

# **Forensic Applications of Infrared Spectral Imaging**

by  
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Doctor of Philosophy (Science)

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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 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 information sources and literature used are indicated in the thesis.

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Katherine Bojko (nee Flynn)

21st February 2008

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## **Table of Contents**

<b>CERTIFICATE OF AUTHORSHIP AND ORIGINALITY .....</b>	<b>II</b>
<b>ACKNOWLEDGEMENTS.....</b>	<b>III</b>
<b>TABLE OF CONTENTS.....</b>	<b>VI</b>
<b>LIST OF FIGURES .....</b>	<b>X</b>
<b>LIST OF TABLES .....</b>	<b>XV</b>
<b>LIST OF PUBLICATIONS.....</b>	<b>XVI</b>
<b>ABSTRACT.....</b>	<b>XIX</b>
<b>CHAPTER 1: INTRODUCTION.....</b>	<b>2</b>
1.1 INFRARED SPECTROSCOPY .....	2
<i>1.1.1 What is Infrared Spectroscopy? .....</i>	<i>2</i>
<i>1.1.2 Forensic Applications of Infrared Spectroscopy.....</i>	<i>4</i>
1.2 CHEMICAL IMAGING IN FORENSIC SCIENCE .....	6
1.3 FTIR SPECTRAL IMAGING .....	10
<i>1.3.1 Development of FTIR Spectral Imaging.....</i>	<i>10</i>
<i>1.3.2 General Applications of Infrared Spectral Imaging.....</i>	<i>14</i>
<i>1.3.3 Forensic Applications of Infrared Spectral Imaging.....</i>	<i>16</i>
<i>1.3.4 Infrared Spectral Imaging Instrumentation Used Throughout This Research.....</i>	<i>22</i>
<i>1.3.5 Infrared Sampling Techniques Used Throughout This Research.....</i>	<i>23</i>
1.3.5.1 Transmission Methods .....	23
1.3.5.2 Reflectance Methods.....	25
1.4 PROJECT OVERVIEW.....	27
<b>CHAPTER 2: FORENSIC ANALYSIS OF MULTI-LAYERED PAINT CHIPS USING</b>	
<b>INFRARED SPECTRAL IMAGING .....</b>	<b>31</b>
2.1 INTRODUCTION.....	31

2.1.1 Forensic Paint Evidence.....	31
2.1.2 Infrared Microscopy in Forensic Science: Paint Chips .....	32
2.1.3 Infrared Spectral Imaging for Paint Analysis.....	35
2.1.4 Overall Aims.....	36
2.2 MATERIALS AND METHODS .....	36
2.2.1 Sample Details.....	36
2.2.2 Infrared Spectral Imaging.....	39
2.2.3 Cluster Analysis.....	39
2.3 RESULTS AND DISCUSSION.....	41
2.3.1 Sample Preparation Considerations.....	41
2.3.2 Infrared Spectral Images.....	43
2.3.3 Cluster Analysis: Comparison of Spectral Images.....	50
2.4 CONCLUSIONS.....	62
2.5 FUTURE WORK RECOMMENDATIONS .....	64
 <b>CHAPTER 3: FORENSIC ANALYSIS OF BICOMPONENT FIBRES USING INFRARED SPECTRAL IMAGING .....</b>	 <b>68</b>
3.1 INTRODUCTION.....	68
3.1.1 Forensic Fibre Evidence .....	68
3.1.2 Bicomponent Fibres.....	68
3.1.3 Bicomponent Fibres as Forensic Evidence .....	70
3.1.4 Overall Aims.....	74
3.2 MATERIALS AND METHODS .....	74
3.2.1 Sample Details.....	74
3.2.2 Conventional Testing.....	74
3.2.2.1 Microscopic Techniques.....	74
3.2.2.2 Environmental Scanning Electron Microscopy (ESEM).....	75
3.2.3 Infrared Spectral Imaging.....	76
3.2.3.1 Transmission .....	76
3.2.3.2 Diamond Anvil Cell (DAC) Accessory.....	77

3.2.3.3 Attenuated Total Reflectance (ATR) Microscope Accessory (Side-on analysis) .....	77
3.2.3.4 Cross-Sectional Analysis - Transmission .....	78
3.2.3.5 Cross-Sectional Analysis – ATR Analysis .....	78
3.3 RESULTS AND DISCUSSION.....	79
3.3.1 Conventional Testing.....	79
3.3.2 Infrared Spectral Imaging.....	84
3.4 CONCLUSIONS .....	105
3.5 FUTURE WORK RECOMMENDATIONS .....	107
 <b>CHAPTER 4: EXAMINING INTERSECTING LINES USING ATR-FTIR SPECTRAL IMAGING.....</b>	 <b>111</b>
4.1 INTRODUCTION.....	111
4.1.1 Questioned Documents.....	111
4.1.2 Writing and Printing Materials .....	112
4.1.2.1 Ballpoint Pens .....	112
4.1.2.2 Porous-tip Pens.....	113
4.1.2.3 Roller Ball Pens.....	114
4.1.2.4 Gel Pens .....	114
4.1.2.5 Ink-jet Printing .....	114
4.1.2.6 Laser Printing.....	115
4.1.3 Forensic Document Examination – Intersecting Lines.....	116
4.1.4 Infrared Spectroscopic Imaging for Examining Line Crossings .....	122
4.1.5 Overall Aims.....	124
4.2. MATERIALS AND METHODS .....	124
4.2.1. Sampling.....	124
4.2.2. Infrared Spectral Imaging.....	125
4.2.3. Feasibility Study and Optimisation of the Sampling Method .....	125
4.2.4. Validation Study and Blind Testing.....	127
4.3. RESULTS AND DISCUSSION.....	131
4.3.1. Feasibility Study.....	131
4.3.2. Ink-Ink Intersections.....	140

4.3.3. <i>Validation Study for Ink / Toner Intersecting Lines</i> .....	142
4.3.4. <i>Blind Testing for Ink / Toner Intersecting Lines</i> .....	145
4.4. CONCLUSIONS .....	151
4.5 FUTURE WORK RECOMMENDATIONS .....	152
<b>CHAPTER 5: OVERALL DISCUSSION</b> .....	<b>156</b>
<b>CHAPTER 6: REFERENCES</b> .....	<b>162</b>

## List of Figures

<b>Figure 1.1</b> - Diagrammatic representation of ‘datacube’ generated by focal plane array (FPA) detector.....	7
<b>Figure 1.2</b> - Digilab Stingray infrared imaging system.....	23
<b>Figure 2.1</b> - a) Visible light image of paint chip #36, b) FTIR spectral image of paint chip #36 at $1606\text{ cm}^{-1}$ , c) – g) Infrared spectra of paint layers 1-5.....	47
<b>Figure 2.2</b> - a) – d) Four image frames captured at various wavelengths from movie comparing two paint chips from same source (#36).....	48
<b>Figure 2.3</b> - Dendrogram result from a hypothetical hierarchical cluster analysis.....	53
<b>Figure 2.4</b> - Cluster images resulting from hierarchical cluster analysis (HCA) of paint chip #36 with a) five clusters b) six clusters and c) seven clusters.....	55
<b>Figure 2.5</b> - a) Visible light image of two paint chips mosaicked together (#442) b) Cluster image resulting from hierarchical cluster analysis (HCA) of paint chips with six clusters c) Cluster image resulting from hierarchical cluster analysis (HCA) of paint chips (with KBr spectra removed) with four clusters.....	56
<b>Figure 2.6</b> – a)Visible light image of two paint chips from the same source (#264, BMW 320i) b) Spectral image ( $1492\text{ cm}^{-1}$ ) of the two paint chips with regions of interest (ROI) selected using ENVI. c) Resulting cluster image of paint chips using Mahalanobis distance classification method.....	58
<b>Figure 2.7</b> - a) Visible image of the two paint chips mosaicked together (#442) b) FTIR chemical image (using intensity at $987\text{ cm}^{-1}$ ) of two paint chips showing selected ‘regions of interest’ c) results of Mahalanobis distance	



classification in ENVI, d-g) Infrared spectra of paint layers 1-4.....	61
<b>Figure 3.1</b> - Common configurations for bicomponent fibres.....	69
<b>Figure 3.2</b> - Brightfield microscopy visible light image of Orlon 21 (DuPont) at 200x magnification.....	81
<b>Figure 3.3</b> - Brightfield microscopy visible light image of Trevira 256 (Trevira) at 200x magnification.....	81
<b>Figure 3.4</b> - Brightfield microscopy visible light image of Monvelle (Monsanto) at 200x magnification, showing faint division line visible down middle of sample.....	82
<b>Figure 3.5</b> - Polarised microscopy image of Trevira 256 (Trevira).....	82
<b>Figure 3.6</b> - Cross-section image of Monvelle (Monsanto) obtained using environmental scanning electron microscopy (ESEM).....	83
<b>Figure 3.7</b> - Cross-section image of Trevira 256 (Trevira) sheath-core bicomponent fibres obtained using environmental scanning electron microscopy (ESEM).....	84
<b>Figure 3.8</b> - Infrared spectral image of Monvelle (Monsanto) formed by imaging at (a) $1641\text{ cm}^{-1}$ and (b) $1735\text{ cm}^{-1}$ . Infrared spectrum of (c) bottom component, identified as nylon, and (d) top component, identified as polyurethane, from Monvelle (Monsanto).....	91
<b>Figure 3.9</b> - (a) Visible image of Trevira 256 fibre and (b) infrared spectral image of Trevira 256 formed by imaging at $2916\text{ cm}^{-1}$ . Infrared spectra of (c) sheath component, identified as PE (d) combined core and sheath components (PE and PET) and (e) core component, identified as PET, from Trevira 256.....	92
<b>Figure 3.10</b> - Infrared spectral image of Beslon F040 (Toho Rayon) formed by	

imaging using the peak area at (a) 2244 $\text{cm}^{-1}$ and (b) 1684 $\text{cm}^{-1}$ . c) Infrared spectra of the two components in Beslon F040 (Toho Rayon).....	94
<b>Figure 3.11</b> - Infrared spectral image of Orlon 21 (DuPont) formed by imaging using the peak area at (a) 2244 $\text{cm}^{-1}$ and (b) 1036 $\text{cm}^{-1}$ . (c) Infrared spectra of the two components in Orlon 21 (DuPont).....	97
<b>Figure 3.12</b> - Infrared spectral image of Dralon K (Bayer) formed by imaging using the peak area at (a) 2244 $\text{cm}^{-1}$ and (b) 1732 $\text{cm}^{-1}$ . (c) Infrared spectra of the two components in Dralon K (Bayer), with the increased peak intensity indicated at 1730 $\text{cm}^{-1}$ .....	98
<b>Figure 3.13</b> - Infrared spectral image of Cantreze (DuPont) formed by imaging using the peak area at (a) 1246 $\text{cm}^{-1}$ and (b) 1201 $\text{cm}^{-1}$ . (c) Infrared spectra of the two components in Cantreze (DuPont).....	99
<b>Figure 3.14</b> - Transmission infrared spectral image (1648 $\text{cm}^{-1}$ ) of a fibre cross-section from Monville (Monsanto).....	103
<b>Figure 3.15</b> - ATR infrared spectral image (1648 $\text{cm}^{-1}$ ) of a fibre cross-section from Monville (Monsanto).....	103
<b>Figure 4.1</b> - Example of ballpoint pen ink under laser printing showing a) visible image of intersection; b and c) infrared spectra of laser printing and ballpoint pen ink; d and e) infrared spectral images of laser printing and ballpoint pen ink formed by imaging at 1724 $\text{cm}^{-1}$ and 1584 $\text{cm}^{-1}$ .....	135
<b>Figure 4.2</b> - Example of ballpoint pen ink over laser printing showing a) visible image of intersection; b and c) infrared spectra of laser printing and ballpoint pen ink; d and e) infrared spectral images of laser printing and ballpoint pen ink formed by imaging at 1724 $\text{cm}^{-1}$ and 1584 $\text{cm}^{-1}$ .....	136

<b>Figure 4.3</b> - Comparison of the quality of infrared spectral images obtained when using different ATR crystals. Visible image of ink over toner shown in (a); (b-c) shows the toner and ink spectral images obtained using a Germanium ATR crystal; (d-e) shows the toner and ink spectral images obtained when using a Zinc Selenide ATR crystal.....	139
<b>Figure 4.4</b> - ‘Live infrared window display’ (total integrated intensity) of line intersection (a) produced when using the (b) Germanium and (c) Zinc Selenide ATR crystal.....	139
<b>Figure 4.5</b> - Example of ink-ink intersection showing (a) visible image of two intersecting ballpoint pen lines; (b) infrared spectra of two ballpoint pens and (c) infrared spectral image of ink lines formed using the integrated peak intensity under $1584\text{ cm}^{-1}$ .....	141
<b>Figure 4.6</b> - Infrared spectra of two main types of ballpoint pen ink found in Wang et al. (2001) study.....	142
<b>Figure 4.7</b> - Example showing results obtained when different pen pressures used. (a-c) shows the visible light images of Sanford ink over Epson toner using pressure indicators of 10, 7 and 4 respectively; (d-f) the respective toner spectral images formed using the integrated peak intensity under $1724\text{ cm}^{-1}$ ; (g-i) the respective ink spectral images formed using the integrated peak intensity under $1584\text{ cm}^{-1}$ .....	145
<b>Figure 4.8</b> – Infrared spectral image results for blind sample 1, with the visible light image shown in (a), the toner spectral image formed using the peak intensity at $1724\text{ cm}^{-1}$ in (b) and the ink spectral image formed using the peak intensity at $1584\text{ cm}^{-1}$ in (c).....	147

<b>Figure 4.9</b> - Infrared spectral image results for blind sample 16, with the visible light image shown in (a), the toner spectral image formed using the peak intensity at $1724\text{ cm}^{-1}$ in (b) and the ink spectral image formed using the peak intensity at $1584\text{ cm}^{-1}$ in (c).....	148
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## **List of Tables**

<b>Table 2.1</b> - Paint sample details.....	38
<b>Table 3.1</b> - Bicomponent fibre sample details.....	75
<b>Table 3.2</b> - Polymer compositions of fibre samples determined by the author using published classification schemes and the Microtrace Fibre Reference Collection.....	88
<b>Table 4.1</b> - Intersecting lines feasibility study samples.....	126
<b>Table 4.2</b> - Ink-ink intersection samples.....	128
<b>Table 4.3</b> - Intersecting lines validation study samples.....	129
<b>Table 4.4</b> - Intersecting lines blind sample details.....	130
<b>Table 4.5</b> - Techniques used by forensic document examiners to examine blind samples.....	131
<b>Table 4.6</b> - Intersecting lines blind testing results.....	150



## List of Publications

Types of Publication	Number	Reference
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1. Flynn, K., O’Leary, R., Lennard, C., Roux, C., Reedy, B. J. “Forensic Applications of Infrared Chemical Imaging: Multi-Layered Paint Chips” *Journal of Forensic Sciences* 2005;50(4):832-41.

2. Flynn, K., O’Leary, R., Roux, C., Reedy, B. J. “Forensic Analysis of Bicomponent Fibers Using Infrared Chemical Imaging” *Journal of Forensic Sciences* 2006;51(3):586-596.

3. Bojko, K., Roux, C., Reedy, B. J. “An Examination of the Sequence of Intersecting Lines using ATR-FTIR Spectral Imaging” Accepted for publication in *Journal of Forensic Sciences*, 2008.

4. Flynn, K., Reedy, B. J., Roux, C., Tahtouh, M., O’Leary, R., Lennard, C. “Forensic Applications of Infrared Chemical Imaging” Presented at the 17th International Symposium on the Forensic Sciences, Australian and New Zealand Forensic Science Society, Wellington, NZ March 2004



5. Flynn, K., Reedy, B. J., Roux, C. “Determining the Sequence of Intersecting Lines Using Infrared Chemical Imaging” Presented at the 17th Meeting of the International Association of Forensic Sciences, Hong Kong, China August 2005.
6. Reedy, B. J., Flynn, K., Tahtouh, M., Burger, F., Roux, C. “Infrared Chemical (Hyperspectral) Imaging: Applications in Forensic Sciences” Presented at the 17th Meeting of the International Association of Forensic Sciences, Hong Kong, China August 2005.
7. Reedy, B. J., Flynn, K., Tahtouh, M., Burger, F., Rutledge, H., Kalman, J., Doble, P., Roux, C. “Forensic Applications of Infrared Chemical Imaging” Presented at the 6<sup>th</sup> Australian Conference on Vibrational Spectroscopy, Sydney, Australia September 2005.
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9. Flynn, K., Reedy, B. J., Roux, C., Lennard, C. “Applications of Infrared Chemical Imaging to Questioned Document Examinations” Presented at the 17th International Symposium on the Forensic Sciences, Australian and New Zealand Forensic Science Society, Wellington, NZ March 2004.

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13. Flynn, K., Reedy, B. J., Roux, C. "Infrared Chemical Imaging of Bicomponent Fibers" Presented at the 6th Australian Conference on Vibrational Spectroscopy, Sydney, Australia September 2005.

14. Tahtouh, M., Flynn, K., Walker, S., Roux, C., Reedy, B. J. "FTIR spectral imaging applications in trace evidence" Presented at the National Institute of Justice (NIJ)/Federal Bureau of Investigation (FBI) Trace Evidence Symposium, Clearwater Beach, Florida, USA August 2007.

## **Abstract**

Fourier transform infrared (FTIR) spectral imaging is emerging as an exciting new tool in forensic analysis. This technique is capable of simultaneously collecting thousands of infrared spectra using an array detector, thus yielding both spectral and spatial information with extremely fast collection times. The aims of this research were to examine potential forensic applications of FTIR spectral imaging, in particular in the physical evidence area.

Infrared spectral images of multilayered paint chips have been successfully obtained, with the chief advantage over conventional infrared analysis being that thousands of infrared spectra are collected in a few minutes across the whole paint sample. As with conventional infrared spectroscopy, chemical species can be identified from their spectra, but there are also a number of different ways to make multi-component spectral (and hence chemical) comparisons between two samples easy to visualise and understand. Infrared spectral images of two paint chips being compared side-by-side can be viewed as a “movie”, in which each frame is an intensity map of the two samples at a given wavenumber (frequency) value. In another approach, the spectra in the image files are classified into chemically similar groups, resulting in a “cluster” image that makes it possible to simultaneously compare all of the layers in two paint chips.

Bicomponent fibres are a special class of fibres that comprise two polymers of different chemical and/or physical properties. In over 50% of the bicomponent fibre

samples analysed, infrared spectral imaging was able to spatially resolve two spectroscopically distinct regions when the fibres were examined side-on. The technique provided characteristic infrared spectra of each component and images which clearly illustrated the side-by-side and sheath-core configuration of these components in the fibre. It was possible to prepare and image a cross-section of one of the fibres, but in general the preparation and analysis of fibre cross-sections proved very difficult. A number of infrared sampling techniques were investigated and spectral imaging results were compared with those obtained using conventional fibre microscopy techniques.

Attenuated total reflectance (ATR) FTIR spectral imaging was shown to be successful for determining the sequence of heterogeneous line intersections produced using ballpoint pens and laser printers. By imaging at the particular frequencies corresponding to the functional groups specific to the ballpoint pen ink and toner materials, it was possible to form spectral images showing their spatial distribution. It was possible to determine whether the ink was above or below the toner, by examining whether there was a gap present in the ink spectral image at the point of intersection with the toner. Blind tests were performed and the results obtained using ATR-FTIR spectral imaging were directly compared to those obtained by experienced forensic document examiners using methods regularly employed in casework. ATR-FTIR spectral imaging was shown to achieve a 100% success rate in the blind tests, whereas some incorrect sequence determinations were made by the forensic document examiners when using traditional techniques. The technique was

unable to image ink-jet printing, gel pens, roller ball pens and felt-tip pens, and was also unable to determine the sequence of intersecting ballpoint pen lines.

Overall, infrared spectral imaging was shown to be a successful technique for analysing multi-layered paint chips, bicomponent fibres and determining the sequence of intersecting ballpoint pen and toner lines. In the past five years, there has been a significant increase in the number of reported forensic applications of infrared spectral imaging. It is anticipated that this technique will continue to grow in importance as a tool for forensic scientists over the next decade, and that infrared spectral imaging will find a regular place in forensic laboratories.