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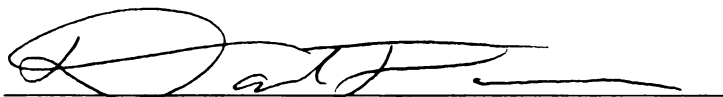
**HEXANE-BASED NINHYDRIN RINSE FOR LATENT PRINT
ENHANCEMENT ON PLASTIC MATERIALS FOLLOWING
APPLICATION OF BLACK POWDER**

presented by

KELLIE LEA KINCAID

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of the requirements for the

M.S. degree in Forensic Science



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By

Kellie Lea Kincaid

A THESIS

**Submitted to
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ABSTRACT

HEXANE-BASED NINHYDRIN RINSE FOR LATENT PRINT ENHANCEMENT ON PLASTIC MATERIALS FOLLOWING APPLICATION OF BLACK POWDER

By

Kellie Lea Kincaid

Plastic items can be difficult to process for latent prints using black powder as the prints become engulfed in powder and any fingerprint ridge detail can be lost. In the research presented, over 100 plastic items and nearly 300 fingerprints were tested to examine what plastic characteristics result in an enhanced print when the powdered print was washed with a ninhydrin hexane solution. Features such as plastic type, inked printing, presence or absence of labels, color, surface finish, surface tension, and surface roughness were analyzed to evaluate their influence on the rinsing method success. Microscopic examinations were made using Scanning Electron Microscopy to identify the changes that occurred to the print between the cycles of powdering and rinsing. Scanning Electron Microscopy – Energy Dispersive X-Ray Spectrometry was used to examine the chemical interactions among the plastic, cyanoacrylate, black powder, and rinsing solution. High-density polyethylene plastic containers and bags demonstrated a strong success in enhancing latent prints after becoming engulfed in black powder. Rough textured surfaces tended to benefit from the rinsing solution. Inked surfaces typically had a lower success rate than those surfaces with a label or where a label had been removed. Results show that the powder/rinsing technique can act as another layer of latent print processing when other methods of enhancement have failed or powdering has obscured a print.

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Introduction

Forensic science is the application of science to criminal justice in an effort to assist in answering civil and criminal questions. The study of fingerprints, or dactylography, has been useful in answering these questions. Fingerprint processing is probably one of the most well known forensic techniques and typically among the first evidentiary items that crime scene investigators will search for at a scene (Beckman 2001). Latent print processing gives investigators direction for solving these questions and it also helps to identify and associate individuals with evidence or crime scenes.

Anatomical Development of Fingerprints

To better understand the basic importance of fingerprint classification and identification, it is necessary to understand how fingerprints develop and what makes them unique. Friction ridge skin, formed in unique patterns of ridges and furrows, is found on the soles of the feet, palmar surfaces, and fingers. The ridges comprise the raised areas of the skin where the sweat pores are located while the furrows make up the space between the ridges helping to distinguish the rows of ridges (Coppock 2001). The spatial relationships of the ridges and furrows are fully developed at birth and remain unchanged throughout life, changing only in size during aging, unless damage has been done to the dermal layer through scars or burns. This permanence and uniqueness help to make fingerprints a very valuable piece of evidence.

Individualization of Fingerprints for Identification

There are three levels of detail that help in fingerprint identification. The first consists of the pattern type or the pattern of ridge flow, the second involves the individual ridge characteristics such as enclosures, ridge endings and bifurcations, and the third

involves identification by pore configuration and ridge shapes (Parsons et al.). General fingerprint patterns can be divided into three different groups. The simplest of these is the arch, comprising about 5% of all fingerprints, is further divided into the plain arch and tented arch. The plain arch is a ridge flow from side to side with a peak in the center, while the tented arch consists of the same side to side flow except the ridges have an up thrust at a 45 degree angle or greater near the center of the pattern. A second fingerprint pattern is the loop, comprising about 65% of all pattern types. The loop pattern is defined by two structures, the core and the delta, where the core is the center of the pattern and the delta is the characteristic nearest the point of two diverging ridges. This type can be described as radial or ulnar when in reference to a particular hand or a ten-print fingerprint card. The radial loop is a pattern where one or more ridges flow from one side, recurve and either touch or pass an imaginary line between the core and retreat to the side where the ridges entered, in this case the side of the hand where the radial bone is located. The same rule applies to the ulnar loop. If there is no reference to the hand of where the finger was, it is simply called a left or right slanted loop (SWGFAST http://www.swgfast.org/Glossary_Consolidated_ver_1.pdf).

The last fingerprint pattern, the whorl, defined as having at least two deltas with recurving ridges between them, comprise about 25 – 35% of all fingerprint patterns. Whorls can be divided into four sub-patterns: the plain whorl, central pocket whorl, double loop, and accidental whorl (Coppock 2001).

The second level of detail in fingerprint identification involves the analysis of friction ridge characteristics, also called minutiae. These include the ending ridge, bifurcation, dot, enclosure, short ridge, right angle intersection, bridge, spur, and

triradius. In a forensic context, these minutiae are examined in a spatial relationship by noting the location and number of intervening ridges between minutiae points. Minutiae are generally the characteristics that make fingerprints unique however, the exact number of minutiae required to individualize a fingerprint is a source of ongoing debate (Stacey 2005).

The third level of fingerprint detail involves poroscopy, the study of pore structures along friction ridge skin, and edgeology, the study of edge structures on friction ridge skin. Pores line the ridges and secrete sweat, which helps to leave the impression of the fingerprint behind. Combining both poroscopy and edgeology help to identify or eliminate the fingerprint in question however, in many instances this level of detail is not always present or clear on latent prints (Coppock, 2001).

Fingerprinting Pioneers

There were several people who assisted in discovering the importance of fingerprints and their role in identifying individuals. Lee and Gaensslen (1991) have detailed the history of fingerprint identification methods and those individuals who were responsible for recognizing them. Johannes Purkinje is thought to be responsible for the first modern study of fingerprints when in 1823 he proposed a system of fingerprint classification however, it had little response from law enforcement agencies or the community. During the second half of the 19th century, Sir William Herschel became the first to confirm that the ridges that develop on the hands and feet while in the womb do not change unless there is injury done deep in the muscles and tissues. At about the same time, a Scottish doctor in Japan, Henry Faulds, was asked to help in an investigation where fingerprints had been left in soot at the scene. This became the first case in which

fingerprint evidence was used to solve a crime. As a result of this discovery, Faulds wrote to Charles Darwin requesting aid in obtaining finger impressions of lemurs, anthropoids, etc. Darwin responded to Faulds by directing him to Sir Francis Galton, which ultimately led to Galton's study on the uniqueness of fingerprints, and in the late 19th century, Galton began using fingerprints as a means of identification. He wrote a detailed study of fingerprints in which he presented a new classification system using prints of all ten fingers, which is the basis for identification systems still in use. Sir Edward Richard Henry used his knowledge of fingerprinting in the 1890s to assist the police in Bengal, India to identify criminals. As assistant commissioner of the metropolitan police, Henry applied methods developed by Galton to establish the first British fingerprint files in London in 1901 (Lee and Gaensslen 1991). This filing system became the greatest means for identification, surpassing the Bertillion system which previously had been a method of personal identification using various body location measurements.

Fingerprint Individuality

Although fibers, paint, shoe and tire impressions can be left behind to associate the criminal with the crime scene, a fingerprint uniquely places the suspect at a scene. Even DNA evidence, which is generally individualizing, can be shared by individuals if they are identical twins. In contrast, because fingerprints have both a genetic component and environmental component, identical twins, while having similar fingerprints, can still be differentiated through points of minutiae. Likewise other family members are likely to have prints more similar to each other than to unrelated individuals, but also can be distinguished (Richards).

Latent Fingerprints

Fingerprints can be a means for identification and individualization however, knowing this is of no value unless a fingerprint from a crime scene is available for comparison with a known print. Through the commission of a crime, criminals may leave behind a latent print: a print that is present but is not visible and must be developed or enhanced for collection and comparison purposes. Latent prints are primarily composed of sweat, oils, and amino acids that are exuded from the pores and deposited on any surface to which the finger comes in contact. Other materials such as cooking oil, hair oil, and hand cream can also be left behind giving the shape and characteristics of the latent prints. It is also important to note that not all latent prints are a result of material that is left behind; they can result from removing material such as powder or dust from the surface as well (Cowger 1993).

Latent prints can be deposited onto a number of different surface types, either porous, semi-porous or non-porous, and thus require different processing procedures. Although there is a range of materials that are conducive to latent fingerprint enhancement, porous surfaces, those that allow gases and liquids to pass through, are better able to preserve the latent fingerprint for comparison. Examples of porous materials include paper, cardboard, or unfinished wood. Semi-porous materials such as wood, concrete, glossy labels, photographs, and glossy magazines, allow liquids or gases to penetrate but not pass through. Finally, non-porous materials do not allow liquids or gases to pass through. Latent prints left on these media are typically less conducive to preservation because the print resides on the surface and is exposed to further contact or

destruction. Examples of non-porous materials include glass, finished wood, firearms, plastic bags, and plastic bottles.

Latent Fingerprint Processing Techniques

Latent Prints on Non-Porous Materials

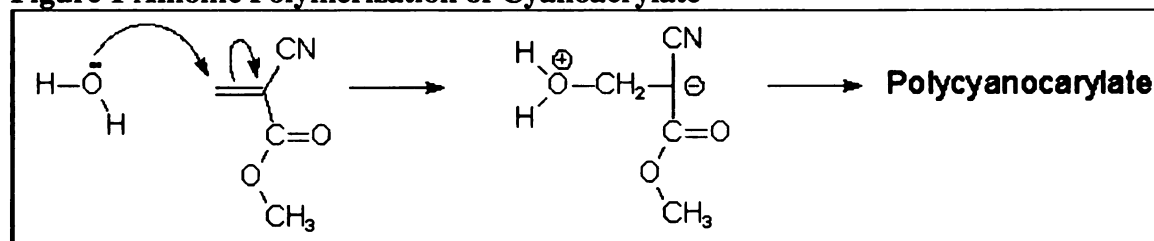
Although latent prints may be present on the item of interest, without enhancement techniques, they are of no value. Whether processing a crime scene or evidence, powdering is one of the simplest forms of latent print development. Powdering fingerprints, for both semi-porous and non-porous materials, is employed for its effectiveness in enhancing latent prints and capturing minutiae for identification. This technique has been used for latent fingerprint development since the early nineteenth century. The powder helps enhance the latent print by adhering to its moisture and organic contaminants, helping in visualization of ridge detail (Lee and Gaensslen 1991). There are various colors of powders, including the more traditional black, white, and silver. These are chosen based on the contrast in color between the powder and the evidentiary item. Unfortunately, while many items are enhanced by the powdering process, others react negatively by blurring or engulfing the latent print to the point of obscuring them.

When latent prints are to be developed on multicolored, non-porous surfaces, a fluorescent powder may prove useful. These powders help when ordinary colored powders do not produce contrast along the entire latent print. To visualize the print, an ultraviolet light is used to make the powder fluoresce, eliminating the background distraction. A third type of powder includes the magnetic kind, which are comprised of very thin shavings of colored magnet. The magnetic powder is chosen due to its

nondestructive nature where the brush never comes in contact with the latent print. This powder is ideal for developing latent prints on porous surfaces such as raw wood, paper, and leather, and is also useful for applying to the undersides and sides of objects where normal powders are not effective (Moennsen 1971).

Powdering may be preceded by cyanoacrylate fuming, a technique for processing semi-porous and non-porous materials to stabilize the latent fingerprint and assist in visibility. Cyanoacrylate, $C_5H_5NO_2$, commercially known as Superglue, was first employed in 1978 by the Criminal Identification Division of the Japanese National Police Agency (Brown 1990). When the cyanoacrylate is vaporized, it reacts with moisture and adheres to amino acids and organic components of the latent fingerprint, polymerizing on the fingerprint ridges, resulting in a hard white outline (Margot and Lennard 1994). In the presence of a weak base, cyanoacrylate undergoes anionic polymerization, and then becomes stabilized with the addition of a weak acid. When the cyanoacrylate comes into contact with a surface, weak bases, such as water or alcohol, can act to neutralize any acid stabilizer that may be present and speed up the polymerization (Courtney and Verosky 1999). Figure 1 displays the anionic polymerization that cyanoacrylate undergoes in the presence of water.

Figure 1 Anionic Polymerization of Cyanoacrylate



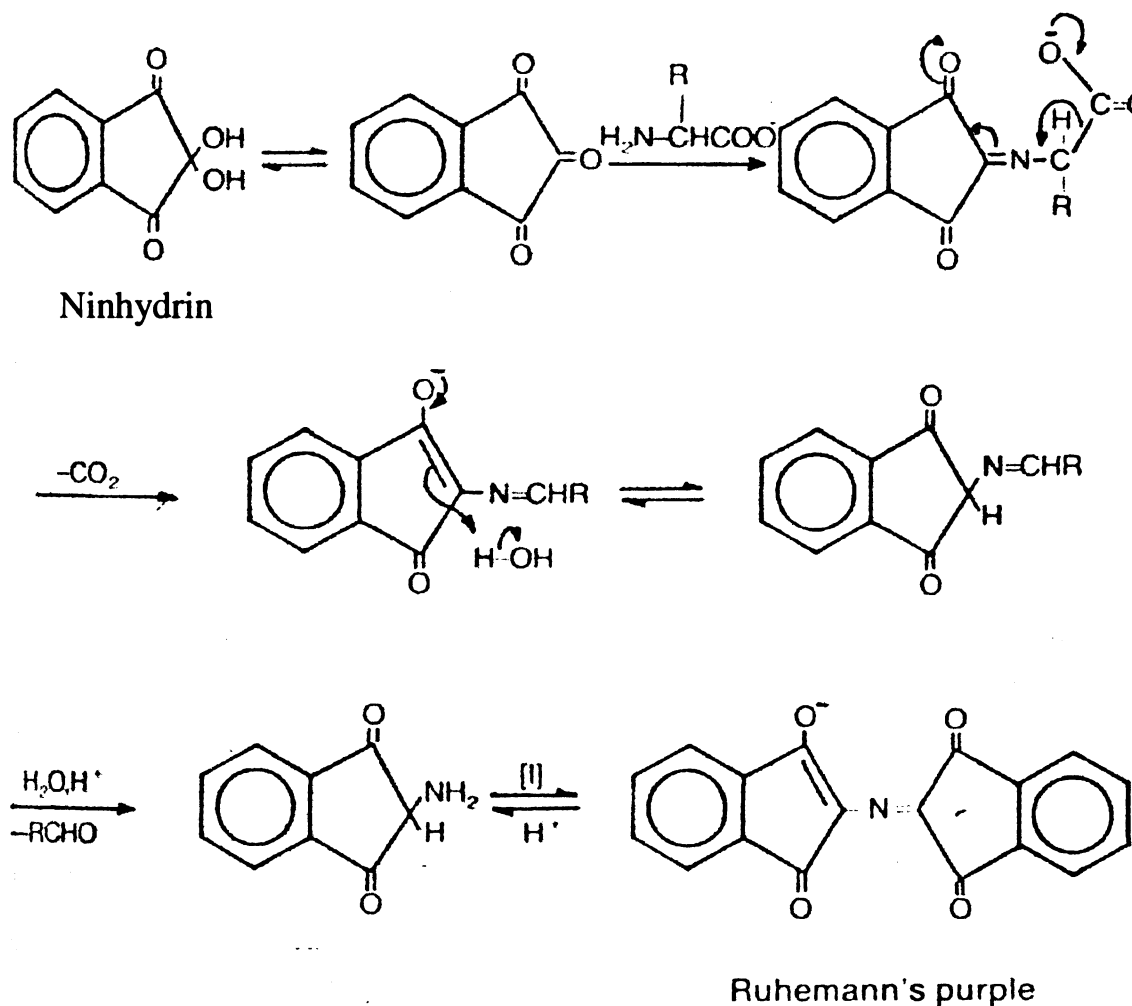
With the addition of water, cyanoacrylate undergoes anionic polymerization.
(<http://www.devicelink.com/mddi/archive/99/09/006.html>)

Several dye stains can be used following cyanoacrylate fuming to further enhance latent prints. One of these is ardrox, a fluorescent dye that has proven effective for latent print processing on non-porous items, making weakly developed latent prints more visible against a background with an array of colors. When illuminated with an ultraviolet lamp or fluorescent light source, these prints fluoresce brightly and are easily seen for photography and identification. A number of other fluorescent dyes, such as Rhodamine 6G, R.A.M. (rhodamine, ardrox and methanol), and R.A.Y. (rhodamine, ardrox and basic yellow 40), can be used in combination with cyanoacrylate fumed prints to assist in visualization (Chesapeake Bay Division of the International Association for Identification, <http://www.cbdi.ai.org/>). The latent prints processed with these dyes are visualized with fluorescent light sources of various wavelengths such as lasers, Polilights, and Ruvus. These commercially available light sources are effective due to their ability to alternate the wavelengths of light that are directed across the sample, displaying different degrees of clarity for the latent fingerprint.

Latent Prints on Porous Materials

Ninhydrin (1,2,3-tri-keto-hydrindene hydrate), in the 1950's was discovered to be a valuable tool for processing porous items for latent prints, where it reacts with amino acids (Wertheim). The reaction between ninhydrin and amino acids (Figure 2) produces a colored product, known as Ruhemann's purple. The speed of the reaction can be increased in a humidity chamber (Lee and Gaennslen 1991).

Figure 2 Ruhemann's Purple Reaction



The chemical reaction that occurs between ninhydrin and an amino acid to yield the end product, Ruhemann's Purple (Lee and Gaennslen 1991).

Over the years, the solution in which the ninhydrin is dissolved has included components such as acetone or heptane, whereas more recently, laboratories have begun altering the solution to help eliminate inks on porous evidence from running, which often occurred with the earlier solutions. Scarborough (2001) developed a ninhydrin solution containing ninhydrin, methanol, ethyl acetate and hexane that has helped to alleviate this problem.

The Chesapeake Bay Division of the International Association for Identification's website lists a number of techniques for processing porous items. The first is silver chloride, which is the oldest chemical technique for uncovering latent prints. Silver chloride reacts with the chloride component of the print however, its use has diminished as it is only effective on fresh fingerprints. Further, silver chloride reacts with the substrate, producing a dark background that can obscure the print. Other techniques/chemicals such as iodine fuming and 5-Methylthioninhydrin (5-MTN) are used for processing porous items as well. Fluorescence techniques include 1,8-Diazafluoren-9-one (D.F.O.), which reacts with the amino acid component of the latent print, developing more ridge detail than ninhydrin. 1,2-Indanedione, in combination with forensic light sources, yields fluorescing ridges. Porous items that have been wet can be processed with physical developer by applying the solution over ninhydrin if the latter was not successful in enhancing the print.

Fingerprint Processing Sequences

Depending on the porosity of the material, different sequential steps will be taken for processing non-porous items (which are the focus of the research below). First, an examination of the item is completed for any visible prints, and photographs are taken to ensure documentation of prints in the chance that any alteration or erasure of the fingerprint occurs during processing. Following photography, the item can be either powdered or placed in a cyanoacrylate chamber. A positive control, generally a fingerprint placed on a piece of acetate backer, is placed in the chamber with the questioned item to ensure the procedure is working. If any fingerprints are visible following fuming, they are photographed. If prints are not visible as a result of fuming,

fingerprint powder can be applied for enhancement (which may occur in crime laboratories with smaller budgets and less fingerprint sophistication and technology) or fluorescent dyes can be applied to eliminate the background distraction. In some instances the addition of powder at this step results in lost latent print detail, with the print becoming engulfed in the powder and minutiae are no longer visible. When this occurs, it is the last step for processing; the latent print has been lost within the black powder, and perhaps only the pattern type and any photographs that have been taken are of value for identification.

Difficult Substrates for Powdering

Wood, leather, cardboard, metals and in particular items made of plastic can be difficult for processing and capturing enhanced latent prints. Porous materials are problematic because of their nature to absorb moisture, while the non-porous materials can become engulfed in the black powder, making the latent print no longer visible. Plastic materials can exhibit this same problem with the entire background becoming black, resulting in a print that is indistinguishable and has few visible ridges, as the powder not only adheres to the print but the background as well. There are four results that can occur as a result of the reaction between the powder and plastic. First, the latent print may become enhanced, which produces visible minutiae for identification. Second, the powder can adhere to all of the ridges, but at times also fill some of the furrows, causing the ridges and minutiae to become difficult to distinguish and identify. Third, the powder can fill most of the furrows, leaving few ridges and identification points visible. Finally, the area becomes engulfed, with powder adhering to ridges, furrows and background plastic, allowing only a few or no ridges or minutiae to be visible.

The chemical makeup of a plastic item may influence how a fingerprint adheres to it and therefore the success of subsequent processing. Plastics have properties that are chosen and altered to meet a range of applications. The type of plastic encountered can be deduced from its Plastic Identification Number or Resin Identification Code (Table 1), which is placed on the bottom of the item. This code was developed in 1988 by The Society of the Plastics Industry to give manufacturers a uniform convention for labeling the different types of materials and also provides a label to distinguish plastics and their chemical components for recycling (The Society of Plastics Industry).

Table 1 Plastic Identification Table

Plastic Identification Number	Material Composition	Surface Tension (dynes/cm)	Sample Materials
 PETE	Poly(ethylene terephthalate)	43	Soda bottles, water bottles, medicine containers, lotion bottles.
 HOPE	High-density polyethylene	33	Containers (laundry/dish detergent, fabric softeners, bleach, milk, pill bottles, butter, shampoo, conditioner, and cleaning supplies) grocery bags
 V	Poly(vinyl chloride)	39-40	Pipes, shower curtains, cooking oil bottles, shrink wrap, clear medical tubing, vinyl dashboards and seat covers, coffee containers, medical containers.
 LOPE	Low-density polyethylene	31	Wrapping films, grocery bags, sandwich bags.
 PP	Polypropylene	29	Tupperware®, syrup bottles, yogurt tubs, cd spindles.
 PS	Polystyrene	33	Coffee cups, meat trays, packing peanuts, styrofoam insulation, beverage lids.
 OTHER	“Other”		These materials can be made of any combination of plastic identification #1-6.

Plastic identification numbers with their respective chemical names along with surface tension values for the untreated plastic and example materials for each plastic type. Surface tensions obtained from Flexocon. ‘Other’ indicates a chemical makeup of any combination of resins #1-6.

Manufacturers modify the behavior of the plastic depending on the interaction that is required between the item and internal or external sources. These modifications

typically come in the form of additives which diffuse within the polymer, and tend to migrate toward the surface. Additives include antiblocking agents which reduce the polymer's tendency to stick to an adjacent polymer (e.g. synthetic and natural silicas, as well as minerals), slip agents (e.g. oleic acid for polyethylene and erucamide for polypropylene), antislip agents (e.g. ethylene/maleic anhydride copolymers), lubricants (e.g. fatty-acid esters and amides, polyethylene waxes and silicones) and mold release agents. Antifogging agents keep the material transparent and increase the surface tension of the polymer. Additional additives include antistatic agents (e.g. alkyl phosphonium and alkyl sulfonium salts), fillers and reinforcements, antimicrobials or biocides (e.g. 2-n-octyl-4 isothiazolin-3 and copper-8-quinoleate), desiccants (e.g. ethylene vinyl alcohol) and fragrance enhancers. Plasticizers are another additive type, that increases the polymer's flexibility, workability, and extensibility, and modify the polymer's ratio of polar to non-polar groups depending on the plasticizer's application. Common plasticizers include diethylhexyl phthalate and di(2-ethylhexyl) adipate (DEA) combined with epoxidized soybean (Hernandez et al. 2000).

Some plastic items may have a surface treatment applied to improve barrier properties, or to enhance a plastic's ability to retain inked printing or adhesives. To improve the bonding of inks and adhesives (e.g. labels), treatments that supply polar groups which provide stronger secondary bonding are used, ultimately increasing the surface energy of the material. Other manipulations include flame treatments, corona discharge treatments, and ozone treatments, which all increase adherence of inks and adhesives by promoting oxidation at the surface (Hernandez et al. 2000). Some plastic types, such as polystyrene, are modified to absorb proteins, which could include the

protein left behind from a fingerprint. Such characteristics could increase a plastic's tendency to hold/lose a latent print more so than another plastic type (Seradyn 1999).

Characterization of Fingerprint Adhesion to Plastics

Surface Tension Analysis

There are a number of factors that alter the surface tension of plastic materials, typically measured in dynes/cm, affecting their ability to retain inks, labels, and glues, which also could conceivably influence the adhesion of fingerprints. These include the plastic composition, additives, and surface treatments (Hernandez et al. 2000). To measure surface tension, calibrated liquids may be applied. If the surface energy of the liquid is greater than the substrate, the liquid will “wet out” or spread over the surface. When the surface energy of the liquid is less than the substrate, the liquid will “bead up” or shrink to a thin line. The surface energy of the liquid that closely relates to that of the substrate results in the liquid holding for one to three seconds before “de-wetting” (ACCU DYNE TEST Diversified Enterprises). Materials that have been coated with the same surface treatment but are chemically different may exhibit different surface tensions (Van Iseghem).

Microscopic Characteristics of Fingerprints

The Scanning Electron Microscope (SEM), introduced in 1965, has proven to be very useful to the scientific community due to its large depth of field allowing more of the sample to be in focus at one time. In addition, the SEM is also useful for its wide range of magnification and simple sample preparation techniques. The SEM is designed to send a beam of electrons that strike the surface of a sample resulting in interactions which produce secondary products such as secondary electrons, X-rays, heat and light.

The secondary electrons produce the image of the sample (Flegler et al. 1993). An SEM can be used to examine sample topography by producing a magnified image of the item. This technique aids forensic analysis of items such as metal fragments or paint. The SEM also has the ability to examine morphology, displaying the shapes and sizes of the particles that make up the sample. Typically the SEM in forensic science has been used to visualize shell casings, shot from shotgun shells, and those items mentioned above, but it is also possible to look at fine details in fingerprints.

Scanning Electron Microscopy – Energy Dispersive X-Ray Spectrometry

The SEM equipped with an Energy Dispersive X-Ray Spectrometer (EDS) can be used to obtain an elemental analysis of a sample by detecting the emitted X-rays of many organic and inorganic samples depending on coatings and atomic weight of the elements analyzed. These X-rays have an energy that is characteristic to parent elements, allowing the SEM-EDS to generate a qualitative and quantitative elemental profile. Sample preparation for SEM-EDS is simple for non-biological samples: the sample is placed on an aluminum stub with adhesive tabs, double-sided tape, rubber cement or carbon tape. Sample preparation is the same for biological samples once it has been critically point dried, which removes water while preserving morphological features. If the sample is not conductive, it must be coated, typically with carbon, to achieve a signal strong enough for the detector to measure (Saferstein 1988). SEM-EDS can be used in forensic analysis to determine the composition of a sample by identifying the elements and compounds present (e.g. soil samples).

Profilometry

A profilometer can be used to measure surface texture by dragging a stylus across the surface of the sample. It measures the step heights along the sample (the differences between the high points and low points) which provides data for calculating the surface roughness. This is done by a graph output of step height versus position (Stanford Nanofabrication Facility). Typical limits in sample thickness are 10mm with a horizontal diameter limit of 125mm.

Background on the Research Presented Here

The research detailed below originated from observations made by Lieutenant Kathy Boyer, a latent print supervisor in the Bridgeport Laboratory of the Michigan State Police. Lieutenant Boyer processed a box containing a label by cyanoacrylate fuming. When applying black powder to the label however, it became engulfed and the palm print was barely visible. To develop latent prints on the box, Lieutenant Boyer applied the ninhydrin hexane solution, described by Scarborough (2001), with a foam brush across the box and unintentionally wiped it across the label. The black powder was rinsed from the label, and the palm print became visible and identifiable. This rinsing also developed a new print that was previously not visible or developed. Lieutenant Boyer attempted this rinsing on other semi-porous and non-porous items, where successful enhancement occurred on magazines, photographs and plastic items.

Research Goals

The research project described below was designed to determine what plastic types (such as poly(ethylene terephthalate), polypropylene, etc.) would benefit from this rinsing technique through the examination of physical (plastic color, surface roughness,

and surface tension) and chemical characteristics (plastic type, presence or absence/removal of inked printing and/or labels) in order to identify what properties of the plastic items resulted in successfully or unsuccessfully enhanced results. The research was also designed to analyze the effects of different cyanoacrylate chambers and inter-individual variability effects on rinsing results, as well as rinsing solution compositions to determine the optimal solution makeup.

To achieve these goals, over 100 plastic containers and bags, each with a plastic identification number, were processed. Surface tension values were obtained for items to determine if there was a correlation between these values and the processing results. A SEM was used to visually identify locations where the black powder was adhering, and to determine when and where changes in the amounts of cyanoacrylate and powder occurred. Examination of elemental changes in the cyanoacrylate, powder, and ninhydrin hexane solution during the procedure was attempted using SEM-EDS. Lastly, a profilometer was used to examine the surface texture of the plastic items to determine if there was a correlation between the texture and successful or unsuccessful results. The surface roughness was evaluated on items that had at least one successfully and one unsuccessfully rinsed print.

Materials and Methods

Sample Collection

Plastic household items were donated by individuals and collected. Items had plastic identification numbers and were of various composition, uses, sizes, colors, and

surface textures. Some items had labels and/or inked printing while others had neither.

APPENDIX A details these items.

Rinsing Solution

A ninhydrin hexane solution (Scarborough 2001) was prepared by adding approximately 5 grams (+/- 0.05g) of Ninhydrin to a 50 mL beaker along with 10 mL of methanol. The solution was mixed on a stir-plate using a stir-bar for 10 minutes and then poured into a 1 L brown bottle, to which 200 mL of ethyl acetate and 790 mL of hexane were added and stirred for an additional 10 minutes. The solution was tested each time by placing a few fingerprints on white test paper, to which the solution was applied by submersion. The paper was then placed into an oven at 120° F with hot water in a beaker for 10 minutes. A positive result was demonstrated by the presence of a purple print.

Sample Processing

Fingerprints were placed on the plastic items by wiping a thumb across the face to ensure that each latent print contained adequate sweat and oil, and touching the items. The fingerprints were circled with a black permanent marker and labeled. Notations were made if the fingerprint had been placed on top of inked printing, if an adhesive label had been removed, and if the fingerprint had been placed fully on or half on/half off of the removed label location.

The items were then placed in a Fisher Hamilton cyanoacrylate chamber along with an acetate backer containing a latent print to ensure that the chamber was working properly. The hot water tap was run for 30 seconds, and 150 mL of hot water was placed in a beaker, which was put in the chamber. Enough cyanoacrylate was placed in a small

tray to cover the bottom and was heated using a heating element in the chamber, allowed to vaporize for 20 minutes, then allowed to vent for 10 minutes.

Eight items were also fumed in a Mason Vactron, MVC 5000 cyanoacrylate chamber and processed to ensure that the results were not affected by different cyanoacrylate fuming conditions. All plastic items were then processed with a fiberglass brush and Carbon Black powder from Lightning Powder Company, Inc. by swirling the brush across the surface for 5 – 10 seconds, followed by print photography.

The rinse solution was applied to the fumed and powdered prints using a foam brush with mild pressure, by wiping across the sample until the excess black powder had been removed (as many as five or six times depending on the plastic item). The print was allowed to dry for 10 minutes and photographed. Initially, the brush was oversaturated with solution before applying it to the item, but as the technique developed, the solution was allowed to drain from the brush until there was enough to just wet the brush. Following photography, the item was processed with black powder for a second time, followed by a second rinse. This cycle of events, powdering/rinsing, continued until one of seven events occurred: the latent print became identifiable or enhanced, the latent print had areas that were enhanced but also areas where ridges and minutiae were removed, the latent print lost detail when the ridges or minutiae wiped off, the latent print lost detail when ridges blurred together, the latent print wiped from the surface leaving a black surrounding background, the latent print became further engulfed in the black powder, or the print remained but black powder would not adhere.

To ensure that inter-individual variability did not affect rinsing results, 21 latent fingerprints from 10 items, five prints on zip close bags and 16 prints on Kroger grocery

bags, were collected. These items were laid on a table and handled by anonymous donors, and processed.

Rinse Solution Analysis

Variations in the chemical composition and ratios of the rinse solution were tested to determine if there was an optimal composition for the rinse, as well as if heptane or hexane was more effective (Table 2). The original quantity of ninhydrin hexane solution was cut by 1/5 for the first seven solutions to reduce waste. In addition, an eighth ninhydrin solution (Wertheim), developed to reduce the running of inks on porous surfaces, was made and tested.

Table 2 Rinsing Solution Chemicals

Solution Number	Ninhydrin (grams)	Methanol (mL)	Ethyl Acetate (mL)	Hexane/Heptane (mL)	Other (mL)
1	0	2	40	158-Heptane	
2	1	0	40	160-Hexane	
3	1	2	0	198-Hexane	
4	1	2	40	158-Heptane	
5	1	2	0	198-Heptane	
6	0	0	40	160-Hexane	
7	1	2	40	0	
8	1	15-EtOH	5	200-Heptane	3/5-Acetic Acid

Quantities of ninhydrin, methanol, ethyl acetate and hexane/heptane in the various wash solutions are shown. Solution eight came from Wertheim and is composed of ethanol (EtOH) and acetic acid in addition to the other chemicals.

Each solution with ninhydrin and methanol was stirred for 10 minutes in a 10 mL beaker to dissolve the ninhydrin and then combined with the remaining components in a 250 mL flask and mixed for 10 minutes on a stir-plate with stir-bar. If the solution contained ninhydrin but not methanol, the ninhydrin was combined with ethyl acetate and heptane/hexane in a 250 mL flask and stirred for an additional 10 minutes. The eighth solution was made by mixing the ninhydrin, ethanol, acetic acid, and ethyl acetate for 10 minutes in a 50 mL beaker and then combined with heptane in a 250 mL flask and stirred

for another 10 minutes. Each solution was used to process a white, #2 high-density polyethylene Kroger grocery bag with two latent fingerprints present.

Instrumental Techniques

Surface Tension Determination

ACCU DYNE TEST Marker Pens, accurate to ± 2.0 dyne/cm, were used to measure the surface tension of the plastic items. Preliminary tests showed that surface tension readings were unchanged at different stages of the processing cycle, i.e., prior to cyanoacrylate fuming, after cyanoacrylate fuming, after powdering, or after rinsing, thus, the readings were taken after the fingerprints were marked and the item had been cyanoacrylate fumed. The surface tension was measured near each fingerprint by choosing a surface tension pen and drawing it across the surface three times and evaluating the ink swath's reaction to the material. If the line of ink beaded up, the next lower surface tension pen was examined. If the line of ink remained "wetted out" on the surface for more than two seconds, the next higher surface tension pen was then examined. If the ink swath held for one to three seconds, that surface tension was recorded.

Scanning Electron Microscopy

A JSM-6400 Scanning Electron Microscope was used with the AnalySIS computer program to produce digital images of fingerprints at various stages of the powdering/rinsing cycle. An accelerating voltage of 20kV and a working distance of 39mm were chosen with a magnification of 10 to 13X. Four fingerprint samples were laid on a white #2 Kroger grocery bag, cyanoacrylate fumed and processed to various stages. Table 3 displays the fingerprint samples that were analyzed. Samples were coated with

gold for two minutes using an Emscope Sputter Coater, SC 500. Images included ridges only, furrows only, and an overall view of the fingerprint.

Table 3 Sampling Stages

Sample Number	Latent Print Processing
1	Cyanoacrylate fumed only.
2	Cyanoacrylate fumed and powdered.
3	Cyanoacrylate fumed, powdered, and rinsed once.
4	Cyanoacrylate fumed, powdered, and rinsed three times.

The sample numbers with the amount of processing that the sample had undergone are displayed.

A second set of images was taken of a single latent fingerprint at various stages of the powder/rinsing cycle as described in Table 3. At each stage, the print was coated with gold for two minutes using an Emscope Sputter Coater, SC 500. SEM parameters remained the same however, a magnification of 20X was used.

Scanning Electron Microscopy – Energy Dispersive X-Ray Spectrometry

SEM-EDS with a Vantage 1.5.1, Thermo Electron computer program was used to examine chemical changes that may be occurring to the fingerprint and processing chemicals during the procedure. Two sample sets were collected as described in Table 3. One sample set was carbon coated using an EFFA MkII Carbon Coater No. 12560. An SEM accelerating voltage of 20kV was chosen with a working distance of 8mm and a magnification of 2300X. The condenser lens setting was a course focus of 8 and a fine focus of 60 in order to achieve a strong enough signal to detect. Carbon elemental information was collected as well as titanium, calcium, magnesium, aluminum, etc.

Profilometry

Eight plastic items previously processed were examined using a Dektak IIA profilometer. These items were chosen based on two variables. First, the sample needed at least one successfully rinsed print and at least one unsuccessful result. Comparing

surface texture results for prints on the same container yielded a correlation between texture values and successful responses. The second variable dealt with limitations in the profilometer itself, for which the tested material must be thin (less than 10mm) and perfectly flat. A small section, approximately 1 inch by ¼ inch, near each fingerprint was cut from the plastic using a razor blade, taped horizontal to the stage, and read using low speed over 8mm of sample. Each sample was scanned three times and each scan generated an average height to give a surface texture measurement.

Results

Rinsing Technique Evaluation

After processing the 102 plastic items and nearly 300 fingerprints, it appeared that there were seven common results following the powdering/rinsing procedure (Table 4). The rate of fingerprint enhancement, where a success was a print that was either enhanced or enhanced but lost detail, was 53.1%. Outcomes included Enhanced Print “EP” (print became enhanced with minutiae details visible), Enhanced Print/Lost Detail “EP/LD” (print had areas where it was enhanced and areas where minutiae were lost), Lost Print/Detail “LP/D” (areas of print wiped off resulting in the loss of minutiae), Lost Print/Blurred “LP/B” (minutiae were lost by ridges blending together), Lost Print/Background Black Powder Surrounding “LP/BP” (a majority of print wiped away with background black powder adhering to surroundings leaving a nearly clean outline of the print) , Black Powder Engulfed “BP” (print and background became engulfed with powder and minutiae were not visible), and Print Remains/No Black Powder Remaining

“PR/NBP” (print remained and could be seen obliquely however, no black powder was adhering to ridges or background).

Table 4 Processing Results

Rinsing Result	EP	EP/LD	LP/D	LP/B	LP/BP	BP	PR/NBP
Number of Occurrences	83	72	52	25	6	44	10

The number of times that each processing result occurred is shown. EP-Enhanced Print, EP/LD-Enhanced Print/Lost Detail, LP/D-Lost Print/Detail, LP/B-Lost Print/Blurred, LP/BP-Lost Print/Background Black Powdered, BP-Black Powder Engulfed, PR/NBP-Print Remains/No Black Powder Present

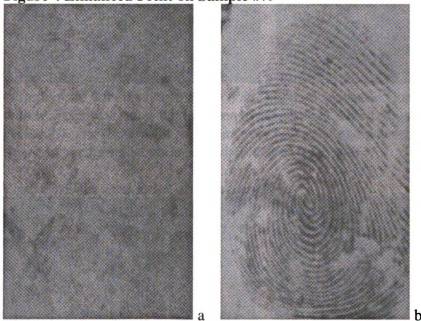
The entire processing results for each print can be found in APPENDIX A along with the items’ plastic identification number, color, visible surface finish, and surface tension measurements. The most frequent result (28.4%) was print enhancement following the powder/rinse procedure, “EP” (Figures 3 – 9). This occurred when most of the background black powder rinsed clean from between the ridges and surrounding areas making the ridges distinct and the print identifiable.

Figure 3 Enhanced Print on Sample #96-a



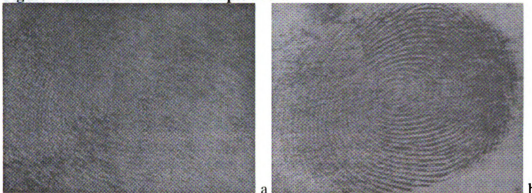
A fingerprint left on sample #96-a, Minute Maid OJ Container, that was processed with black powder after being cyanoacrylate fumed (a), and after three rinsing cycles (b). The minutiae have been enhanced and individual ridges are present in the rinsed image.

Figure 4 Enhanced Print on Sample #79



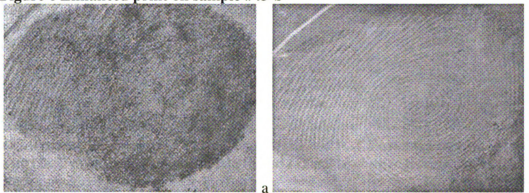
A fingerprint left on sample #79, Lid from Chlorox2 Container, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). In the powdered image only a few ridges are visible, but after the rinsing, the ridges and minutiae are observable.

Figure 5 Enhanced Print on Sample #78-a



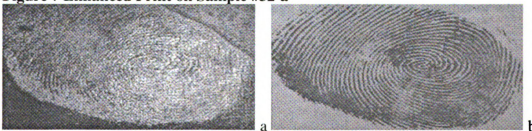
A fingerprint left on sample #78-a, Chlorox2 Bleach Container, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). In the powdered image only a few ridges are visible, but after the rinses, the ridges and minutiae are observable.

Figure 6 Enhanced print on sample #45-b



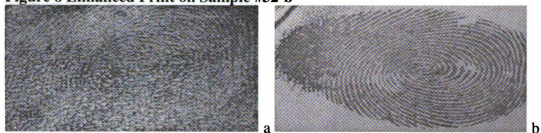
A fingerprint left on sample #45-b, Paul Mitchell Shampoo Container, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). The fingerprint ridges are very blurred in the powdered image whereas in the rinsed image minutiae points are visible and identifiable.

Figure 7 Enhanced Print on Sample #32-a



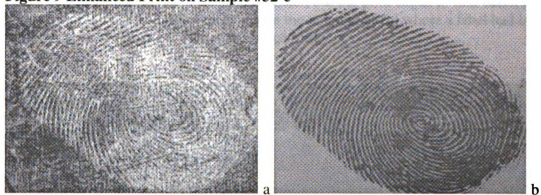
A fingerprint left on sample #32-a, Kroger Half and Half Container, that was processed with black powder and cyanoacrylate fumed (a) and after three rinsing cycles (b). The black powdered image appeared to have reversed ridges that were blurred while the rinsed print had distinct ridges and identifiable minutiae. Note that a label had been removed prior to placing the latent print on the surface.

Figure 8 Enhanced Print on Sample #32-b



A fingerprint left on sample #32-b, Kroger Half and Half Container, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). The black powdered image appeared to have reversed ridges that were blurred while the rinsed print had distinct ridges and identifiable minutiae.

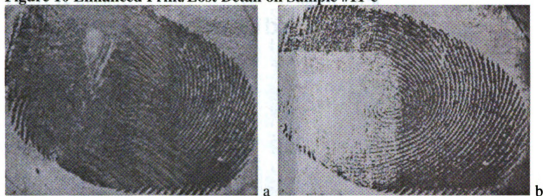
Figure 9 Enhanced Print on Sample #32-c



A fingerprint left on sample #32-c, Kroger Half and Half Container, that was processed with black powder and cyanoacrylate fumed (a) and after three rinsing cycles (b). The black powdered image appeared to have reversed ridges that were blurred while the rinsed print had distinct ridges and minutiae.

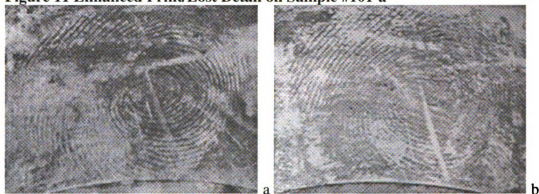
The next most frequent result (24.7%) was a print that was enhanced but lost detail, “EP/LD” (Figures 10 – 13). These latent prints had areas that were enhanced and areas where minutiae were lost either through the ridges blurring together or wiping off and losing minutiae.

Figure 10 Enhanced Print/Lost Detail on Sample #11-c



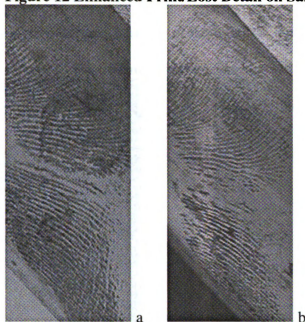
A fingerprint left on sample #11-c, Small Pill Bottle, that was processed with black powder after having been cyanoacrylate fumed (a) and after six rinsing cycles (b). The ridges became more distinct near the perimeter, but the print began to lose detail near the core. Note the white square-shaped area on the left side of (b) where a label had been removed prior to leaving the print and processing.

Figure 11 Enhanced Print/Lost Detail on Sample #101-a



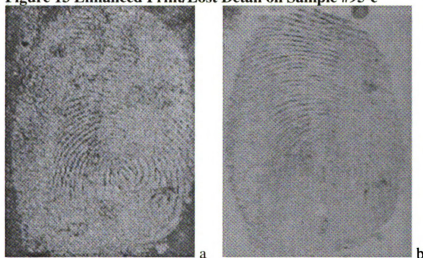
A fingerprint left on sample #101-a, Clairol Hair Conditioning Container, that was processed with black powder after having been cyanoacrylate fumed (a) and after five rinsing cycles (b). The fingerprint was enhanced near the perimeter and lost detail near the core.

Figure 12 Enhanced Print/Lost Detail on Sample #87-a



A fingerprint left on sample #87-a, Joy Dish Soap Container, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). The print was enhanced near the tip and core where it had been over glued with the fuming and lost detail below the tip.

Figure 13 Enhanced Print/Lost Detail on Sample #95-c

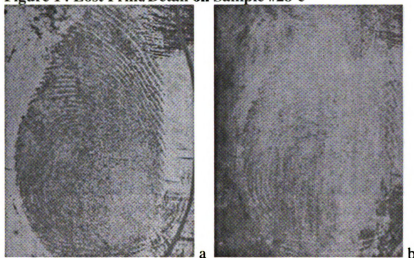


A fingerprint left on sample #95-c, Tropicana OJ Container, that was processed with black powder after having been cyanoacrylate fumed (a) and after one rinsing cycle (b). The fingerprint was enhanced near the perimeter and away from the core and lost detail near the core and surrounding ridges.

The third most frequent result (17.8%) was when the entire print was lost or a majority of the ridges were removed and minutiae were lost, “LP/D” (Figures 14 – 15).

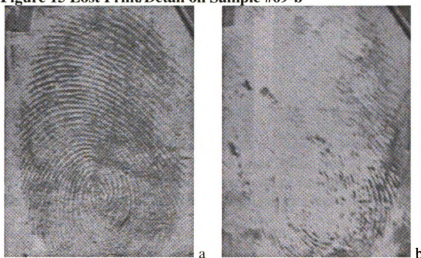
These results occurred when most of the latent print wiped clean, leaving very few visible ridges or when a majority of the minutiae, previously visible, wiped away.

Figure 14 Lost Print/Detail on Sample #28-c



A fingerprint left on sample #28-c, Daily Defense Container, that was processed with black powder after having been cyanoacrylate fumed (a) and after four rinsing cycles (b). The latent print had lost a majority of the minutiae that were present in the powdered print. The surrounding background became darkened by the powder.

Figure 15 Lost Print/Detail on Sample #69-b

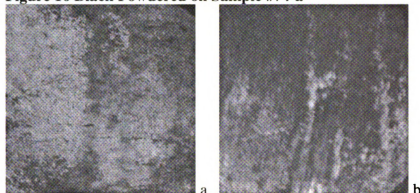


A fingerprint left on sample #69-b, Fresh Cut Lettuce Bag, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). The latent print had lost a majority of the minutiae that were present in the powdered print.

The fourth most frequent result (15.1%) was when the print became engulfed in black powder, “BP” (Figures 16 – 18). This occurred when the black powder adhered to

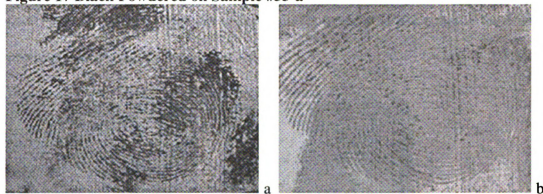
not only the latent print, but also the surrounding background making it indistinguishable and resulting in the absence of visible ridges.

Figure 16 Black Powdered on Sample #74-a



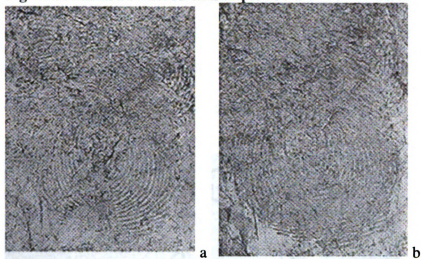
A fingerprint left on sample #74-a, Humidifier Bacteriostat, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). The print became engulfed in the black powder and no distinction could be made between the fingerprint and the surrounding area. No ridges were visible in the rinsed print.

Figure 17 Black Powdered on Sample #33-a



A fingerprint left on sample #33-a, Kroger Toilet Bowl Cleaner, that was processed with black powder after having been cyanoacrylate fumed (a) and after five rinsing cycles (b). The print had become engulfed in black powder and ridge detail was indistinguishable.

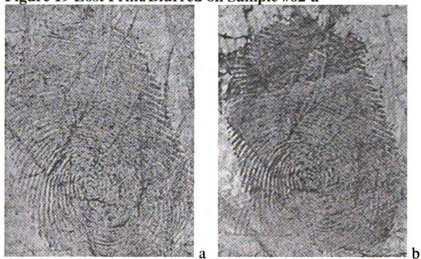
Figure 18 Black Powdered on Sample #56-a



A fingerprint left on sample #56-a, Meijer VegeTable Bag, that was processed with black powder after having been cyanoacrylate fumed (a) and after four rinsing cycles (b). The print became engulfed in the black powder and minutiae could not be identified.

The fifth most frequent result (8.6%) was when the latent print was lost or became blurred, “LP/B” (Figure 19). On these black powder either remained in the furrows of the print or the ridges came together and were indistinguishable as a result of the rinsing process. Few, if any, minutiae were visible.

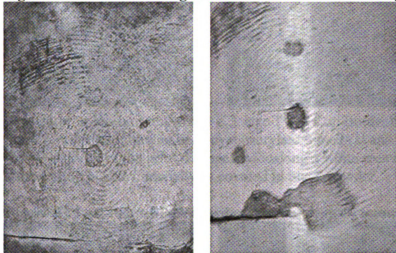
Figure 19 Lost Print/Blurred on Sample #62-a



A fingerprint left on sample #62-a, Meijer Grocery Bag, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). The rinsed print had become blurred where the ridges blended together in the area surrounding the core and minutiae were lost.

The sixth most frequent result (3.4%) was a print that remained, but no black powder was present, “PR/NBP” (Figure 20). This occurred when no black powder adhered to the latent print or the surroundings, but the latent print was still present and could be seen through oblique lighting.

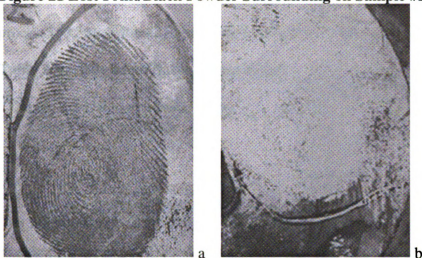
Figure 20 Print Remaining/No Black Powder Surrounding on Sample #102-b



A fingerprint left on sample #102-b, Dannon Yogurt Container-Large, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). The print retained the minutiae, but the black powder would not adhere to the ridges to further enhance the print. The black powder did not adhere to the background either except in a few areas. The print could be seen if held at an oblique angle.

The least frequent result (2.1%) was a latent print that was lost and the surrounding background was black powdered, “LP/BP” (Figures 21 – 22). This result occurred when a majority of the latent print wiped from the plastic material leaving the print area free of powder with the only black powder present surrounded the area.

Figure 21 Lost Print/Black Powder Surrounding on Sample #13-e



A fingerprint left on sample #13-e, Large Twist Cap Bottle, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). A majority of the print disappeared leaving a white area in its place and the surrounding plastic material was covered in black powder.

Figure 22 Lost Print/Black Powder Surrounding on Sample #15-c



A fingerprint left on sample #15-c, Yoplait Yogurt Cup-Strawberry, that was processed with black powder after having been cyanoacrylate fumed (a) and after three rinsing cycles (b). The print lost all detail and black powder covered the surrounding area.

Processing Identifiable Prints

There were 19 plastic items and 30 fingerprints that when first processed with black powder, did not require further enhancement. Although these fingerprints were identifiable after being powdered, they were processed with the rinsing solution

nonetheless (Table 5). Sixteen of the fingerprints became further enhanced by this process (53.3%), while the remaining results were “LP/D”, “LP/B” or “BP”.

Table 5 Initially Identifiable Latent Prints

Item	Fingerprint Number	Processing Result
12-Laundry Detergent Bottle (Xtra)	12-c	EP/LD
13-Large Twist Cap Bottle	13-a	EP/LD
	13-b	EP/LD
	13-c	EP/LD
	13-d	LP/B
15-Yoplait Yogurt Cup (Strawberry)	15-a	LP/D
16-Yoplait Yogurt Cup (Cherry)	16-b	LP/D
	16-c	LP/D
17-Dannon Yogurt Cup	17-a	LP/D
21-Vita Tabs Bottle	21-a	EP/LD
22-Sprite Bottle	22-a	EP/LD
	22-b	EP/LD
	22-c	LP/D
	22-d	LP/D
23-Alcon Bottle	23-b	LP/D
	23-c	EP/LD
	23-d	EP/LD
27-Appearance Body Wash Container	27-a	EP
41-International Delight Creamer Container	41-b	EP/LD
60-Target Bag	60-b	LP/B
62-Meijer Grocery Bag	62-b	EP/LD
64-Dollar General Bag	64-a	EP/LD
	64-b	BP
67-Ear Care Container	67-a	EP/LD
	67-b	EP/LD
69-Fresh Cut Lettuce Bag	69-b	LP/D
70-Blue Container	70-a	EP
82-CD Holder Base	82-b	BP
83-CD Holder Base	83-b	EP/LD
87-Joy Dish Soap Container	87-a	EP/LD

Sample containers with an identifiable print prior to rinsing are detailed, along with the overall processing result. EP-Enhanced Print, EP/LD-Enhanced Print/Lost Detail, LP/D-Lost Print/Detail, LP/B-Lost Print-Blurred, LP/BP-Lost Print/Background Black Powdered, BP-Black Powder Engulfed, PR/NBP-Print Remains-No Black Powder Present.

Effect of Plastic Variables on Fingerprint Enhancement

To better understand the relationships between the plastic variables, including plastic type, color, surface finish, inked printing/adhesives, and surface tension, data for each were placed on a Microsoft Excel spreadsheet (APPENDIX A), sorted, and compared to the processing results.

Plastic Types

The plastic types collected (APPENDIX A) were compared to their fingerprint enhancement success rates (Table 6). The #7 and #3 produced the highest enhancement success rates (60% each), although they had small sample sizes. Of the large sample sizes (40 or more fingerprints) #2 produced the highest success rate (50.6%) with #5 having nearly the same success (48.8%). Remaining success rates were in the low 40% range. Plastic types #1 and #7 lost prints at a higher rate followed by 5 and 3. Large sample sizes tended to have a higher percentage of lost prints. Plastic #4 and #6 were more likely to produce engulfed prints. Plastic #3 never lost a print however, 40% of the time the rinsing technique could not enhance the print and black powder would not adhere.

Table 6 Plastic Type Enhancement Success Rates

Plastic Type	Number of Fingerprints	Percent Successes	Percent Lost Print	Percent "BP"	Percent "PR/NBP"
1	41	43.9	46.3	9.8	0
2	170	50.6	25.9	14.1	11.8
3	5	60.0	0.00	0	40.0
4	10	40.0	10.0	40.0	10.0
5	43	48.8	30.2	11.6	9.3
6	20	45.0	15.0	35.0	5
7	5	60.0	40.0	0	0

Plastic types with the number of fingerprints processed on each are displayed. The success rates are included for each plastic type, defined as a print that was either enhanced or enhanced but lost detail. The percent lost print includes those where the print was either uninformative through loss of details, blurring, or only background powder remaining. BP-Black powder engulfed, PR/NBP-Print remains/no black powder adhering.

Plastic Color

There were 11 different colors of plastic items that were processed, generating a range of results (APPENDIX A). Table 9 displays the different colors represented, the number of fingerprints that were processed within each color category, and the percent of successful enhancements. The three orange fingerprints were all enhanced, although they were least represented (2 items). Fingerprints on white materials, with the larger sample size (39 items), exhibited the lowest success rate (49.6%). Enhancement rates on other colors ranged from 71.4% for red to 50% for blue, cream, green, and yellow. Cream colored items lost prints most frequently (50%) while orange, pink and red, never lost prints. Pink and yellow tended to have latent prints that became engulfed by the black powder.

Table 7 Color Analysis

Color	Number of Fingerprints	Percent Successes	Percent Lost Print	Percent "BP"	Percent "PR/NBP"
Blue	12	50.0	16.7	16.7	16.7
Brown	10	60.0	10.0	20.0	10.0
Clear	93	52.7	31.2	12.9	3.2
Cream	14	50.0	50.0	0	0
Gray	13	69.2	7.7	15.4	7.7
Green	8	50.0	25.0	12.5	12.5
Orange	3	100	0	0	0
Pink	3	66.7	0	33.3	0
Red	7	71.4	0	28.6	0
White	123	49.6	32.5	16.3	1.6
Yellow	6	50.0	16.7	33.3	0

Plastic colors with the number of fingerprints processed. The success rates are included for each color, defined as a print that was either enhanced or enhanced but lost detail. The percent lost print includes those where the print was either uninformative through loss of details, blurring, or only background powder remaining. BP-Black powder engulfed, PR/NBP-Print remains/no black powder adhering.

Surface Finish

Plastic items were given a surface finish description based on the appearance and texture (APPENDIX A). The four categories included “glossy”, which had a very smooth, shiny surface, “smooth” which had a flat surface, “textured” which had a mildly rough surface, and “rough textured” which had large pits on the surface. While all finish types had a greater success rate compared to losing the print, the rough textured items had the greatest success (67.5%) while glossy finished items had the least (45.2%). The reverse order occurred for losing prints with glossy items occurring more frequently (40.9%) than rough textured items (10.0%). The percent of “BP” and “PR/NBP” for each finish were similar for all finishes, <18% and <8%, respectively.

Table 8 Surface Finish Analysis

Surface Finish	Number of Fingerprints	Percent Successes	Percent Lost Print	Percent “BP”	Percent “PR/NBP”
Glossy	93	45.2	40.9	11.8	2.2
Smooth	118	50.9	18.6	17.0	4.2
Textured	41	63.4	19.5	17.1	0
Rough Textured	40	67.5	10.0	15.0	7.5

Surface finish with the number of fingerprints processed. The success rates are included with a success being a print that was either enhanced or enhanced but lost detail. The percent lost print includes those where the print was either uninformative through loss of details, blurring, or only background powder remaining. BP-Black powder engulfed, PR/NBP-Print remains/no black powder adhering.

Inked Printing and Adhesive Analysis

Surface treatments are applied to plastic items in order to increase the plastic’s ability to retain inked printing and adhesives (labels) (APPENDIX A). The effect of these modifications on the fingerprint processing varied (Table 9). A notation was made as to whether there was inked printing present in the location of the latent print and whether an adhesive label had been removed where the latent print was deposited. The presence or

removal of a label resulted in just over 50% successfully enhanced prints, while the presence of inked printing resulted in a greater number of lost prints (48.4%) than successful rinses (35.5%). There were instances where prints that were placed where a label had been were enhanced and instances where they were lost. No predictions could be made as to whether a certain result type would occur. Given an adequate sample size, it appears that ink impacts the processing result.

Table 9 Inked Printing/Adhesive Analysis

Surface Modification	Number of Fingerprints	Percent Successes	Percent Lost Print	Percent "BP"	Percent "PR/NBP"
Inked Printing	31	35.5	48.4	9.7	6.5
Label	55	54.5	30.9	14.5	0.0
No Label	206	55.3	24.8	16.0	3.9

Surface modification with the number of fingerprints processed. The success rates are included for each modification with a success being a print that was either enhanced or enhanced but lost detail. The percent lost print includes those where the print was either uninformative through loss of details, blurring, or only background powder remaining. BP-Black powder engulfed, PR/NBP-Print remains/no black powder adhering.

Surface Tension

Surface tension readings were taken for each item (APPENDIX A). Table 10 displays the range in readings for each plastic identification number category in addition to their literature values. Overall, higher success rates occurred with the higher surface tension readings. The highest success rate (70.6%) happened with a surface tension reading of 36 dynes/cm whereas a surface tension reading of less than 30 dynes/cm had the lowest success rate (20.0%). The remaining readings were near 60% while a reading of 32 dynes/cm had a success rate of 48.9%.

A comparison of experimental surface tensions to those in the literature showed some substantial differences. The surface tension displayed a large decrease for #1 plastics (32.7 dynes/cm) which was 10 dynes/cm less than the literature value. Plastic #3

(32.4 dynes/cm) decreased about seven dynes/cm from the literature value. The remaining plastic types were close (within 1 or 2 dynes/cm) to their respective untreated surface tension literature value. The surface tension values for each plastic category are displayed in APPENDIX B. Within each reading fingerprints are sorted based on their processing result, with a success rate shown below the number of fingerprints. Surface tension values within each plastic id number that created the largest success rate were #1: 36 dynes/cm (100%), #2: 30 dynes/cm (66.7%) and 38 dynes/cm (66.7%), #3: 32 dynes/cm (75%), #4: 36 dynes/cm (100%), #5: 34 dynes/cm (100%), #6: 34 and 36 dynes/cm (100%), and #7 (other): 34 dynes/cm (100%). However, it is important to note the small sample sizes for several of these classifications. For nearly all plastic types, except #3, a higher surface energy resulted in a higher success rate. Those items with a reading of 32 dynes/cm (#1, #2, #3, #5, #6 and #7) usually resulted in the lowest success rate (six of the seven plastic types).

Table 10 Surface Tension Readings

Plastic ID #	S.T. Literature Values for U.T.P. (dynes/cm)	<30	30	32	34	36	38	Total F.P.	Average S.T.
1	43	0	2	24	13	2	0	41	32.7
2	33	0	28	87	40	12	3	170	32.5
3	39 – 40	0	0	4	1	0	0	5	32.4
4	31	0	2	0	7	1	0	10	33.4
5	29	6	17	13	7	0	0	43	31.1
6	33	4	6	7	2	1	0	20	31.2
7		0	0	2	3	0	0	5	33.2
Totals		10	55	137	73	16	3	294	

Surface tension reading occurrences with their respective plastic identification category. Each reading (dynes/cm) corresponded to a fingerprint within that plastic identification category. An overall average surface tension reading was calculated for each plastic identification category. Literature values for untreated surface tensions for their respective plastic type are displayed in dynes/cm. #=Number U.T.P. = Untreated plastics F.P.=Fingerprints S.T.=Surface Tension

Profilometry

A profilometer was used to analyze the surface texture of a subset of plastic items and note correlations between the readings and processing results. Due to the profilometer's thickness limitations as well as the flatness requirement, only eight samples were analyzed (Table 11). Readings were taken adjacent to two fingerprints, one that was enhanced and the other which was not. Average surface texture readings ranged from 32779.3 amps to 204335.3 amps, with the roughest reading being a #2, white, rough textured Rid-X container (sample 76-b), while the smoothest was #2 white, glossy Michigan Cottage Cheese Lid (sample 43-a). In half of the cases the region with the higher surface tension exhibited a higher fingerprint enhancement success rate (EP + EP/LD), while in the remainder the opposite was the case.

Table 11 Profilometer Analysis

Plastic Item	Rinsing Result	Profilometer Reading (Amps)			Average Profilometer Reading (Amps)
Red Lid #65	65-a-BP	45846	58573	83485	62634.6
	65-b-EP	59373	71517	49472	60120.6
Blue Lid #66	66-a-BP	56618	59992	72655	63088.3
	66-b-EP	42665	50319	27945	40309.7
Dinty Moore Lid #47	47-a-LP/D	78328	80187	81125	79880.0
	47-b-EP	46878	35746	53341	45321.7
Michigan Cottage Cheese Lid #43	43-a-EP/LD	37699	30899	29740	32779.3
	45-b-EP	31801	45076	29399	35425.3
Brummel & Brown Lid #48	48-a-LP/D	86874	134802	90494	104056.7
	48-b-EP/LD	105904	131162	150979	129348.3
Rid X Cont. #76	76-a-BP	83420	113000	91804	96074.7
	76-b-EP	226006	165000	222000	204335.3
Chlorox2 Cont. #78	78-a-EP	30100	56600	48900	45200.0
	78-b-BP	83000	92700	100000	91900.0
Bacteriostat Cont. #75	75-a-BP	74000	28900	47000	49966.7
	75-b-EP	151000	163000	145000	153000.0

The plastic items with the individually labeled fingerprints' sample number and their corresponding rinsing result. Near each fingerprint, three separate readings were taken and an overall surface roughness average was calculated. EP-Enhanced Print, EP/LD-Enhanced Print/Lost Detail, LP/D-Lost Print/Detail, and BP-Black Powder Engulfed.

Cyanoacrylate Chamber Variation

Eight items, 88-a – 94-f, encompassing 38 fingerprints, were cyanoacrylate fumed in a Mason Vactron, MVC 5000 and processed using the powdering/rinsing sequence identified in the Materials and Methods section. The processing results for each category were: 10-“EP” (26.3%), 12-“EP/LD” (31.6%), 11-“LP/D” (28.9%), 0-“LP/B”, 0-“LP/BP”, 5-“BP”, 0-“PR/NBP”. These results were similar to those of the main sample set which were fumed in a Fisher Hamilton cyanoacrylate chamber, in that they had nearly the same number of enhanced prints as the main sample set (57.9% vs. 53.1%, respectively). While the main sample set had more successfully enhanced prints than any other result, this sample set had slightly more enhanced prints/lost detail results. The third most frequent result was lost print/detail for both sample sets.

Inter-Individual Variability Analysis

Sixteen #2 Kroger grocery bags and five #2 zip close plastic bags were laid on a table and handled by anonymous individuals to determine whether the rinsing process was affected by inter-individual variation. These yielded the following results: 16 Kroger grocery bags (11-“EP” (68.8%), 1-“EP/LD” (6.25%), 4-“LP/B” (25.0%)) had an overall successful result of 75% which was consistent with the main sample set. The lost print/blurred result occurred more frequently (25.0%) than the main sample set (8.6%). The results obtained for the 5 zip close plastic bags were 1-“LP/D” (20.0%) and 4-“LP/B” (80%). Overall, the zip close bags did not produce any enhanced prints or enhanced prints/lost detail results.

Rinse Solution Variation Analysis

Table 12 displays the results obtained from using eight different rinsing solutions over eight sets of two latent prints that were placed on separate #2 high-density polyethylene Kroger grocery bags. A number of different reactions occurred as a result of the variations in solution compositions. The only solution to produce enhanced print/lost detail results was eight. Although it did have a successful result, it did not produce the same quality result that the original solution did. A majority of these solutions did not effectively enhance the print and four of the eight exhibited difficulties in removing the background black powder while three produced “PR/NBP” results.

Table 12 Rinsing Solution Results

Solution	Rinsing Result	Processing Result
1 -N Hep	After the 5 th rinse, prints remained light, and most of the black powder wiped off after each rinse. Surrounding black powder began to build making the plastic background very dark.	LP/BP
2 -M Hex	After the 6 th rinse, prints started to darken, but remained much lighter in comparison to the surrounding area where the black powder became thick and dark. The powder was thicker than in solution one.	LP/BP
3 -EA Hex	After the 4 th rinse the entire bag remained black and black powder would not wipe off. It appeared to stick to the plastic and the powder felt thicker and rough with each successive rinse. Thick precipitate formed in the bottom of the solution flask.	BP
4 Hep	After the 4 th rinse and all following rinses, no black powder adhered to prints or background. Prints did not darken.	PR/NBP
5 -EA Hep	After the 4 th rinse entire plastic remained black and black powder would not wipe off. It appeared to stick to the plastic and the black powder felt thicker and rough. Thick precipitate formed in the bottom of the solution flask.	BP
6 -N -EA Hex	After every rinse, the plastic wiped clean, and the black powder would not adhere to prints. The print could be seen obliquely.	PR/NBP
7 -Hex -Hep	After the 5 th rinse and all following rinses, the print remained light and no black powder adhered. The background black powder wiped clean and free of interference after each rinse.	PR/NBP
8 -M +E +AA Hep	After the 1 st rinse, prints cleared up a little and were light. Multiple rinses darkened print, but after six rinses, the print remained light. One print blurred and one was moderately enhanced allowing for few details to be seen. Excess black powder that was removed by sponge did not appear to drain off with of sponge with rinsing solution like other six solutions.	EP/LD

The rinsing solution was varied in composition and ratio and noted below each solution number. The observed results from each are displayed. -N=no Ninhydrin present, -M=no methanol present, -EA=no ethyl acetate present, +E=ethanol present, +AA=acetic acid present, Hep=heptane, Hex=hexane

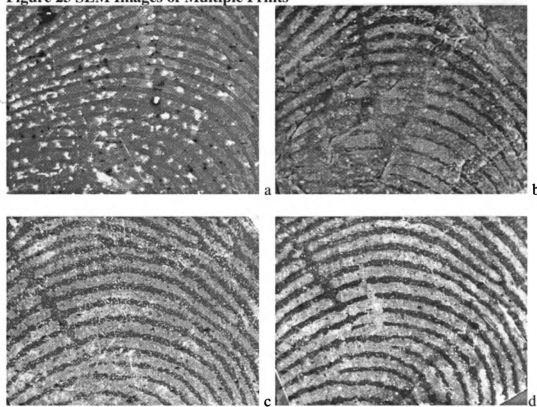
Microscopic Analysis of Enhancement Progression

Scanning Electron Microscopy

Two separate sets of images were taken to help determine microscopically what occurred between the plastic item, cyanoacrylate, black powder, and the latent fingerprint

through the powder/rinse cycles. The first set of images (Figure 23) depicts four separate latent prints that were processed to different stages of the cycle (Table 3). The first image (Figure 23 a) displays an identifiable print whereas the powdered fingerprint (Figure 23 b) shows that the powder not only adhered to the ridges but it also collected in the furrows. After the first (Figure 23 c) and ultimately the third rinsing cycle (Figure 23 d), the ridges became more distinct and sharp as the excess black powder was removed, allowing for better visibility of minutiae.

Figure 23 SEM Images of Multiple Prints

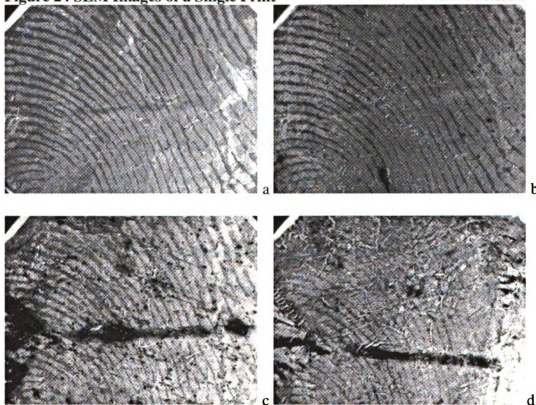


SEM images of a cyanoacrylate fumed only print (a), a cyanoacrylate fumed and powdered print (b), a cyanoacrylate fumed, powdered and rinsed print (c), and a print that had been cyanoacrylate fumed then powdered/rinsed three times (d). Note the ridges in the black powdered print appear to be closer together and not as distinct as the third rinsed print where they are more distinct.

The second set of images (Figure 24) is of one latent print that was processed and imaged following each step (Table 3) after having applied a layer of gold. An attempt

was made to image the fingerprint without applying successive layers of gold, but the signal was too weak, producing a dark screen with a very small amount of fingerprint visible. The cyanoacrylate fumed fingerprint (Figure 24 a) produced an image that was much like that in Figure 23 (a). The fingerprint however, became degraded and lost detail after the powdering step (Figure 24 b) and ultimately after the first (Figure 24 c) and third rinsing step (Figure 24 d). The black powder would not wipe from the fingerprint, thus the minutiae were lost and the print was less identifiable.

Figure 24 SEM Images of a Single Print



SEM images of a single fingerprint sample: a cyanoacrylate fumed only print (a), the fingerprint having been cyanoacrylate fumed and powdered (b), the fingerprint having been cyanoacrylate fumed, powdered and rinsed once (c), and the fingerprint that had been cyanoacrylate fumed then powdered/rinsed three times (d). A layer of gold was applied after each step. Note the cyanoacrylate fumed print was completely identifiable, but the fingerprint minutiae started to disappear and blur with successive powder/rinsing cycles as seen in the third rinse.

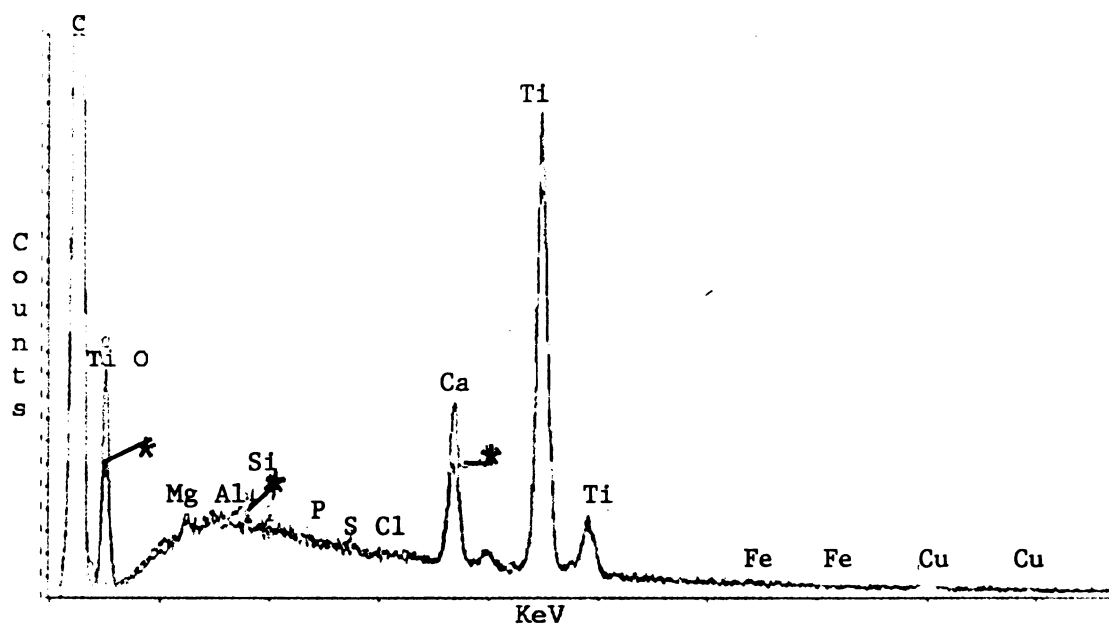
Elemental Analysis of Enhancement Progression

Scanning Electron Microscopy – Energy Dispersive X-Ray Spectrometry

SEM-EDS was employed to analyze chemically what occurred during the powder/rinse cycles among the plastic, fingerprint, cyanoacrylate, powder and hexane. A cyanoacrylate fumed print was analyzed, comparing a ridge location with a furrow location. An overlaid graph of the SEM-EDS output is shown in Figure 25. Note the tremendous similarity in the two graphs. Similarly, an overlay resulting from two different ridge locations is shown in Figure 26. The Center for Advanced Microscopy at Michigan State University uses carbon as the coating material for SEM-EDS. Unfortunately, carbon, being the main element in black powder, as well as in fingerprint components and the wash solution, meant that reasonable quantitative analysis could not be made (note the large carbon peak in all graphs). Any elements lighter than carbon were also undetectable, while a few other substantial peaks, including titanium (presumably a whitener in the bag) and calcium, were seen. An attempt was made to analyze the same samples without carbon coating however, the signal was not strong enough to send elemental and topographical information back to the detector, producing an uninformative image.

Figure 25 SEM-EDS Cyanoacrylate Fumed Print – Ridge and Furrow

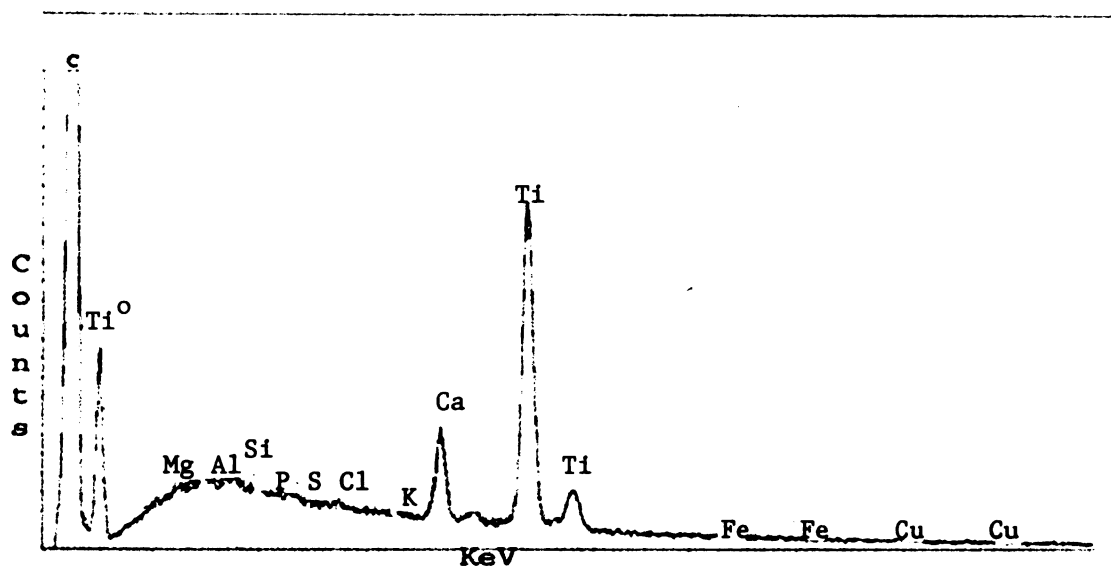
ThermoNORAN



An SEM-EDS overlay of a sample that has been cyanoacrylate fumed is displayed. One line designates the result for the furrow only of that print and one line designates the result for the ridge only (*)

Figure 26 SEM-EDS Cyanoacrylate Fumed Print-Ridge 1 and Ridge 2

ThermoNORAN



An SEM-EDS overlay of a sample that has been cyanoacrylate fumed is displayed. One line designates the result of one location on the ridge of that print and the other line represents another location on the same ridge. The locations produced very similar results making it difficult to make a distinction between the two. The only difference that can be seen is at the magnesium peak.

Discussion

The primary purpose of this research was to assess the utility of a ninhydrin hexane solution for processing latent prints on plastic materials following cyanoacrylate fuming and powdering. Over 100 plastic items and nearly 300 latent prints were processed to identify the most effective rinsing solution for enhancing fingerprints which had become engulfed in black powder and were no longer identifiable. The research was also aimed at identifying the characteristics of plastics that made them conducive to achieving successful results, where the fingerprint was enhanced such that ridge detail and minutiae could be easily discerned, or those that were enhanced but lost detail through the loss of minutiae. Plastic characteristics such as plastic type, presence or

absence/removal of inked printing and/or labels, color, surface finish, surface tension, and surface roughness were analyzed to evaluate their influence on the rinsing method success. Microscopic examinations were made to determine what changes occurred to the print between the cycles of powdering and rinsing, as was elemental analysis to examine the chemical variations among the plastic, cyanoacrylate, powder and rinsing solution during the powder/rinse cycles.

Item Collection and Sample Sizes

Plastic household items were collected from donations. The most common plastic types received were #2 (55 items) and #5 (17 items) while plastic types #3 and #7 were fewest, represented by only two items each, with the other types in between (APPENDIX A). At first glance the disparity in plastic types might seem to nullify the utility of the research presented here however, this is likely not the case. While some plastic types were underrepresented, overall the sampling represents those types that occur in a day to day setting. The items were collected by individuals who were requested to bring in any plastic items they used, so it likely is a reasonable representation of each plastic type's occurrence.

Processing Results

As a result of this research, seven different processing outcomes were noted (see Results and Figures therein for details on these). Once a latent print was enhanced (print was enhanced or enhanced but lost detail) which occurred in 53.1% of the instances, further processing either left it unharmed and identifiable (usually on the more textured surfaces), or it began to wipe away (on smoother or glossy surfaces). Prints and background that started to darken from the black powder typically darkened further with

additional rinses. There was no print recovery with more washes for those items that began to lose detail through loss of minutiae or blurring as they continued to lose detail and blurred. “PR/NBP” prints remained after multiple rinses however, further processing did not enhance the print. Latent prints that were identifiable as a result of the initial powder application often were further enhanced through rinsing, but at times the print disappeared.

Plastic Types

To uncover what properties influenced the success of enhancement, different plastic types were evaluated (Table 1). Those types with the greatest percent of enhanced prints were #3 and #7 both at 60% (Table 6). It is important to note the small sample size for these however (5 prints each), so the results may not accurately represent their functional processing outcome. For plastic types with more than 40 fingerprints (#1, #2, and #5), #2 plastic types had prints that were enhanced nearly 51% of the time, while the others were < 50%, as were types #4 and #6 with smaller sample sizes. Plastic types #1, #5 and #7 lost details >30% of the time. Plastic #6 items tended to become further engulfed in the black powder (35.0%). From these results, a general conclusion is that the plastic type most likely to benefit from the powdering/rinsing technique is #2, while #3 and #7 also seem to be effective. However, for all plastic types some portion of the items became enhanced using the technique; in no case is the method to be fully avoided based on plastic type, assuming it is the last method available for latent print enhancement.

The Influence of Color

The plastic items were further differentiated based on color (Table 7). To produce variations in plastics, colorants are added that could potentially influence the prints

ability to adhere or be enhanced. Orange and red items had the highest enhancement rates (100% and 71.4%, respectively) however, their sample sizes were small (3 and 7 prints, respectively). Plastic colors represented by large sample sizes (10 or more fingerprints) had lower success rates, with gray items being the most successful at 70%. Clear, green, and white containers (excluding bags) were the least successful based on the combination of the percent of enhanced prints (52.7%, 50.0%, and 49.6%, respectively) and the percent of lost prints (31.2%, 25.0% and 32.5%, respectively). On the other hand, clear and white bags were successful 75.9% of the time. It is possible that the color additives that are put into plastics may bond or repel fingerprints, cyanoacrylate, or powder, and influence the print's ability to adhere to the surface. Most likely however, this is not the case. The colors with large sample sizes had quite average rates of enhancement (around 50%), indicating color additives do not affect the enhancing results.

The Influence of Surface Finish and Surface Roughness

Surface finishes were noted for items as either “glossy”, those items that were shiny and smooth to the touch, “smooth”, those items that had a flat surface, “textured”, those items that were mildly rough, and “rough textured”, those items that had pits on the surface. When the surface roughness increased, the success rate for developing enhanced prints also increased. Rough textured items produced the highest level of enhanced prints (67.5%), followed by textured and smooth, while glossy items were the least successful (40%). One possible reason latent prints left on rough textured items were more often enhanced is that the prints were better able to adhere to the item by filling the valleys (pits) of the plastic. In contrast, the smoother surfaces allowed the print to be easily wiped off. This rinsing technique proved most useful for rough textured #2 items, as they

produced a large number of enhanced results (69.4%). Plastic #5 white, glossy items rarely benefited from this technique (36.0%), probably because the fingerprints are more exposed to the rinsing solution and/or the prints are not able to adhere as strongly.

Interestingly, when surface texture was tested using profilometry, the enhancement showed no correlation with the surface texture. However, it is important to note that only eight items were evaluated using this method, because of the technical requirements of the instrument. Each of the eight items had one successful and one failed print that had been processed using this rinsing technique. Profilometry was used to distinguish the surface texture at the microscopic level, and in half the cases the enhanced print was on the rougher surface, while half the time it was on the microscopically smoother surface. Therefore, at that level surface texture does not seem to be important for success.

For five of the eight items (#43, #47, #48, #75 and #78), the surfaces for successful/failed prints appeared visually to be the same, while on the remaining three (#65, #66 and #76) there was a clear distinction in roughness. In two of the three remaining items, #65 and #66, the successful print was on the visibly rougher surface however, at the microscopic level the failed print was on the rougher surface, or the profilometer produced results opposite from visual inspection. On the other hand, for item #76 the successful print was on the visibly smoother surface which was supported by profilometer readings. It appears that the profilometer is measuring the surface at such a detailed level, it does not fully evaluate the overall roughness or smoothness of the item. While profilometers are not readily available to lab personnel, the visual evaluation

appears to be sufficient when determining the surface finish which is helpful in determining whether the rinsing technique should be employed.

The Influence of Inked Printing and Adhesives

Locations of inked printing and areas where labels had been removed were evaluated to identify if there was a correlation between these plastic characteristics and processing results. While surface treatments are applied to increase the retention of the inked printing and labels, additives also may affect the success of obtaining an enhanced print. Inked printing appeared to have a negative effect on the processing, being enhanced 36% of the time, while 48% of latent prints were lost. It seems likely that when the inked printing is applied to the surface, the printing smoothes it, resulting in a glossy texture that does not retain the print however, it may not smooth #2 plastic surfaces to such an extent allowing for more successful results. Typically #2 plastic items with inked printing achieved enhanced prints 50.0% of the time which may be due to a variation in the surface treatments and additives used for these plastics.

In contrast, regardless of whether a label had or had not been present on the item prior to leaving the latent print, the prints were enhanced 55% of the time. However, in some cases a print left where a label had been removed lost detail (e.g., Figure 10) while in other cases it generated successful results (e.g., Figure). Latent prints that were placed half on and half off of a location where a label had been removed exhibited the same success rate for both sides of the print (33.3%). Naturally, a label or the treatment beneath it need not be single entities. Manufacturers use many different labels and adhesives containing different chemicals based on the requirements for the container, including if it will contain liquid or is likely to become wet (e.g. laundry, bath, and food containers), if

solvents come into contact with it (e.g., a rubbing alcohol bottle), or if it will be heated or frozen, etc. It is not surprising that the labels and adhesives behaved differently during the rinse procedure due to these variations.

The Influence of Surface Tension

Surface tension was evaluated using *ACCU DYNE TEST Markers* to determine how surface energy influenced the retention and enhancement of latent prints (Table 10). Since surface treatments are generally applied to increase surface energy, the resulting value for the plastic items might be predicted to be greater than that of the literature value (Hernandez et al. 2000). In contrast, a number of surface tension values were found to be lower than published standards. For instance, the average surface tension for #1 plastic items (32.7 dynes/cm) was 10 dynes/cm lower than the literature values, while plastic #3 (32.4 dynes/cm) was about seven dynes/cm lower. These decreases may suggest that no surface treatment had been applied, or certainly no treatment designed to increase surface tension, and in fact the opposite could be true. In this regard, one notable feature is that all plastic types had average surface tension values around 32 dynes/cm. It is possible that this surface tension is ideal for adhering inks and labels, or to otherwise generate characteristics sought by the manufacturers for commercial products.

Six of the seven plastic types exhibited a trend showing that as surface energy increased the percent of enhanced prints also increased, the sole exception being type #3, which displayed the opposite trend (APPENDIX B). Plastic types #1, #2, #3, #5, #6, and #7 each had average surface tension readings near 32 dynes/cm. In general, enhancement success rates were lower with a surface tension reading of 32 dynes/cm whereas readings that were greater than 32 dynes/cm had a higher success rate (except #3 items). The

correspondence of surface tension with print enhancement suggests that this surface energy helps to increase the bonding strength of the latent print to the surface, which allows for further powder/rinse cycles and enhancement of the print with few or no details lost.

Processing Variations

The use of two different cyanoacrylate chambers, which generated very similar enhancement results, demonstrated that the processing technique was not influenced by chamber variations. It appears that any differences in the amount of cyanoacrylate vaporized, cyanoacrylate adhering, and the amount of humidity in the chamber did not affect the overall enhancement results. Inter-individual variability demonstrated that processing results were independent of latent print sources as well.

Rinsing Solution Component Analysis

Modifications were made to the original rinsing solution (Scarborough 2001) and used to process #2 grocery bags that had successfully been enhanced with the original solution. An alternate solution described by Wertheim was also evaluated. From these experiments, it became apparent that methanol was required to fully dissolve the ninhydrin, in that when methanol was not present the print would not return to the dark print that was achieved by the original solution. Ninhydrin and hexane helped to darken the latent print as the ninhydrin may have been adhering to the ridges and minutiae and the hexane facilitated this process, resulting in a darkened outline although there was no indication of purple coloration. It may also be possible that the ninhydrin and hexane may be assisting the black powder in adhering to the ridges in both identifiable and engulfed prints. When ethyl acetate was left out of the solution, a thick precipitate formed that

prevented the solution from thoroughly mixing. As a result, the fingerprints were not enhanced. Also, in the absence of ethyl acetate, the rinsing solution did not remove the excess background black powder from the item, increasing the background darkness until the print became engulfed. Replacing hexane with heptane resulted in the black powder being wiped from the print, and further powder/rinsing did not darken the print to make it identifiable. Finally, the eighth rinsing solution (Wertheim), consisting of ninhydrin, ethanol, ethyl acetate, acetic acid, and heptane, provided the best enhancement when compared to the other seven modifications. It did not however, produce the impressive results that the original solution achieved. Since both the seventh and eighth solutions had heptane as a reagent, the latent print was not darkened as extensively as when hexane was present, indicating that the solution requires hexane in order to produce the most successful results.

Scanning Electron Microscopy Analysis

The SEM was used to image four separate latent prints (Figure 23), including a cyanoacrylate fumed only print, a cyanoacrylate fumed and powdered print, a cyanoacrylate fumed, powdered and rinsed once print, and a cyanoacrylate fumed, powdered and rinsed three times print. It is important to note that the ridges are light in comparison to the furrows. This shows that the ridges are closer to the detector and this contrast increases as the furrows increase in distance from the detector when the powder is removed. The cyanoacrylate fumed image (Figure 23 a) was identifiable, but did not have sharp details. The print that was powdered (Figure 23 b) started to blur as the powder settled in the furrows causing the ridges to blend together, but after the first rinse (Figure 23 c) the black powder was removed from the furrows and the ridges became

more distinct and clear. Ridge detail was further improved after the third rinsing (Figure 23 d). The contrast differences shown in the Figure 23 images demonstrated the difference in depth between the low points (furrows) and high points (ridges) of the print. These contrast differences increase from Figure 23 (a) through Figure 23 (d) as the print undergoes more rinsing cycles and the black powder that had settled in the furrows may be removed as a result.

In the second set of images (Figure 24) a single fingerprint was placed on a white, #2 grocery bag and processed to various stages of the powdering/rinsing cycle as was done for the previous SEM images and were imaged after each step. One major observation was made. After successive applications of gold, the latent print could no longer be rinsed to produce an enhanced print. Upon evaluation of the black powdered image (Figure 24 b), it appeared that the powder may be adhering to all areas where the gold coating was applied, outlining the structures of the print, ultimately producing a partially identifiable image. The first and third rinses (Figures 24 c and d) produced blurred images that had fewer areas that could be used for identification. As the layers of gold were applied, no distinction could be made between the ridges, resulting in a print that showed little detail and was of little value.

Scanning Electron Microscopy – Energy Dispersive X-Ray Spectrometry Analysis

An SEM-EDS was employed to image and elementally determine the changes that occurred between stages of the powdering/rinsing cycle among the print, cyanoacrylate, powder, and rinse solution. The high resolution of this procedure meant that a ridge and furrow could be individually tested. Because cyanoacrylate is an organic compound, changes in carbon levels after each step were to be examined. Unfortunately,

the only coating element available for these experiments used carbon, resulting in off scale carbon readings for all portions of the plastic item. However the large number of organic compounds involved in the procedure, including the plastic itself, some fingerprint components, the cyanoacrylate, powder, ninhydrin, and rinse solution, means that a variable other than carbon will need to be investigated if this technique is to prove useful. Overlaying ridge and furrow graphs (Figures 25 and 26) showed no notable differences in the levels of elements except for calcium and titanium. Although calcium is potentially a component of the fingerprint, it is not found in any of the other reagents. Titanium would not be contained in any component except the bag itself, and it is widely used as a whitener for plastics and other products. Differences between the ridges and furrows could be due to the amount of whitener in the #2 plastic bag on which the print was placed. Different locations on the bag may demonstrate a range in the amount of these elements, or result from small fluctuations in the SEM-EDS procedure itself. Regardless, because of carbon coating the technique was not helpful in understanding elemental changes occurring during the rinse procedure. Although alternative coating methods are not currently available at MSU, it is possible to coat samples with materials such as nickel or a silicon lubricant, and thus it may be possible to collect qualitative and quantitative data regarding the amount of cyanoacrylate, black powder, and rinsing solution (hexane and ninhydrin) during the rinsing process.

Elemental analysis may also help to determine if the black powder is solely what is causing the fingerprint to turn black, or if the ninhydrin and hexane assist in darkening the ridges and minutiae in the fingerprint. The SEM-EDS may also provide information on what causes the latent print to stay light in those trials where the print remained but

the black powder was not adhering to it or the background. The SEM-EDS could also help in determining where the black powder was adhering. Other elemental analysis techniques such as atomic absorption, inductively coupled plasma-mass spectrometry, and inductively coupled plasma – optical emission spectroscopy could be employed for determining chemically what occurs among the components involved in the powder/rinsing cycles.

Potential Mechanisms of the Rinsing Method

Plastic types, additives, surface treatments, surface textures, and surface tensions are designed to manipulate the physical characteristics of a plastic, and therefore might react differently with a number of chemicals analyzed in this research, including those in the fingerprint itself. The first step in the rinsing technique was cyanoacrylate fuming, which coats the print, helping to stabilize it. Cyanoacrylate, widely used for latent fingerprint development, undergoes anionic polymerization with a weak base and becomes stabilized with a weak acid (Courtney and Verosky 1999), thus pH extremes may act to decrease the success of the rinsing technique. While the pH of these plastics was not tested, and it is not clear if they differ, this is one variable that could influence the success of the technique. These changes could alter the amount and location of cyanoacrylate polymerization and ultimately alter the environmental factors affecting the rinsing technique.

Surface texture also influences the success of the technique. Here again the cyanoacrylate may be affected, in that the rougher surfaces may act as a better adhesive for the polymer. On the other hand, glossy and smooth items do not have these valleys or

pits on the surface for the cyanoacrylate to adhere to, making the print easier to wash away.

The function of the wash solvents and ninhydrin are also interesting to consider. SEM examination of a single fingerprint after each step in the processing cycle showed that the gold coating blocked subsequent enhancement of the print. This indicates that the cyanoacrylate may be permeable (or being made permeable by the various solvents applied), allowing rinsing solution and black powder to reach the latent print beneath the cyanoacrylate. However, it is also possible that the rinsing solution and powder are reacting with the cyanoacrylate and not the print itself, a process that would also be stopped by the gold coating.

When examining the black powder's role in fingerprint enhancement, two possibilities exist. One is that the powder not only adheres to the latent print, but also adheres to the cyanoacrylate. If the cyanoacrylate binds predominantly to the print, then the powder also would adhere to the print, enhancing it. On the other hand, if the cyanoacrylate binds over a larger region, the powder may engulf the print, and perhaps adhere to other areas of the plastic as well.

The hexane-based ninhydrin solution may be serving three purposes. First, it could help dissolve cyanoacrylate, exposing the latent print. Second, the solution may help enhance, darken, and sharpen ridge detail of the print. Third, the solution wipes away excess black powder, exposing just the ridges and minutiae for identification. When comparing heptane versus hexane, rinses that contained hexane proved superior to those that contained heptane. It is possible that the heptane reduced the solubility of the ninhydrin, or otherwise negatively impacted one of the other reagents. It may also have

reacted with cyanoacrylate differently, perhaps making it less soluble (see above). Other variations from the original rinsing solution described by Scarborough (2001) were evaluated and it appears that the original formula was most successful. However, it may prove useful to further examine different compositions to determine if there are more effective solutions or if specific solutions are effective for specific plastic items and conditions. The reagents could possibly be replaced in the original rinsing solution with alcohols, ketones, ethers and alkanes.

Overall Recommendations and Observations

The sequence for mixing the rinse solution should be followed as outlined in the materials and methods section, otherwise the ninhydrin will not completely dissolve, resulting in sub optimal processing results. When applying the rinsing solution to the plastic items, a glass or plaster bowl should be used, which allows the black powder removed from the plastic item to settle to the bottom, and provides a clean rinse solution at the top for further applications. Firm pressure should be applied to the plastic item when drawing the foam brush across the sample to remove the excess black powder. Using the foam brush to trace the pattern of the print can produce a darker image, as the excess black powder from the brush may stick to the ridges and darken them, resulting in more distinct ridge details. However, at times, the ridges can be wiped away. Therefore, it is important to photograph the latent print after each step in the powder/rinse cycle. In some instances, a print that is initially identifiable may wipe clear or lose detail after only one rinse, whereas at other times, one rinse results in excellent detail (e.g. Figure 13). Nitrile gloves should be worn when handling the rinsing solution as it can penetrate latex gloves.

After being processed with black powder, some plastic items develop latent prints that are engulfed in the powder and are no longer visible or identifiable. Unless the black powder can be removed, the print is of no value. Though the rinsing procedure did not prove useful in removing excess powder in all cases, it did provide a new step for recovery of minutiae that were not identifiable through black powder. The technique works best on rough textured items and success is independent of presence or location of a removed label. It is less successful on smooth or glossy items, as the print is more likely to wipe from the surface. However, this technique ultimately can be used as a last resort for any surface type as enhancement can ultimately work on any plastic. Further processing should not be attempted when the amount of black powder adhering starts to increase and the print begins to lose detail or becomes blurred, as the latent print will continue to darken, lose detail, and blur. This rinsing technique also provides the possibility of developing prints that were not visible after application of black powder alone. Although there are exceptions to all of these cases, it is suggested that if the latent print is of little or no value and photographs have been taken, using this technique can provide an additional processing step, increasing the probability of producing an identifiable print.

APPENDICES

APPENDIX A

Sample Characterizations and Processing Results

Plastic items are detailed with labeled fingerprints for each item. If the fingerprint was placed over an inked printing, "Inked Printing" is noted. If a fingerprint was placed where a label was removed, "Label" is noted. If there was no label initially present where the fingerprint was placed, "No Label" is noted. The absence of notations in the inked printing/label area, indicates that no label was removed or no label had been present where the fingerprint was placed. In addition, details regarding the plastic's characteristics are noted including the plastic ID number, color and surface finish. The surface tension (dynes/cm) for each fingerprint is noted as well as the overall processing result.

EP-Enhanced Print

EP/LD-Enhanced Print/Lost Detail

LP/D-Lost Print/Detail

LP/B-Lost Print/Blurred

LP/BP-Lost Print/Background Black Powdered

BP-Black Powder Engulfed

PR/NBP-Print Remains/No Black Powder Adhering

Sample Number	Plastic Item	Resin ID number	Color	Surface Finish	Surface Tension (Dynes/cm)	Results
1	Kroger Grocery Bag		2 clear	smooth		
1-a						32 LP/B
1-b						32 LP/B
1-c						32 LP/B
1-d						32 LP/B
2	Kroger Grocery Bag		2 clear	smooth		
2-a						32 EP
2-b						32 EP
2-c						32 EP
2-d						32 EP
3	Kroger Grocery Bag		2 clear	smooth		32 EP
4	Kroger Grocery Bag		2 clear	smooth		
4-a						32 EP
4-b						32 EP
4-c						32 EP
4-d						32 EP
4-e						32 EP
4-f						32 EP
5	Kroger Grocery Bag		2 clear	smooth		32 EP/LD
6	Zip Close		2 clear	smooth		32 LP/B
7	Zip Close		2 clear	smooth		32 LP/D
8	Zip Close		2 clear	smooth		32 LP/B
9	Zip Close		2 clear	smooth		32 LP/B
10	Zip Close		2 clear	smooth		32 LP/B
11	Small Pill Bottle		2 white	glossy		32
11-a1	1/2 on Label					32 EP
11-a2	1/2 off Label					32 EP
11-b	Label					32 LP/D
11-c						32 EP/LD
11-d						32 EP
11-e	No Label					32 LP/D

	12 Laundry Detergent Bottle (Xtra)	2 white	textured	
12-a				34 LP/D
12-b				34 LP/D
12-c				34 EP/LD
12-d				34 EP/LD
12-e				34 LP/D
12-f				34 LP/D
12-g				34 LP/B
13 Large Twist Cap Bottle		1 white	glossy	
13-a	On Label			34 EP/LD
13-b1	1/2 on Label			34 EP/LD
13-b2	1/2 off Label			34 EP/LD
13-c				34 EP/LD
13-d				34 LP/B
13-e				34 LP/BP
13-f				34 EP
14 Small Twist Cap Bottle		2 white	glossy	
14-a				32 LP/BP
14-b1	1/2 on Label			32 BP
14-b2	1/2 off Label			32 BP
14-c				32 EP/LD
14-d	On Label			32 EP/LD
14-e	On Label			32 EP/LD
14-f				32 BP
15 Yoplait Yogurt Cup (Strawberry)		5 white	glossy	
15-a	Inked Printing			32 LP/D
15-b	Inked Printing			32 LP/D
15-c				32 LP/BP
16 Yoplait Yogurt Cup (Cherry)		5 white	glossy	
16-a	Inked Printing			32 LP/BP
16-b	Inked Printing			32 LP/D
16-c				32 LP/D

17	Dannon Yogurt Cup		5 white	glossy		
17-a	Inked Printing					30 LP/D
17-b	Inked Printing					30 LP/D
17-c	Inked Printing					30 LP/D
18	Pop lid-lid-Arby's		6 clear	textured		32 BP
19	Dinty Moore lid		2 white	glossy		32 LP/D
19-a	Inked Printing					32 LP/D
19-b	Inked Printing					32 LP/D
20	Dinty Moore Container		2 white	glossy		30 LP/D
20-a	Inked Printing					30 LP/D
20-b	Inked Printing					30 LP/D
20-c	Inked Printing					30 LP/D
21	Vita Tabs bottle		2 clear	textured		34 EP/D
21-a	Inked Printing					34 EP/D
21-b	Inked Printing					34 EP/D
22	Sprite bottle		1 green	smooth		32 EP/D
22-a	Label					32 EP/D
22-b	Label					32 EP/D
22-c	Label					32 LP/D
22-d	Label					32 LP/D
23	Alcon Bottle		1 white	glossy		32 LP/BP
23-a1	1/2 on Label					32 LP/D
23-a2	1/2 off Label					32 LP/BP
23-b1	1/2 on Label					32 LP/D
23-b2	1/2 off Label					32 EP/D
23-c	Label					32 EP/D
23-d	Label					32 EP/D
24	Pantene Bottle		2 cream	smooth		34 LP/D
24-a1	1/2 on Label					34 LP/D
24-a2	1/2 off Label					34 EP/D
24-b	Label					34 EP
24-c1	1/2 on Label					34 EP
24-c2	1/2 off Label					34 LP/D
24-d	Label					34 LP/D

25	20 Oz. Mt. Dew Bottle	1	green	smooth	
25-a	Label				36 EP/LD
25-b	Label				36 EP/LD
26	Appearance body wash bottle	1	clear	smooth	
26-a	Label				32 BP
26-b					32 EP
26-c	Label				32 LP/B
26-d					32 BP
27	Kroger Churn Gold Butter Lid	2	brown	glossy	
27-a	Inked Printing				36 EP
27-b	Inked Printing				36 EP
27-c					34 EP
27-d					34 EP
28	Daily Defense Container	2	white	textured	
28-a	Inked Printing				36 EP
28-b	Inked Printing				36 BP
28-c					36 LP/D
29	Bausch & Lomb Saline Sol'n	2	white	glossy	
29-a	Label				34 EP
29-b					32 EP/LD
29-c1	1/2 on Label				34 LP/B
29-c2	1/2 off Label				32 LP/B
29-d	Label				34 LP/B
30	Bausch & Lomb Renu	2	white	glossy	
30-a	Label				34 EP/LD
30-b					32 BP
30-c1	1/2 on Label				34 LP/B
30-c2	1/2 off Label				32 LP/B
31	Tylenol Arthritis Bottle	2	white	smooth	
31-a1	1/2 on Label				36 BP
31-a2	1/2 off Label				34 BP
31-b	Label				34 BP

39	Bath and body Works Hand Soap		1	clear	glossy		
39-a	Label					32	LP/D
39-b1	1/2 on Label					32	LP/D
39-b2	1/2 off Label					32	LP/D
39-c						32	LP/D
40	Minced Onion Container Safeway		1	clear	smooth		
40-a						34	BP
40-b						34	BP
41	International Delight Creamer		1	white	glossy		
41-a						32	EP/LD
41-b						32	EP/LD
42	Bath and Body Works Bath Oil Powder		1	clear	smooth		
42-a	Label					32	EP/LD
42-b1	1/2 on Label					32	EP
42-b2	1/2 off Label					34	EP
42-c						34	LP/D
43	Michigan Cottage Cheese Lid		2	white	glossy		
43-a						34	EP/LD
43-b						32	EP
44	Jergens Skin Care Lotion		2	white	smooth		
44-a	Label					36	BP
44-b1	1/2 on Label					36	BP
44-b2	1/2 off Label					32	BP
44-c						32	BP
45	Paul Mitchell Conditioner		2	white	textured		
45-a	Inked Printing					32	EP
45-b	Inked Printing					32	EP
46	Purex Laundry Detergent		2	blue	rough texture		
46-a						32	LP/D
46-b						32	PR/NBP
46-c						32	PR/NBP
47	Dirty Moore Lid		2	white	glossy		
47-a	Inked Printing					32	LP/D
47-b						30	EP

48	Brummel and Brown Lid		4 white	glossy	
48-a	Inked Printing				34 LP/D
48-b					34 EP/LD
49	Brummel and Brown Lid		4 white	glossy	
49-a	Inked Printing				34 PR/NBP
49-b					34 BP
50	Green Lid		5 green	rough texture	
50-a					30 PR/NBP
50-b					30 BP
51	Blue Bonnet Butter Container		5 white	glossy	
51-a	Inked Printing				30 EP/LD
51-b					32 EP
52	Brummel and Brown Container		5 white	smooth	
52-a	Inked Printing				32 BP
52-b					30 BP
53	Country Crock		5 brown	glossy	
53-a	Inked Printing				32 PR/NBP
53-b					30 BP
54	Churn Gold Butter Container		5 brown	glossy	
54-a	Inked Printing				30 EP/LD
54-b					32 BP
55	Santa Sweets Container		6 clear	smooth	
55-a	Label				
55-b					30 LP/D
56	Meijer Vegetable Bag		2 clear	smooth	
56-a	Inked Printing				30 LP/D
56-b					
57	Kmart Bag		2 brown	smooth	
57-a	Inked Printing				30 BP
57-b					30 BP
58	Great Harvest Bag		2 cream	smooth	
58-a	Inked Printing				32 EP/LD
58-b					30 EP/LD

59	Super Saver Bag		2	yellow	smooth		
59-a	Inked Printing						32 LP/B
59-b							32 BP
60	Target Bag		2	white	smooth		
60-a	Inked Printing						34 LP/B
60-b							34 LP/B
61	Long John Silver's Bag		2	white	smooth		
61-a	Inked Printing						32 EP
61-b							32 EP
62	Meijer Grocery Bag		2	white	smooth		
62-a	Inked Printing						32 LP/B
62-b							32 EP/LD
63	Kroger Grocery Bag		2	white	smooth		
63-a	Inked Printing						32 EP
63-b							32 EP/LD
64	Dollar General Bag		4	yellow	smooth		
64-a	Inked Printing						30 EP/LD
64-b							30 BP
65	Red Lid		4	red			
65-a					glossy		34 BP
65-b					smooth		34 EP
66	Blue Lid		4	blue			
66-a					glossy		34 BP
66-b					smooth		36 EP
67	Ear Care Container		3	white	glossy		
67-a							32 EP/LD
67-b							32 EP/LD
68	Era Laundry Container		2	red	rough texture		
68-a	Inked Printing						34 EP/LD
68-b							34 EP
69	Fresh Cut Lettuce Bag		7	clear	smooth		
69-a	Inked Printing						32 LP/D
69-b							32 LP/D

70	Blue Container	5 blue			
70-a			glossy		34 EP
70-b			smooth		34 EP/LD
71	Goodrich Grocery Bag	2 white	smooth		
71-a					32 EP
71-b					32 EP
72	Goodrich Grocery Bag	2 white	smooth		
72-a					32 EP/LD
72-b					32 EP
73	1/2 Gallon Food City Milk Carton	2 white	rough texture		
73-a					32 BP
73-b	Label				32 EP
74	Humidifier Bacteriostat	2 white	rough texture		
74-a	Label				32 BP
74-b					32 EP
75	Humidifier Bacteriostat	2 white	rough texture		
75-a	Label				34 BP
75-b					34 EP
76	RID-X	2 white	rough texture		
76-a	Label				32 BP
76-b					32 EP
77	Downy Fabric Softner	2 blue	rough texture		
77-a					36 EP
77-b					36 EP
77-c					36 EP
78	Chlorox2 Bleach	2 pink			
78-a			smooth		32 EP
78-b			textured		32 BP
78-c			rough texture		32 EP
79	Lid from Chlorox2 Bleach	5 orange	rough texture		30 EP
80	Ferrero Prestige Container	6 clear	smooth		
80-a	Label				32 EP
80-b					36 EP/LD

89	Krystal Kleer Washer Fluid		2	clear	rough texture	
89-a						30 EP
89-b						30 EP
89-c						30 EP
89-d						30 EP
89-e						30 EP
89-f						30 EP
89-g						30 EP/LD
89-h						30 EP
89-i						30 EP/LD
89-j						30 EP/LD
90	5 A Day Plastic Bag		2	clear	smooth	
90-a						32 LP/D
90-b						32 LP/D
91	Speedway Cup		5	clear	glossy	
91-a						<30 LP/D
91-b						<30 LP/D
91-c						<30 LP/D
91-d						<30 LP/D
91-e						<30 EP
92	Speedway Plastic Lid		6	clear	textured	<30 BP
93	Pita Chips Container		6	clear	smooth	
93-a						<30 BP
93-b						<30 BP
93-c						<30 BP
94	Clean Shower		2	white	textured	
94-a	Label					32 LP/D
94-b	Label					32 EP
94-c						32 EP/LD
94-d						32 EP
94-e						32 EP/LD
94-f						32 EP/LD

95	Tropicana OJ Container	7 white	textured	
95-a				34 EP
95-b				34 EP
95-c				34 EP/LD
96	Minute Maid OJ Container	2 orange	textured	
96-a				34 EP
96-b				34 EP/LD
97	Cheer Laundry Detergent	2 blue	textured	
97-a				34 BP
97-b				32 LP/D
98	Tide Laundry Detergent	2 red	textured	
98-a				32 EP/LD
98-b				34 BP
98-c				32 EP
99	Pantene Hair Conditioning Container	2 cream	smooth	
99-a				34 EP
99-b				34 EP
100	Bath & Body Works Container	3 clear	smooth	
100-a				32 EP/LD
100-b				32 PR/NBP
100-c				34 PR/NBP
101	Clairon Hair Conditioning Container	2 yellow	smooth	
101-a				32 EP/LD
101-b				32 EP
102	Dannon Yogurt Container-Large	5 white	smooth	
102-a	Inked Printing			34 EP/LD
102-b	Inked Printing			32 PR/NBP

APPENDIX B

Surface Tension and Plastic Type Processing Results

The surface tension values within a plastic category are displayed. Within each surface tension reading, the fingerprints are sorted based on their processing result, with a success rate (EP + EP/LD) calculated below the number of fingerprints.

Plastic I.D. #= Plastic Identification Number F.P.=Fingerprints

EP-Enhanced Print

EP/LD-Enhanced Print/Lost Detail

LP/D-Lost Print/Detail

LP/B-Lost Print/Blurred

LP/BP-Lost Print/Background Black Powdered

BP-Black Powder Engulfed

PR/NBP-Print Remains/No Black Powder Adhering

Plastic ID #	<30	30	32	34	36	38	Total F.P.	Avg. S.T.
1	0	2	24	13	2	0	41	32.7
		0.0%	41.7%	46.2%	100%			
		2-LP/B	EP-2	EP-2	EP/LD-2			
			EP/LD-8	EP/LD-4				
			LP/D-9	LP/D-1				
			LP/B-1	LP/B-3				
			LP/BP-2	LP/BP-1				
			BP-2	BP-2				
2	0	27	85	40	13	3	168	32.6
		66.7%	55.3%	55.0%	61.5%	66.7%		
		EP-8	EP-32	EP-13	EP-8	EP-1 EP/LD-1 BP-1		
		EP/LD-10	EP/LD-15	EP/LD-9	EP/LD-0			
		LP/D-6	LP/D-11	LP/D-7	LP/D-1			
		LP/B-0	LP/B-13	LP/B-6	LP/B-0			
		LP/BP-0	LP/BP-1	LP/BP-0	LP/BP-0			
		BP-3	BP-11	BP-5	BP-4			
			PR/NBP-2					
		3	0	0	4			
	75.0%			0.0%				
	EP/LD-3			PR/NBP-1				
	PR/NBP-1							
4	0	2	0	7	1	0	10	33.4
		50.0%		28.6%	100.0%			
		EP-0		EP-1	EP-1			
		EP/LD-1		EP/LD-1				
		LP/D-0		LP/D-1				
		LP/B-0		LP/B-0				
		LP/BP-0		LP/BP-0				
		BP-1		BP-3				
				PR/NBP-1				
5	6	17	13	7		0	0	43
	33.3%	52.9%	23.1%	100.0%				
	EP-2	EP-5	EP-2	EP-3				
	EP/LD-0	EP/LD-4	EP/LD-1	EP/LD-4				
	LP/D-4	LP/D-3	LP/D-4	LP/D-0				
	LP/B-0	LP/B-0	LP/B-0	LP/B-0				
	LP/BP-0	LP/BP-0	LP/BP-2	LP/BP-0				
	BP-0	BP-3	BP-2	BP-0				
		PR/NBP-2	PR/NBP-2	PR/NBP-0				

Plastic ID #	<30	30	32	34	36	38	Total F.P.	Avg. S.T.
6	4	6	7	2	1	0	20	31.2
	0.0%	50.0%	42.9%	100.0%	100.0%			
	BP-4	EP-0	EP-1	EP/LD-2	EP/LD-1			
		EP/LD-3						
		LP/D-2	EP/LD-2					
		LP/B-0	LP/D-1					
		LP/BP-0	BP-2					
		BP-1	PR/NBP-1					
7	0	0	2	3	0	0	5	33.2
			0.0%	100.0%				
			LP/D-2	EP-2				
				EP/LD-1				

REFERENCES

REFERENCES

- Brown EW. "The Cyanoacrylate Fuming Method". *NU-ENG*. 1990.
<http://www.ccs.neu.edu/home/feneric/cyanoacrylate.html>
- Beckman R. "From Fingerprints to DNA". *Helix*. 2001.
- Cheseapeake Bay Division of the International Association for Identification.
<http://www.cbdi.ai.org/>
- Coppock CA. *Contrast; An Investigator's Basic Reference Guide to Fingerprint Identification Concepts*. Charles C Thomas Publisher, LTD. Springfield, IL. 2001.
- Courtney PJ, Verosky C. "Advances in Cyanoacrylate Technology for Device Assembly". *Medical Device & Diagnostic Industry Magazine*. 1999.
- Cowger JF. *Friction Ridge Skin, Comparison and Identification of Fingerprints*. CRC Press. 1993.
- Flegler SL, Heckman, JW. and Klomparens KL. *Scanning and Transmission Electron Microscopy An Introduction*. 1993.
- Flexocon. <http://www.flexocon-ag.com/pdf/sherman/sherman/dynes.pdf>
- Hernandez RJ, Selke SEM, and Culter, JD. *Plastics Packaging Properties, Processing, and Regulations*. Hanser Gardner Publications, Inc. Cincinnati, OH. 2000.
- Lee H, Gaensslen RE. *Advances in Fingerprint Technology*. Elsevier Science Publishing Co. Inc. New York, NY. 1991.
- Margot P, Lennard C. *Fingerprint Detection Techniques*. 6th Ed. 1994.
- Moenssens AE. *Fingerprint Techniques*. Chilton Book Company. Philadelphia, PA. 1971.
- Nave R. Department of Physics and Astronomy and Georgia State University
<http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html#c1>
- Parsons N, Puch Solis RO, Smith JQ, Thönnnes E, Wang L, Wilson RG. "Statistical Evidence of Level Three Features".
<http://www2.warwick.ac.uk/fac/sci/statistics/staff/academic/thonnes/personal/fingerprints>

- Richards EP. "Phenotype v. Genotype: Why Identical Twins have Different Fingerprints". <http://www.forensic-evidence.com/>
- Saferstein R. *Forensic Science Handbook*. Vol. II. Prentice Hall. Upper Saddle River, NJ. 1988.
- Scarborough S. "Success of hexane-based ninhydrin amino acid reagent processing on various inks and ages of porous evidence". *Journal of Forensic Identification*. Alameda: Vol.51, Iss. 6. 2001. .
- Seradyn, "Polystyrene and Carboxylate-Modified Microparticles". 1999. <http://www.seradyn.com/technical/pdf/polystyrene.pdf>
- Stacey R. "Report on the Erroneous Fingerprint Individualization in the Madrid Train Bombing Case". *Forensic Science Communications*. Vol. 7. Number 1. 2005.
- Stanford Nanofabrication Facility
<http://snf.stanford.edu/Equipment/dektak/dektak.html>
- SWGFAST. http://www.swgfast.org/Glossary_Consolidated_ver_1.pdf
- The Societies of Plastics Industry. <http://www.socplas.org/>
- The University of Southern Mississippi and School of Polymers and High Performance Materials, "What do those Recycling Numbers Mean?"
<http://www.pslc.ws/macrog/work/recycle.htm>
- Van Iseghem LC. "Coating Plastics - Some Important Concepts from a Formulators Perspective." Van Technologies, Inc., <http://www.vtcoatings.com/plastics.htm>
- Wertheim PA. "Ninhydrin: Basic to Advanced". Forensic Identification Training Seminars, Ltd. <http://www.geocities.com/cfpdlab/ninhydri.htm> .

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