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Synthesis Testing and On-Field of Novel Low-Cost Latent Fingerprint Development Powders

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Abstract

Background: A series of novel and low-cost powders were synthesised for the detection and extraction of the latent fingerprints deposited on various porous and non-porous surfaces. The template materials for these novel products range from silica nanoparticles to iron nanoparticles and activated charcoal. Preliminary lab testing indicated high quality fingerprints that were developed on various porous and non-porous surfaces such as glass slides, polymer plastic bags, aluminium foil, cardboard and paper.

Results: The silica based nano-fingerprint powders gave extremely fine visual prints as compared to commercial SIRCHIE® powders, with a white pattern of the ridges. Activated charcoal based and iron nanoparticles based powders on the other hand yielded fine black fingerprint patterns similar to the commercial SIRCHIE® powders. These series of powders were subjected to on-field testing by utilising the state-of-art facility of the General Department of Forensic Science and Criminology, Dubai Police. The samples were tested here under both lab conditions and virtual crime scenes, alongside the SIRCHIE® commercial powders already in standard use by the Dubai Police. The qualities of print developed were assessed based on the AFIS (Automated Fingerprint Identification System) report and visual inspection by the senior fingerprint experts of the Dubai police.

Conclusion: The study revealed distinct advantages of the novel synthesised products over the commercial powders. There was higher uniformity of the developed print patterns, higher score of AFIS analysis and advanced recovery of damaged fingerprints using the novel powders, which makes these novel products highly commercially viable.

Keywords: Latent fingerprint • Powder dusting • Carbon powder • Forensic science • Fingermarks • Magnetic powder

Introduction

Evidence identification and collection are one of the most critical processes in crime scene investigation. Various types of evidence are sought after at a crime scene, but the key evidence that is undeniably critical for any case are the fingerprints. This is because fingerprints represent a unique identification marker for each individual that can easily differentiate between people. However, the presence of fingerprints on various types of surfaces at a crime scene makes it a challenge to successfully identify and record it. It is the quality and details of these recorded or extracted fingerprints that is adjudged permissible in the court for criminal conviction [1].

A good and permissible fingerprint for judicial purposes must meet some official criteria that are based on a number of parameters. For instance, the most frequent judicial scrutiny of submitted fingerprints is based on errors in the ACE-V process. This includes, but not restricted to, 4 stages of forensic expert's methodology in presenting the fingerprint evidence. These stages are grouped as analysis stage, comparison stage, evaluation stage and verification stage. Furthermore, the qualification and experience of the fingerprint expert handling this critical piece of evidence is also often taken into account during a ruling. Finally, the procedure and the elements involved at various stages of extracting and developing the fingerprints should be well-established and scientifically acceptable [2,3].

Latent fingerprint development has evolved a great deal over the century, especially with regards to various chemical and physical methods that are employed to uncover hidden fingerprint evidences from different surfaces. However, the pros and cons exist for each of the physical and chemical methods and therefore, it is the awareness and experience of the fingerprint expert to employ an appropriate method for successful development of latent fingerprints [4]. A rule of thumb is to use an appropriate fingerprint powder with specific surface-related properties to develop the latent fingerprints from any solid surface. However, often the commercial fingerprint powders are limited to only specific surfaces and development conditions which restrict its use on other surfaces, crime scenes or even to the level of user expertise.

SIRCHIE® is a current global leader among the manufacturers of latent fingerprint powders and other kits and tools used extensively for forensic examination. More than 120 countries and their law enforcement agencies use SIRCHIE® products, including the highly advanced and reputed *the General Department of Forensic Science and Criminology, Dubai Police*. The authors' research group was approached by this prestigious department of Dubai Police to explore and exploit the group's nano-technological advancement towards fingerprint applications. Therefore, the focus of this research was to improve the quality of developed latent fingerprints, by synthesizing highly efficient novel nanoparticles-based fingerprint powders that are low-cost and can be used on both porous and non-porous surfaces. Furthermore, the developed fingerprinting powders were run through an automated database (AFIS) by the Dubai Police Department, to minutely analyse the level of details exhibited by the novel powders, in comparison to the SIRCHIE® products.

Materials and Methods

The reagents used for the experiments were purchased from Sigma Aldrich

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and Sirchie Co. Ltd. The chemicals were used as it is without any modifications and all the safety procedures were followed. Fumehood was used constantly for all the fuming and strongly odoured liquids. n-Dodecyl trimethoxysilane, Tetraethyl-orthosilicate 99.9% (TEOS), concentrated Ammonium Hydroxide (28%), Mesitylene 98% and Activated Charcoal powder were purchased from Sigma Aldrich. Iron (II) chloride tetrahydrate, 99$^+$% and Iron (III) chloride hexahydrate, 99+% were purchased from ACROS organics of FisherScientific. Regular Hi-Fi Volcano Latent Print Powder (CAT.No. 101L), Magnetic Latent Print Powder (No. BPM114L), Standard Size Fiberglass Brush with Plastic Handle, White $1^{1/2}$ inch x 2 inch Hinge Lifter and Standard Magnetic Powder Applicator Anodized Aluminium were purchased from SIRCHIE®.

The fingerprint development powders were characterised using primary analytical techniques such as SEM (Scanning Electron Microscopy), XRD (X-Ray Diffraction method) and particle sizer. In this work, Bruker D2 Phaser diffractometer was used with a DIFFRAC SUITE software, scan time of 5 minutes, Cu wavelength of 1.5406 Å and a scan range of 2ϴ = 5 to 80°. Malvern Mastersizer 2000 was used for analyzing the particle size using a vortexed suspension in deionised water. FEI Quanta 200 SEM was used to study the morphological appearance of the synthesised materials. An accelerating voltage of 20 kV was applied for SEM analysis and the spot size between 2 to 3 was used to get high quality images. The novel powders were subjected to a series of physical tests in laboratory environment followed by on-field testing and AFIS match scoring at Dubai Police Department.

Synthesis of silica nanoparticles based powder

Silica nanoparticles can be easily synthesised using modified Stober's method [5]. In a reaction flask of 500 mL, 125 mL of absolute ethanol was mixed with 125 mL ammonium hydroxide (5M). The solution was kept for ultra-sonication treatment in a water bath for 5 minutes. At the end of this, 17.5 mL of tetraethyl orthosilicate (TEOS) was added in the reaction flask and the solution was treated again in ultra-sonication bath for another 30 minutes. A white suspension was achieved at the end of sonication period that was subjected for dialysis with deionised water for 2 to 4 days until the pH of the dialysis reached pH 7. The suspension was centrifuged or vacuum filtered, dried 50°C oven and finely ground to obtain a white fingerprint powder. The powder hereon will be referenced to as basic silica, for the rest of the text.

Magnetised silica powder

In a reaction flask of 500 mL, 0.85 grams of iron (ll) chloride and 2.16 grams iron (lll) chloride was measured and were mixed in solution containing (20 mL ethanol and 40 mL deionised water) while it was covered with Para film. The reaction mixture was then mixed with 250 mL of basic silica suspension or 1g of silica powder and kept for stirring for 1 hour. 30 mL ammonium hydroxide (5M) was prepared and was added to the solution drop wise while it was stirring. The final mixture was kept for stirring for another hour, sample was filtered using vacuum filtration technique and deionised water was added to wash out the excess of ammonium hydroxide. Finally, the sample was kept to dry at 50°C oven overnight and ground to a fine powder. The powder hereon will be referenced to as magnetised silica for the rest of the text.

Mesitylene-charcoal based powder

Activated charcoal was commercially purchased from sigma-aldrich with an approximate size of about 75 microns. 60 mL of mesitylene was taken in a conical flask and 4 g of activated charcoal was added to it with constant stirring. After 20 mins, the solution was kept in a hydrothermal bomb for 36 hours at 200°C. The solution was then filtered and washed with copious amounts of deionised water, followed by drying the filtered product at 80°C for 2 hours using a hot air oven. The sample obtained as fine black powder with characteristic mesitylene smell. The powder hereon will be referenced to as basic mesitylene for the rest of the text.

Magnetised mesitylene-charcoal powder

60 mL of mesitylene was taken in a conical flask and mixed with 3g of activated charcoal with continuous stirring for 10 mins. The solution was sonicated for 60 mins using sonicator water bath, where 60ml of mixed iron solution (prepared separately as described earlier) was added dropwise after 10 mins into sonication. The mixture was left for the rest of the sonication duration, after which 120 ml of 5M ammonia solution (in 1:3 water-ethanol solution) was added dropwise and sonicated for another 30 mins. The final solution was then filtered, washed and dried at 80°C for 2 hours. The sample obtained as fine black magnetic powder with characteristic mesitylene smell. The powder hereon will be referenced to as magnetised mesitylene for the rest of the text.

Characterisation techniques

The fingerprint development powders were characterised using primary analytical techniques such as SEM, XRD and particle sizer. In this work, Bruker D2 Phaser diffractometer was used with a DIFFRAC SUITE software, scan time of 5 minutes, Cu wavelength of 1.5406 Å and a scan range of 2ϴ = 5°C to 80°C. Malvern Mastersizer 2000 was used for analyzing the particle size using a vortexed suspension in deionised water. FEI Quanta 200 SEM was used to study the morphological appearance of the synthesised materials. An accelerating voltage of 20 kV was applied for SEM analysis and the spot size between 2 to 3 was used to get high quality images.

Powder testing details

All the fingerprints were deposited by authors working in lab and the senior fingerprint expert of Dubai police using the thumb impression. The procedure which was followed for depositing the thumb prints involved slight rubbing of the thumb to the forehead to collect sweat and oily secretions of the body, followed by depositing the prints on the surfaces using varying degree of forces. The thumb was not pre-rinsed with any soap or solvents, so as to accumulate mixed natural body secretions, similar to that found in the fingerprints at the crime scenes. This ensures that any cosmetics and other contaminants can contribute to test the efficiency of the powders in developing latent fingerprints. Two sets of fingerprints were deposited in each experiment on a particular surface so as to compare the novel powders with the SIRCHIE® products. The developed fingerprints were photographed in lab using iPhone 6, 8MP, f/2.2 camera with phase detection autofocus and dual LED flash, whereas it was tape-lifted and tested for AFIS at the Dubai Police Department.

Five surfaces were used for testing the fingerprint powders based on their classification of porous or non-porous nature. Non-porous surfaces included glass slides, polymer plastic bags and aluminium foil, whereas the porous surfaces included the cardboard and paper. The non-magnetised basic powders were used with a fibre glass brush and standard brushing techniques employed by fingerprint experts. Firstly, a good amount of the powder was dropped on to a platform, followed by dipping a brush in it gently for its strands to accumulate a good amount of powder. The brush is then shaken slowly over the entire surface to be analysed and further dipped in the powder available on the platform, in case more powder is required to be sprinkled. Finally, the brush is stroked gently over the surface in one direction only at first to observe if any fingerprints develop. To test the powder's efficiency of adhering to the fingerprints, more rigorous approach is taken which involved using more forceful brush strokes and in all directions. This ensures the optimum affinity or efficiency of the powder to adhere to the latent fingerprints without getting damaged due to brushing. However, extremely rough brushing techniques can cause abrasion of fingerprints, irrespective of the efficiency of the fingerprint development powder. Therefore, certain practice and skill is required to safely develop latent fingerprints using powders, without permanently damaging any details during brushing.

A magnetic applicator is used for testing the magnetic fingerprint powders that overcomes most of the brushing limitations. The magnetic brushing involves cleaning the tip of the magnetic applicator brush with a clean alcohol tissue, followed by magnetically attracting the powder to it and carefully dropping the powder at the exact site in focus. Next, the powder is again lifted using the magnetic brush and normal brushing technique is used gently all over the fingerprint surface. Finally, dropped powder is magnetically lifted again using the magnetic brush and standard brushing technique is used. Care should be taken as to not press the magnetic brush on the surface as it could diminish or eradicate the prints permanently. However, such a practice is again not advisable for actual crime scene investigation, along with any rough brushing techniques, as it may cause permanent loss of fingerprint evidences.

The analysis of developed fingerprints involved close inspection of ridge pattern by visual observations using a magnifying glass. This practice is purely based on the experience and knowledge of the fingerprint expert, who decides to take forward the presumably good quality powder samples for next stages of analysis and testing. This procedure was repeated on a virtual crime scene, where trainee fingerprint experts at the department of Dubai Police were asked to locate and develop the latent fingerprints. This ensured understanding of the performance of the synthesised powders in regard to the skills and expertise levels of a professional's on-field.

Furthermore, all the developed fingerprints were lifted using a SIRCHIE® tapelifter, which is a standard procedure to collect fingerprint evidences, in addition to photographic recordings. It is done by using a contrasting tape background in regard to the colour of the developed fingerprint, which is placed on one end of its sticky surface at a good margin from fingerprint boundaries. Next, the tape is slowly pressed onto the surface and slight even pressure is applied by rubbing the surface, so as to uniformly stick the adhesive to the developed fingerprint pattern, avoiding any air bubbles in it. The tape is then lifted slowly and carefully from the surface without touching the area and side containing the fingerprint pattern.

This tape lifting method ensures that the novel powders were able to keep the developed fingerprints pattern intact and facilitate its transfer to another substrate without compromising its quality or levels of detail. It also ensures the storage stability of the lifted patterns in optimum conditions for prolonged periods of time without deterioration of the print.

AFIS analysis

The photographed or lifted latent fingerprints were analysed using either of the mode functions of the AFIS that uses both pictures and physical surfaces for analysis. There are a number of parameters that are adjusted and corrections are applied before hitting for search in the AFIS database. These adjustments include the geometric image accuracy, signal to noise ratio, modulation transfer function, gray-scale range, linearity and uniformity [6,7]. One of the most important features of AFIS analysis is the likelihood ratios that facilitates the mark to print comparison to give a score. There could be an inherent variability of AFIS scoring for between-fingers analysis, but overall a number of factors play an important role in obtaining an accurate match. These are directly linked to the quality of the developed fingerprint that evidently enhances the total number of scoring minutiae patterns [8,9].

SAFRAN MorphoBIS 2.0 from MorphoTrak® software was used by Dubai Police headquarters to analyse all latent fingerprints and match it effectively to its criminal database. This software has an option to automatically or manually detect fingerprint traits such as ridges, whorls and loops. There is a score which is assigned to the fingerprint evidence based on AFIS's detection of these traits and a unique code is run for a potential match in the criminal database. The use of AFIS is entirely based on the skills and knowledge of the fingerprint experts as damaged or partially developed fingerprints can also yield positive matches based on the region that is focussed on for analysis.

Results and Discussion

The individual fingerprint powders were first analytically analysed in lab to confirm its identity, followed by testing for efficiency to develop the latent fingerprints on different surfaces as compared to commercial SIRCHIE® powders.

Silica based powder

Basic silica powder was synthesised as spherical nanoparticles of smooth morphological surface as shown by SEM results shown in Figure 1.

The Mastersizer results showed that synthesised basic silica powder had an average particle size of 622 nm. This is approximately similar to the results shown in SEM analysis where the average particle size was about 300-400 nm. The difference in Mastersizer result is due to the slight aggregation of particles that were dispersed in deionised water during analysis. XRD pattern of basic silica powder shown in Figure 1, confirmed that the synthesised silica nanoparticles were amorphous in nature with the presence of a broad peak at around $2\theta = 21°$ indicating a typical amorphous silica's diffraction pattern.

The basic silica powder was tested on 3 surfaces and the results are shown in the Figure 2.

It can be seen from the results shown in Figure 2 that basic silica powder gave brilliant white fingerprints with high levels of uniformity, evenness and details. All the ridge patterns were distinctly seen on foil and glass surface, as opposed to commercial powders which showed partial smudging and faded areas. This explains the characteristic interaction of the silica nanoparticles with the constituents of fingerprint marks. Silica nanoparticles being hydrophilic in nature with abundant hydroxyl groups, uses electrostatic interactions to bind with the sweat components (98% water, amino acids, inorganic ions, urea, glucose and proteins). Furthermore, regular smooth surface along with homogeneity are other main reasons which causes clear ridge patterns without any smudging or fading.

However, when the silica nanoparticles were magnetised, it led to a characteristic change in colour and performance of the basic silica powder towards fingerprinting applications. The magnetic silica powder gave weaker and brownish prints with faded regions along with slight smudging. However, the magnetism was quite strong as it formed a fine magnetic powder with a flaky appearance that shows strong attraction to a magnetic brush.

Furthermore, testing of basic silica powder towards porous surfaces such

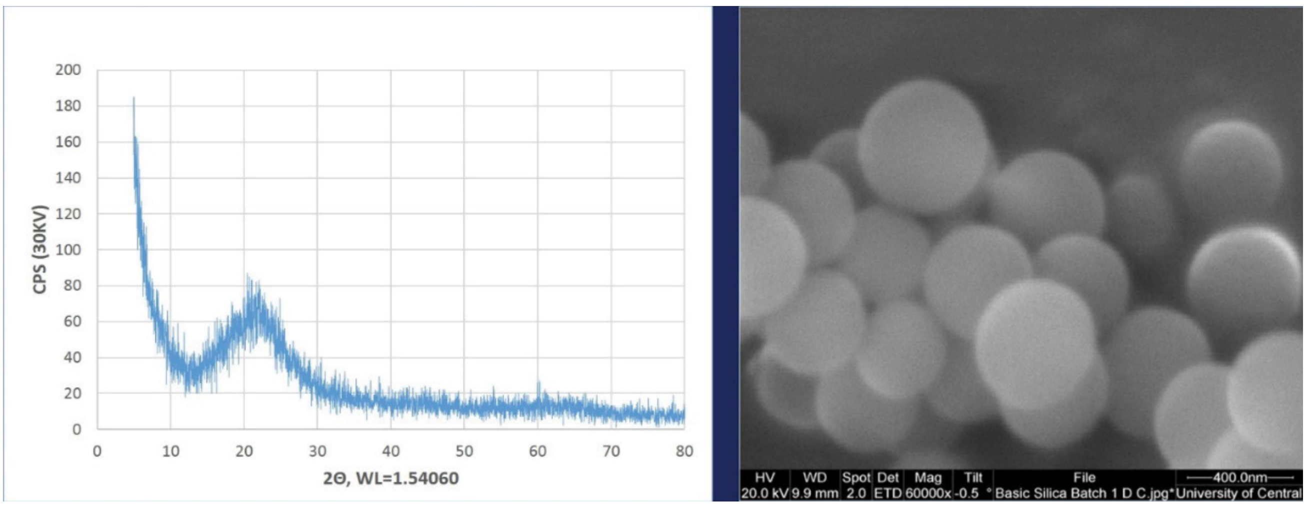

Figure 1. XRD pattern (left) & SEM image (right) of basic silica nanoparticles.

as cardboard (Figure 2), gave very weak prints which were quite invisible and certainly required further enhancement. This is understood to be due to its weak interaction with the fingerprint secretions that penetrate deep into the pores of the porous substrates, hence causing obstruction to adherence with the molecules absorbed within the substrate [10]. Therefore, further testing of the basic silica powder on porous surfaces was not done. However, on testing of magnetised silica powder on porous surfaces such as a cardboard, it was found that the quality of fingerprints was improved as compared to basic silica powder. This is possibly due to the very fine contact between the magnetic particles and the fingerprint secretions present within the pores. But the magnetised silica showed weak brownish fingerprints, which ideally requires further enhancement to illuminate minor details of the pattern. One possible solution could be to surface-functionalise the silica nanoparticles with different organic and inorganic groups [11]. However, an alternative and simpler discovery was made while testing for organic ligands in the form of mesitylene, therefore the subsequent work was focussed on it.

Novel mesitylene-based powders

Mesitylene has a boiling point of 165°C, forming vapours denser than that of air. It is a benzene derivative that is yet to be explored extensively for research purposes. However, while focussing our efforts on understanding the fingerprint compositions (especially of sweat and oily residues) we discovered that mesitylene was explored for its magnificent properties in binding to amino acids. Heinis et al. showed that peptides can remarkably bind to organic solvents such as mesitylene at the cysteine residues. Although the exact mechanism of the reaction remains unknown, an electrophilic substitution is expected to take place between the amino group of the peptides and the ortho-carbon site of the mesitylene group. This is thought to be of high importance for fingerprint residues as mesitylene can effectively bind to the amino acids present in the sweaty part of the deposited fingerprint. However, since the practical application is to use a powder for developing the prints, therefore a suitable template for mesitylene is needed.

It is know that the oily residues also constitute a large part of the deposited fingerprints and therefore it too requires specific targeting. It is well documented in literature, that charcoal powder [8] had been used extensively since decades, to develop latent fingerprints on both non-porous and semi porous surfaces such as wood. This is due to the fascinating properties of charcoal to adsorb organic chemicals due to its large surface (as high as 3000 m^2). Furthermore, one of the most advanced analytical application of activated charcoal involves separating the carbohydrates (mono-, di-, tri-saccharides) using ethanol as mobile phase in low pressure chromatography. Activated charcoal is thought to have fullerene-like structure [3] and at low temperatures such as 21°C, adsorption of mesitylene is possible. However, raising temperatures to as high as the boiling point of mesitylene (165°C) could lead to the formation of novel complexes. Therefore, these properties of mesitylene were explored in this research and both non-magnetic and magnetic powders were synthesised using mesitylene as a ligand and activated charcoal as a template [11].

Basic mesitylene powder

The novel black basic mesitylene powder that was synthesised hydrothermally at 200°C was tested for developing latent fingerprints on 5 surfaces: 3 non-porous and 2 porous surfaces. The analytical results from SEM and XRD showed a very amorphous powder with irregular morphological structure for the commercially purchased activated charcoal. Furthermore, the particle size was measured to be around 25 µm, which is attributed to aggregation and poor dispersion of the powder in water.

The results of latent fingerprint development from all 5 surfaces for comparison of basic mesitylene powder's performance with the commercial SIRCHIE® powder is shown in Figure 3.

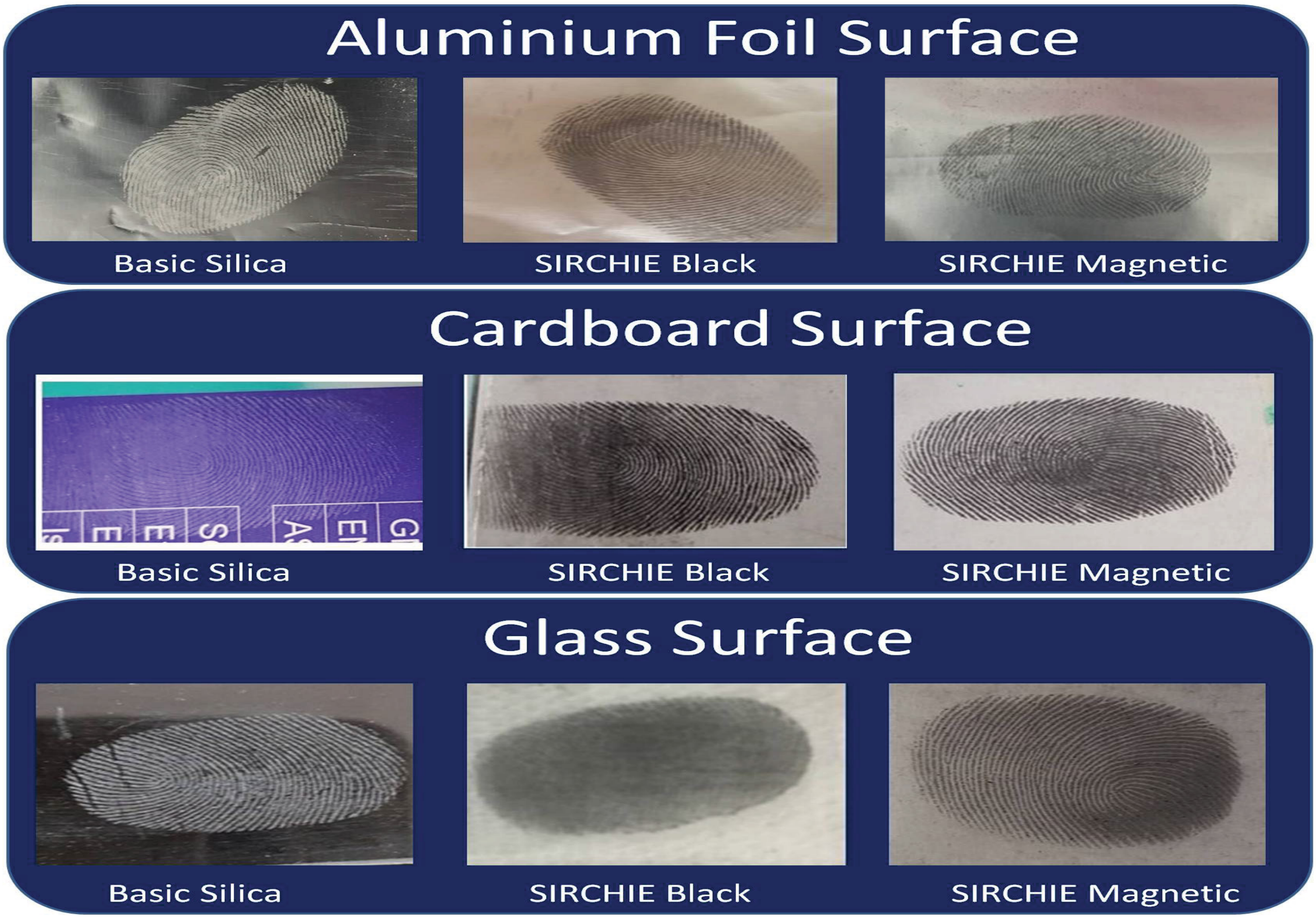

Figure 2. Visual comparison of latent fingerprints developed from basic silica and two commercial SIRCHIE® powders on 3 surfaces.

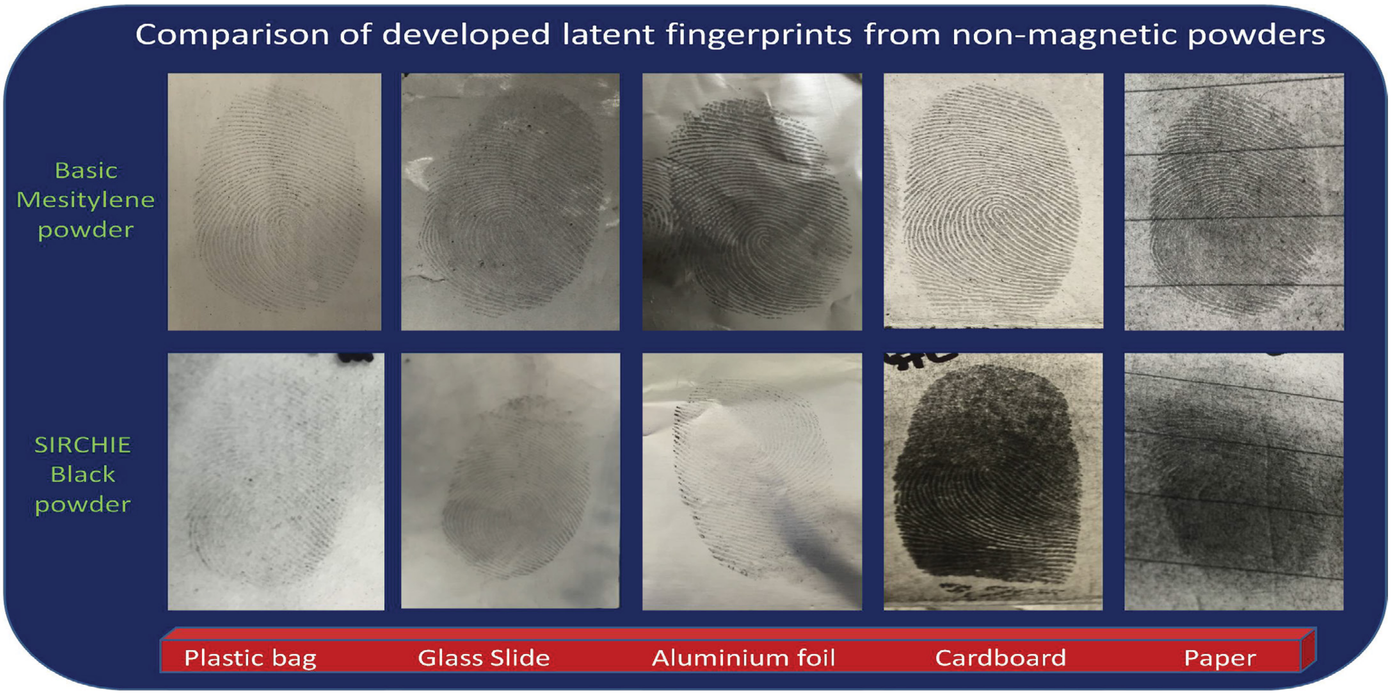

Figure 3. Comparison of the quality of developed latent fingerprints between the synthesised basic mesitylene powder (top row) and the commercially available SIRCHIE® black powder (bottom row) on 5 surfaces.

The results show a clear distinction between the quality and details generated by the novel powder and the commercial powder. The basic mesitylene powder showed clear ridge patterns and high levels of details on both non-porous and porous surfaces, as compared to SIRCHIE® black powder. Commercial powder was found to work poorly on non-porous surfaces, giving faded prints and also potentially damaging the details. However, its performance on the cardboard surface showed a high contrast with dark black appearance, but the overall pattern is observed to be smudged. On the other hand, synthesised novel powder gave lighter print on cardboard, but the ridges were developed with high levels of details. Moreover, the novel powder gave more or less consistent contrast and performance on all 5 surfaces.

Furthermore, the greatest strengths of the novel powder can be observed in its fine detailing and distinction of the ridge patterns, as it does not cause smudging or fading patches on the fingerprint pattern. The developed prints on paper and cardboard are of particular advantage here, as it can be seen that the commercial powder gave a poor quality of print on the paper, as compared to very finely detailed print developed by the novel powder. This demonstrates the superiority of the synthesised powder to successfully develop very high quality latent fingerprints on porous surfaces such as paper, as opposed to most commercial powders that face this limitation.

Magnetised mesitylene powder

The magnetised novel powder was synthesised using ultrasonication to incorporate magnetic properties into the basic mesitylene powder. The magnetised-mesitylene powder was also black in appearance and the analytical results from Mastersizer show a particle size of 18 µm. The XRD pattern presented in Figure 4 shows an overall amorphous material with a sharp peak at around 2ϴ=26.5o. This is corresponding to the typical crystalline silica peak, due to the incorporation of magnetic iron nanoparticles on its surface. The SEM analysis also compliments these results, as it can be seen from Figure 4 that the magnetised-mesitylene based powder does not show a spherical morphology of a typical silica nanoparticle. Instead the morphology consists of aggregated flakes formed due to surface-deposited iron nanoparticles.

The synthesised magnetic powder was tested on both non-porous and porous surfaces and the results were compared with the SIRCHIE® magnetic powder. The developed fingerprints from both the powders are shown in the Figure 5.

The results show that the fingerprints developed using the synthesised magnetic powder resulted in darker prints on all surfaces, except plastic bag. Furthermore, the prints on porous surfaces such as cardboard and paper had an overall wet background appearance. However, on comparison of the ridge patterns closely using a magnifying glass, it can be seen that synthesised magnetic powder performs consistently in terms of uniformity of ridge contrast and level of details, as opposed to commercial powder that gave faded and smudged prints.

AFIS analysis

A detailed on-field analysis of the synthesised powders was done by the Dubai Police's Forensic Department. The powders were tested using their default lab-based procedures and also on the virtual crime scenes that are created for training purposes. The prints were deposited on 3 surfaces in both cases: Wood table, glass container and aluminium can. Furthermore, the virtual crime scene contained partial fingerprints that were deposited on these surfaces and destroyed partially to mimic evidences found at actual crime scenes. The prints were deposited by senior fingerprint expert and were developed by both the senior expert and trainee officers at the crime scene.

Silica nanoparticles based fingerprint powder was tested first by the department on a separate occasion and it was found to be superior to most commercial powders that are capable of developing prints on non-porous surfaces. However, the white colour appearance of the powder was least desired by the department as dark coloured powders are particularly used for providing contrast to the developed fingerprints. AFIS results yielded magnificent level of details which almost gave a perfect match instantaneously. But, difficulties were faced to analyse white prints on light backgrounds and additional colour correction procedures had to be applied for AFIS.

Magnetised silica on the other hand showed clear brownish prints on most coloured surfaces that were easily identifiable. However, the magnetised silica yielded slightly faded fingerprints as compared to basic silica powder. Furthermore its performance on the porous surfaces was not impressive as reported by the department's experts. Therefore further AFIS analysis was not conducted and instead black coloured novel powders were specifically requested by the department for advanced testing.

The detailed report provided by the department for mesitylene-based powders highlighted key advantages and disadvantages along with few AFIS results that are presented in Figures 6-8. It was reported that both basic mesitylene powder and magnetic-mesitylene powder showed high quality

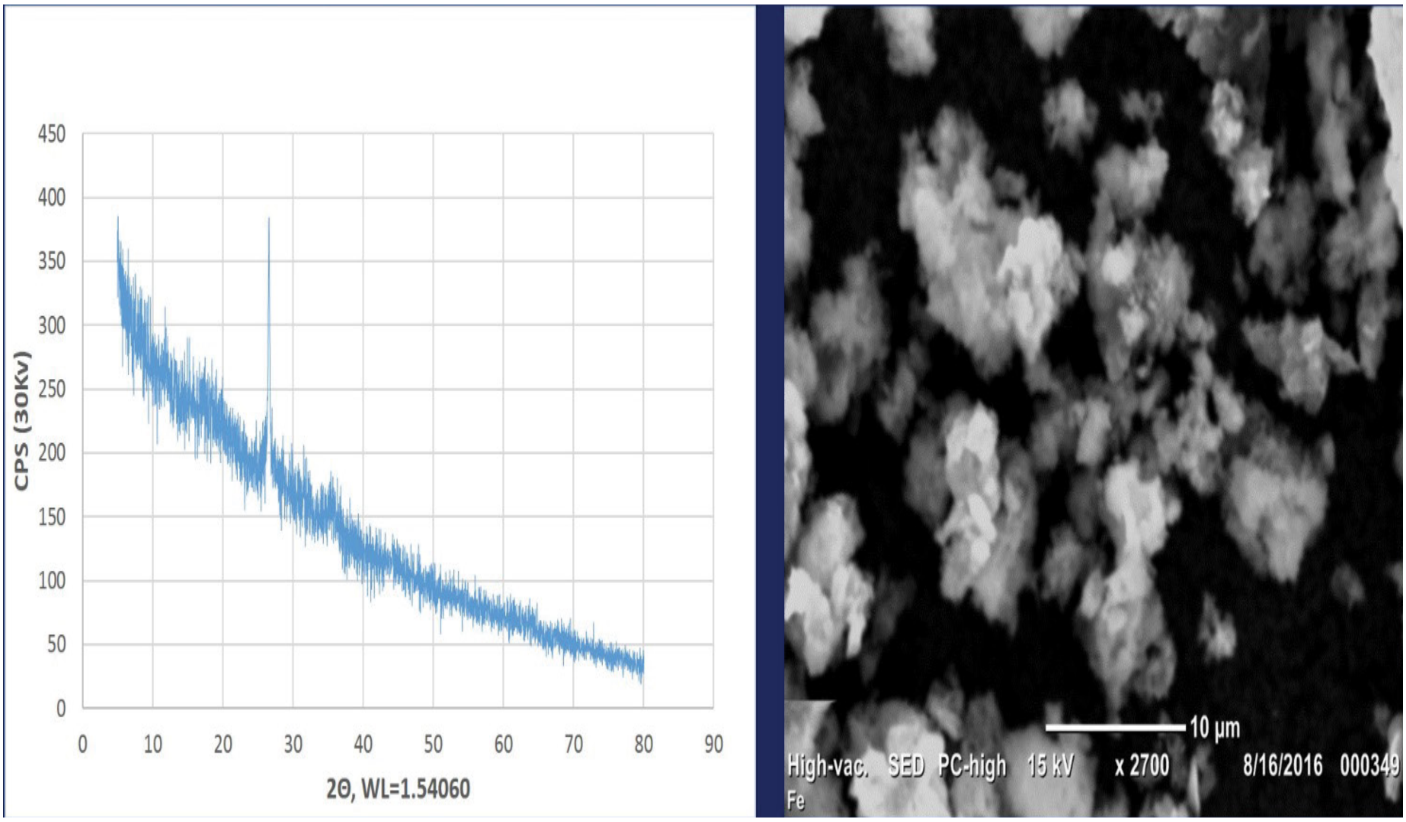

Figure 4. XRD pattern (left) & SEM (right) for magnetised-mesitylene powder.

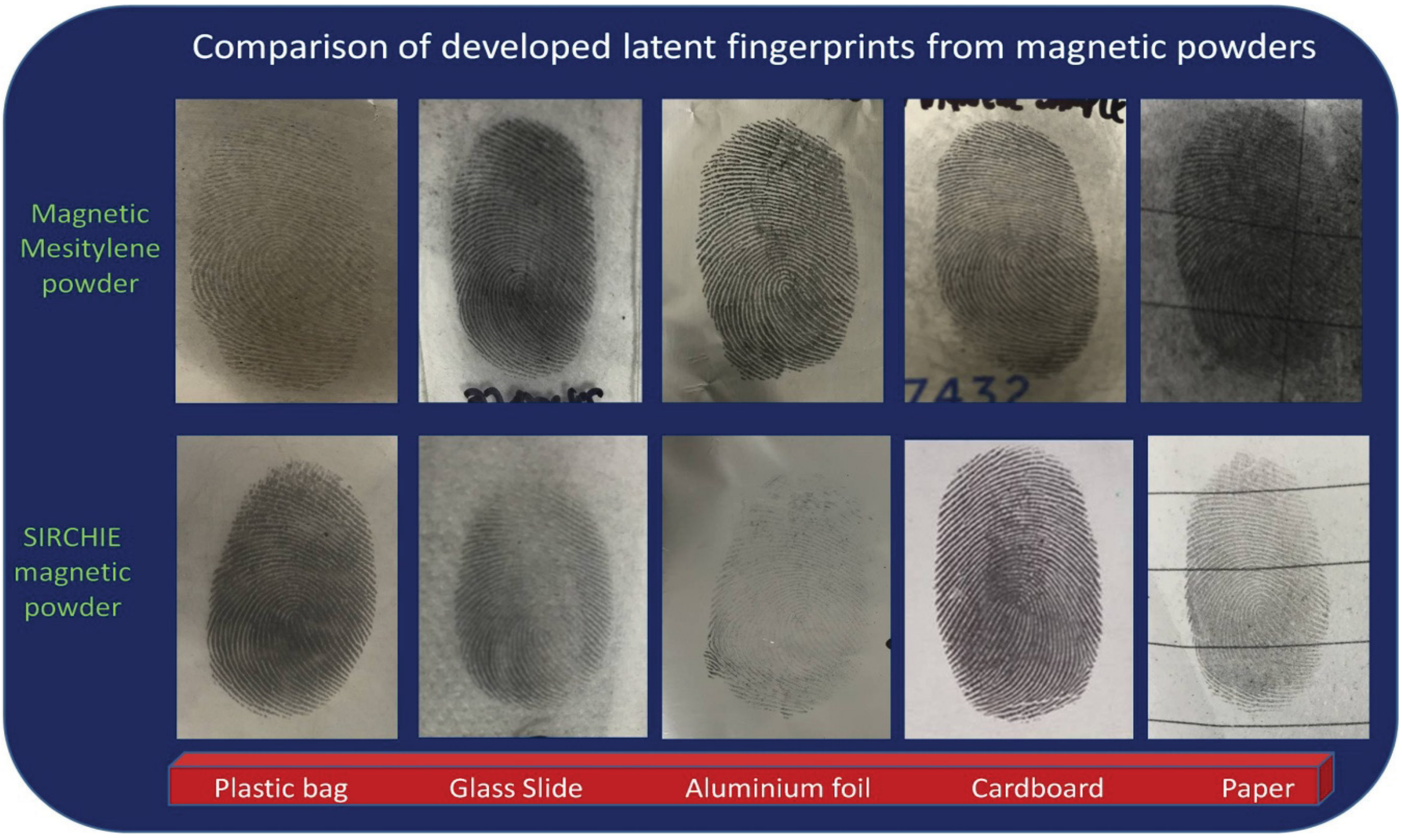

Figure 5. Comparison of the quality of developed latent fingerprints between the synthesised magnetic-mesitylene powder (top row) and the commercially available SIRCHIE® black powder (bottom row) on 5 surfaces.

responses consistently on both porous and non-porous surfaces, which commercial powders fail to do. Furthermore, the powders behaved very similar to the commercial powders in terms of ease of use by the forensic experts and evidence collection protocols such as tape-lifting and photographs. However, some disadvantages were seen with the performance of magnetic-mesitylene powder as compared to magnetic commercial powders that made it

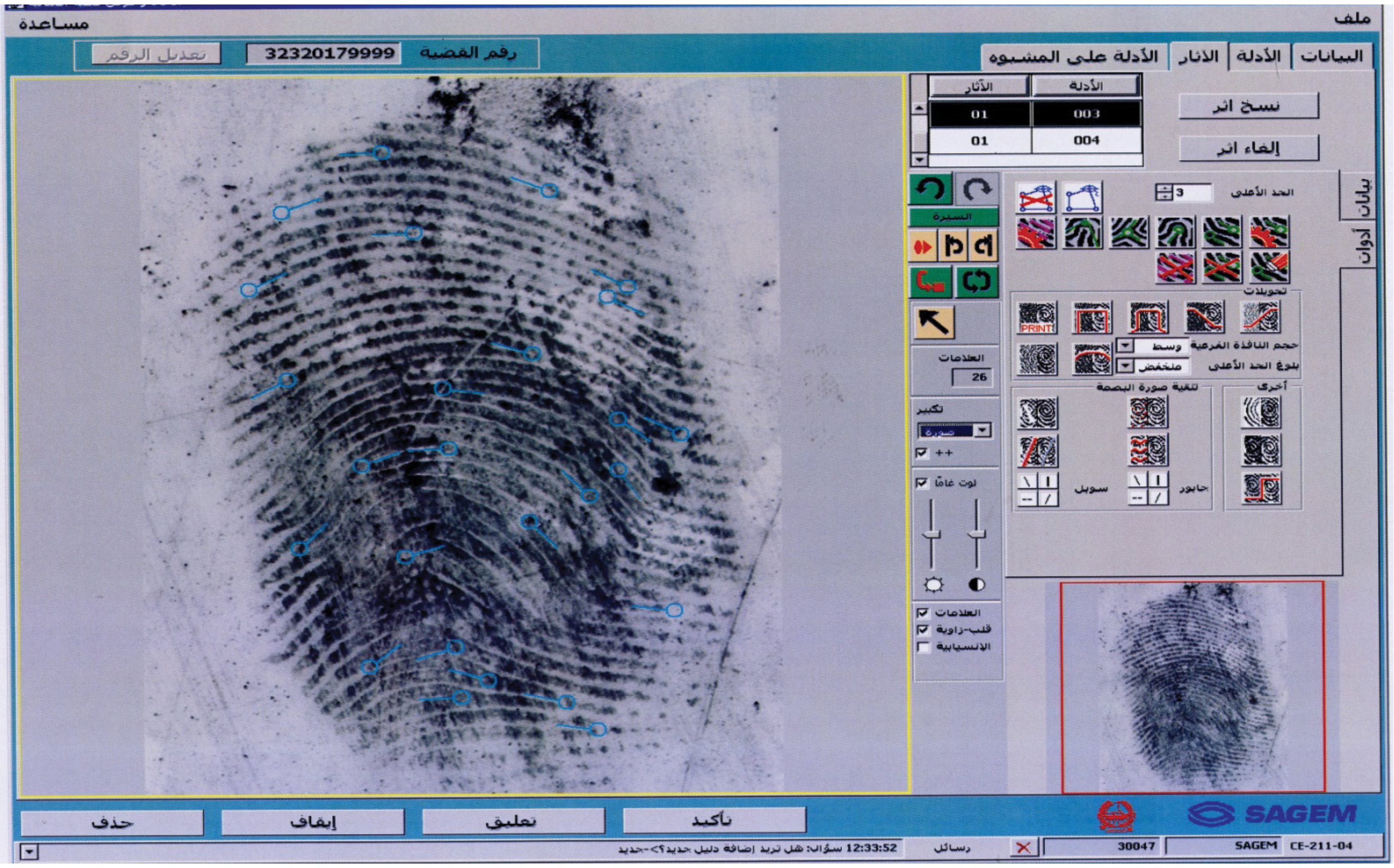

Figure 6. AFIS analysis for tapelifted latent fingerprint developed on glass using magnetic-mesitylene powder.

Figure 7. AFIS analysis for tapelifted latent fingerprint developed on glass using basic-mesitylene powder.

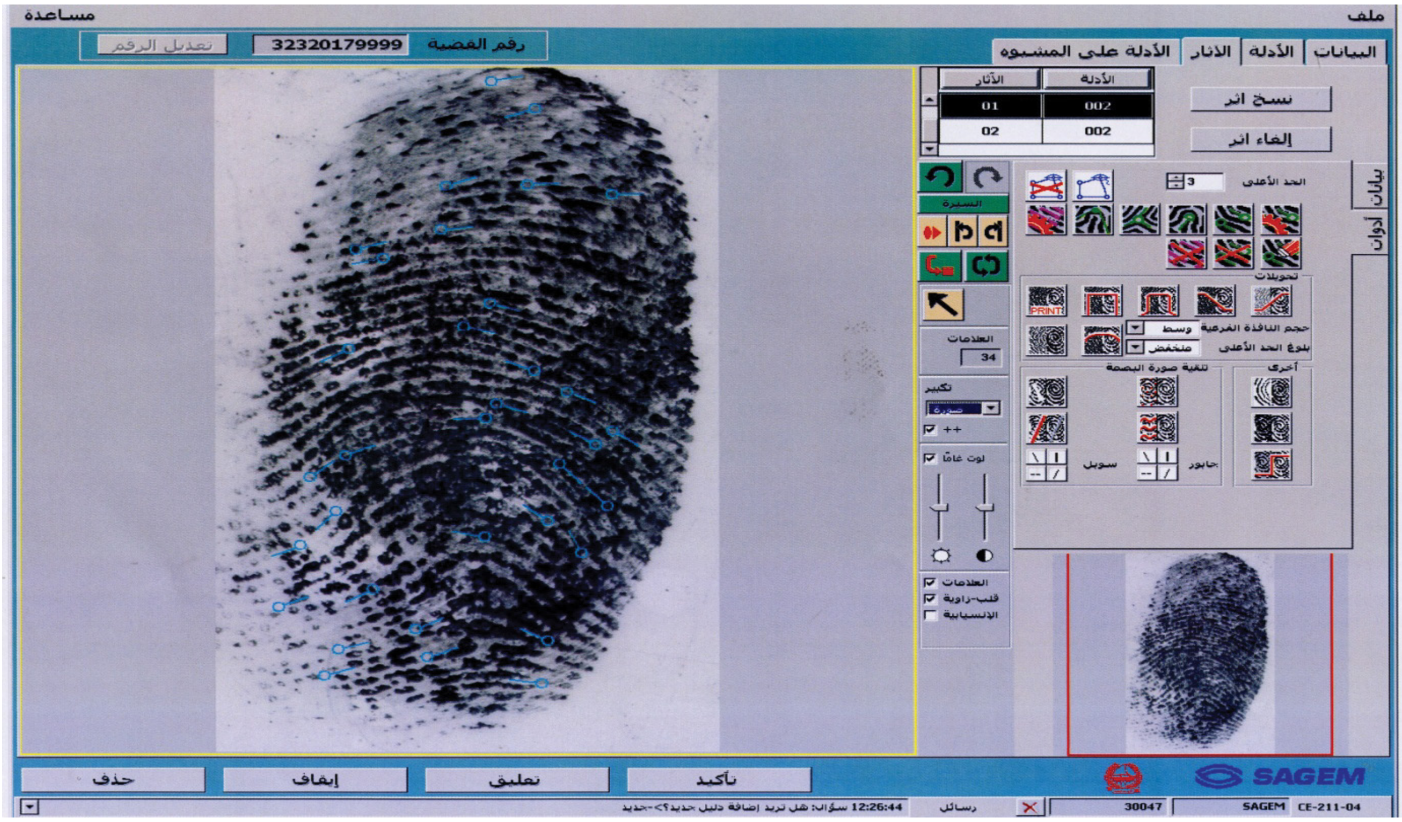

Figure 8. AFIS analysis for tapelifted latent fingerprint developed on glass using commercial powder (smudging and non-uniform ridge intensity is evident here).

unfavourable for use on absorptive surfaces. The synthesised magnetic powder showed higher wetness than the normal powders and performed slightly less efficient as compared to basic mesitylene powder too. This was consistent with the lab-based results as both the mesitylene-based powders showed excellent prints, but tainted backgrounds were visible in prints developed from magnetised-mesitylene powder.

However surprisingly, the fingerprint department found background wetness to be of striking advantage for rough non-porous surfaces such as crushed aluminium cans. This is due to contaminated and dried fingerprint residues that do not adhere well to normal powders. Therefore, the mesitylene could revive and expose fingerprint constituents for effective adherence to the powders. Furthermore, the synthesised powders were explored to be of great importance to develop fingerprints that are partially developed by the cyanoacrylate. The interaction of mesitylene with cyanoacrylate somehow enhances the poor prints, once applied after the fuming step. Both of the synthesised powders performed equally well for developing partially-developed cyanoacrylate latent fingerprints. An acceptable AFIS score was achieved for these smudged prints that were developed from the novel powders. There was a positive match with at least a second-level early-out. This was an impossible feat to achieve for normal commercial powders as mostly the chemical interactions with the fingerprint compositions are hindered once cyanoacrylate fumes are deposited onto the fingerprint surfaces.

Another key advantage that was discovered by the department for the synthesised mesitylene-based powders was that these powders were capable of recovering fingerprints that failed to develop once by another commercial powder. This means that a failed fingerprint development procedure can be compensated by using these novel powders. It is an important application which had never been thought before, since there had been cases where a particular fingerprint was attempted to be developed by a certain powder or tried to be tapelifted but the details were lost in that procedure. Therefore, it would be advantageous to use a highly efficient powder that can bind to the remains of the last development procedure and re-develop the fingerprints on a surface to get it successfully recorded again.

Conclusion

The 3 powders that were synthesised towards latent fingerprint development application, proved to be highly efficient and cost-effective. The silica based powders have the potential to yield white fingerprints on all non-porous surfaces such as glass, aluminium foil and plastic bags. However, to overcome its weaknesses of colour contrast and application to porous surfaces such as wood, paper and cardboard, novel mesitylene-based powders were synthesised. The undiscovered affinity of mesitylene towards both sweat and oily residues of the fingerprints make these powders show remarkable properties on both porous and non-porous surfaces. Furthermore, on-field testing of these powders by fingerprinting experts of Dubai Police Department highlights its key advantages for re-developing fingerprint evidences that have already gone through a chemical development procedure. Therefore, these novel powders have high commercial value due to its cheaper cost of synthesis, high performance and added advantages.

However, in order to make these products commercially viable, a focus is required to tackle the key problems of wettability and low magnetism that comes along the strengths of mesitylene. There is a possibility that the chemical hindrances or binding site restrictions limit the incorporation of magnetic nanoparticles and mesitylene together onto the activated charcoal framework. Another reason that contributes towards the weaknesses of the wettability and lower magnetism is that the extremely small iron nanoparticles are masked by the bulkier mesitylene groups or its interaction with the carbon framework is hindered. In fact, the wettability of the magnetised-mesitylene powder is certainly due to excessive unwashed mesitylene remaining onto the product that gets easily detached from the host material onto the substrate. Therefore, further work would be needed to stabilise the complex by using specific binding site interaction or surface functionalisation approach so that both the organic and inorganic elements could be constituted together. Nonetheless, the experts' report detailed by the Dubai police department concluded equal performance and strengths of the synthesised mesitylene based powders, as that of the commercial powders. This promotes further research in this direction for exploring the commercial viability of these novel powders.

Declarations

Ethics approval and consent to participate

All fingerprint used in this work are provided by the authors and members of their team, both in lab and in the Dubai Police's fingerprint testing team. The fingerprints were taken with consent and completely randomised prior to testing, in order to prevent any biased results. No fingerprints were taken any unauthorised person, or without permission from anyone, along with all ethical approvals granted by both university research team and Dubai Police's forensic department. There are no conflicts of interest in this study and no funding grants applicable to be disclosed.

Consent for publication

Both authors consent to publication. All donors of fingerprint marks consent to publication

Availability of data and materials

Data can be shared on request, in regard to some aspects of measureable research entities. It is available in the form of report and analysis files from software, wherever applicable.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

Dr. Gurpreet Singh is the main author as he has done most of the advanced synthesis and characterisation work in the lab. The second author Mr Mohammad Alsuwaidi has carried out substantial work on initial synthesis, physical development of latent fingerprints, as well as final analysis using commercial AFIS software.

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