Badge Based Resin: A Novel Method For The Durable Preservation Of Powder Developed Latent Fingerprints

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ABSTRACT:

The preservation of latent fingerprints is a crucial aspect of forensic investigations, as it enables the identification of individuals involved in criminal activities. Traditionally, the lifting methods have been widely used for capturing latent prints; however, it presents limitations in terms of durability, clarity, and applicability to different surfaces. This paper investigates a novel method for preserving latent fingerprints which is powder developed, using bisphenol A diglycidyl ether (BADGE) based resin, which offers several advantages over the conventional lifting technique. There already exist various lifting methods for the powder developed fingerprints such as tape lifting, using hinge lifters and gel-lifters (gelatin-lifters). However, these methods have disadvantages over the novel method of powder developed latent fingerprint using BADGE based resin method discussed here, for a long-term preservation of fingerprints.

BADGE based resin, with its superior clarity, strength, and resistance to environmental degradation, ensures long-term preservation of fingerprint details with minimal distortion, even under adverse conditions. Unlike hinge lifters, which rely on adhesive-backed materials that can be prone to damage or leave behind residue, BADGE based resin provides a more durable and rigid medium for lifting prints, ensuring better preservation and clarity. Its structural integrity allows for the precise handling of prints without the risk of distortion, which is especially important when lifting from textured or irregular surfaces. In addition, BADGEbased resin is more resistant to environmental conditions like temperature and humidity, which can influence the adhesive properties of hinge lifters. The adhesive tape lifters can leave adhesive residue on prints, in addition to this may distort or damage delicate prints. According to some studies gel lifters can easily deform the prints under pressure as they are susceptible to temperature and humidity changes, affecting adhesive strength. This hardened resin preserves the fine details of the fingerprint ridges and minutiae, providing an exceptionally clear and stable record of the print over a long period of time. The study delivers the effectiveness of BADGE based resin as a fingerprint lifting cum preservation method by evaluating factors such as print preservation quality, ease of application, and potential for future analysis. The results indicates that BADGE based resin provides better clarity and structural integrity, making it a promising alternative for forensic fingerprint preservation. Furthermore, this novel method demonstrates significant potential in improving the reliability and accuracy of fingerprint analysis in criminal investigations.

Keywords: BADGE; Resin; Latent Fingerprints; Preservation; Forensic Investigation

INTRODUCTION

Across the globe, fingerprint evaluation maintains its pivotal role in criminal investigations, with its usage exceeding that of any other forensic procedure. Its demonstrated success in case resolution, significantly surpassing the contributions of DNA analysis, confirms its position as a fundamental instrument for law enforcement. However, the continued utility of fingerprint evidence in criminal investigations relies not only on the established individuality of these patterns, but also on the efficiency of techniques employed to retrieve them from a multitude of surfaces. Given the intricate range of environmental variables and surface materials encountered at crime scenes, the ability to consistently and accurately obtain fingerprint evidence is essential for effective identification (1). Fingerprints play a crucial role in forensic investigations due to their uniqueness, individualisation, permanence and classifiable which makes them a valuable tool in criminal identification and evidence analysis. Each individual's fingerprints are distinct, formed during foetal development (formed during 3-4th month and gets fully developed by 6th month), and remain unchanged throughout their lifetime. This characteristic ensures that fingerprints can serve as an irrefutable means of identifying individuals involved in criminal activities. Furthermore, advancements in fingerprinting technology, such as automated fingerprint identification systems (AFIS), have greatly enhanced the speed and accuracy of matching prints, reinforcing their significance in modern forensic science (2).

Fingerprints are generally classified into three primary types: latent, patent, and plastic. Latent, or unseen, prints are created when natural skin secretions like sweat or oils transfer the ridge patterns of a finger onto a surface. These are typically invisible to the naked eye and require forensic methods like specialized lighting, chemical treatments, or powders to be seen. Sometimes, when a latent print is readily visible without processing, it's considered to be a patent print. Latent prints are often incomplete and vary in clarity, as they're left unintentionally. In contrast, a patent print or a visible print is a deliberate recording of a fingerprint onto a surface that provides good contrast, such as a fingerprint card. This can be done using traditional ink, chemical methods, or digital scanning systems. Lastly, a plastic print or a 3-d cast is formed when a finger presses into a soft material like wax or clay, leaving a three-dimensional imprint of the ridge pattern (3). Over time, methods for developing and recovering latent prints have been developed. In recent years, advancements in latent print processing have introduced new dimensions, transforming the fingerprint identification field. For developing the latent fingerprints, we use two methods physical methods and chemical method. In the past, the most widely used techniques for developing latent prints included powder dusting, ninhydrin spraying, iodine fuming, silver nitrate soaking, cyanoacrylate fuming, and amido black, among others. Fingerprint powders can generally be divided into four main types: regular, luminescent, metallic, and thermoplastic (4). Regular fingerprint powders usually consist of a resinous polymer for adhesion and a colorant for enhanced visibility. The adhesive interacts with the moisture and oils present in sweat residues through a pressure differential, while the colorant attaches to the adhesive. Common adhesives used in fingerprint powders include starch, kaolin, rosin, and silica gel. The colorant can be either an inorganic salt or an organic compound (5). Luminescent powders are substances that emit light when stimulated by external energy sources like ultraviolet (UV) light, electric fields, or heat. These powders are composed of substances that undergo a process called luminescence, where they absorb energy and re-emit it as visible light. Common luminescent powders include phosphors, which are typically made from inorganic compounds such as zinc sulfide or strontium aluminate. These materials are widely used in various applications, including glowin-the-dark products, display technologies, and safety signage. The color and intensity of the emitted light depend on the chemical composition and structure of the luminescent material, as well as the type of energy it absorbs (6). Metallic powders are finely ground particles of metals that are used in a variety of industrial and manufacturing processes. These powders are typically produced through methods such as atomization, grinding, or chemical reduction, and they are essential in industries such as powder metallurgy, additive manufacturing, and coating applications. Metallic powders are valued for their ability to be moulded into complex shapes and structures, allowing for the production of parts with specific mechanical properties and reduced waste compared to traditional machining. They are commonly made from metals like aluminum, copper, iron, and titanium, and their size, distribution, and surface characteristics can be carefully controlled to meet the requirements of specific applications (7). Thermoplastic powders are fine, granular forms of thermoplastic polymers that become mouldable or flowable when heated and solidify upon cooling. These powders are widely used in processes like powder coating, Selective Laser Sintering (SLS), and additive manufacturing, where precise control over material deposition is essential. Common thermoplastic powders include materials such as polyethylene, polypropylene, polyamide (nylon), and polystyrene, each offering distinct advantages depending on the specific application (8). In the book titled " Advances in Fingerprint Technology, Second Edition " authored by " Henry C. Lee, Robert Ramotowski, R. E. Gaensslen" during the year "2001" reported the composition of various powders as like mentioned below (4):

Black Fingerprint Powder Formulas

Ferric oxide powder

Black ferric oxide	50%
Rosin	25%
Lampblack	25%

Manganese dioxide powder

Manganese dioxide	45%
Black ferric oxide	25%
Lampblack	25%
Rosin	5%

Lampblack powder

Lampblack	60%
Rosin	25%
Fuller’s earth	15%

White Fingerprint Powder Formulas

Titanium oxide powder

Titanium oxide	60%
Talc	20%
Kaolin lenis	20%
Chalk-titanium oxide powder	
Chalk	15%
Kaolin lenis	15%
Titanium oxide	70%

Gray Fingerprint Powder Formulas

Chemist gray powder	
Chemist gray	80%
Aluminum powder	20%
Lead Carbonate Powder	
Lead carbonate	80%
Gum arabic	15%
Aluminum powder	3%
Lampblack	2%

Chemical fuming techniques:

The iodine fuming method is a commonly employed technique for revealing latent fingerprints on non-porous surfaces. This process involves heating or sublimating iodine crystals, which release iodine vapors that bind to the oils and fatty acids in the fingerprint residue. The iodine forms a temporary yellowish-brown stain on the print, which can be visualized and photographed. This method is particularly useful for fingerprints on surfaces like glass, plastic, or metal. However, the developed print fades quickly, so it often requires immediate documentation or fixation (9).

Silver nitrate is another chemical technique used to enhance latent fingerprints, particularly on porous surfaces like paper. When applied, silver nitrate reacts with the chloride in sweat residues, resulting in the formation of silver chloride. The silver chloride is then exposed to ultraviolet light, which causes it to darken, revealing the fingerprint pattern. This technique is effective for detecting prints on surfaces that cannot be treated with other methods, though it requires careful handling due to the sensitivity of silver nitrate to light and the potential for staining. Iodine fuming and silver nitrate are both essential techniques in forensic investigations, providing complementary methods for revealing latent prints on various surface types (10).

The cyanoacrylate method, commonly referred to as superglue fuming, is a popular technique for revealing latent fingerprints on non-porous surfaces. During this process, cyanoacrylate vapors are heated and then allowed to react with the fingerprint residue. The vapours polymerize when they come into contact with the oils and moisture in the print, forming a white, visible polymer coating over the ridge patterns. This technique is especially effective for surfaces such as plastic, metal, or glass. The developed prints can then be further enhanced through various staining or imaging methods (11).

The ninhydrin method is frequently employed to reveal latent fingerprints on porous surfaces like paper or cardboard. Ninhydrin reacts with the amino acids in fingerprint sweat residues, resulting in the formation of a purple-blue color called Ruhemann's purple. This reaction makes the fingerprints visible and can be photographed for analysis. Ninhydrin is particularly useful for prints that are older or faint, as it can be applied to a variety of porous materials without requiring specialized equipment. While the process is effective, it can take time to fully develop the prints and requires careful handling to avoid premature exposure to light (12).

Amido Black is a chemical dye frequently used in forensic science to reveal latent fingerprints on various surfaces, especially porous materials like paper, fabric, or wood. It interacts with the proteins in fingerprint residues, producing a dark blue-black color that enhances the visibility of the fingerprint patterns. The technique is especially effective for detecting older or faint prints, as Amido Black binds to the proteins, enhancing contrast and allowing for easier visualization. After application, the stained fingerprints can be photographed and analyzed. This method is widely used in crime scene investigations due to its ability to reveal prints that may otherwise be undetectable using other techniques. However, it is important to note that Amido Black can also stain other materials, so care must be taken during its application (13).

Once the latent Fingerprints are developed using powder techniques, they have to be lifted and preserved. As reported, there exist various methods of lifting of developed fingerprints such as Tape lifting, by use of Hinge lifters and gel-lifters. Firstly, the most straightforward and common method for preserving visible prints is high-quality photography. Proper lighting techniques (such as side lighting or backlighting) help to enhance the details of the fingerprint (14). A widely used and simple technique for lifting fingerprints involves the use of specialized adhesive tape. This method works particularly well for capturing prints from smooth, non-porous surfaces like glass, plastic, or metal (15). Gel lifters are an effective technique for lifting fingerprints, especially from rough or uneven surfaces. The gel adheres gently to the print without damaging or distorting it. To lift a print, the gel lifter is pressed over the fingerprint, allowing it to pick up the details. Once the print is secured, the gel is carefully removed and placed onto a contrasting background for preservation and analysis. This method is ideal for delicate or irregular surfaces where traditional adhesive tape may not work as effectively (16). Hinge lifters are commonly used in fingerprint preservation, particularly for prints on smooth surfaces. This method involves placing a transparent adhesive sheet onto the fingerprint, followed by a hinged backing card. The adhesive sheet captures the fingerprint without distortion, and the backing card provides support during the lifting process. Once the print is secured on the adhesive sheet, the lifter is carefully closed, preserving the fingerprint for further analysis. Hinge lifters are especially useful when prints need to be stored and transported safely without damage (17).

Here in this paper, we investigate a novel method for preserving the fingerprints that are developed using powder method by employing BADGE (bisphenol A diglyceride epoxy) based epoxy resins.

Epoxy resin is a polymer commonly utilized across various industries because of its strong adhesive qualities and versatility. It is a two-component system, made up of a resin and a hardener, which, when combined, undergo a chemical reaction that results in the creation of a solid and durable material. Epoxy resins are often utilized in applications such as coatings, adhesives, electrical components, and even crafting projects, including the making of badges. When used in the creation of badges, epoxy resin can provide a glossy finish, added durability, and protection to the design. It can be poured over custom artwork or designs, creating a domed effect that enhances both the visual appeal and the longevity of the badge. The resin also serves as a protective layer against scratches, UV rays, and moisture, making badges made with epoxy resin long-lasting and resistant to wear (18). The diglycidyl ether of bisphenol-A (DGEBA) is produced by reacting epichlorohydrin with bisphenol-A using a basic catalyst. The characteristics of DGEBA resin are determined by the number of repeating units in its molecular structure. Molecules with lower molecular weight generally exist as liquids, whereas those with higher molecular weight tend to be more viscous, either in liquid or solid form. Yang et al. developed a low-viscosity epoxy resin by reacting polyethylene glycol with DGEBA. This resin was cured using a cationic photo initiator under UV light, achieving a curing degree of over 90% within 40 seconds. They also created high-molecular-weight epoxy resins by modifying natural oils and combining them with bisphenol A or bisphenol A-based resins, resulting in highly viscous liquid products (19).

Epoxy resins containing both phosphorus and silicon were developed by combining phosphorus diol and silicon diol with bisphenol A-based epoxy resins. These modified resins exhibited tailored glass transition temperatures ranging from 77°C to 159°C, exceptional thermal stability (above 320°C), and high char yields when exposed to 700°C in an air atmosphere. The improved char yield was attributed to the synergistic interaction between phosphorus, which promoted char formation, and silicon, which helped protect the char from thermal degradation. Moreover, the epoxy resins demonstrated excellent flame retardancy, as indicated by a high limiting oxygen index (LOI) value of 42.5 (20).

The widespread interest in epoxy resins stems from the vast range of chemical reactions and materials that can be employed during the curing process, leading to a variety of distinct properties. Epoxy resins have unique chemistry compared to other thermosetting resins. Unlike formaldehyde-based resins, epoxy resins do not release volatile compounds during curing. As a result, they require minimal pressure during fabrication processes. Additionally, their shrinkage is significantly lower than that of vinyl polymerization used in unsaturated polyester resins, reducing stress in the final product. Moreover, understanding the chemistry behind epoxy resins allows for curing over a broad temperature range and offers the ability to control the extent of crosslinking (18).

METHODOLOGY

a) Latent Fingerprint Deposition

A latent fingerprint was deposited on a non-porous substrate after rolling the fingers over the face and forehead to collect enough oily residues. The deposited fingerprint was developed using contrast colour powder based on the surface; in this case it was a black surface, white powder was employed.

b) Preparation of resin and preservation of [powder developed fingerprint

A well-ventilated area with a flat surface was chosen. The resin and the hardener were taken in a 3:1 ratio, placed in a clean cup, and mixed thoroughly using a silicone spatula. The developed latent fingerprint was placed on a hexagon-shaped silicone mould, and the prepared resin mixture was carefully poured over the mould containing the developed prints, ensuring no air bubbles formed. The mould was then left undisturbed for 24 hours in a dust-free area to achieve better results. The entire procedure was carried out with the use of appropriate personal protective equipment (PPE) to prevent direct contact with the resin. The lifted powder developed fingerprints are shown in figure 1 and the closeup image of the prints showing the clarity of fingerprint ridges (minutiaes') are depicted in figure 2:

Figure 1. Lifted and preserved powder developed fingerprints using BADGE based resin.

Figure 2. Clarity of fingerprint ridges and minutiaes' in the lifted fingerprint using BADGE based resin.

RESULTS

This novel method for lifting and preserving the powder developed latent fingerprints gave high quality results in terms of clarity and durability. The uneven lifting nature of fingerprints by tape lifting, hinge lifters and gelatine lifters had been taken over by this method. The lifted prints where durable also and hence will also help in the long-term preservation. The methodology is less tedious and only needs knowledge about preparation of the epoxy resin base. This method can be only implemented for powder developed fingerprints on any plane and horizontal surfaces.

CONCLUSION

In this study we introduced a novel BADGE-based resin as an advanced method for the long-term preservation of powder-developed latent fingerprints. The resin demonstrated excellent performance in maintaining fingerprint detail and clarity, offering enhanced protection against environmental and physical damage. The use of BADGE (bisphenol A diglycidyl ether) resin significantly improved the durability of the preserved prints, preventing degradation over time. The findings suggest that this approach provides a reliable and efficient solution for preserving fingerprint evidence, ensuring it remains intact for future analysis. This method holds substantial potential for forensic applications, offering a practical alternative to conventional preservation techniques. Further investigations could optimize the resin's formulation and assess its effectiveness with various fingerprint powders and in diverse conditions, paving the way for more robust fingerprint evidence handling and storage in criminal investigations.

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