BIBLIOGRAPHIC RESEARCH COMPARING DIFFERENT PARAMETERS FOR THE OPTIMISATION OF FINGERPRINT POWDERS

UNIVERSITAT ROVIRA i VIRGILI

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ABSTRACT

CATALÀ

Aquest treball ha sigut una continuació del projecte el qual s'estava estudiant i desenvolupant en la meva mobilitat d'Erasmus a Nottingham Trent University. Tractava de la síntesis i la comparació de l'efectivitat de diferents tipus de pols els quals estaven funcionalitzats amb sílice.

La segona part ha consistit en una recerca bibliogràfica en busca de diferents paràmetres els quals poguessin millorar la visualització de les empremtes digitals, LFP, eina necessària per a la busca de persones presents en un crim.

Dintre d'aquests factors, la superfície en la qual es deixa la LFP, els reactius utilitzats, la mida de partícula de la pols usada són de gran importància, el temps d'espera entre que succeeix el crim i es troba i d'altres com futures aplicacions.

Seguidament i per finalitzar la recerca, s'han proposat una sèrie de proves que podrien ajudar a millorar tots aquests factors per a un millor desenvolupament de les empremtes dactilars latents.

ANGLÈS

This work was a continuation of the project which was being carried out and developed in my Erasmus mobility at Nottingham Trent University. . It dealt with the synthesis and comparison of the effectiveness of different types of powders which were functionalized with silica.

The second part consisted of a bibliographic research in looking for different parameters which could improve the visualisation of the fingerprints, LFP, a tool necessary for the search of people present in a crime.

Within these factors, the surface where the LFP is left, the reactants used, the particle size of the powder used is quite important, the waiting time between the crimes and is found and others as future work.

Finally, using the published research, a series of tests have been proposed that could help to improve all these factors for an improved development of latent fingerprints.

AIM

This bachelor's thesis is inspired by the topic I worked on during my Erasmus stay. During the first and half month I was synthesizing four fingerprint powders, which are silica dye-doped nanoparticles un-functionalized or functionalized with relevant functional groups for better visualisation. And later I had characterized and discovered which one was the best to visualize the latent fingerprints (LFP).

Because COVID '19 circumstances, we had to look for another way to investigate how we could improve some aspect of this issue *via* bibliographic research. As the work cannot be experimental anymore, bibliographical study was undertaken with the following objectives:

- Investigate what are the parameters to take into account when optimizing the fingerprint powders.
- Studying their effects, with respect to improved visualization of LFP, and what their importance.
- Focus on the most important parameters and thus be able to make a project proposal.

It was hoped that during this bibliographical research we can obtain good results from all our objectives, using this information and optimised method will be proposed.

INTRODUCTION

Dactiloscopy is the study of fingerprints to identification, which is one of the fundamentals sciences of criminal investigations, because they are one of the most valuable to determine the guilty for a criminal scene due to their specificity. [1]

Fingerprints are formed by the sweat release from the pores present in the skin of the hands of friction. When the finger touches any surface, the sweat of these pores is deposited in the form of contours, leaving trace evidence. [1]

Within the different techniques, the choice of technique used to view the latent fingerprints (LFP) is based on factors such as surface porosity and softness, the age of the fingerprint, the composition of the mark and the recovery conditions. Conventional methods are useful for the visualization and development of LFP but are of non-specific nature, which causes that it is difficult to understand the mechanism of interaction with sweat residues causing them to improve. It must be clear that no powder will be useful for every type of surface (in the sensitivity and efficiency). Studying the composition of the sweat, the correct powder so that the interaction is the best and thus be able to visualise the LFP can be developed. However, the conventional methods should not be forgotten, as they are practical and efficient within justice system. [6]

In order to visualization LFP, it must be provided with properties that differentiate it from its substrate, it is a good contrast between the crest and surface. Usually, this is done by adding properties of colour or luminescence to the fingerprint through an optical, physical or chemical processing, or by a combination of them. [5]

The size, the shape and the state of the agglomeration of the powder particles have a major role in determining the amount of adhesion they have to the fingerprint. Recent innovations in nano-technology allow manufacturing nanoparticles that have desired form, size and agglomeration. [7]

One of the most traditional and common method is the use of powder, which is very easy to apply. It consists of dusting the area that is believed to have LFP and finally remove the excess with a brush or simply blowing. Despite this, there are inconvenient such that contact with the brush when it comes into contact with the LFP surface that destroys the impression. [8]

As for the type of powder, it must be taken into consideration, which is essential not only to synthesize a new nanoparticle that is sustainable, non-toxic and bio-compatible, but thus adopt a process of green synthesis with renewable precursors. [6]

BIBLIOGRAPHICAL RESEARCH

LFP are very important to find information from the suspect, the victim, or about the witness. There are three types of fingerprints that can be found: latent, patent, and plastic. Latent fingerprints are made of the sweat and oil on the skin's surface. This type of fingerprint is invisible to the naked eye and requires additional processing in order to be seen. This processing can include basic powder techniques or the use of chemicals. Patent fingerprints can be made by blood, grease, ink, or dirt. This type of fingerprint is easily visible to the human eye. Plastic fingerprints are three-dimensional impressions and can be made by pressing your fingers in fresh paint, wax, soap, or tar. Like patent fingerprints, plastic fingerprints are easily seen by the human eye and do not require additional processing for visibility purposes. [20]

In this work many factors that depend on the optimization when visualizing the best way fingerprints will be considered. Using published articles, it can be seen that the methodology used to take samples of donors, healthy humans about 25-30 years, with any defects that may affect the result (such as scars to the fingers), is common in all of them. It consisted of washing with soap and water, drying the hands and finally passes them by the parts with more sweat from the face, as could be forehead or the upper lip. Thus, a LFP with residue could be left in order to obtain a good result. What varied depending on what we wanted to study, for example, the type of powder, the surface, and the number of donors.

A feature that is also common in almost all articles is the powder method used to visualize the LFP. However, there are others powders that may be considered better due to their lower toxicities.

Before starting to focus on studying the effect of parameters that can improve the visualization of the LFP the most important parameters must be defined. All parameters to improve need to be considered sensitivity, selectivity, achieve a good contrast, great affinity between residue and powder, decrease and even eliminate interference background.

This bibliographic research focus on studies from 2016 to 2020 because it is a type of science that is in continuous progresses and improves its use is as optimal as possible.

Finally, it may be interesting to know the part of a fingerprint and that is what makes them so special and unique. Fingerprint features are generally classified into three levels: [13]

- Level 1: are macro details including unique points and global crest patterns, which are not distinctive enough to recognize the fingerprint and are used primarily for the classification of the fingerprint.
- Level 2: refers to the functions or minutiae, of Galton, like the bifurcation and the ending. These characteristics are sufficiently distinctive and stable and are widely used to distinguish the uniqueness of fingerprints.
- Level 3: it is defined as dorsal dimension attributes, including sweat pores, crest contours, providing more precise and robust details for recognition of fingerprints.

The following image *(Figure. 1)* displays a fingerprint powder with silica doped by epoxide. There are several features of different levels. [13]

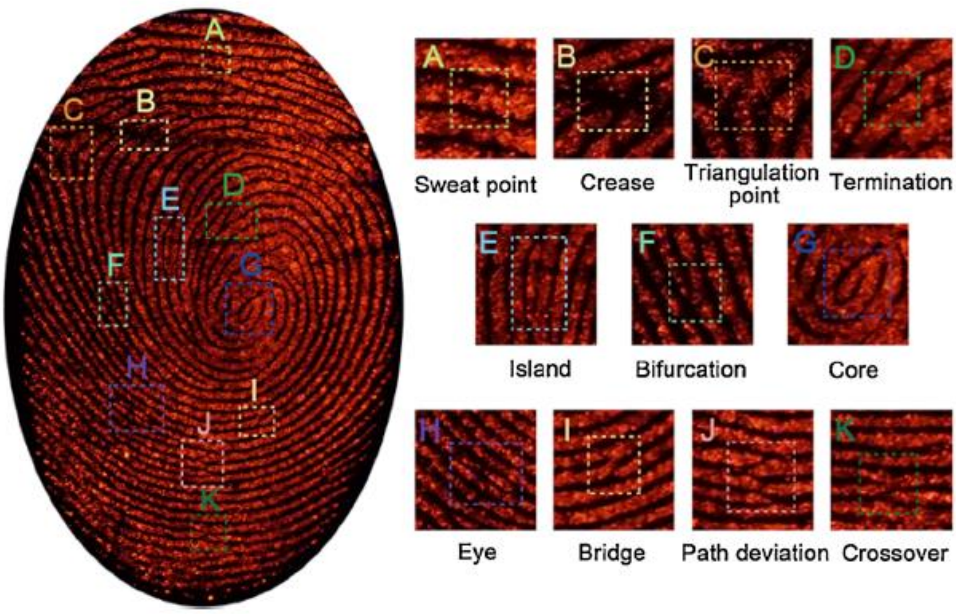


Figure 1. LFP with different levels. Sweat pore (level 3), crease (level 3), triangulation point (level 2), termination (level 2), island (level 2), bifurcation (level 2), core (level 1), eye (level 2), bridge (level 2), path deviation (level 3) and crossover (level 2). Adapted from Yang *et al. (2019)* [13]

Several articles were consulted and then the most common ones have been *(Figure. 2)* [23] and *(Figure. 3)* [17]:

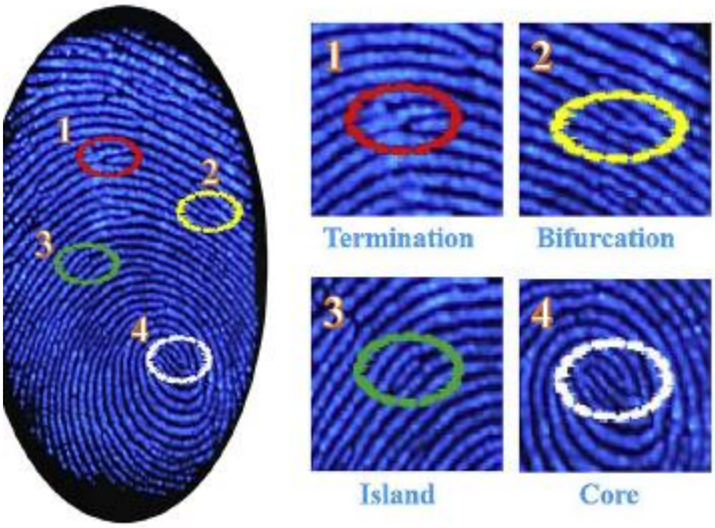


Figure 2. Fluorescence images of the latent fingerprints show specific details. [23]

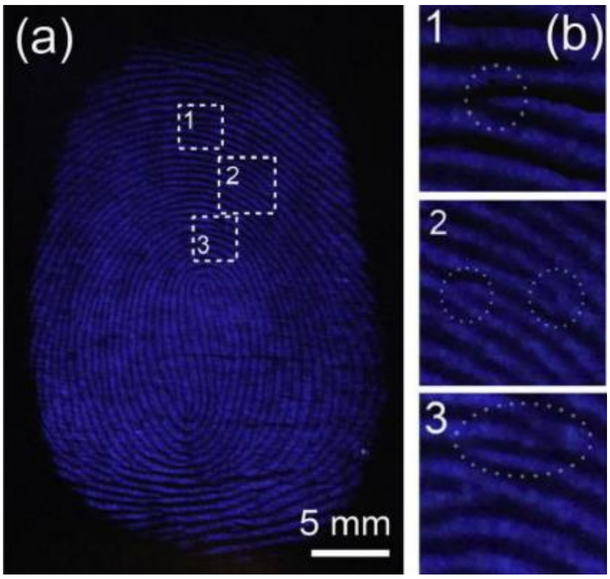


Figure 3. Latent fingerprint (a) and magnified fluorescence images of fingerprints showing specific patterns including termination (1), bifurcation (2), and crossover (3). [17]

SURFACE

In a crime scene fingerprints can be left on any type of surface. That is why, one of the parameters to take into account when optimizing the visualization of LFP is the type of surfaces are the most suitable or what type of powder is most suited.

When it is time to look at what is characterized by the process, there is its adherence (also called aggregation), good affinity to the print, selectivity and sensitivity. [2]

Within the different surfaces studied in most articles consulted, the most common categories are porous, semi-porous and non-porous, such as glass, paper of various types and metals, because they are present in a crime scene. It is clear that the most suitable is when there is a contrast surface, it means like, if the surface is dark, a good powder should be white or light and if the surface is clear, a good powder should be black or dark. [5] A type of surface with stripes is not very suitable as surface lines and fingerprint can be mixed *(Figure. 4).*

However, contrasting colours to facilitate the visualization of LFP, such as the blue of methylene (MB), water-soluble colouring due to the structure *(Figure. 5)* but which at the same time is absorbed in more hydrophobic areas, producing a good result. This characteristic blue colour is due to the properties of light absorption. It means like, maximum light absorption is about 670 nm. The specific characteristics of absorption depend on several factors, including protonation. As we can see in the figure the positive charge is one of the factors that give this blue colour. [3]

Figure 4. Difference between a surface without stripes and with stripes with the dye blue of methylene. [3]

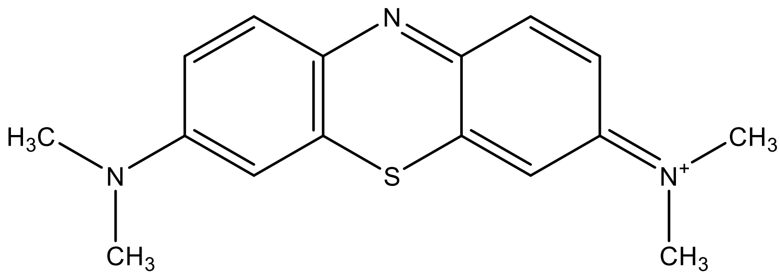


Figure 5. Blue of methylene structure. [3]

Another type of powders widely used in the forensic field which provides a high contrast in bright surfaces is carbon black (CB) due to its black coloration *(Figure. 6a).* In the case that the objective was increase the adhesion to the surface we can add sodium acetate by providing an ionic interaction, which would also give a more intense coloration. On the other hand also there is titanium dioxide (TD) which on the contrary is used in dark surfaces as it is white *(Figure. 6b).* **[4]**

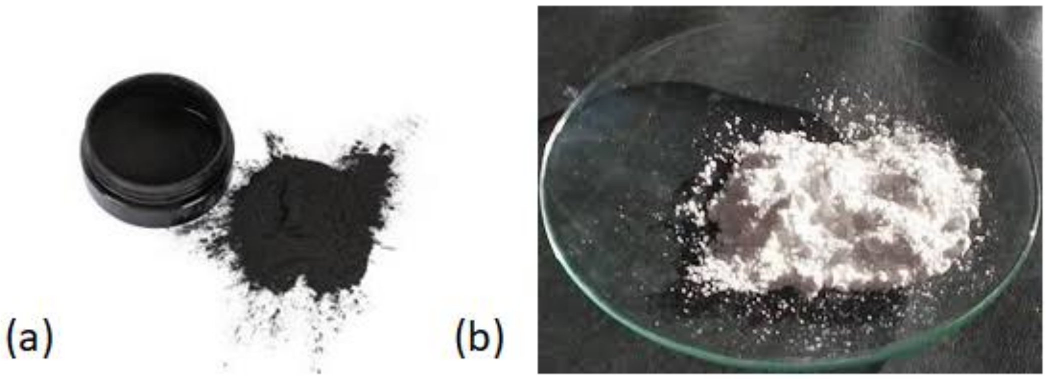


Figure 6. Carbon black powder (a) and titanium dioxide powder (b). [4]

Komalasari *et al. (2017)* studied two types of powder (black and green) were compared with the powder dusting method, a traditional method, and with another that reduced their toxicity, chamber method *(Figure. 7).* The last consists of using fans in a closed chamber with a fixed capacity that can prevent the users from being exposed *(Figure. 8)*. The green powder was better in the traditional method. This may be because this powder is very thin; making the chamber method leaves a too thin coating to interact with residue. Black powder works equally well with both methods. It is generally said that the LFP residues are destroyed or lost more rapidly in fingerprints that are left on the plastic surface than the surface of the glass. The green fluorescent powder used with the plastic surface with the chamber method did not distinguish anything, unlike the conventional method. This may be because the plastic (PET) can generate electrostatic interactions on the surface, making friction between the powder causing it to adhere indiscriminate. Kim *et al. (2019)* tried to improve the problem. A 50/50 silica gel was introduced (a non-stick hygroscopic powder, which was expected to reduce adhesion between the organic PET's surface and the fluorescent powder). Although this is only a pilot study there are many parameters to be optimized such as the type of powder, the stoichiometric amount from the powder and solvents, etc. [14]

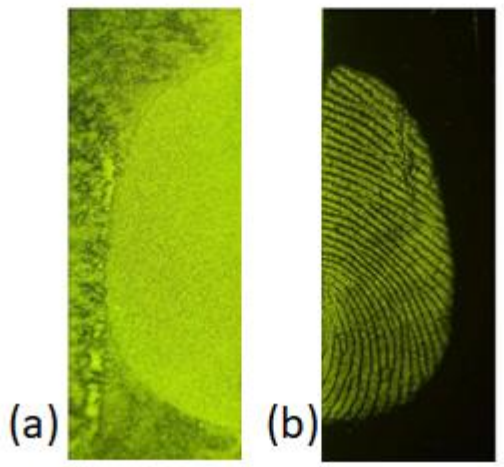


Figure 7. Visual comparison LFP of fluorescent green powder with chamber method (a) and conventional method (b). [14]

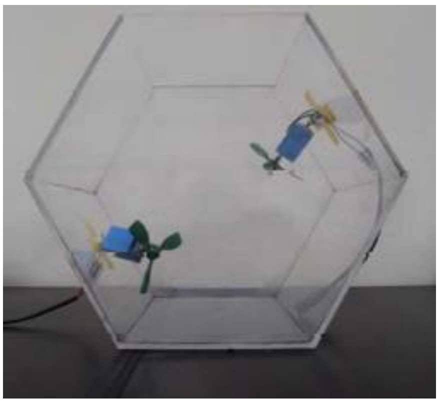


Figure 8. Chamber method. [14]

To determine the sensitivity of LFP three tests were performed by Rajan *et al. (2018)* [9]:

- Multiple studies of depletion: consists of making ten consecutive marks on each surface, a total of three repetitions.

- Depletion: comparison of the powders studied on the same surface, a total of three repetitions.

- Ageing: study at 50 and 100 º C at 1-2-3 hour's intervals.

The results obtained determine how sensitive the powder is to the type of surface. It must be taken into account, that there may be too much adhesion causing confusion, because it becomes very difficult to differentiate the lines that characterize a fingerprint of the rest. [9] On the contrary, if there is a lack of adherence one option is to introduce starch to the powder, thanks to its structure and properties. [12] On non-porous surfaces there is more clarity, as there is a good contrast and visualization because it is smooth. [10] On the other hand, if the sensitivity is low, it can be improved it by modifying the surface of the powder with additional functional groups. For example silica NPs can be doped with amino groups, alcohol, or epoxide that can react particularly with the most abundant components present in fingerprint residue and not with the substrate. [11, 13] The fingerprint residues consist of intrinsic components (natural secretion glands, exocrine and sebaceous) and extrinsic (makeup, food contaminants, blood, dirt and fats). What vary from one LFP to another are sex, age, medication and diet. Studies have indicated that only between 20 and 40 sweat pores are needed to generate necessary patterns for LFP identification. [6]

As mentioned above, a factor to consider is the affinity between the residue and the surface where it is deposited. Yang *et al. (2019)* studied four types of fingerprint powders "hybrid NPs" (powder with silica, doped powder with alcohol groups, doped with amino and doped groups with epoxide) *(Figure. 9)* on four types of surface. Finally it was concluded that, the one that worked best in any type of surface was the doped silica powder with epoxide groups *(Figure. 10)*, because the others have a superior particle size causing difficulties to contact the residual substances *(Figure. 11)*. What is produced is that the epoxy group has a strong affinity to the hybrid NPs of fingerprints, as the surface area is positively charged in forming hydrophobic interactions with footprints. [13]

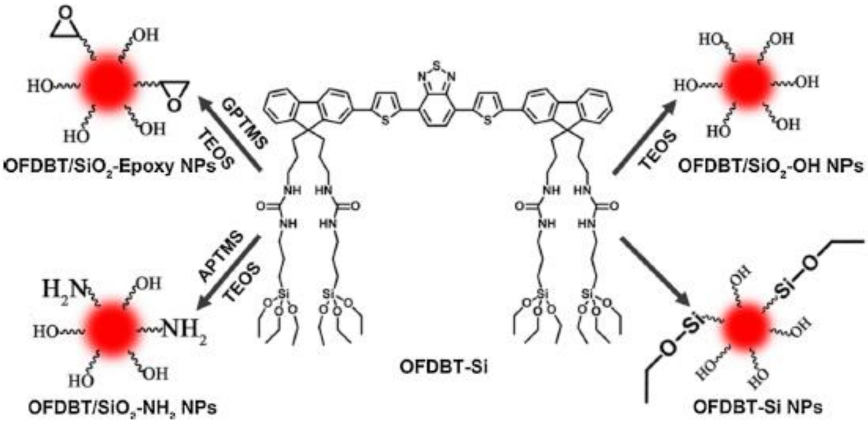


Figure 9. Schematic of the synthesis of the four powders. [13]

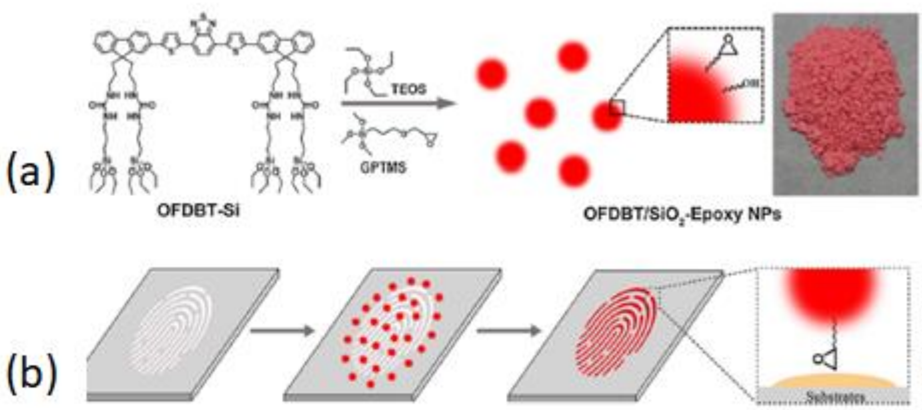


Figure 10. (a) Schematic illustration of the chemical structure of the silica powder doped with epoxide and synthesis groups. (b) Strategy to visualize the LFP. [13]

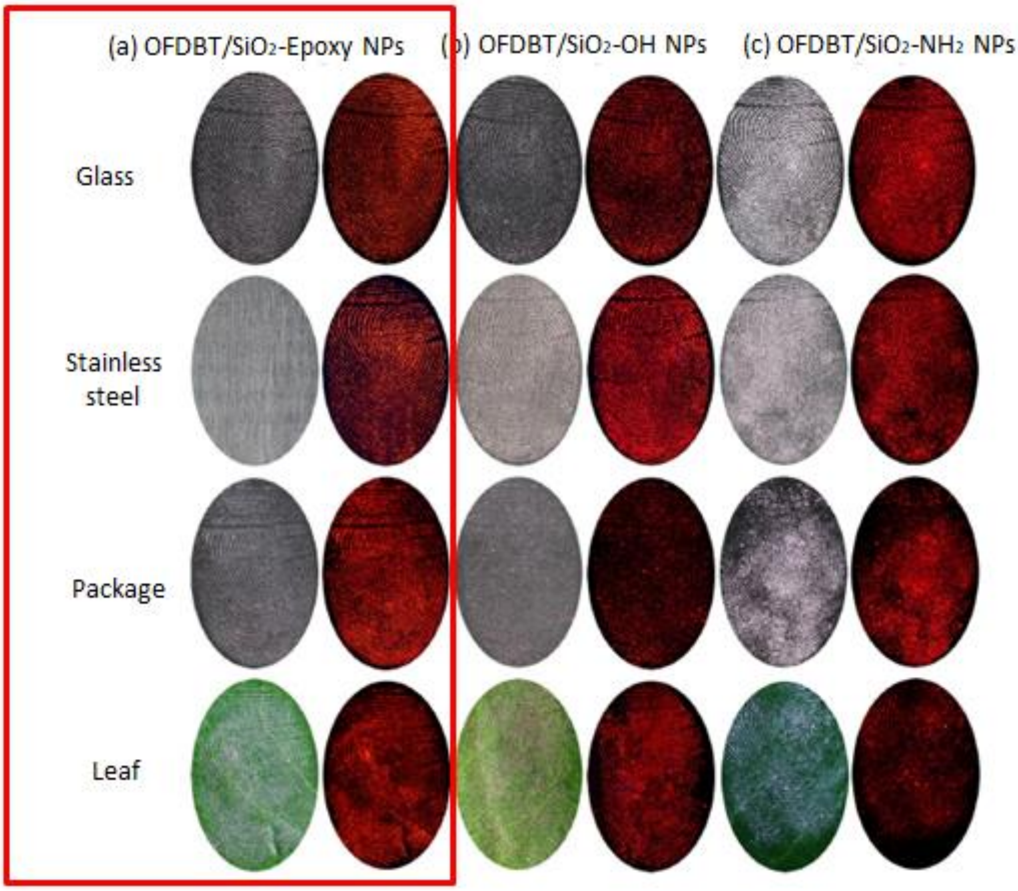


Figure 11. Bright-field optical images under room light and fluorescent images under 365 nm UV lamp of LFPs developed by the different powders on different substrates. [13]

When considering the surfaces analysed, in the last four years there has not been a major evolution regarding improvement, although there are currently good solutions for any type of surfaces, not having major advances. However, it is a field to consider and improve. For example, getting a universal powder that can be used in any type of surface.

REAGENTS

This section will discuss everything related to the reagents. For example, which are used to synthesize NPs as they can be of silica or other powders that are not these.

This work focused on the silica NPs. In order to make them it has been observed that the input of the silica element is given by the reagent TEOS (Tetraethyl-orthosilicate) *(Figure 12).* [2, 3, 7, 8, 11, 13, 16, 17]

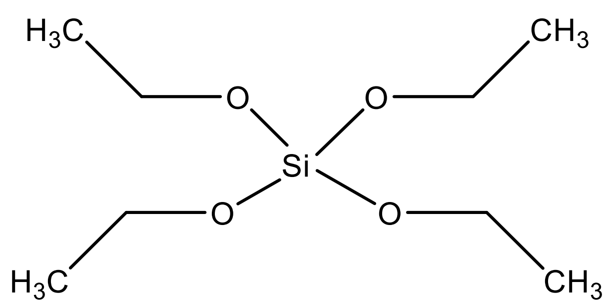


Figure 12. Tetraethyl-orthosilicate (TEOS) structure. [13]

Preparation of these silica NPs can be done through two types of processes, the Stöber method and the WORM method. The first one is more commonly used because it has more advantages: [11]

- Stöber method is chemical process used to prepare silica NPs of controlled and uniform size. It is an example of a sol-gel process, a method to prepare solid materials from small molecules. The method is used for the manufacture of oxides such as silica or titanium. It involves the conversion of a monomer into a colloidal solution (sol) which acts as a precursor of an integrated network (gel) of discrete particles. The typical precursors are the metallic alkoxides, for example, tetraethyl orthosilicate (TEOS). It is first reacting with water in an alcoholic solution, and then the resulting molecules are linked, to build bigger structures. The reaction produces silica particles with diameters ranging from 50 to 2000 nm, depending on conditions of the reactions *(Figure 13).* One important advantage of the process of Stöber is that it can produce silica particles almost mono-dispersed, and thus provides an ideal model for use in the study of colloidal phenomena, allowing the synthesis of mono-disperse spherical silica particles of controlled sizes. In addition to mono-dispersity, these materials have very large surface areas, as well as uniform, adjustable and highly orderly pores structures that make meso-porous silica especially appealing for applications such as liquid catalysis and liquid-chromatography. [19]

- WORM method is another chemical process to make silica NPs. These have the advantage that they show less polydispersivity with better control of the allowed particle size. However, the WORM method can involve various processing, technical and environmental limitations that make the production process more complicated to expand commercial applications. [11]

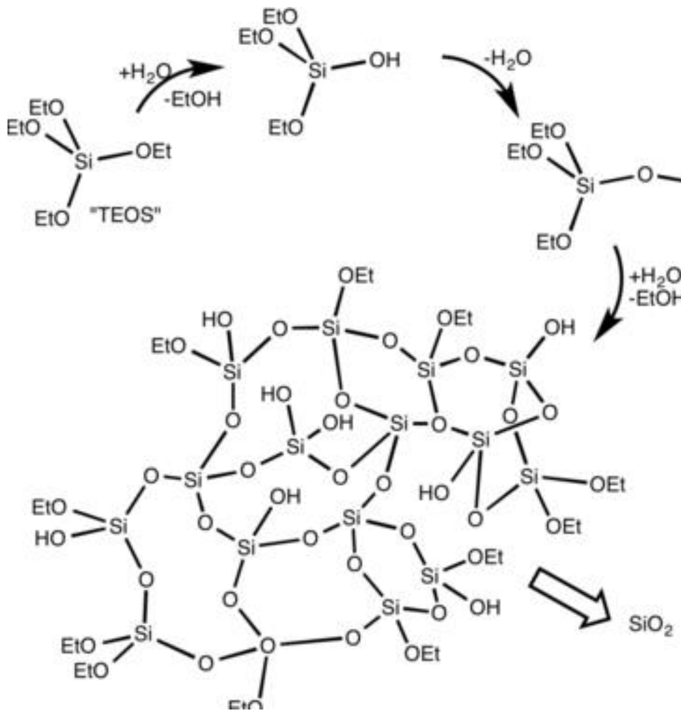


Figure 13. Simplified representation of TEOS hydrolysis and condensation in the Stöber process. [19]

Another common type of powder is composed of a small amount of silica and a larger part of carbon. The silica is the cause to the adhesion of the sweat residue. Having little quantity in the market of the chemical components, the image looks unclear. If we increase the composition of this we would not solve this problem, so the aim of the study is to improve the visualisation of the image without increasing the amount of silica, but of another element, in this case the organic molecules dye. Silica is used as a base material and carbon as a dye and contrast agent to improve the visualization. Komalasari *et al. (2017)* had chosen the MB to improve the colour intensity, because it is a cation dye, cheap and easy to find. It will make good interaction with the silica as it has a negative charge and the MB has positive charge. [16]

As has been seen carbon, sometimes sourced from the rice husk, is widely used because of its coloration. Elemental carbon is obtained from the digestion of this product.

It can be used for many applications, for example, in this case biomass such as rice husk, to produce NPs carbon, because the production of this is being finished. [9]

One other factor taken into account when optimising all parameters is the toxicity of the powder used. This is because the fingerprint experts using this powder may think that it is not harmful (little amount is not, but if you are exposed for a while, it is). That is why there are studies that looked for other types of powder, such as turmeric, cumin, garam massala, limestone, gram flour or coriander. These products are cheap and not harmful to your health. The best results, respect visualization, were with limestone and gram flour. A partial the print appeared with turmeric and cumin. Those with worse visualization are garam massala and coriander. It is due to its structures, which interact better or worse according to the waste present *(Figure 14)*. [15] For example, coriander has only an alcohol group, which causes less interaction.

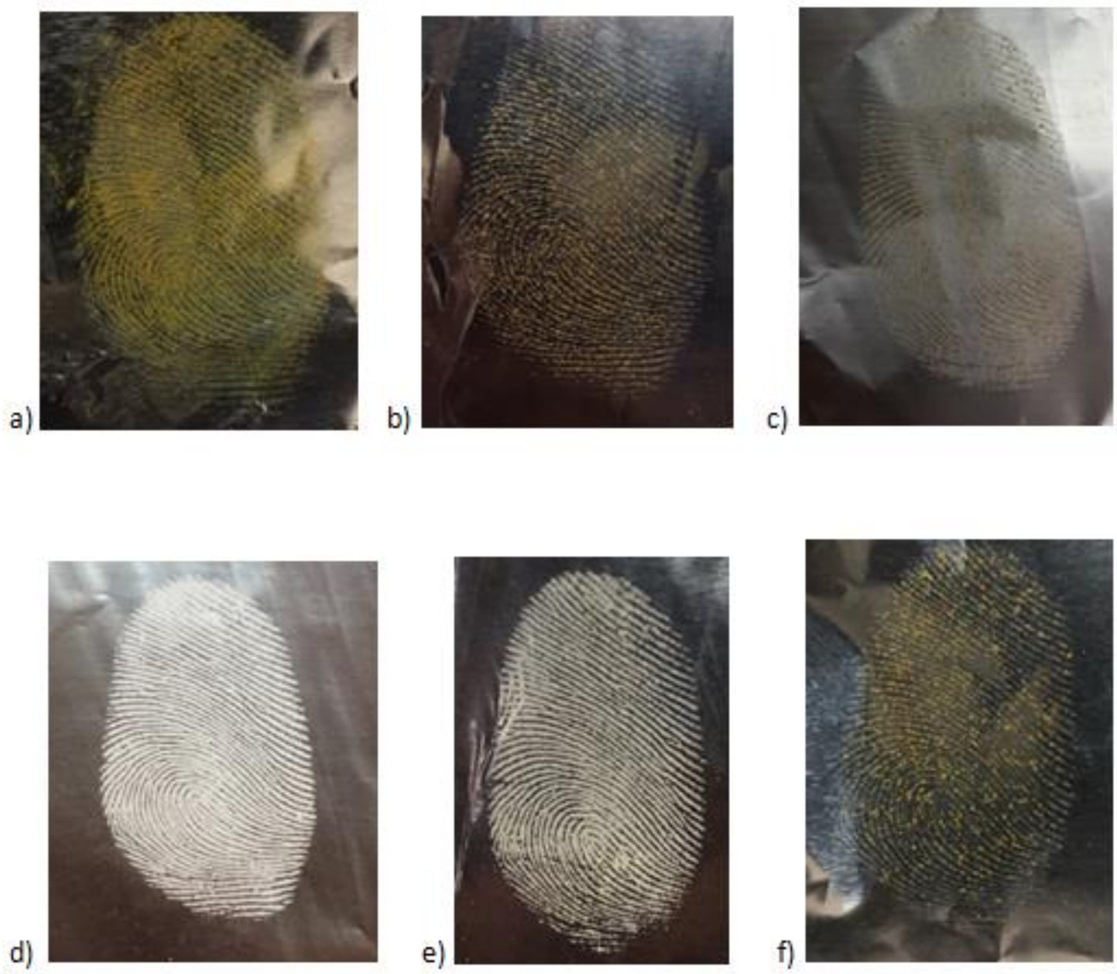
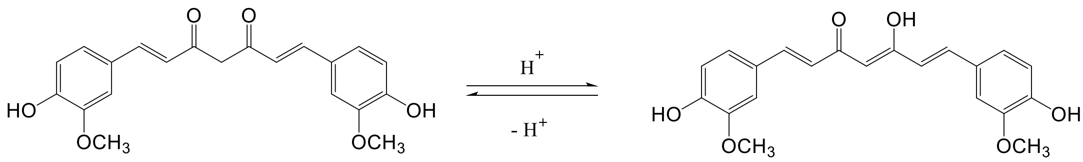


Figure 14. Development of Latent fingerprint by a) turmeric, b) cumin, c) garam masala, d) limestone, e) gram flour and f) coriander powder on aluminium foil. [15]

Turmeric was considered further as it is where more information is available and it has fluorescent properties. This alimentary species has many benefits for forensic such as its low toxicity, price (as it is widely used in Asian cultures). Chemically speaking, it also has a good adhesion due to hydrogen bonds between the fatty acids of the LFP residues and the carbonyl and hydroxyl group of turmeric *(Figure 15).* [1]



Keto form of curcumin

Enol form of curcumin

Figure 15. It can exist in two tautomèric forms (keto and enol). [1]

SIZE

The particle size is a measure to compare dimensions between solid, liquid or gaseous particles. Within the different types of particles are the colloids, which have a typical size of a diameter of between 1-1000 nanometres. To measure the particle size and particle size distribution there are different methods, some of them are based on light, other on ultrasound, electric field, gravity or centrifugation.

In most of articles, particle size is mesured by electron microscopy, which is used by certain types of lenses to be able to visualize particles that are not visible to the naked eye. It has to work in the vacuum. The two techniques are SEM (Scanning Electron Microscope) *(Figure. 16a and 17a)* and/or TEM (Transmission Electron Microscopy) *(Figure. 16b and 17b)*:

- SEM: is a microscopic technique that works with a range of between 10-0,05µm. It is used to look at the morphology and the particle size, the homogeneity of the sample and the distribution and quantification of atoms.
  As a result, there is information about the shape and if there are clusters or small particles together with the location. It is for observed electrons that leave bounties from the surface.
- TEM: is a microscopic technique which works with a range of between 0-100nm approximately. It is used for the previous technique. The difference is that this is by observed electrons that cross the surface, of little thickness.

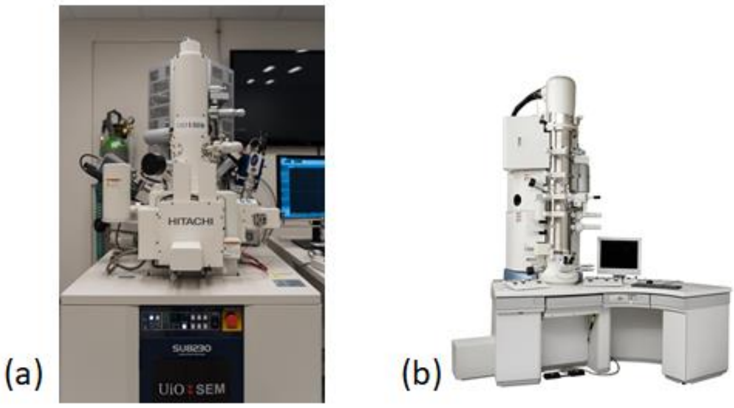


Figure 16. SEM (a) and TEM (b).

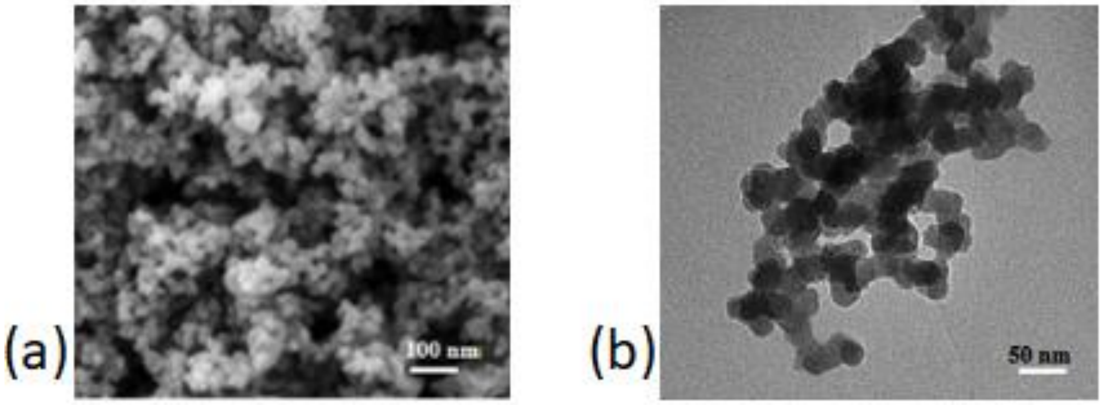


Figure 17. SEM image (a) and TEM image (b) of silica NPs. [23]

In the study of the size of NPs it measures their structure and morphology following the pore structure *(Figure. 18).* [2]

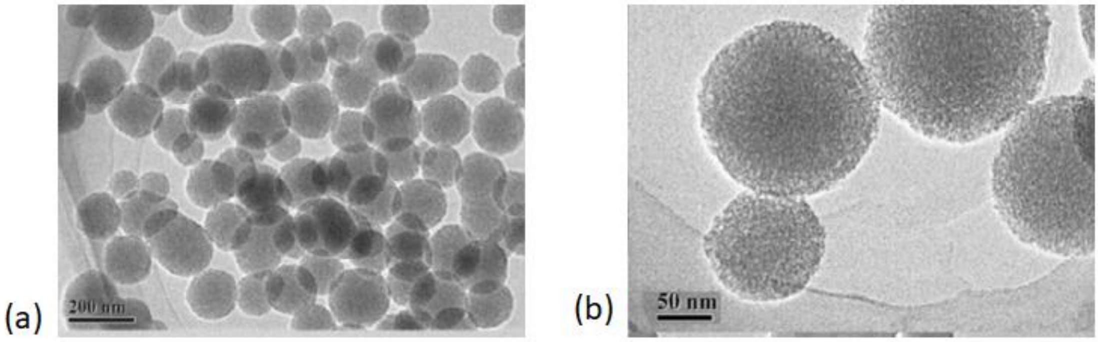


Figure 18. TEM image taken with low and high magnifications of NPs pa articles of silica. [2]

A concept which is spoken in most articles is meso-porous structures which relates to the isotherm, characteristic for each solid. There are 4 types, depending on the porosity of the material, which will determine how the pores will be filled. Type IV is for meso-porous solids, which follows this graph *(Figure. 19):*

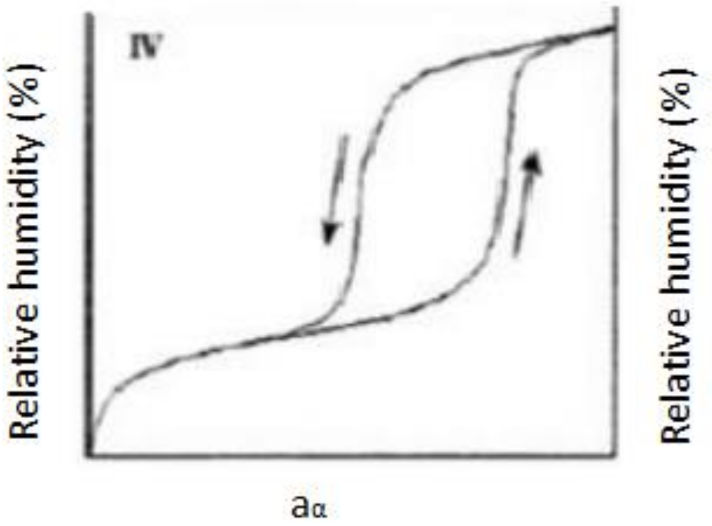


Figure 19. Graphical structure of a meso-porous solid.

Komalasari *et al. (2017)* studied two types of particles. Some with a size of between 400-600nm and others with a particle size of about 27µm. It was seen that the ability of adhesion and the form of the particles of the powders are affected by the ability to adhere to latent digital markings. The smaller ones have better adhesion than the upper-sized particles. [4]

However, at first the particles were 400-600nm, but by means of a process of calcination at 800 º C the size decreased to 30-100nm (size from SEM) *(Figure. 20).* [4]

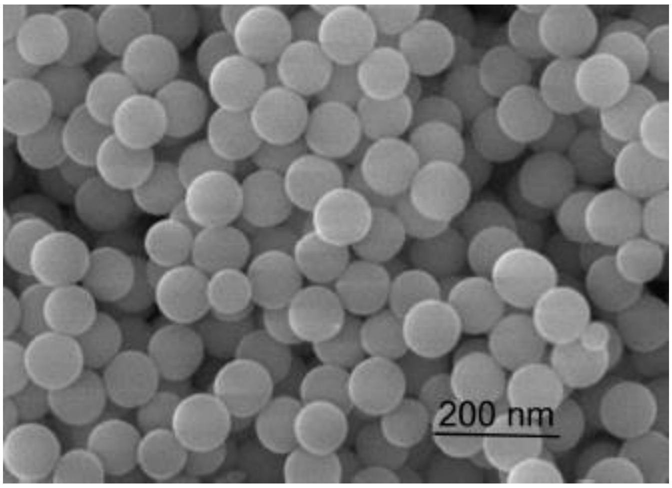


Figure 20. Scanning electron microscopy (SEM) image of nanoparticle silica after went through calcination process at 800 °C. [4]

Sharma *et al. (2017)* also wanted to study if the particle size influences the grip of the powder on the crests. A hybrid molecule (PTF) with and without silica coating was compared *(Figure. 21),* where the particle size is between 1-2µm. It was noted that when the particle size decreases, the surface increases which influences the number of molecules that can bind and thus see clear, crisp and high contrast images. That is to say, smaller and finer, better grip. [10]

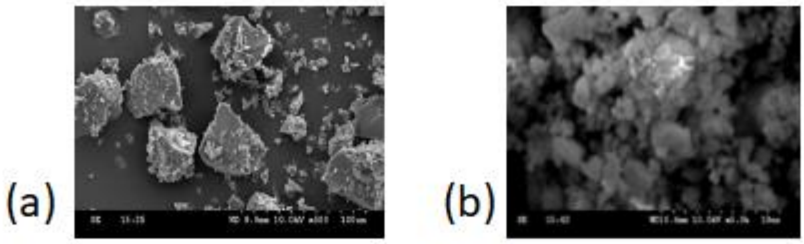


Figure 21. SEM images of PTF before coating (a) and after coating (b) with silica. [10]

Rajan *et al. (2018)* analysed if the shape of the particle was important. Through TEM it was seen that the fine and rounded particles adhere better. The increase of the surface was caused by the reduction of the particle size, that increased the amount of molecule that joins the fingerprint, giving a better result, it means like, the small particle size improves fingerprint detection due to greater resolution because small particles can adhere to the residue of fingerprints with high affinity to the powder. [9, 11]

Another way of varying the size of the particle is adding different functional groups and see if it improves the affinity and adherence of the powder with the sweat residue. Yang *et al. (2019)* studied four types of powders. The first powder was with silica NPs *(Figure. 22a),* the second was with epoxy groups which had a spherical particle size of 22nm *(Figure. 22b).* The third powder was doped with alcohol groups with a 42nm particle size *(Figure. 22c).* And the fourth and final powder with amino groups with a particle size of between 60-150nm *(Figure. 22d)*. It was observed, as in the rest of the aforementioned articles, that the small particle size causes the interactions to be good and causing better visualization of the LFP. [13]

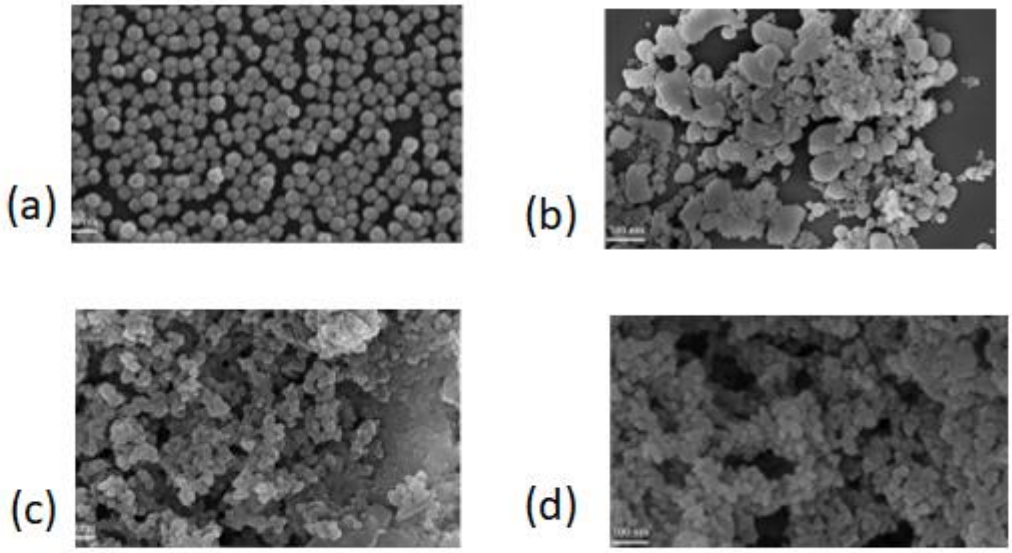


Figure 22. SEM image of NPs of silica (a), doped with epoxide groups (b), doped with alcohol groups (c) and doped with amino groups (d). [13]

Another advantage that the small particle size is that if it is less than the width of the LFP crests there is a high contrast and greater resolution as there is much more sensitivity and selectivity. [23]

If the surface/volume ratio is higher it gives a better fixation of particles to the LFP causing good affinity. [18]

Another positive factor in terms of the small size of the particle is that when it is to produce a powder, it is necessary to avoid its extensive aggregation to restrict the interaction of only the ridges rather than the holes on the ridges. The images of Dibya *et al. (2020)* show that all silica powder are inherently present in the form of ultra-small particles with dimensions less than 10µm, and aggregation behaviour is negligible. [24]

Although most NPs are spherical, there are also elongated ones such as Wang *et al. (2018).* They have a length of 100nm and a diameter of 20nm *(Figure. 23).* [8]

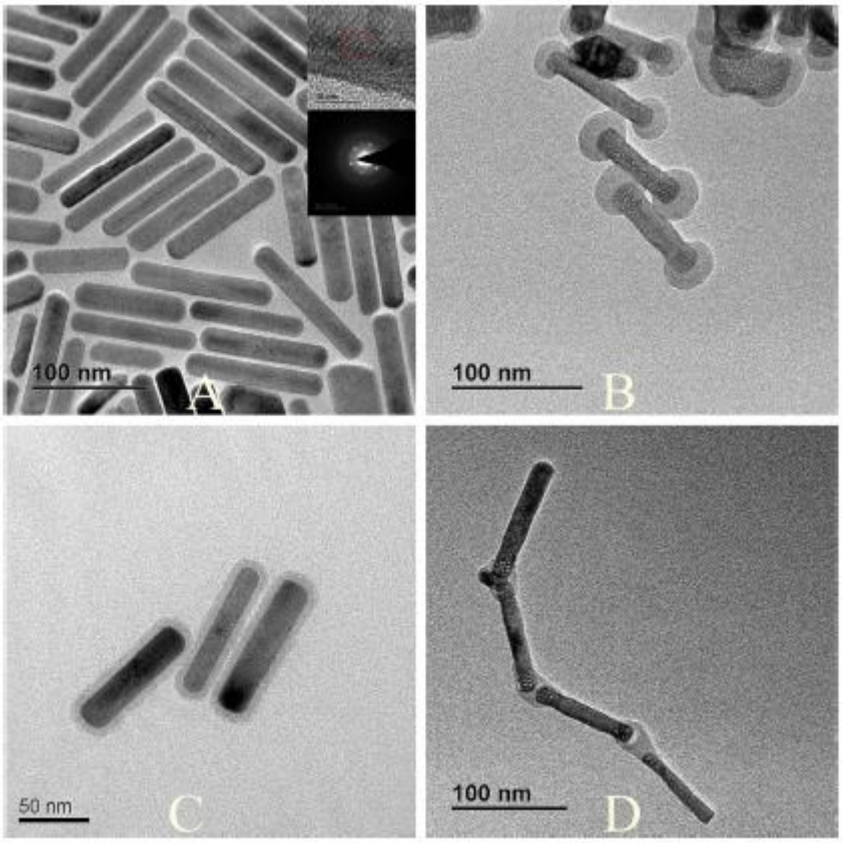


Figure 23. TEM image of long NPs. [8]

TIME (between deposition and lift)

The LFP are characteristics of each person. However, the crime scene is rarely accessed minutes after to the homicide. That is why time must be taken into account as an essential factor when visualizing and analysing a latent fingerprint.

The chemical composition of latent residues changes as time passes due to the evaporation of volatile components. [5] It is assumed that, over time, small volatile molecules will evaporate, however, long-chain fatty acids, lipids, sterols, inorganic salts and solid porous structures of the dorsal ones are still present. [24]

Li *et al. (2017)* studied the importance of time in fingerprints composition. Glass was used as a surface with silica-NPs powder. It can be seen in the images *(Figure. 24).* The visualization of these is clear in all cases although the image is not of the same evidence as time goes by. It means like, the quality of the image is decreasing, but not enough to keep them in mind. [17]

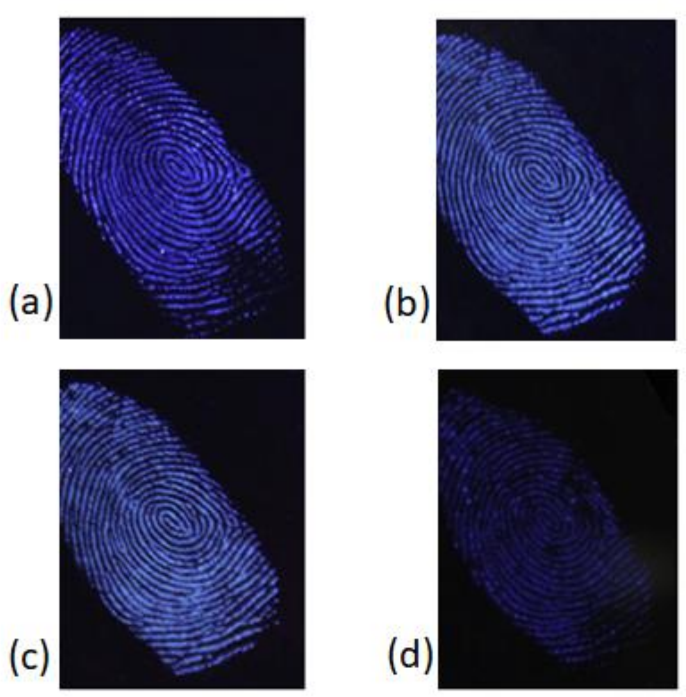


Figure 24. Latent fingerprints aged on the surface of glass for various periods of time, stained by silica NPs powder. (a) 1 day, (b) 1 week, (c) 1 month, (d) 3 month. [17]

Rajan *et al. (2018)* wanted to study the sensitivity of the NPs and carried out various tests mentioned in section of SURFACE. One of these is to leave them at different temperatures in 1-2-3h intervals to see the effect of time on the visualization of the LFP.

The quality of the developed digital marks deteriorated with the increase in time and the temperature of aging, due to the loss of moisture and the absorption/dispersal of digital marks in the substrate of the bearing of the fingerprints. [9]

There are substances in fingerprints that are hydrophilic so if they are left in immersion they can be removed as the time passes for immersion causing them to lose some of them. Yang *et al. (2019)* studied four types of powders and it was found that in the case of the epoxide decreased slightly although the contrast was still present. This means that the hydrophilic interactions are a small part compared to the other interactions. In the case of alcohol, it was more complicated, because hydroxyls groups are even more hydrophilic. The epoxide and amino groups (due to charges) are the least affected by immersion but, the epoxide work better.

There are several factors affecting the resolution: size, hydrophobic interactions and electrostatic attractions.

As time goes by, all are diminishing as time passes. Due to the affinity they have with the functional groups, the best were the epoxide *(Figure. 25).* [13]

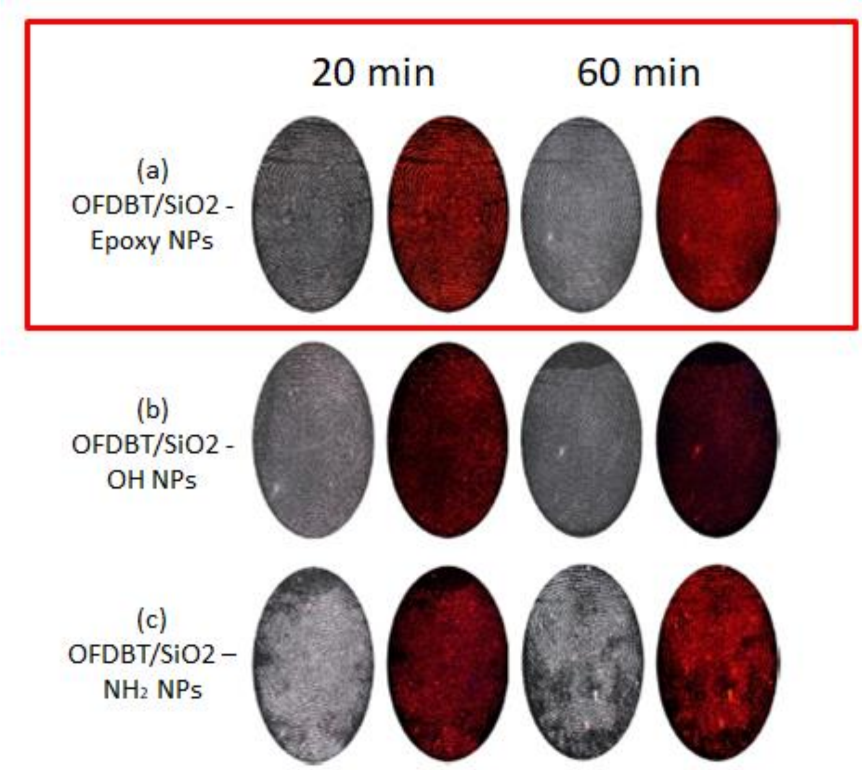


Figure 25. LFPs immersed in water for 20 min and 60 min. [13]

OTHERS

This section will discuss other non-essential parameters to be taken into account, which do not fit into any of the preceding paragraphs. The reason why it has not dedicated a special space for them is the lack of information in comparison with the rest.

The background signal originates from, partly, from the background chromophores of the surfaces. Chromophores *(Figure. 26)* are a part of a molecule responsible for its colour. The colour arises when a molecule absorbs certain wavelengths of visible light and transmits or reflects others. [6]

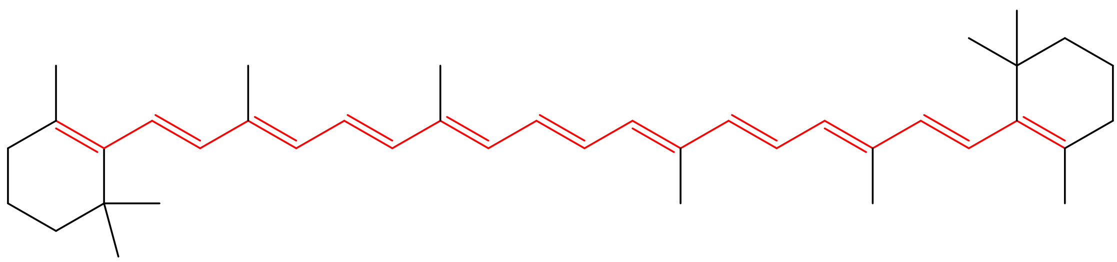


Figure 26. Chemical structure of beta-carotene. The eleven double conjugated bonds that form the molecule's chromophore are highlighted in red.

The solution is that contrast agents that can be excited at a significantly different wavelength of chromophores are candidates to reduce this interference by changing excitation. This is done with NIR because the vast majority of the background chromophores cannot be excited by the NIR light. Some contrast agents are organic dyes, based on polymers and inorganic NPs:

- Organic dyes: amino acids are present in sweat. Ninhydrin is an amino acid-sensitive agent, obtaining a blue-purple colour. Fluorescent prints can be improved with zinc and cadmium salts. The amino acids, some are insoluble in water. It can be used by means of hydrophobic interaction.

- Based on polymers can be chosen for their properties. When fluorescent functional groups are introduced, they may have different properties. This got a better contrast. Hybrid materials can also be possible.
- Non-silica based inorganic NPs: they are of interest for their physicochemical properties, such as controlled synthesis, diverse morphology, tuned optical properties and excellent stability. They provide an image of the LFP without background interference. [6]

Komalasari *et al. (2017)* attempted to establish the best stoichiometric amount suitable for obtaining between smooth and uniform particles (Figure. 27). Finally the different reagents (silica, carbon, MB and sodium acetate (AcONa)) were optimized with a final composition of 2:4: 1:1 (Figure. 28). [16]

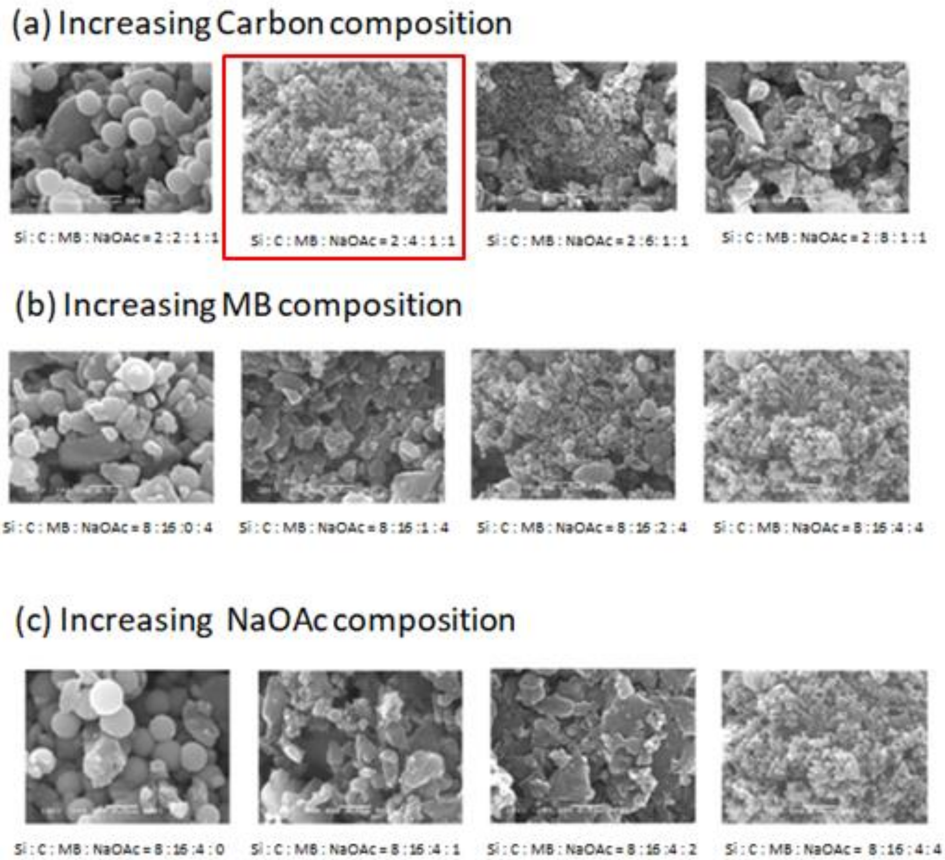


Figure 27. SEM images at 40000x magnification for each composition of Nano silica (Si) : Nano carbon (C) : methylene blue (MB) : sodium acetate (NaOAc). [16]

Figure 28. Final composition (previously highlighted in red). [16]

Another study related to the stoichiometric amount of the reactants was that of Aisyiyah *et al. (2020)* where silica NPs was reacted with NaOH. As the amount of base increases, at a constant temperature, the surface increases. This may be because the base reacts with silica oxide to form sodium silicate. However, from a certain concentration, the surface area decreases since the volume of the pores is collapses. [7]

Another very important aspect to consider is the reduction of toxicity when producing powders. Rajan *et al. (2019)* developed a silica powder from rice husk and turmeric. The new powder is much less harmful than the commercial because it is made from natural products. When being less harmful for health they are also cheaper due to the large amount there is, it is availability. [12]

However, there are also chemical products that are low in toxicity such as Fouad *et al. (2020)*, which synthesized bio-compatible compounds like phosphorus and cadmium. [18]

FURTHER WORK

The forensic field is very advanced; however there is always room for improvements and to solve problems such as background interference, sensitivity, selectivity, toxicity. In short, it is an effective, simple, stable and sensitive study.

The method selection depends on the surface, the texture, the state, the colour of the surface, etc. Other parameters are the applied force, the area, the angle and the time of contact.

Bumbrah *et al. (2016)* studied different ways in order to improve everything related to the improvement to visualize the LFP. In order to enhance the bad reproducibility, a device was developed that made artificial LFP which, were deposited as a viscose fraction of the residue on liquid surfaces. Heptane was also used to remove oil-similar products on porous surfaces to better visualize LFP. White light sensors can be used to calculate the age of LFP on various surfaces. Factors such as sweat composition, temperature and size, can affect the outcome. Time, finger pressure and substrate are less effective parameters. Normally the dusting method is used to visualize the LFP. This article uses the sticky side of a tape. However, it is not applicable in porous surfaces that are highly absorbent. Another option was the use of a sensor in smooth and curved materials like pens. [1]

Apart from having applications in the forensic field there may also be space in the field of medicine for silica based particles. Recently, a study was carried out with Fouad *et al. (2020)* where two complexes were compared, the phosphor-cadmium and the phosphor-cadmium for silica. The anti-tumour activity of the phosphorus complex Cd (II) is inferior to that of the silica-dispersed Cd (II). This is because it is because doping a very low concentration of the phosphor Cd (II) complex that decreases its anti-tumour activity. It has been compared with other drugs, giving a positive response. [18]

PROJECT PROPOSAL

This section will propose an idea of the project to carry out and resolve all the objectives proposed at the beginning of the work. The main consisted of investigating what were the parameters that could improve the LFP visualization. Then study its effect and its importance. And finally, focus on the most important ones.

Taking into account all the objectives, during the research has been seen that the most important parameters have been the following:

- Surface: regarding the type of surface has been seen to be very important, as it depends on how it is, can be distinguish or not clearly the fingerprint. As seen, in most articles, the same kinds of surfaces are studied as they are the most viewed in a crime scene. These are wood, glass, plastic, stainless steel and leaf.

- Reagent is a very decisive factor to improve the visualization of a fingerprint. It has been seen that clarity is good when there is a strong interaction between the powder used and the components of the residue that leaves the LFP impregnated. Therefore, studying which reactants should be used is of great importance. Finally, the best powder with NPs with silica was with epoxide groups.

- Size: it is observed that the particle size is crucial so that the adhesion between dust and residue is ideal.

- Time: it is extremely important to know who has been on the scene at a specific time. It can be a complication makes an involvement to study how the difficulty of time can be eliminated.

The following proposed study will investigate one parameter at the time.

STUDY 1:

In most articles, not to say at all, no distinction is made between man and woman or age, but I think it is important because it can help to find out who is involved or otherwise discard it. To see if it is, a study will be carried out close to whether the LFP is different between the two genders. Will be used a conventional powder, because it is not an important parameter to study.

RESULTS STUDY 1:

Table 1. Results of gender-age STUDY 1.

AGE	SURFACE	GENDER	
		Woman	**Man**
15-25 years old	**Wood**		
25-35 years old	**Glass**		
35-45 years old	**Plastic**		
45-55 years old	**Stainless steel**		
55-65 years old	**Leaf**		

The age range is between 15 and 65 years old because it is thought that it is more likely to find suspect of those ages present in a crime scene, or at least, that their fingerprints may be important. The different surface types have been chosen, thinking in which they may be in a criminal scene.

STUDY 2:

Another possible situation the state of the surface, whether it is a wet or dry surface as the crime scene may be outdoors and to rain, causing part of the LFP to be lost. The following study consists of observing whether the presence of water on the surface is important.

RESULTS STUDY 2:

Table 2. Results of wet or dry surface STUDY 2.

SURFACE		GENDER
Wet	**Wood**	
	Glass	
	Plastic	
	Stainless steel	
	Leaf	
Dry	**Wood**	
	Glass	
	Plastic	
	Stainless steel	
	Leaf	

In the case that the previous study saw that there is a difference between genders; this will also be distinguished between them. If not, the study will be done randomly. This table is the results in the event that no distinction is made between genders.

STUDY 3:

The study should be done on samples which vary from smooth to rough surface. It is important, because sometimes because the surface is rough, the powder does not adhere completely, but only partially.

RESULTS OF STUDY 3:

Table 3. Results of smooth-rough surface STUDY 3.

SMOOTH SURFACE	ROUGH SURFACE
Woman/Man	**Woman/Man**

STUDY 4:

Next, the study will correlate two factors, surface and reagents, and continue of the work started in the laboratory. In other words, the importance of the powder on different surfaces will be studied and the powders of synthesized powders in the stay at Nottingham Trent University would be used.

RESULTS OF STUDY 4:

Table 4. Results of surface-powder STUDY 4.

SURFACE ↓ POWDER →	**Powder 1**	**Powder 2**	**Powder 3**	**Powder 4**
Wood				
Glass				
Plastic				
Stainless steel				
Leaf				

The different powders were as follows:

- Powder 1: Micro-doped silica particles
- Powder 2: functionalization of FITC particles with amino groups
- Powder 3: Amino acid functionalization with carboxyl groups
- Powder 4: Activation of carboxyl groups with N-hydroxysuccinimide

STUDY 5:

In Duhnna *et al. (2018),* different types of powder were studied on the same surface. The fact is that although the limestone and gram flour were the best powder, it was studied more in detail the turmeric. For this reason it will be the same as in the previous study but with these two powders.

RESULTS OF STUDY 5:

Table 5. Results of surface-natural powder STUDY 5.

SURFACE ↓ POWDER →	**Limestone**	**Gram flour**
Wood		
Glass		
Plastic		
Stainless steel		
Leaf		

STUDY 6:

In another case, Komalasari *et al. (2017)* tried to find the perfect combination of silicon, carbon, MB and NaOAc in order to see in rounded shape and clear silica particles. However, in no time they changed the composition of silica, for this reason we will study how silica NPs vary their stoichiometric amount.

RESULTS OF STUDY 6:

Table 6. Results of different compositions of silica STUDY 6.

Si : C : MB : NaOAc	**2 : 4 : 1 : 1**	**4 : 4 : 1 : 1**	**8 : 4 : 1 : 1**	**16 : 4 : 1 : 1**
IMAGES				

STUDY 7:

In the section on how important the particle shape was there was talk of some non-spherical NPs but not found much more information. It is for this reason that they would make several studies with them on different surfaces to see their adhesion capacity and will be compared with a conventional powder which is composed of spherical NPs.

RESULTS OF STUDY 7:

Table 7. Results of spherical-elongated NPs in different surfaces STUDY 7.

SURFACE ↓ POWDER →	Spherical NPs	Elongated NPs
Wood		
Glass		
Plastic		
Stainless steel		
Leaf		

STUDY 8:

As time between the crimes is committed and it is being discovered is rarely a matter of minutes, it would be very interesting to do several studies where the waiting time is the key factor. In the following four studies the same time range will be studied, which is an estimate of when it may be the time it takes to discover a scene of crime.

RESULTS OF STUDY 8:

Table 8. Results of time-wet/dry STUDY 8.

SURFACE		1 DAY	1 WEEK	2 WEEKS	3 WEEKS	1 MONTH
Wet	**Wood**					
	Glass					
	Plastic					
	Stainless steel					
	Leaf					
Dry	**Wood**					
	Glass					
	Plastic					
	Stainless steel					
	Leaf					

STUDY 9:

In this study the important factor is still the time, but in this case instead of vary if the surface be dry or wet, it will make the surface is in a closed or open space, because other meteorological elements can also affect the visualization of the LFP.

RESULTS OF STUDY 9:

Table 9. Results of time-enclosed/open space STUDY 9.

SURFACE		1 DAY	1 WEEK	2 WEEKS	3 WEEKS	1 MONTH
Enclosed space	**Wood**					
	Glass					
	Plastic					
	Stainless steel					
	Leaf					
Open space	**Wood**					
	Glass					
	Plastic					
	Stainless steel					
	Leaf					

STUDY 10:

In this case, as in the STUDY 3, will observe how can vary the adhesion of the powder in a smooth surface and rough to measure that spends the time.

RESULTS OF STUDY 10:

Table 10. Results of time-smooth/rough surface STUDY 10.

SURFACE	1 DAY	1 WEEK	2 WEEKS	3 WEEKS	1 MONTH
Smooth					
Rough					

STUDY 11:

It has been observed that if the surface is white/clear it is suitable to use a black powder, due to contrast. And, on the contrary, if the surface is black/dark it is advisable to use a clear powder. However, what is the recommended powder if the surface is of another colour? The following study will perform a search with different colours of surfaces in black and white to see which ones obtain greater contrast over time.

RESULTS OF STUDY 11:

Table 11. Results of time-white/black powder STUDY 11.

SURFACE		1 DAY	1 WEEK	2 WEEKS	3 WEEKS	1 MONTH
White powder	**Turquoise**					
	Orange					
	Red					
	Green					
	Blue					
Black powder	**Turquoise**					
	Orange					
	Red					
	Green					
	Blue					

STUDY 12:

Moreover, we are interested in small size NPs because so adhere better and more selectively to the LFP ridges. There are cases but that are not but in the article Komalasari *et al. (2017)* they use a calcination process at 800 º C which decreases the size notoriously. Therefore, the following study will perform several tests at different temperatures, below and above 800 º C, with different powders (powder 5-8), which are larger than desired.

RESULTS OF STUDY 12:

Table 12. Results of surface-powder STUDY 12.

TEMPERATURE↓ POWDER→	**Powder 5**	**Powder 6**	**Powder 7**	**Powder 8**
400ºC				
600ºC				
800ºC				
900ºC				
1000ºC				

These have been a number of different studies which propose to study several factors in order to achieve that the place and the LFP is a problem. It can be said that all these studies could not be done in a same search because they are too extensive but have been made to get an idea of what shortcomings are, or at least that I have not found information, regarding this issue.

CONCLUSIONS

CATALÀ

Després d'haver realitzat una recerca el qual s'han consultat vàries revistes on-line i llibres, s'ha conclòs la cerca. Un cop finalitzada es pot dir que la darrera sensació és de satisfacció ja que crec que els objectius establerts s'han aconseguit amb èxit. Recordant quins eren, a continuació, s'exposarà el seu resultat:

- Es recorda que el primer de tots era la recerca de diferents paràmetres els quals poguessin afectar a la millor visualització de les LFP. Finalment, amb un total de 24 consultes, es pot dir que s'ha trobat força informació per a la qual es pot fer un bon treball.
- El següent objectiu, el qual ja era més específic, consistia en estudiar com afectaven aquests factor a l'hora de millorar al màxim la visualització. Dintre de tots els paràmetres, s'ha trobat quina seria la millor versió de cadascun per a que la resposta fos correcta i favorable. Com per exemple, en el cas de la mida de partícula, s'ha vist en vàries ocasions que la millor opció és quan és de mida petita, ja que així la seva adherència amb les crestes de les empremtes digitals és més selectiva obtenint un resultat òptim i clar.
- Per últim, ens havíem de focalitzar en els més importants. En el curs de la recerca, es van trobar altres factors, no presents en aquest treball, el quals també podien afectar a la visualització de les LFP. Com per exemple el pH de la pols en solució, les millors longitud d'ona per aconseguir veure-les amb total claredat o com la temperatura a la qual havia d'estar l'entorn. Tots aquest són importants però ens hem centrat en d'altres més importants i decisius.
- Una última conclusió subjectiva, un cop haver acabat el treball, és que una bona idea seria estudiar 3 paràmetres. Per saber quins són de gran importància podríem canviar-ne un i veure quin efecte té.

Finalment, dir que, tot i la situació present del COVID '19, la qual ha dificultat a l'hora de fer un treball final de grau, es pot dir que s'ha après una gran quantitat de conceptes necessaris per a poder fer una pràctica amb coneixement. És a dir, dintre de tot això, s'ha obtingut un resultat positiu i d'alt enriquiment acadèmic.

ANGLÈS

After having done a search which has been consulted several online journals and books, the search has been completed. Once finished, you can say that the last sensation is satisfaction as I think that the established objectives have been achieved successfully. Recalling what were, next, will expose your result:

- It is recalled that the first of all was the search for different parameters which could affect the best visualization of the LFP. Finally, with a total of 24 references, you can say that it has found quite a lot of information for which you can do a good project.
- The next objective, which was already more specific, consisted of studying how these factors affected the time of improving the visualization. Within all parameters, it has been found which would be the best version of each so that the answer was correct and favourable. As for example, in the case of the particle size, it has been repeatedly seen that the best option is when it is small size, as this way its adhesion with the fingerprints is more selective obtaining an optimal and clear result.
- Finally, we had to focus on the most important parameters. In the course of the research, other factors were found, not present in this work, which could also affect the visualization of the LFP. As for example the pH of the powder in solution or the best wavelength to get see them with total clarity or how the temperature to which it should be the environment. All these are important but we have focused on other important and decisive ones.
- One last subjective conclusion, once you have finished the work, is that a good idea would be to study 3 parameters. To know which ones are of great importance we could change one and see what effect it has.

Finally, to say that, despite the present situation of the COVID ' 19, which has difficulty in doing a final project of degree, it can be said that has learnt a lot of concepts necessary to be able to make a practice with knowledge. In other words, we have obtained a positive and high academic enrichment.

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