Article

Preliminary Investigations into a Commercial Thermal Fingerprint Developer for the Visualization of Latent Fingermarks on Paper Substrates

Patrick Fritz [1]
Wilhelm van Bronswijk [1]
Darren Fisher [2]
Simon W. Lewis [1]

Abstract: The Thermal Fingerprint Developer (TFD-2) developed by Foster and Freeman is the first commercially available instrument to solely utilize heat treatment to visualize latent fingermarks. The chemical-free TFD-2 was able to develop latent fingermarks on a variety of substrates. The manufacturer's guidelines with regard to the optimal treatment settings were suitable for the more common substrates such as white copy paper; however, new protocols were required for the treatment of thermal paper. The TFD-2's ability to develop these samples and its use in sequence with traditional chemical reagents, such as 1,2-indanedione and physical developer, were demonstrated. The thermal developer may offer quick and easy heat application options for existing fingermark development reagents. However, the TFD-2-developed samples lacked the detail and contrast afforded by conventional amino acid-sensitive reagents under most conditions.

[1] Department of Chemistry, Curtin University, Perth, Western Australia, Australia
[2] Western Australian Police Forensic Fingerprint Bureau, Perth, Western Australia, Australia

Introduction

Several amino acid-sensitive reagents exist to develop latent fingermarks on porous surfaces (e.g., ninhydrin, 1,8-diazofluoren-9-one (DFO), p-dimethylaminobenzaldehyde (DMAB), 1,2-indanedione-zinc chloride (IND-Zn) [1−4]. In addition, sebaceous-sensitive reagents [e.g., physical developer (PD), Oil Red O (ORO), Nile Red and Blue] are also available [4−8]. These differ from the amino acid-sensitive reagents in that they can be used on porous surfaces that have been previously wetted [9, 10]. Although these methods are effective techniques for developing latent fingermarks on porous surfaces, they do have some disadvantages. These include the necessity of a wet chemistry laboratory, the ongoing cost of chemicals and their waste management, as well as the hazards associated with such chemicals. For example, ninhydrin has been shown to cause rhinitis, which is the inflammation of mucous membranes inside the nose [11].

Reagent-free and contactless thermal fingermark development may alleviate some of these concerns. This involves the heating of porous surfaces, such as paper, to develop latent fingermark impressions [12]. Although the potential for thermal development of fingermarks on paper was first recognized in the 1940s, it was not seen as a viable fingermark development technique [13−15]. More recent research conducted by Dominick et al. resulted in fluorescent fingermark development and visible charring on paper substrates, which was also observed by Song et al. [12, 16] Bond et al. likewise used direct heat to successfully develop latent fingermarks with good results, albeit using thermal paper substrates [17, 18]. In comparison to the commercially available Thermanin, an analogue of ninhydrin, their findings indicate significantly improved fingermark ridge detail with thermal development [18]. The research conducted by Song et al. indicated that heating plain copy paper at low temperatures for short periods of time produced a fluorescent fingermark, and heating at higher temperatures for longer periods of time produced visible fingermarks [12]. Although the exact ridge development mechanism is unknown, it has been suggested that the ridge contrast is "simply an acceleration of the thermal degradation of the paper", rather than an actual reaction between the fingermark and paper substrate [12]. This research led to the commercial development of the Thermal Fingerprint Developer (TFD-2) by Foster and Freeman. Paper exhibits are placed on a conveyor and are subsequently exposed to a heating element for differing lengths of time and levels of heat [12]. The TFD-2 is

described by the manufacturers as a portable device that allows for a large number of exhibits to be processed in a short period of time, while providing controlled and reproducible results without the need for chemicals [19].

The primary aim of the current investigation was to examine the manufacturer's claims. A series of investigations using different substrates was conducted, and the developed fingermarks were compared to the DMAB, ninhydrin, or IND-Zn alternatives. Furthermore, the use of TFD-2 in sequence with ORO and PD was also examined and compared to the sequence proposed by Frick et al. [20] Additionally, the development of amino acid-sensitive reagents using the TFD-2 as an alternative heat source was explored.

Materials and Methods

Chemicals

1,2-Indanedione (CASALI/Optimum Technology, Australia), absolute ethanol (CSR Chemicals, Australia), anhydrous zinc chloride (Sigma-Aldrich, U.S.A.), citric acid (Ajax Finechem, Australia), ethyl acetate (Univar Analytical, Australia), ferric nitrate nonahydrate (Chem-Supply, Australia), ferrous ammonium sulphate hexahydrate (Sigma-Aldrich, U.S.A.), glacial acetic acid (Lab-Scan, Thailand), HFE-7100 (1-methoxynonafluorobutane, 3M Novec, Australia), maleic acid (Sigma-Aldrich, U.S.A.), n-dodecylamine acetate (Optimum Technology, Australia), ninhydrin (CASALI/Optimum Technology, Australia), p-dimethylaminobenzaldehyde (BDH, U.S.A.), Oil Red O (Sigma-Aldrich, U.S.A.), propylene glycol (Sigma-Aldrich, U.S.A.), silver nitrate (Chem-Supply, Australia), and Tween 20 (Sigma-Aldrich, Australia) were all used as received and were of analytical reagent grade unless otherwise stated.

Fingermark Collection

Latent fingermarks were collected on various substrates from five donors who had not consumed food or handled chemicals in the 30 minutes prior to providing specimen fingermarks. Both charged fingermarks, prepared by having donors rub their fingers on their face or hair immediately prior to fingermark deposition, and uncharged fingermarks, requiring no preparation, were collected. Donors were instructed to gently place fingertips onto the substrate and not to remove their hands until fingers had been outlined in graphite pencil. Fingermarks were

treated within 24 to 36 hours following deposition unless stated otherwise. At least two to four fingermarks were collected from each donor for each experiment. In the case of the comparison studies to existing fingermark reagents, split prints were used as recommended by the International Fingerprint Research Group [21].

Substrates

The substrates used in this study consisted of white A4 copy paper (Fuji Xerox Professional, 80 g/m^2), Green Wrap 60% recycled copy paper, brown wrapping paper, gloss thin card used by WA Police for the "Burglary–What Happens Now?" brochure, *The West Australian* newspaper, gloss paper Young's Noodle Inn take-out menu, and white Coles brand 11B envelopes. Thermal paper was used in the form of unprinted thermal register rolls (Officeworks, Australia) and printed receipts from several supermarkets. Substrates used to test the ability of the TFD-2 to develop wetted specimens were submerged in water for 1 minute after fingermark deposition and were subsequently allowed to air dry.

The TFD-2 operates by applying heat to fingermark exhibits mounted on a moving stage (Figure 1). The intensity of the heat (5% increments) and the speed of the stage (250–6500 mm per minute) can be varied as deemed necessary for the substrate in question [19]. The number of passes made underneath the heating element can affect the ridge development.
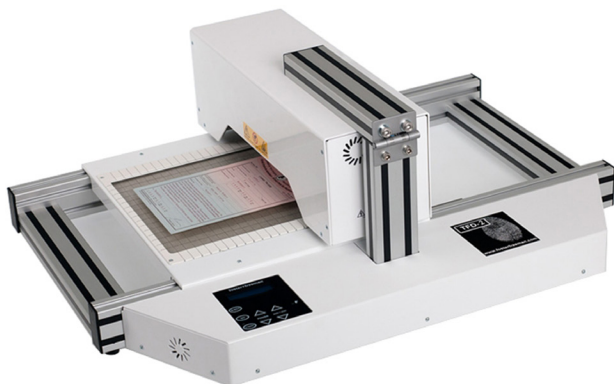

Figure 1
The Thermal Fingerprint Developer (TFD-2). Image courtesy of Foster and Freeman [20].

Method Development for the Use of the TFD-2 on Various Substrates

The general approach to developing fresh fingermark deposits on a variety of substrates consisted of taking the lowest heat setting with the highest tray speed and then increasing the intensity until development occurred. If the manufacturer's recommendations were known, they were used as a starting point. If charring of the substrates occurred, either the intensity of the heat was decreased or the tray speed was increased until satisfactory ridge detail was achieved.

Thermal Paper Development Using the TFD-2

The following procedure was developed to treat thermal paper to achieve sufficient contrast while preventing charring or overdevelopment:

1. The TFD-2 was set to 6500 mm per minute tray speed and 40% heating intensity.

2. The thermal paper was removed after its first pass under the heating element, at the point where the tray pauses to go back under the heating element and to the load position.

3. Step 2 was repeated twice, if necessary.

4. If there was still no development, the sample was left on the tray for the complete cycle.

5. Step 4 was repeated, if necessary, by reducing the tray speed by 500 mm per minute steps at a time until development or until 2000 mm per minute was reached.

6. If there was still no development, the heat setting was increased by 10% and step 5 was repeated, starting at a tray speed of 6500 mm per minute.

7. Step 6 was repeated as necessary.

Preparation of Reagent Solutions

The preparation of all stock and working solutions is summarized in Table 1.

To prepare the treatment papers for the DMAB and IND-Zn dry contact method, either white A4 copy paper or chromatography paper (Whatman No.1) was immersed into the working solution and air dried before being stored in a sealed zip-lock plastic bag that was stored under ambient conditions in the dark. The PD stock and working solutions used in this study (Table 1) were prepared as described by the Australian Federal Police (AFP) [4] with the following modification: Tween 20 was substituted for Synperonic N, as described in Sauzier et al. [8] The PD working solution was made fresh as needed and was used twice before being discarded.

	Solution	Reagent Preparation
Wet Contact DMAB [1]	DMAB stock solution	1 g DMAB in 22 mL ethyl acetate and 3 mL acetic acid
	Working solution	1 mL stock solution diluted with 9 mL HFE-7100
Dry Contact DMAB [1]	Working solution	4 g DMAB in 100 mL ethyl acetate
Wet Contact IND–Zn [2, 4, 23, 24]	IND stock solution	4 g 1,2-indanedione dissolved in 450 mL ethyl acetate and 50 mL glacial acetic acid
	Zinc chloride stock solution	8 g zinc chloride dissolved in 200 mL absolute ethanol
	Working solution	2 mL zinc chloride stock solution and 50 mL stock solution added to 450 mL HFE-7100 solvent
Dry Contact IND–Zn [23]	1,2-Indanedione stock solution	0.75 g 1,2-indanedione and 20 mg zinc chloride dissolved in 0.5 mL ethanol, 15 mL dichloromethane, and 35 mL ethyl acetate
Ninhydrin [4]	Working solution	5 mL stock solution added to 45 mL HFE-7100
	Ninhydrin stock solution	30 g ninhydrin dissolved in 410 mL absolute ethanol and 25 mL ethyl acetate, followed by 65 mL glacial acetic acid
	Working solution	80 mL stock solution added to 920 mL HFE-7100 solvent
Oil Red O [7]	Working solution	0.05 g ORO dissolved in 100 mL propylene glycol at 95 °C with constant stirring. Cooled solution is vacuum filtered before use
Physical Developer [4, 8]	Detergent-surfactant solution	0.5 g n-dodecylamine acetate and 0.5 g Tween 20 dissolved in 125 mL deionized water
	Redox solution	7.5 g ferric nitrate nonahydrate, 20 g ferrous ammonium sulphate hexahydrate, 5 g citric acid, and 10 mL detergent-surfactant solution (in order given) dissolved in 225 mL deionized water
	Silver nitrate solution	10 g silver nitrate dissolved in 50 mL deionized water
	Maleic acid pre-wash	6.25 g maleic acid dissolved in 250 L deionized water
	Working solution	7.5 mL silver nitrate stock solution added to 142.5 mL redox stock solution

Table 1

Preparation of stock and working solutions.

Development of Latent Fingermarks Using DMAB

The DMAB treatment procedure was carried out as described by Fritz et al. [1] For the wet contact working method, the sample was immersed into the working solution for ~ 1 to 2 seconds before being air dried on paper towels at room temperature. The samples were then heated in an oven (Zhicheng ZRD-A5055) at 150 °C for 20 minutes. In the dry contact method, the samples were placed either between treatment papers in an Elna laundry press at high temperature for 45 seconds (heat insensitive samples) or between treatment papers in a zip-lock bag for 2 days in the dark (heat sensitive samples).

Development of Latent Fingermarks Using IND-Zn Methods

"Wet contact" IND-Zn treatment was carried out as described by the AFP [4]. Samples were developed by briefly dipping the exhibits in the working solution, allowing them to air dry, and then heat-treating them for 10 seconds with an Elna laundry press (set at 160 °C).

"Dry contact" IND-Zn treatment was carried out as described by Patton et al. [22] Samples were sandwiched between two treatment papers and stored in a zip-lock plastic bag for 24 to 36 hours in the dark. No heat treatment was applied to dry contact-treated samples.

Development of Latent Fingermarks Using the Ninhydrin Method

Ninhydrin treatment was carried out as described by the AFP [4]. Samples were developed by briefly dipping the exhibits in the working solution and then allowing them to air dry before being stored out of direct sunlight for 24 hours prior to examination.

Development of Latent Fingermarks Using ORO

Sample treatment with ORO was carried out as described by Frick et al. [7] Samples were placed in a glass tray and immersed in ORO reagent for 15 minutes, with manual agitation provided by gently rocking the tray for 30 seconds at the beginning of treatment. After development, ORO-treated samples were rinsed twice in a deionized water bath under running water and air dried on paper towels at room temperature.

Development of Latent Fingermarks Using PD

Fingermark development with PD was carried out as described by Sauzier et al. with one minor modification: the maleic acid pre-treatment step was increased from 5 minutes to 30 minutes, as recommended by Salama et al. [8, 23] Each step was carried out in a separate glass tray. Samples were rinsed twice in deionized water for 10 minutes, immersed in maleic acid for 30 minutes, and then rinsed again in deionized water for 10 minutes. Samples were then immersed in the working solution for up to 20 minutes. After development, samples were rinsed several times in deionized water and air dried on paper towels at room temperature, away from direct light.

Photography of Samples

Samples were photographed with a Nikon D300 camera, equipped with an AF-S Micro-Nikkor lens, mounted on a Firenze Mini Repro tripod, and connected to a computer running Nikon Camera Control Pro version 2.0.0. Illumination in luminescence mode was achieved using a Rofin Polilight PL500 (Rofin, Australia), with an excitation wavelength filter of 490 nm (40 nm bandwidth) for the TFD-2- and DMAB-developed prints and 505 nm (40 nm bandwidth) for IND comparisons. An orange camera filter attachment (Foster + Freeman Schott OG550, 529 nm barrier filter) was used. Illumination in absorbance mode was achieved using incandescent light with no camera filter attachments. Photographic conditions are summarized in Table 2. The images are presented as captured with no additional enhancement.

	Absorbance Mode	Luminescence Mode
Focal Length/mm	60	60
Exposure Mode	Manual	Manual
White Balance	Auto	Auto
Shutter Speed/s	1/20	1
Aperture	f/11	f/11
Sensitivity	ISO 200	ISO 200

Table 2

Camera settings for absorbance and luminescence mode photographs.

Results and Discussion

The ability of the TFD-2 to develop latent fingermarks was investigated on a variety of substrates, in sequence with conventional treatment options and for the development of amino acid-sensitive reagents. The only instrumental parameters that could be altered were the stage speed and the temperature intensity. For specimens requiring prolonged heating, the number of passes of the exhibit that were made underneath the heating element was also evaluated.

Substrate Investigations

Several substrates were investigated, and sample halves treated with ninhydrin served as a point of comparison. Ninhydrin-developed exhibits provided good detail on the white copy paper, gloss cards, and wrapping paper substrates that were tested. The TFD-2 results indicated that white copy paper appeared to be the best receiving substrate for thermal development. The manufacturer's recommendations of 100% heat at 1250 mm per minute gave the optimum results [19]. Fingermarks deposited on gloss cards were very poorly developed, with 1750 mm per minute at 100% heat offering the best outcomes. However, the type and color of gloss on these cards can vary greatly, and different batches may therefore offer more promising results. Fingermarks deposited on brown wrapping paper were visible at tray speeds of 1000 mm per minute to 1750 mm per minute and 100% heat, however, only the samples at 1000 and 1250 mm per minute were suitable for identification purposes. The thermal development results that were obtained for these three surface types are consistent with the findings listed in the TFD-2 user manual, as well as the findings of Song et al. with regard to white copy paper [12, 19].

The possibility of using the TFD-2 instrument as a viable treatment technique for substrates that had been wetted after fingermark deposition was investigated. As expected, wetted samples did not appear to be amenable for thermal treatment, with only 3 out of 40 specimens exhibiting any development (Figure 2). These results support the findings of Song et al. that thermal development relies upon the eccrine (water soluble) component of the fingermark deposits for visualization to occur [12]. It should be noted that the substrates were submerged in water for only 60 seconds compared to the 5 to 10 minutes used by Song et al., which may explain the success with certain specimens.
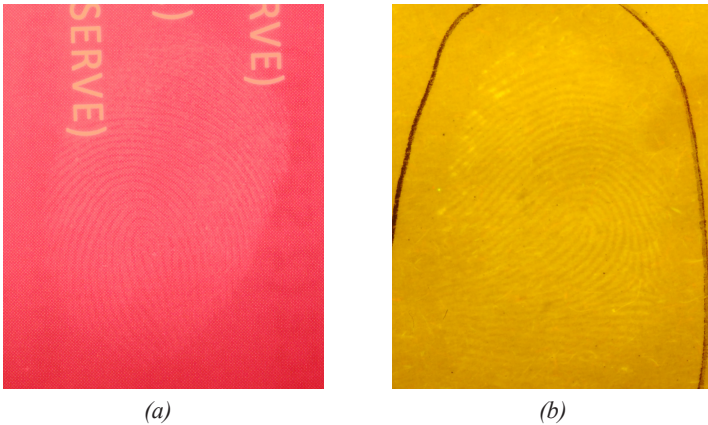
(a)　　　　　　　　　　　　*(b)*

Figure 2

*Examples of ridge detail observed in charged fingermarks on gloss paper
(2a) and white copy paper (2b); where, following deposition, substrates
were immersed in water and allowed to air dry prior to TFD-2 treatment.
Photograph taken with a Nikon D300 camera in luminescence mode at an
excitation wavelength of 505 nm, focal length: 60 mm, shutter speed: 1
second, and aperture: f/11.*

Fingermarks deposited on thermal paper can be problematic to develop, because every thermal paper exhibit differs according to its source and age [17]. For the purposes of this report, thermal paper was broadly classified as strong or weak. Thermal paper was deemed as strong if it was very sensitive to the application of heat, whereas weak thermal paper required more intense heating to provoke a change in the active layer. In general, weak thermal paper consisted of faded receipts, and strong thermal papers consisted of receipts with high contrast characters. Fingermarks deposited on strong thermal paper were susceptible to over-development, and the thermal paper could quickly become darkened completely, obscuring any ridge detail. Fingermarks deposited on weak thermal paper were found to be demanding to develop, with little contrast resulting from low heat conditions. Because exhibits could easily be misclassified as consisting of strong or weak thermal paper, a gradual approach was taken in order to develop fingermarks reliably (Figure 3).

This consisted of taking the lowest heat setting with the highest tray speed and then progressively increasing the intensity until development occurred (as per the Materials and Methods section). In this preliminary study, most receipts were successfully treated using this approach. However, it has to be noted that overheating is irreversibly detrimental to the integrity of the print, and extreme caution should be taken when processing vital or fragile exhibits. Good luminescent prints could be observed on the underside of receipts, at the expense of darkening the active side (Figure 4).

Interestingly, no luminescence was observed from the active (top) side of any developed thermal paper in this study. Because the active side is much more temperature sensitive than the underside, it should be developed first to preserve potential ridge detail. A comparison study using split prints on thermal paper was also undertaken with the dry-contact methods of IND-Zn and DMAB, where DMAB and the TFD-2 developed prints to a similar level. The IND-Zn-treated specimens gave overall better and more reliable friction ridge detail than TFD-2-treated samples.

In comparison, a study conducted by Bond et al. resulted in a higher rate of successful treatment of thermal paper specimens. However, the fingermarks were deposited onto new thermal paper rolls rather than actual used thermal paper receipts [17]. When Bond et al. inspected used thermal paper receipts, no further fingermarks were deposited in addition to any existing from the time of purchase, resulting in a very low number of developed prints.
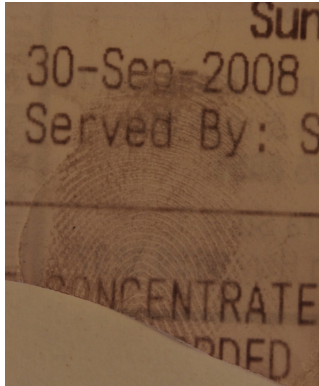
Figure 3

Ridge detail displayed by a TFD-2-treated uncharged fingermark deposited on the active side of a thermal paper receipt.
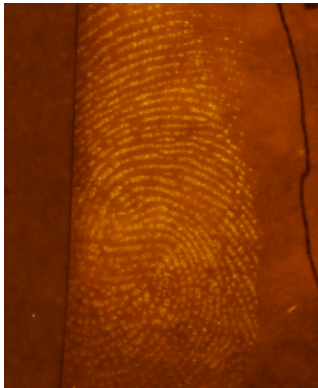

Figure 4

Ridge detail displayed by an uncharged fingermark deposited on the underside of a thermal paper receipt and treated with the TFD-2. Photograph taken with a Nikon D300 camera in luminescence mode at an excitation wavelength of 505 nm, focal length: 60 mm, shutter speed: 1 second, and aperture: f/11.

TFD-2 in Sequential Fingermark Treatment

It is common practice to apply several reagents in sequence [2, 20, 24, 25] with difficult to visualize evidence, and the TFD-2 was evaluated in combination with ORO and PD. The IND-Zn → ORO → PD sequence reported by Frick et al. was tested as a point of reference [20]. Comparatively, IND-Zn offers vastly superior fingermark development to TFD-2 for deposits on plain white copy paper (Figure 5).

However, in sequence, the ORO treatment presented much better contrast and ridge detail when it was preceded by the TFD-2 rather than IND-Zn (Figure 6). The nonpolar solvent used in the IND-Zn formulation may dissolve some of the "fragile" lipids, which ORO stains, therefore reducing the overall intensity of the ORO-developed print.

Although PD was used last in the tested sequences, it appeared unaffected by the preceding treatments (Figure 7). Because PD is thought to react with the more stable "robust" lipids, it should be less sensitive to the preceding methods applied in a sequence as seen here. Overall, the sequence proposed by Frick et al. is much more sensitive for most operational purposes because of the considerably superior 1,2-indanedione step [20].
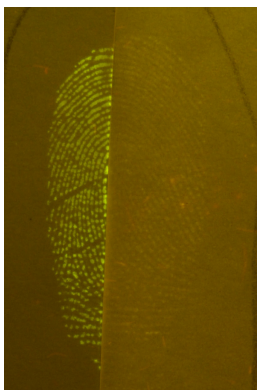

Figure 5

Luminescence observed in a split charged fingermark on plain copy paper treated with IND-Zn (left-half) and the TFD-2 (right-half). Photograph taken with a Nikon D300 camera in luminescence mode at an excitation wavelength of 505 nm, focal length: 60 mm, shutter speed: 1 second, and aperture: f/11.
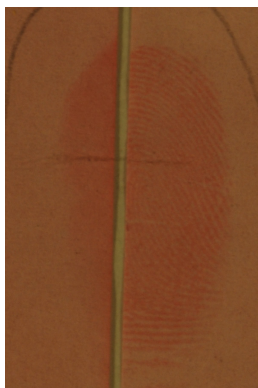
Figure 6

A split charged fingermark on plain copy paper treated with ORO following IND-Zn (left-half) and the TFD-2 (right-half) treatment.

Figure 7

A split charged fingermark on plain copy paper treated with PD following ORO and IND-Zn (left-half) and the TFD-2 (right-half) pre-treatment.

The TFD-2 as the Heat Source for Reagent Development

Although samples treated with some reagents, such as IND, can be visualized without the application of heat, the development rate is greatly increased when heat is applied (~ 10 seconds instead of 5 days) [26]. In the case of DMAB and IND-Zn, either an oven or an Elna heat press is conventionally used as a heat source. However, fingermarks immersed in either the IND-Zn or DMAB working solution, then air dried, could subsequently be very successfully heat treated using the TFD-2. Initial results suggest that the conventional method of heating may offer slightly more sensitivity in the case of IND-Zn (Figure 8).

Marks were developed using a range of settings, from 40% heat at a tray speed of 3000 mm per minute to 100% heat at 1500 mm per minute; the development was improved with longer and stronger heating. Good development with DMAB-treated samples could only be gained from more intense heating with an intensity of at least 80% at 1500 mm per minute (Figure 9).

This provides a rapid way of developing latent fingermarks in conjunction with existing fingermark reagents, while avoiding direct contact of the sample with the heating elements. This contactless approach could prove beneficial for very fragile samples, however, charring of the paper can still occur.

Figure 8

Uncharged fingermark on plain copy paper treated with IND-Zn,
where heat was applied with the TFD-2 (left-half) or the conventional Elna
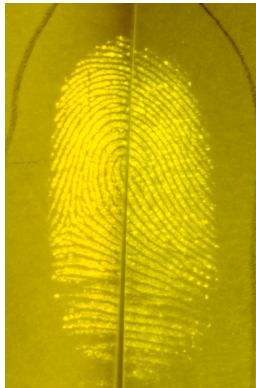*press method [4] (right-half).*

Figure 9

Luminescent uncharged fingermark on plain copy paper treated
with DMAB, where heat was applied with the TFD-2 (left-half)
or with an oven (right-half) [1].
Photograph taken with a Nikon D300 camera in luminescence
mode at an excitation wavelength of 490 nm,
focal length: 60 mm, shutter speed: 1 second, and aperture: f/11.

Conclusion

This study tested a thermal fingerprint developer (TFD-2) on a variety of substrates and assessed its viability as an alternative to chemical treatments for developing latent fingermarks. Brown and white paper samples were reliably developed; however, the sensitivity was significantly decreased compared to conventional chemical reagents. Fingermarks deposited on glossy paper substrates offered very poor ridge detail overall. The ability of the TFD-2 to successfully treat thermal paper samples and its use in sequence with other visualization methods was demonstrated, and samples treated with IND-Zn offered superior ridge detail. Extreme caution has to be applied when treating thermal paper, because overheating can quickly destroy exhibits. The TFD-2 offered quick and easy heat treatment options for fingermark development reagents such as IND-Zn and DMAB. This investigation supports the findings of studies conducted by Song et al. regarding eccrine secretions being the critical component required for fingermark impressions to be developed thermally, as demonstrated by the inability of the TFD-2 to reliably develop previously wetted samples [12]. The TFD-2 may find use in remote regions where the operation of a wet chemistry laboratory (including the ongoing cost of chemicals and their appropriate disposal) is not feasible. However, on the basis of these preliminary results, the TFD-2 cannot be recommended for the treatment of latent fingermark deposits when conventional methods are readily available. Much broader studies, including a wider range of donors and attempted development after extended periods of time, are needed to properly establish the validity of this technique for operational purposes.

For further information, please contact:

Simon W. Lewis
Department of Chemistry, Curtin University
GPO Box U1987
Perth, Western Australia, Australia 6845
S.Lewis@curtin.edu.au

References

1. Fritz, P.; van Bronswijk, W.; Lewis, S. W. p-Dimethylaminobenzaldehyde: Preliminary Investigations into a Novel Reagent for the Detection of Latent Fingermarks on Paper Surfaces. *Analytical Methods* **2013**, *5* (13), 3207–3215.

2. Jelly, R.; Patton, E. L. T.; Lennard, C.; Lewis, S. W.; Lim, K. F. The Detection of Latent Fingermarks on Porous Surfaces Using Amino Acid Sensitive Reagents: A Review. *Anal. Chim. Acta* **2009**, *652* (1–2), 128–142.

3. Pounds, C. A.; Grigg, R.; Mongkolaussavaratana, T. The Use of 1,8-Diazafluoren-9-One (DFO) for the Fluorescent Detection of Latent Fingerprints on Paper. A Preliminary Evaluation. *J. For. Sci.* **1990**, *35* (1), 169–175.

4. Stoilovic, M.; Lennard, C. *AFP Workshop Manual: Fingerprint Detection & Enhancement*, 3rd ed.; Forensic Services, Australian Federal Police: Canberra, Australia, 2006.

5. Braasch, K.; de la Hunty, M.; Deppe, J.; Spindler, X.; Cantu, A. A.; Maynard, P.; Lennard, C.; Roux, C. Nile Red: Alternative to Physical Developer for the Detection of Latent Fingermarks on Wet Porous Surfaces? *For. Sci. Int.* **2013**, *230* (1–3), 74–80.

6. Frick, A. A.; Busetti, F.; Cross, A.; Lewis, S. W. Aqueous Nile Blue: A Simple, Versatile and Safe Reagent for the Detection of Latent Fingermarks. *Chem. Comm.* **2014**, *50* (25), 3341–3343.

7. Frick, A. A.; Fritz, P.; Lewis, S. W.; van Bronswijk, W. A Modified Oil Red O Reagent for the Detection of Latent Fingermarks on Porous Substrates. *J. For. Ident.* **2012**, *62* (6), 623–641.

8. Sauzier, G.; Frick, A. A.; Lewis, S. W. Investigation into the Performance of Physical Developer Formulations for Visualizing Latent Fingermarks on Paper. *J. For. Ident.* **2013**, *63* (1), 70–89.

9. Beaudoin, A. New Technique for Revealing Latent Fingerprints on Wet, Porous Surfaces: Oil Red O. *J. For. Ident.* **2004**, *54* (4), 413–421.

10. Wood, M. A.; James, T. ORO. The Physical Developer Replacement? *Sci. & Just.* **2009**, *49* (4), 272–276.

11. Piirila, P.; Estlander, T.; Hytonen, M.; Keskinen, H.; Tupasela, O.; Tuppurainen, M. Rhinitis Caused by Ninhydrin Develops into Occupational Asthma. *European Respiratory J.* **1997**, *10* (8), 1918–1921.

12. Song, D. F.; Sommerville, D.; Brown, A. G.; Shimmon, R. G.; Reedy, B. J.; Tahtouh, M. Thermal Development of Latent Fingermarks on Porous Surfaces–Further Observations and Refinements. *For. Sci. Int.* **2011**, *204* (1–3), 97–110.

13. Olsen, R. D.; Scott, W. R. *Scott's Fingerprint Mechanics*; Charles C. Thomas: Springfield, IL, 1978.

14. Almog, J.; Marmur, A. Chemical Reagents for the Development of Latent Fingerprints. IV: The Charring Process. *J. For. Sci.* **1981**, *26* (2), 393–397.

15. Dominick, A. J.; NicDaéid, N.; Bleay, S. M. The Recoverability of Fingerprints on Paper Exposed to Elevated Temperatures–Part 1: Comparison of Enhancement Techniques. *J. For. Ident.* **2010**, *59* (3), 325–339.

16. Dominick, A. J.; Daéid, N. N.; Bleay, S. M.; Sears, V. G. The Recoverability of Fingerprints on Paper Exposed to Elevated Temperatures–Part 2: Natural Fluorescence. *J. For. Ident.* **2010**, *59* (3), 340–355.

17. Bond, J. W. Development of Latent Fingerprints on Thermal Paper by the Controlled Application of Heat. *J. For. Sci.* **2013**, *58* (3), 767–771.

18. Bond, J. W. Comparison of Chemical and Heating Methods to Enhance Latent Fingerprint Deposits on Thermal Paper. *J. For. Sci.* **2014**, *59* (2), 485–489.

19. Foster+Freeman. TFD-2: Thermal Fingerprint Developer. http://www.fosterfreeman.com/index.php/fingerprint-evidence/tfd-2-col-180-thermal-fingerprint-developer (Accessed June 2013).

20. Frick, A. A.; Fritz, P.; Lewis, S. W.; van Bronswijk, W. Sequencing of a Modified Oil Red O Development Technique for the Detection of Latent Fingermarks on Paper Surfaces. *J. For. Ident.* **2013**, *63* (4), 369–385.

21. International Fingerprint Research Group. Guidelines for the Assessment of Fingermark Detection Techniques. *J. For. Ident.* **2014**, *64* (2), 174–200.

22. Patton, E. L. T.; Brown, D. H.; Lewis, S. W. Detection of Latent Fingermarks on Thermal Printer Paper by Dry Contact with 1,2-Indanedione. *Analytical Methods* **2010**, *2* (6), 631–637.

23. Salama, J.; Aumeer-Donovan, S.; Lennard, C.; Roux, C. Evaluation of the Fingermark Reagent Oil Red O as a Possible Replacement for Physical Developer. *J. For. Ident.* **2008**, *58* (2), 203–237.

24. Almog, J. Fingerprints (Dactyloscopy): Visualization. In *Encyclopedia of Forensic Sciences*, 1st ed.; Siegel, J. A., Saukko, P. J., Knupfer, G. C., Eds. Academic Press: San Diego, CA, 2000; p 890–900.

25. Champod, C.; Lennard, C. J.; Margot, P.; Stoilovic, M. *Fingerprints and Other Ridge Skin Impressions*; CRC Press: Boca Raton, FL, 2004.

26. Roux, C.; Jones, N.; Lennard, C.; Stoilovic, M. Evaluation of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione for the Detection of Latent Fingerprints on Porous Surfaces. *J. For. Sci.* **2000**, *45* (4), 761–769.