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Improvement in Latent Fingermark Detection on Thermal Paper using 5,6-Dimethoxy-1,2-indandione/PVP

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Abstract

A new method for improvement of 1,2-indandione-treated latent fingermarks on thermal paper will be described in this paper. Treatment with conventional techniques like ninhydrin in petroleum ether or DFO solution produces a black color on the thermosensitive side of thermal paper. The new method using 5,6-dimethoxy-1,2-indandione with polyvinyl pyrrolidone (PVP) can reduce this dark staining without removing the thermosensitive layer and parts of the developed fingermarks. An advantage of this method is that the developed fluorescent fingermarks appear in sharp lines and high contrast . The developed fingermarks can be observed when excited in the 535 nm region and using an orange-red goggles. There is no background coloration in this method. In addition, some tests were performed, leading to an optimized working solution, which charges the paper with a minimum of chemicals, is cheap, and enables a large quantity of papers to be treated in a short time and without involving any pre- or post treatment.

Keywords: 5,6-Dimethoxy-1,2-indandione; Polyvinylpyrrolidones; Thermal paper; Latent fingerprint

Introduction

The thermal paper has been extensively used in modern day life, such as fax machines, ATM receipts, store receipts, lotteries, bus tickets etc. For this reason, it is collected as a physical evidence from the crime scene more and more common. However, most thermosensitive surfaces of thermal paper turn black when they come into contact with polar organic solvents or are exposed to high temperature. This black background staining reduces the contrast of the developed fingermarks, often rendering them useless for identification purposes [1]. So, the continuing need for new reagents and methods to develop and visualize latent fingermarks on thermal papers for forensic examination has been well-investigated by forensic science researchers. A desirable attribute of fingermark development techniques is high sensitivity, selectivity, and maximization of the contrast between the developed fingermarks and the background.

In 1991, Takatsu et al. [2] showed that a solution of alkyl analogues of ninhydrin could be used to develop latent fingermarks on thermal paper, but only obtained partial development of the fingermarks [2,3]. Using INON (2-hydroxy-2-(3,5,5-trimethyl-hexyloxy)-indan-1,3-dione) they reduced the blackening of the surface and obtained the better results [2]. By fuming thermal papers with dimethylaminocinnamaldehyde (DMAC) and iodine, Brennan and Jasuja were able to develop clear fingermarks with no background coloration [4,5], although vapor-phase staining method had been known for many years as a general development technique for depositions on paper. To enhance ninhydrin treated latent fingermarks on thermal paper, Schwarz used a solution containing pyrrolidone based compounds referred to as 'G3', to decolorize the blackened paper [6]. The majority of the techniques discussed above suffer from one or more drawbacks such as being complex or cumbersome, some requiring pre- or post treatment, or being less efficient at developing aged fingermarks. In 2010, Schwarz improved the methodology by adding polyvinyl pyrrolidone (PVP) into the solution of ninhydrin and achieved very promising results which there is no black background anymore. No mark of fluorescence has been noted by the purple fingermark developed by ninhydrin. There will be background interference when the developed purple mark was on the printed words [7]. This encouraged us to pursue a method for the development of latent fingermarks on thermal paper solving the problems. Quite recently, we have reported a new DFO/PVP development method that can be successfully applied to develop fresh as well as aged latent fingermarks on thermal paper with no background coloration [8]. 1,2-Indanedione belongs to a class of compounds which have demonstrated great potential in the processing of latent fingermarks. It has been proved to be a viable alternative for the detection of latent fingermarks on porous surfaces, with more fingermarks being developed using this reagent on real samples than both DFO, ninhydrin and a combination of the two reagents. Although the synthesis of

1,2-indanediones had been reported many years ago, these compounds had never been tested before on latent prints until 1997. 1,2-Indanedione was proposed as a fingermark reagent by Ramotowski [9]. Following this discovery, much effort has been devoted to the latent fingermarks development by using 1,2-indanediones. Researchers worldwide have conducted research into the optimization and evaluation of 1,2-indanedione as an adequate reagent for fingermark detection [10-15].

An evaluation of 5,6-dimethoxy-1,2-indandione in latent fingermarks detection began with the work of Almog, et al. [11]. The fluorescence of this new compound was comparable to the best ninhydrin analogs. The fluorescence was significantly enhanced by the subsequent application of a zinc nitrate solution. We envisioned that using the 5,6-dimethoxy-1,2-indandione/PVP system, where the presence of a latent fingerprint was visualized by luminescence, would provide a simple and effective method for latent fingerprint detection on thermal paper. In the current work, the mixture solution of 5,6-dimethoxy-1,2-indandione with PVP was utilized as working solution to detect latent fingermarks on thermal paper. Integrating PVP into a 5,6-dimethoxy-1,2-indandione solution prevents the black staining, and the developed fingermarks appear in clear contrast to the background under the fluorescence conditions.

Using the resultant optimized formulation, performance comparisons were then made. The quality score of developed marks was used to evaluate the effects. The sensitivity, selectivity and stability of the method were also investigated.

Material and methods

Materials

All the solvents (AR grade) were purchased from Beijing Chemical Co., Ltd (Beijing) and used without further purification. 5,6-Dimethoxy-1,2-indandione was supplied by Chinese People's Public Security University. PVP with lower molar mass Kolloidon® 12 PF (Mw = 2000–3000; BASF ChemTrade GmbH, Burgbernheim, Germany) was employed.

Preparation of the 5,6-dimethoxy-1,2-indandione Solution consisted of fully dissolving 0.8 g of 5,6-dimethoxy-1,2-indandione in 90 ml ethyl acetate and 10 ml acetic acid. Then mixing thoroughly with 80ml zinc chloride solution (prepared with zinc chloride, ethyl alcohol, petroleum ether and ethyl acetate) and 820 ml petroleum ether.

The DFO/PVP working solution: The best ratio of DFO solution in PVP(5%), in ethanol solution, was 1:10 (v/v). Fingermarks developed on thermal paper by DFO/PVP were visualized at 515 nm excitation and observed with an orange-red goggles.

Fingermark samples

5 individuals (1 female, 4 males) aged from 20-25 were chosen as donors for the experiments. Donors were requested not to wash their hands during the experiments in order to produce natural fingermarks. Donors were asked to deposit a depletion series, which consisted of 5 successive contacts on the thermal paper with a single finger.

Every individual followed and repeated the same procedure for 10 times. We tried our best to ensure that each volunteer impress their fingermarks with similar force and within the same duration. The fingermarks were stored under room temperature in the laboratory for 1, 3, 5, 7, 15 and up to 30 days before being treated. The comparison between different methods was performed by cutting the series of fingermarks in halves before dipping them in their respective staining solutions. Developed marks were photographed using a digital camera (Nikon D70, AF Micro-Nikkor 60mm f / 2.8D, Japan).

Detection of latent fingermarks

The detection of the latent fingermarks was performed as follows: (1) Each sample was immersed in various staining solutions for 10s; (2) After that, the treated samples were heated in an oven at 100 °C, relative humidity 60% for 10 min. (3) The samples were then observed in the luminescence mode using a Polilight lamp with the emission set at an excitation wavelength of 535 nm.

Results and discussions

Optimization of 5,6-dimethoxy-1,2-indandione/PVP staining solution

PVP is a type of non-ionic polymer, with low volatility and nontoxic, it can be easily dissolved in polar solution and difficult to dissolve in the less or non-polar solvents. To increase the solubility and fluorescence, the influence of solvent and the ratio of PVP to 5,6-dimethoxy-1,2-indandione on detecting latent fingermarks was also explored. It was determined that use of ethanol as a solvent to assistant solubility exerts a substantial influence on the sensitivity of the reagent. The optimum ratio of 5,6-dimethoxy-1,2-indandione solution with PVP, in ethanol solution, was 1:7.5(v/v) and the best concentration of PVP in the ethanol solution was determined to be around 5% (Table 1). Encouraged by this result, further optimization studies using fingermarks deposited on thermal papers were extended to different remaining days and afforded similar results.

Concentration of PVP solution	PVP to indandione ratio				
	1: 1	1: 2.5	1: 5	1: 7.5	1: 10
1%	+	+	+ +	+ + +	+ +
2.5%	+	+	+ +	+ + +	+ +
5%	+	+	+++	++++	+++
7.5%	+	++	+++	++++	+++
10%	+	+	+ +	+ + +	+ +

The test result is indicated by +. ++++ indicates very high quality fingermarks, +++ indicates clear visible fingermarks, ++ indicates that the fingermarks are clear in general but certain parts are difficult to identify, + indicates that the fingermarks are incomplete, not clear enough for identification; - indicates that the fingermarks do not appear on thermal paper.

Table 1: Detection results developed with 5,6-dimethoxy-1,2-indandione/PVP for fingermarks impressed on thermal paper within 1 day.

Efficiency of the new PVP/DFO staining solution

Figure 1 shows a typical example of freshly deposited latent "natural" fingermark, developed by 5,6-dimethoxy-1,2-indandione/PVP under the above mentioned conditions. Fresh fingermarks developed with 5,6-dimethoxy-1,2-indandione/PVP solution for all donors appear in sharp lines, high contrast, excellent fluorescence and without background coloration. The fluorescent fingermarks can be observed and photographed when excited in the 535 nm region through an orange-red goggles.

Figure 1: Photographic images of a latent "natural" fingermark from a single donor deposited on thermal paper. The fresh latent fingermark developed with 5,6-dimethoxy-1,2-indandione/PVP solution, visualised at 535 nm excitation and observed with an orange-red goggles.

Comparison of the 5,6-dimethoxy-1,2-indandione/PVP and the, 6-dimethoxy-1,2-indandione

The comparison between 5,6-dimethoxy-1,2-indandione/PVP formulation with those obtained only using 5,6-dimethoxy-1,2-indandione was performed by splitting the fingermarks in half before dipping them in their respective staining solutions (5,6-dimethoxy-1,2-indandione/PVP for the left halves and 5,6-dimethoxy-1,2-indandione for the right halves). Latent fingermarks on thermal papers developed with 5,6-dimethoxy-1,2-indandione turned dark on the thermosensitive side, while those developed with 5,6-dimethoxy-1,2-indandione/PVP showed stronger luminescence, excellent quality of ridge detail and better contrast with the background. (Figure 2).

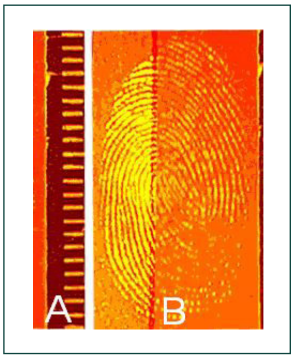

Figure 2: Latent fingermark developed on thermal paper by (A) 5,6-Dimethoxy-1,2-indandione/PVP (left halve) and (B) 5,6-Dimethoxy-1,2-indandione (right halve). All the developed fingermarks were visualized at 535 nm excitation, observed using orange-red goggles. The results from all samples test showed that the change trend of enhancement for different donors were consistent.

Comparison of the 5,6-dimethoxy-1,2-indandione/PVP and the PVP/DFO

Subsequently, we compared the efficiency of DFO/PVP with 5,6-dimethoxy-1,2-indandione/PVP methods. The merits of the new method are clear. Figure 3 shows an example where both methods detected fingermarks on the thermal paper without turning dark on the thermosensitive side, while those developed with 5,6-dimethoxy-1,2-indandione/PVP provided greater fluorescence, better detection sensitivity and clearer detail than that obtained with PVP/DFO.

Figure 3: Latent fingermark developed on thermal paper with (A) 5,6-Dimethoxy-1,2-indandione/PVP, polilight lamp at 535 nm excitation, observed using orange-red goggles in the luminescence mode. (B) One-step PVP/ DFO, polilight lamp at 515 nm excitation, observed using orange-red goggles in the luminescence mode. The results from all samples test showed that the change trend of enhancement for different donors were consistent.

Sensitivity and stability of the 5,6-dimethoxy-1,2-indandione/PVP treatment for latent fingermarks

Next, the sensitivity and stability of the one-step 5,6-dimethoxy-1,2-indandione/PVP treatment for latent fingermarks were also explored. A depletion series of marks with decreasing quantities of material deposited were test. The typical depletion series consisting of five consecutive finger depositions (Figure 4) showed that the new method provided sharp and clear development of latent fingermarks, without background staining, even dramatically diminished the amounts of residue deposited in fingermarks, the image still showing ridge detail (Figure 4E). Furthermore, the efficiency of development for all samples showed that principally fingermarks from different donors were consistently visualized and the tendency of the depletion for different donors were similar.

Conclusions

In this report, a new one-step indandione /PVP development method has been proposed for detecting latent fingermarks on thermal paper with no background coloration. 5,6-Dimethoxy-1,2-indandione/PVP has been successfully synthesized and we suggest its use as the working solution to detect latent fingermarks on thermal papers. The new technique could obtain even better results compared with the existing efficient reagents. It is a simple method to detect latent fingermarks that provides sharp and clear development of latent fingermarks, without background staining, dramatically diminished the

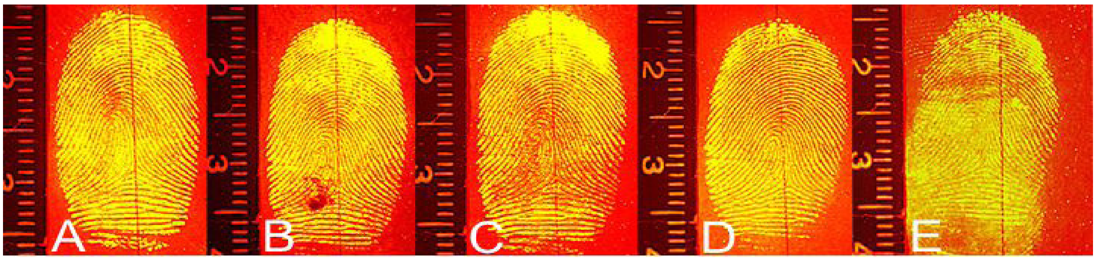

Figure 4: Illustration of typical depletion series consisting of five consecutive finger depositions on thermal paper, aged for 1 day and treated with the 5,6-dimethoxy-1,2-indandione/PVP. All the developed fingermarks were visualised at 535 nm excitation and observed using an orange-red goggles.

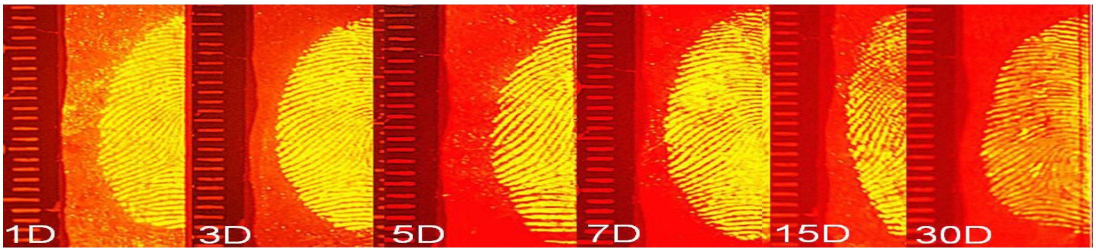

Figure 5: Photographs of 5,6-dimethoxy-1,2-indandione/PVP developed latent fingermarks on thermal papers aged for 1day, 3 days, 5 days, 7 days, 15 days and 30 days.

steps, with simple operation. This technique establishes a new possibility for the detection of latent fingermarks in forensic science. Finally, we have checked the shelf-life of synthesized developer, the visual contrast of developed fingermarks did not change with the developer stored time over periods of several months and the developer also did not deteriorate significantly when stored under ambient conditions.

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