

An investigation of latent fingerprint 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

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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.

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Abstract

The detection of fingerprints on porous surfaces that have been wet is currently limited to only one routine technique, Physical Developer (PD). PD is a well-established fingerprint 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 fingerprints are developed in casework.

This research has also considered Nile Red (NR), a technique known to develop fingerprints 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 fingerprints. 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 fingerprints, 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 fingerprints 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 fingerprint 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 fingerprints on a substrate, and the development of other fingerprints 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 fingerprints.

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 fingerprints 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 fingerprint residue–substrate interactions.

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Acronyms

Abbreviation	Word
BSTFA	Bis(trimethylsilyl)trifluoroacetamide
CA	Cyanoacrylate
CHCl₃	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	Trimethylchlorosilane
UV	Ultra-violet
w/o	water in oil (emulsion)

Table of Contents

ABSTRACT	III
ACKNOWLEDGEMENTS	V
ACRONYMS	VII
LIST OF TABLES.....	XII
LIST OF FIGURES.....	XX
RESEARCH COMMUNICATION	XXVI
PUBLICATIONS.....	XXVI
CONFERENCES.....	XXVI
PODCASTS/ EXHIBITIONS.....	XXVI
1 THE DEVELOPMENT OF FINGERMARKS ON POROUS SUBSTRATES.....	2
1.1 LATENT FINGERMARK DEPOSITION.....	2
1.1.1 <i>Chemical Composition</i>	2
1.1.2 <i>Factors affecting deposition</i>	3
1.2 LATENT FINGERMARK DEVELOPMENT ON POROUS SUBSTRATES THAT HAVE BEEN WET.....	6
1.2.1 <i>Physical Developer</i>	7
1.2.2 <i>Oil Red O (ORO)</i>	9
1.2.3 <i>Nile Red</i>	10
1.3 PROJECT AIMS AND OBJECTIVES	13
2 AN INVESTIGATION OF THE COMPONENTS OF FINGERMARK RESIDUE TARGETED BY NILE RED AND PHYSICAL DEVELOPER	19
2.1 INTRODUCTION	19
2.2 FINGERMARK QUALITY ASSESSMENTS FOR COMPARATIVE TESTING	20
2.2.1 <i>Objective assessment</i>	20
2.2.2 <i>Subjective assessment</i>	27
2.3 DEPOSITION FACTORS.....	32
2.3.1 <i>Fingerprint type</i>	32
2.3.2 <i>Deposition parameters</i>	36
2.4 COMPOSITION OF FINGERMARK RESIDUE	41
2.4.1 <i>Chemical Analysis by GC-MS</i>	42
2.4.2 <i>Preliminary experiments</i>	44
2.4.3 <i>Analysis of fingerprint residue using DCM and EtOAc extraction solvents</i>	54
2.4.4 <i>PD reactivity with various compounds and their EtOAc extraction and GC-MS analysis</i>	57
2.5 CONCLUSION	60
3 THE APPLICATION OF NILE RED FOR LATENT FINGERMARK DEVELOPMENT.....	62
3.1 INTRODUCTION	62
3.2 NILE RED WORKING SOLUTION RE-EVALUATION.....	64
3.2.1 <i>Evaluation experiments</i>	65
3.3 COMPARISON OF THE OPTIMISED SOLUTION WITH THE STANDARD SOLUTION	67
3.4 COMPARISON OF AQUEOUS NILE BLUE AND A NILE RED MICROEMULSION	70
3.4.1 <i>Solution formulations</i>	70
3.4.2 <i>Fingerprint deposition conditions</i>	71
3.4.3 <i>Sample treatment</i>	72

3.4.4	Sample visualisation	73
3.4.5	Results and Discussion	73
3.5	NR AND NB IN AQUEOUS AND ORGANIC MEDIA	76
3.5.1	Thin layer chromatography	77
3.6	CONCLUSIONS	85
4	PHYSICAL DEVELOPER FORMULATION AND METHOD	87
4.1	INTRODUCTION	87
4.2	DETERGENT SURFACTANT SOLUTION	89
4.2.1	Storage and aging	91
4.2.2	Concentration	92
4.3	SILVER NITRATE	94
4.3.1	Storage and aging	100
4.4	REDOX SOLUTION	103
4.4.1	Storage and aging	103
4.4.2	Concentration	106
4.5	PD WORKING SOLUTION	106
4.5.1	Storage and aging	106
4.5.2	Control samples	110
4.6	CONCLUSIONS	115
5	DETERMINATION OF THE TARGETS OF PHYSICAL DEVELOPER PART I	117
5.1	INTRODUCTION	117
5.2	IS PD DEVELOPMENT PROPAGATED BY LIGHT EXPOSURE?	119
5.2.1	Experimental Method	119
5.2.2	Results and Discussion	121
5.3	DOES PD TARGET LIPIDS IN FINGERMARK RESIDUE?	122
5.3.1	Experimental Method	122
5.3.2	Results and Discussion	126
5.4	DOES PD TARGET ECCRINE MATERIAL IN FINGERMARK RESIDUE?	133
5.4.1	Experimental method	135
5.4.2	Results and Discussion	138
5.5	CONCLUSIONS	151
6	DETERMINATION OF THE TARGETS OF PHYSICAL DEVELOPER PART II	154
6.1	INTRODUCTION	154
6.2	SYNTHETIC FINGERMARK RESIDUE	156
6.2.1	Preparation of synthetic sebum	158
6.2.2	Preparation of synthetic sweat	159
6.2.3	Reactivity assessment of synthetic components	160
6.3	IS PD DEVELOPING A MIXTURE OF ECCRINE AND LIPID CONSTITUENTS?	161
6.3.1	Experimental method	161
6.4	IS PD DEVELOPING AN EMULSION OF ECCRINE AND LIPID CONSTITUENTS?	162
6.4.1	Emulsion type	162
6.5	EXPERIMENTAL METHOD	164
6.6	RESULTS AND DISCUSSION	168
6.7	IS PD DEVELOPING AN EMULSION?	181
6.7.1	Experimental method	181
6.7.2	Results and Discussion	182

6.8	CONCLUSIONS.....	187
7	CONCLUSIONS AND FUTURE DIRECTIONS	190
7.1	CONCLUSIONS.....	190
7.1.1	<i>The composition of fingerprint residue.....</i>	<i>190</i>
7.1.2	<i>The application of Nile red to latent fingerprint detection.....</i>	<i>191</i>
7.1.3	<i>Modifications to the physical developer technique.....</i>	<i>192</i>
7.1.4	<i>The determination of the targets of physical developer.....</i>	<i>193</i>
7.2	FUTURE DIRECTIONS.....	194
APPENDIX I. DEVELOPMENT TECHNIQUE MATERIALS, FORMULATION, APPLICATION AND VISUALISATION		199
I.1	PHYSICAL DEVELOPER.....	199
I.2	INDANEDIONE-ZINC	200
I.3	NILE RED	200
I.4	NINHYDRIN	201
APPENDIX II. FINGERMARK GRADING AND GC-MS DATA.....		203
II.1	FINGERMARK CONTRAST GRADING	203
II.2	GC-MS DATA	204
APPENDIX III. NILE RED EXPERIMENTAL DATA		211
III.1	PRELIMINARY OPTIMISATION TRIALS	213
III.2	THIN LAYER CHROMATOGRAPHY	231
APPENDIX IV. PHYSICAL DEVELOPER EXPERIMENTAL DATA		233
IV.1	UV-VIS SPECTRA	233
APPENDIX V. PHYSICAL DEVELOPER PROTOCOL AND TROUBLESHOOTING		237
V.1	GENERAL CONSIDERATIONS	237
V.2	PREPARATION OF SOLUTIONS USED IN DEVELOPMENT	238
V.3	DEVELOPMENT OF SAMPLES.....	239
V.4	TROUBLESHOOTING.....	240
REFERENCES.....		243

List of tables

Table 2-1: Grades assigned using the CAST and UNIL assessment schemes for four different NR working solution formulations compared in Figure 2-4	24
Table 2-2: Comprehensive grading scheme used during the optimisation of the Nile red working solution formulation (continued on to page 28)	25
Table 2-3: Grades assigned* to fingerprint quarters in Figure 2-4 using the evaluation scheme detailed in Table 2-2	27
Table 2-4: A series of three fingerprint depletions that have been developed by Nile red (left – images have been inverted) and PD (right)	30
Table 2-5: Donor and deposition methodology used for the investigation of the effect of deposition force on subsequent PD and Ind-Zn development	37
Table 2-6: Split natural fingerprints developed with PD (left half) and Ind-Zn (right half; images have been inverted for comparison purposes) deposited by two donors using deposition forces necessary to produce a reading of 100 g, 200 g, 500 g and 1000 g on a laboratory balance	39
Table 2-7: Donor and deposition methodology for fingerprints that were exposed to four different (lipid extraction) solvents and subsequently developed using PD and then NR	46
Table 2-8: Split fingerprint depositions developed with PD and NR after solvent exposure to the left side of the marks. All NR images have been taken in the luminescence mode using 180 ms exposure times	47
Table 2-9: Development of fingerprints by PD followed by NR that had been washed with EtOAc for varying lengths of time (left side). Exposure times for NR visualisation were 100-600 ms	50
Table 2-10: Donor and deposition methodology for the assessment of the effect of residue derivatisation using two extraction solvents for subsequent GC-MS analysis	53
Table 2-11: Description of the GC-MS Parameters and temperature program used in this research	54

Table 2-12: Spot tests of compounds where the lower half of each sample was extracted with EtOAc for GC-MS analysis, and both halves developed with PD.	58
Table 3-1: Donor and deposition methodology for Nile red working solution evaluation experiments	66
Table 3-2: Donor and deposition methodology used in the comparison of the NR-OP and NR-STD solutions.....	67
Table 3-3: Donor and deposition methodology used in the comparison of the NR-OP and NB solutions.....	72
Table 3-4: Formulation and preparation of NR and NB solutions that were compared by TLC analysis.....	78
Table 3-5: R _f values for samples spotted onto a TLC plate and developed with mobile phase	279
Table 3-6: Formulations of working solution made by incorporating NB and TB into a NR microemulsion	81
Table 3-7: Donor and deposition methodology for the assessment of four working solutions(NR-OP, NB, NR-OP/NB and NR-OP/TB) on natural and groomed quartered fingerprint sets	82
Table 3-8: Development of quartered fingerprints using the four working solutions (NR-OP, NB, NR-OP/NB and NR-OP/TB)	84
Table 4-1: Experimental methodology used for the analysis of the different concentration, storage and ageing parameters of the various components in a PD working solution, and how they affect PD developmental effectiveness	89
Table 4-2: Detergent-surfactant solutions used to make PD working solutions (A-E) in experiments investigating the storage, aging and concentration of various components of a PD working solution	90
Table 4-3: Formulation of surfactant and silver nitrate pre-mixed solutions used to make altered PD working solutions which are compared to the current reference formulation [137]*	96

Table 4-4: PD solution formulations used to determine whether a PD solution is more effective in developing fingermarks when it is aged containing silver nitrate or not	101
Table 4-5: Redox solution formulations analysed by UV-Vis to observe degradation of a PD working solution not containing a surfactant or silver nitrate	104
Table 4-6: Donor and deposition methodology used for experiments in for the analysis of the storage and ageing effects of a PD working solution on subsequent fingermark development	107
Table 4-7: Age of PD working solutions made with the described surfactant formulations that were used to investigate the effect of surfactant concentration on the aging of a PD working solution inclusive of the reference formulation* [2].....	108
Table 4-8: Donor and deposition methodology used to assess the effectiveness of different PD working solutions on fingermarks and synthetic fingermark analogues.....	112
Table 4-9: Natural and groomed fingermark samples were compared to stamped deposits of a Latent Print Standard Pad and SFR to assess the suitability of an SFR as a control for four different PD working solutions inclusive of the reference formulation* [2].....	113
Table 5-1: Donor and deposition methodology used in the assessment of a PD working solution being propagated by light exposure	120
Table 5-2: Middle fingermarks from groomed and natural 3-finger depositions developed in PD in normal laboratory lighting conditions (left half of images) and in a photographic darkroom (right half of images).....	121
Table 5-3: Donor and deposition methodology for the assessment of PD reactivity with the lipids in fingermark residue	122
Table 5-4: Properties of organic solvents used to wash the fingermark samples, including dipole moment, dielectric constant, solubility of the solvent in water and solubility of water in the solvent [154].....	124
Table 5-5: Images of spot tests of palmitic acid, cholesterol, stearic acid, squalene and oleic acid in varied concentrations developed by PD.....	126
Table 5-6: Assessment of the reactivity of PD with spot tests of palmitic acid, cholesterol, stearic acid, squalene and oleic acid in varied concentrations; assessed images are in Table 5-5.	

+++ denotes dark/medium silver deposition across sample loaded area, ++ denotes light silver deposition across sample loaded area, + denotes very light silver deposition across sample loaded area, 0 denotes minimal/no silver deposition across sample loaded area 127

Table 5-7: Natural and groomed fingermarks developed by PD after the left side was washed with acetone, chloroform, ethyl acetate, dichloromethane, methanol and hexane. Images were aquired using the VSC 6000 under white light and 7.5X magnification. 129

Table 5-8: Typical amino acid volumes found in a deposited single wet thumb print and a classification of their polarity [156] 133

Table 5-9: Donor and deposition methodology used in experiments assessing the reactivity of PD working solutions on the eccrine constituents contained in fingerprint residue..... 135

Table 5-10: Donor and deposition methodology used in the assessment of PD reactivity on fingermarks deposited successively with a 10-second time interval, and fingermarks that have been exposed to water at various times after deposition, and subsequently aged 137

Table 5-11: PD treated samples (left halves) visualised by high resolution scanning of samples on an Epson scanner and Ind-Zn treated samples (right halves) visualised with a Polilight PL500 forensic light source coupled to a Rofin Poliview IV forensic image capturing and enhancement system (excitation 505 nm with a 555 nm band-pass barrier filter). Natural (left column) and eccrine (right column) fingerprint depletions were obtained with no time interval between depositions..... 138

Table 5-12: PD treated samples (left halves) visualised by high resolution scanning of samples on an Epson scanner and Ind-Zn treated samples (right halves) visualised with a Polilight PL500 forensic light source coupled to a Rofin Poliview IV forensic image capturing and enhancement system (excitation 505 nm with a 555 nm band-pass barrier filter). Natural (left columns) and eccrine (right columns) fingerprint depletions were obtained with a 10-second time interval between depositions 142

Table 5-13: Natural and groomed fingerprint depositions from three donors. Left side of the marks has been washed with water 12 hours after deposition. Marks were aged for 4 months and then developed using PD 148

Table 6-1: Constituents in synthetic sebum (dissolved in 30 mL of DCM) 158

Table 6-2: Molar ratios of constituents in synthetic sweat stock solution..... 159

Table 6-3: PD and Ind-Zn development of synthetic eccrine and lipid constituents. PD-developed fingermarks were recorded using an Epson XP-200 A4 flatbed scanner using 2400 DPI resolution. Ind-Zn-developed fingermarks were visualised with a Polilight PL500 forensic light source coupled to a Rofin Poliview IV forensic imaging system (excitation 505 nm with a 555 nm band-pass barrier filter).....	160
Table 6-4: Synthetic sebum and sweat weights used to make SFR emulsions.....	165
Table 6-5: Artificial ageing parameters for the top and bottom layers of the synthesised SFR prior to decanting	167
Table 6-6: PD and Ind-Zn development on white copy paper for the bottom, middle and top layers of emulsions made with varying ratios of synthetic sebum and sweat. PD-developed fingermarks were recorded using an Epson XP-200 A4 flatbed scanner using 2400 DPI resolution. Ind-Zn-developed fingermarks were visualised with a Polilight PL500 forensic light source coupled to a Rofin Poliview IV forensic imaging system (excitation 505 nm with a 555 nm band-pass barrier filter).....	169
Table 6-7: PD and Ind-Zn development on filter paper for the bottom, middle and top layers of emulsions made with varying ratios of synthetic sebum and sweat. PD-developed fingermarks were recorded using an Epson XP-200 A4 flatbed scanner using 2400 DPI resolution. Ind-Zn-developed fingermarks were visualised with a Polilight PL500 forensic light source coupled to a Rofin Poliview IV forensic imaging system (excitation 505 nm with a 555 nm band-pass barrier filter).	171
Table 6-8: Aging of the top layer (w/o emulsion) and bottom layer (o/w emulsion) of the SFR and subsequent development by PD. PD treated samples were recorded using an Epson XP-200 A4 flatbed scanner using 2400 DPI resolution.....	177
Table 6-9: 15 μ L of SFR deposited onto RP and 10 μ L of SFR deposited onto FP which was then developed with PD 4 and 14 days after deposition. PD treated samples were recorded using an Epson XP-200 A4 flatbed scanner using 2400 DPI resolution.....	178
Table 6-10: Volumes and concentrations of oleic acid and NaCl used to make each emulsion and the number of layers visible after sonication	182
Table 6-11: PD development of layered spot tests using oleic acid (OA) and sodium chloride (NaCl) solutions of varying concentration. Left columns have 5 μ L of NaCl solution pipetted	

onto two different types of paper followed by 5 μ L of oleic acid on top. Right columns have 5 μ L of OA pipetted onto two different types of paper followed by 5 μ L of NaCl solution on top. PD treated samples were recorded using an Epson XP-200 A4 flatbed scanner using 2400 DPI resolution.....	183
Table 6-12: Final NaCl concentration of 3 mL NaCl emulsified with 1 mL oleic acid in the emulsion. PD development on 15 μ L spots on RP of the top (left image) and bottom (right image) fractions of emulsions. PD treated samples were recorded using an Epson XP-200 A4 flatbed scanner using 2400 DPI resolution.	185
Table II-1: Description and colour examples for grading fingermarks developed using a luminescent development technique.....	203
Table II-2: Gas chromatograms for cholesterol, oleic acid, stearic acid and palmitic acid extracted from paper using ethyl acetate	209
Table II-3: Gas chromatogram for squalene, stigmaterol, vegetable oil and lanolin extracted from paper using ethyl acetate.....	210
Table III-1: Donor and deposition methodology for Nile red working solution evaluation experiments.....	212
Table III-2: Grades assigned to developed fingermarks out of 5 for the development of groomed marks using working solutions containing different organic solvents at four different pH in Trial 1. Averages of the three replicates are reported.	213
Table III-3: Grades assigned to developed fingermarks out of 5 for the development of natural marks using working solutions containing different organic solvents at four different pH in Trial 1. Averages of the three replicates are reported.	214
Table III-4: Grades assigned to developed fingermarks out of 5 for the development of groomed marks using working solutions with pH 4 (made with HCl), pH 7 (deionised water), pH 9 (made with NaOH) and pH 11 (made with NaOH) aqueous components with EtOH and IsoP in Trial 2. Averages of the three replicates are reported.	215
Table III-5: Grades assigned to developed fingermarks out of 5 for the development of natural marks using working solutions with pH 4 (made with HCl), pH 7 (deionised water), pH 9 (made	

with NaOH) and pH 11 (made with NaOH) aqueous components with EtOH and IsoP in Trial 2. Averages of the three replicates are reported.	216
Table III-6: Grades assigned to developed fingermarks out of 5 for the development of groomed marks using working solutions with pH 4 (made with HCl), pH 4 (buffer), pH 7 (deionised water) and pH 7 (buffer) aqueous components with EtOH and IsoP in Trial 3. Averages of the three replicates are reported.	217
Table III-7: Grades assigned to developed fingermarks out of 5 for the development of natural marks using working solutions with pH 4 (made with HCl), pH 4 (buffer), pH 7 (deionised water) and pH 7 (buffer) aqueous components with EtOH and IsoP in Trial 3. Averages of the three replicates are reported.	217
Table III-8: Grades assigned to developed fingermarks out of 5 for the development of groomed marks using working solutions with EtOH compared to the NR-STD formulation, and IsoP compared to the STD formulation in Trial 4. Averages of the three replicates are reported.	218
Table III-9: Grades assigned to developed fingermarks out of 5 for the development of natural marks using working solutions with EtOH compared to the NR-STD formulation, and IsoP compared to the STD formulation in Trial 4. Averages of the three replicates are reported. .	219
Table III-10: Grades assigned to developed fingermarks out of 5 for the development of groomed marks comparing EtOH and EtOAc working solution formulations in Trial 5. Averages of the three replicates are reported.	220
Table III-11: Grades assigned to developed fingermarks out of 5 for the development of natural marks comparing EtOH and EtOAc working solution formulations in Trial 5. Averages of the three replicates are reported.....	220
Table III-12: Order of the addition of the working solution components in solutions 6A and 6B	221
Table III-13: Working solutions 7A–7G prepared using Nile red stock solutions of different concentrations in EtOAc.	222
Table III-14: Grades assigned to developed fingermarks out of 5 for the development of groomed marks comparing stock solution Nile red concentrations of solutions 7A-7D in Trial 7-1. Averages of the three replicates are reported.	223

Table III-15: Grades assigned to developed fingermarks out of 5 for the development of groomed marks comparing stock solution Nile red concentrations of solutions 7D-7G in Trial 7-2. Averages of the three replicates are reported.	223
Table III-16: Solutions compared for developmental effectiveness against the STD solution on natural and groomed split fingerprint samples.....	224
Table III-17: Solvents assessed for use in Nile red stock solutions used to prepare Nile red microemulsions.....	225
Table III-18: Working solutions prepared using stock solutions of four different concentrations of Nile red in DCM.	227
Table III-19: Nile red in DCM stock solution (0.01 mg/mL) and surfactant volumes in solutions used to optimise their volume ratio in a Nile red microemulsion containing 25 mL deionised water.....	229
Table III-20: Comparison of Nile red stock and surfactant ratios on split groomed fingerprint samples using solutions described in Table III-19. Developed fingerprint halves were imaged using the exposure best for each solution.....	230
Table III-21: Mobile phases used to separate components on TLC plates	231
Table III-22: TLC plates developed and visualised under various lighting conditions	232
Table V-1: Solution formulations [161], storage conditions and typical appearance for solutions used in the PD development process	238

List of figures

Figure 1-1: Development method for physical developer. *This step is not recommended in the literature [1, 2], however its inclusion stops the PD working solution from becoming too acidic and destabilising after processing multiple items	8
Figure 1-2: Structure of ORO (Adapted from (Wood and James 2009); Chemskech 2017)	9
Figure 1-3: ORO fingerprint development procedure	10
Figure 1-4: Structure of Nile red	11
Figure 2-1: CAST grading scheme for the evaluation of developed fingerprints [100]	21
Figure 2-2: UNIL grading scheme for the assessment of developed fingerprints [101]	22
Figure 2-3: UC grading scheme for the assessment of developed fingerprints [96]	22
Figure 2-4: Four different formulations of a Nile red working solution compared using the quartered fingerprint method	24
Figure 2-5: Schematic representation of the deposition of a fingerprint depletion series	29
Figure 2-6: Layout of deposited fingerprints when comparing techniques using the quartered fingerprint method	31
Figure 2-7: Split fingerprints developed by different formulations of the same technique. Single (left) or three finger depositions (right) can be used	32
Figure 2-8: Fingerprint developed by PD (left) followed by Nile red (right) on natural and groomed fingerprints	35
Figure 2-9: Nile red developed fingerprints deposited using deposition forces required to produce a reading of 100 g (left), 200 g (centre) and 300 g (right) on a laboratory balance	40
Figure 2-10: Compounds in glass-extracted sebaceous fingerprint residue detected using different extraction solvents [113]	43

Figure 2-11: representative gas Chromatogram of natural fingermark halves (of the same deposition) extracted with DCM (black) and EtOAc (green) with an anthracene internal standard (peak at 14.0 min). Full chromatogram can be found in Appendix II.....	55
Figure 2-12: Representative gas chromatogram of groomed fingermark halves (of the same deposition) extracted with DCM (black) and EtOAc (green) with an anthracene internal standard (peak at 14.0 min). Full chromatogram can be found in Appendix II.2.....	56
Figure 3-1: Two synthesised water soluble NR derivatives [5].....	63
Figure 3-2: Three NR derivatives synthesised and evaluated for the development of latent fingermarks [4].....	63
Figure 3-3: Method of processing used for assessment of different NR formulations	65
Figure 3-4: Groomed fingermarks developed by the NR-OP solution (left half) and the NR-STD formulation (right half) at 382 ms (left image - optimal exposure for NR-OP solution) and 163 ms (right image - optimal exposure for the NR-STD formulation).....	69
Figure 3-5: Natural fingermarks developed by the NR-OP formulation (left half) and the NR-STD formulation (right half) at 305 ms (left image – optimal exposure for the NR-STD formulation) and 382 ms (right image – optimal exposure for the NR-OP solution)	69
Figure 3-6: Colour change observed after addition of the NR stock solution to the surfactant solution with stirring to then produce the NR microemulsion.....	71
Figure 3-7: Groomed fingermarks developed with NR-OP (left) and NB (right) at 126 ms exposure (optimal for NR-OP).....	74
Figure 3-8: Groomed fingermarks developed with NR-OP (left) and NB (right) at 636 ms exposure (optimal for NB)	74
Figure 3-9: Natural fingermarks developed with NB (left) and NR-OP (right) at 428 ms exposure (optimal for NR-OP)	75
Figure 3-10: Natural fingermarks developed with NB (left) and NR-OP (right) at 1.87 s exposure (optimal for NB)	75
Figure 3-11: Proposed mechanism for the spontaneous hydrolysis of NB A to NR in aqueous media [84].....	77

Figure 3-12: TLC plates developed using mobile phase 2 and visualised at 490 nm excitation with 550 nm bandpass filter (left) and 490 nm excitation with 630 nm band-pass filter (right)	79
Figure 3-13: NB in equilibrium with NR	80
Figure 3-14: Description of the areas of a quartered fingerprint treated with each solution (NR-OP, NB, NR-OP/NB and NR-OP/TB).....	83
Figure 4-1: Natural fingerprint samples. Left side of each developed using PD-A (stored in the fridge), right side of each developed using PD-B (stored at RT).....	92
Figure 4-2: Natural fingerprint samples. Left side of each developed using PD-A (surfactant contains 3 g n-DDAA, 3 g Tween 20, 1 L H ₂ O), right side of each developed using PD-C (surfactant contains 1.5 g n-DDAA, 1.5 g Tween 20, 1 L H ₂ O).	93
Figure 4-3: Natural fingerprint samples. Surfactants used in both solutions contain 1.5 g n-DDAA, 1.5 g SynN, 1 L H ₂ O. Left side of each developed using PD-D (surfactant stored at RT for 8 months), right side of each developed using PD-E (surfactant stored at RT for 1 week).....	94
Figure 4-4: Natural fingerprints developed using solution PD-F (surfactant contains 6 g n-DDAA, 6 g Tween 20, 1 L DI H ₂ O pre-mixed with 1.18 M AgNO ₃) (left) and solution PD-G (surfactant contains 6 g n-DDAA, 6 g Tween 20, 1 L DI H ₂ O pre-mixed with 0.59 M AgNO ₃) (right)	97
Figure 4-5: Natural fingerprints developed using solution PD-H (surfactant contains 3 g n-DDAA, 3 g Tween 20, 1 L DI H ₂ O pre-mixed with 1.18 M AgNO ₃) (left) and solution PD-I (surfactant contains 3 g n-DDAA, 3 g Tween 20, 1 L DI H ₂ O pre-mixed with 0.59 M AgNO ₃) (right)	98
Figure 4-6: Natural fingerprints developed using solution PD-J (surfactant contains 1.5 g n-DDAA, 1.5 g Tween 20, 1 L DI H ₂ O pre-mixed with 1.18 M AgNO ₃) (left) and solution PD-K (surfactant contains 1.5 g n-DDAA, 1.5 g Tween 20, 1 L DI H ₂ O pre-mixed with 0.59 M AgNO ₃) (right)	98
Figure 4-7: Natural fingerprints developed using solution PD-L (surfactant contains 3 g n-DDAA, 1 L DI H ₂ O pre-mixed with 1.18 M AgNO ₃) (left) and solution PD-M (surfactant contains 3 g n-DDAA, 1 L DI H ₂ O pre-mixed with 0.59 M AgNO ₃) (right)	99

Figure 4-8: Natural fingerprint samples. Left side of each developed using PD-N (silver nitrate added 30 mins before use after 2 months ageing), right side of each developed using PD-O (silver nitrate added when solution was made 2 months prior to use).	102
Figure 4-9: UV-Vis spectrum of redox solution 1 overlaid with its individual solution components	105
Figure 4-10: Redox solutions 1 (left) and 3 (right) photographed after 8 months of aging. Both solutions exhibited an unknown white aggregate dispersed throughout.....	106
Figure 4-11: Groomed (left) and natural (right) quartered fingerprint samples developed using PD-P (4 day old PD solution made with surfactant containing 3 g n-DDAA, 3 g Tween 20, 1 L DI H ₂ O) (top left), PD-Q (4 day old PD solution made with surfactant containing 1.5 g n-DDAA, 1.5 g Tween 20, 1 L DI H ₂ O) (top right), PD-R (4 day old PD solution made with surfactant containing 6 g n-DDAA, 6 g Tween 20, 1 L DI H ₂ O) (bottom left) and PD-S (4 month old PD solution made with surfactant containing 3 g n-DDAA, 3 g Tween 20, 1 L DI H ₂ O) (bottom right)	109
Figure 5-1: PD development of ridges only (left), both ridges and pores (middle) and only pores (right)	146
Figure 6-1: (Left) Two immiscible layers; (Centre) an oil-in-water emulsion; (Right) a water-in-oil emulsion (blue is representative of water, white is representative of oil).....	163
Figure 6-2: Schematic representation of the transition of the layers in the vials after sonication	166
Figure 6-3: Proposed schematic representation of an oil-in-water emulsion with a concentration gradient into a water-in-oil emulsion.....	168
Figure 6-4: Natural fingerprint (left), 10 uL SFR (centre) and a groomed fingerprint (right) were deposited and aged for 4 days in the dark. Samples were then developed using Nin (top), Ind-Zn (middle) and PD (bottom). Nin and PD developed fingerprints were recorded using an Epson XP-200 A4 flatbed scanner using 2400 DPI resolution. Ind-Zn-developed fingerprints were visualised with a Polilight PL500 forensic light source coupled to a Rofin Poliview IV forensic imaging system (excitation 505 nm with a 555 nm band-pass barrier filter).	176

Figure 6-5: Emulsions made using oleic acid (1 mL) and NaCl solution (3 mL) at varied NaCl concentrations (left to right) 1000 mM, 500 mM, 250 mM, 200 mM, 100 mM, 50 mM and 0 mM.....	184
Figure II-1: Gas chromatogram of natural fingermark halves (of the same deposition) extracted with DCM (black) and EtOAc (green) with an anthracene internal standard (peak at 14.03 min)	204
Figure II-2: Gas chromatogram of groomed fingermark halves (of the same deposition) extracted with DCM (black) and EtOAc (green) with an anthracene internal standard (peak at 14.03 min)	205
Figure II-3: Gas chromatogram of a natural fingermark half (black) and groomed fingermark half (green) extracted with DCM with an anthracene internal standard (peak at 14.03 min). Depositions were made from the same donor within 5 minutes of each other.	206
Figure II-4: Gas chromatogram of a natural fingermark half (black) and groomed fingermark half (green) extracted with EtOAc with an anthracene internal standard (peak at 14.03 min). Depositions were made from the same donor within 5 minutes of each other.	207
Figure II-5: Gas chromatogram of a natural 3-finger deposition (black) and a groomed 3-finger deposition (green) extracted with DCM containing an anthracene internal standard (peak at 14.03 min). Depositions were made from the same donor within 5 minutes of each other... ..	208
Figure III-1: Method of processing used for assessment of different Nile red formulations....	211
Figure III-2: Quartered fingermark layout to compare four different working solutions.....	212
Figure III-3: Split fingermark sample developed by solution 11-1 (left) and solution 11-2 (right)	228
Figure III-4: Split fingermark sample developed by solution 11-2 (left) and solution 11-3 (right)	228
Figure III-5: Split fingermark sample developed by solution 11-3 (left) and solution 11-4 (right)	228

Figure IV-1: UV-Vis spectrum of redox solution 2 overlaid with its individual solution components 233

Figure IV-2: UV-Vis spectrum of redox solution 3 overlaid with its individual solution components 234

Figure IV-3: UV-Vis spectrum of redox solution 4 overlaid with its individual solution components 234

Figure V-1: Trays 1–5 used for development methods 1 and 2 for PD..... 239

Research communication

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Podcasts/ Exhibitions

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