development for use on the adhesive side of tape and, by doing so, aims to assist in determining whether one-step CA fuming may prove to be a more effective and versatile method of enhancement for these surfaces. In order to comprehensively understand the interaction between fingerprint, substrate, and method of development, background information on fingerprints and the nature of adhesive tape will be included in this review as these properties vastly affect the choice of development procedures utilised.

2. DISCUSSION

2.1 Fingerprint Background

2.1.1 Friction Ridge Skin Development

The general anatomy of the skin is what forms the underlying fundamentals of the examination process of fingerprints. Human skin, comprising of three anatomical layers, is responsible for several tasks, including temperature regulation and excretion.[20] The outermost layer, the epidermis, forms the protective barrier of the body and is home to the friction ridge skin (FRS), consisting of ridges and furrows, on the fingers, palms, feet, and toes.[21] FRS is formed due to the papillae at around the 10th week of the gestation period and remains unchanged throughout life.[22, 23] Despite the continuous sloughing of cells on the surface, from everyday activities, the structural features of the FRS is maintained as a result of several levels of attachment within the epidermis.[1] These attachment levels involve cell-to-cell interaction between keratinocytes throughout the layers of the epidermis, which are anchored in position by the interwoven epidermal basal cells and the dermis, creating a fibrous sheet of cells, locking the epidermis to the dermis.[1] Primary and secondary ridges, formed at the intersection of the dermis and epidermis, code for the fingerprint pattern visible on the surface of the skin (Figure 1).[22]

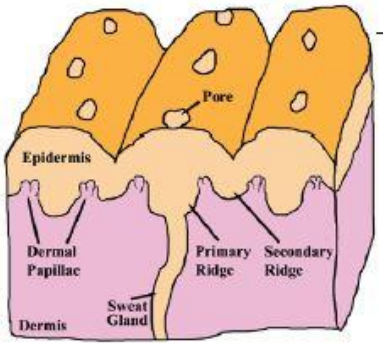

Figure 1 *Structural characteristics of friction ridge skin.*[1]

Due to this intricate attachment, alteration of the FRS is only possible if the basal keratinocyte template is altered, as a result of ageing, trauma and scars.[1, 3, 24]

2.1.2 Ridge Characteristics and Patterns

The ridge characteristics of a fingerprint are unique to an individual and are analysed in three levels of detail; the general fingerprint class, the changing flow patterns of ridges and the characteristics of individual ridges. Defining a fingerprint's class relies on the use of singularities, such as cores and deltas. The core is the most central region of the overall pattern where the direction of the inner-most ridge pivots, whereas the delta is the area where two ridges diverge after previously running parallel.[23] Fingerprints can be segregated into one of three classes; loops, whorls, and arches. Loop patterns consist of a central core that curves toward the left or right and a delta on the opposite side of the ridge flow, while whorl patterns contain a central core with a delta on either side. Unlike loops and whorls, arch patterns only contain a core, with no deltas (Figure 2).[21, 22] Loops and whorls are the most predominant patterns observed, occurring in approximately 93.4% of all fingerprints, and arch patterns being the least common.[23] From these three classes, fingerprints can be further divided into subclasses depending on the flow of ridges that structure the main fingerprint pattern; Loops can be further divided into radial or ulnar loops, determined by the ridges flowing more toward the ulnar or radius of the forearm; whorls can fall under four subclasses of either plain, central pocket loop, double loop or accidental loop whorls; and arches can be further divided into plain or tented arches depending on the prominence of the arch (Figure 3).[25]

Figure 2 *The three main fingerprint classes from left to right; loop, whorl, and arch.*[23]

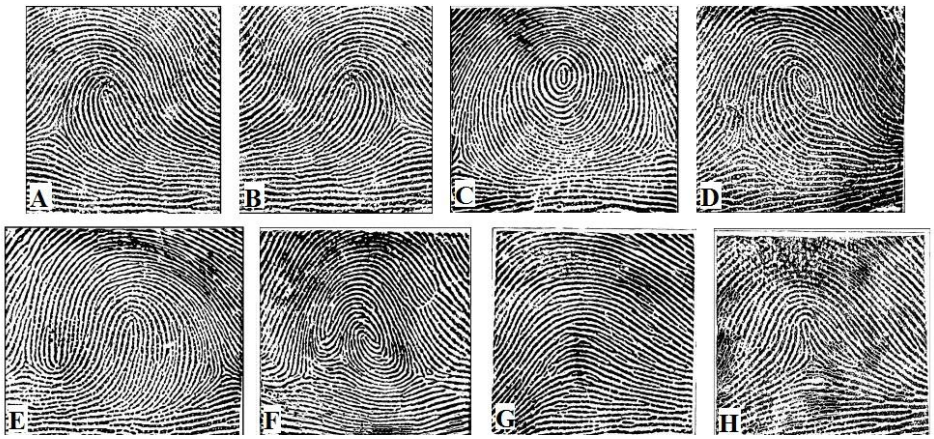

Figure 3 *Fingerprint sub-classes.* ***A)*** *Right Loop;* ***B)*** *Left Loop;* ***C)*** *Plain Whorl;* ***D)*** *Central Pocket Loop Whorl;* ***E)*** *Double Loop Whorl;* ***F)*** *Accidental Loop Whorl;* ***G)*** *Plain Arch;* ***H)*** *Tented Arch.* [23]

Though fingerprints are broadly classed into these pattern types, the unique identifiers come down to the discontinuities within the ridges and the features associated with these individual ridges.[23] Individual ridge patterns, known as minutiae, embody the individuality of the fingerprint, making them the most discriminating feature used in fingerprint analysis.[23] The two types of minutiae that form the basis of varying ridge patterns are ridge endings and bifurcations; where a ridge terminates and where a ridge diverges into two, respectively.[23] Other minutiae patterns, such as trifurcations, enclosures, spurs and bridges are simply a combination or variation of these (Figure 4).[26, 27] A general fingerprint will contain up to 80 minutiae, though fewer will be present in a latent fingerprint due to the presence and position of pores (Figure 5).[1] When analysing the individual characteristics of ridges, the ridge size, and shape, as well as the location of pores, are the main focus. These low-level details are not commonly used in fingerprint comparison using automated systems

due to the need for high-resolution scans but can be used by human experts in their analysis.[28, 29] Despite this, the significance of sweat pores present on the FRS is important as they are responsible for the composition and deposition of latent fingerprints.

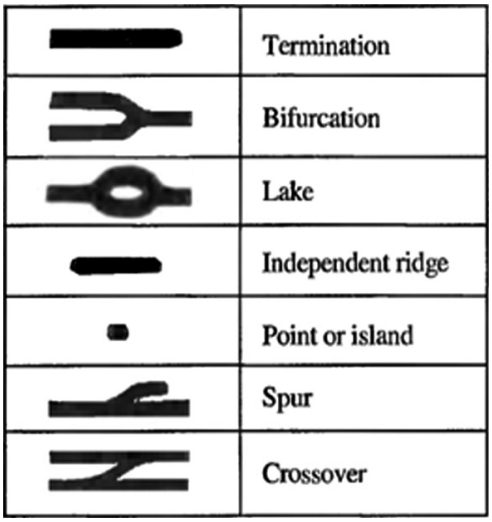

Figure 4 *Most common types of minutiae observed in a fingerprint.*[30]

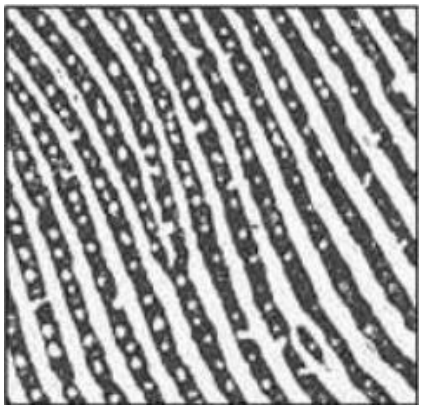

Figure 5 *Image displaying the presence of pores along the friction ridge skin.*[23]

2.1.3 Latent Fingerprint Composition

The three possible types of fingerprints encountered at a crime scene are plastic, patent, and latent. Plastic fingerprints are deposited into a surface, such as gum or fresh paint, leaving a 3D impression, whereas patent fingerprints are a result of residues from the finger, such as blood or dirt, depositing onto the substrate.[11, 31] Both plastic and patent fingerprints

are readily visible to the human eye, generally without need for enhancement; however, latent fingerprints require special visualisation techniques.

Among these three impression types, latent fingerprints are the most common fingerprints encountered at a crime scene and are a result of excreted chemicals through the pores present on the FRS.[32] When a surface is touched, residue on the pads of the fingers, comprised of natural secretions, epidermis components, and environmental contaminants, are deposited.[32] Natural secretions from the body are the product of one of the three types of gland present in the skin; apocrine, sebaceous and eccrine. Apocrine glands are primarily present in the groin, breasts, and armpits whereas sebaceous glands are present over the entire body except for the hands and feet.[20] The only glands present in the FRS are the eccrine glands, with 2500—3000 per 2.5cm^2 of skin and are the largest glands of this type in the body.[1] Though the two major origins of latent fingerprints are from sebaceous and eccrine glands, latent eccrine fingerprints are more representative in latent fingerprint identification because of the eccrine glands present on the FRS.[32] Primarily, the major component of eccrine secretions is water (99.0—99.5%) and a mixture of organic and inorganic elements; however, in relation to latent fingerprints, activities such as touching the face or hair can alter the chemical constituents through contamination from sebaceous gland secretions (Table 1).[33]

Despite water constituting majority of eccrine sweat production, this does not guarantee that typical latent fingerprints would reflect the same percentage of water. Water secreted through eccrine sweat glands is often evaporated or reabsorbed into the skin during temperature regulation.[32] In addition to this, other factors such as age, medication, recent activities, environmental conditions, and substrate surface can alter the chemical

composition of a latent fingerprint.[24] These various factors need to be taken into consideration when choosing the appropriate visualisation technique, especially in relation to techniques that rely on chemical interactions with latent fingerprint components.

Table 1 *Chemical components of glandular secretions.*[34, 35]

Secretory Gland	Chemical Components	
	Organic	**Inorganic**
Eccrine	Amino acids Choline Creatinine Lactic Acid Polypeptides Proteins Sugars Urea Uric acid	Ammonia Bicarbonate Chloride Metal ions (Na+, K+, Ca2+) Phosphate Sulphate Water
Sebaceous	Fatty acids (30—40%) Wax esters (20—30%) Glycerides (20—25%) Squalene (10—15%) Sterols (3—4%) Sterol Esters (2—3%)	
Apocrine	Carbohydrates Proteins Sterols	Iron Water

2.2 Adhesive Tape Background

2.2.1 Brief History

Adhesive tapes have been in common use for over a century. Dating back to the 1900s, the world's first scotch masking tape was developed as a solution to auto painter difficulties in creating clean lines between two paint jobs.[8] In 1942, during World War II, duct tape was developed in order to repair weapons and seal ammunition cases.[8, 36] Not too long after the development of duct tape was the creation of clear scotch tape in the 1930s, which is often used for packaging items.[8, 37] Since then, the manufacture of adhesive tapes and their

multiple uses have evolved and continue to do so. As adhesive tapes are ubiquitous, it is not uncommon for them to be utilised in the commission of a crime.[6] Duct tape is often recovered from crimes where abduction or murder has occurred, but can occasionally be retrieved from packages that contain contraband or explosive devices.[38] In these cases, the potential to recover forensic evidence is imperative to aid the investigation. In relation to forensic analyses of adhesive tapes, complications arise due to the assortment of adhesive tapes commercially available.[16]

2.2.2 Adhesive Tape Composition

The composition of adhesive tapes varies with each brand and batch, the manufacturer and the types of glues used.[16] Tapes cannot be adequately compared and analysed using visual examination, but laboratory methods, such as Fourier-transform infra-red spectroscopy, can be utilised to distinguish tapes of different sources and compositions.[16] Adhesive tape generally consists of a plastic layer with a glue layer but can also be as complex as to contain a release coating, a backing film, a primer layer, and an adhesive layer.[39, 40] In order to avoid the adhesive side from sticking to the backing side when rolled, a release coating is applied.[40] Not only does this prevent the adhesive from sticking to the tape beneath it, but it also reduces the tension that may arise during unrolling.[40] The backing film, more commonly known as the non-adhesive side of tape, can come in a variety of colours as well as a variety of materials. Duct tape is made using a polyethylene backing, which is traditionally silver, with a layer of woven cloth for added strength.[38] The woven cloth, also known as the 'scrim', is a mixture comprised of both natural and synthetic fibres.[38] In comparison to duct tape, plastic packaging tape is often developed using a transparent or brown polypropylene and masking tape uses a polyester film.[37, 41] Some adhesive tapes contain a primer layer, which is

responsible for enhancing the adhesive force between the tape and the substrate.[42] Despite the fact that latent fingerprints can be present on both sides of adhesive tape (non-adhesive and adhesive) the same method of enhancement often cannot be applied to both sides, primarily due to the adhesive properties.[15] Glues frequently used in the manufacture of adhesive tapes are pressure-sensitive adhesives, which are either rubber-based (natural or synthetic) or acrylic-based.[16, 37] Generally, pressure-sensitive adhesives are a complex polymer, or a mixture of both polymer and resin.[37] The adhesive layer itself proves to play the most important role in fingerprint deposition on the adhesive side of tape because it is this layer that mostly comes into direct contact with the finger.[37] Adhesive tapes recovered from crimes often adhere together or to a substrate, which complicates analysis of the adhesive side.[43] Proposed methods, such as freezing, have been successful in assisting with separation of the tape but will not be explored in detail for the purpose of this review. Other studies have been conducted, focusing on developing methods of fingerprint enhancement on the adhesive side of tape, but with the various types of adhesives available some tapes have been proven to be problematic in these approaches. For example, it has been found that development of latent fingerprints on acrylic-based adhesives is likely to result in high background staining causing poor contrast in visualisation.[44] This is an issue in forensics as it is not always the same type of adhesive tape encountered at every crime scene.

In order to evaluate existing methods of latent fingerprint development, with regards to the adhesive side of tapes, the findings of current literature will be compared and contrasted to establish the issues with each technique, for the purpose of producing an alternative method.

2.3 Enhancement Techniques

2.3.1 Powder Suspensions

Fingerprint powders have proven to be successful in enhancing latent fingerprints; however, a range of surfaces, such as wetted or rough materials, fabrics, and adhesives have limited suitability with this forensic technique.[16] The use of powder suspensions has been successful in developing latent fingerprints without interference from the adhesive.[43] Powder suspensions are generally a mixture of three components; powder, detergent, and water.[5] Before use, it is important to thoroughly mix the suspension, as suspensions left to stand are inclined to separate the components within the mixture.[45] There is no single powder formulation to accommodate all adhesives and fingerprints as the effectiveness of varying powder suspensions are dependent on the adhesive structure.[16] Due to this, a range of powder suspensions have been created in an attempt to accommodate the diverse compositions and colours of adhesive tapes.

2.3.1.1 Sticky-Side Powder

Sticky-side powder, as the name suggests, was developed specifically to develop latent fingerprints on the adhesive side of tape.[1] The sticky-side powder is mixed with water and the detergent, Kodak Photo-Flo, to facilitate a thick suspension that is applied to the adhesive surface by painting it on with a brush before rinsing the tape in water.[45] The resulting developed fingerprint is a dark grey colour.[6] This method has been found effective on the majority of adhesive surfaces, though it has limitations in relation to dark surfaces due to the resulting developed print being grey in colour.[6] In a study by Sock *et al.*[6] sticky-side powder was applied to masking tape, transparent tape, and black electrical tape. Latent

fingerprints on both transparent and masking tapes were successfully developed but did not provide enough contrast on black electrical tape, despite being able to develop the prints. In concurrence to this, Martin[46] yielded the same results in relation to developing fingerprints on black electrical tape due to the dark colouring of the developed print. Alternatively, Brzozowski *et al.*[44] applied sticky-side powder to various brown and transparent tapes and achieved good results on tapes with adhesives made with synthetic rubber, however, produced poor results on adhesives composed from natural rubber.

2.3.1.2 Black Powder Suspension

Black powder suspensions (BPS) work much the same as sticky-side powder, where a powder is mixed with a detergent and water. The detergent used is typically Liqui-Nox, but Photo-Flo can be used too.[5, 45] The importance of the detergent in the suspension allows for easy application due to the surfactant reducing the surface tension.[45] Particles suspended in the mixture can be either iron-oxide or carbon-based, depending on the manufacturer of the product.[1] Studies conducted by Bleay *et al.*[47] illustrated that carbon-based BPS were more successful in developing fingerprints on the adhesive side of tape in comparison with the iron-oxide version. It was also observed that there was extensive background staining on the tapes with acrylic-based adhesive, whereas there was no observable background staining on tapes with rubber-based adhesives. Bailey *et al.*[43] conducted a study observing whether fingerprints on the adhesive side of duct tape could be recovered and developed with BPS after separation using a freezing technique. Findings stated that fingerprint detail was not observable until treated with suspension powder, in which 48% of the fingerprints developed illustrated numerous minutiae and more complete pattern details. In addition to this, there was only 12% of fingerprints in which there was no, to limited, visible minutiae.[43]

2.3.1.3 White Powder Suspension

The mixture of titanium dioxide (TiO_2) powders in suspension, more commonly known as white powder suspension (WPS), has provided a successful alternative to black powder suspensions, with regards to dark coloured adhesive tapes.[46] Though there are several commercial products of this technique available, various studies have found that the effectiveness varies with suspensions from different companies.[16] TiO_2 is a non-toxic, very fine, non-flammable white powder, which has been proven useful in the development of latent fingerprints on dark surfaces.[16, 45] Scheimer *et al.*[45] suggested that the use of TiO_2 powder can be a viable substitute to sticky-side powder, in which superior results can be achieved on black electrical tape. Different compositions of WPS were tested to analyse which suspension produced the best result on black electrical tape.[45] WPS was mixed with Photo-Flo, Citron detergent, or both, in which the Citron detergent formulation developed fingerprints slighter better in comparison to the Photo-Flo formulation, but produced discolouration of the background which impacted the contrast. The fingerprints developed from these two methods also showed to decrease in quality in relation to weaker deposited fingerprints. Additionally, this study illustrated that WPS using a mixture of Photo-Flo and Citron detergents was consistent in developing high-quality fingerprints when compared to Photo-Flo only and detergent only suspensions. The combined mixture had less background discolouration and worked consistently on all of the types of black electrical tape tested, even allowing the observation of third level detail like creases and pores.[45] Williams and Elliot[48] agreed with this, with successful results on both duct and dark-coloured electrical tapes. Furthermore, a study conducted by Brzozowski *et al.*[44] tested the efficiency of the WPS Wetwop™ and found it to be the most universal and effective method to develop

fingerprints on brown and transparent tapes in comparison to other development methods. Despite these successes, Bleay *et al.*[47] recommend that WPS should not be used on adhesive tapes, unless in the case of wetted, dark coloured tapes.

2.3.1.4 Physical Developer

Physical developer, also known as silver powder suspension, is an aqueous, silver-based reagent that develops latent fingerprints by reacting with the components of sebaceous sweat.[13] Essentially, silver(I) ions are reduced to elemental silver that interacts with the fatty acids present in a latent fingerprint, resulting in a dark grey or black fingerprint.[13] Scheimer *et al.*[45] tested physical developer, much like WPS, where the effectiveness of the developer was analysed depending on the mixture components. It was found that the Photo-Flo only solution rarely developed any fingerprints and, where it did, only developed very faint fingerprints.[45] Opposing to this, the detergent only solution demonstrated excessive background staining on all of the black electrical tapes tested, despite only applying one coat of the mixture.[45] Although Scheimer *et al.*[45] had successes with combining both Photo-Flo and detergent in the WPS, with regards to silver powder, the results were found to be the opposite. The developer had extensive background staining as the silver powder adhered to the adhesive background, which vastly decreased the quality of the developed fingerprint.[45] In contrast, Sodhi and Kaur[13] found physical developer to be successful in the development of fingerprints on adhesive tape, and especially suitable for detecting fingerprints on porous and wetted surfaces, as it relies on interactions between lipid components and fatty acids, which are not soluble in water.

2.3.1.5 Small Particle Reagent

Despite being much like its powder suspension counterparts, small particle reagent (SPR) traditionally utilises molybdenum disulfide particles, which results in a grey developed fingerprint.[17] Black charcoal powder and zinc carbonate can also be used in place of molybdenum disulfide.[17] Due to the resultant grey deposit, SPR has been deemed a suitable method for the use on black or dark-coloured tapes.[45] Bumbrah *et al*.[17] determined that the quality of the latent prints developed varied with the solubility and concentration of surfactant in the SPR mixture. In conventional SPR, suspension material and surfactant are the main components.[49] The role of the surfactant is to enhance substrate moisture and reduce any potential surface tension, thus allowing uniform spreading of the reagent.[17] This is particularly important in relation to the quality of developed prints as high concentrations can increase the likelihood of the developed prints being weak in nature.[49]

2.3.1.6 Cadmium-selenide Nanoparticle Suspension

The use of nanoparticles in latent fingerprint development has been increasing due to their versatility, and sensitivity.[50] Cadmium-selenide (CdSe) nanoparticle suspensions require the particles to be stabilized before use.[51] Wang *et al.*[50] applied the suspension to yellow sealing tape, black electrical tape and regular adhesive tape and observed developed fingerprints on all three tapes, with minimal background staining. Tape colour proved to be no issue with this technique as the strong fluorescent property of CdSe under ultra-violet (UV) light provided sufficient contrast between the fingerprint and background.[50]

2.3.2 Dye Methods

2.3.2.1 Gentian Violet

Gentian violet, also known as crystal violet, is a dye method that results in a dark purple developed fingerprint.[44] The dye works by reacting with the fatty constituents in the deposited fingerprint, primarily being absorbed by these components and staining the fingerprint.[45] There are two methods by which the dye can be prepared, either dissolving gentian violet in ethanol (GV-E), or a combination of ethanol and phenol (GV-P), followed by dilution with water.[47] Due to the resultant dark colour of the enhanced fingerprint, poor contrast on dark adhesive tapes is problematic.[6, 45] Developed fingerprints on most surfaces can potentially be transferred onto fixed photographic paper, but this solution is not suitable for fingerprints on the adhesive side of tape.[45] In a study conducted by Brzozowski *et al.*[44], both forms of gentian violet solution were tested on different types of brown and transparent tape that varied in adhesive composition. It was found that the GV-E solution demonstrated to be an ineffective method for fingerprint development. The best results achieved with this method was in relation to adhesives with natural rubber, but even this proved to be the worst method applied in comparison to the other methods conducted in the study.[44] It was also shown to be ineffective in the development of aged fingerprints. In comparison to this, gentian violet with both ethanol and phenol also demonstrated poor results, with only slight fingerprint development on fresh deposits, again, only if the adhesive was made of natural rubber.[44]

2.3.2.2 Ardrox and Liqui-Drox

Ardrox is a fluorescent agent which was initially developed to detect small fractures found within construction materials.[45] Due to its fine composition, Ardrox is able to penetrate and enter small openings, thus making it a viable option for enhancing ridge patterns in fingerprints.[45, 52] The use of Ardrox involves mixing the reagent with detergent and distilled water in order to produce a thick, milky-yellow solution.[53] The mixture is generally painted onto the substrate, followed by being rinsed and dried before analysis using UV light.[53] This method has had some successes in developing latent fingerprints on black adhesive tape due to its fluorescent property; however, it poses some issues with high background staining, making photography and visualisation difficult.[45] Unwanted background fluorescence can potentially be eliminated using orange or yellow glasses but does not produce optimum results.[52] Scheimer *et al.*[45] argued that Ardrox was not suitable for use on aged fingerprints and only developed very faint ridge detail on fresh fingerprints. It was also demonstrated that fingerprints developed with this method significantly faded within 15 minutes of development, and completely disappeared after 12 hours.[45] This was a significant issue as the method only produced faint fingerprints initially. Alternative solutions to Ardrox have been developed in an attempt to increase its usability. Liqui-Drox is a solution composed of Ardrox, Liqui-Nox, and distilled water.[52] Much like Adrox solution, Liqui-Drox is painted onto the surface where it develops for 10 seconds before it is rinsed until there is no visible stain.[53] The developed prints are then examined under a long-wave UV light, presenting green-yellow fluorescence.[52] Despite this method improvement, Rees and Schwartz[54] applied Liqui-Drox to 25 different types of adhesive tape but proved

unsuccessful on 11 of the tapes, which included: heavy duty tape, cloth tape, duct tapes of varying colours, masking tape and transparent packaging tapes.

2.3.2.3 Novel Fluorescent Dyes; HB-7, HB-9, HB-11

Another method of fluorescent dye staining has been proposed by Barros and Valter[4], in order to overcome limitations inherent to gentian violet and other enhancement methods. The fluorescent dyes (HB-7, HB-9, and HB-11) were developed to combat the issue of current dyes generally only being successful on light-coloured or transparent tapes.[4] Barros, and Valter[4] were able to clearly observe fingerprint ridge detail on transparent tape, brown tape, black electrical tape and silver duct tape. As these novel fluorescent dyes are still patent pending, the literature exploring this method is limited.

2.3.2.4 Phase Transfer Catalyst

Phase transfer catalysts (PTC) assist in the interaction between dyes and the chemical constituents of latent fingerprints.[15] Dyes suspended in solutions often have issues with poor development due to the fact that the dyes are in the aqueous phase, and the sebaceous components in latent fingerprints are in the organic phase.[55] The incorporation of PTC often resolves the issue of insolubility during the chemical reaction process.[55] Jasuja *et al.*[15] used tetrabutylammonium iodide as the PTC and mixed it with a solution of Rose Bengal dye, resulting in developed fingerprints on all of the adhesive tapes analysed in the study. The developed fingerprints resulted in a pink colour, which gave sufficient contrast between fingerprint and background, except in the case of black electrical tape.[15] Visualisation of the developed fingerprints even demonstrated the presence of third level detail.[15] Jasuja *et al.*[55] also evaluated the effectiveness of Rose Bengal-PTC on aged

fingerprints, in which, again, all of the tapes utilised responded consistently, much to the same quality to that of freshly deposited fingerprints. There was an exception in this study, where aged fingerprints developed on double-sided foam and cloth-based medical tape had a loss of level three detail.[15]

2.3.3 Cyanoacrylate Fuming

CA fuming is an age-old technique for developing latent fingerprints. The method involves the heating of CA within an enclosed chamber, thus causing it to vaporise and circulate within the chamber.[56] During its circulation, the CA vapour comes into contact with the latent fingerprint and forms a white polymer, known as polycyanoacrylate, along the ridge detail because of an anionic polymerization reaction.[57] As CA fuming essentially fixes the fingerprints to the substrate, subsequent analysis is able to be carried out without risking the loss of the fingerprint.[49] Sock *et al.*[6] examined the effectiveness of latent fingerprints developed by CA fuming and resulted in successes on both transparent and black electrical tape. With regards to these substrates, the white polymerisation created a good contrast between the developed fingerprint and the background; however, when the technique was applied to masking tape, any possible detail failed to be observed, despite a latent fingerprint being deposited.[6] This result was also observed in a study conducted by Matthias[58]. CA fuming is almost always coupled with a powder or dye method to enhance the developed fingerprint further.[45] Olenik[59] proposed using Basic Yellow-40 dye alone following CA to further enhance the developed fingerprints on duct tape and had successful results, but observed some noticeable background staining. Wilson[60] utilised CA fuming with gentian violet, alternate black powder and a mixture of Rhodamine 6G (R6G), Ardrox, and Basic Yellow-40 (RAY dye) in attempt to increase visualisation of the latent fingerprints.

Tapes to be tested were separated into two groups of CA fuming in which Group 1 was followed by subsequent analysis using gentian violet, alternate black powder (or white powder for black electrical tape) and, finally, RAY dye, whereas Group 2 was followed with RAY dye only. Analysis of fingerprints from Group 1 showed level one detail after treatment with gentian violet and worked best on the black and brown tapes. Following the addition of alternate powder, detail decreased with little to no development able to be observed. RAY dye application increased the detail of developed fingerprints with the majority exhibiting many visible minutiae. Group 2 results only exhibited detail of some minutiae and gave little to no development on packaging and duct tapes. In a study conducted by Scheimer *et al.*[45], the use of R6G or a combination of Basic Yellow-40 and Basic Red-28 (BY40/BR28) was used to further enhance CA developed fingerprints. It was apparent that BY40/BR28 treated fingerprints gave off a brighter fluorescence in comparison to those treated with R6G. The selectiveness of R6G to the fingerprint was also less than BY40/BR28 and had a tendency to stain the background.[45] With regards to aged fingerprints, CA fuming was proved successful, but as the age of fingerprint increased, the more time was required for the fuming process.

2.3.4 One-step Cyanoacrylate Fuming

The development of one-step CA fuming was intended to fundamentally incorporate the dye method into the CA fuming method.[61] Attempts of this integration have started since the 1980s and, since then, several commercially available products such as PolyCyano UV (Foster and Freeman Ltd.), PECA Multiband (BVDA) and Lumicyano™ (Crime Scene Technology) have been marketed.[62] PolyCyano UV was evaluated by Hahn and Ramotowski[63] and resulted in the product being comparable with conventional CA fuming. Farrugia *et al.*[62] argued that one-step CA fuming produced a noticeable advantage in

comparison to the other methods tested, in relation to background fluorescence reduction. Hahn and Ramotowski[63] also noted that, much like traditional CA fuming, PolyCyano UV effectiveness was very dependent on the substrate it was applied to. Chadwick *et al.*[64] stated that an advantage of one-step fuming methods was that they are more efficient and minimised hazardous chemical use. It also demonstrated to be superior in the sense that it can be applied to semi-porous and porous surfaces, which most conventional stains cannot. Khuu *et al.*[61] evaluated several one-step fuming methods, including PolyCyano UV, PECA Multiband, and Lumicyano™, in which these techniques showed better results on polystyrene in comparison to traditional CA fuming. It was also found that one-step CA fuming has the potential to produce superior results on aged fingerprints when compared to traditional CA fuming. Various studies[61, 63, 64] noted that despite the successes with one-step fuming processes, the high heating temperatures involved requires the modification of existing fuming cabinets and, as such, cyanoacrylates exposed to high temperatures could potentially produce toxic hydrogen cyanide gas. It should be taken into account that the previously discussed one-step CA studies were not applied to developing latent fingerprint on the adhesive side of tapes. At this time, no published research has been available on the application of PolyCyano UV and PECA multiband on the adhesive side of tape. A recent study by Chung[65] applied Lumicyano™ to varying dark-coloured adhesive tapes and yielded successful results comparable to traditional CA fuming. The study did, however, demonstrate an issue with developing latent fingerprints on tapes with rubber-based adhesives, but did not state whether the rubber was natural or synthetic. In addition to this, the study solely focused on dark-coloured tapes, therefore excluding other types of tape.[65] Regardless of the increased cost of one-step CA fuming in comparison to other techniques,

the cost of time would be greatly reduced, and the need for subsequent analysis materials would be made redundant.[63]

2.4 Comparison of Enhancement Techniques

Scheimer *et al.*[45] found the sticky-side powder to be less effective than gentian violet, and BPS on black electrical tape in which the ridges developed were too faint to enable adequate analysis even when transferred onto fixed photographic paper, and were much too dark to give adequate contrast on the tape alone. Hollars *et al.*[52] and Rees and Schwartz[54] both argued that sticky-side powder was inferior in comparison to gentian violet and Liqui-Drox on black electrical tape, and Liqui-Drox on orange transparent tape. In contrast to this, Brzozowski *et al.*[44] recommended sticky-side powder for the use on adhesive tape with rubber-based glues, but not for acrylate-based glues. Additionally, the sticky-side powder was observably more efficient than gentian violet when used to develop aged fingerprints.[44]

BPS were found to be superior when compared to sticky-side powder and developed intense visual marks.[45] When analysed alongside gentian violet, results were comparable.[45] Rees and Schwartz[54] found BPS to be a better method of enhancement to Liqui-Drox when developing latent fingerprints on grey duct tape. BPS also demonstrated quality fingerprints on yellow, green, and red transparent tapes. In addition to this, fingerprints developed on light brown packaging tape was higher in quality using BPS in comparison to Liqui-Drox. Alternatively, Jasuja *et al.*[15] had issues with BPS showing considerable amounts of background staining on all adhesive tapes tested.

Scheimer *et al.*[45] detailed WPS to be comparable to CA fuming, but more superior in comparison to a physical developer and Ardrox, developing even depleted fingerprints as well as strong fingerprints. Background staining was occasionally observed, but was minimal and could potentially be reduced by limiting the number of coats of the suspension or decreasing the development time.[45] Brzozowski *et al.*[44] concurred with these findings and concluded that WPS was the most efficient agent, especially in relation to most aged fingerprints. Bleay *et al.*[47] recommended that WPS only be applied to dark-coloured tapes that had been wetted.

Physical developer was observed to be an ineffective method of development on the adhesive side of tape. Sodhi and Kaur[13] raised the issues of physical developer being expensive, destructive, time-consuming, and requiring pre and post treatments. Scheimer *et al.*[45] observed high background staining and stated that if the powder was more selective to the fingerprint, increased quality of contrast would have been apparent. Additionally, physical developer was inferior when compared to WPS and CA fuming. Results were comparable, though potentially worse than the poorly developed fingerprints by Ardrox. In an attempt to enhance the development method, more coats of the developer were applied, as well as increased development time, but proved only to create more background staining and no fingerprint development.[45]

SPR was less effective than gentian violet, and BPS, as the ridge detail developed, was too faint to enable analysis.[45] It was also observed to be prone to background staining.[50] An issue with the use of SPR is the requirement of a surfactant, which is generally a synthetic detergent, sometimes containing harmful organic compounds.[17] There is limited literature on the use of SPR on the adhesive side of tape, so its comparison to other development

methods cannot be commented on extensively. This is the case for CdSe nanoparticle reagent, but it was found to demonstrate less background staining and improved contrast in comparison to TiO_2 SPR and gentian violet.[51]

Studies showed gentian violet to be a more superior method to sticky-side powder and SPR, but comparable to BPS, except in the case of aged fingerprints.[45, 47] Jasuja *et al.*[15] stated that gentian violet gave better results on non-porous tapes as it would develop extensive background staining on porous tapes. Alternatively, when compared to Liqui-Drox and novel fluorescent dyes, it was less effective in development due to the background staining.[4, 52] The main issue with the use of gentian violet is that it is an irritant to the skin and eyes, and some studies have tried to determine whether it has carcinogenic properties.[66]

Scheimer *et al.*[45] found Ardrox to be unsuitable for aged fingerprints, but developed fresh fingerprints, despite being faint in nature. Hollars *et al.*[52] found Liqui-Drox to be a more superior method on black adhesive tape when compared to sticky-side powder and gentian violet, only if the tape is not damaged by excessive heat or environmental conditions. Results were comparable with BPS, with the exception of grey duct tape in which BPS developed higher quality fingerprints. It yielded high-quality fingerprints on brown packaging tape and blue transparent packaging tape and outperformed BPS on dark brown packaging tape. With regards to orange transparent tape, Liqui-Drox was more effective than sticky-side powder, and on cloudy scotch tape, it was found to be superior in development in comparison with gentian violet.[52]

With limited studies conducted on novel fluorescent dyes, this method was only compared to gentian violet, in which the proposed developed dyes gave stronger fluorescence, as well as better contrast and excellent ridge detail quality on transparent tape, brown packaging

tape, black electrical tape and grey duct tape.[4] As these dyes are water soluble, there is no use of potentially hazardous organic solvents, thus making it a safer alternative.[4]

The use of PTC tends to have less background staining in comparison to BPS and gentian violet but proves problematic in the case of fabric adhesive tapes, as with the majority of dye staining techniques.[15] It was also found to be a suitable method for use on aged fingerprints.[15] An advantage to using PTC is that the reagent can potentially have a long shelf life without interfering with the quality of the developed fingerprints.[15] In addition to this, Jasuja *et al.*[55] observed PTC to be a much more viable and effective method in the case of substrates that have been submerged, when compared to gentian violet.

CA fuming has repeatedly demonstrated to be the most effective method for the development of latent fingerprints on the adhesive side of tapes, with very minimal background staining when fumed in the correct conditions.[56, 67] Not only does this method adequately develop latent fingerprints, but also does not interfere with subsequent DNA analysis as some fingerprint powders and dyes do.[56] Scheimer *et al.*[45] indicated that developing fingerprints on the adhesive side of black electrical tape was most successful using CA, being effective on both fresh and aged fingerprints. With regards to the 5 different types of black electrical tape used in the study, CA fuming was not only able to develop prints on all types, but also on both sides of the adhesive tape. Despite results of CA fuming being comparable to WPS, it should be noted that the two types of methods are mutually exclusive; i.e., if one is applied, the other cannot be used in succession.[45] This provides an advantage of using CA over WPS as fingerprints developed by CA fuming can be treated in succession using other techniques, such as dyes, without risking the loss of detail.[56] The main advantage to using CA fuming over other methods is that it is probably the cheapest

technique to use, without sacrificing the quality of enhancements.[63] There is, however, risk of overdevelopment of the fingerprint which is irreversible, henceforth the technique requires constant monitoring.[56] The amount of humidity within the fuming chamber also needs to be taken into account as humidity in CA fuming greatly influences the eccrine constituents more than the sebaceous constituents in latent fingerprints.[67] Studies conducted have stated that the optimum humidity level to enable the most efficient CA fuming is approximately 80%, in which humidity levels lower or higher than this value will greatly affect the ridge detail observed due to polymer formation.[68, 69]

3. EXPERIMENTAL AIMS AND OBJECTIVES

The purpose of this study will be to overcome common issues associated with current methods of latent fingerprint enhancement, with regards to the adhesive side of tape. As a result of its sticky-nature and surface composition, such issues include the high potential of background staining, lack of enhancement or difficulty in visualisation, possible detail and DNA loss, and tedious processing. For the purpose of this research, the application of several one-step CA fuming processes will be assessed in comparison to traditional CA fuming and staining with RG6 dye. The one-step CA fuming reagents to be utilised in this study will be PolyCyano UV (Foster and Freeman Ltd.) and Lumicyano™ (Crime Scene Technology). These reagents will be applied to various compositions of adhesive tape including, but not limited to, clear sticky tape, brown packaging tape, white masking tape, black electrical tape and grey duct tape. Therefore, this study aims to evaluate the efficiency of one-step fuming methods on latent fingerprints on the adhesive side of tape by achieving the following objectives:

- Assess the ability to detect and enhance latent fingerprints on the adhesive side of tape using traditional CA fuming and enhancement with R6G.
- Assess the ability to detect and enhance latent fingerprints on the adhesive side of tape using one-step CA fuming methods.
- Assess the ability to detect and enhance latent fingerprints on the adhesive side of tapes with varying material and adhesive compositions.
- Assess the ability to detect and enhance aged latent fingerprints on the adhesive side of tape using traditional CA fuming and one-step CA fuming.
- Assess the sensitivity of detection of latent fingerprints on the adhesive side of tape using various CA fuming methods.

4. CONCLUSION

Latent fingerprint detection and enhancement methods have continued to develop and adapt to the various types of surfaces that are presented in forensic investigations. From the examined literature, sticky-side powder, SPR, and physical developer demonstrated to be the most ineffective methods of enhancement. With regards to light-coloured adhesive tapes, BPS, gentian violet, and PTC performed the best but still often posed issues with background staining due to the dark coloured deposits developed. In relation to dark-coloured adhesives, Ardrox/Liqui-Drox and novel fluorescent dyes were advantageous in comparison to other methods owing to their fluorescent properties. Though WPS were also found to be effective on dark-coloured adhesives, it was recommended that they are only used in the case of wetted substrates. When tested on their effectiveness on aged or depleted fingerprints, sticky-side powder, PTC and WPS gave the best results. CA fuming

was the only method that performed well in all of these cases. It was observed to produce detailed fingerprints on most colours of adhesive tape, as well as sufficient detail on aged or depleted fingerprints. CA fuming only gave background staining when the development time of the technique was used in excess. In addition to this, CA fuming does not require pre-treatment processes and can often be used alone without post-treatment dyes or powders, especially with regards to darker-coloured adhesives. The use of developed one-step CA fuming methods removes the need for the application of potentially hazardous dyes and reduces the total development time of fingerprints. It has been proven to produce quality fingerprints comparable with traditional CA fuming, but with a reduced amount of steps. Research into the application of one-step fuming methods to the development of latent fingerprints on the adhesive side of tape could potentially reduce the amount of time to analyse fingerprints, thus providing faster results with the same, if not better, quality of detail. It can also prove to be a safer method of development and require fewer elements and chemicals during analysis.

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Part Two

Manuscript

EVALUATING THE EFFICIENCY AND SENSITIVITY OF ONE-STEP CYANOACRYLATE FUMING METHODS IN THE DETECTION AND VISUALISATION OF LATENT FINGERPRINTS ON THE ADHESIVE SIDE OF TAPE

ABSTRACT

The detection and identification of fingerprints is critical, as they can provide valuable information regarding who has been at the crime scene. Adhesive tape is ubiquitous, therefore, its use in committing a crime is likely. The process of recovering latent fingerprints on the adhesive side of tapes proves problematic due to the stickiness of the adhesive. Traditional cyanoacrylate fuming treated with post-development dyes have been shown to be successful on these substrates; however, use of these dyes can be time consuming and hazardous. Proposed one-step fuming methods, such as PolyCyano UV and Lumicyano™ have been successful in developing latent fingerprints on a variety of substrates, although research for their applicability on the adhesive side of tape is sparse. This study evaluated the efficiency and quality of PolyCyano UV and Lumicyano™ in comparison to conventional cyanoacrylate fuming treated with Rhodamine 6G. Lumicyano™ yielded better results in efficiency and quality over varying saturated and aged fingerprints, compared to the other two methods. Despite PolyCyano UV producing relatively good results, its fluorescence was weaker, and the development of aged fingerprints was minimal. Conventional cyanoacrylate fuming was successful in developing fingerprints; however, the use of Rhodamine 6G dye appeared to degrade some of the tape samples, thus inhibiting development. Inclusion of longer aging periods and method effect on subsequent DNA analysis should be explored in future studies to determine the ranging use of one-step cyanoacrylate fuming methods.

KEYWORDS

One-step cyanoacrylate fuming; Lumicyano™; PolyCyano UV; adhesive tape; latent fingerprints; Rhodamine 6G

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LIST OF ABBREVIATIONS

ALS	Alternative Light Source
CA	Cyanoacrylate
CA + R6G	Cyanoacrylate treated with Rhodamine 6G Dye
DMAB	p-Dimethyleaminobenzaldehyde
DNA	Deoxyribonucleic acid
R6G	Rhodamine 6G
RH	Relative Humidity
SWGFAST	Scientific Working Group on Friction Ridge Analysis, Study and Technology

1. INTRODUCTION

Adhesive tape, acquired at a crime scene, can present multiple types of identifying evidence, including fibres, hair, deoxyribonucleic acid (DNA) and fingerprints.[1-3] The value of a fingerprint has been utilised as a unique signature to each individual. The probability of two people, including twins, having identical fingerprint characteristics is unlikely as a result of the analyses, over multiple levels of detail, involved in fingerprint identification.[4, 5] With regards to the adhesive side of tape, latent fingerprints are likely to be deposited due to preferred handling without gloves owing to its sticky nature.[6] Various optical, physical, and chemical methods can be utilised to detect and enhance possible fingerprints; however, most are not suitable for use on the adhesive side of tape.[7, 8]

Cyanoacrylate (CA) fuming, more commonly known as superglue fuming, is a well-established method that has proved to be beneficial in ascertaining latent fingerprints on a variety of surfaces, including the adhesive side of tape.[9-12] The heating of liquid CA initiates its transition into the gaseous phase, that preferentially polymerises on deposited fingerprint residues.[7] This provides vital contrast, necessary for further examination and analysis.[7] However, as a result of the white polymer formed, fingerprints present on lighter-coloured substrates lack sufficient contrast and often require the use of secondary techniques.[4, 13] Powdering methods can be utilised after CA fuming; however, a dye method is more suitable for use on adhesive tapes. Rhodamine 6G (RG6) is a highly fluorescent dye that, when coupled with CA fuming, provides fluorescence of the fingerprint ridges using alternative light sources (ALS) at specific wavelengths; varying with the solvent used.[14] Despite the increased contrast, the addition of organic solvents can have a negative impact on the developed fingerprint. This limitation leads to the development of one-step CA fuming.[15]

One-step CA fuming incorporates a fluorescent dye, or fluorophore within the CA fuming process, that simultaneously develops and enhances the fingerprint.[4, 16] PolyCyano UV (Foster + Freeman Ltd.), unlike liquid superglue, is a solid polymer that contains the fluorescent compound p-Dimethyleaminobenzaldehyde (DMAB), which varies in concentrations from 5% up to 15%.[17] Takatsu *et al*.[18] reported that DMAB selectively binds to CA polymers, which could prove beneficial for substrates that are sensitive to organic solvents involved in two-step processes. Previous studies involving PolyCyano UV have given results comparable to that of conventional CA fuming, despite quality varying by substrate.[16, 19, 20] However, it has been commonly observed that PolyCyano UV fluorescence lacks intensity when compared to two-step methods using dyes.[16, 19] Unlike conventional CA fuming, which requires a heating temperature of approximately 120°C, PolyCyano UV requires 230°C, thus requiring modification of existing fuming chambers.[20, 21] Cyanoacrylates exposed to high temperatures like this pose the risk of producing toxic hydrogen cyanide gas.[22]

Lumicyano™ (Crime Science Technology [CST], France) is one of the newer commercially available methods. This product involves the combination of a solid powder fluorescent dye ($C_4H_5ClN_4O$) and liquid CA.[23-25] Much like traditional CA fuming, Lumicyano™ requires a heating temperature of 120°C , meaning the modification of existing fuming cabinets is not required.[19] Prete *et al*.[26] indicated that Lumicyano™ developed fingerprints with equal or better ridge detail and sensitivity when compared to CA fuming, and gave excellent contrast and ridge clarity on various non-porous surfaces. In addition to this, Farrugia *et al*.[21] examined the development of latent fingerprints deposited onto plastic carrier bags using Lumicyano™ and deemed it a suitable technique for use, even on light coloured substrates.

A recent study conducted by Chung[27] observed Lumicyano™ to give comparable results to that of CA fuming when applied to the adhesive side of various dark-coloured duct tapes. As the adhesive used on tape can vary between manufacturer and tape type, the ability of one-step CA fuming methods to develop latent fingerprints on different adhesive types should be investigated.

Though more expensive than conventional CA fuming, one-step fuming has its advantages, including eliminating the need for a second step. Its effectiveness has been investigated on various porous, semi-porous and non-porous substrates, with much success, but has had limited research done on its applicability to the adhesive side of tape.[21, 26, 28] Therefore, this study aims to assess the applicability of PolyCyano UV and Lumicyano™ on the development of latent fingerprints on the adhesive side of various tapes and evaluate the quality and performance against conventional CA fuming with a post-treatment using RG6 dye. Comparisons of the different treatments were analysed according to efficiency, sensitivity, and ability to develop aged fingerprints on varying adhesive compositions.

2. MATERIALS & METHODS

2.1 Fingerprint Samples

A range of adhesive tapes were obtained for use in this study (Appendix 1). Each adhesive tape was dispensed sufficiently to ensure a length of approximately 20 cm could be cut from the middle to avoid latent fingerprints deposited during handling. The non-adhesive side of each tape was adhered to a transparent acrylate sheet using double sided sticky tape and repeated once onto nine acrylate sheets. A total of 18 transparent acrylate sheets were

used, each with five tape samples adhered to it. Each tape was divided into three areas, using a marker, to allow adequate spacing of fingerprints.

Hands were thoroughly washed using soap and water and dried prior to depositing fingerprints. A nominated finger was pressed into a Latent Print Standards Pad (Sirchie®, North Carolina, United States) using light pressure and three subsequent fingerprints were deposited onto one tape sample from left to right, producing three prints of varying saturation; high, medium and low. Between fingerprint deposits on each sample, the finger was thoroughly cleaned on a new Kimwipes® tissue (Kimberly-Clark Worldwide, Inc.). Tape samples were separated into three groups; to be developed within 24 hours of the fingerprints being deposited and after 7 and 14 days of aging. Aged samples were stored in an enclosed cardboard box and stored at room temperature.

2.2 Fuming Conditions

2.2.1 Chamber Set-Up

An enclosed, 85 L plastic tank was used as a make-shift fuming chamber. The chamber was cleaned using methanol and allowed to dry completely in a fume hood before each fuming session. A dual hotplate (Kmart, Australia) was placed inside, and the temperature was monitored using an infrared thermometer (Generic Infrared Thermometer with Laser Aimpoint GM-300). A 500 mL beaker with approximately 100 mL water was placed on one of the hotplate burners to induce humidity into the chamber before fuming.

2.2.2 *Fuming Process*

Dosages and conditions of each method were adjusted to suit an 85 L tank and are outlined in Table 1. Fuming reagents were measured into a small, metal baking dish and placed onto one of the hotplate burners. Samples to be developed were placed into the chamber before

turning on the hotplate, allowing the reagent to heat gradually. Samples were monitored continuously during the fuming process to limit the possibility of over-development. All samples were fumed for 10 minutes, stopping the fuming process by removing them from the chamber. Between each fuming method, the hotplate was cooled completely.

Table 1 *Dosage summary of fuming conditions*

Method	Dosage	Temperature Required
Cyanoacrylate (CA + R6G) (Loctite® Super Glue 5 g) Rhodamine 6G in 100% methanol (Sigma-Aldrich, St Louis MO, USA)	1 g Liquid Superglue *Post-fuming:* 1 x 10^{-5} g/mL R6G	120°C
Lumicyano™ kit LK1-20 (Crime Science Technology, Loos, France)	34 mg Lumicyano Powder™ + 0.8 g Lumicyano Solution™	120°C
PolyCyano UV 10 g (Foster + Freeman Ltd.)	0.268 g PolyCyano UV Powder	230°C

2.2.3 Post-development

Samples developed with CA were dyed with R6G for approximately 10 seconds by spraying the dye onto the tapes before rinsing with methanol and repeating the process. Samples were placed in a fume hood to dry before analysis.

2.3 Visualisation

Developed fingerprints were photographed using a Nikon D5500 DSLR camera equipped with a macro lens (AF-S Micro NIKKOR 60mm f/2.8G ED) within 30 minutes after development. Camera settings were fixed to JPEG Fine (Large 6000x4000). ISO and aperture were kept consistent at 100 and F11 respectively, while shutter speed was dependent on the photography conditions. Photographs were not digitally enhanced, but digital image enhancement software (GNU Image Manipulation Program 2.6.7, GIMP) was used to crop

the images to the appropriate size. All fingerprints were photographed under white light. Additionally, prints were photographed under various Polilight Flare® Plus 2 (Rofin Australia) depending on the enhancement method; 505nm wavelength for CA + R6G and Lumicyano™, and 365nm UV light for PolyCyano UV. A HOYA HMC lens (Orange G 62) was coupled with the macro lens for use with the 505nm Polilight.

2.4 Classification/Reporting of Results

All results were obtained through the examination of the sample photographs and recorded using Microsoft® Word and Excel. Samples were scored using the Bandey Five-Point Scale System to determine the efficiency of development; its criteria are described in Table 2. Sample quality was also assessed based on the presence of first, second and third level detail, following SWGFAST terminology.[29]

Table 2 *Bandey Five-Point Scale System*.[30]

GRADE	CRITERIA
0	No development
1	No continuous ridges; all discontinuous or dotty
2	One-third of the mark comprised of continuous ridges; the remainder either show no development or dotty
3	Two-thirds of the mark comprised of continuous ridges; the remainder either show no development or dotty
4	Full development; whole mark comprised of continuous ridges

3. RESULTS & DISCUSSION

3.1 Sample Visualisation

3.1.1 Visualisation Under White Light

Sample images are present in Appendix 2. Under white light, the appearance of all samples varied between substrates. Fingerprint deposits were most visible on the tapes with darker coloured adhesive sides (Black PVC, Grey PVC and Brown Packaging tape) showing evidence

of fingerprints without the need for ALS; however, fingerprint deposits on the tapes with lighter coloured adhesive sides (Clear Packaging Tape, Masking Tape, and Cloth Tapes) were not as visible to the naked eye. Since the resultant developed fingerprint was white, this may explain the limited visibility under white light.

3.1.2 Visualisation Under Alternative Light Sources

Samples treated with CA + R6G displayed fluorescence, though it was apparent that some samples exhibited more fluorescence than others; this could be due to the time allowed for dyeing. The use of fluorescent dyes on particular surfaces can develop background staining, making the contrast difficult between the area of interest and the substrate.[21] With regards to this, less time that the dye is in contact with the substrate can result in less background staining, but as a consequence, less adherence to the developed fingerprint.[19] Additionally, the methanol wash step following dyeing with R6G generally removes excess dye to decrease potential background staining, however loss of dye adhering to the fingerprint is also likely.[16] The ALS wavelength applied could have been a factor in the reduced fluorescence observed, as R6G has been tested in various organic solvents to assess whether its fluorescence was influenced by the solvent selected.[14] The R6G in this study was dissolved in methanol, which was found to have the highest fluorescence intensity, as observed in a study by Zehentbauer *et al.*[14], though it was also indicated that the underlying principles of the fluorescence process are not notably influenced by the solvent. It was also observed that application of the RG6 dye on the tapes with acrylic-based adhesives began to interact chemically and appeared to separate the adhesive from the polypropylene backing. This is an issue with a potential loss of fingerprints due to degradation of the tape itself.

Lumicyano™ fluorescence allowed optimal contrast between fingerprint and substrate, particularly with regards to the darker adhesive tapes. Much like samples treated with CA + R6G, fluorescence varied over different tape samples. The concentration of Lumicyano™ used in this study was an 8% concentration to maximise fluorescence, which was apparent when examining fingerprints not easily visualised under white light. Beerman *et al.*[4] observed fingerprints fumed with higher concentrations of Lumicyano™ to give greater fluorescence when compared to lower concentrations of Lumicyano™; however, there was noticeably more overdevelopment. There was some observable over-development on the high saturated fingerprints on the smoother adhesive tape substrates, which poses the question as to whether over-development was a result of high saturation or the method utilised.

Fluorescence of PolyCyano UV was not as high intensity as Lumicyano™ or CA + R6G, but utilisation of UV light detected fingerprints that were not visible under white light. Some grey PVC tape samples did not exhibit fingerprints under white light, yet evidence of a fingerprint was apparent when observed under UV light (Figure 1). Chadwick *et al.*[16] also observed PolyCyano UV to give weaker fluorescence compared to CA + R6G developed fingerprints, but found that subsequent sequencing with R6G gave greater contrast.

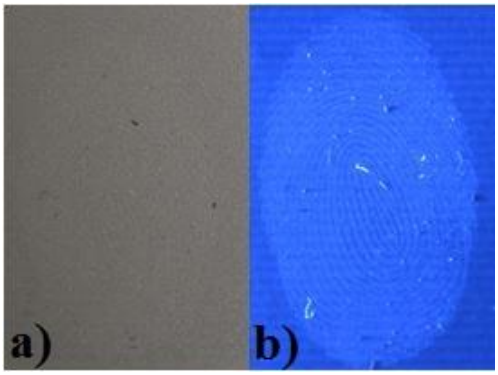

Figure 1 *PolyCyano UV developed fingerprint under:* ***a)*** *white light;* ***b)*** *UV light*

3.1.3 Visualisation on Substrate Surface

Fingerprint samples were more easily visible on the tape substrates with smooth adhesive sides. Due to the flat surface of the PVC and packaging tapes, fingerprints presented more detailed characteristics in comparison to those deposited on the rough textured cloth tapes. It was also apparent that more of the overall fingerprint was able to be observed, whereas the cloth tape fingerprint deposits appeared to only exhibit portions of the print. The higher sticky quality of the tapes with rubber-based adhesives tended to retain the fingerprint deposits more than the tapes with acrylic-based adhesives.

3.2 Method Evaluation

Fingerprints were able to be developed on all tape samples except for masking tape. Samples treated with CA + R6G had the highest percentage of developed fingerprints with a total of 90.12%; however, the distribution of percentages was relatively even across grades 1—4. Despite Lumicyano™ resulting in around 21% of samples having no development, 33.33% displayed full development with continuous ridge detail, giving the highest result of complete fingerprints over all methods used. PolyCyano UV was the least successful, with no development over almost 35% of samples; however, it did give the highest percentage of samples with two-thirds of development (Table 3).

In terms of quality analysis, samples treated with CA + R6G gave the highest percentage of level 1 details. Level 2 detail observed for Lumicyano™ was as good as CA + R6G, with Lumicyano™ proving more superior in relation to level 3 detail. PolyCyano UV gave the lowest results with less than 31% in all levels of detail (Figure 2).

Table 3 *Total Bandey Scale Percentages*

Bandey Scale Grade	Cyanoacrylate + R6G (%)	Lumicyano™ (%)	PolyCyano UV (%)
0	9.88	20.99	34.57
1	22.22	16.05	11.11
2	22.22	12.35	13.58
3	17.28	17.28	20.99
4	28.40	33.33	19.75

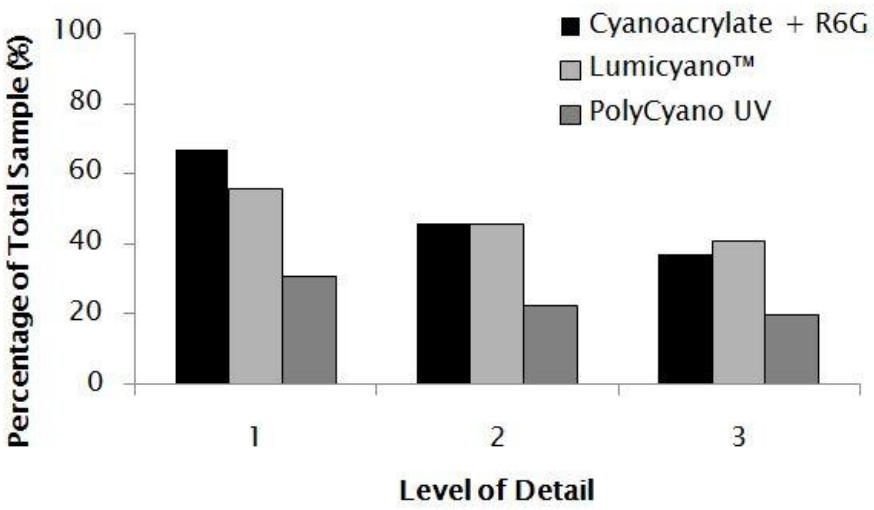

Figure 2 *Total quality analysis* of *Cyanoacrylate + R6G, Lumicyano™ and PolyCyano UV treated fingerprints*

3.3 Sensitivity Analysis

Sensitivity evaluation demonstrated Lumicyano™ to have results comparable to CA + R6G. With regards to high saturation deposits, Lumicyano™ performed better than CA + R6G with 48.15% of the sample exhibiting full development with continuous ridge detail. Medium and low saturated deposits gave similar results between CA + R6G and Lumicyano™; however, Lumicyano™ performed better in reference to two-thirds development of medium and low

saturated fingerprints. In contrast to the comparability of CA + R6G and Lumicyano™, PolyCyano UV was observed to be less efficient in the case of full development of high saturated fingerprints; 22.22% and 7.40% less than Lumicyano™ and CA + R6G, respectively. Medium saturated fingerprints, full development results, were comparable to the low saturated fingerprints full development results of CA + R6G and Lumicyano™, thus demonstrating its low sensitivity of detection and development (Table 4). Results from this study conclude that the sensitivity of CA + R6G and Lumicyano™ are comparable; however, Lumicyano™ is more likely to result in higher full developed fingerprints on highly saturated samples.

Table 4 *Sensitivity efficiency of Cyanoacrylate + R6G, Lumicyano™, and PolyCyano UV treated fingerprints*

Bandey Scale Grade	Cyanoacrylate + R6G (%)			Lumicyano™ (%)			PolyCyano UV (%)		
	High	Medium	Low	High	Medium	Low	High	Medium	Low
0	0.00	7.41	22.22	11.11	14.81	37.04	29.63	33.33	40.74
1	18.52	22.22	25.93	14.81	18.52	14.81	7.41	11.11	14.81
2	29.63	22.22	14.81	14.81	11.11	11.11	7.41	14.81	14.81
3	18.52	14.81	18.52	11.11	22.22	18.52	25.93	22.22	14.81
4	33.33	33.33	18.52	48.15	33.33	18.52	25.93	18.52	14.81

As expected, there was an increased percentage of detail associated with high saturated fingerprints. CA + R6G treated samples were the most successful in developing fingerprints that exhibited level 1 detail. Unlike previous results in this study, Lumicyano™ and PolyCyano UV were similar in results in reference to level 1 detail; however, this pattern did not continue over level 2 and 3 details. CA + R6G and Lumicyano™, again, were comparable with regards to level 2 detail, though Lumicyano™ showed higher quality development on

low saturated fingerprints. Once again, Lumicyano™ presented the highest percentage of fingerprints exhibiting level 3 detail across all saturation levels (Figure 3). This reflects its excellent efficiency; increased complete development increases the likelihood of higher quality fingerprints. These findings concur with those of Prete *et al.*[26], in which Lumicyano™ was observed to be more sensitive in comparison to conventional CA fuming.

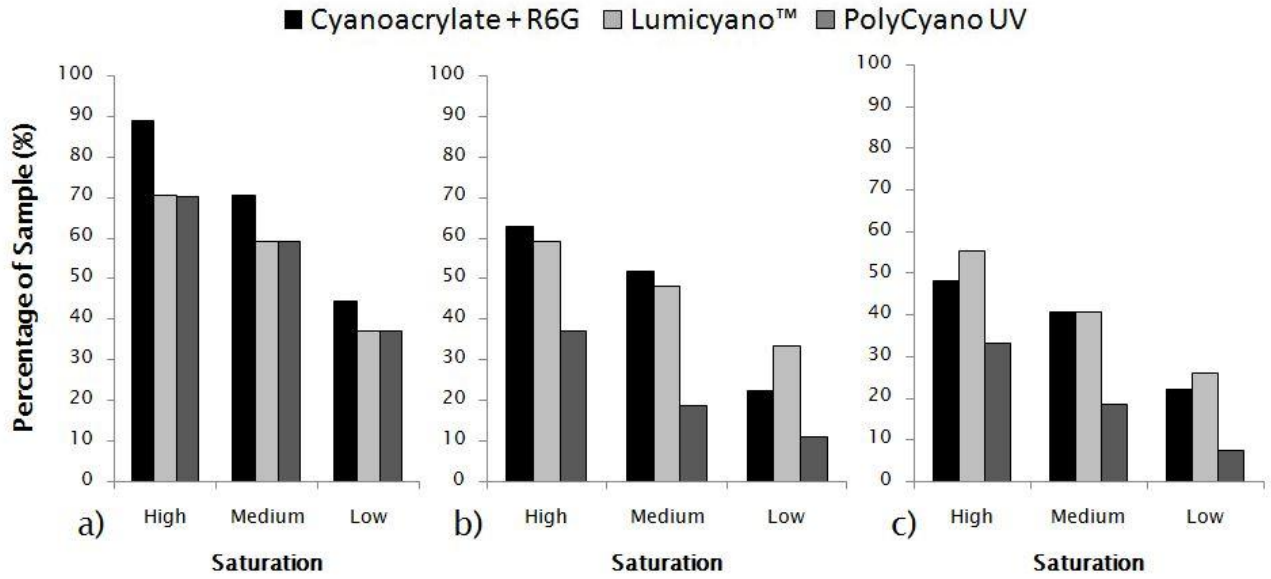

Figure 3 *Sensitivity quality of Cyanoacrylate + R6G, Lumicyano™ and PolyCyano UV treated fingerprints exhibiting:* ***a)*** *Level 1 detail;* ***b)*** *Level 2 detail;* ***c)*** *Level 3 detail*

3.4 Aged Samples

The efficiency of each method decreased over time. Samples treated within 24 hours of fingerprint deposits were more likely to result in detection and development. CA + R6G and Lumicyano™ performed much the same on aged samples; however, CA + R6G had higher detection of fingerprints. After 7 days, loss of development was minimal for CA + R6G with an approximate 50% decrease in full developed samples compared to the 65% and 70% decrease for Lumicyano™ and PolyCyano UV, respectively. The number of fingerprint

samples with no development after 14 days ranged between an increase of approximately 67% for CA + R6G and PolyCyano UV and 77% for Lumicyano™ (Table 5). Beerman *et al*.[4] and Khuu *et al*.[19] suggested that an 8% Lumicyano™ solution is acceptable for fresh fingerprints, but a 10% solution would be more appropriate for fingerprints 7+ days old; this could account for the high percentage of fingerprint samples with no development.

Table 5 *Efficiency of Cyanoacrylate + R6G, Lumicyano™ and PolyCyano UV on aged fingerprints*

Bandey Scale Grade	Cyanoacrylate + R6G (%)			Lumicyano™ (%)			PolyCyano UV (%)		
	Immediate	7 Days	14 Days	Immediate	7 Days	14 Days	Immediate	7 Days	14 Days
0	0.00	7.41	22.22	3.70	11.11	48.15	0.00	25.93	77.78
1	7.41	18.52	40.74	3.70	22.22	22.22	7.41	25.93	0.00
2	18.52	33.34	14.81	7.41	18.52	11.11	7.41	22.22	11.11
3	29.62	18.52	3.70	22.22	25.93	3.70	48.15	14.81	0.00
4	44.45	22.22	18.52	62.97	22.22	14.82	37.04	11.11	11.11

Most fingerprint samples decreased in quality over time. Immediate development observed CA + R6G and Lumicyano™ to have comparable results with regards to level 1 detail; however, Lumicyano™ had a higher percentage of level 2 and 3 detail. Following the 7 day aging period, CA + R6G exhibited more developed fingerprints with both level 1 and 2 detail, but was still lower than Lumicyano™ in developing fingerprints with level 3 detail. After 14 days, it was apparent that CA + R6G still had almost 50% of fingerprints displaying level 1 detail, and had comparable results with Lumicyano™ in exhibiting level 3 detail fingerprints.

It was evident that PolyCyano UV did not perform well on aged fingerprints, with only 7.41% of the sample presenting levels 1—3 detail after 14 days (Figure 4).

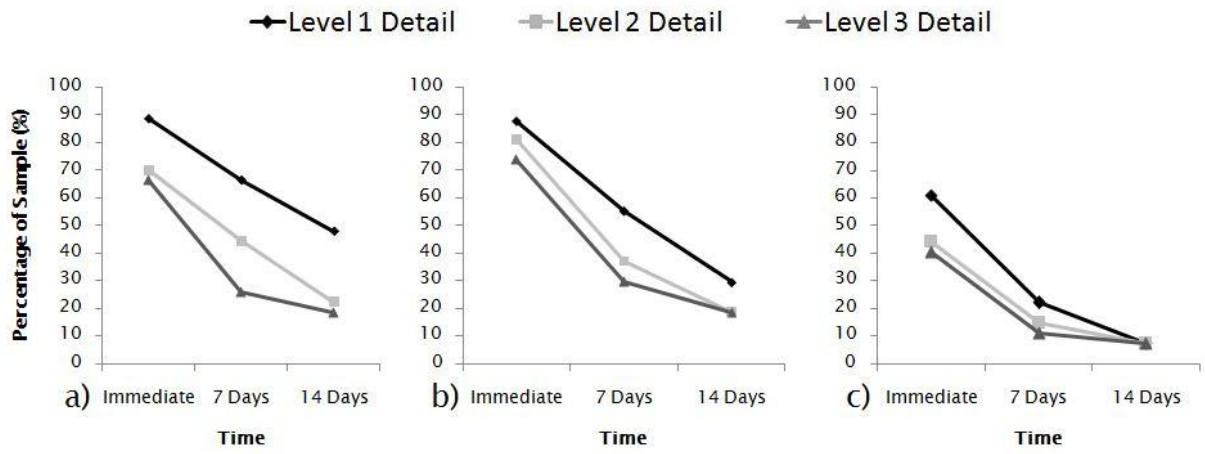

Figure 4 *Quality of aged fingerprints exhibiting level 1, level 2 and level 3 details using:* ***a)*** *Cyanoacrylate + R6G;* ***b)*** *Lumicyano™;* ***c)*** *PolyCyano UV*

With regards to aged fingerprints, studies have found the degradation of fingerprint details due to loss of water content. As water constitutes the majority of a latent fingerprint, evaporation of water over time can increase its susceptibility to decay.[13] The aging process, such as exposure to light, moisture, and heat, have been reported to lead to the degradation of fingerprints.[31] Wargacki *et al*.[13] postulated that the loss of water over time is a major contributor to susceptibility to decay due to airflow. As a result of this, latent fingerprint degradation is strongly dependent on moisture. A high amount of water can cause a less efficient reaction; however, a small amount can help to initiate the polymerisation process.[4] In CA fuming, relative humidity (RH) greatly influences the eccrine constituents of latent fingerprints, but has shown to be less influential on sebaceous marks.[7] Studies have analysed that the optimum RH level for efficient CA fuming is between 75—80%; where RH above or below this level is more likely to result in poor ridge detail and a

decrease in polymer formation.[32] Prete *et al*.[26] found that Lumicyano™ was efficient in the same RH conditions as conventional CA fuming; however, Chadwick *et al*.[16] noted that the optimal RH level for PolyCyano UV is around 90%, which most existing fuming chambers cannot reach. This may account for the lack of developed fingerprints using PolyCyano UV in this study as RH was not monitored.

3.5 Substrate Type

Fingerprint development on different adhesive compositions was variable across the methods used. With regards to the tapes with acrylic-based adhesives, all methods had between 30—45% of fingerprints not developing; however, Lumicyano™ was the most successful with almost 17% displaying full development and continuous ridge detail. This could be a result of the eliminated need for post-development dyeing, as it was observed that the R6G solution interfered with tapes that had acrylic-based adhesives. All three methods were relatively successful in developing fingerprints on tapes with natural rubber-based adhesives, giving excellent contrast of ridge detail (Appendix 2). CA + R6G gave the highest percentage of full developed fingerprints on natural rubber-based adhesives, followed by Lumicyano™ and PolyCyano UV. Fingerprints deposited on synthetic rubber-based adhesives had less complete development using CA + R6G and PolyCyano UV but had a very high percentage of approximately 89% using Lumicyano™ (Table 6). A previous study by Chung[27] noted difficulties with developing fingerprints on rubber-based duct tapes using both CA + R6G fuming and Lumicyano™; however, there were no issues with this in this study.

Table 6 *Efficiency of Cyanoacrylate + R6G, Lumicyano™ and PolyCyano UV on acrylic-based, natural rubber-based and synthetic rubber-based adhesives*

Bandey Scale Grade	Cyanoacrylate + R6G (%)			Lumicyano™ (%)			PolyCyano UV (%)		
	Acrylic	Rubber (Natural)	Rubber (Synthetic)	Acrylic	Rubber (Natural)	Rubber (Synthetic)	Acrylic	Rubber (Natural)	Rubber (Synthetic)
0	33.33	0.00	4.44	44.44	0.00	20.00	38.89	16.67	40.00
1	33.33	0.00	26.67	22.22	5.56	17.78	33.33	0.00	6.67
2	3.70	0.00	37.78	5.56	0.00	20.00	5.56	5.56	17.78
3	3.70	5.56	26.67	11.11	5.56	24.44	5.56	11.11	31.11
4	14.81	94.44	4.44	16.67	88.89	17.78	11.11	66.67	4.44

4. CONCLUSION

Traditional two-step and emerging one-step fuming techniques can successfully develop latent fingerprints on the adhesive side of tape. Despite the advantage of its low cost, conventional CA fuming results were observed to be surpassed by Lumicyano™ in quality. With regards to a forensic investigation, the quality of a fingerprint is more valuable than quantity, particularly in terms of identification. Given that all samples throughout the three methods were developed in a 10-minute time frame, studies evaluating the optimal timing of these processes with regards to particular substrates should be conducted. For the use on masking tape, both conventional and one-step CA fuming was found to be unsuccessful, due to the porosity of the tape; however, Lumicyano™ showed evidence of a fingerprint being present despite the lack of finer detail. Alternative development methods, such as Ninhydrin pr sticky-side powder, may be more suitable for application on this type of tape. Although CA + R6G fuming was more successful in detecting aged fingerprints, the effect of RH on aged samples deposited onto adhesive tape should be further explored. With regards to the adhesive used, Lumicyano™ was observed to be the most successful across all the adhesive

types tested, making it the most versatile for use on adhesive tapes. Studies assessing the various methods of tape removal should be evaluated in relation to the use of one-step fuming methods, to determine if they are still more successful than conventional CA fuming.

Though PolyCyano UV was able to develop fingerprints, its fluorescence and development on aged samples was less superior to CA + R6G and Lumicyano™. Despite this, the advantage of one-step fuming methods is that they are compatible with post-treatment dyes if needed; however, this removes the novelty of having a one-step method. Additionally, the high heating temperature of PolyCyano UV, posing a risk to the user, as well as additional costs to modify existing fuming chambers, proves this method to be less advantageous in comparison to the other two methods. Further studies involving the optimisation of RH and quantity of PolyCyano UV should be conducted, as the overall cost of PolyCyano UV does not merit its efficiency.

The fluorescent signal observed on fingerprints developed using Lumicyano™ allows analysis of sample quality to be carried out immediately. In general, Lumicyano™ proved to be a simple and effective technique in comparison to the other two methods utilised. There was no requirement for any dyeing or drying facilities, which substantially cuts down on time and saves lab space. In addition to this, the use of Lumicyano™ does not require the utilization of flammable liquids (e.g., methanol) which omits the added costs and hazards associated with the disposal of these chemicals. As Lumicyano™ operates under the same conditions as conventional CA fuming (120°C, RH 80%), there is no requirement for modification of existing equipment previously used with CA fuming. Due to the heating temperature of Lumicyano™, production of toxic hydrogen cyanide gas is avoided. Studies[21, 33] have shown that Lumicyano™ treated fingerprints are less likely to interfere with

subsequent DNA analysis, whereas samples treated with post-dyeing procedures tend to have issues. Current and previous studies have demonstrated that the one-step CA fuming method, Lumicyano™, has the potential to surpass the use of conventional two-step CA fuming. As such, further investigation of this method should be conducted.

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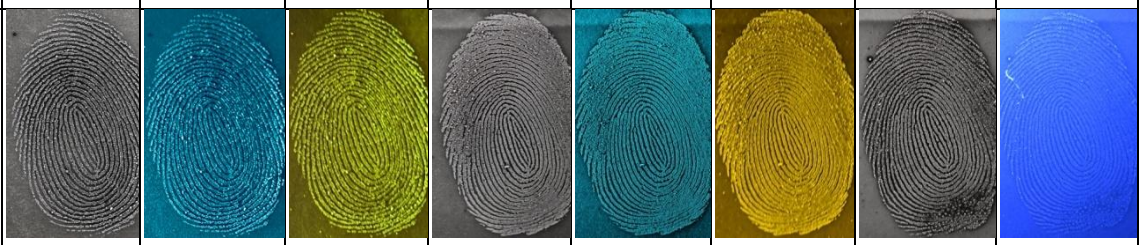
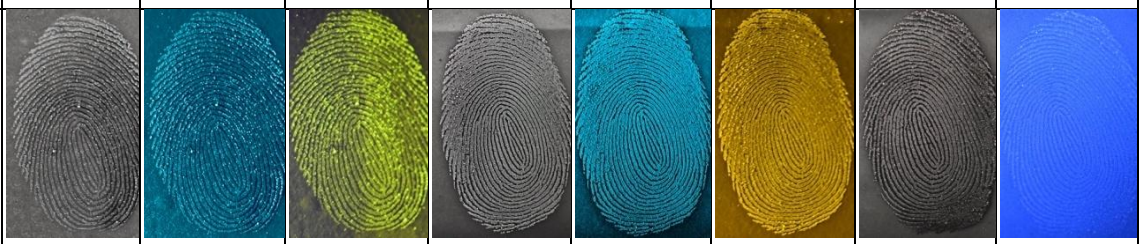
6. APPENDIX

Appendix 1: Tape samples used in this study

Brand	Type	Colour		Backing Material	Adhesive Type
		Non-adhesive Side	Adhesive Side		
Norton Bear (Saint-Gobain Abrasives Pty Ltd.)	PVC Duct Tape	Black	Black	PVC/Vinyl	Rubber (natural)
		Silver/Grey	Grey		
	Packaging Tape	Clear	Clear	Polypropylene	Acrylic
		Brown	Brown		
	Masking Tape	Off-white	Off-white	Crepe Paper	Rubber (synthetic)
	Cloth Tape	Red	White	Woven Cotton Cloth with Polyethylene	Rubber (synthetic)
		Green	White		
		Yellow	White		
		Black	White		
		White	White		

Appendix 2: Photographs of samples after development: **a**) Immediate; **b**) 7 days; **c**) 14 days

a)

		Cyanoacrylate + R6G Dye			Lumicyano			PolyCyano UV	
	#	White Light	505nm	505nm + Orange Filter	White Light	505nm	505nm + Orange Filter	White Light	UV
Black PVC Tape	1								
	2								
	3								
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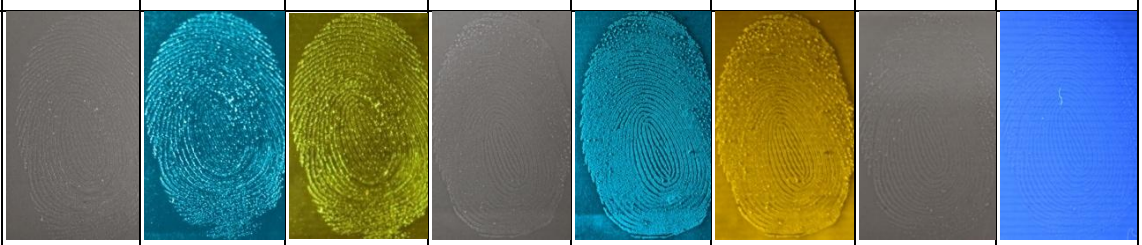
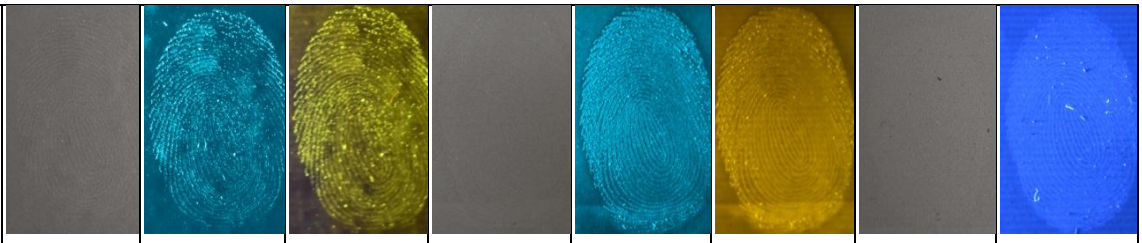
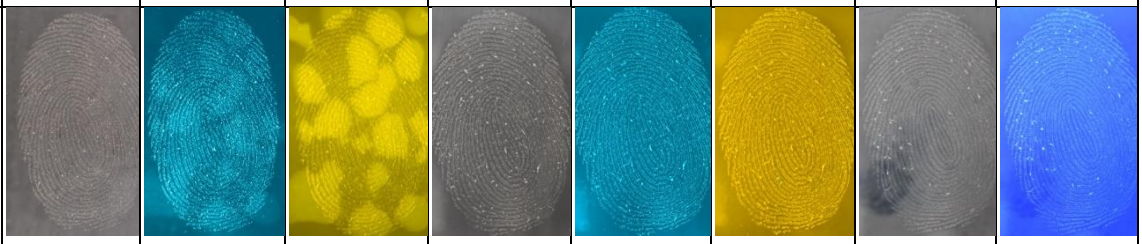
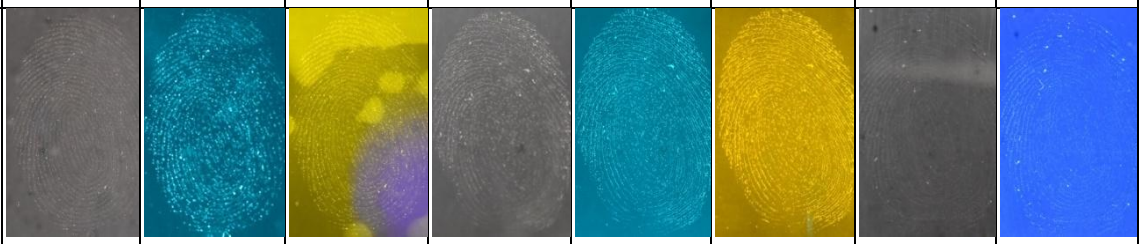
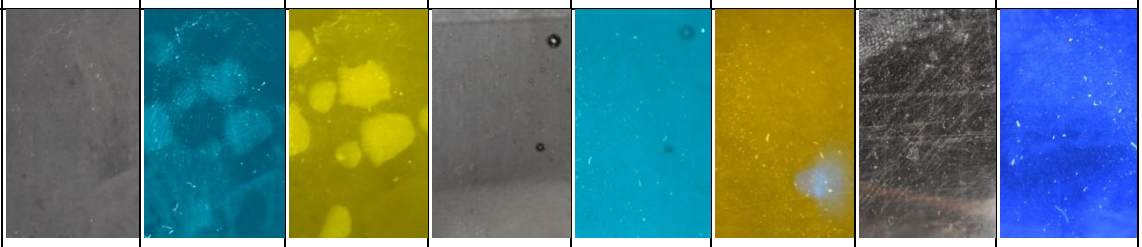
	2								

	3								
Clear Packaging Tape	1								
	2								
	3								
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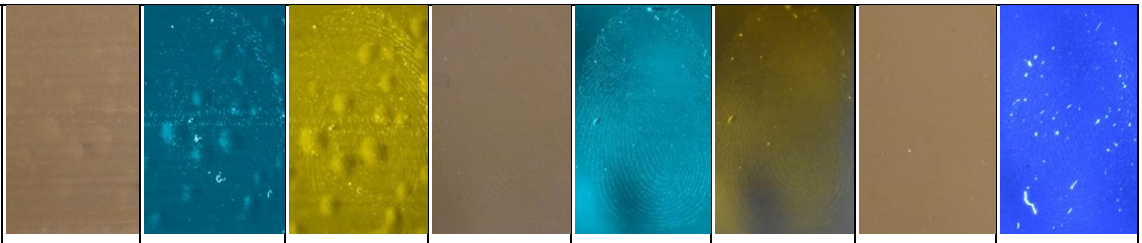
	2								

	3								
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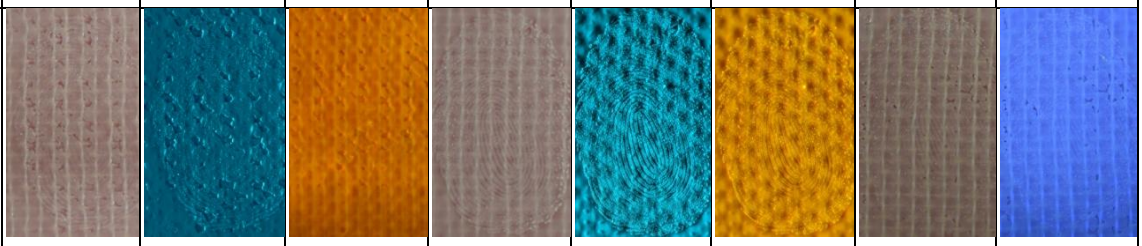
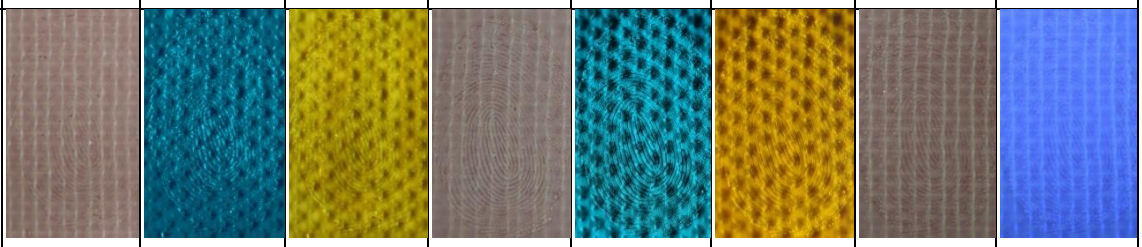
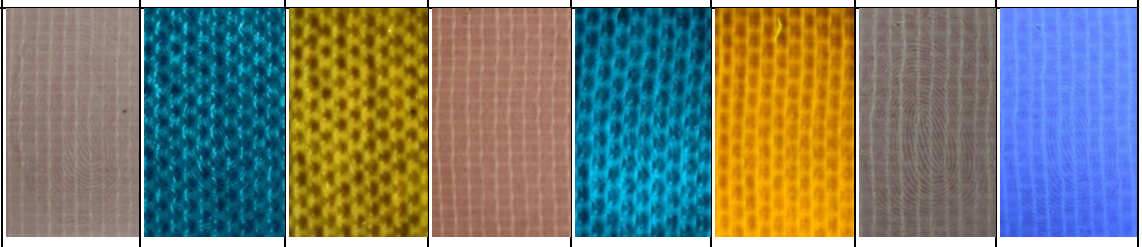
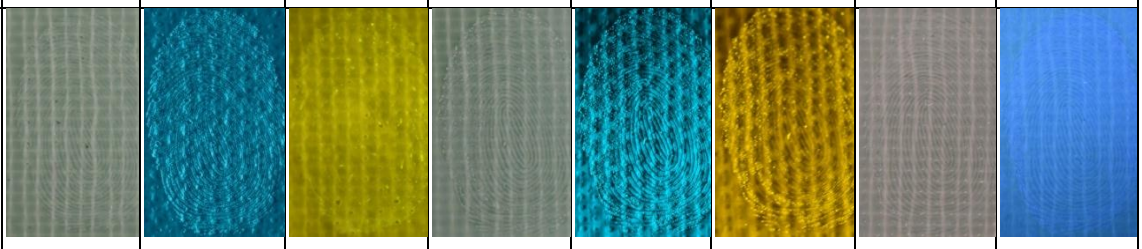
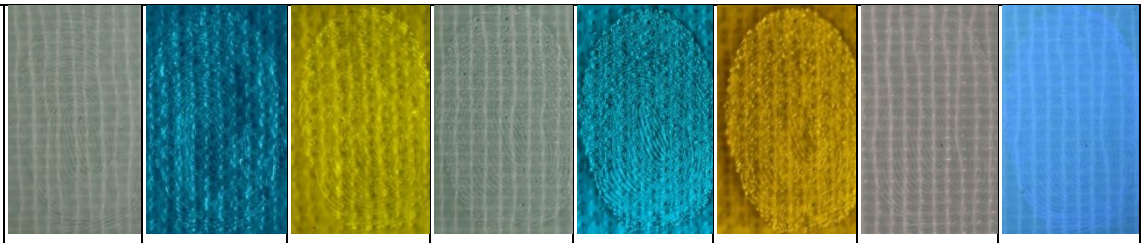
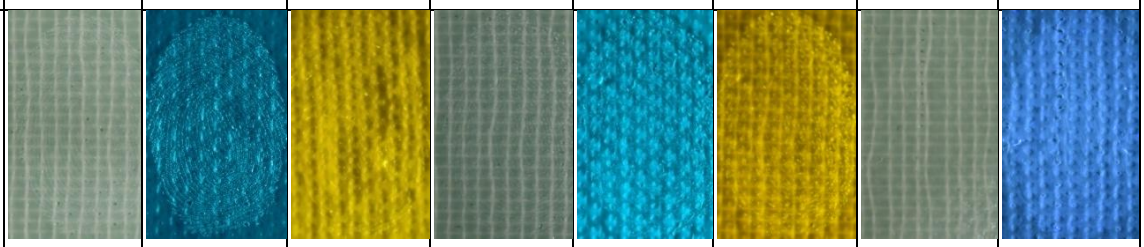
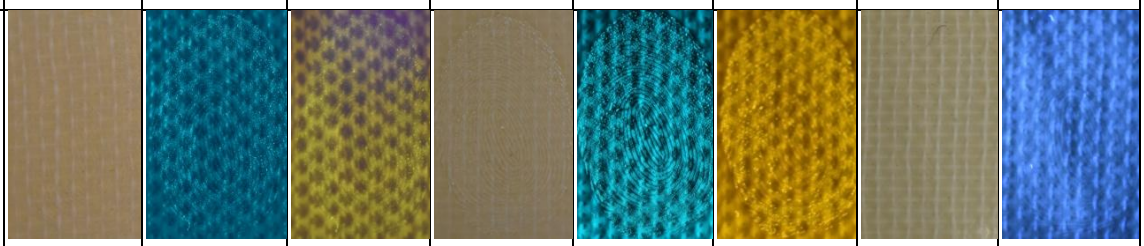
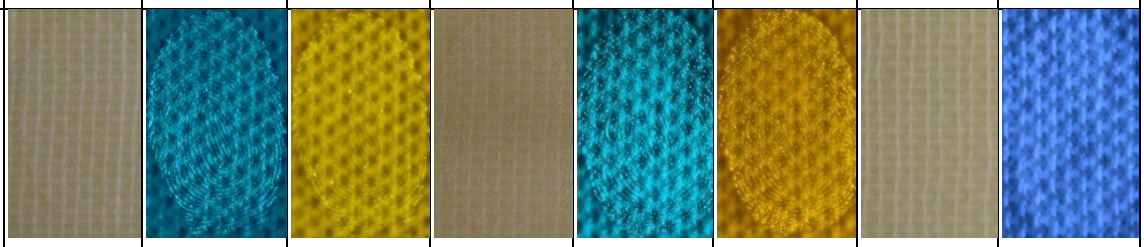
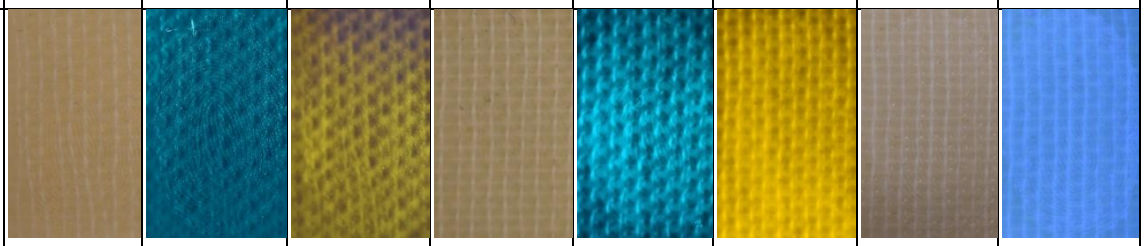
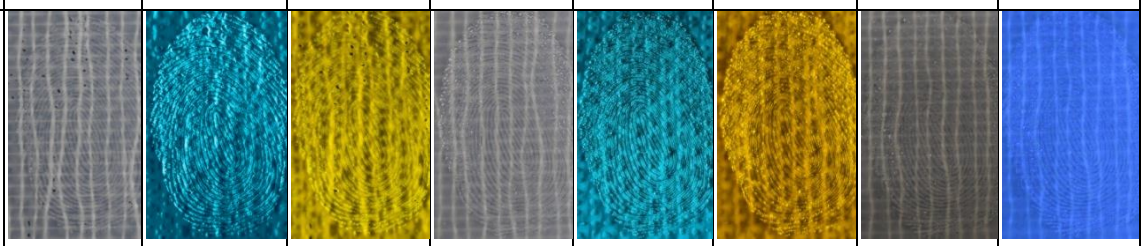
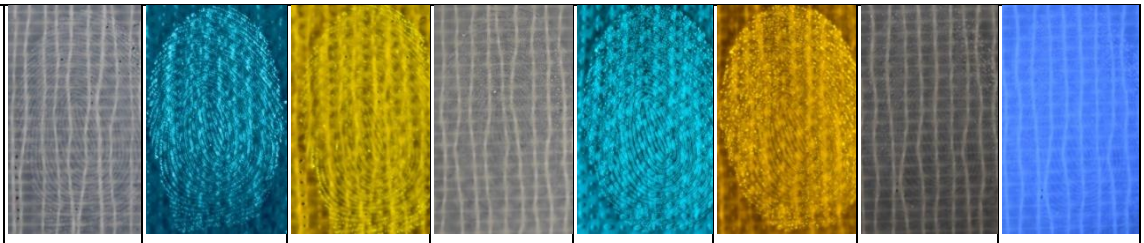
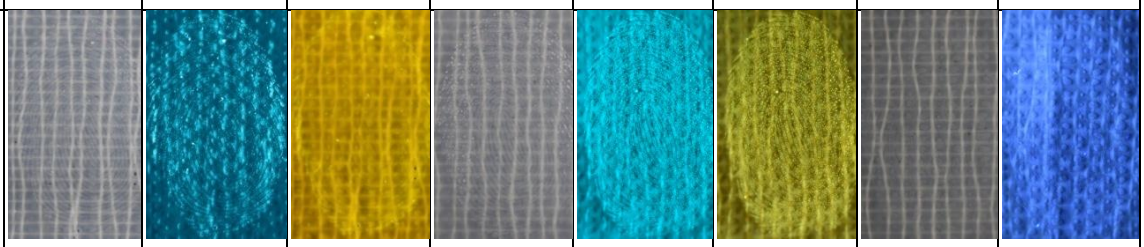
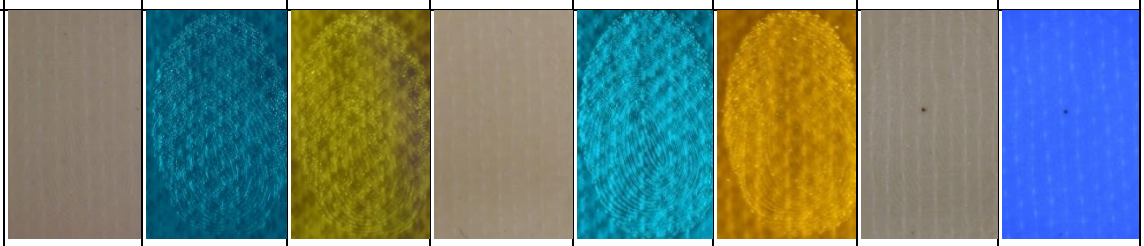
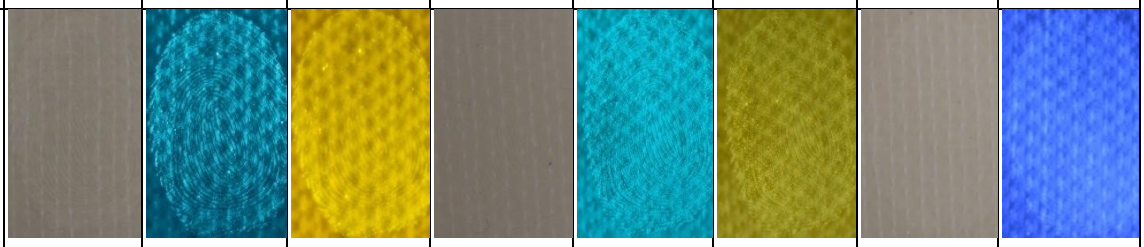
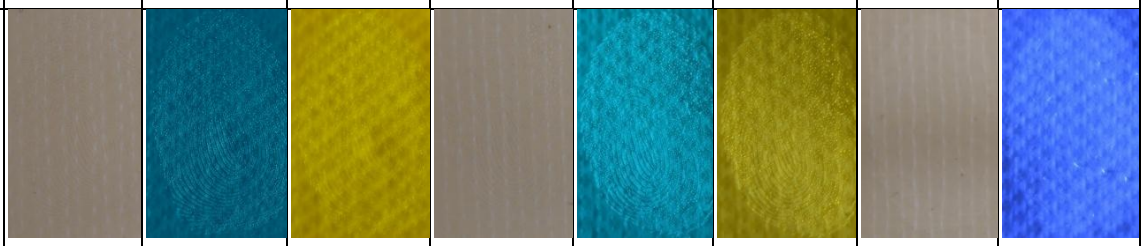
	2	no result	no result	no result	no result	no result	no result	no result	no result
	3	no result	no result	no result	no result	no result	no result	no result	no result
Red Cloth Tape	1								
	2								
	3								
Green Cloth Tape	1								

	2								
	3								
Yellow Cloth Tape	1								
	2								
	3								
Black Cloth Tape	1								

	2								
	3								
White Cloth Tape	1								
	2								
	3								

b)

		Cyanoacrylate + R6G Dye			Lumicyano			PolyCyano UV	
	#	White Light	505nm	505nm + Orange Filter	White Light	505nm	505nm + Orange Filter	White Light	UV
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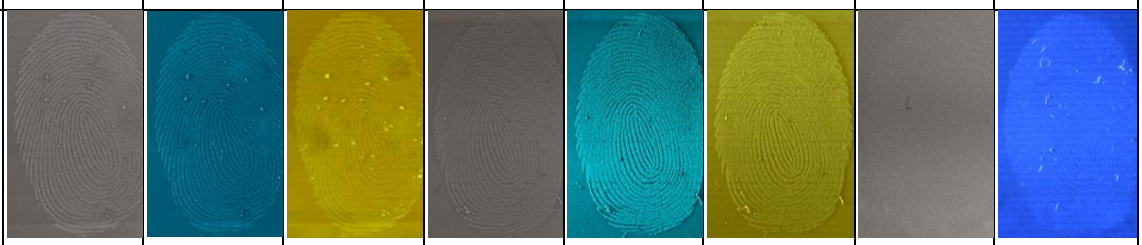
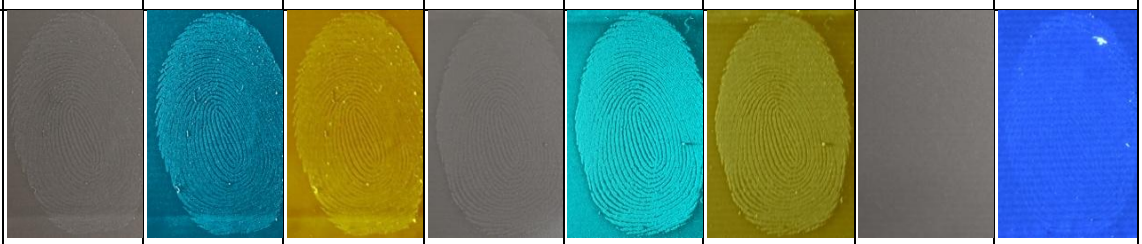
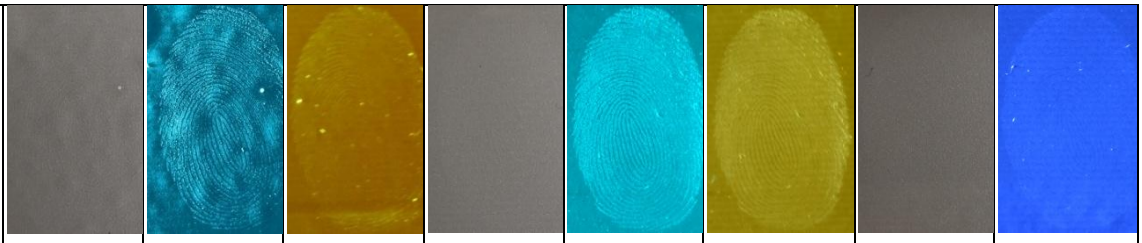
	2								
	3								
Grey PVC Tape	1								
	2								

	3								
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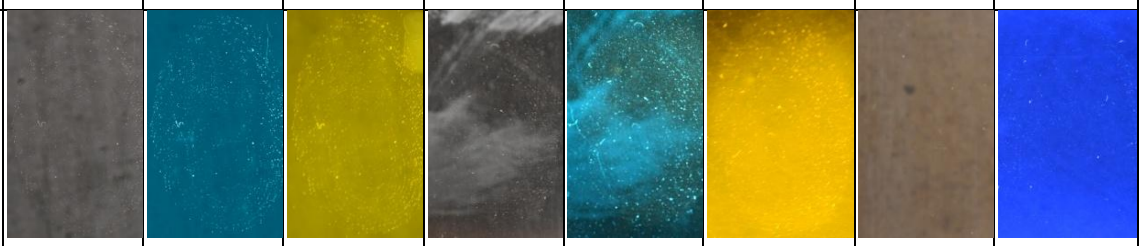
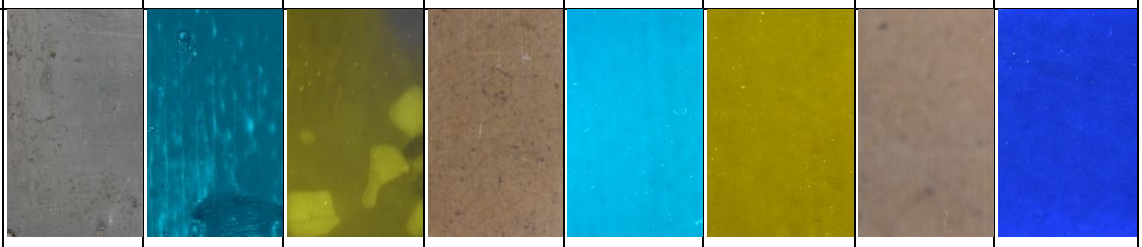
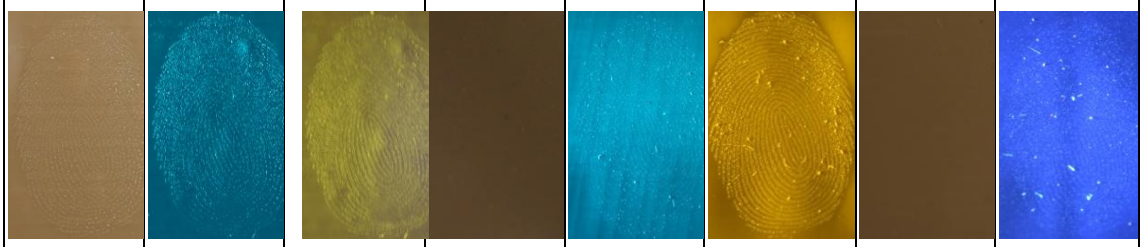
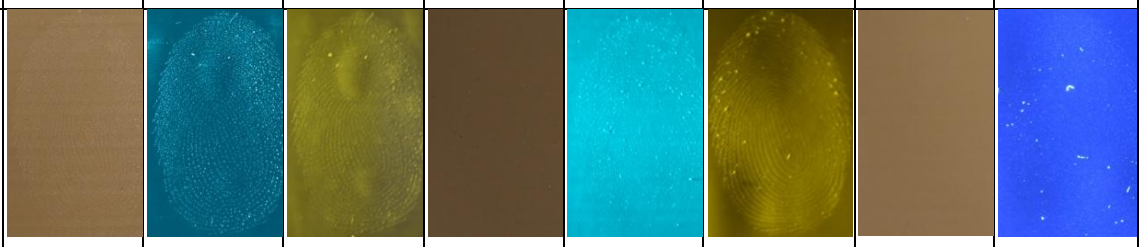
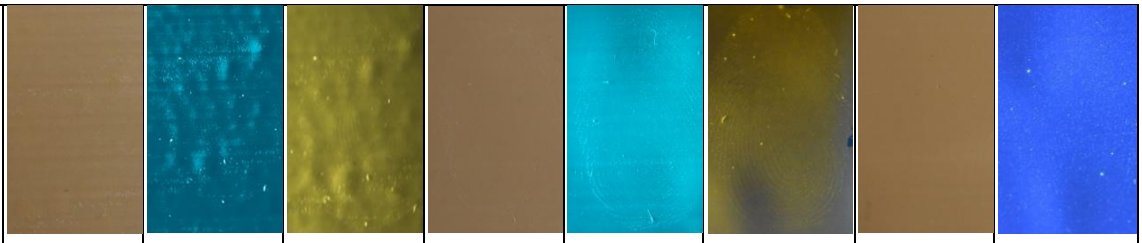
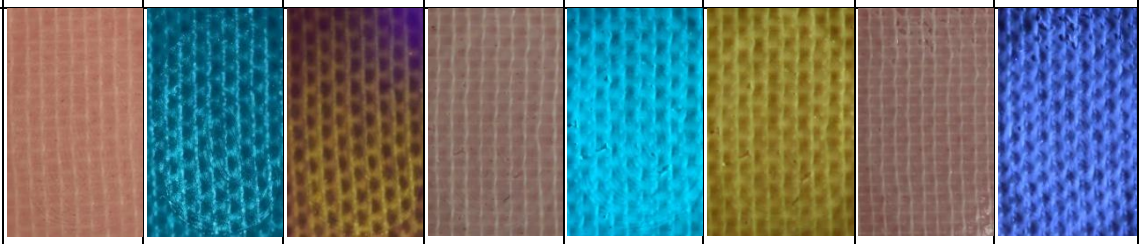
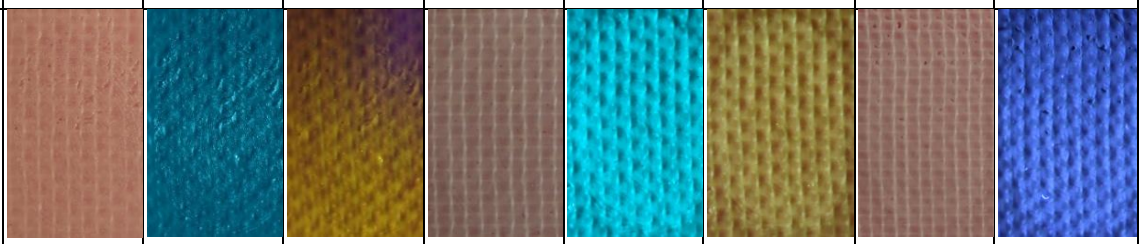
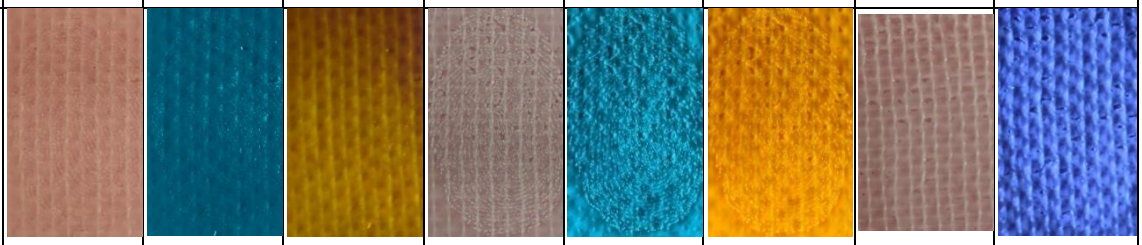
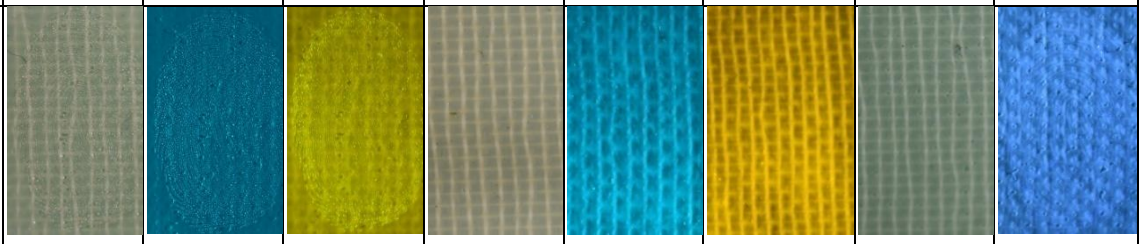
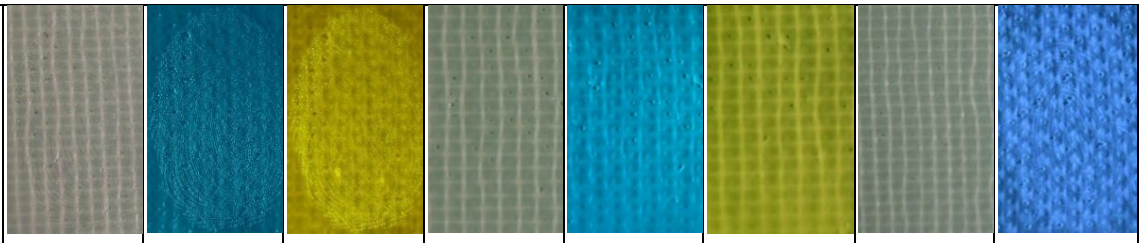
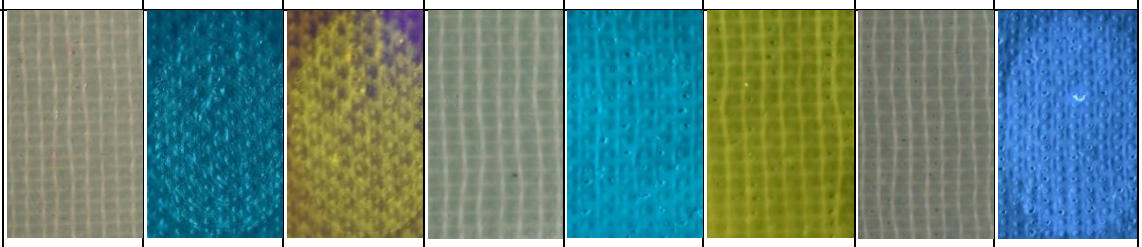
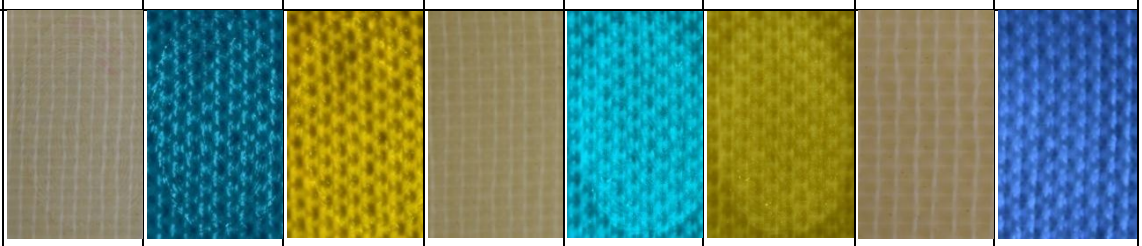
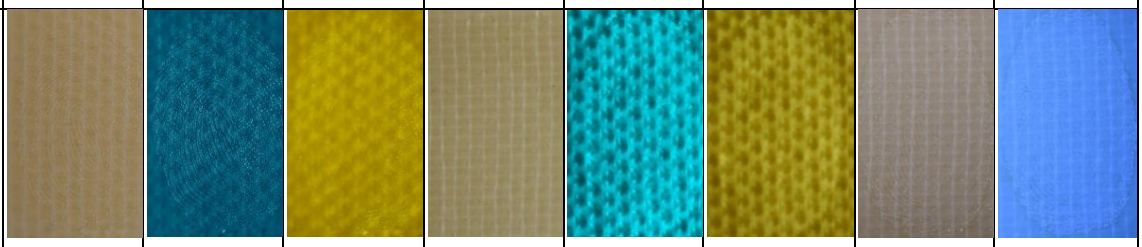
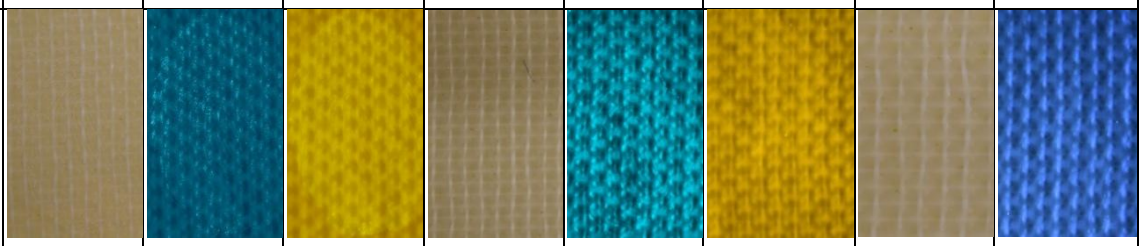
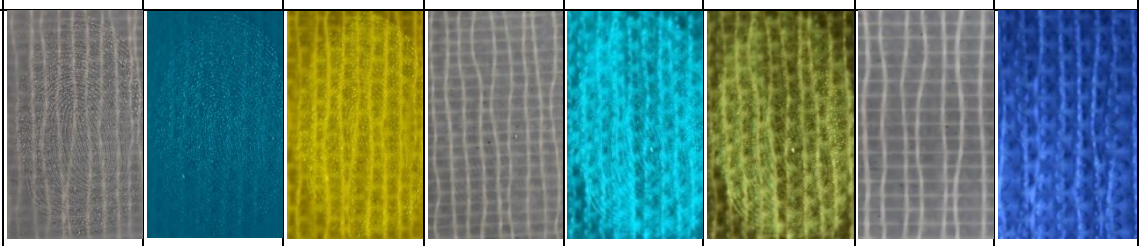
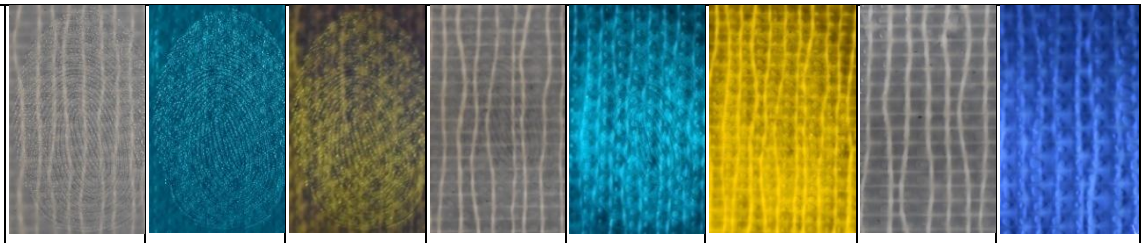
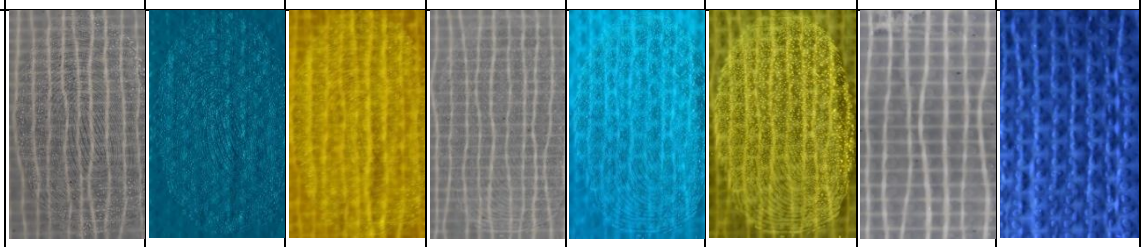
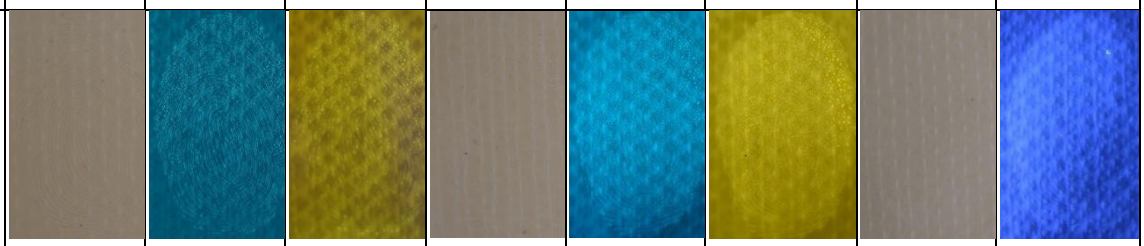
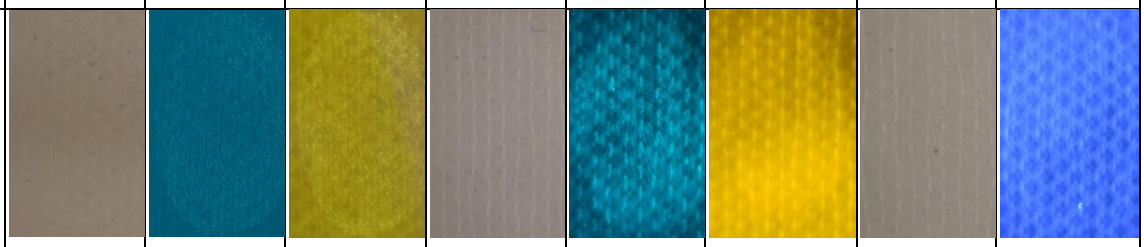
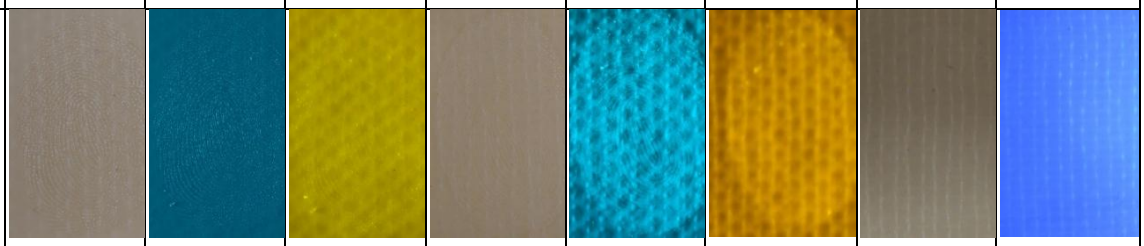
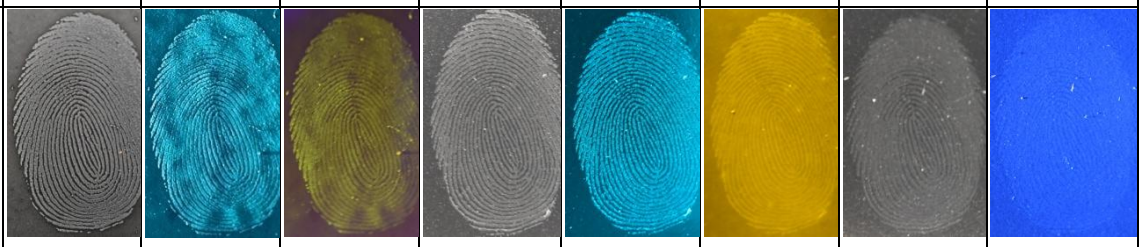
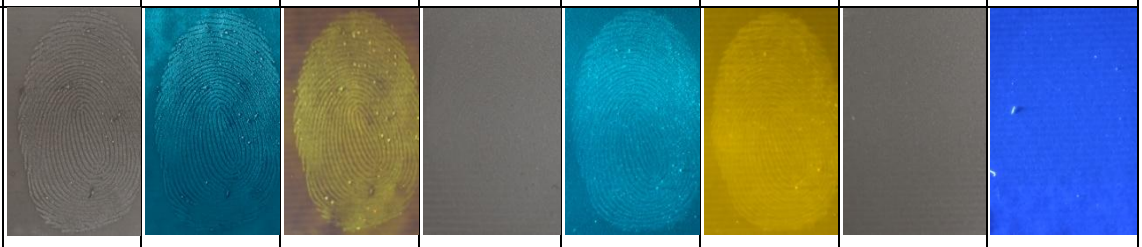
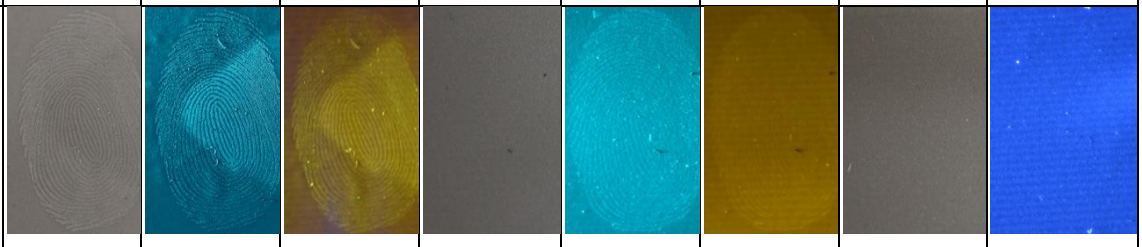
	2								
	3								
Brown Packaging Tape	1								
	2								

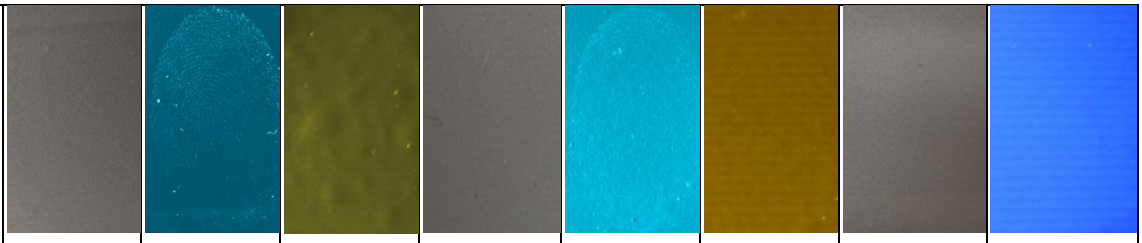
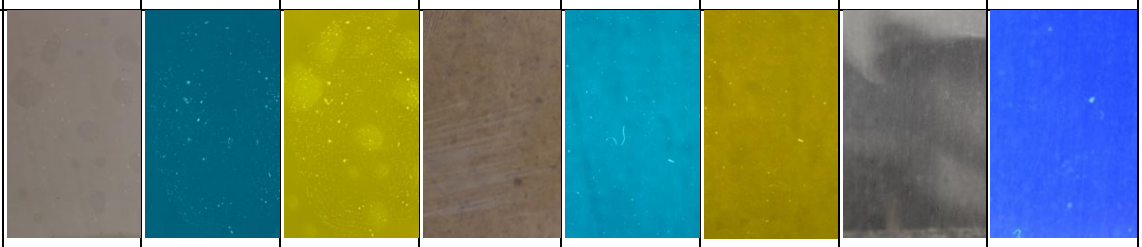
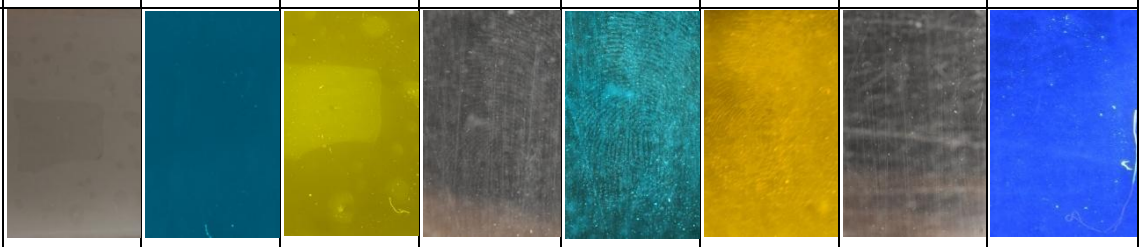
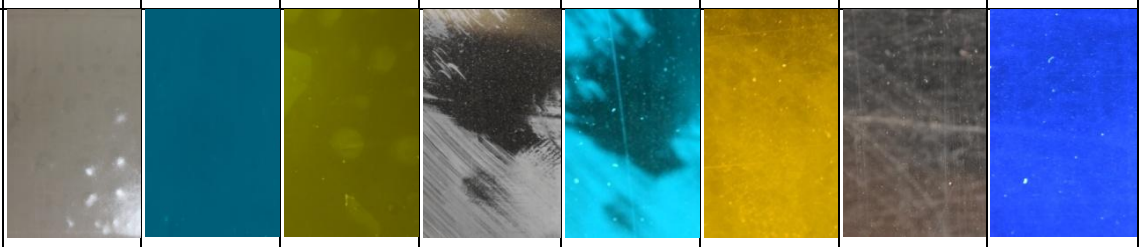
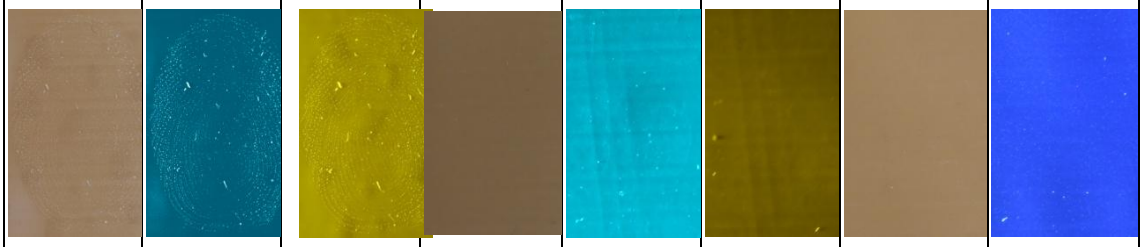
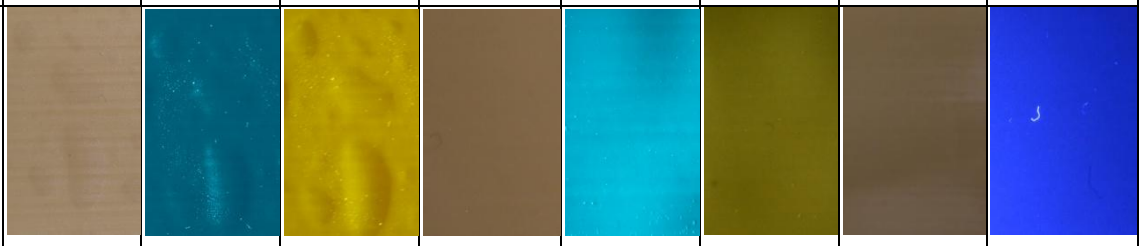
	3								
Masking Tape	1	no result	no result	no result	no result	no result	no result	no result	no result
	2	no result	no result	no result	no result	no result	no result	no result	no result
	3	no result	no result	no result	no result	no result	no result	no result	no result
Red Cloth Tape	1								
	2								
	3								
Green Cloth Tape	1								

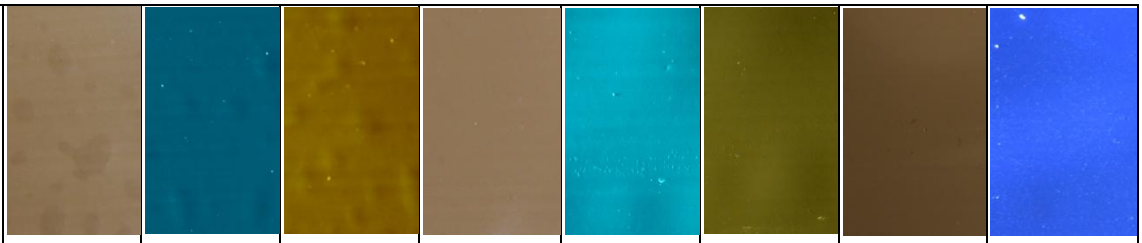
	2								
	3								
Yellow Cloth Tape	1								
	2								
	3								
Black Cloth Tape	1								

	2								
	3								
White Cloth Tape	1								
	2								
	3								

c)

		Cyanoacrylate + R6G Dye			Lumicyano			PolyCyano UV	
	#	White Light	505nm	505nm + Orange Filter	White Light	505nm	505nm + Orange Filter	White Light	UV
Black PVC Tape	1								
	2								
	3								
Grey PVC Tape	1								
	2								

	3								
Clear Packaging Tape	1								
	2								
	3								
Brown Packaging Tape	1								
	2								

	3								
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	2	no result	no result	no result	no result	no result	no result	no result	no result
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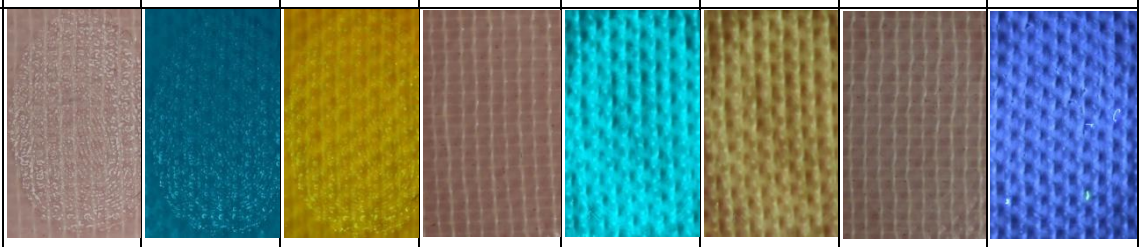
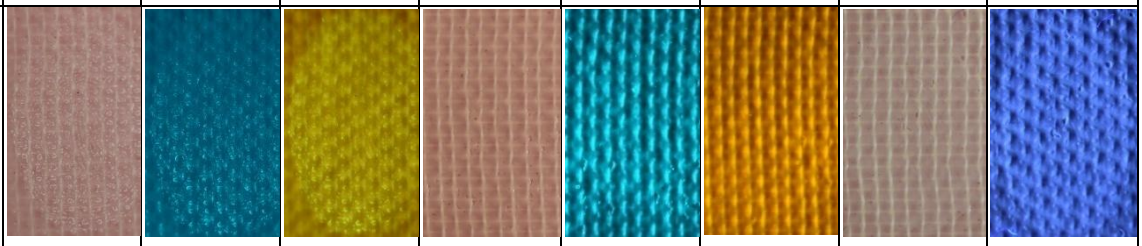
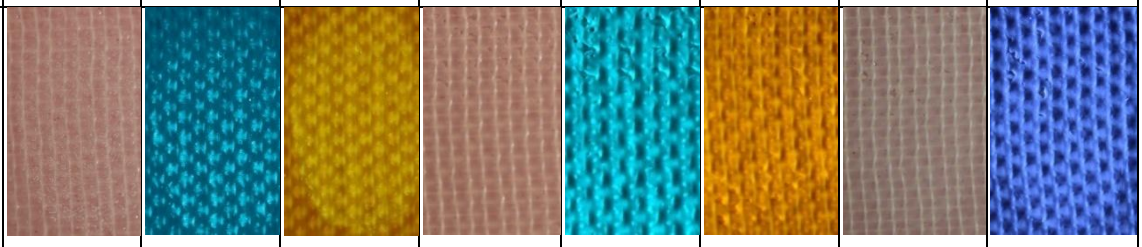
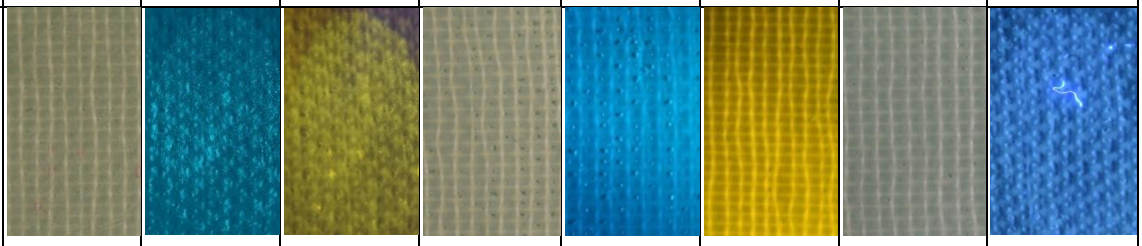
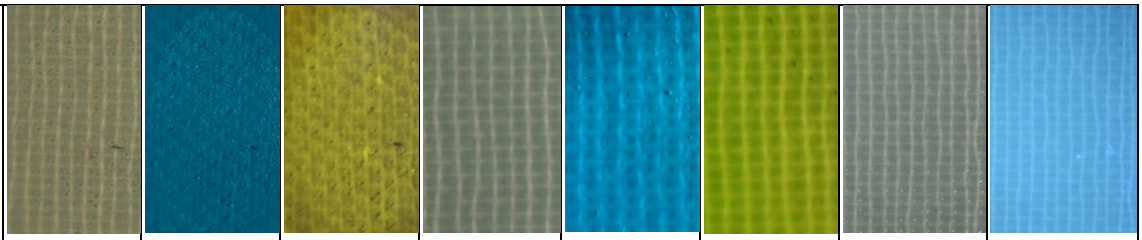
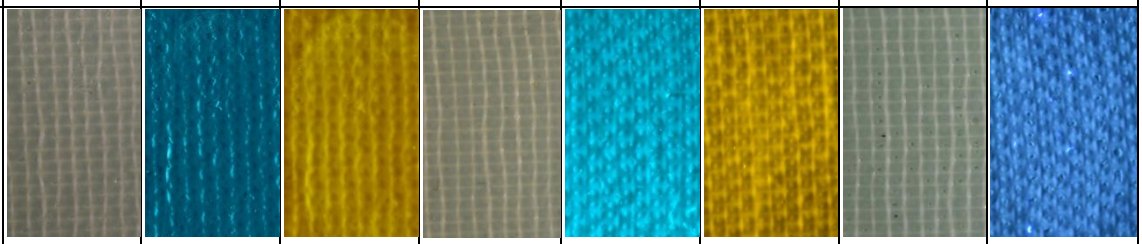
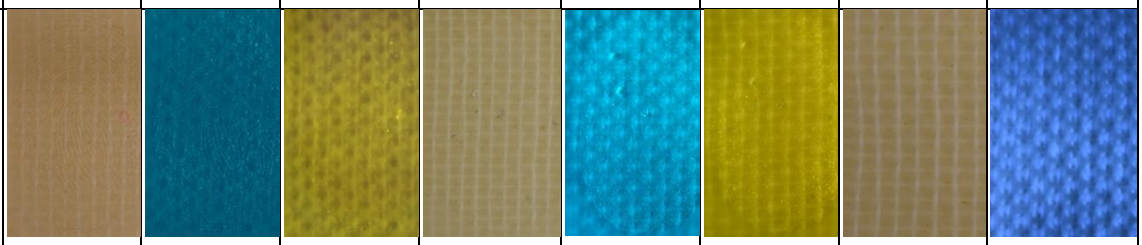
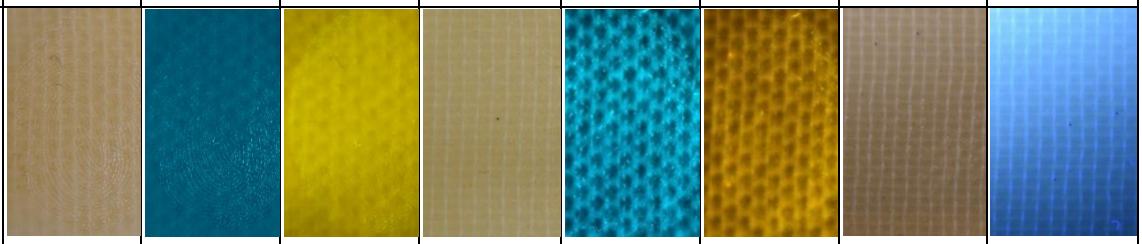
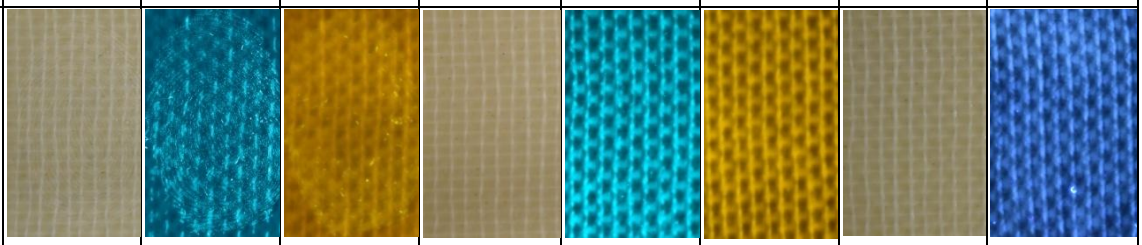
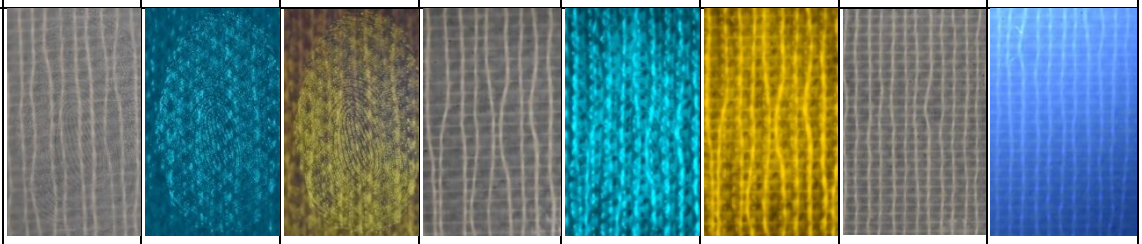
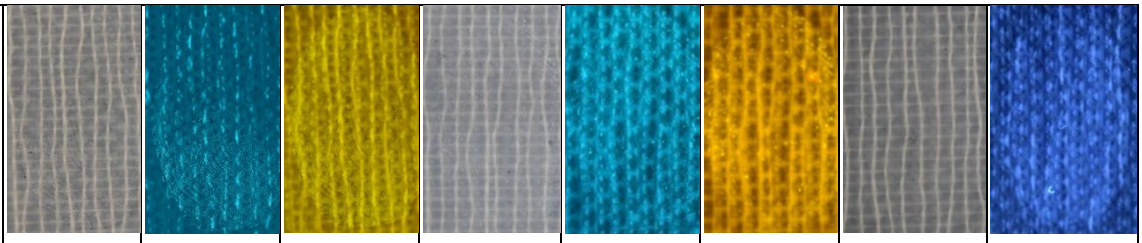
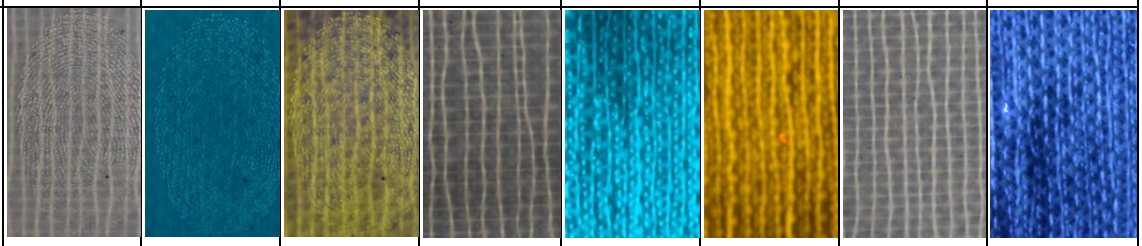
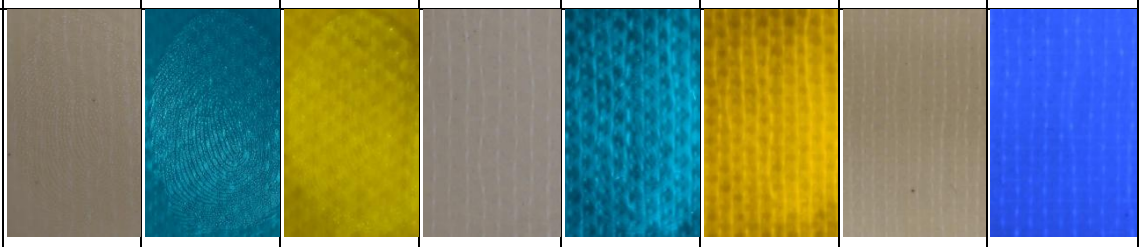
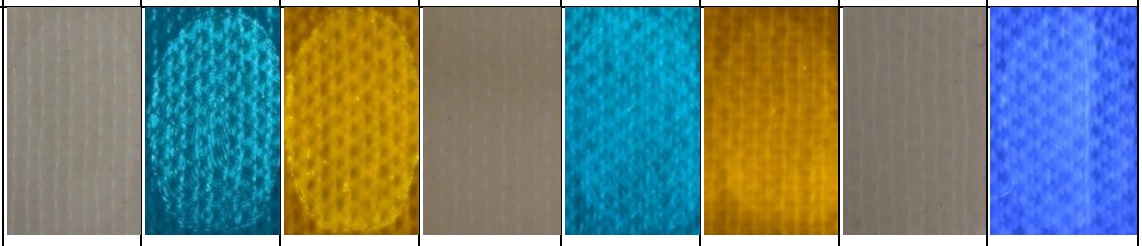
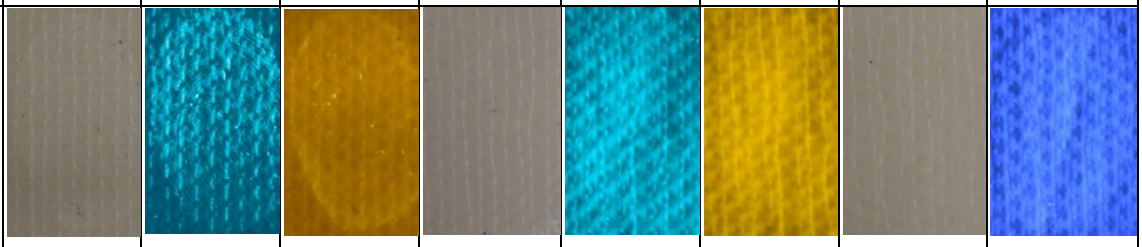
Red Cloth Tape	1								
	2								
	3								
Green Cloth Tape	1								

	2								
	3								
Yellow Cloth Tape	1								
	2								
	3								
Black Cloth Tape	1								

	2								
	3								
White Cloth Tape	1								
	2								
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