Near Infrared Laser Dyes for the Detection of Latent Fingermarks

by

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Certificate of authorship and originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as 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 the information sources and literature used are indicated in the thesis.

NAME

DATE

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imagine and for that I am very grateful. I can only imagine what it would have been like being the only guy in the office but I can imagine it would have ended in me wearing a wig and discussing the proper way to apply fake eyelashes.

On that rather disturbing note I will close with a quote: “You are born with two things: existence and opportunity, and these are the raw materials out of which you can make a successful life”. I want to thank everyone for the opportunities they have given me and to my friends who have made my existence a very enjoyable one.

Table of contents

List of figures

List of tables

Abbreviations

^{13}C NMR	Carbon 13 spectroscopy
^{1}H NMR	Hydrogen-1 (proton) nuclear magnetic resonance spectroscopy
AA	Acetic acid
Ala	Alanine
ATR-FTIR	Attenuated Total Reflectance Fourier Transform Infrared
CB	Cyanobloom
CCD	Charged-coupled device
$CdCl_3$	Deuterated chloroform
CdS	Cadmium sulfide
CdTe	Cadmium telluride
CdTe-MMT	Cadmium telluride montmorillonite
CTAB	Cetyl trimethylammonium bromide
Δ^9-THC	Δ^9-Tetrahydrocannabinol
DESI-MS	Desorption electrospray ionisation-mass spectrometry
DEUS	Digital enclosed ultra-violet imaging system
DFO	1,8-Diazafluoren-9-one
DMAB	p-Dimethylaminodbenzaldehyde
DMF	Dimethyl formamide
DMSO	Dimethyl sulfoxide
DMSO-d_6	Deuterated dimethylsulfoxide
DNA	Deoxyribonucleic acid
Em	Emission
ESA	Europium-doped strontium aluminate
Ex	Excitation
FRET	Forster resonance energy transfer
FTIR	Fourier transform infrared spectroscopy

GD	Good development
Gly	Glycine
His	Histidine
IND	1,2-Indanedione
IND-Zn	1,2-Indanedione zinc
Leu	Leucine
LED	Light emitting diode
λmax	Wavelength of maximum absorbance or luminescence
LOD	Limit of detection
Lys	Lysine
MALDI-MSI	Matrix-assisted laser desorption ionization mass spectroscopy imaging
MeOH	Methanol
MAO	Monoamine oxidase
MHz	Megahertz
MMD	Multi metal deposition
mp	Melting point
ND	No development
NIN	Ninhydrin
NIR	Near-infrared
NMR	Nuclear magnetic resonance spectroscopy
OPSC	Optically pumped semi-conductor
Orn	Ornithine
PC UV	PolyCyano UV
PD	Physical developer
PD	Poor development
Phe	Phenylalanine
QD	Quantum dots
R6G	Rhodamine 6G

RAY	Rhodamine 6G, Ardrox™ and basic yellow 40 dye mixture
RH	Relative humidity
RP	Ruhemann's purple
RUVIS	Reflected ultra-violet imaging system
SDS	Sodium dodecyl sulfate
Ser	Serine
SMD	Single metal deposition
SPR	Small particle reagent
SPR UV	Small particle reagent ultra-violet
SSP	Sticky side powder
STaR 11	Styryl 11 and rhodamine 6G mixture
SWGFAST	Scientific working group on friction ridge analysis, study and technology
SWGIT	Scientific working group on imaging technology
TEC	Thenoyl europium chelate
TECTOPO	Thenoyl europium trioctylphosphine oxide
Thr	Threonine
THF	Tetrahydrofuran
TIFF	Tagged image file format
Tyr	Tyrosine
UTS	University of Technology Sydney
UV	Ultra violet
Val	Valine
VMD	Vacuum metal deposition
VSC	Video spectral comparator
Zn-RP	Zinc Ruhemann's purple complex

Abstract

The near infrared region (700 nm – 2000 nm) of the electromagnetic spectrum provides significant potential for fingermark detection. Many ubiquitous commercial surfaces give luminescent interferences that can present a challenge for latent fingermark enhancement. Background interference from these types of surfaces can be reduced when viewed in the near infrared region. The development of near infrared luminescent techniques for latent fingermarks would improve the possibility of imaging an exploitable fingermark. This research aimed to develop methods for near infrared detection of latent fingermarks across a number of different surface types and assess the effectiveness of the developed techniques by comparing them to conventional detection methods.

A mixture of two dyes, styryl 11 and rhodamine 6G (STaR 11), was coated onto a range of metal oxide powders to produce a luminescent fingerprint powder. This was applied as a dry powder for fingermarks on non-porous surfaces as well as a suspension for developing fingermarks on adhesive and wetted surfaces. The dry powder was successful in developing fingermarks and gave comparable results to a commercially available luminescent fingermark powder. The suspension for adhesive surfaces was able to develop fingermarks however when compared to the commercial method, the developed fingermarks were of significantly poor quality. The suspension for wetted surfaces, when used in conjunction with the EcoSpray® device (a pressurised sprayer which delivers the suspension in a fine mist to prevent fingermark damage), had shown significant promise when compared to conventional luminescent SPR. Ultimately, however, the suspension was unable to develop natural fingermarks, which affected its potential for routine use.

Styrylisatin was trialled as a potential near infrared luminescent amino acid sensitive reagent for the detection of latent fingermarks on porous surfaces. Styrylisatin was successfully synthesised, however there were several issues that made it unsuitable for use as a fingermark detection technique. Despite attempts to optimise the formulation, the sensitivity of styrylisatin to amino acids was not improved, thus it was not pursued any further.

The use of one-step luminescent cyanoacrylate (PolyCyano UV®) was also explored in this research and compared to conventional cyanoacrylate development subsequently stained with rhodamine 6G and STaR 11. PolyCyano UV® developed fingermarks were assessed for

development and visualisation under UV illumination as well as how they performed in a sequence. PolyCyano UV® developed fingermarks were applied successfully in sequence with rhodamine 6G and STaR 11. Sequencing allowed the developed marks to be visualised in the luminescence mode for two different visible wavelength regions as well as in the near infrared region, which was found to improve the possibility of imaging an exploitable fingermark.

A range of imaging systems are available to forensic laboratories, however, the suitability of these systems for near infrared imaging has not been explored in any published study. Four imaging systems (Condor, Fuji IS Pro, Poliview IV and VSC 6000) were compared based on their ability to image fingermarks developed with STaR 11 magnetic powder and cyanoacrylate developed fingermarks stained with STaR 11. Overall, the Poliview IV and VSC 6000 were found to give the best imaging capabilities of all the systems tested. Generally the VSC 6000 was better suited for well-developed fingermarks; however the Poliview IV produced better quality images for poorly developed fingermarks. The Fuji IS Pro was suitable as a lab based near infrared camera; however when used for field purposes it displayed a significant decrease in effectiveness.

The research has successfully developed a range of fingermark detection techniques that are luminescent in the near infrared region. These techniques can be used in conjunction with conventional techniques to improve and possibly increase the number of exploitable fingermarks.