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Introduction

Latent fingermark detection and identification remains a cornerstone of forensic science due to the ease and high volume of recovery (compared to DNA), rapid turn-around time from crime scene to identification, and an ability to be exploited for intelligence or court-driven investigations. Traditional fingermark detection techniques for non-porous surfaces such as powdering, cyanoacrylate fuming, blood enhancement reagents, and chemical detection methods for paper substrates are established, with functional methods available for visualization of latent fingermarks on simple low-background substrates [1]. However, highly reflective, patterned, luminescent, reactive or textured substrates pose a problem for capturing clear images of enhanced fingermarks. Attempts to overcome these issues through the use of next-generation luminescent materials or chemical imaging have been met by their own challenges [2-6]. New security features on banknotes, passports, and other identity and security documents are being developed in the same wavelength space as fingermark detection techniques, leading to problems of interference. For example, polymer banknotes (which are becoming increasingly common amongst currencies world-wide) often obstruct fingermark ridge detail throughout the visible and near-infrared spectrum. Consequently, novel methods that solve this problem are needed. Furthermore, all the aforementioned techniques require time and expertise to implement, and leave a visible record of their application, making them unsuitable for covert detection during intelligence and counter-terrorism operations or deployment at rapid-response scenes. This is especially true for porous surfaces that have to be removed from the scene and transported back to the laboratory for treatment [7]. Moreover, it has been estimated that, on porous substrates, around 50% of fingermarks escape detection [8]. Therefore, a large amount of important forensic traces remains unexploited [9]. Research efforts must be maintained, and novel techniques must be found to increase detection sensitivity for such substrates and improve both selectivity and ease of application.

In this context, fingermark lifting techniques can provide an intriguing solution as they are a simple but highly effective method for removing fingermarks from difficult backgrounds or substrates prior to imaging. These techniques are usually confined to gelatin or adhesive tape lifts of powdered (i.e., previously developed) fingermarks. Earlier research – mostly focused on footwear impressions – suggested that lifting materials can be used to transfer a latent mark prior to development on the lifter material [10-14], but this method still requires a chemical enhancement process and carries an innate risk of leaving a scene without recovering fingermarks. Despite the overwhelming advantages posed by reactive fingermark lifters, this area of research remains largely unexplored, with the few published examples not proceeding beyond superficial "proof-of-concept" studies or, in some cases, reporting more effective mechanisms for transferring reagents onto marks, i.e., no lifting [13,15,16].

The approach described herein introduces a new type of fingermark lifter, which provides instantaneous visualization of lifted latent fingermarks on the lifter surface. The underlying detection principle is based on the reaction of either pH-sensitive or amine-reactive substances – immobilized on suitable solid supports such as membranes – with natural chemical components found in fingermark residues (e.g., lactic acid, amino acids, proteins, and amino sugars). The exposure of appropriate reagents to such an environment causes a change in their spectroscopic properties, which can be visualized, depending on the type of reagent, under either ambient (white) light or luminescence conditions.

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Goals and Objectives

Interference from substrate chemistries, background luminescence, and end-user unfriendliness (and sometimes OH&S concerns) are major drawbacks with current fingermark detection methods. This research addressed these collective issues through the development and validation of a novel class of lifting devices.

In particular, this project aimed at generating and validating novel and user-friendly lifter-based fingermark detection techniques that may be applicable in standard police laboratories as well as at crime scenes, and in covert operations. With the latter, onsite techniques need to be rapidly applied, leaving no trace that a detection method has been conducted.

The specific aims of the project were to:

1. Identify, synthesize, and optimize reagents for combined fingermark lifting and instantaneous visualization.

2. Develop and improve strategies for the immobilization of these reagents onto solid supports suitable for lifting purposes.

3. Optimize, test, and validate the newly developed lifting devices for operational application by end-users.

Summary of Research Design and Accomplishments

Fingermarks are composed of natural secretions and exogenous contaminants such as blood, dirt, and cosmetics [17]. There are three types of glands – eccrine, apocrine, and sebaceous – that participate in the production of sweat. However, only two of these, eccrine glands, which are particularly abundant in the palms and soles, and sebaceous glands, including those associated with hair follicles and those found in hairless regions such as the eyelids and lips, significantly contribute to the deposits found in latent fingermarks. About 98-99% of eccrine sweat and anywhere between 20-70% of freshly deposited fingermarks is water [18,19], which contains a variety of water-soluble organic molecules including acids (e.g., lactic acid) that, depending on the sweat rate, cause an overall slightly acidic pH of skin ranging from about pH 4 to 6.5 [20,21]. Human sweat and fingermarks also comprise a number of different amine-containing molecules such as proteinogenic and nonproteinogenic amino acids, peptides, proteins, amino sugars, and ethanolamine [18,22,23].

Ever since Odén and von Hofsten, in 1954, first reported the use of ninhydrin for the visualization of marks on paper, amine-reactive compounds have become commonly used reagents in dactyloscopy [24,25]. In contrast, the overall acidic nature of fingermark deposits has, to the best of our knowledge, never before been exploited for detection purposes.

Realizing that the halochromic and luminescent properties, respectively, of pH indicators and amine-reactive compounds could be exploited for the creation of reactive fingermark lifters, we immobilized such reagents on various types of membranes through simple physical adsorption and tested whether the resulting devices could be used for lifting and visualizing latent marks (Fig. 1-4).

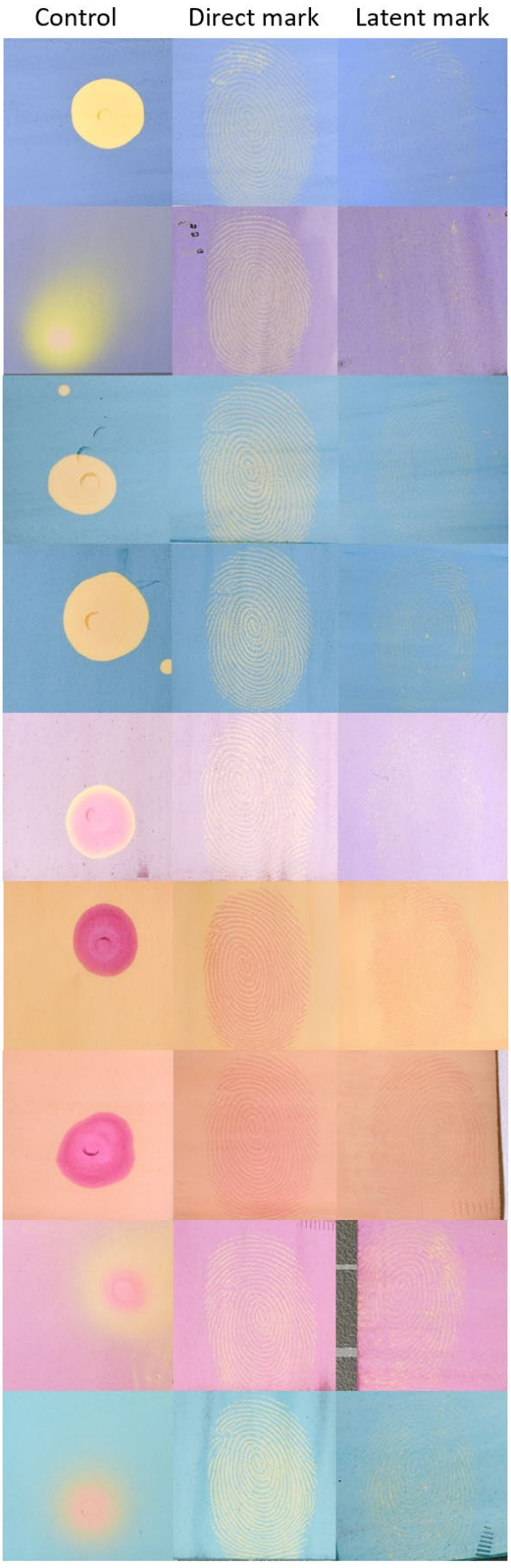

Fig. 1: Functionalized pH-reactive membranes that produced a visual signal upon contact with an index finger as well as a latent fingermark.
Panels show commercially available indicators immobilized on positively charged nylon, followed by contact with a drop of 1 M HCl (left column), an index finger laid directly on the surface (center column), or a latent fresh fingermark deposited onto a glass slide and lifted (right column). Photographs were taken immediately after contact or transfer under ambient light.
From top to bottom, the indicators are bromocresol purple, bromophenol red, bromothymol blue, bromoxylenol blue, cresol red, methyl red, mixed indicator 5, phenol red, and universal indicator.

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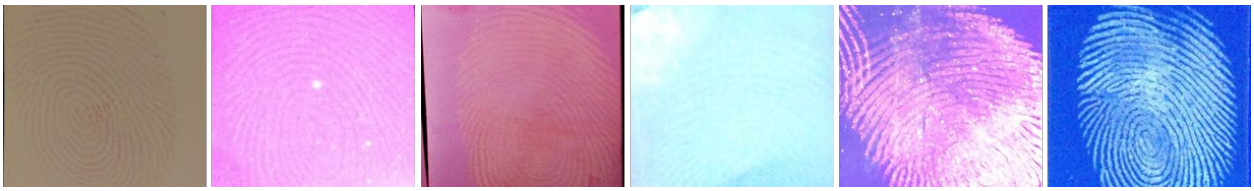

Fig. 2: Fingermarks deposited directly on positively-charged nylon impregnated with amine-reactive indicators. From left to right, ninhydrin, dabsyl chloride, pDMAC, genipin, DFO, and indanedione. All marks were visualized under UV light, except for ninhydrin, which was visualized under ambient white light.

Fig. 3: Fingermarks deposited directly on PVDF impregnated with amine-reactive indicators. From left to right, fluorescamine, genepin, and lawsone. All marks were visualized under UV light.

Fig. 4: Marks lifted from glass using membranes functionalized with, from left to right, DFO, indanedione, and fluorescamine. DFO and indanedione were immobilized on positively-charged nylon, fluorescamine on PVDF. Visualization was under UV light.

Several commercially available pH indicators and amine-reactive compounds were found to be suitable for creating lifters that enable detection not only of directly deposited but also of lifted latent marks. For the latter, lifters had to be pressed onto the substrate for only a few seconds to achieve visualization of the (negative) marks on the lifter surface.

Of the pH-reactive indicators shown in Fig. 1, overall, phenol red (phenolsulfonphthalein) gave the strongest signal and, therefore, was selected as a model compound for further investigations. This compound not only displays an easily recognizable color change from pink to yellow under ambient light when exposed to acids, but likewise changes its luminescent properties. This allows visualization of fingermarks also under luminescent conditions, which increases sensitivity. Depending on the excitation wavelength used for visualization under luminescent conditions, marks lifted with phenol red-impregnated membranes display a “black and white reversal” (Fig. 5), which is due to the spectral properties of this indicator [26].

Fig. 5: Directly deposited fingermarks on a phenol red lifter illuminated using (left) an excitation wavelength of 450 nm combined with a 555 nm bandpass barrier filter (BBF) and (right) excitation at 555 nm and observed with a 610 nm BBF.

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Another pH-sensitive indicator that was found to be suitable for fingermark detection is the luminescent indicator 8-hydroxypyrene-1,3,6-trisulfonic acid trisodium salt, which is also known under the name pyranine [27]. Like phenol red, it displays a "black and white reversal" depending on the conditions used for illumination (Fig. 6) and was selected for further investigations.

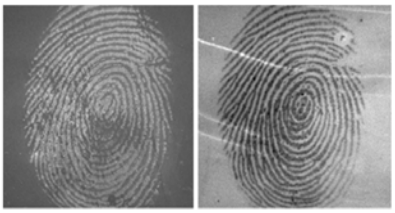

Fig. 6: Fresh fingermarks lifted from glass using pyranine-impregnated positively-charged nylon, visualized under (left) 350 nm excitation coupled with a 450 nm BBF, and under (right) 475 nm excitation coupled with a 550 nm BBF.

Of the amine-reactive reagents, fluorescamine showed the best signal-to-noise ratio in combination with the transferred marks being long-lasting and was, therefore, selected as another model compound. Membranes impregnated with any of the three model compounds were attached to a silicone backing to facilitate handling and minimize the risk of inadvertently touching the reactive lifter surface.

Fig. 7 presents examples of latent natural marks lifted from a variety of different substrates using lifters impregnated with the pH indicator phenol red.

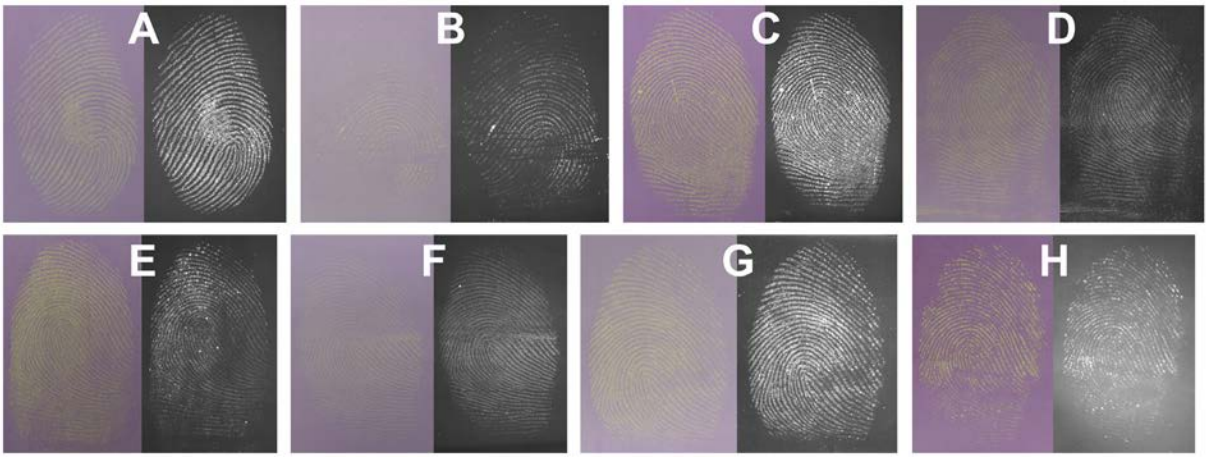

Fig. 7: Natural fingermarks lifted from A) a plastic water bottle, B) a wooden door frame, C) aluminum foil, D) a plastic computer keyboard, E) a glossy magazine cover, F) a glass iPad screen, G) printer paper, and H) an Australian $5 polymer banknote using phenol red-impregnated membrane lifters. The left side of each panel shows visualization of the mark under ambient white light, while the right side of each panel shows visualization using an excitation wavelength of 445 nm coupled with a 550 nm BBF. Marks shown in panels A-F were 1 hour old when lifted, whereas marks shown in panels G and H were lifted immediately after deposition.

While marks lifted with either phenol red- or pyranine-impregnated membranes could be visualized over an extended period using the same visualization conditions, it was found that marks on fluorescamine-functionalized membranes change their spectral properties with time. It is known that fluorescamine can react with various types of nucleophiles, forming products that may differ in their spectral properties and whose luminescence intensity is pH-dependent [28]. However,

several illumination conditions were identified that allow visualization of marks lifted from various substrates. It was found that the strongest luminescence was obtained when marks lifted with fluorescamine-impregnated membranes are developed for at least 4 hours before visualization. Fig. 8 shows examples of one-hour-old fingermarks that were successfully lifted from painted ceramic tile, textured polypropylene, LDPE Ziploc bags, borosilicate microscope slides, aluminum foil, and holographic cellophane gift wrap.

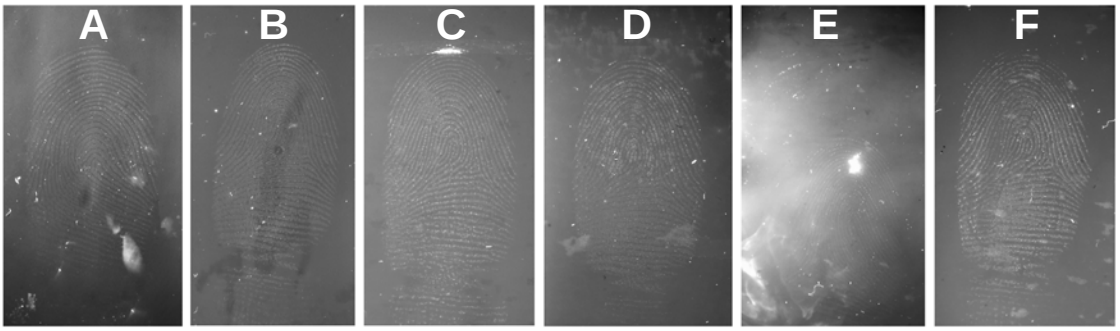

Fig. 8: Natural, one-hour-old fingermarks lifted from A) aluminum foil, B) ceramic, C) cellophane, D) borosilicate glass, E) textured polypropylene, and F) LDPE using fluorescamine-impregnated lifter membranes and visualized with either 350 nm or 550 nm excitation coupled with a 555 nm BBF.

Both phenol red- and fluorescamine-based membrane lifters allowed lifting of marks from paper (see Fig. 7G and Fig. 9). However, natural marks could only be successfully visualized when they were fresh. Charged marks, though, could still be lifted and visualized when they were a few days old (Fig. 9C).

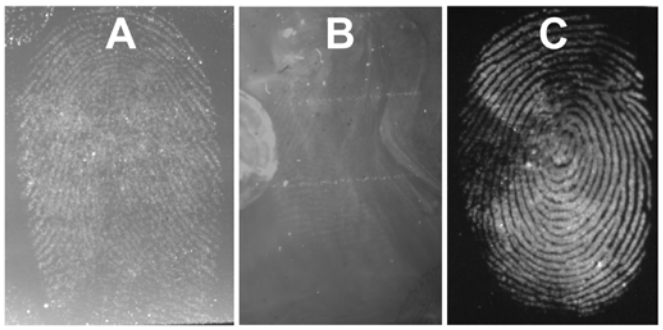

Fig. 9: Fingermarks lifted from copy paper with A) a phenol red lifter and fluorescamine lifters (B and C) after aging for one hour (A,B) and four days (C). Marks in A) and B) were natural, while the mark in C) was charged and deposited after physical exercise. Visualization was achieved with 450 nm (A) or 350 nm (B,C) excitation coupled with a 555 nm BPF.

It is noteworthy that besides the aforementioned “off-the-shelf” pH indicators, other pH-sensitive reagents were investigated for their utility to enable fingermark detection. This includes several “lysosensors” that have found wide application in cytology for the localization and pH-determination of acidic organelles such as lysosomes [29], as well as synthetically produced BODIPY-derivatives [30]. While some of these compounds were capable of visualizing marks, the observed signal intensity was significantly lower compared to that obtained with either phenol red or pyranine. Even though lysosensors are commercially available, they are quite expensive. Similarly, the in house-synthesis of BODIPY-derivatives proved to be unreasonably costly and labor-intensive. For these reasons, these compounds were abandoned.

Also, other methods for the immobilization of pH-sensitive or amine-reactive compounds onto membranes were not further pursued after initial investigations (e.g., on the covalent

immobilization of derivatives of ninhydrin) did not show any advantages of such methods over simple physical adsorption. Likewise, incorporation of these compounds in natural polymers (e.g., gelatin or agarose) or synthetic polymers was intensely examined. Although some promising results were obtained, the quality of visualized marks did not exceed that observed with membrane lifters, and the production of these devices was time- and labor-intensive. Physical adsorption of pyranine or phenol red onto positively-charged nylon (at 0.1 mg/mL and 0.2 mg/mL, respectively, in a 2 mM solution of NaOH in 50% ethanol), and of fluorescamine onto PVDF (at 0.1 mg/mL in a 90:10 mixture of acetone and water) was found to be the significantly most straightforward and cost-effective way of producing these lifters. In addition, lifters produced in this manner did not show any significant transfer of indicator onto the substrate (Fig. 10), which is a particularly desirable property for covert operations.

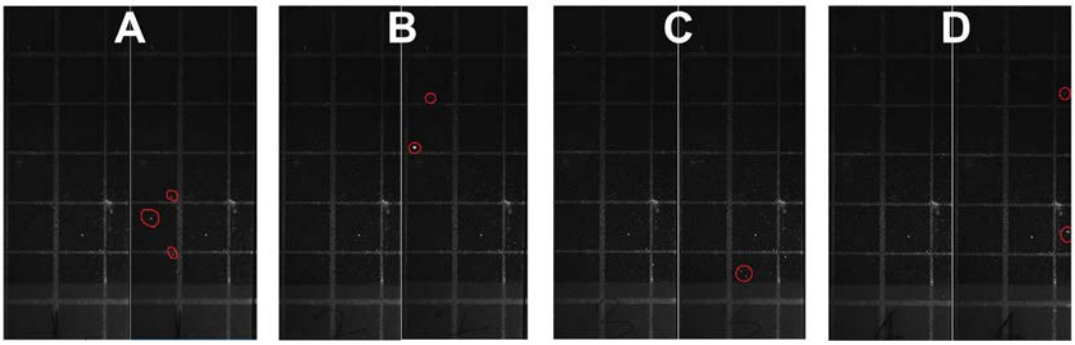

Fig. 10: Glass microscope slides assessed for transfer of phenol red from lifters onto the substrate. Fingermarks were deposited on the slides and lifted with a phenol red lifter. Shown are four separate experiments (A-D) with the glass slides shown prior to lifting on the left and after lifting on the right. Fluorescent spots appearing after the lifting event are marked by red circles, but these are believed to be caused by environmental surface contamination such as dust particles. Images were recorded under 450 nm excitation in combination with a 555 nm BBF.

Additional tests including comparative and pseudo-operational studies were performed to investigate the effect of factors such as the age of fingermarks, the pressure with which they are deposited, and depletion series on the quality of lifted marks. Furthermore, it was assessed as to whether sequencing is possible, i.e., if the membrane lifters can be combined with subsequently applied fingerprint methods, such as powder dusting and cyanoacrylate fuming, or DNA-detection techniques.

It was found that pressure has a significant effect. This is exemplified in Fig. 11, which shows results obtained in a study in which the effect of the amount of force exerted during fingermark deposition was assessed. Instant retraction of the finger from the substrate leads to the deposition of poor latent fingermarks due to insufficient transfer of skin surface matter. Increased pressure and contact time between the finger and the substrate, however, transfers enough skin matter onto the substrate to yield a clear fingermark.

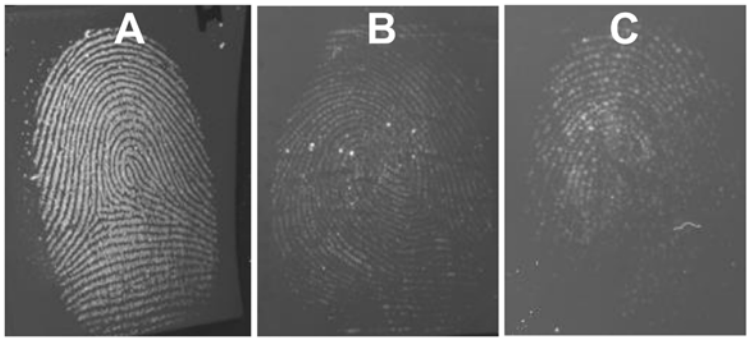

Fig. 11: One-hour-old fingermarks lifted from glass using phenol red-based membrane lifters. Marks had been deposited on glass with A) heavy, B) moderate, or C) light pressure. Visualization was performed using 450 nm excitation in combination with a 555 nm BBF.

Marks deposited with sufficient pressure can, furthermore, be visualized with good clarity after aging for extended periods of time as seen in Fig. 12, which shows a comparison of pyranine lifters with commercial black gelatin lifters. Moreover, depletions were found to have a minimal impact on lifter performance (Fig. 13).

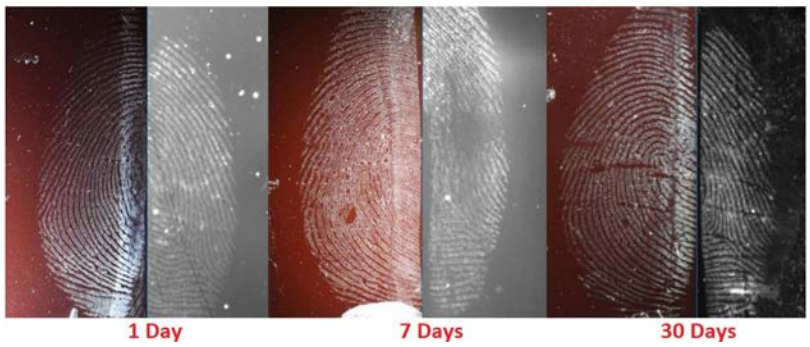

Fig. 12: Natural, split fingermarks aged 1 day (left), 7 days (center), and 30 days (right), lifted from painted ceramic using either black gelatin lifters (left half of each fingermark) or pyranine lifters (right half). Marks on gelatin lifters were visualized under oblique white light, and marks on pyranine lifters under 350 nm excitation coupled with a 450 nm BBF.

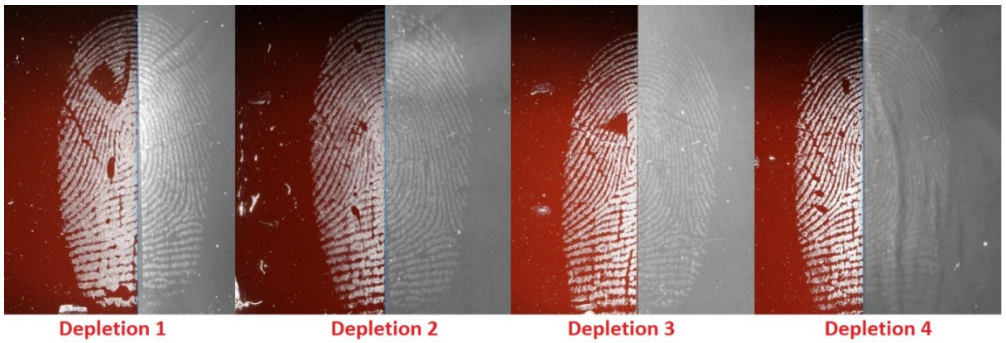

Fig. 13: Depletion series of natural, one-day-old split fingermarks, lifted from glass with black gelatin lifters (left half of marks) or phenol red lifters (right half). Marks on gelatin lifters were visualized under oblique white light, and marks on phenol red lifters under 450 nm excitation coupled with a 555 nm BBF.

The quality of visualized marks was found to heavily depend on whether fingermarks were from good, average, or poor donors (Fig. 14). This is not surprising as the effectiveness of such lifters is directly linked to the amount of fingermark residue deposited. This, in turn, is in agreement with the aforementioned dependence on applied pressure (Fig. 11).

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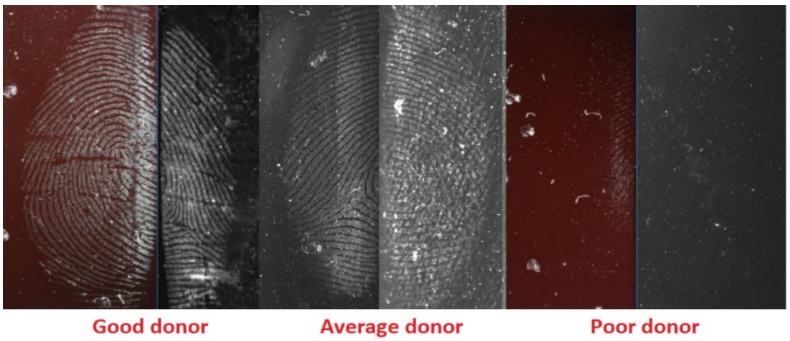

Fig. 14: Thirty-day old natural, split marks from different donors, lifted from painted ceramic with gelatin lifters (left half of fingermarks) and pyranine lifters (right half). Marks on gelatin lifters were visualized under oblique white light, and marks on pyranine lifters under 350 nm excitation coupled with a 450 nm BBF.

While both the novel pH-sensitive and amine-reactive lifters generally performed poorer with regard to the overall quality of visualized marks when compared to commercially available black gelatin lifters, it was found that they may have some advantage in sequencing experiments. That is, when fingermarks were visualized on the substrate using powder-dusting or cyanoacrylate fuming after pH-sensitive or amine-reactive lifters had been applied, typically, greater ridge detail was obtained compared to marks that had first been lifted with black gelatin lifters (Fig. 15). It can be hypothesized that the gelatin lifters – due to their adhesive surface characteristics – leave less fingermark residue behind on the substrate, which impairs further sequencing techniques. The novel pH-sensitive and amine-reactive membranes, on the other hand, appear to leave behind a greater portion of the originally deposited residue.

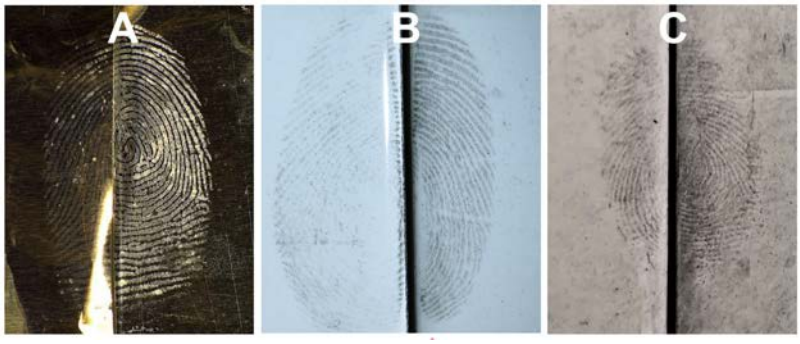

Fig. 15: Natural, split marks were first lifted from aluminum foil (A) or ceramic (B,C) using gelatin lifters (left half of all marks), a phenol red lifter (right half of mark in panel A), a pyranine lifter (right half in panel B), or a fluorescamine lifter (right half in panel C) and then visualized on the substrate using cyanoacrylate fuming (A) or black powder (B,C).

Additional sequencing experiments indicated that the novel lifters may also be combined with DNA-detection techniques. Substrates swabbed following the application of phenol red-impregnated membrane lifters yielded amounts of DNA sufficient for allele detection. Interestingly, DNA could also be detected on the lifters themselves. However, the amounts were much lower than those recovered from swabs (0.3 ng vs. 1.5 ng, on average). Furthermore, it could not be conclusively determined whether the DNA stemmed from the donor or possible contaminations.

It is important to note that the performance of these novel lifters strongly depends on some residual moisture that needs to be retained on their surface after production. Typically, lifters were packaged in vacuum-sealed plastic pouches and stored at room temperature. However, it was found that the available vacuum-sealing equipment did not produce consistent seals, which resulted in a significant variation in lifter performance. Fig. 16 shows, as an example, results of two studies ("Study I" and "Study II," respectively) – performed with different batches of amine-sensitive fluorescamine lifters – that investigated the effect of depletion series in comparison to commercial

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black gelatin lifters. Note that, for these studies, the UC comparative scale (Table 1) was used to assess all treated fingermarks [31], with method A being the fluorescamine lifters and method B being black gelatin lifters. As such, negative comparative scores indicate that, on average, the black gelatin lifters outperformed the fluorescamine lifters.

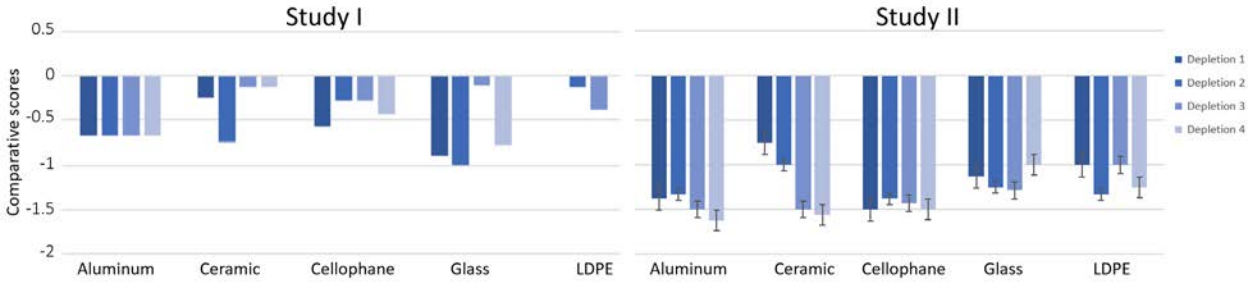

Fig. 16: Results obtained in two studies ("Study I," left, and "Study II," right) where different batches of fluorescamine lifters were compared with black gelatin lifters regarding the effect of depletion series on the quality of marks lifted from various substrates. The experimental approach was the same for both studies with the exception that only one assessor evaluated the results of the first study ("Study I") whereas three assessors evaluated the results of the repeat study ("Study II") and the median of their scores was taken as the final score.

Table 1: Outline of the UC grading scheme [31].

Score	Definition
+2	Half-impression developed by method A exhibits far greater ridge detail and/or contrast than the corresponding half-impression developed by method B
+1	Half-impression developed by method A exhibits slightly greater ridge detail and/or contrast than the corresponding half-impression developed by method B
0	No significant difference between the corresponding half-impressions
-1	Half-impression developed by method B exhibits slightly greater ridge detail and/or contrast than the corresponding half-impression developed by method A
-2	Half-impression developed by method B exhibits far greater ridge detail and/or contrast than the corresponding half-impression developed by method A

While the performance of the fluorescamine lifters in "Study I" (with UC values ranging between 0 and -1) was comparable to that of commercially available black gelatin lifters, results were poorer with the batch of lifters used in "Study II" (with most UC scores lying between -1 and -2). Considerable batch-to-batch and lifter-to-lifter variations are suspected to have negatively impacted not only comparative but also pseudo-operational studies, where a readiness for operational application of the pH-sensitive or amine-reactive lifters could – as of now – not be established.

Several approaches were pursued to maintain or regain an optimal amount of moisture on the lifter surface. This included remoistening dry lifters with ethanol before use. However, lifters "rejuvenated" in this way need to be dried for a few minutes before they yield optimal results, which is inconvenient for field applications by end users and requires experience to obtain an ideal moisture level on the lifter surface. Covering membrane lifters with a hydrogel such as agarose before packaging in evacuated pouches was found to allow storage and "out-of-the-box" use for several months (Fig. 17), but this method did not yield consistent results and will require further optimization, such as finding the optimal storage temperature.

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Fig. 17: Three-week-old, charged fingermark lifted from glass using a phenol red-impregnated membrane lifter that had been stored for two months with a hydrogel cover in a vacuum-sealed pouch. The hydrogel consisted of 5% agarose in 2 mM NaOH containing 0.1% benzalkonium chloride as a preservative.

More recently, promising results were obtained with airtight containers and simple "humidors" (Fig. 18). The latter were produced by placing super-absorbent sodium polyacrylate beads (that had been swelled either in water or in basic solutions of varying pH values) in an airtight box. It was found that within 30 minutes the relative humidity in such boxes reaches values of 80-90% and is maintained for extended periods of time, allowing out-of-the-box use of membranes stored in such containers.

Fig. 18: Fresh, natural fingermark lifted from glass with a phenol red-impregnated membrane. The membrane had been stored in an airtight container in the presence of sodium polyacrylate beads (previously swelled in water) for one year before use. Visualization was achieved under ambient white light (left) and under 445 nm excitation combined with a 550 nm BBF (right), respectively.

Further research, though, is required to assess whether this form of storage will lead to more consistent results, and to determine if readiness for operational use of pH-sensitive and/or amine-reactive lifters can eventually be established.

Conclusions

This study demonstrated that the immobilization of appropriate pH-sensitive or amine-reactive compounds onto suitable solid supports can yield fingermark lifters, which allow instantaneous, on-the-spot visualization of marks without leaving behind signs of their application. While several compounds and synthetic techniques were investigated to fabricate such lifters, simple adsorption of commercially available indicators onto membranes proved to be the most cost-effective approach. Lifters impregnated with phenol red, pyranine, or fluorescamine, in particular, were shown to allow detection of marks of varying ages and from many different substrates. Comparative studies showed that these lifters can, under ideal conditions, produce results close to those obtained with commercial black gelatin lifters. However, the requirement of a certain degree of residual moisture on their surface represents a significant challenge, which needs to be overcome before these novel lifters are ready for operational evaluation. Several storage methods were examined for their utility to allow out-of-the-box use of the lifters. Of those, vacuum-sealing appears to be the most straightforward option. Despite the fact that, due to equipment limitations, this method did not yield consistent results in this study, there is no reason why, with industrial-

level materials, it should not be possible to package lifters in a way that the necessary level of moisture is retained. Also, the incorporation of moisture-retaining hydrogels in the packaging promises to facilitate the application of the lifters by end-users and yield more consistent results. While the lifters, at the current stage, do not possess any advantages over established detection techniques for routine applications, they have the potential to be of use for specialized applications such as covert operations.

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Products and Dissemination

- A. Mlakar, S. Armen, S. Moret, X. Spindler, C. Lennard, C. Roux, and O. Hofstetter, "On-the-Spot Reactive Lifters for Field-Based Latent Fingermark Detection," oral presentation at the International Fingerprint Research Group Biennial Meeting, June 24-29, 2019, Sheffield, UK.
- O. Hofstetter, A. Mlakar, S. Armen, S. Moret, X. Spindler, C. Lennard, and C. Roux, "Next-Generation Fingermark Lifters with Instant Visualization Capability," oral presentation at the 3rd Annual National Institute of Justice Forensic Science Symposium at PITTCON 2020, Pittcon and The Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, March 2, 2020, Chicago, IL.
- O. Hofstetter, A. Mlakar, S. Armen, S. Moret, X. Spindler, C. Lennard, and C. Roux, "Next-Generation Fingermark Lifters with Instant Visualization Capability," oral presentation at the Northern Illinois Research Foundation meeting, March 4, 2020, Hoffman Estates, IL.
- O. Hofstetter, A. Mlakar, S. Armen, H. Soni, S. Moret, X. Spindler, C. Lennard, and C. Roux, "Next-Generation Fingermark Lifters with Instant Visualization Capability." This contribution was accepted as a poster to be presented at the 23rd Triannual Meeting of the International Association of Forensic Sciences (IAFS 2020) in Sydney, Australia, September 21-25, 2020. However, due to the COVID-19 pandemic, the meeting was eventually rescheduled for the year 2023.
- A. Mlakar, S. Armen, H. Soni, A. D. Feliciano, X. Spindler, S. Moret, D. McNevin, C. Lennard, C. Roux, and O. Hofstetter, "pH-Sensitive Lifters for On-The-Spot Visualization of Latent Fingermarks," manuscript to be submitted.
- O. D. Hofstetter; A. Mlakar; C. Roux; X. Spindler; C. Lennard, "Fingermark Lifting and Visualization Device and Methods of Use." U.S. Patent 10,866,188 issued December 15, 2020. This patent application is considered Background IP, as the invention was both conceived and first actually reduced to practice before the start date of this grant. It, therefore, does not qualify as subject invention.

Participants and Other Collaborating Organizations

Northern Illinois University (NIU)

- Oliver Hofstetter (PI). Prof. Hofstetter was in charge of all scientific and administrative aspects of this project and supervised the Research Assistants at NIU.
- Andrei Mlakar (Research Assistant). Mr. Mlakar worked under Prof. Hofstetter's supervision on the preparation of pH-sensitive and amine-reactive reagents and their immobilization onto and incorporation into suitable solid supports. He also performed the initial evaluation of such devices to determine if they are useful for instantaneous lifting and visualization of latent fingermarks. Mr. Mlakar, furthermore, prepared all membranes shipped to and used by the collaborators at the University of Technology Sydney.
- Andrew Feliciano (Research Assistant). Mr. Feliciano participated in the testing of pH-sensitive lifters and the development of storage conditions.

University of Technology Sydney (UTS)

- Claude Roux (Collaborator). Prof. Roux provided his expertise in fingermark detection and was in charge of all administrative aspects at UTS and the overall supervision of UTS personnel participating in this project.
- Xanthe Spindler (Collaborator). Dr. Spindler provided her expertise in fingermark detection and oversaw the Research Assistants working at UTS.
- Sébastien Moret (Collaborator). Dr. Moret provided his expertise in fingermark detection and oversaw the Research Assistants working at UTS.
- Dennis McNevin (Collaborator). Prof. McNevin assisted with his expertise in DNA collection and analysis.
- Sam Armen (Research Assistant). Mr. Armen worked on the evaluation of pH-sensitive and amine-reactive lifters under laboratory conditions.
- Heli Soni (Research Assistant). Dr. Soni worked on the evaluation of pH-sensitive and amine-reactive lifters under laboratory and pseudo-operational conditions. She also investigated the sequencing capability with DNA-detection methods.
- Georgina Meakin (Collaborator). Dr. Meakin assisted with DNA collection and analysis.

Western Sydney University

- Chris Lennard (Collaborator). Prof. Lennard provided his expertise in fingermark detection.

Other Collaborators

- Della Wilkinson (Practitioner Partner; Royal Canadian Mounted Police's Integrated Forensic Identification Services). Dr. Wilkinson provided valuable feedback and a practitioner's perspective.
- Glenn Langenburg (Practitioner Partner; Elite Forensics Services, LLC). Dr. Langenburg provided valuable feedback and a practitioner's perspective.
- Rudolf Viereckl (Collaborator; Rahn USA Corp.). Mr. Viereckl worked with Mr. Mlakar on the incorporation of pH-sensitive and amine-reactive-compounds into synthetic polymers.
- Sean Des Roches (Collaborator; Rahn USA Corp.). Dr. Des Roches provided his expertise in polymer chemistry.