RGC Ref. No.:
UGC/FDS17/P01/20
(please insert ref. above)

**RESEARCH GRANTS COUNCIL**
**COMPETITIVE RESEARCH FUNDING SCHEMES FOR**
**THE LOCAL SELF-FINANCING DEGREE SECTOR**

**FACULTY DEVELOPMENT SCHEME (FDS)**

**Completion Report**
*(for completed projects only)*

***Submission Deadlines:***
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

## Part A: The Project and Investigator(s)

### 1. Project Title

An investigation into the use of fire extinguisher dry powder to develop latent fingerprints

### 2. Investigator(s) and Academic Department(s) / Unit(s) Involved

| Research Team | Name / Post | Unit / Department / Institution |
|---|---|---|
| Principal Investigator | Dr. MAK, Deejay Suen-yui, Senior Lecturer | School of Medical and Health Sciences, Tung Wah College |
| Co-Investigator(s) | Prof. LEE, Joseph Sai-kit, Professor | School of Medical and Health Sciences, Tung Wah College |
| | Dr. LAM Chuen, Associate Professor | School of Optometry, The Hong Kong Polytechnic University |
| | Dr. CHEUNG, Ka-tik Associate Professor | School of Science and Technology, Hong Kong Metropolitan University |

### 3. Project Duration

| | Original | Revised | Date of RGC / Institution Approval *(must be quoted)* |
|---|---|---|---|
| Project Start Date | 1-January-2021 | Nil | Nil |
| Project Completion Date | 31-December-2022 | 1st extension: 30-June-2023<br>2nd extension: 31-December-2023 | 1st extension: 18-May-2022<br>2nd extension: 4-May-2023 |
| Duration *(in month)* | 24 months | Nil | Nil |

| | | | |
|---|---|---|---|
| Deadline for Submission of Completion Report | 31-December-2024 | Nil | Nil |

4.4 Please attach photo(s) of acknowledgement of RGC-funded facilities / equipment.

## Part B: The Final Report

## 5. Project Objectives

5.1 Objectives as per original application

*1.* Characterize fire extinguisher dry powder by particle size, shape and morphology.

*2.* Determine the suitability of fire extinguisher dry powder to develop latent fingerprints on glass surfaces stored in environments of various temperatures for periods up to 24 weeks to obtain a realistic assessment of the technique's selectivity and sensitivity and to compare the effectiveness with two common routine fingerprint development methods (cyanoacrylate fuming and black magnetic powder).

*3.* Provide insight into the mechanism of ABC powder in detecting various types of latent fingerprints (eccrine, sebaceous and natural).

*4.* Determine whether the spraying process affects the subsequent mass spectrometry imaging for both chemical information and spatial information of endogenous and exogenous chemicals in friction ridges (i.e., compatibility with chemical imaging of latent fingerprints).

5.2 Revised objectives

Date of approval from the RGC: Nil

Reasons for the change: Nil

*1.*

*2.*

*3.* ....

5.3 Realisation of the objectives
*(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)*

Objective 1:
Characterize fire extinguisher dry powder by particle size, shape and morphology.

- Objective 1 was fully achieved.
- This part focused on the characterization of three different brands of ABC powder and two traditional fingerprint powders to determine the particles sizes, shapes and morphology using scanning electron microscopy (SEM), as the size and shape of the powder particles affect the quality and number of developed fingerprints.
- This study focused only on fire extinguishers that are approved by the Hong Kong Fire Services Department for use in commercial and residential settings.
- Elemental composition analysis for each powder was also studied by an energy dispersive X-ray spectroscopy (EDX) detector, with each element and the corresponding atomic composition being quantitatively measured.

Objective 2:
Determine the suitability of fire extinguisher dry powder to develop latent fingerprints on glass surfaces stored in environments of various temperatures for periods up to 24 weeks to obtain a realistic assessment of the technique's selectivity and sensitivity and to compare the effectiveness with two common routine fingerprint development methods (cyanoacrylate fuming and black magnetic powder).

- Objective 2 was fully achieved.
- In the stability study (i.e., time study), natural and sebaceous fingerprints were deposited on microscopic glass slides by three healthy individuals, who represented weak, average and strong fingerprint donors, and the slides were stored at various temperatures for nine ageing periods of 6 hours, 24 hours, 72 hours, 1, 2, 4, 8, 12 and 24 weeks before visualizing with one of the six development methods.
- The ability to reveal the detailed features (level 1, level 2 and level 3) of latent fingerprints and the contrast of fingerprints developed by different methods were investigated.

Objective 3:
Provide insight into the mechanism of ABC powder in detecting various types of latent fingerprints (eccrine, sebaceous and natural).

- Objective 3 was fully achieved.
- A comparative study was carried out to investigate the possible mechanism of powder to detect three types of latent fingerprints (natural, eccrine and sebaceous fingermarks) with different residue compositions on four types of glass substrates.
- The sensitivity of the powder to various fingerprints containing decreasing amounts of residue deposited was also investigated using spilt fingerprints for direct comparison of the development methods from the same fingerprint deposition.

Objective 4:
Determine whether the spraying process affects the subsequent mass spectrometry imaging for both chemical information and spatial information of endogenous and exogenous chemicals in friction ridges (i.e., compatibility with chemical imaging of latent fingerprints).

- Objective 4 was fully achieved.
- Matrix-assisted desorption/ionization mass spectrometry imaging (MALDI-MSI) protocol for fingerprint analysis was first optimized. Three parameters such as matrix selection, matrix concentration and number of passes of matrix were tested.
- The optimized method of matrix application was used to reveal the complex molecular information of various endogenous compounds and exogenous compounds embedded in the powder-developed fingerprints at a micron-scale resolution.
- Operational use of the method was further supported by successful separation of overlapping powder-treated fingerprints without disturbing the fingerprint patterns.

5.4 Summary of objectives addressed to date

| **Objectives** *(as per 5.1/5.2 above)* | **Addressed** *(please tick)* | **Percentage Achieved** *(please estimate)* |
|---|---|---|
| 1. Characterize fire extinguisher dry powder by particle size, shape and morphology. | ✓ | 100% |
| 2. Determine the suitability of fire extinguisher dry powder to develop latent fingerprints on glass surfaces stored in environments of various temperatures for periods up to 24 weeks to obtain a realistic assessment of the technique's selectivity and sensitivity and to compare the effectiveness with two common routine fingerprint development methods (cyanoacrylate fuming and black magnetic powder). | ✓ | 100% |
| 3. Provide insight into the mechanism of ABC powder in detecting various types of latent fingerprints (eccrine, sebaceous and natural). | ✓ | 100% |
| 4. Determine whether the spraying process affects the subsequent mass spectrometry imaging for both chemical information and spatial information of endogenous and exogenous chemicals in friction ridges (i.e., compatibility with chemical imaging of latent fingerprints). | ✓ | 100% |

## 6. Research Outcome

### 6.1 Major findings and research outcome
*(Maximum 1 page; please make reference to Part C where necessary)*

A new and novel fingerprint detection method - fire extinguisher dry powder was demonstrated to be quick, simple, cost-effective, sensitive and selective to detect latent fingerprints. This study first characterized different brands of fire extinguisher dry powder by particle sizes, morphology and elemental composition, and compared the selectivity (ability to develop homogenous fingermark ridges with fine details), sensitivity (ability to develop visible fingermarks even with weak deposits) and stability (ability to develop visible fingermarks which have been aged for a period of time) in detecting latent fingermarks with those of the current fingermark development methods using traditional fingerprint powders and cyanoacrylate fuming in an in-depth and systematic way. Using scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM/EDX), particles from three commercial fire extinguishers, measuring less than 60 μm, were found to exhibit similar size, distribution, and morphology. This size enables effective capture by face masks, thereby reducing harmful and carcinogenic risks to users when using titanium dioxide-based fingerprint powders. EDX analysis also confirmed the presence of poly(methylhydrosiloxane) (PMHS) with hydrophobic -Si-$CH_3$ groups, as well as the hydrophobic silica micro-particles, which could attribute to the selectivity of fire extinguisher dry powders to fingerprint residues. All sebaceous fingermarks developed with fire extinguisher dry powders were graded 4 with sufficient ridge detail and were categorized as “useful” for potential identification. Over 63% of deposited natural fingermarks (i.e., with natural secretions from glands in the skin and environmental contaminants), which are representative of actual operational casework, were graded 3 or 4, demonstrating the feasibility of using fire extinguisher dry powder to develop latent fingerprints operationally. Among the three commercial fire extinguishers, Eversafe fire extinguisher dry powder performed the best; the mean grades of aged fingerprints developed were in the range of 2.8 to 3.7 and were consistently higher than other development methods for any storage time interval. Even for old fingerprints up to 12 weeks old, over 88% had a grade of 3 or 4 and were categorized as “useful” for potential identification, proving that the fire extinguisher dry powders were hydrophobic enough to adhere strongly to the hydrophobic constituents which made up the bulk of aged latent fingermarks. These works are presented in the papers [Attachment 1] and [Attachment 3].

To be incorporated into the field of forensic science, the use of fire extinguisher dry powder must be compatible with matrix-assisted desorption/ionization mass spectrometry imaging (MALDI-MSI) which is a powerful analytical tool to provide both chemical information and spatial information of endogenous and exogenous chemicals in friction ridges. MALDI-MS protocol for fingermark analysis was first optimized. Three parameters such as matrix selection, matrix concentration and number of passes of matrix were tested. The best results were achieved in the MS positive mode when using 4 passes of α-cyano-4-hydroxycinnamic acid (CHCA) at a concentration of 5 mg/mL in 70:30 ACN/ 0.1%TFA solution using the HTX TM-Sprayer, giving the richest ion populations and ion signal intensities, as well as the clarity of fingerprint ridge details. The spraying process of fire extinguisher dry powder to develop the latent fingermarks allowed the direct analysis of endogenous compounds (e.g., amino acids, fatty acids, cholesterol esters, diglycerides, wax esters and triacylglycerols) and exogenous compounds (due to prior handling of a condom, an aspirin pill or personal and household products) embedded in the fingermarks, as well as the imaging of their distributions without disturbing the fingermark patterns. The simultaneous visualization of latent fingerprints and the recording of its molecular images not only provide valuable evidence about the individual such as his/her lifestyle and recent activities, but also resolve overlapping fingerprints. The feasibility of using MALDI-MSI with fire extinguisher dry powder as the new *in-situ* fingermark development technique was demonstrated, showing the significant potential to be integrated into the routine fingerprint forensic analysis. These works are presented in the papers [Attachment 2] and [Attachment 4].

*6.2* Potential for further development of the research and the proposed course of action *(Maximum half a page)*

This study provided critical scientific evidence for using fire extinguisher dry powder to replace fingerprint powdering and other conventional techniques, especially for crime scenes with a large surface area and evidence items that are bulky. Future studies may explore the possibility of incorporating crime-scene lifting tape to powder-developed latent fingerprints for potential operational use on various surfaces to reveal individual lifestyles using MALDI-MSI. The findings will provide valuable guidance for forensic scientist and criminologists to make informed decisions in choosing a fingerprint detection technique and lifting tape for "*in situ*" latent fingerprints encountered in criminal cases that are also compatible with the use of MALDI-MSI to profile fingerprint compositions and image papillary ridges.

## 7. Layman's Summary

*(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)*

Latent fingerprints, frequently present on evidence at crime scenes, are one of the most powerful physical evidence because of their uniqueness and substantial value in biometric identification. Current fingerprint development methods fail to detect all the invisible fingerprints, and it can be very time consuming and labor-intensive when processing large crime scenes and bulky evidence items with large surface areas. In this study, a new "*in situ*" latent fingerprint detection method that makes use of dry powder from a fire extinguisher was developed, and its selectivity, sensitivity and stability were compared with those of the current fingermark development methods. The application of matrix-assisted desorption/ionization mass spectrometry imaging (MALDI-MSI) for the chemical analysis of powder-developed fingerprints was also reported for the first time. The spraying process of fire extinguisher dry powder allows latent fingerprints to be developed within seconds at crime scenes, while imaging of each developed fingerprint allows simultaneous pattern visualization and chemical analysis for building a profile of the individual who left the fingerprint. Our method effectively combines the advantages of fire extinguisher dry powder as a new fingerprint development technique with MALDI-MSI, showing the significant potential for the powder to be integrated into the routine fingerprint forensic analysis.

## Part C: Research Output

### 8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

*(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)*

| The Latest Status of Publications | | | | Author(s) *(denote the corresponding author with an asterisk*)* | Title and Journal / Book *(with the volume, pages and other necessary publishing details specified)* | Submitted to RGC *(indicate the year ending of the relevant progress report)* | Attached to this Report *(Yes or No)* | Acknowledged the Support of RGC *(Yes or No)* | Accessible from the Institutional Repository *(Yes or No)* |
|---|---|---|---|---|---|---|---|---|---|
| **Year of Publication** | **Year of Acceptance** *(For paper accepted but not yet published)* | **Under Review** | **Under Preparation** *(optional)* | | | | | | |
| | | Yes | | Deejay Suen-yui Mak*, Zhong-Ping Yao | Latent fingermark detection using fire extinguisher dry powder as a novel "in situ" development powder | No | Yes [Attachment 1] | Yes | No |
| | | Yes | | Deejay Suen-yui Mak*, Zhong-Ping Yao | Chemical Analysis of Latent Fingermarks Developed with Fire Extinguisher Dry Powder with Matrix-Assisted Laser Desorption/Ionization Mass Spectrometry Imaging | No | Yes [Attachment 2] | Yes | No |

### 9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered

*(Please attach a copy of each conference abstract)*

| Month / Year / Place | Title | Conference Name | Submitted to RGC *(indicate the year ending of the relevant progress report)* | Attached to this Report *(Yes or No)* | Acknowledged the Support of RGC *(Yes or No)* | Accessible from the Institutional Repository *(Yes or No)* |
|---|---|---|---|---|---|---|
| March, 2022/Virtual | Latent fingerprint detection using fire extinguisher dry powder on common porous and non-porous surfaces | 4th Global Webinar on Forensic Science | No | Yes [Attachment 3] | Yes | Yes |
| August 2023/Korea | Development of Fire Extinguisher Dry Powders for Analysis of Latent Fingerprints by MALDI-MS | Asia-Oceania Mass Spectrometry Conference and the Annual Meeting of the Korean Society for Mass Spectrometry (AOMSC-KSMS 2023) | No | Yes [Attachment 4] | Yes | Yes |

Most relevant conferences were cancelled during the COVID period.

**10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning**
*(Please elaborate)*

As a teacher at Tung Wah College, the first and only institution in Hong Kong to offer an undergraduate programme in forensic science, my research experience in fingerprint detection and chemical analysis have significantly enhanced my teaching and learning practices. The research outcomes developed, particularly the application of innovative fingerprint development techniques to real-world scenarios, have been seamlessly integrated into the forensic science courses and shared as case study examples. Additionally, this project has strengthened my ability to supervise and mentor research students, encouraging them to think creatively and engage in learning experiences beyond the classroom.

**11. Student(s) Trained**
*(Please attach a copy of the title page of the thesis)*

| Name | Degree Registered for | Date of Registration | Date of Thesis Submission / Graduation |
|---|---|---|---|
| | Bachelor of Medical Science (Honours) – Major in Forensic Science | 2017 | Graduated in 2021.<br>Skills learnt:<br>i. Fingerprint development techniques<br>ii. Microscopic techniques |
| | | | |
| | | | |

**12. Other Impact**
*(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)*

This research was conducted in close collaboration with our research partners from various universities, such as The Hong Kong Polytechnic University. Such partnerships are vital in advancing our forensic science initiatives, as they provide access to specialized equipment (e.g., scanning electron microscope and mass spectrometer) and expertise that enhance our research capabilities.

## 13. Statistics on Research Outputs

| | Peer-reviewed Journal Publications | Conference Papers | Scholarly Books, Monographs and Chapters | Patents Awarded | Other Research Outputs (please specify) | |
|---|---|---|---|---|---|---|
| **No. of outputs arising directly from this research project** | 2 under review | 2 | | | Type | No. |
| | | | | | | |

## 14. Public Access Of Completion Report

*(Please specify the information, if any, that cannot be provided for public access and give the reasons.)*

| Information that Cannot Be Provided for Public Access | Reasons |
|---|---|
| Nil | Nil |