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Efforts to improve latent fingerprint impression processing using fluorescent and colored superglues

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EFFORTS TO IMPROVE LATENT FINGERPRINT IMPRESSION PROCESSING USING FLUORESCENT AND COLORED SUPERGLUES

by

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EFFORTS TO IMPROVE LATENT FINGERPRINT IMPRESSION PROCESSING USING FLUORESCENT AND COLORED SUPERGLUES

DESTINY BROOKE COSTLEY

ABSTRACT

The use of cyanoacrylate (CA) as a fuming technique for the development of latent friction ridge skin impressions has been widespread for decades within the forensic lab as well as in the field at crime scenes. Important features of processing latent print impressions using this method include that it makes visible latent print impressions that for the most part cannot be seen with the unaided eye and it preserves latent print impressions for future processing/examination. The superglue fumes "fix" the latent print impression to the substrate making it difficult to wipe away, thereby decreasing the chances of destruction during packaging at the scene, transportation, and processing in the lab. One of the disadvantages to this technique is the lack of contrast between the white polymers that are formed on the latent print impression residue and light colored backgrounds on which the latent print impression may be present.

Attempts were made to develop a one-step cyanoacrylate fuming method that would enhance visualization of latent print impressions on light colored backgrounds without the need for an alternative light source, dye staining, or powdering. Latent print impressions were applied to black and white ceramic tiles, white painted wood and white/translucent textured plastic. Protein and hemoglobin stains, commercial colorants, sublimation dyes, hair dye, and printer ink were added to ethyl-CA in an attempt to create

a co-polymerization process of the vaporized cyanoacrylate monomers and colorant molecules on latent print residue. Fuming was also attempted using pre-colored commercial glues with the assumption that the attached CA polymers on the latent print impression residue would retain their original color properties. None of these methods proved successful.

The practical use of a new fluorescent CA, Lumicyano™, was also examined. Following fuming, an ALS is utilized for the excitation of the developed latent print impressions using this technique. Strong fluorescence could not be observed on all substrates. In this particular study, fuming with traditional CA followed by the application of powder or dye stains to latent print impressions currently appears to be the most efficient technique for latent print enhancement on the white or light colored substrates used in this study.

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LIST OF ABBREVIATIONS

ALS	Alternative Light Source
BMT™	Blue-Merge Technology
C	Celsius
CA	Cyanoacrylate
°	degrees
DMAB	p-Dimethylaminobenzaldehyde
ECA	Ethyl-Cyanoacrylate
g	grams
HCN	Hydrogen Cyanide
μg	microgram
mL	milliliters
M.W.	Molecular Weight
nm	nanometers
®	Registered Trademark
RUVIS	Reflected Ultraviolet Imaging System
NaOH	Sodium Hydroxide
TGA	Thermal Gravimetric Analysis
™	Trademark
UV	Ultraviolet

1. INTRODUCTION

1.1 Latent Fingerprint Impressions

Friction ridge skin impressions, otherwise known as fingerprints, are a unique identifying marker of individuals. The use of fingerprints to identify individuals is one of the most invaluable tools in forensics that has been utilized for more than a century[1] Fingerprint impressions can be categorized into three different types: patent, latent, and plastic impressions. Patent and plastic prints are often visible to the unaided eye. Only a good source of lighting and photography are generally needed for the visualization of these prints. Latent print impressions, however, are difficult if not impossible to observe with the unaided eye. A physical or chemical process is needed to enhance and preserve the visualization of a latent print impression.

Latent print impressions are frequently encountered at crime scenes and on physical evidence submitted to crime laboratories. Because of their probative value in investigations, it is necessary to recover and preserve these latent print impressions by using various chemical and physical development techniques that allow for enhanced visualization. A variety of methods can be utilized that include powdering, dye staining, iodine fuming, and cyanoacrylate fuming.[1–4] The technique chosen and utilized for latent print enhancement and the efficiency of that chosen method primarily depend on the surface on which the latent print residue is deposited. The composition and age of the latent print impression residue are also factors to consider, as they may affect the quality of the ridge detail obtained following enhancement.[1–3,5–9]

1.1.1 Composition of Latent Print Residue

Sweat is the primary component of latent print residue, however, studies have shown that this is a very complex mixture.[1,8,9] Eccrine, sebaceous, and apocrine glands are the three glands that produce sweat secretions on the skin's surface. Latent print residue is a mixture of some or all of the secretions from these three glands due to migration of materials on the skin's surface and natural activity by humans, with eccrine sweat being the primary component of latent print residue.[1,10]

Sebaceous sweat is composed mostly of lipids and contains the fatty, oily material commonly found in hair follicles or on the nose to produce "oily" print impressions. The eccrine glands produce perspiration on the non-hairy surfaces of the body including the palms of the hands and soles of the feet. Eccrine sweat is made up of over 99% water but also contain salts, amino acids, and other trace components that produce "clean" print impressions. The apocrine glands are found in areas with coarse hair such as the armpits and pubic region, thus its components are typically not found in high concentrations in latent print impression residue.[10]

The components of secretions from all three of these glands can vary based on sex, age, and diet within an individual and between individuals. Therefore, latent print impression residue is a complex mixture that often undergoes significant changes once deposited on a surface. Environmental factors such as temperature, humidity, light, and airflow can also have an effect on the aging process of deposited latent fingerprint impressions.[1,5]

1.1.2 Substrate Surface

The surface on which the latent print impression is applied can be classified into three general categories: porous, non-porous, and semi-porous.[1] A porous item is one such as paper or a napkin that will allow liquid materials to pass or soak through. A non-porous item is an impenetrable item that will not allow liquids to pass through, such as glass. Semi-porous items allow liquids to pass through slowly or partially, but not completely through, such as some cardboards or a glossy magazine cover. These three types of surfaces can then be further categorized according to degrees of texture: rough, such as a plastered, painted wall or smooth, such as a ceramic mug. There are recommended latent print processing techniques for each type of surface.[1–4,6]

1.1.3 Enhancement of Latent Print Impressions

Based on the surface texture and color on which the print is applied, an enhancement technique is chosen. The physical latent print impressions are often impermanent once applied to certain substrates. Because of the changes in latent print residue over time, it is recommended that non-porous items with possible latent print impressions are processed as soon as possible, even at the crime scene itself.[6,11]

Latent print impressions on non-porous substrates can be enhanced in multiple ways including with a brush and powder, Reflected Ultraviolet Imaging System (RUVIS), fluorescent dye staining and cyanoacrylate fuming.[1–3,12] RUVIS is an imaging technique that allows for the visualization of untreated and cyanoacrylate-fumed latent print impressions using shortwave ultraviolet light. Fluorescent dye staining is a chemical technique used to stain the latent print impressions following cyanoacrylate fuming. The liquid stain adheres to the fumed print impressions and fluoresces when viewed with an alternative light source (ALS). The brush and powder technique is a physical enhancement technique that utilizes a fine powder or particle applied with a brush to the substrate. The powder will adhere only to the residue of the print, not the substrate, allowing ridge detail to be observed. The brush and powder technique, RUVIS and cyanoacrylate fuming can be used at the crime scene with relative ease.

1.2 Cyanoacrylate Fuming

The use of cyanoacrylate as a fuming technique for the development of latent friction ridge skin impressions has been widespread for decades within the forensic lab as well as in the field at crime scenes. Cyanoacrylate was initially discovered in 1951 for use as an adhesive when equipment used to measure the refractive index of the chemical became bonded together.[13,14] The use of the adhesive in a fuming process to develop latent fingerprint impressions was not discovered until the late 1970s in Japan. A trace evidence examiner was able to observe the ridges of his fingerprints after mounting a sample on a glass microscope slide with cyanoacrylate.[13,15] By the 1980s, latent fingerprint development using cyanoacrylate was beginning to be utilized in many labs in the United States, United Kingdom, and Canada.[1,13]

Cyanoacrylate (CA) is the chemical name for the common commercial adhesive known as superglue. The adhesives used for latent print impression development generally consist of ethyl-2-cyanoacrylate, alky-2-cyanoacrylate, methyl-2-cyanoacylate, or a combination.[16] The most widely used adhesive for fuming is the ethyl-2-cyanoacrylate (Figure 1).[17] Important features of processing latent print impressions using this method are that it makes latent print impressions visible that otherwise may not be seen with the unaided eye and it preserves latent print impressions for future processing/examination. The superglue fumes "fix" the latent print impression to the substrate making it difficult to wipe away, thereby decreasing the chances of destruction during packaging at the scene, transportation, and processing in the lab.

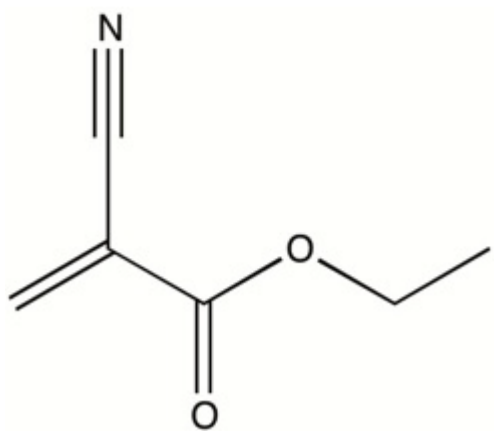


Figure 1: ethyl-cyanoacrylate

Cyanoacrylate fuming is a versatile technique that is frequently utilized over other methods because of its ease of use and ability to accentuate latent print impressions on multiple types of non-porous substrates such as metal, glass, ceramic, plastic, and leather.[10,18] The fuming method is versatile enough that latent print impressions can be processed at crime scenes or in the laboratory. It acts as a preservative of the impressions for subsequent powdering, dye staining, and other processing techniques.

1.2.1 Mechanism

A latent print is developed typically by heating liquid CA in an enclosed chamber. The enclosed chamber can be a commercial fuming chamber with controlled settings, a portable plastic fuming tent, or any inexpensive solid structure such as a glass fish tank. One single ethyl-cyanoacrylate molecule (Figure 1) is considered a monomer. The liquid CA monomers become vaporized into a gaseous phase that adhere to the latent print residue, causing the ridges to appear white.[10,15] These monomers continuously link together forming long solid polymer chains consisting of hundreds of monomers along the ridges of the latent print (Figure 2).

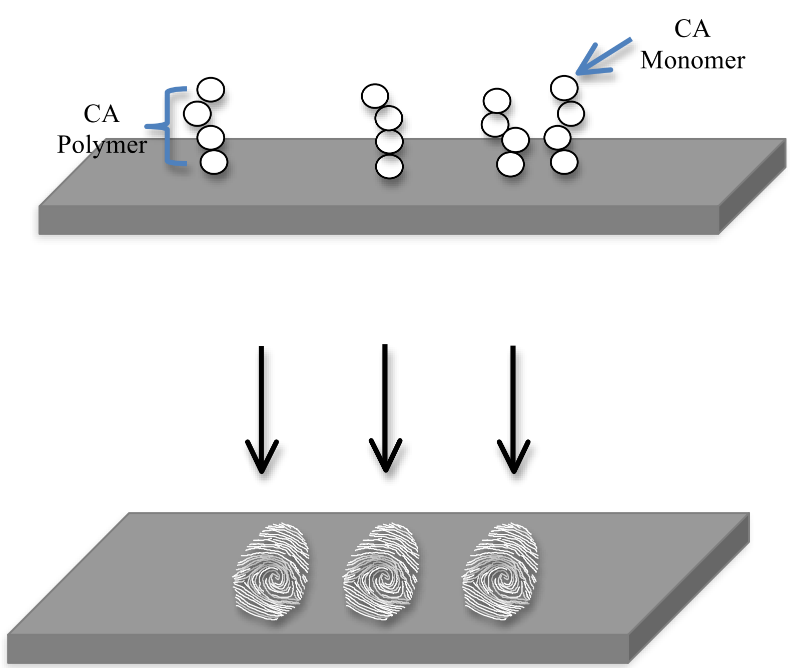


Figure 2: Polymerization of Cyanoacrylate Monomers

Basic, electron-rich nucleophiles such as water, alcohol, and amines are reported to be the initiating groups of the polymerization process on latent print residue.[10,14,15,19] They seek positively charged groups in attempts to donate a pair of electrons. The initiating group attacks the cyanoacrylate monomers at positively charged bonds such as the double bonded carbonyl group. Once this attack occurs, the cyanoacrylate monomer becomes a zwitterion with a positive charge on one end and negative charge on the other end, allowing for a chain reaction with the CA monomers creating polymerized branches. This chain reaction continues until the supply of CA is depleted or a terminating group is added onto the end of the polymer chain.[10,14,15,20]

Polycyanoacrylate, or solid phase super glue, can also be fumed to develop latent print impressions, however, higher temperatures are required.[21,22] The hardened white polymer created during the fuming process of both liquid and solid CAs does not accumulate on the background substrate between the ridges, thus allowing contrast between the print and the substrate (Figure 3).

Figure 3: Cyanoacrylate Polymer Formation on Black Ceramic Tile

There is an alternative method for cyanoacrylate fuming that does not require the application of heat. CA can be applied to cellulose pads such as a cotton swab that has been saturated in sodium hydroxide. An exothermic chemical reaction occurs, producing vaporized CA monomers without the need for heat. CA polymerization occurs similarly to the heat fuming method.[1]

It is not yet known exactly what components of sweat the cyanoacrylate monomers adhere to for polymerization and latent print development.[5,6,8,9] The reason for the affinity of the CA polymer to the latent print residue is unknown due to the limited knowledge of which component of latent print residue initiates the polymerization reaction. It is known that the water and lipid secretions in the residue will evaporate out over time through varying chemical processes.[3,5,9] This makes the likelihood of obtaining a quality print using the cyanoacrylate method decrease as the latent print ages.[6]

1.2.2 Factors that Affect Polymer Formation

Cyanoacrylate fuming has been used to develop latent fingerprint impressions since the late 1970s. The methods utilized then were not very efficient, as they required long exposure times and often polymer formation accumulated on the substrate background, decreasing contrast.[18] New methods have been developed to reduce the fuming time by increasing the temperature and humidity and reducing the pressure to create a vacuum system within the chamber. [18,23] There are many variables that can affect the formation of polymers on latent print residue: the temperature to which the cyanoacrylate is being heated, humidity and pressure within the chamber, age of the latent print residue, quantity and viscosity of glue used, substrate surface, substrate/ambient temperature, and latent print composition. A few of these variables cannot be controlled, especially if the latent print impressions are being processed from evidence at a crime scene. Primarily of concern is the temperature to which the glue is being heated and the humidity within the chamber.

The optimum humidity for cyanoacrylate fuming is approximately 80%. Humidity above and below 80% results in a decrease in polymer formation and poor ridge detail.[16]

Depending on the humidity within the fuming chamber, the cyanoacrylate polymers take on various shapes. At 80% humidity, high quality polymers are formed for development of the latent print impressions. Because of the effect of humidity on the quality of the developed print during the fuming process, especially eccrine residues, it is unknown whether water acts as the primary initiator of polymerization or if it increases the function of another component of fingerprint residue that initiates the polymerization of CA monomers.[15,16] There is a risk that over-development of the latent print impression could occur in high humidity, resulting in CA deposition on the substrate background. The use of a vacuum chamber decreases this chance due to the constant circulation of vapors.[16] One study evaluated the effect of humidity on items of evidence in long-term storage from 2 weeks to 6 months. It was found that the humidity at which evidence is stored before processing occurs does not play a role in polymer formation during fuming.[24]

The temperature at which cyanoacrylate is heated plays a critical role in polymer formation on the latent print ridges. Generally, the higher the temperature, the faster the CA polymers will vaporize and attach to the latent fingerprint impressions.[18] However, production of hydrogen cyanide (HCN), a highly toxic gas, was reported following the heating of two commercial CA's in temperatures ranging from 200°C to 280°C.[22] Trapped HCN was quantified using ultraviolet-visible spectrophotometry and trace amounts, approximately 10 micrograms (µg), of HCN were detected at 200°C compared to 100 µg of HCN detected at 280°C.[22]

The amounts of HCN produced at 240°C and below are well below occupational safety exposure limits.[22,25] Commercial fuming units are generally programmed to heat

CA at relatively low temperatures. For example, Foster and Freeman cabinets are set to 120°C as HCN has not been detected at this temperature[26] In makeshift systems, such as a plastic tent or fish tank, hot plates are generally used that can reach temperatures above 200°C, increasing the chances of exposure to HCN gas. Proper precautions must be taken when fuming at temperatures that can exceed 200°C. Utilization of a well ventilated area, fume hood, respirator, or face mask can reduce the risk of exposure to HCN.

Pre-treatment techniques to increase CA polymer formation on latent print impressions have been studied. Many studies recommend exposure of the latent print impressions to vapors from acidic and basic solutions, along with water vapor.[6,10,18,20,27] The items containing the latent print impressions are placed next to either ammonia (basic solution), or acetic acid (acid solution), for a few minutes prior to fuming. These techniques result in increased polymer growth compared to latent print impressions not pre-treated. One researcher experimented with these solvents as well as the organic solvents methylamine, diethylamine, and ethanolamine, and determined exposure to methylamine to be the more efficient pre-treatment technique.[20]

1.2.3 Difficulties Encountered in Cyanoacrylate Fuming

One disadvantage when fuming evidence with a light colored background is that the glue creates poor contrast between the developed latent print impression and the substrate background, making it difficult to detect without further enhancement. [28,29] The CA polymers that adhere to the latent print impression residue are white, making it easy to see on darker backgrounds. Currently, dye stains, ALS and powdering techniques are used post-fuming to enhance the contrast and make visualization of the fumed latent print impressions easier. These post-fuming processes are easy and relatively quick; however, they represent additional steps in the development of latent print impressions, making it a two-step or three-step process instead of a one-step method.

Over-fuming is another shortcoming of the CA fuming method. When an item remains in the CA vapors for a longer time than necessary, the polymers will adhere to the background of the substrate including in between the ridges of latent print impression residue, decreasing the quality of ridge detail. Latent print impressions may also fume unevenly on an item due to lack of circulation of the vapors or irregular surfaces. Altering the heat and creating a chamber under vacuum pressure can decrease the chances of uneven development or over-fuming.[23,30]

An additional difficulty encountered with cyanoacrylate fuming is processing aged latent print impressions that have been exposed to harsh environments with increased airflow and exposure to light. Certain chemicals that CA monomers are attracted to can be applied to the impressions in an attempt to increase polymer formation.[6] Limited studies have been performed on enhancement techniques for fuming aged latent print impressions.[6,7,20]

1.3 Attempts to Improve Enhancement of Latent Prints

Techniques to improve the contrast between latent print residue and its background are continuously being studied. Methods have been created that add fluorescent materials to CA, resulting in a developed print that can be readily detected with the use of an ALS.[31-33] The approach of adding fluorescent materials to CA has proven to be successful, however, relatively little has been published about this technique, which still requires the use of an additional step of viewing the developed print with the necessary lighting equipment. Efforts have been made previously to add a colorant to the CA prior to fuming in anticipation that the colorant would sublimate along with the vaporized CA monomers to produce a readily visible print; however, the colorants were not able to co-polymerize with the CA or positive results could not be repeated.[28,34]

1.4 Study Purpose

The purpose of this study was to attempt the development of a one-step fuming process for latent fingerprint impressions using a colorant incorporated into the glue prior to fuming. Such a method would develop readily visible latent fingerprint impressions on non-porous, lightly colored or white substrates; therefore, the subsequent use of an ALS, dye staining technique, or powdering would not be necessary. Both traditional cyanoacrylate fuming and heatless sodium hydroxide fuming were utilized in the attempt to develop this one-step method. Colorants were chosen based on their affinity for the components of fingerprint residue and their sublimation properties. Commercially colored super glues were also utilized in the traditional cyanoacrylate fuming process.

2. MATERIALS AND METHODS

2.1 Fuming Chamber and Substrate Preparation

A glass tank measuring approximately 20 inches by 10 inches by 12 inches was used to hold the items being fumed. Fitted cardboard was placed over the top to create an enclosed chamber (Figure 4). A laboratory hot plate (Fisher Scientific™, Pittsburgh, PA) with controllable temperature settings was used as the heating source for the superglue and water. Disposable aluminum trays (Arrowhead Forensics, Lenexa, KS) were used to hold the glue being heated on the hot plate. A glass beaker containing water was heated on the hot plate until the humidity of the chamber reached approximately 80% (ranging from 75% to 85% humidity) prior to each fuming. Humidity and chamber temperature were monitored within the chamber by using an ACURITE® Indoor Comfort Monitor (Chaney Instrument Company, Lake Geneva, WI).

Figure 4: Enclosed Fuming Chamber

Black and white ceramic tiles, white painted wood pieces, and translucent plastic pieces were the four substrates on which the latent print impressions were applied. The plastic used was from textured milk cartons. The wood pieces were obtained by cutting paint stir sticks (Home Depot®, Atlanta, GA) into approximately 3-inch pieces. They were then painted using white, flat paint (Behr®, Santa Ana, CA) and allowed to dry overnight.

Prior to beginning the fuming trials, latent print impressions from one donor were applied by gently touching the thumb to each substrate. The latent print impressions were then powdered using Black Onyx or White fingerprint powder and a fiberglass fingerprint brush (Lightning Powder® Company, Inc., Jacksonville, FL) (Figure 5) to ensure that latent print residue would adhere to and quality ridge detail could be obtained from the chosen substrates.

(A) White Powder on Black Tile

(B) Black Powder on White Tile

(C) Black Powder on Plastic

(D) Black Powder on Wood

Figure 5: Powdered Latent Print Impressions Prior to Cyanoacrylate Fuming

For each trial, one black ceramic tile, one white ceramic tile, one white painted wood piece, and one piece of plastic was placed in the fuming chamber. The black tile served as the positive control as to the occurrence of polymer formation when fuming the items. The black background allowed for good contrast with the white superglue, thus polymer formation could be easily observed on this substrate.

Using the same single donor, latent print impressions were deposited by first swiping the right thumb finger once across the forehead or nose, targeting the oils from the sebaceous glands on the skin. The latent print impressions were then applied in a depletion series of three touches to each substrate in which the thumb was placed consecutively on the substrate three times, resulting in less fingerprint residue deposition as the print application on that item continued. Approximately one hour of time passed prior to fuming the substrates.

2.1.1 Pre-Colored Cyanoacrylate Fuming

Varying amounts of colored super glue, ranging from 0.1 grams (g) to 0.5 g, were added to aluminum fuming trays: a purple ethyl-cyanoacrylate, Coralline Colored Reef Glue (Boston Aqua Farms, Boston, MA), a black ethyl-cyanoacrylate with a rubber additive, Tire Glue IC-2000™ (Bob Smith Industries Incorporated, Atascedero, CA), a blue butyl-cyanoacrylate, 3M™ Vetbond™ Tissue Adhesive (3M™ Animal Care Products, St. Paul, MN), and a black ethyl-cyanoacrylate with acrylic polymer, Stick Fast™ Instant CA Adhesive Black Flex (TMI Products, Peachtree City, GA). The substrates were placed inside the chamber, and the tray containing a measured amount of glue was placed on the hot plate. The glue was heated to temperatures of 150 degrees Celsius (°C), 200°C and 300°C. The sets of depleted latent print impressions on all four substrates were processed twelve times for each colored CA, 4 sets within each temperature range. The four substrates were allowed to fume until prints could be seen on the black tile inside the chamber. The approximate time for the print to develop was recorded. The substrates were removed and visually observed with the unaided eye and with an ALS.

2.1.2 Addition of Colorants to Clear Cyanoacrylate Prior to Fuming

Ratios of colorant to glue (2:1, 1:1, and 1:2) were prepared in separate trials with a clear ethyl-2-cyanoacrylate, E-Z Bond superglue, (K & R International, Laguna Nigel, CA) and solid or liquid colorants. The solid colorants utilized included Bigen® Oriental Black permanent powder hair color (Hoyu™ Co., Ltd., Nagoya, Japan), Sudan Black B (AMRESCO®, Solon, OH), Rhodamine 6G (TCI America, Portland, OR), Rit® fuchsia colored dye (Phoenix Brands™, Stamford, CT), and Crystal Violet (Lightning Powder® Company, Inc., Jacksonville, FL). The liquid colorants utilized were De La Cruz® Gentian Violet (DLC Laboratories, Paramount, CA), PROsperse Red D360 Disperse Dye (PRO Chemical & Dye™, Somerset, MA) and fuchsia heat transfer printer ink (Freshinkjets, Anaheim, CA). Liquid solutions of the powdered colorants were also created using water or ethanol and then mixed with CA.

In instances where the CA quickly cured upon addition of the colorants, fuming was continued using the solid polymers. Latent print impressions on the substrates were fumed 36 times using each colorant in separate trials; four sets of each ratio within each temperature range. The glue was heated to temperatures of 150°C, 200°C and 300°C. The four substrates were allowed to fume until prints could be seen on the black tile inside the chamber. The approximate time required for the print to develop was recorded. The substrates were removed and visually observed with the unaided eye and with an ALS. The same colorants were then added to the blue 3M™ Vetbond™ Tissue Adhesive, a CA ester structurally distinct from E-Z Bond superglue, using the same steps previously mentioned.

A separate experiment was conducted heating the magenta ink and PROsperse Red without any CA in an aluminum tray at temperatures ranging from 200°C to 500°C. The PROsperse Red was made into a liquid solution using water. The temperature was increased by 100°C every two minutes. This was to determine if the colorants would sublimate at higher temperatures than allowed for CA.

2.1.3 Sodium Hydroxide Fuming

Approximately 2 g of sodium hydroxide (NaOH) was mixed with 100 milliliters (mL) of distilled water.[35] Cotton swabs were dipped in the NaOH solution and allowed to dry. Liquid colorants were applied to the NaOH swabs and allowed to dry. Liquid solutions of powdered colorants were prepared using water, applied to the NaOH swabs, and allowed to dry.

Only the tiles were used for this method. The black tile was tested prior to the white tile to ensure development of the latent print would occur. The tiles were placed over the aluminum tray so the fumes from the swab would directly contact the latent print impressions. One dry swab containing a colorant was placed in an aluminum fuming tray. Three to four drops of glue were initially applied to the swab. Additional glue was added until white polymers could be seen on the black tile. When fuming the white tile, similar glue amounts were used. Exact amounts of glue and colorant added to the swab were not recorded. Humidity of the chamber was not altered or monitored during this experiment.

2.1.4 Fluorescent Fuming Techniques

All four substrates were fumed following the manufacturer's instructions for Lumicyano™ (Arrowhead Forensics, Lenexa, KS) at approximately 120°C and 80% humidity. The substrates were allowed to fume until the latent print impressions could be seen on the black tile.

2.2 Alternative Light Sources and Photography

Following fuming, all substrates were viewed using an UltraLite™ ALS (CAO Group, Incorporated, West Jordan, UT) with Ultraviolet (UV), Red, Blue-Merge Technology (BMT™), Green, and Yellow light attachment heads. Substrates were also viewed using the blue and white Crime-lite™ (Foster & Freeman, Worcestershire, UK) light sources. The appropriate barrier filter (red or orange) was used in conjunction with the light sources (Table 1).

Table 1: Alternative Light Source Wavelengths and Appropriate Filters

Color &Wavelength in nanometers (nm)	Barrier Filters
UltraLite™ UV (405 nm)	Orange
UltraLite™ BMT™ (450 nm)	Orange
UltraLite™ Green (525 nm)	Orange
UltraLite™ Yellow (590 nm)	Red
UltraLite™ Red (630 nm)	Red/Clear
Crime-lite™ - White (400-700 nm)	None
Crime-lite™ - Blue (430nm-470 nm)	Orange

If latent print impressions could be observed with an ALS or with the unaided eye, the substrate was placed in a MK Photo-eBox ™ Digital Imaging System (MK Digital Direct, Chula Vista, CA) and photographed using an Olympus XZ-1 digital camera attached to a forensic photography stand. The aperture priority and shutter speed were altered as necessary for each photograph due to the differences in lighting with the ALS.

Subsequent to the development of the latent print impressions using Lumicyano™, the substrates were viewed following the manufacturer's instructions by using the green light attachment with an orange filter, as this provided the best fluorescence of the latent print impressions. The latent print impressions were also viewed using all other wavelengths of light.

3. RESULTS & DISCUSSION

3.1 Latent Print Samples

The composition of latent print residue varies between individuals and within individuals. This will affect the way polymer formation will occur, and potentially affect the attachment of colorant molecules to the latent print residue. The latent print impressions were collected on different days prior to each experiment, likely creating variation in the residue composition of the latent print impressions from day to day. Because of rapid changes in the composition of latent print residue once applied to a substrate, ideal situations for polymer formation were utilized for initial investigation of a new method for fuming. Therefore, the latent print impressions were processed almost immediately.

The latent print impressions were applied in a depletion series to account for differences in polymer formation with varying amounts of latent print residue. Although the primary components of latent print impression residue come from eccrine secretions, sebaceous secretions also have a significant presence. CA polymers are more likely to attach to secretions from the sebaceous glands than secretions from the eccrine glands.[16,18] A drawback to using sebaceous secretions as opposed to eccrine secretions is the detail of the latent ridges will suffer if using sensitive reagents. Due to contamination and movement of the oily secretions from the sebaceous glands moving into the space in between ridges, ridge detail may not be observed; only a fingerprint outline may be visible.[36]

3.2 Pre-Colored Cyanoacrylate Fuming

Numerous colored glues are available commercially for a variety of applications. Coralline Colored Reef Glue is used to repair fish tanks and equipment, black Tire Glue IC-2000™, for tire repairs. 3M™ Vetbond™ Tissue Adhesive is a glue that can bind skin together and is frequently used in place of sutures, and black Stick Fast™ Instant CA Adhesive is a black colored glue similar to E-Z Bond, but with a thicker viscosity. Generally, they are not used for forensic purposes; however, they all contain a cyanoacrylate ester such as methyl-cyanoacrylate, thus it is reasonable to assume they would function similarly to ethyl-cyanoacrylate in CA-fuming of latent print impressions.

Vaporized CA monomers and polymerization on the latent print impression residue was observed for the 3M™ Vetbond™ Tissue Adhesive and black Stick Fast™ Instant CA Adhesive; however, polymer formation was only observed on the black tiles during fuming. Despite the original color of the glues, all polymer formation appeared to be white when viewed under white light with the unaided eye. Polymers could not be seen on the white tile, wood, or plastic. No fluorescence of the latent print impressions was observed for any of the substrates when viewed with an ALS.

The colorant in the Stick Fast™ Black Flex Instant CA appeared to separate from the cyanoacrylate during heating. The volume of glue began to decrease as it was being heated, and the black colorant decreased in size faster than the rest of the compound leaving an outer ring of clear residue. The exact colorant used in this glue is not provided by the manufacturer.

The 3M™ Vetbond™ Tissue Adhesive produced an iridescent film on the black and white tiles after being fumed. There was a contrast between the background and the latent print impressions on the tiles that created a negative-like appearance, with a white void where the latent fingerprint impressions were placed. No ridge detail could be observed (Figure 6).

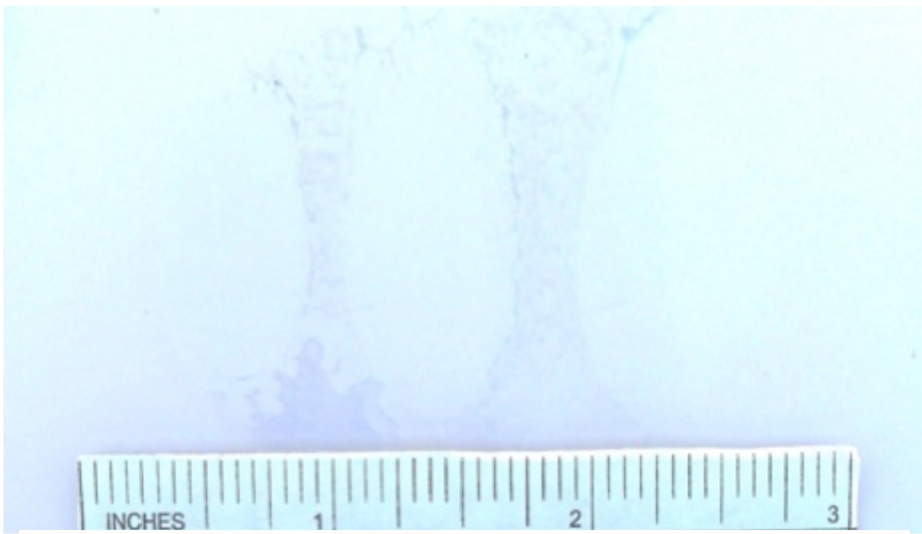


Figure 6: Close-Up of Latent Print Impressions on White Tile Fumed with 3M™ Vetbond™ Tissue Adhesive (Brightness of Image Enhanced to Show Contrast)

The Coralline Colored Reef Glue and the black Tire Glue IC-2000™ did not develop polymers on the latent fingerprint impressions residue, nor did the black tire glue produce visible fumes when heated like the other glues. The Reef Glue produced white fumes, but they did not appear to attach to the latent print impression residue on the substrates.

Cyanoacrylates used for fuming latent fingerprint impressions tend to be of low viscosities.[16,31] The 3M™ Vetbond™ Tissue Adhesive and Stick Fast™ Black Flex Instant CA had very low viscosities. Their flow and thickness was almost similar to water. The viscosity of these two glues appeared to be lower than the viscosity of the E-Z Bond. In comparison, the purple Coralline Colored Reef Glue and the black Tire Glue IC-2000™ had thick viscosities. The black tire glue had the highest viscosity overall. Viscosity increases as the strength between the bonds of the compound increase.[37] Because of the stronger bonds, the cyanoacrylates with high viscosities potentially require more heat for them to break and become volatile.

The viscosity of a liquid tends to decrease, or fluidity of that liquid increases, as temperature increases.[37] However, the variation of the temperature did not have a significant effect on the results in this study, nor did the viscosity appear to change during the heating process for the thicker glues. The amount of fumes produced was the only observed difference when the temperature was increased. For 3M™ Vetbond™ Tissue Adhesive, Coralline Colored Reef Glue, and Stick Fast™ Black Flex Instant CA, more visible fumes were produced when heated at higher temperatures. These glues were heated up to a maximum temperature of 300°C using a fume hood due potential production of HCN gas.[22]

3.3 Addition of Colorants to Clear Cyanoacrylate Prior to Fuming

Efforts are continuously being made to create a one step latent print impression processing method that will not require an ALS, powdering or dye staining subsequent to

CA fuming.[28,34] Numerous biological stains and dyes are known to have an affinity to the components of latent print impression residue. Many of these colorants are used to process latent print impressions after the CA fuming process or they are used as a stand-alone technique for the processing of porous substrates and other items such as tape. Gentian Violet, Rit® fabric dye, Rhodamine 6G, and Amido Black have been used as dye stains because of their ability to attach to latent print residue or CA-developed latent print impressions.[2,4,29] Because of their affinity to CA-developed latent print impressions and the components of latent print residue, they could potentially have the capability to co-polymerize with the cyanoacrylate on latent print impression residue depending on the chemical properties of the stains.

3.3.1 Gentian Violet

Gentian violet is a purple colored staining solution that contains the dye crystal violet. The reduced, colorless form is known as leucocrystal violet. Leucocrystal violet is used for presumptive testing of blood and enhancement of latent fingerprint impressions in blood, while gentian violet is used for non-bloodied latent print enhancement.[4,29,38] In the presence of blood, an oxidation-reduction reaction occurs in which the colorless crystal violet becomes oxidized and turns purple. Hydrogen peroxide is generally added to act as the oxidizer, though water can also act as an oxidizer as it contains oxygen[39]. Air can likewise act as a natural oxidizer if exposed to an open environment for long periods of time.[1,38]

In this study, gentian violet showed the capability to vaporize. Trace amounts were found in the fuming tank, on the substrates, and on other surfaces. The colorant was not visible until during the cleaning process when water or ethanol was applied and wiped with a paper towel (Figure 7). Once cleaning takes place by applying water or alcohol, the compound may become oxidized again producing color.

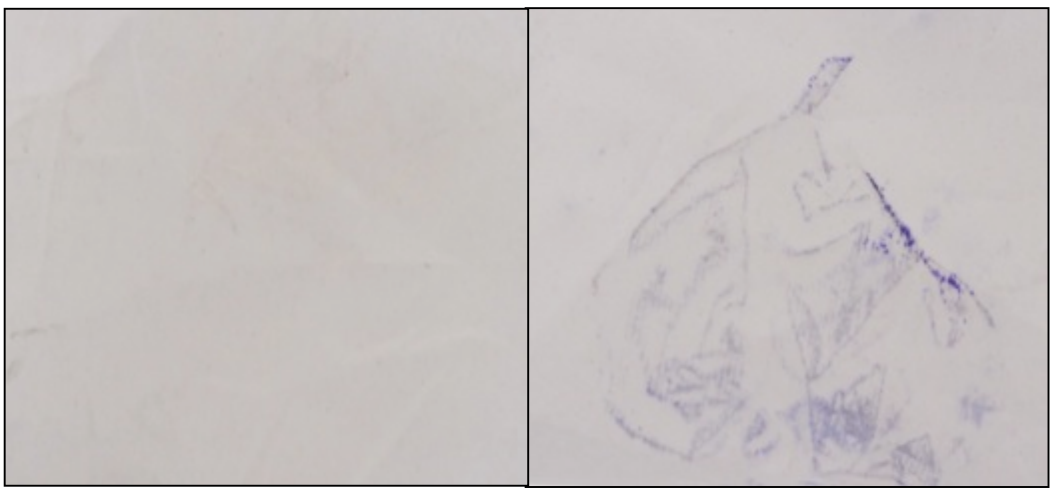


Figure 7: Purple-Violet Color on Paper Towel Prior to Cleaning (Left) and After Cleaning (Right)

Gentian violet did not attach to the latent print residue, as it was not observed on the substrates in white light or to the unaided eye subsequent to fuming. Gentian violet is weakly fluorescent under medium wave UV light (312 nm).[29] Others recommend an excitation wavelength of 532 nm which also yields weak fluorescence.[1] The substrates were viewed with the UV UltraLite™ attachment head that emits a wavelength of light at 405 nm and with the green light attachment that emits a wavelength of 525 nm. No fluorescence was observed when the substrates were viewed with these or with any other wavelength of light tested. The quantity of gentian violet utilized may have affected the accumulation of the colorant on the latent print residue, decreasing the amount of fluorescence that could be observed.

Gentian violet has the capability to appear blue, violet, or green, as well as colorless depending on the acidity of its environment. In strongly acidic or basic environments, gentian violet becomes colorless. The color is restored as it approaches a neutral environment.[40] Gentian violet contains ethanol as a minor component keeping the dye neutrally charged. When the dye comes in contact with the environment (e.g. during the fuming process), ethanol evaporates out of the solution, potentially making the dye more basic and therefore colorless. Thus, if co-polymerization of the colorless vapors with the CA molecules did occur, it would not be observed on the developed latent print impressions. No purple color was visible to the unaided eye and no fluorescence was observed with an ALS after fuming had taken place.

3.3.2 Crystal Violet

Although crystal violet has similar chemical properties to gentian violet, it reacted differently to the fuming; the crystals did not exhibit the same color changing properties as the liquid form when tested. After cleaning the chamber, substrates, and workbench, there were no traces of colorant on these surfaces. No color was visible to the unaided eye on the substrates in white light and no fluorescence was observed with an ALS after fuming had taken place.

3.3.3 Rhodamine 6G & Sudan Black B

Rhodamine 6G, also known as Basic Red 1, is a fluorescent dye stain that can be utilized following cyanoacrylate fuming.[1] The molecular weight of this stain is 479.01 g/mole. This molecule could likely be too large to be able to sublimate. Rhodamine 6G was found to be carcinogenic by the United States Department of Health and Human Services.[41] Due to these health concerns, testing using the 3M™ Vetbond™ Tissue Adhesive was not performed as creating a new method utilizing a carcinogenic component would not be advantageous.

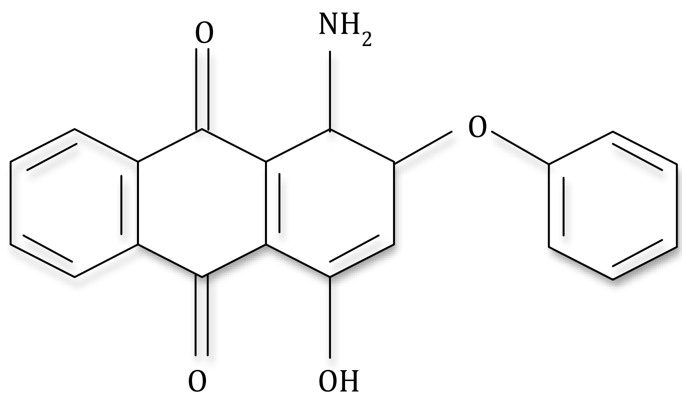
Sudan Black B is a technique utilized for greasy stains. It has the ability to stain the fatty secretions from the sebaceous glands, components of latent print impression residue.[1] The stain appears blue-black once it adheres to latent print impression residue.

No color or fluorescence was observed on the latent print impression residue in white light or with an ALS when fuming was attempted with these two dye stains.

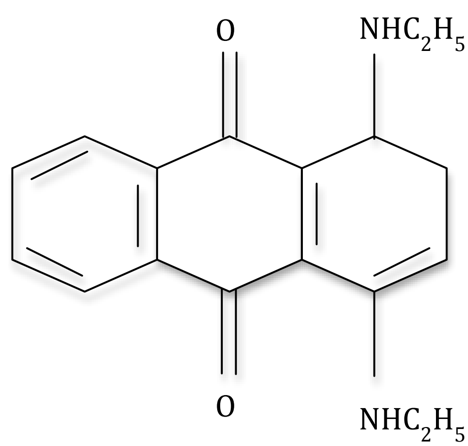
3.3.4 Sublimation Dyes

Most previous studies targeted dyes that were of small molecular weights so the colorants could potentially sublimate along with the CA as it is being heated. A majority of colorants only have the ability to sublimate at higher temperatures than are recommended for heating cyanoacrylate due to the production of HCN gas. Sublimation dyes generally transition to a gaseous state at temperatures between 250°C and 750°C, while the maximum temperature recommended for safely heating CA is 180°C.[22,28,34]

The components of dyes in the anthraquinone family, which are commonly used as textile dyes, have the ability to sublimate and appear to be able to adhere to latent print residue with and without CA-development.[28,34,42] Two of the sublimation dyes utilized in a previous study are 1,4-bis (ethylamino)-9,10-anthraquinone and Disperse Red 60 (1-amino-2-phenoxy-4-hydroxy-anthraquinone) (Figure 8).[3,28] Studies by others using these dyes utilized techniques that required separate steps to prepare the colorant or were not able to yield reproducible results.[28,34]



Disperse Red 60 (1-amino-2-phenoxy-4-hydroxy-anthraquinone)



1,4-bis (ethylamino)-9,10-anthraquinone

Figure 8: Dyes of the Anthraquinone Family

PROsperse Red D360 Disperse Dye was originally designed to dye synthetic fabrics. This dye was chosen for testing with CA fuming because it is a member of the anthraquinone family. The exact anthraquinone dyestuff and molecular weight is unknown. A mixture of the dye and CA together was only heated to temperatures up to 300°C due to risks of producing harmful quantities of HCN gas.

Sublimation dyes can also be used in printing. The colorant is applied by using high temperatures to heat the molecules. When heated to a specific temperature, the molecules sublimate and adhere onto the surface of a specific substrate. The surface could be fabric, paper, plastic polymer, or glass depending on the type of dye utilized. The magenta ink utilized in this study was a heat transfer printing ink that has the ability to vaporize upon addition of heat. One study successfully created a co-polymerization process of CA and a colorant utilizing a thermal magenta dye (3M™, St. Paul, MN) in the styryl family in 1989.[42] An ALS was needed for visualization of the developed latent print impressions with this thermal styryl dye. Research using this dye has since ceased, and the dye is no longer available from the manufacturer.

No color was visible on the substrates to the unaided eye and no fluorescence was observed with an ALS subsequent to fuming with the CA for either of these colorants. When the red disperse dye solution and magenta ink were heated to higher temperatures alone (no CA added), white fumes were observed around 300°C. At this temperature, both liquids began to boil and bubble. They initially began as pink-red colors, and then changed to a dark purple color (Figure 9). At approximately 400°C, the PROsperse Red began to exhibit darker colored fumes; the magenta ink began to exhibit darker colored fumes at approximately 500°C. At these high temperatures the colorants may be going though a degradation process during heating, shown by the color change, potentially hindering the co-polymerization of CA and colorant vapors.

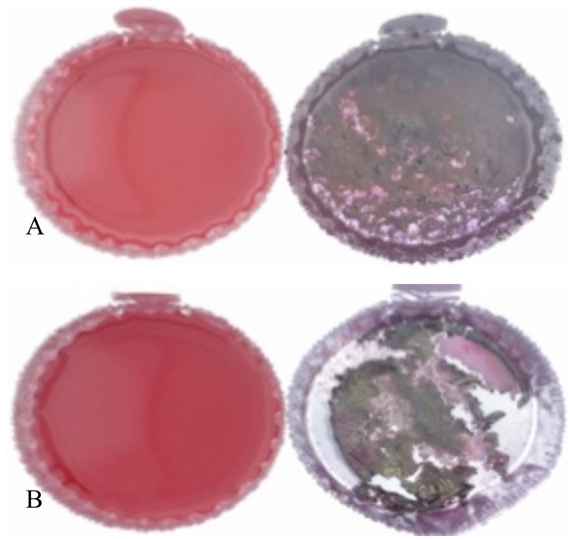


Figure 9: Colorants Subsequent to Heating with Gradient Temperature Change (A) Magenta Ink (B) PROsperse Red

3.3.5 Rit® fabric dye

Rit® fabric dye is a commercial product used to dye textiles, wood, paper, and certain plastics. Fuchsia Rit® dye was chosen because of its ability to be easily observed. It has previously been used as a dye stain for enhancing latent print impressions prior to and after cyanoacrylate development on non-porous surfaces.[29,43] Due to its ability to stain latent print impressions prior to CA fuming, this dye may have an affinity for components of latent print residue. The exact components of the Rit® dye are proprietary, but the compound is a powdered mixture containing dyes of the anthraquinone and azo dye families.[28] The anthraquinone dye family has been noted to have sublimation properties.[28,34,42] Dyes in the azo family such as Janus green B and Rit® fabric dye have been shown to stain and attach to cyanoacrylate developed non-porous items (Figure 10). [29]

There was no color observed on the substrates in white light or by ALS subsequent to fuming with CA and fuchsia Rit® dye.

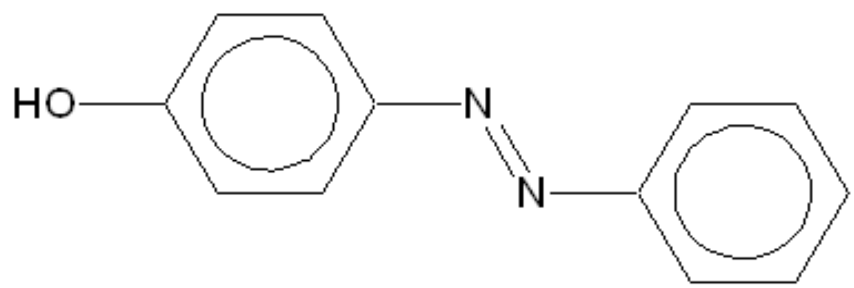
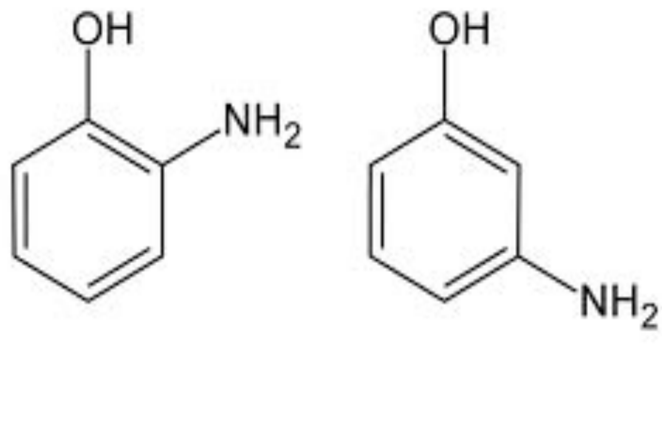


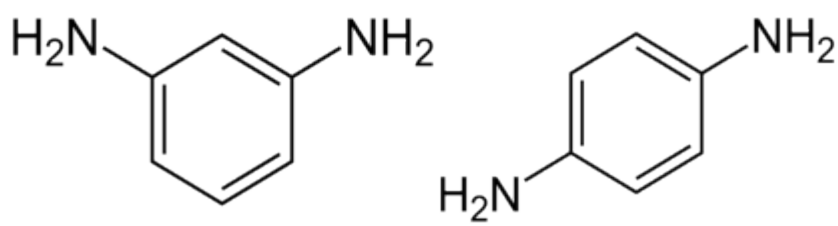
Figure 10: Example Molecular Structure of Azo Dyestuff: 4-hydroxyphenylazobenzene

3.3.6 Bigen® Hair Dye

The coloring components of the Bigen® dye include para-aminophenol, ortho-aminophenol, meta-aminophenol, para-phenylenediamine, and meta-phenylenediamine sulfate (Figure 11). Generally, one aminophenol and diamine are present within the dye.[44] These dyes are commonly used in hair dyes and facial cosmetic products. These dyes have the ability to stain the skin and hair a color of choice. It was theorized that the dye might also have an affinity towards the latent print impression residue if the dye is able to sublimate during the CA fuming process.



Meta-aminophenol ortho-aminophenol para-aminophenol



metaphenylenediamine paraphenylenediamine

Figure 11: Isomers of Aminophenol and Phenylenediamine

Bigen® hair dye is an oxidation dye that requires the presence of an oxidizer to display a color. Phenylenediamine, in particular, is known to be a reduced compound that remains colorless until oxidized. Once in the presence of an oxidizer, this compound exhibits a dark gray-black color.[45] According to manufacturer instructions, only the addition of water to the powder is required before applying to the hair. The dye is left on the hair for at least 15 minutes until the desired color is achieved.[46] As the time the dye is in contact with the hair increases, the color achieved will intensify, producing a darker color.

This compound contains amine and alcohol groups, which are known to increase the polymerization rate of the E-Z Bond CA.[47,48] After the fuming process with this dye, white polymers formed on the black tile; however, no color was visible on the latent print impression residue when viewed with the unaided eye or with an ALS.

3.4 Addition of Colorants to 3M™ Vetbond™ Tissue Adhesive

Due to the immediate curing of the glue upon addition of the colorants, a different approach was attempted using 3M™ Vetbond™ Tissue Adhesive, a butyl-cyanoacrylate. Compared to ethyl-cyanoacrylate, butyl-cyanoacrylate has a longer chain of alkyl hydrocarbons (Figure 12). All colorants, with the exception of the magenta printer ink, were able to be mixed in without immediate curing of the butyl-cyanoacrylate. Upon addition of the magenta ink, the butyl-CA rapidly polymerized.

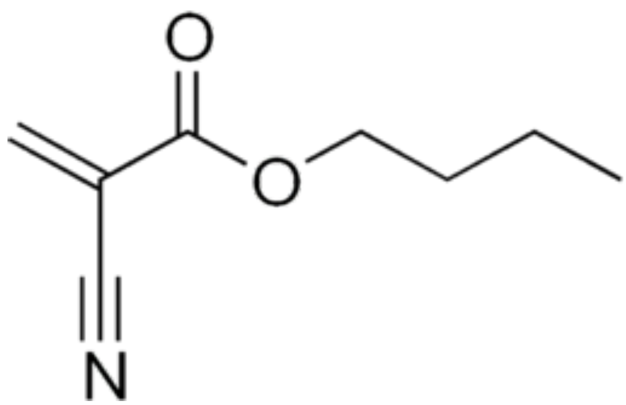


Figure 12: butyl-cyanoacrylate

Using Thermal Gravimetric Analysis (TGA), it has been shown that cyanoacrylates with smaller alkyl hydrocarbon chains degrade faster than the longer chained hydrocarbons at higher temperatures. Cyanoacrylate esters with longer alkyl hydrocarbon chains have higher boiling points and higher viscosities.[49] TGA is the assessment of the thermal stability of a compound by analyzing the compound's mass in an environment with an isocratic or gradient temperature over time.[50] Considering that the temperature at which degradation occurs increases as the hydrocarbon chain increases, 3M™ Vetbond™ Tissue Adhesive may be able to withstand the higher temperatures that are required for colorants to exhibit their sublimation properties. A literature search on the production of toxic HCN gas and polymer formation on latent print impression residue was unsuccessful in finding studies that included butyl-CA as well as other CA with large hydrocarbons chains.

White polymer formation was visible on the black tile of the trials that used Gentian Violet, Crystal Violet, and PROsperse Red. Butyl-CA combined with the magenta printer ink, Rhodamine 6G, Rit® dye, and Sudan Black did not develop visible white polymers on the latent print impression residue on the black tiles. No colored polymerization was visualized with the unaided eye or with an ALS on the white tiles.

3.5 Sodium Hydroxide Fuming

Fuming using sodium hydroxide is a technique that does not require a heat source. When cyanoacrylate is applied to a cotton swab soaked in sodium hydroxide, an exothermic reaction occurs, producing its own heat and vaporizing the CA monomers to create fumes.[1]

This technique was attempted with all of the colorants. No visible color was observed on the developed latent print impressions on any of the substrates. Upon application of the CA to the cotton swabs with the added colorant, the glue began to cure and the swab hardened within a few seconds, a similar reaction to the traditional fuming technique. Vaporized white fumes were observed for all trials. Polymer formation was still able to occur and was observed on the black tiles.

The temperature of the heat produced from the NaOH method was not measured. Compared to the radiation of heat given off using the hot plate, the sodium hydroxide method did not produce as much heat. It is reasonable to assume that the heat being produced is not hot enough for the colorants being used to sublimate due to the high temperatures required for the vaporization process.

3.6 Fluorescent Fuming with Lumicyano™

The principal advantage of fluorescent cyanoacrylate is to increase contrast between the latent print impression and the background in a single step. The development of a new cyanoacrylate fuming glue, Lumicyano™, has allowed for a quicker process for developing latent fingerprint impressions without the need to dye stain or powder. [31,33] This glue incorporates a fluorescent component that allows the latent print impression to be visualized with an ALS and an orange barrier filter once developed. Photographs can be taken of the fluorescent print impression in green light with the correct lens attachment. Additional fluorescent techniques that have been developed include: fluorescent powders that can be added to heated cyanoacrylate to sublimate along with the CA monomers, such as PolyCyano UV (Foster and Freeman, Worcestershire, UK), fluorescent crystals that can be heated directly in fuming guns, and a vapor phase staining technique using p-dimethylaminobenzaldehyde (DMAB), utilized after traditional CA fuming. [32,51]

The vapor phase staining technique utilizes crystals that are placed in a chamber with cyanoacrylate-fumed latent print impressions. At room temperature, DMAB becomes volatile and has the ability to attach to the CA polymers. This technique, along with Lumicyano™ and PolyCyano UV fuming, is less destructive compared to dye stains that require the immersion of the substrate into a liquid bath. They reduce the opportunities for damaging or distorting the latent print impressions, as contact is not required.

In this study, processing was performed using Lumicyano™. The polymer formation that occurred appeared white; however, the developed latent print impressions were visible to the unaided eye on both the black and white tiles. There was a high concentration of polymer on the latent print impressions, creating a noticeable difference between the texture of the ridges of the latent print impression and the background.

The substrates were viewed under red, yellow, BMT™, UV, and green light with the Ultra-lite™ and under blue light with the Crime-lite™. The latent print impressions did not fluoresce under the BMT™ or UV light. The latent print impressions fluoresced under yellow and red light with a red barrier filter on the black tile, but not on the white tile, wood or plastic. The latent print impressions fluoresced for all substrates using the green ALS with an orange barrier filter; however, the ridge detail on the wood and plastic substrates was faint. The camera was not able to capture the fluorescence on the wood and plastic substrates. The manufacturer recommends re-fuming to increase fluorescence.[52] Re-fuming was attempted, yet the fluorescence did not increase. In contrast, the fluorescence on the black tile was very bright and showed high quality ridge detail.

Wavelengths between 425 nm to 530 nm and UV wavelengths between 300 nm and 350 nm are recommended by the manufacturer for viewing latent print impressions fumed with the Lumicyano™ cyanoacrylate. Sufficient detail was observed when viewing the latent print impressions on a dark background without a light source, when viewed in green light at wavelength 525 nm with an orange barrier filter, and when viewed in red light at wavelength 630 nm without a filter (Figure 13). The images of the latent print impression viewed with the unaided eye and with the red light appear to exhibit the best detail. The red Ultralite™ produced the strongest fluorescence.

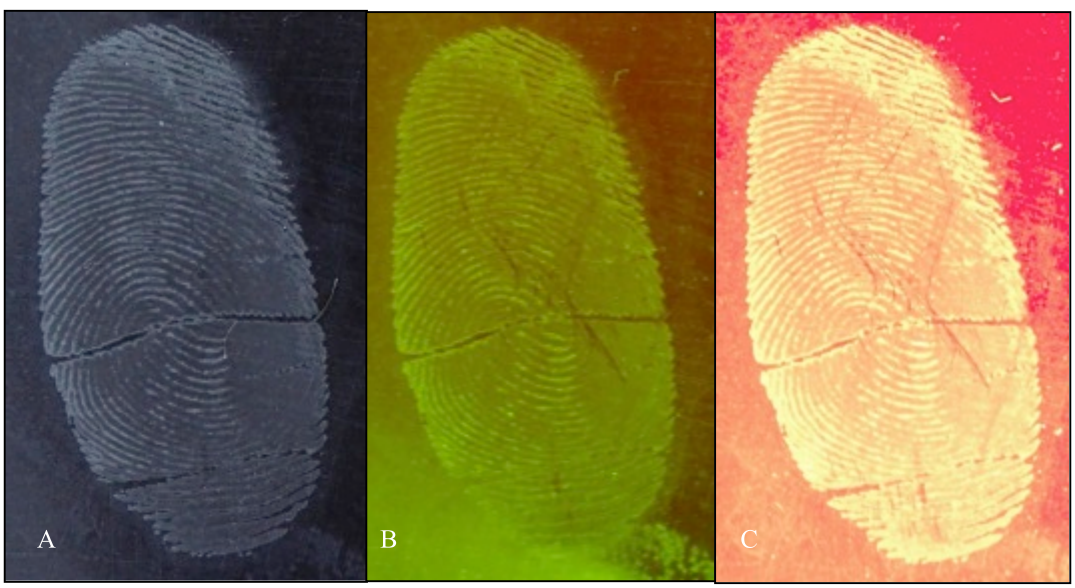


Figure 13: Lumicyano™ Fumed Latent Print Impression on the Same Black Tile Viewed in Different Wavelengths of Light. (A) White Light (B) Green Ultralite™ with Orange Barrier Filter (C) Red Ultralite™ with No Filter

Latent print impressions on a white background were viewed using the same recommended wavelengths of light as well as all other wavelengths tested. The latent print impressions did not exhibit as much fluorescence on the white colored background as on the black background (Figure 14). The best fluorescence on white tile was observed using the blue Crime-Lite™ (430 nm-470 nm) with an orange filter (Figure 15), which falls within the manufacturer's recommended range for fluorescence. It appears the white background may be masking the fluorescence of the polymers depending on the wavelength of light. Instead of viewing only the emitted wavelengths of light from the fluorescing CA, all wavelengths of light from the tiles may be reflecting, overwhelming whatever weak fluorescence may be present in the latent print impressions.

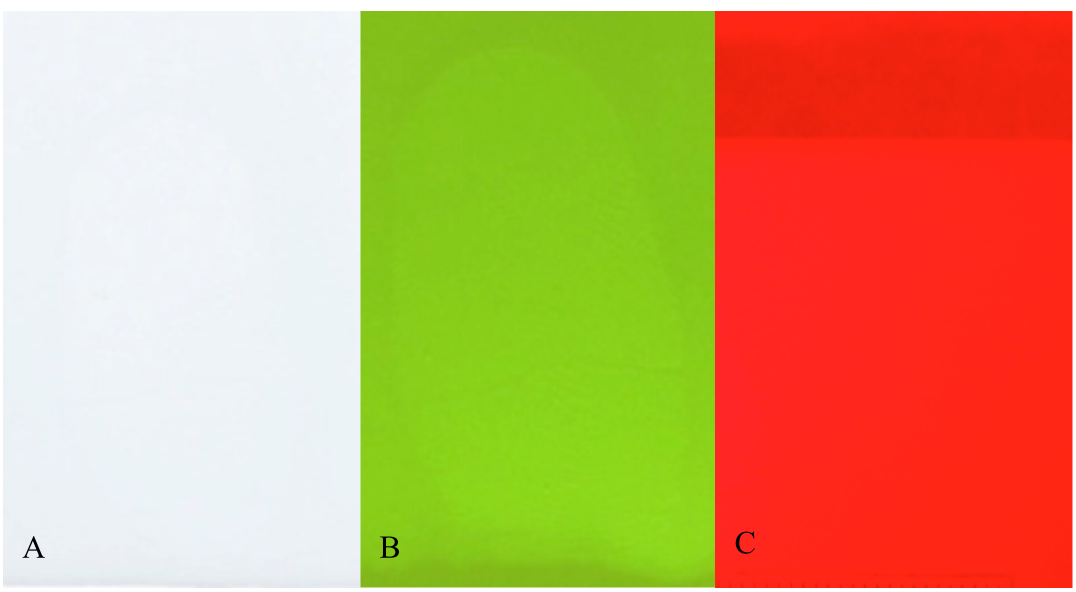


Figure 14: Latent Print Impressions on White Tile Subsequent to Lumicyano™ Fuming. (A)White Light (B) Green UltraLite™ with Orange Filter (C) Red Ultralite™ with No Filter

Figure 15: Lumicyano on White Tile Subsequent to Lumicyano™ Fuming Viewed with Blue Crime-lite™ with Orange Filter

Although all four substrates were fumed at the same time in the same chamber for every trial, the Lumicyano™ could have polymerized predominantly on the black tile making fluorescence more visible on the black tile than on the others. The chamber used in the testing was not under vacuum pressure nor did it have a fan to rotate the fumes to ensure even distribution of the fumes in the chamber.[23] If there had been constant movement of the CA fumes, then polymer formation would have been more likely to be equally distributed among all of the substrates, leading to stronger fluorescence on each.

It is noted in the manufacturer's instructions that the chamber must be completely clean and not contain any old CA residue within the fuming chambers; this will attract fluorescence to the residue within the chamber instead of to the latent print impressions.[52] There were many items such as the hot plate, beaker of water, and humidity monitor within the fuming chamber being used in this trial. It was not possible to completely remove all CA residue from these items. It is possible that these items, instead of the latent print impressions on the substrates, could have preferentially attracted the CA monomers causing a decrease in fluorescence on the latent print impressions. A reported advantage with Lumicyano™ is that an item can be refumed to increase fluorescence on items not easily visible and over-fuming will not occur.[52] In the present study, a large amount of polymer formation was observed across the background on one of the black tiles when the fuming process was carried out after the latent print impressions had developed (Figure 16). When viewed in closer detail (Figure 16a), ridge detail is still distinguishable from the background after over-fuming occurred.

Figure 16: Lumicyano™ Polymer Formation on Substrate Background and Latent Print Impressions

Figure 16a: Close-Up of Lumicyano™-Developed Latent Print Impression on Far Right of Figure 16

Results obtained from the Lumicyano™-fumed latent print impressions were compared to those on corresponding substrates fumed with traditional CA and powdered (Figure 17). The level of detail observed in the latent print impressions on the powdered substrates was greater than in the latent print impressions fumed using Lumicyano™. Ridge details for the fluorescent and powdered latent print impressions on the black tile were both of high quality. The powdered print impressions appeared to give better detail, however, the print appeared partially smeared. It is unknown whether the latent print impression was smeared during the deposition of the latent print impression or when brushing the print with powder. The weak fluorescence of the glue on the white tile produces poor quality in the ridge details. Photographs of the wood and plastic substrates were not able to capture the weak fluorescence they exhibited. The ridge detail of the wood and plastic substrates that were powdered was also weak, although ridge detail was still observed in these latent print impressions after processing. Ridge detail was observed on all substrates that were fumed with traditional CA then processed with a brush and powder. Because validation studies by other researchers utilizing Lumicyano™ were successful, it is likely that the success of this technique depends on the substrate.[31,33] Clear, glass microscope slides, black trash bags, and plastic carrier bags potentially will yield greater fluorescence than a white ceramic tile, white wood, and translucent plastic from a milk container.

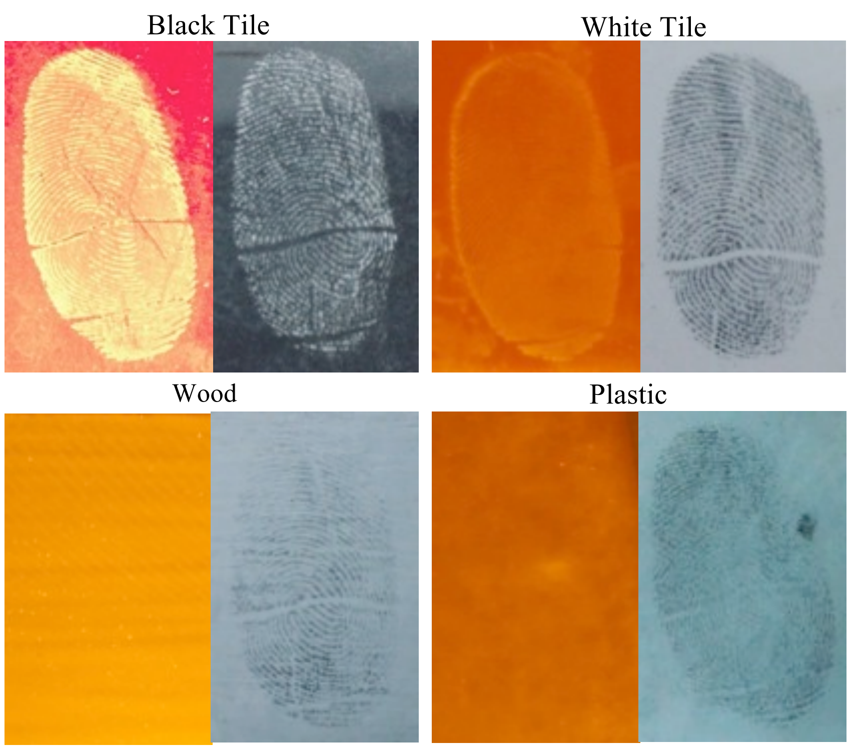


Figure 17: Comparisons of Lumicyano™-Fumed Substrates Viewed with Red Ultralite™ (No Filter) on Black Tile and Blue Crime-lite™ with Orange Filter on all other substrates (Left) and Traditional-CA-Fumed Substrates Viewed in White Light (Right).

3.7 Summary of Observations

Fuming with Lumicyano™ can be performed with relative ease, similar to traditional fuming, although strong fluorescence with quality ridge detail was not observed on the light colored substrates. Unlike the clear EZ-Bond glue, not all colored glues formed polymers on latent print impression residue; the reef glue and tire glue did not exhibit any polymer formation. Although white polymer formation could be observed on the black tile in a majority of the experiments, no results were obtained on the light colored substrates, the surface type on which ready observation of polymers and ridge detail would be most beneficial. Fuming with traditional CA followed by the application of powder to latent print impressions currently appears to be the more efficient technique for latent print impression enhancement on these particular substrates. It was the only technique that allowed quality ridge detail to be observed on all four substrates (Table 2 & 3).

Table 2: Observations of Latent Print Impressions Fumed Utilizing Pre-Colored Cyanoacrylates

	Black Tile	White Tile	Wood	Plastic
Coralline Colored Reef Glue	No polymer development	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
3M™ Vetbond™ Tissue Adhesive	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
Stick Fast™ Black Flex Instant CA	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
Tire Glue IC-2000™	No Polymer development	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
Lumicyano™	Polymer Formation, Fluorescence Observed	Weak Fluorescence, Poor Ridge Details	Weak Fluorescence, No Ridge Detail	Weak Fluorescence, No Ridge Detail

Table 3: Observations of Latent Print Impressions Fumed Utilizing Added Commercial Colorants and Protein/Hemoglobin Stains to Clear EZ-Bond Cyanoacrylate

	Black Tile	White Tile	Wood	Plastic
Gentian Violet	Polymer Formation, No Color or Fluorescence Observed Trace Colorant Observed after Clean Up	No Color or Fluorescence Observed Trace Colorant Observed after Clean Up	No Color or Fluorescence Observed Trace Colorant Observed after Clean Up	No Color or Fluorescence Observed Trace Colorant Observed after Clean Up
Crystal Violet	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
Rhodamine 6G	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
Sudan Black B	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
PROsperse Red D360	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
Magenta Ink	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed	No Color or Fluorescence Observed
Rit® Dye	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence	No Color or Fluorescence	No Color or Fluorescence
Bigen® Hair Dye	Polymer Formation, No Color or Fluorescence Observed	No Color or Fluorescence	No Color or Fluorescence	No Color or Fluorescence

4. CONCLUSIONS

Cyanoacrylate fuming is one of the easiest and most widely used methods in forensics as it performs best on most non-porous substrates and can be performed in the laboratory or in the field. It reveals and preserves latent fingerprint impressions on evidence by acting as a stabilizer, which is important when handling and transporting evidence. One of the disadvantages to this technique is the lack of contrast between the white polymers that are formed on the latent print impression residue and light colored backgrounds on which the latent print may have been applied.

Attempts were made to develop a one-step cyanoacrylate fuming method that would enhance visualization of latent print impressions on light colored backgrounds without the need for an alternative light source, dye staining, or powdering. Protein and hemoglobin stains, commercial colorants, sublimation dyes, hair dye, and printer ink were added to ethyl-CA in attempts to create a co-polymerization process of the vaporized cyanoacrylate monomers and colorant molecules on latent print impression residue. Fuming was also attempted using pre-colored commercial glues with the assumption that the attached CA polymers on the latent print impression residue would retain their original color properties.

None of these co-polymerization methods proved successful. When present, the polymers that formed on the latent print impression residue from the pre-colored glues and the clear E-Z bond glue mixed with various colorants were white; none exhibited fluorescence when viewed with an ALS. The colorants utilized did not sublimate at temperatures suitable for cyanoacrylate fuming.

Upon addition of the colorants to clear E-Z bond CA, rapid polymerization occurred within the fuming tray prior to heating. A butyl-cyanoacrylate was utilized in place of the ethyl-cyanoacrylate to decrease the rate of polymerization. The butyl-cyanoacrylate utilized was a tissue adhesive, 3M™ Vetbond™ Tissue Adhesive. This CA ester behaved differently from ethyl CA in that it mixed with the colorants without rapid polymerization. White polymers also formed on latent print impression residue when this CA was utilized.

Lumicyano™ is a fluorescent CA that allows for a shortened development process by eliminating the need for a dye stain or powdering. The CA monomers adhere to latent print impression residue similar to traditional CA; however, the polymers from Lumicyano™ are designed to fluoresce when illuminated by the appropriate ALS. This technique allowed for an easy, quick fuming process without the need for harsh solvents. It also eliminated the direct contact with the latent print impression that occurs with powder and brush techniques. One downside to using Lumicyano™ is the cost of the product. The price for about 20 mL of Lumicyano™ is approximately $50 (Arrowhead Forensics, Lenexa, KS) while the cost of traditional CA is approximately $6 for about 30 mL. Even considering the relatively nominal cost of dye stains and powders, Lumicyano™ is not cost-effective compared to traditional CA fuming and processing.[53] In this study, Lumicyano™ performed poorly on the white tile, wood, and plastic substrates, while regular CA and powdering allowed for the development and enhancement of latent print impressions on these particular substrates. On dark ceramic surfaces, wavelengths between 525 nm and 630 nm appeared to yield the best fluorescence. On the white ceramic surface, wavelengths between 430 nm and 470 nm (blue light) exhibited the best fluorescence. The latent print impressions weakly fluoresced when UV light was utilized.

4.1 Future Considerations

Further research should attempt to create a technique for the co-polymerization of cyanoacrylate monomers using a colorant that can be viewed by the unaided eye on light colored backgrounds. The time it takes to process a latent print impression would decrease and expensive and carcinogenic dye stains would no longer be necessary in many cases.

The components of latent print impression residue need to be further studied and characterized. Knowing the exact mechanism and reactions that occur when cyanoacrylate monomers adhere to latent print impression residue would be advantageous. Further studies using natural and synthetic mixtures of sweat that would generally be produced from clean and oily latent print impressions could allow for the exclusion and inclusion of components involved in the polymerization process.

When the temperature of the substrate is warm, CA polymer formation decreases.[54] Additional testing should compare polymer formation when the substrates are cold and when the substrates are at ambient temperature of the chamber. It is possible that decreasing the substrate temperature may increase the chances of the colorant molecules attaching to the latent print residue or to the CA polymers.

The sublimation of dyes is more likely and easier to occur within a vacuum system. Having a vacuum system for fuming may allow for the sublimation of dyes to occur at lower temperatures that are appropriate for the heating of cyanoacrylate. Sublimation chambers have been created for use in portable fuming devices such as the Vapor Wand and Fuma-Dome.[1,34,42] These sublimation devices allow for the slow production of vapor fumes at high temperatures. Finding colorants with similar molecular structure and properties as the fluorophores that have been used in the development of the one-step fluorescent fuming methods would be significant, as many of these compounds have the ability to easily vaporize and attach to the CA polymers.[34,42,51]

Derivatization is a process used to alter compounds making them suitable for gas chromatography. This process uses specific reagents to increase the volatility, increase the thermostability, and to decrease the polarity of compounds. Only compounds containing certain functional groups would be suitable for derivatization. Compounds containing functional groups involving oxygen, nitrogen and sulfur such as alcohols, phenols, or amines are ideal.[55] A few of the colorants utilized in this study likely contain these functional groups assuming they follow the same chemical structure of the dye families to which they belong. If the volatility of these compounds could be increased, then certain colorants may be able to vaporize at a lower temperature and faster rate making co-polymerization of the colorant and CA monomers simultaneously on latent print impression residue a possibility.

Additional testing must be performed using cyanoacrylates with more hydrocarbon chains, such as butyl-cyanoacrylate and octyl-cyanoacrylate. Cyanoacrylates with more bonds potentially degrade slower in higher temperatures, thus increasing the temperature at which hydrogen cyanide gas is produced and increasing the temperature to which CA can be heated. They may also have better solubility and compatibility for certain colorants. As observed in this study, butyl-cyanoacrylate was able to mix with certain colorants without rapid polymerization, which occurred with ethyl-cyanoacrylate.

The use of oil-based colorants could also prove successful, assuming these colorants do not have water molecules that will initiate the polymerization of the cyanoacrylate. Many of the colorants used appear to have a water or alcohol component, which causes rapid polymerization when being added.

Knowledge of the exact chemical and physical properties of compounds in the cyanoacrylate and colorant would likely improve the success of a colorant-CA co-polymerization fuming method. In addition, due to inter- and intra-personal compositional differences in fingerprint residue, latent print impressions deposited by multiple donors under various conditions should be included in future studies.

LIST OF JOURNAL ABBREVIATIONS

Anal Chem	Analytical Chemistry
Anal Chim Acta	Analytica Chimica Acta
Forensic Sci Int	Forensic Science International
J Am Chem Soc	Journal of the American Chemical Society
J Chem Educ	Journal of Chemical Education
J Chem Phys	The Journal of Chemical Physics
J Forensic Ident	Journal of Forensic Identification
J Forensic Sci	Journal of Forensic Sciences
J Polym Sci Part A Polym Chem	Journal of Polymer Science Part A: Polymer Chemistry
Sci Justice	Science and Justice

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