An investigation of latent fingermark residues and their development on porous substrates using physical developer and nile red

This thesis is submitted in fulfilment of the requirements for the degree of Doctor of Philosophy.

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student:

Date:

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Abstract

The detection of fingermarks on porous surfaces that have been wet is currently limited to only one routine technique, Physical Developer (PD). PD is a well-established fingermark development method that has a plethora of issues associated with its use, principally based around the preparation and relative instability of the working solution and lack of contrast on dark substrates as it is non-luminescent. While these issues have been mostly addressed at an operational level, in-depth chemical remedies for the PD process cannot be devised because the mechanisms and specific targets of PD remain largely unknown. This highlights the need to understand the fundamental chemistry of the technique to recognise what may be improved and what complementary detection methods could be applied to ensure that the maximum number of available fingermarks are developed in casework.

This research has also considered nile red (NR), a technique known to develop fingermarks on porous substrates that have been wet that remain undeveloped by treatment with PD. An investigation of the optimisation of the NR working solution was undertaken. An oil-in-water microemulsion containing NR was prepared using the solvent-diffusion method. The optimized NR solution was demonstrated to be effective in developing fresh latent fingermarks. The working solution is prepared with the slow addition of a NR in dichloromethane stock solution to a dual surfactant solution to create a lactescent dual organic-aqueous phase intermediate. Stirring promotes the evaporation of the solvent, resulting in a transparent NR microemulsion. The solution contains less hazardous solvents than the previously published formulation, with an extended shelf life and at a much lower cost. The optimized microemulsion was shown to outperform a previously reported aqueous nile blue working solution on both natural and groomed fingermarks, with shorter exposure times for image capture after development.

The storage, ageing and concentration of the components of a PD working solution was evaluated to determine the most effective formulation and protocol for the use of PD. A more thorough understanding of the working solution components of PD has allowed a refinement of the development method and the formulation itself, resulting in increased development success and a better understanding of when fingermarks will and will not be effectively developed by the technique. A revised PD working solution formulation and development protocol has been established that has been successfully utilised by undergraduate forensic science students.

An investigation of the chemical targets of PD contained in latent fingermark deposits through reactivity assessments of various lipid, eccrine and lipid–eccrine mixtures in the residue was undertaken. Experimental results showed that silver deposition from the PD working solution occurs in the presence of an emulsion of both lipid and eccrine constituents. PD was interestingly shown to also be reactive towards emulsions of oleic acid and water, indicating that the silver deposition may occur as a result of nucleation sites at the emulsion phase boundary, or as a result of desorption of constituents from the substrate that promote silver reduction. These results explain the anomalies seen with the selective development by PD of a proportion of fingermarks on a substrate, and the development of other fingermarks by other techniques when used in sequence, such as Oil Red O (ORO) or NR. A consideration of the various processes that emulsions undergo also helps to rationalise the fluctuating developmental effectiveness of PD on ageing fingermarks.

A better understanding of the PD technique permits a more informed selection of alternative or complementary detection methods. This research provides further insight into not only the application of the PD technique but, more importantly, into the reasons behind the observed development. This increased understanding highlights the need to sequence PD with a lipid sensitive technique, such as NR, for the development of latent fingermarks on porous substrates that have been wet as the two techniques have discrete and complementary targets. It also emphasizes the need to develop a better understanding of latent fingermark residue–substrate interactions.

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Acronyms

Abbreviation	Word
BSTFA	Bis(trimethylsilyl)trifluoroacetamide
CA	Cyanoacrylate
$CHCl_3$	Chloroform
DCM	Dichloromethane
ECF	Ethyl chloroformate
EDTA	Ethylenediaminetetraacetic acid
EtOAc	Ethyl acetate
EtOH	Ethanol
FP	Whatman no. 41 ashless filter paper
GC-MS	Gas Chromatography Mass Spectrometry
Hex	Hexane
HLB	Hydrophilic-lipophilic balance
Ind-Zn	Indanedione + zinc chloride
IS	Internal standard
IsoP	Isopropanol
LPSP	Latent print standards pad
MeOH	Methanol
MMD	Multi-metal deposition
MSTFA	N-methyl-N-(trimethylsilyl)trifluoroacetamide
NB	Nile blue A
n-DAA	N-dodecylamine acetate

Nin	Ninhydrin
NP	Lined note paper
NR	Nile red
NR-OP	Optimised nile red working solution
NR-STD	Standard nile red working solution
o/w	oil in water (emulsion)
PD	Physical developer
PIT	Phase inversion temperature
RecP	100 % Recycled paper
RH	Relative humidity
RP	80 gsm Reflex Virgin Fibre UltraWhite copy paper
RT	Room temperature
SFR	Synthetic fingermark residue
SMD	Single-metal deposition
SynN	Synperonic N
TB	Toluidine blue
TIC	Total ion chromatogram
TLC	Thin Layer Chromatography
TMCS	Trimethylcholorosilane
UV	Ultra-violet
w/o	water in oil (emulsion)

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Research communication

Publications

de la Hunty, M., Moret, S., Chadwick, S., Lennard, C., Spindler, X., and Roux, C., *Understanding physical developer (PD): Part I – Is PD targeting lipids?* Forensic Science International, 2015. 257: p. 481-487

de la Hunty, M., Moret, S., Chadwick, S., Lennard, C., Spindler, X., and Roux, C., *Understanding Physical Developer (PD): Part II – Is PD targeting eccrine constituents?* Forensic Science International, 2015. 257: p. 488-495.

de la Hunty, M., Spindler, X., Chadwick, S., Lennard, C., and Roux, C., *Synthesis and application of an aqueous nile red microemulsion for the development of fingermarks on porous surfaces.* Forensic Science International, 2014. 244: p. e48-e55.

Conferences

Oral presentation at the 23rd International Symposium on the Forensic Sciences held by the Australian and New Zealand Forensic Science Society (ANZFSS) in Auckland, New Zealand– September 2016

Oral presentation ANZFSS NSW Branch Meeting - Australian Museum – Sydney, Australia – August 2016

Oral presentation at the UTS Science Research Day 5MT competition – December 2015 (Awarded Best Presentation)

Oral presentation at 7th European Academy of Forensic Science Conference in Prague, Czech Republic – September 2015

Oral presentation at 22nd International Symposium on the Forensic Sciences held by the Australian and New Zealand Forensic Science Society (ANZFSS) in Adelaide, Australia– September 2014 (Awarded Best Oral Presentation in the Fingerprint Examination discipline)

Oral presentation at the University of Technology Sydney – University of Canberra Forensic Conference in Sydney, Australia– July 2014

Oral presentation at the University of Technology Sydney – University of Canberra Forensic Conference in Canberra, Australia– July 2013

Podcasts/ Exhibitions

Double Loop Podcast – Episode 140 (Interview with Glenn Langenburg and Eric Ray) - Released January 2017

Interactive installation and oral presentation of PhD research at the University of Technology Sydney Library – UTS Science Week – August 2016