FLUORESCENT CHEMICAL DEVELOPMENT OF LATENT FINGERPRINTS

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CAPSTONE ABSTRACT

Fluorescent Chemical Developments of Latent Fingerprints

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Fingerprints are crucial pieces of evidence that can be used both for identification purposes but also to exonerate those people who have been wrongfully convicted. When fingerprints are found at crime scenes, seldom are they presented in an "ideal" manner. Most are partial, distorted, compromised, or a combination of all three. The usefulness of recovered fingerprints depends on their ability to be recovered and enhanced without disruption of the original detail, while also enhancing that detail. Fluorescent reagents are typically used to recover these marks, especially from objects with poor background contrast or from objects that have been compromised (e.g., submerged in water, exposed to extreme weather, damaged by fire, etc.) They allow for greater visual enhancement in marks that would otherwise be "invisible". Fluorescent reagents typically work best with latent fingerprints, prints that have been left in the sebum (oil) or sweat present on the fingertips. In order for fluorescent fingerprints to be made visible, they must be viewed under the stimulation of an alternative light source and with a viewing filter. Rhodamine B, a fluorescent chemical and biological staining agent, along with several other

components, was used in this study to create a novel formulation of a fluorescent fingerprint powder. The powder was tested on latent fingerprints that were deposited on nonporous objects. The latent fingerprints were deposited as a "loaded series" or as a "depletion series". The novel formulation was able to recover both sebum-rich and eccrine-rich latent fingerprints from nonporous objects with strong detail, though the powder showed better detail and enhancement capabilities with the sebum-rich fingerprints. The detail was greater in the loaded sebum-rich series, but good detail as able to be recovered in the depletion-series, as well. The powder exhibited strong fluorescence across all samples. Further studied should be conducted to determine the reproducibility and sensitivity of this novel powder, but its use as a method of recovery for latent fingerprints is a great addition to the latent fingerprint community, as well as the field of forensic science.

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Introduction

Fingerprints, when found at crime scenes, are crucial pieces of evidence that can be used for the identification of criminals, but also for the exoneration of those who have been wrongly accused or convicted. The two types of fingerprints primarily seen at crime scenes are latent marks and patent marks. Latent marks are the mark left behind by the sweat on one's fingertips when they come into contact with a surface. Patent marks are impressions left in another substance, called a matrix, such as blood, mud, ink, clay, etc.

It is necessary to address the issue of "terminology" when it comes to fingerprints. Technically, the term "fingerprint" is informal and considered slang. The same goes for the shortened version "print". When referring to latent vs. patent, the correct term would be "mark", considering that it is a mark left by the friction ridges on the fingertip. Latent marks and patent marks are made by an unknown source. This is what distinguishes them from exemplar prints. The term "print" in this case is correct, as exemplar prints are actual prints taken by inking the fingertip and pressing it onto a piece of paper. The result is what would be, by definition, a print of the friction ridges. Exemplar prints are deliberately taken from a known individual[25]. Throughout the paper, the field of fingerprinting, in general, will be referred to as such. However, the correct terminologies of latent mark and exemplar print will be used when applicable.

The marks recovered from crime scenes are seldom ideal. The majority recovered are partial marks or ones which have been haphazardly deposited. Latent marks are invisible to the naked eye and must undergo visualization techniques in order to be properly analyzed. There are numerous visualization techniques, most of which involve powder dusting or aqueous reagents. The method of visualization deployed on a latent mark is determined by a variety of factors, including the composition of the mark, the material of

the object the mark has been deposited on, the environment the mark and object were exposed to, and how long the mark has been on that object[8]. Each of these factors can greatly influence the recoverability of a latent mark.

Latent print examination, or LPE, has withstood the test of time and though it is now relying more heavily on technology, the basics of fingerprinting will always play an important role in forensics. The new and ever-evolving technology and the basics must work in tandem. The ability to develop a high-quality latent mark from a crime scene or from a piece of evidence is necessary for analysis and comparison. More often than not, the latent marks that are able to be recovered from a crime scene are partial marks that have been distorted and/or compromised due to environmental effects or attempted removal. The ability to recover all forms of latent marks (and be able to use them for comparisons is the goal of any fingermark recovery technique.

Fingerprint examination as a whole is considered more of an art than a science, mainly due to the subjectivity involved. The ability to connect a recovered latent mark to a specific individual, i.e., proving the individuality of the mark, relies heavily on the analytical and interpretive abilities of the examiner[15]. This looming cloud of subjectivity is what prevents this field from being considered a science. Science relies on accuracy and reliability, as well as the ability to quantify each. When it comes to fingerprints, the accuracy and reliability is a factor associated with the analyst as opposed to the results. This is what keeps the field of latent mark examination as being considered an art, compared to being a hard science. It is important, however, to persist by applying scientific methods to the area of latent mark examination wherever possible.

Statement of Purpose

The research objective was to create a Rhodamine B based dusting powder that recovers high quality marks, both sebum- and eccrine-rich, from various surfaces. The overall purpose of this paper is to introduce the novel fluorescent fingerprint powder formulation and discuss its use in the recovery of latent marks. Rhodamine B was the fluorescent component used for this study and was chosen due to its ability to exhibit intense fluorescence at low concentrations. Fluorescent fingerprint powders allow for a better contrast between the mark and the object the mark is on, when compared to typical white-based or black-based powders. The fluorescent species in this study was introduced into a white-based powder to allow visualization with the naked eye and under an alternative light source.

Background

Fingerprints in Forensics

Fingerprints are the marks that are left behind by the friction ridges that are present on each fingertip when they come in contact with another surface. The impressions can be visible (e.g., patent or plastic impressions) or invisible (e.g., latent marks)[14]. Plastic impression, though similar to patent, differ due to plastic impressions being three-dimensional. These impressions are left in another substance, such as paint, clay, wax—any substance that is soft and malleable. Latent marks, which were the focus of this study, are any impressions that are left on another surface by the natural residue present on the fingertip. This residue is composed of the sweat, oils, dead skin cells, and other organic and inorganic compounds[8]. To make these marks visible, they must be treated chemically and/or enhanced with a powder.

Composition of a Latent Mark

The chemical composition of latent fingerprints can differ greatly from person to person, and even from finger to finger on one person. The major component of the chemical composition is eccrine sweat. Eccrine sweat is secreted from the eccrine glands (see Figure 1), which are found all over the human body. These glands are found within the dermis of the skin and extend up through the epidermis to an exit known as a sweat pore[9]. These glands are especially numerous on the hands (palms, fingertips) and the feet (soles, toe pads). Eccrine sweat is ~98% water, with the remaining 2% being made up of products of

metabolism, such as proteins, amino acids, sugars, and choline, as well as products of catabolism, such as urea, uric acid, lactic acid, and creatinine[3,9].

Figure 1. Cross-section of skin showing eccrine and sebaceous glands

Other components of latent marks include sebum (oil) which comes from sebaceous glands. Sebaceous glands are found all over the body, except for the hands and feet. They are responsible for the production of over 90% of the skin's surface lipid content. They are especially numerous on the face and scalp (deep within the hair follicle) and their secretions are easily transferred onto the fingertips through contact. Their secretions are a mixture of glycerides, fatty acids, squalene, and sterols/sterol precursors[15]. One study[8] noted that contact with the sebum-rich areas of the face (nose, forehead) immediately before depositing a mark, intentional or not, results in a significant increase in the number of fatty acids and squalene present within the mark.

Fingerprint Patterns

The patterns seen on a fingerprint are a result of the numerous small lines, called friction ridges, that cover the surface of one's fingerpad. Generally speaking, there are three main categories in which the patterns fall into: arch, loop, or whorl[17]. It is important to note

that there are many variations that can exist within these three categories, as well as crossovers between them. However, the specific pattern is determined based on the number of 'deltas' present within a mark. Deltas are named due to their resemblance of the Greek letter *delta*, Δ.

Arches are classified as such when there are no deltas present on the mark. They consist of wave-like patterns, which rise to an apex. Generally, there are two main categories of arches–plain arch or tented arch. Tented arches have a more pronounced apex. Arches are responsible for about 5% of all patterns.

Figure 2. Fingerprint patterns – plain arch, tented arch

Loops are classified by the presence of one delta. This pattern shows a recurve back on itself to create the characteristic loop shape. Loops can be categorized based on their orientation. They are considered radial when the loop points towards the thumb (radius) and are considered ulnar if they are pointing towards the ulnar bone. Loops are the most common pattern seen amongst people, making up a little over 60% of all patterns.

Figure 3. Fingerprint patterns – ulnar loop, radial loop

Lastly, there are whorls, which are identified by their presence of two or more deltas. Whorls are circular or spiral shaped, similar to whirlpools (hence the name). However, there are a number of different variations of whorls that exist, namely plan whorls, central pocket loop, double loop, and accidental (irregular shaped). Whorls are responsible for the remaining 35% of mark patterns seen throughout humans[15].

Figure 4. Fingerprint patterns (whorl)

What Makes Fingerprints Unique?

It is a well-known fact that no two fingerprints are the same. But what makes each fingerprint so unique? As shown above, there are many different patterns, but fingerprints often can look extremely similar to one another. The uniqueness and individuality of fingerprints comes from the smaller details present within the mark. These details are able to be classified, providing framework for determining the individuality of a mark.

As mentioned previously, a fingertip is made up of various ridges, called friction ridges, which create the pattern that is seen on the fingertip. The spacing between the friction ridges, the position of each ridge relative to the others, and the ridge thickness, to name a few, are characteristics that are unique to each individual. According to SWGFAST

Analysis Guidelines[25], there are three different levels of detail which the quality of a fingerprint can fall under.

Level 1 detail refers to the ridge flow, or the pattern, present in the fingerprint. The discernible features include the core, the presence or absence of deltas, and the orientation of the mark. Level 1 detail cannot be used to make an identification, but it can be used to eliminate potential suspects.

Level 2 detail refers to the path the of the individual ridges. There are many ridge variations, which are referred to as minutiae, that can exist within a fingerprint. Examples include an abrupt ridge ending, bifurcations, spurs, crossovers, lakes, and eyes. Level 2 detail offers the most valuable information out of the three levels and can be used to make an identification. Note: There is no standard/universal terminology to describe the various ridge characteristics. Generally, as a group they are referred to as minutiae points. It is at the discretion of the examiner to determine which terms to use and maintain consistency with those terms.

Level 3 detail, which is the highest level of detail that can be observed, refers to the individual ridge attributes. Each friction ridge has a unique shape, whether it be straight or curvy. Each ridge also has sweat pores. The presence, positioning, and spacing between these sweat pores on each ridge is also unique. Level 3 detail is not any more discriminatory than Level 2. It is more specific than Level 2. Level 3 detail, on its own, is rarely used for identification purposes. It is important to note that the 3 levels of detail within the mark are not mutually inclusive. It is possible for an enhanced or recovered mark to exhibit Level 2 and Level 3 detail without Level 1 detail being present.

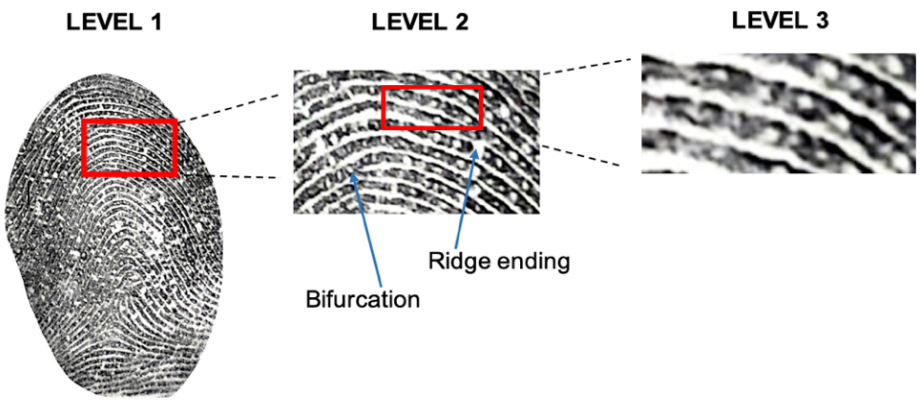


Figure 5. Level 1, 2, and 3 detail examples Source: K. Smith

All of the factors listed are genetic, but there are outside factors that can affect the level of detail, as well. Scars, warts, the wrinkles made from sweating…each of these factors help to improve the uniqueness of a fingerprint. Depending on the level of detail present, the mark can be associated with a particular individual if there is a well detailed known (exemplar) mark to compare it with. These factors, however, are only a fraction of what information goes into the examination process of a recovered mark.

Deposition Factors

There are a multitude of factors which go into the depositing of the mark, and all of these factors will ultimately affect the visibility, recoverability, and detail of that mark. When a fingertip is pressed onto a surface with great pressure, there should be a more noticeable mark left behind than when a fingertip is pressed lightly onto the same surface. The intention with which the fingertip is pressed onto a surface determines how the resulting mark will look, as well. A haphazardly placed mark might be smudged and partial. An intentionally placed mark is likely to provide more detail, given the conditions allow for it. The surface on which the mark was deposited also affects the longevity, visibility,

and recoverability of the mark. Porous surfaces, like paper or money, may absorb the components of the mark that will react with chemical treatments or dusting powders. There are numerous chemical treatments which allow for the enhancement of marks made on these types of surfaces.

Latent Mark Residue

The composition of a latent mark is extremely important to the mark's longevity as well as to the recovery process. If the mark is eccrine-rich, the chemical treatment to be used will be different than if the mark is made up of sebum. Eccrine-rich and sebum-rich marks warrant specific treatment that reacts with the chemical components of each. Sebum-rich latent marks can be treated with chemicals typically used to stain biological samples. These staining agents adhere to the fats, oils, and proteins within the mark, allowing for enhanced visibility to the naked eye.

Sebum-rich latent marks are likely to last longer when left untouched for an extended period of time compared to eccrine-rich latent marks. Eccrine-rich marks, as mentioned before, consist primarily of water, which will evaporate. They can also be washed away much easier than sebum-rich marks. When both types of marks are subjected to destructive conditions, e.g., water, extreme temperatures, fire, etc., their resistance is dependent on their composition, and how long it was there prior to being compromised. The use of fluorescent powder reagents is beneficial when it comes to marks that have been exposed to destructive conditions. They are the best chance any mark that may be on a piece of evidence has at being recovered.

Both sebum-rich and eccrine-rich marks were examined throughout the duration of this study. The details regarding how the marks were generated and deposited will be discussed in a later section.

How does fingerprint dusting work?

For sebum-rich marks, recovery methods typically involve the use of a chemical that will react with the oils and proteins present in the mark. There are liquid and solid (powder) enhancing reagents, all of which have their own benefits and drawbacks. There is not one method that will yield results in all cases. Based on the researcher's personal experience and preference, a fingerprint dusting powder was chosen as the focus of this study. The fluorescent aspect was chosen based on the idea that submerged objects would be examined during the study. Though this particular aspect of the study was changed, the fluorescent powder proved to work well on the non-porous objects in general.

ACE-V Examination Guidelines[25]

Latent mark examination incorporates four main aspects: analysis, comparison, evaluation, and verification (ACE-V)[13]. Below, each are discussed in detail. Analysis includes the assessment of the marks as they appear on the objects. This includes the analysis of the visibility of the mark, which involves determining the level of detail present. The end goal of analysis is to determine if a mark is valuable. This is where most of the issues in latent mark examination can arise, as much of the analysis is very subjective. The result depends on the competency and experience of the analyst.

This step includes the determination of the three levels of detail that could be present within each mark. Level 1 detail suggests clear visual of the friction ridge pattern on the mark. Specific classifications include arch, loop, whorl, etc. Level 1 detail cannot be used to make a source conclusion, but it can be used to make a source exclusion. Level 2 detail suggests clear minutiae characteristics, e.g., bifurcation, ridge ending, bridge, etc. Level 2 is the minimum level required to make a same source conclusion[25], and it is the level that this study is hoping to attain from each enhanced latent mark.

Level 2 detail will be required before any further examination or comparison can be performed. Lastly, Level 3 detail suggests the presence of various ridge attributes. These include, but are not limited to, pores, spacing between certain pores, dimensions of ridge characteristics, and the location of the minutiae on the mark. Although Level 3 detail provides a more precise identification of the source of the mark, the examination of it is very much subjective. The analysis step sets the stage for further examination and will influence the final determination to a great extent. It is important that the analysis is done carefully and with intention.

Comparison for the purposes of this study relies upon the comparison of the known (exemplar) marks and the latent marks. Proper documentation necessary for these comparisons must be made for all exemplar prints and all latent marks. This documentation includes the anatomical source of the mark (e.g., thumb), the orientation (e.g., distal, proximal), the medium in which the mark was created (e.g., eccrine sweat, ink), and the origin of the mark (e.g., marked, direct submission, recovered, etc.)

Consistency in documentation is also a necessary component. Using shapes, such as those seen in Figure 6, can help denote specific features an analyst would want to convey. Symbol 1 denotes a ridge ending with high confidence, Symbol 2 signifies a bifurcation with high confidence, Symbol 3 signifies a feature when the exact left to right positioning is in doubt, and Symbol 4 signifies a feature when the exact left to right positioning and the exact start and stop position of the feature are in doubt[22]. These symbols were proposed by SWGFAST but are not something all examiners use.

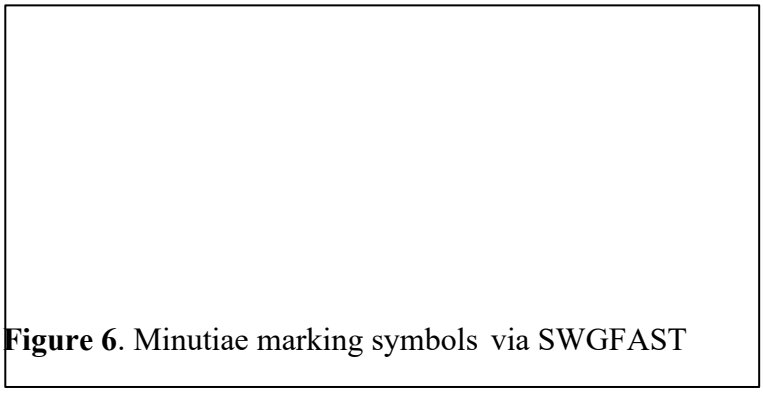


Figure 6. Minutiae marking symbols via SWGFAST

One study made note that, in relation to comparison and analysis of latent marks, the phrase "the marks had *N* corresponding minutiae marked" is not the same as the phrase "the marks had *N* corresponding minutiae." It is good practice to maintain consistency with documentation both in the initial analysis step and the following comparison step. Using symbols, such as those shown above, can help an analyst keep track of specific characteristics, especially when analyzing hundreds to thousands of latent marks. Although this is an academic research project, annotating the marks efficiently and properly can lead to improvements as well as greater transparency in forensic casework.

Evaluation is the next step, which again, relies heavily on documentation[22], both photographic and handwritten. The biggest aspect of evaluation includes the evaluation of

minutiae. This will include, but is not limited to, the number of corresponding minutiae between the latent marks and the exemplar prints, the presence/absence of a corresponding core pattern/deltas, and the number of corresponding deltas (if applicable). Proper documentation of minutiae characteristics on the latent marks and the exemplar prints is necessary to carry out proper analysis.

The purpose of the evaluation step is to evaluate the determined corresponding characteristics between the latent marks and the exemplars and the level(s) of detail present on each mark. Ultimately the analyst will designate one of the following: same source conclusion, source exclusion, indeterminate. Level 1 detail can be used to make a source exclusion, but it is not unique enough to make a same source conclusion. Level 2 detail is what is used to make a same source conclusion, as the characteristics present are unique to an individual[22]. Level 2 detail can also be used to make a source exclusion.

When evaluating the levels of detail present on an exemplar print against an unknown latent mark, a disagreement in the level of detail present will result in a source exclusion determination. However, it is noted in the National Criminal Justice Reference Service's *Fingerprint Sourcebook* that a source exclusion does not mean the person is being excluded[17]. Source exclusion simply refers to the relationship between the unknown latent mark and the exemplar it has been compared to. It is the analyst's duty to indicate whether the excluded source is a hand, a foot, an exact finger, or a particular person. A same source conclusion requires this, as well. Proper documentation is a large aspect of the evaluation step and must be done with careful attention to detail.

Verification is the final step in the ACE-V method. According to SWGFAST guidelines, this involves the examination of the exemplars and latent by an independent

examiner. For this to be considered a verification, the independent examiner must reach the same conclusion as the initial examiner did using the ACE method.

Documentation

When it comes to forensic science, documentation is key. It is the most important aspect of working in the field, especially within a subset of the field that relies so heavily on photographed evidence. Photographs were taken at every major step of the study, including but not limited to before deposition, immediately after deposition, immediately after dusting, under the alternative light source, and on the hinge lifter. Each image had two scales, one vertical, one horizontal, with the centimeter side facing the object. Some photographs did not contain the scales, but this was intentional and done in an effort to obtain a better photograph. Each "series" of photographed contained a sufficient number of scaled photographs that allowed for the measurements to be accurately, if needed.

Issues in Fingerprint Examination

As mentioned in the introduction, fingerprint examination is considered more of an art than a hard science. Fingerprint examination relies heavily on the subjective judgement of the examiner/analyst, and often, the only proof provided for their findings is their extensive experience as a fingerprint examiner. Essentially, they are saying, "trust me, I know what I'm talking about." This issue is prevalent across many subsets of forensic science, but not much has been done to directly address it with fingerprint examination.

Ultimately, it is up to the examiner to conduct their analysis and examination thoroughly, properly, and do so in a way that ensures the results can be accepted by the

court. It is important to remember that scientists are working for the side of the truth. By conducting their analysis and examination in a consistent and well-documented way, it allows for the results to be deemed more “reliable”, even with the absence of standardized quantitative data.

This relates to another pressing issue within the field of fingerprinting, which is the lack of universal standards. Ultimately, it is at the discretion of each individual crime lab to create its own standards. There is a great deal of inconsistency surrounding how many corresponding points must be the same for a known print and an unknown latent to be considered as coming “from the same source”. Again, it is at each individual laboratory’s discretion to determine exactly how many corresponding points must be present for them to be able to make a conclusion. There may be some instances when there are 7 very rare characteristics that correspond between a known mark and an unknown mark, giving credence to them being from the same source.

Fluorescence

The electromagnetic spectrum is the general term which is used to describe the complete range of light that exists[12]. Most of this light is not visible to the human eye. In fact, only a very small portion of this spectrum can be seen, which is designated by the small rainbow portion near the center of Figure 7. There is not a precise definition in terms of the wavelength range of the visible spectrum, as perceived color is determined by how much light reaches the retina of the eye. However, the lower limit of the visible range generally falls between 360 and 400 nm and the upper limit generally falls between 760 and 830 nm[22].

The EM spectrum holds an important place in the field of chemistry, providing much insight into the intensities produced by electrons of molecules or atoms. The intensity of fluorescence with respect to its use in fingerprinting powders was of particular interest to this research study.

Figure 7. Electromagnetic Radiation Spectrum[8]

Fluorescence is a multistep process which starts with the excitation of photons in a ground state to an excited state[12]. For fluorescence to occur, both the ground state and the excited state must be singlet states. As the species is returning to its ground state from the excited state via vibrational relaxation, the emission of photons of lower energy, and therefore longer wavelengths than the absorbed photons, occurs, which produces fluorescence. Fluorescence emission is a short-lived occurrence, with an average lifetime of 10^{-10}–10^{-7} seconds[12]. The frequency at which the species is excited and at which it emits EM radiation are both dependent on the identity of the species. These values can be determined using a fluorescent spectrophotometer and are referred to as the excitation wavelength (λmax) and the emission wavelength (λmax).

Fluorescence is mainly exhibited in the ultraviolet (UV) region, but it can be seen in the visible region and the near infrared (IR) region, as well. In forensics, alternative light sources are used to make this fluorescence visible and observable. These alternative light sources are packaged as large flashlights, making them convenient for travel and easy to

operate. To ensure the highest intensity fluorescence is yielded, the excitation source must have a wavelength range which corresponds to the λmax of fluorescent substance. The excitation wavelength depends on the solvent used for the solution as well as the concentration of the solution, although studies have shown that the disparities between solvents are relatively small[20]. When a fluorescent reagent is stimulated by the alternative light source (EM radiation), the latent mark which contains the reagent can be revealed either with or without barrier filters or goggles.

Rhodamine B

The fluorescent formulations used in this experiment involved the use of one compound from the rhodamine family called Rhodamine B. Rhodamine B has the chemical formula $C_{28}H_{31}ClN_2O_3$ (see Figure 7) and a molar mass of 479.01 g/mol[11].

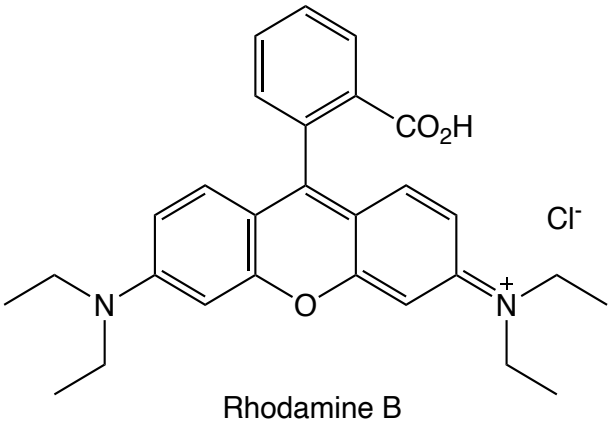


Figure 7. Structure of Rhodamine B
Source: K.Smith | ChemDraw

Rhodamines are xanthene derivatives that are structurally similar to fluorescein. They differ in their substituents, which allow for the elongated excitation and emission spectra wavelengths[2] of Rhodamine B**.**

Rhodamines are often used as fluorescent dyes or fluorescent tracers, but their use in latent mark enhancement has recently began to be explored. Rhodamine B is most commonly used for water tracing, textile dyeing, and other staining industries[23]. Rhodamines are fluorochromes (or fluorophores) which means they can re-emit light upon light excitation and can elicit fluorescence in other non-fluorescent substances through the use of fluorescent markers[24].

The physical appearance of Rhodamine B is a dark green semi-crystalline powder, which can readily dissolve in water, methanol, or ethanol to create bright, almost neon, pink solutions. This characteristic of presenting as an olive-green powder and a bright red-pink solution is something seen in most xanthene dyes, most notably crystal violet. The color change occurs immediately upon mixing the powder with any substance containing alcohol or water. When in solution with distilled water or ethanol, though the resulting color seems fluorescent, the actual fluorescence must be visually observed using an alternative light source and a viewing filter.

Rhodamine B is soluble in both water and ethanol and will exhibit fluorescence in both solutions. To measure the fluorescence of Rhodamine B, a UV-VIS spectrofluorometer is typically used, though this process was not necessary for the purposes of this project. The fluorescence of Rhodamine B was a qualitative aspect of the study, though future studies can be done to determine its quantitative properties. One major advantage of using this fluorescent reagent is that even in dilute solutions, this compound yields fluorescence of strong intensity. This is important when working with Rhodamine B due to its classification as environmentally toxic. This is discussed in the Safety and Hazards section.

Why Rhodamine B?

Rhodamine B was first introduced to the researcher by Dr. George Kumi of Rutgers University – Camden during the lab portion of Instrumental Analysis, a chemistry course offered at the university. After performing a laboratory for the course involving the fluorescence of Rhodamine B, the researcher was interested in examining how effective Rhodamine B would be as a constituent in a fluorescent fingerprint dusting powder. This had only been explored in two previous research studies, both of which were used as references. The primary study that was an influence was done by Kapoor et al. The other study, done by Jasuja et al. was the influence for Kapoor's study, though many changes were made between the two studies. The use of Rhodamine B in a small particle reagent powder spray was examined in the studies completed by both Kapoor and Jasuja.

For this study, it was important to extend the investigation of Rhodamine B in fingerprint powder development past aqueous reagents. This is why, ultimately, a powder formulation was chosen. An annotated bibliography of the two Rhodamine B SPR studies is included below.

PREVIOUS STUDY #1
Small particle reagents: Development of fluorescent variants[9]
Jasuja et al. (2008)

This study incorporates the two aspects of fluorescent reagents and submerged objects with respect to visibility of latent marks after chemical enhancement. Six (6) different surfaces were examined, which included glass, bone chine, plastic, aluminum strips, aluminum foil, and polyethylene sheets. Latent marks from female and male subjects were deposited onto each surface and then the objects were submerged for either 24, 48, or

96 hours. Development of the latent marks was completed immediately after deposition (fresh) and after the assigned time intervals using the various fluorescent small particle reagent formulations.

The fluorescent dyes used in this study were rhodamine B (λmax 543 nm), rhodamine 6G (λmax 524 nm), acridine orange (λmax 489 nm), anthracene (λmax 400–500 nm), cyano blue (λmax <280 nm), basic yellow (λmax <280 nm). The primary dye of interest as it pertains to the present research project is rhodamine B. Rhodamine B is defined by Jasuja et al. as, "a bluish red, fluorescent, amphoteric dye generally used as a biological stain." Its use in enhancement of latent marks has grown in popularity recently.

The general reagent preparation was as follows:

- Add 1.0 mL liquid detergent with 125.0 mL distilled water to create detergent solution. Next, add 7.5 g ZnCO3 into 50.0 mL of the detergent solution.
- Then add either 0.01 g of powder fluorescent dye or 10.0 mL liquid fluorescent dye to create the fluorescent dye solution.
- Mix the detergent solution and the fluorescent dye solutions thoroughly.

The latent marks were treated with the fluorescent SPR suspensions by conventional spraying of the objects, immersion of the objects in the SPR (30-60 seconds), or through brush application. The chemically treated latent marks were then analyzed under an alternative light source. The study used excitation wavelengths of 610 nm, 590 nm, 555 nm, 530 nm, 505 nm, 450 nm. Orange cut-off filter were used to visualize the enhanced marks. Rhodamine B and rhodamine 6G scored the highest overall. They both yielded visible fluorescent marks on both the fresh marks and the aged marks. Both species exhibit fluorescence over a wide range (505 – 555 nm). This study noted that marks with poor

visibility (e.g., marks on patterned/light color surfaces) generally showed enhanced visibility with the application of the fluorescent reagents.

The takeaways from this study were the guidelines involving the alternative light source and the excitation wavelengths. Rhodamine B was not the sole focus of the study, but it demonstrated its ability to strongly fluoresce, which is why it was the focus of the present study.

PREVIOUS STUDY #2

***Visualization of Latent Fingerprints using Rhodamine B: A New Method*[10]**

Kapoor et al. (2015)

In the study by Kapoor et al., rhodamine B was the sole focus. It was examined with respect to its ability to enhance the friction ridge detail of submerged latent marks. One SPR formulation that was used in the study was a dried powder. It was made from a previously aqueous SPR suspension made from the following ingredients: rhodamine B, basic zinc carbonate, lycopodium, and gum rosin liquid detergent, and distilled water. The suspension was allowed to dry into a solid, which was ground up into a fine powder. The resulting powder is approximately 1.5% rhodamine B dye by mass. The powder was dusted onto the objects using a camel hair dusting brush after immersion between 0 and 96 hours.

The fluorescence of the revealed latent marks was seen using a cyan ALS with a wavelength of 505 nm and photographed using a camera filter with IF565 bandpass. The powder was shown to be effective in revealing latent marks on these nonporous objects. The fluorescence was observed even after subsequent running of tap water and drying. Additionally, the study observed that over a 120-day period, the quality of the dusted marks was not compromised.

The takeaways from this study were the general powder methodology, the general powder formulation, and the mass measurements for the chemical reagents. The methodology and the mass measurements were generally kept the same, but the powder formulation differed.

Safety and Hazards

When working with Rhodamine B, it is important that the handler understands and follows the proper precautions that are necessary to take. Rhodamine B, like all chemicals, should never be discarded down a drain. Any item that has come in contact with Rhodamine B should be discarded in a labelled hazardous waste container that is properly sealed.

The signal word for Rhodamine B is “Danger”, and it is classified as “Toxic to Aquatic Life” when in concentrations exceeding 1.0% w/w. Any solution or powder containing Rhodamine B should never be poured down the drain nor should it be placed in the regular garbage. Rhodamine B should be appropriately labelled as ‘Hazardous Waste’ and disposed of through proper chemical disposal methods.

The Rhodamine B contaminated material used throughout this study was all placed into properly labelled plastic bags or bottles. Any excess powder, paper with powder, gloves, weigh boats, and paper towels were placed in plastic zip-close bags. The different materials will be separated into groups prior to a final disposal. Throughout the study, the labware used that had traces of Rhodamine B on it were all washed and drained into plastic storage jars. This was to avoid any of the fluorescent dye from going down the drain of the sink. Each piece of lab glassware used for Rhodamine B was washed out and drained into a hazardous waste container three (3) times before rinsing again with soap and water over the sink.

Lycopodium is another chemical component of this powder with associated hazards. Lycopodium is a very fine powder made from club moss spores. When in this powder form, it is flammable and combustible with air. It is recommended that the handler of lycopodium minimizes the dust generation of the product, which makes it

seem like a strange choice to use for a fingerprint powder. However, the concentration of the lycopodium in the novel formulation was less than 1% w/w.

Based on the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). The chemical reagents listed below are only the ones with associated hazards.

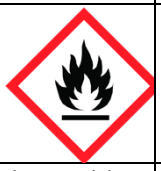
	Flammable (GHS02)	**Corrosive (GHS 05)**	**Toxic Cat. 4 (GHS07)**	**Systemic Health Hazards (GHS08)**
Rhodamine B, ≥95% HPLC CAS# 81-88-9				
Description:		Corrosion; skin damage; burns; corrosive to metals	Irritant; aquatic toxicity (harmful)	
Lycopodium CAS# 8023-70-9				
Description:	Flammable			
Name of Pictogram:	*Flame*	*Corrosion*	*Exclamation mark*	*Health hazard*

Chart made by K. Smith *Information via: OSHO.gov*

Hazard and Precautionary Statements – Rhodamine B

Hazard statements describe the nature of the hazard(s) associated with the chemical and the degree to which the hazard(s) is/are harmful. The following hazard statements are associated with Rhodamine B:

Code	Statement
H302	Harmful if swallowed.
H318	Causes serious eye damage.
H412	Harmful to aquatic life with long lasting effects.

Precautionary statements are used to describe the recommended measures that should be taken when exposed to a hazard imposed by the chemical. The following precautionary statements are associated with Rhodamine B:

Code	Statement
P264	Wash skin thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P273	Avoid release to the environment.
P280	Wear eye protection/ face protection.
P501	Dispose of contents/ container to an approved waste disposal plant.

Storage of Rhodamine B

Rhodamine B is not compatible with oxidizing agents, such as chlorates, perchlorates, permanganates, nitrates, and halogens, namely fluorine, chlorine, and bromine. Rhodamine B is to be stored in a well-ventilated area in a tightly sealed container. Due to the low concentration of Rhodamine B in the powder formulation, plastic storage containers were a sufficient and appropriate choice. Higher concentrations of Rhodamine B typically require storage in glass containers. Rhodamine B has excellent photostability, meaning its properties will not diminish after exposure to natural or artificial light.

However, to err on the side of caution, frosted plastic storage containers were used in an effort to be proactive with the preservation of the powder.

Hazard and Precautionary Statements – Lycopodium

The following hazard statements are associated with lycopodium:

Code	Statement
H228	Flammable solid.

The following precautionary statements are associated with lycopodium:

Code	Statement
P210	Keep away from heat/ sparks/ open flames/ hot surfaces. No smoking.
P240	Ground/bond container and receiving equipment.
P241	Use explosion-proof electrical/ ventilating/ lighting/ equipment.
P280	Wear protective gloves/ eye protection/ face protection.
P370 + P378	In case of fire: Use dry sand, dry chemical or alcohol-resistant foam.

Storage of Lycopodium

Lycopodium should be stored with other hazardous flammables in a designated cabinet away from any sources of heat or sources of ignition.

Methodology

Reagents

NOTE: Proper personal protective equipment (PPE) was worn during all phases of this research study. Proper PPE included below-the-knee lab coat with cuffed sleeves, nitrile gloves (extra-long), and vented safety goggles. Appropriate clothing, i.e., long sleeves, long pants, close-toed shoes, nothing loose) should always be worn in the laboratory. The researcher is certified through Rutgers University's Right to Know lab safety training course and has experience handling and preparing chemical reagents.

Research Study Approval

This study required the use of human fingerprints to be able to conduct scientific research on a fingerprint powder. As per Rutgers University's research policy, any study that involves the use of human subjects must go through a review process conducted by the Institutional Review Board of the university. This is referred to as the IRB Approval Process, or IRB for short. Prior to the start of the testing portion of the research study, an IRB must be completed, submitted, and approved. This portion is also when the fingerprint donor was chosen, as it is required for them to provide their consent for the use of their marks for the study. In an effort to speed up the approval process, the researcher was chosen to be the fingerprint donor. This added an element of control for the experiment, but also made the IRB approval process move swiftly. The process was also expedited due to the materials (i.e., fingerprints) being deemed "non-human subjects" by the board.

The IRB for this study was submitted with all final edits on June 15, 2020 and was approved on June 21, 2020. The study ID for this study is Pro2020000615.

Rhodamine B Fluorescent Powder – Reagents and Methodology

The fluorescent powder used in this study was a novel formulation created by the researcher. The patent for this novel formulation is pending.

Procedure – Fluorescent Powder:

In a clean graduated cylinder, 10.0 mL of distilled water was measured and then poured into a clean 100-mL beaker containing a pre-weighed amount of powdered carbonate salt. Next, rhodamine B dye, TiO_2, lycopodium (club moss spores – powder), and powder gum rosin (pine) were added to the beaker. All constituents were mixed to create a liquid suspension, which was a bright opaque pink color.

Each mass measurement for the reagents was taken using the same balance, which was calibrated each day of use by the researcher. All constituents were measured in designated static-free weight boats with designated spatulas.

The beaker was left to dry under a fume hood and covered with a watch glass for 5 days. This allowed the water to evaporate but protected the solid contents from contamination or from being blown away. Once fully dried, the solid was scraped from the beaker into a clean mortar and was ground up into a very fine powder using the pestle. The powder contained roughly 1.3 w/w% rhodamine B, a concentration value which was close to the concentration used in a previous study[10]. The powder was then placed into a clean storage jar.

The original purpose for this study was to reproduce the Rhodamine B based SPR powder formulation that was used in Kapoor's study[13] and examine its effectiveness on latent marks from different objects submerged in water for various periods of time. For

several reasons, many aspects of this were changed, including the formulation. Several components from Kapoor's study were incorporated, but with some substitutions. The major changes made were only using a powder form as opposed to the SPR powder spray, eliminating the use of detergent and only using distilled water, and substituting another carbonate-based salt for basic zinc carbonate. The final product was less expensive and made with more readily available reagents than other comparable powders.

Method Validation

Donor

The donor for this study was the researcher (female, 27). The donor's right thumb only finger used to create both the exemplar prints and the "unknown" latent marks. Prior to creating both the exemplar prints and the latent marks, the donor's hands were washed thoroughly with soap and warm water to create a "clean surface" to work with on the thumb. The donor's face was cleaned at least 3 hours prior to loading and depositing any marks. This allowed ample time for oil production. As an element of control for this aspect of the study, the donor was not allowed to apply any serums, moisturizer, or sunscreen to the face. The purpose of this was to allow for natural sebum production. Additionally, it is unknown how the chemicals in beauty products would react with the powder or how they would affect the fluorescence.

Most importantly, when conducting scientific research, it is important to have the environment be as sterile as possible. This research study relied on the body's ability to organically produce sebum and sweat because this allowed for the effectiveness of the powder to be studied in the most natural state. Chemicals from other substances can enhance or decrease the observed fluorescence, leading to false results about the novel powder's abilities. Due to the latent mark examination already having a number of different variables that could affect the outcome, adding elements of control wherever possible was an important facet of this research study.

Exemplar prints

The exemplar prints were collected using black fingerprinting ink and a fingerprint card. Multiple inked marks of the donor's right thumb were recorded (see

Figure 8). Classic methods of fingerprint recording were employed during this study. The marks were recorded both by being rolled across the paper and by rolling the thumb upwards on the paper. These techniques ensure that the entire fingerprint is recorded from side to side and from crease to fingertip. Though the right thumb was the only finger used to make marks, all ten fingers of the donor were inked. This was to ensure that any extra marks recovered from the objects throughout the study could be accounted for.

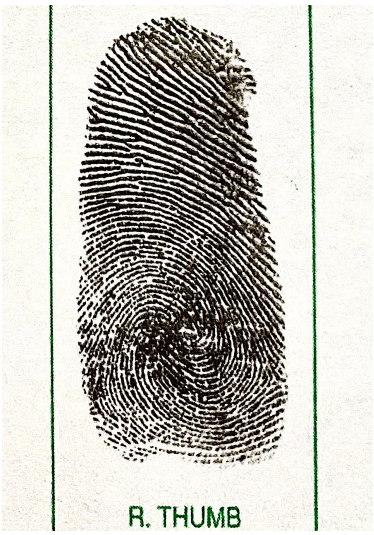


Figure 8. Exemplar print taken of thumb – via K.Smith

Latent Marks

The latent marks examined throughout this study included sebum-rich and eccrine-rich marks. When creating the latent marks, it is important to "load" the fingertip with the matrix of interest. For sebum-rich marks, the donor loaded the tip of their right thumb with the oils from the sides of the nose and forehead. For eccrine-rich marks, a nitrile glove was worn to induce sweat production and was taken off after 3 minutes, before wrinkles could form on the thumb. The thumb, either loaded with sebum or with eccrine sweat, was then

pressed down onto the surface to deposit a loaded mark. This process was repeated until 5 loaded marks were on the object's surface. Together, these marks are called a "loaded series". The purpose of the loaded series was to test the reproducibility of the novel powder.

In addition to the loaded series, depletion series were conducted on each object. In the depletion series, the first mark deposited was fully loaded. The process used to load the thumb for this series is the same as for the loaded series. However, the thumb tip was not "re-loaded" with the matrix before depositing another mark in the series. Each sequential mark made contained less of the matrix. This depletion series posed as a means of measuring the effectiveness of the novel fingerprint powder. The purpose of the depletion series was to test the sensitivity of the novel powder; therefore, it was important to examine how well it recovered marks that were not as "ideal".

Nonporous Objects

During the proposal phase of this study, it was presented that the latent marks would have been deposited on items that were then submerged in water. This idea, among many others, was derived from the Rhodamine B SPR study by Kapoor et al. The focus ultimately was shifted away from submerged objects and centered on non-porous objects in general. Some objects were examined submerged in water, but non-submerged objects were the primary focus of the research experiment.

The first objects examined were blue nitrile gloves (Target brand). Nitrile gloves are generally considered to be non-porous, but there is increased permeability with some chemicals. The effects of Rhodamine B and its permeability with nitrile gloves has not been studied. This study proceeded with the notion that nitrile gloves are considered non-

porous objects. Nitrile gloves were chosen as an object due to their pertinence to crime scenes and evidence collection. Often, those who commit crimes will wear gloves in an effort to prevent their fingerprints from being left at the scene.

The next object of interest was water bottle labels. Inadvertently, two different materials from two different brands of water were used. The Deer Park water bottle brand uses semi-gloss laminated paper labels. Poland Spring water bottle brand uses paper labels that do not have the gloss or lamination applied. Both label types were considered "non-porous" for the purposes of this study. Water bottle labels were chosen in a more roundabout way. The original purpose of the water bottles was to determine if marks could be recovered from the plastic bottle itself. This eventually turned into recovering marks solely from the labels. The specifics of this will be discussed in the results section.

Another object examined during this study was an aluminum can. The particular can used in this study was a Sun Sips High Noon vodka soda can. This was chosen due to the aluminum material and the multi-tone colors present on the can. The marks were randomly deposited on the aluminum can and were all fully loaded with sebum. There were no eccrine-rich marks deposited on the aluminum can. At this point in the study, the sole focus was on the ability to recover sebum-rich marks and examine the wide variety of objects from which sebum-rich marks can be recovered from.

Lastly, the novel powder formulation was used to recover sebum-rich latent marks from an amber beer bottle (Victory Brewing Company brand). All marks made on the beer bottle were fully loaded and randomly placed around, but not on, the label. Only one (1) amber beer bottle was examined during this study.

Submerged Objects

Though the focus of this research study shifted away from the submerged objects, the researcher deemed it necessary to explore if the novel formulation was capable of recovering from wet objects at all. Nitrile gloves with sebum-rich latent marks, as well as water bottle labels (semi-gloss) with sebum-rich latent marks were submerged in distilled water for different periods of time.

Each object was submerged alone in a clean 1000-mL beaker filled with distilled water. To ensure the marks on the objects remained submerged in the water, the nitrile gloves were oriented with the side containing the latent mark facing the water and the water bottles were filled with enough small smooth stones to have the bottle sink enough for the entire label to be submerged underwater. Each object was photographed at the time it was submerged and then at the time it was removed.

Due to the powder being in the form that it is, it was not to be dusted onto the objects while they were wet. Each object was given ample time to dry under observation in a well-ventilated fume hood. For the gloves to be fully dried, the tips of the fingers had to be cut off to drain excess water. The inside of the glove was then treated with a light stream of air from the fume hood nozzle to speed up the drying process. Once completely dried, the powder could then be applied.

Testing of the Powder

The new powder was first tested on a sebum-rich latent mark left on a nitrile glove. The mark was created by loading the thumb with the oils from the sides of the nose then immediately placing the thumb onto a clean nitrile glove. The glove was left untouched for

10 minutes before it was treated with the powder. The glove was dusted under the fume hood.

When treating latent marks with dusting powder, it is important to focus on proper brush handling techniques. The brush is not intended to ever come in contact with the latent mark. The idea is to "load'" the brush with the powder and twist the brush over the mark to allow the powder to fall in a mist-like cloud over the mark. Contact between the brush and the mark can distort the mark or cause micro-abrasions across the surface of the mark, placing the usefulness of the mark in jeopardy with respect to identification.

As mentioned earlier in the paper, an alternative light source was required for the fluorescence to be visible. There are multiple options when it comes to choosing a forensic light source, each corresponding to a different wavelength range. These ranges will relate to the excitation wavelength of the analyte of interest. The maximum excitation wavelength (λ_{ex}) of Rhodamine B has been recorded as 543 nm. This value was the main factor influencing the choice of forensic light source. Ultimately, the Green forensic light source was chosen, as the wavelength range is 500 and 560 nm.

Rhodamine B is a fluorescent compound, which means its excitation wavelength and its emission (fluorescence) wavelength will differ. The emission wavelength relates to the emission of the photon that was originally stimulated by the light source. The emitted photon is of lower energy, which corresponds to a longer wavelength. The maximum emission (fluorescence) wavelength (λ_{em}) of Rhodamine B is between 568 nm and 573 nm, though some sources have shown it to be recorded as high as 580 nm. Though these values correspond to the "yellow" wavelength range, yellow goggles will only block wavelengths below 500 nm[22]. Using yellow goggles would permit the emission (fluorescence)

wavelength to pass through the viewing lens and prevent it from being observed. Ultimately, orange viewing goggles were chosen because of their ability to block any wavelengths below 570 nm, which would allow the theoretical 573 nm emission wavelength of Rhodamine B to be observed.

Figure 9. Forensic light source – Green CrimeLite

Figure 10. Orange viewing goggles

Lifting Dusted Latent Marks

After being dusted and photographed under the alternative light source, the sebum-rich marks were physically removed from specific objects with a black-backed hinge lifter. Hinge lifters are the hybrid of fingerprint lifting tape and fingerprint backing cards. They are used when the dusted/chemically enhanced latent mark.

Hinge lifters contain one sticky side (lifting tape) and one cardstock paper side. Once the plastic protective cover is removed from the sticky side of the hinge lifter, it can

be gently placed over the dusted mark. Once the mark has transferred to the lifter, the sticky side and the paper side are closed together, preserving the lifted mark. The process of lifting a latent mark must be executed with extreme care and attention to detail in an effort to not distort the mark. The black-backed single mark hinge lifter was used for this study because the black color provided excellent contrast for the white-based powder.

Figure 11. Hinge lifter

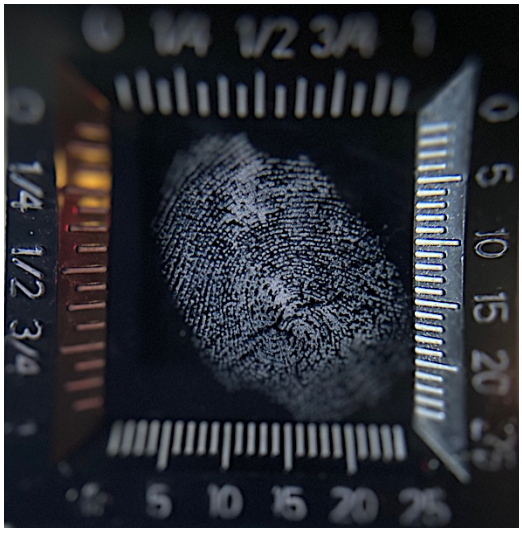


Figure 12. Sebum-rich latent mark in hinge lifter

Results: **Powder Enhancement and Fluorescence**

There was clear enhancement that could be seen by the naked eye and under an alternative light source. Each component that went into the powder was white or light tan in color, aside from Rhodamine B (dark green → bright pink in solution). The resulting powder color was a light pink (see Figure 13) but appeared white when dusted onto a mark and placed against a dark background. The ability to see enhancement of the marks with or without an ALS is an added benefit for this specific formulation.

Figure 13. Novel powder in mortar.

The fluorescence was observed when the mark was excited with the alternative light source (Green CrimeLite, λ 500-560 nm) and an orange bandpass filter was placed over the viewer (eye or camera). When the mark was illuminated under the alternative light source, there was an intense fluorescence observed. The observed fluorescence allowed for enhancement of detail as well as the contrast between the mark and the background. The best results in terms of enhancement of detail, quality, and contrast were

seen when the background was a dark color. The fluorescence against lighter colored backgrounds was observed, especially in the marks on the nitrile gloves. Overall, the intensity of the fluorescence was greater with darker backgrounds, and therefore is recommended for use on dark objects over light color objects.

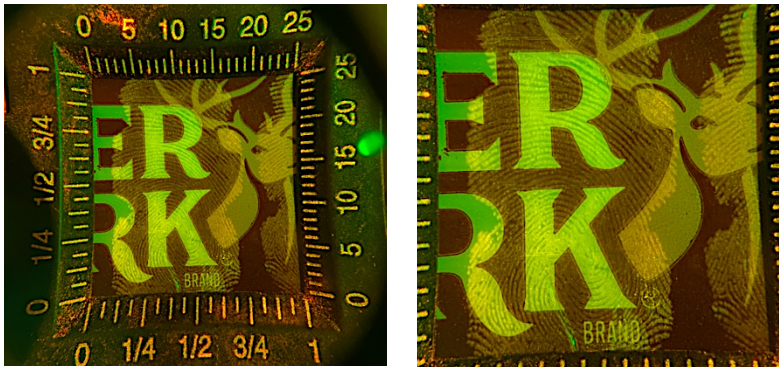


Figure 14. Latent mark on semi-gloss water bottle label; contrast between mark and background

The novel powder formulation was able to visually enhance both sebum-rich and eccrine-rich marks, though the sebum-rich marks had more consistent detail across the samples. The sebum-rich marks were able to be viewed with and without the alternative light source, but the eccrine-rich marks were only able to be viewed under the light source. Overall, the recoverability was much more favorable with the sebum-rich marks.

Results: Sebum-Rich Marks

The sebum-rich latent marks exhibited a high level of detail on most non-porous surfaces/objects throughout the study, namely nitrile gloves, water bottle labels, aluminum cans, and an amber beer bottle.

In Figure 15, all three levels of detail are present in the recovered mark. The double-loop pattern (Level 1) can be seen, identified by the presence of two deltas. This corresponds to the "whorl" category, despite being named as a loop. Again, it is the number of deltas present which determines the category the pattern is placed into. The sweat pores are visible and there are multiple rare ridge characteristics identified in the marks and also seen in the exemplar print.

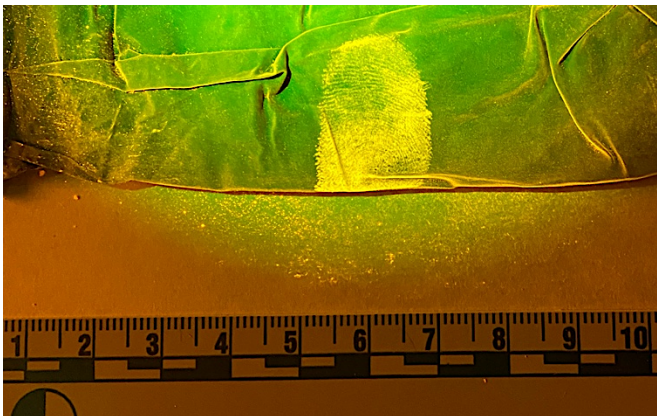


Figure 15. Loaded sebum-rich mark on nitrile glove

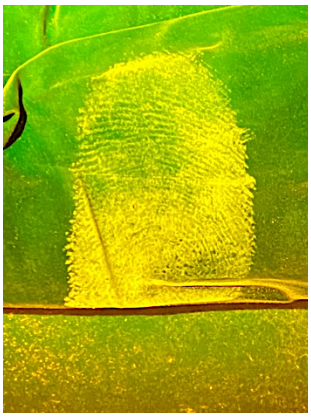


Figure 15 zoomed in

Some series of sebum-rich mark were more loaded than other series, but this aspect was not viewed negatively. The goal of the loaded series was to fully saturate the mark each time as much as possible. The production of oil on the face was not something that could be controlled, but by providing the same skin environment (i.e., clean, untreated skin) for the entire duration of the study, it added a level of control and consistency that could compensate for the aspects that could not be controlled.

Originally, the water bottles were chosen as objects with the intent to examine if marks could be recovered from the plastic bottle itself. The resulting marks, after being dusted, were unable to be visually enhanced with the alternative light source. The powder did not adhere well to the marks deposited on the plastic bottle. Out of pure curiosity, marks

were then deposited on the label of the bottles and dusted. The marks were visible both to the naked eye and under the fluorescent alternative light source (Green, λ=500-560 nm).

Results: Eccrine-Rich Marks

The novel powder is capable of enhancing eccrine-rich marks on nonporous objects, but it is not a reliable method. The only objects that eccrine-rich marks were deposited on were the nitrile gloves and the paper-based water bottle labels. There was Level 2 detail present around the outer edges of the eccrine-rich latent marks that were enhanced with the powder. The center of the mark did not exhibit good detail. However, there was uncertainty surrounding whether this specific formulation would react with eccrine-rich marks at all. The fact that enhanced detail was able to be seen was an unexpected, but welcomed, result.

Figure 16. Eccrine-rich latent marks on paper-based water bottle label

Results: Lifted Latent Marks

After having been dusted, examined under the alternative light source, and photographed under the alternative light source, the sebum-rich latent marks were physically lifted from select groups of objects using the black-backed hinge lifters. Hinge lifters allow for the latent mark to be portable, preserved, and have accurate measurements taken (if the marks were not deposited on a flat surface). Even after having been lifted and preserved within the hinge lifter, the mark was able to be excited with the alternative light source and exhibit fluorescence. This was best viewed under a linen tester (**see Figure X.**) The fluorescence was not adversely affected when the mark was transferred to the hinge lifter.

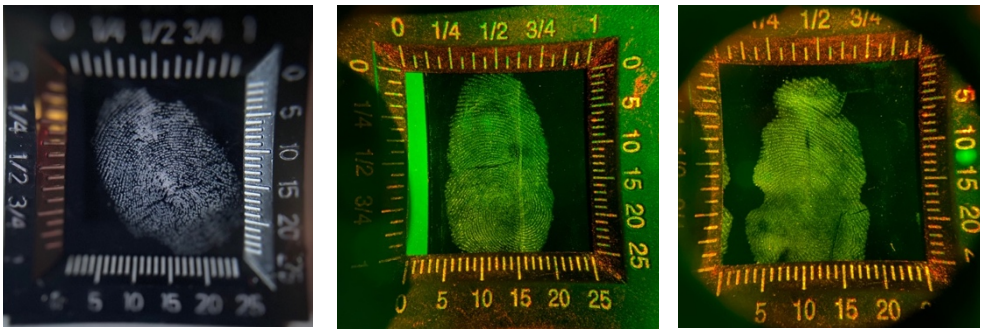


Figure 17. Ambient light (left), alternative light (middle), alternative light (submerged mark, right)

Results: Latent Marks on Submerged Objects

Each mark was fully loaded with sebum and then deposited onto the surface of the object with equal pressure. The latent marks on water bottle label (semi-gloss) shown below was submerged for 2 days (48 hours) (see Figures 19 and 20). Each mark deposited was fully loaded with sebum. It is important to note that these marks were deposited with less pressure than those deposited on the gloves. The label had to remain on the water bottle for submersion.

Figure 19. Eccrine-rich latent marks on paper-based water bottle label viewed under ambient light

Figure 20. Eccrine-rich latent marks on paper-based water bottle label viewed under alternative light source

Discussion

The novel fluorescent fingerprint powder formulation was able to visually enhance sebum-rich latent marks from various non-porous surfaces. Prior to the start of the study, it was hypothesized that the powder might also be able to visually enhance marks composed of eccrine sweat. This hypothesis was proven to be true. Additionally, the novel powder formulation was also able to recover both sebum-rich and eccrine-rich marks from a paper water bottle label, which is porous. The overall level of detail and quality of the marks from the paper label were much lower than those from the non-porous substrates, but Level 2 detail was present in some samples.

There was excellent level 2 detail recovered from the sebum-rich marks on almost all substrates and across both sampling methods (loaded and depletion). The resulting marks from the loaded sebum series were consistent in detail present and overall quality. Good detail was observed across marks within the same series and across the different series examined. As expected, the fully loaded sebum-rich marks yielded the best results, but the depletion series all exhibited detail that could be used to make an identification.

Based on the results of this research study, the novel formulation Rhodamine B fingerprint powder would best be applied for situations involving the recovery of sebum-rich latent marks from nonporous objects. The higher percent composition of the fats and amino acids within the sebum-rich marks contributed to their ability to be recovered with more detail compared to the eccrine-rich marks. This was expected, as Rhodamine B acts as a biological staining dye for fats and proteins. As mentioned in the Background section, eccrine-rich marks can contain a small percent of compounds that will react with biological staining agents. Due to the faint enhancement observed in the eccrine-rich marks during this study, it can be concluded that the percent composition of the compounds that would

react was not consistently sufficient across the marks. This was seen between marks in the same series, as well.

One notable characteristic of the novel fluorescent powder is its ability to separate the mark from the background. There is very little background interference when the mark is viewed under the light. The dusting for each object was performed over a section of white butcher paper. In some photographs, the fluorescence can be observed on the paper due to the powder particles collecting. This characteristic is most likely a result of the Rhodamine B staining the latent mark. This is another added benefit to using Rhodamine B in this specific formulation. Since Rhodamine B is a biological staining dye, both a fluorophore and fluorochrome, it reacts with the mark and dyes it. Most of the fluorescent fingerprint powders that are commercially produced have added fluorescent color which does not stain the mark. Staining the latent mark is beneficial because it helps to preserve the mark and ensure the longevity of the mark.

As mentioned previously, Rhodamine B is extremely photostable. Though the degradation of the fluorescence over time was not observed in this study, it has been noted from other sources that the photostability of this compound contributes to its ability to exhibit intense and consistent fluorescence over time. This becomes important especially in terms of marks being analyzed for court cases. Often, the process of taking a case through court can take months, sometimes years. Throughout that time period, evidence is allowed to be re-examined or examined by new experts. Fingerprints that are recovered using fluorescent reagents will need to have the fluorescence re-examined, and it is important that the intensity of it the same at “day 0” as it is on “day 100”.

There were multiple benefits of this novel formulation. Its strong ability to enhance latent marks stems from the Rhodamine B component being a biological staining dye. This particular powder formulation allowed for the marks to be physically lifted from the objects while maintaining the level of detail. As a result, the developed mark is much more stable over time. Additionally, this powder formulation is cost-effective in terms of production. Ideally, due to the hazards associated with Rhodamine B and lycopodium, this powder would be made in small batches by the latent mark examiner when it was needed.

The hazards related to Rhodamine B and lycopodium typically are associated with its use in high concentrations. The concentration of Rhodamine B in the powder used in this study was calculated to be around 1.3% w/w, and the concentration of lycopodium was less than 1%. Rhodamine B has the ability to exhibit strong fluorescence in small concentrations, so not much of it is needed to produce the desired effects. This helped to mitigate much of the risk associated with using it in the powder. By using Rhodamine B and lycopodium properly and with caution, the risks associated with their use are decreased and consequently, so is the danger.

Ultimately, this novel powder formulation proved to be effective for use with sebum-rich latent marks on the non-porous objects examined throughout this study. There is much future work that can be done using what this study has established. One major project would be to develop a systematic experimental protocol. Much of fingerprint analysis is qualitative. A systematic protocol would present the opportunity to bring quantitative data into the picture. Additionally, the implementation of a systematic protocol would provide the chance for bias to be addressed. Since fingerprint examination currently relies heavily on the humans performing the work, the bias associated with it must be

addressed. More importantly, major sources of error can be determined and dissected, preventing them from being a problem in the future.

Additional studies will also have to be done to examine the reproducibility and the sensitivity of the novel powder with a larger sample size. The more chances the powder is given to demonstrate its abilities, the more chances there are to examine those abilities and understand the associated strengths and weaknesses. The reproducibility is tested by performing multiple sets of marks in a loaded series. The sensitivity is tested by performing the depletion series. Both the reproducibility and the sensitivity were tested during this study, but on a very small sample size. In order for these results to be applicable to the "real world", the sample size will have to be increased greatly. Lastly, it is important to compare this novel formulation to the current fluorescent powder options that are already on the market.

Conclusion

Improvement in all fields, no matter how seemingly basic they are, is vital to the success of forensic science, specifically pattern evidence. Latent mark examination will always have a place in forensic science and humans will always have to be involved in the process. Recovering latent marks from a crime scene or off a piece of evidence requires human knowledge and touch to be executed correctly. Each latent mark made at a crime scene was deposited in a different way, under different physical and physiological circumstances, and by a different person. There are numerous variables that affect how a mark is deposited and numerous ways recovery can go awry. However, by putting time and money into latent mark enhancement research, there can eventually be a wide variety of methods that effectively recover and enhance the marks, despite the wide range of conditions. The novel powder formulation presented in this paper will, hopefully, be one of those methods.

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FIGURE SOURCES

Figure 1* – Cross-section of skin showing eccrine and sebaceous glands
SOURCE: https://guides.hostos.cuny.edu/bio140/4-15

Figure 2* – Fingerprint patterns – plain arch, tented arch
SOURCE: https://sites.psu.edu/jlipton/2014/06/03/fingerprints-unique-to-us-all/

Figure 3* – Fingerprint patterns – ulnar loop, radial loop
SOURCE: https://sites.psu.edu/jlipton/2014/06/03/fingerprints-unique-to-us-all/

Figure 4* – Fingerprint patterns (whorl)
SOURCE: https://sites.psu.edu/jlipton/2014/06/03/fingerprints-unique-to-us-all/

Figure 6* – Minutiae marking symbol
SOURCE: SWGFAST Document #8 Standard for the Documentation of Analysis, Comparison, Evaluation, and Verification (ACE-V) (Latent)

Figure 7* – Electromagnetic Radiation Spectrum
SOURCE: https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

Figure 10* – Orange viewing goggles
SOURCE: https://www.shopevident.com/category/forensic-light-sources/deluxe-forensic-goggles

Figure 11* – Hinge lifter
SOURCE: https://www.sirchie.com/forensics/latent-print-development/latent-print-lifting-backing/black-1-1-2-x-2-hinge-lifter-24-ea.html#.YJL-pxNKgWp

All other figures in this paper are original photographs or renderings done by the researcher, Kristen Smith.