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Comparing the Effectiveness of Photoluminescent Powders for the Development of Latent Fingerprints on Complex Surfaces

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Abstract

Since the end of the 19th century, criminal investigation began to use the invisible impressions of the fingerprints that people leave on the crime scene to relate them to suspected criminal acts.

To make them visible, different technologies have been developed over the last 120 years. One of them was physical powders, and within this group it is also possible to identify different types of powder.

Photoluminescent powders (fluorescent and phosphorescent) have a specific application for those surfaces considered "complex".

This research will investigate the aptitude of these two types of developers on different surfaces, in order to determine what are the advantages and disadvantages of prioritizing the use of each one of them.

Keywords: Forensics; Fingerprint; Development; Print; Fluorescent; Phosphorescent; Latent; Powder; Physical; Dactyloscopy; Surface; Complex

Introduction

Human identification is a very complex concept, and it becomes even more so when it is related to establishing a conviction on a person in criminal acts.

Although there are many different methods of identification, fingerprints are the ones that have been used the most since they have different advantages over the rest, such as their simplicity and practicality, or the fact that they have been applied the most in criminal investigations.

Fingerprints have become over the time a form of absolute identification and possibly the most valuable physical evidence that can be found at a crime scene []. Powder application or fingerprint dusting is one of the oldest and most common methods of latent print detection. Consisting in the application of finely divided particles that physically adhere to the moisture and oily components in latent print residues [].

This adherence provides good visibility and definition of fingerprints details, and the use of the correct color of powder offers contrast against the background surface.

Currently, crime scene experts around the world use fluorescent powders to develop latent fingerprints on complex surfaces. Multi-colored surfaces are usually the clearest examples, where it may not be possible to choose a conventional powder. In these cases, an alternate light source (ultraviolet) is required to examine the developed prints in fluorescence [].

This type of powder has certain drawbacks due to its own photoluminescent characteristics: the developed fingerprint must be always irradiated with ultraviolet light to be observed. Therefore, two individuals must be present for the correct photographic processing. This also carries the risk of the photograph being ruined by surfaces that may also react to ultraviolet lights, such as writing paper, which have optical whiteners.

On the other hand, the lack of commercialization of phosphorescent powder [] -another type of photoluminescent powder- which could have greater advantages over the fluorescent one, led this author to ask himself whether its use would be effective or not for the development of latent prints on this type of surfaces.

Indeed, the idea of using photoluminescent powders for complex surfaces was proposed for the first time by Inbaun [] and Brose [] in 1934. But it was Scott [] who performed experiments of latent fingerprint development using regular phosphorescent powder and analyzed its potential.

The main objective of this study was to establish the scope and limitations of photoluminescent powders for the development of latent fingerprints on complex surfaces.

This research focused on three areas

1) Evaluate the effectiveness of phosphorescence for the development of latent prints on complex surfaces.

2) Describe the advantages and disadvantages of photoluminescent powders through the comparison of results (experimentation).

3) Define the types of surfaces on which latent prints can be developed.

Therefore, an experimental study was carried out taking latent prints samples on complex surfaces that was taken from the same donor, who produced the same fingerprints on the selected surfaces -considered 'complex'- in the same quantity and environmental conditions; performing a control on the possible variables: the surface, the characteristics of perspiration, the revealing technique, and the powder used, among others.

Once the samples had been obtained, they were developed with two photoluminescent fingerprint powders in the same conditions and surfaces and the quality of their results was analyzed. The sample collection procedures were those defined in the previous paragraph. The developing procedures were performed with a magnetic applicator. It was considered that it was the technique that would allow obtaining the best quality of the prints.

For fingerprint development, fluorescent and phosphorescent powders with magnetizable properties -compounds with iron- were used. After this, the fingerprints were subjected to the analysis of the quality obtained with both powders by taking photographs with the simultaneous use of ultraviolet lighting.

All prints were submitted to the same light, forensic scales and photographic conditions, to document and establish the degrees of sharpness and contrast, which would determine, as a whole, the quality of the development.

Materials and Methods

Variables

In the development of latent prints, there are some factors that can influence the quality obtained from it []

- Temperature, since the higher the temperature, the faster the rate of degradation of secretions.

- Sunlight, which produces, on the latent trace, the same effect as the increase in temperature.

- Humidity, which slightly increases the durability of the trace by keeping it hydrated.

- Air currents, which favors the drying of the trace, accelerating their deterioration.

- Heavy rains, which destroy fingerprints quickly.

But also, factors that affect the lifting of fingerprints:

Skin: Skin conditions due to multiple reasons (manual tasks, use of abrasive materials, etc.).

Pressure on the surface: The greater the pressure, the greater the deposit of sweat, consequently the better the quality of the fingerprint. Excessive pressure, however, alters the typeface, blurring it.

Sweat: The development depends on the quality and appropriate quantity of some elements of sweat (amino acids, salts, fat).

Surface: Contaminated surfaces affect to a greater or lesser extent the fingerprint drawing, from a simple deterioration to the total destruction of the drawing.

Climatic factors: The duration depends on the prevailing climate in the place. The cold weather without excess humidity is the most appropriate for conservation.

Characteristics of the site: Adequate protection of the site must be provided, preventing the surface from being exposed to the weather or handling.

In order to avoid -as far as possible- modifications due to the variables mentioned above, the experimentation was carried out using the digits of the third phalanges of the same person to produce the prints to be revealed. In addition, the same production times (exposure time, interval between printing time and development), and the same environmental conditions (temperature, humidity, sunlight, etc.) were applied.

Also, another variable were the different elements used (types of magnetic applicator, types of powders and the same source of ultraviolet illumination for their visualization).

In addition to that, considering the characteristics of the surfaces as another relevant variable affecting the result, the same surfaces were used for each of the experiments.

Finally, the human factor was considered: although the operator's skill should not influence the results of the experiments, to avoid possible variations all operations were performed by the same operator.

As this study was focused on the comparison of the resulting qualities with fluorescent and phosphorescent powders, the variation between experiments were generated by these powders, aimed to control the remaining variables mentioned above.

Samples

Before describing the type of samples selected, it is necessary to consider the types of existing surfaces. Surfaces are directly linked to their capacity to copy the fingerprint designs, being able to be classified in apt (those that can copy the fingerprints, such as glass or metal) and not apt (those incapable of doing so, such as cotton).

Another widely used classification is by porosity [], with porous surfaces (such as paper, which absorbs sweat secretions, reducing the useful life of the papillary trace when exposed to physical powders), and non-porous or smooth surfaces, such as polished metals, glass, etc.

There is also a classification linked to the color of the surface and, therefore, to the type of physical powder to be used. In this category we can find light surfaces, where black powder should be used and dark surfaces, where white powder should be used []. Within this classification, there is also a 'complex' category, which was taken into account in this research. Due to their characteristics, these cannot be revealed with conventional physical powders. There are surfaces that have both light and dark areas, which could be developed with bichromatic physical powders; surfaces that must be directly annulled, such as those with more than one color (multi-colored), which could be developed with fluorescent powders; and surfaces that react to light, such as reflective or fluorescent surfaces.

As references of selected samples, and to be able to make the comparison in the Discussion section, the article by Scott (2013) and the surfaces considered suitable (of the complex type) have been considered.

Characteristics

Specifically, the selected samples were prints of the same digits of the same donor, revealed on specific surfaces.

Selection of the surfaces

The selected surfaces were

1. a CD (reflective surface)

2. a Photograph (smooth multi-color)

3. a Bank check (multi-color surface with ultraviolet reactive and porous background).

4. a Glossy laminated printed cardboard (smooth glossy multicolor surface)

5. a Reflective glass surface (smooth)

Instruments and techniques

For fingerprint development was used inorganic phosphorescent and fluorescent powders mixed with iron powder (magnetic powder) and a magnetic applicator.

Instruments used

For this experimentation the elements used were:

1. Magnetic applicator PRO.

2. Ultraviolet flashlight with 12 LEDs of 395 nanometers.

3. 12 Megapixel resolution digital camera.

4. Amber-colored glasses for Ultraviolet protection.

5. Kit of personal protection elements.

6. Green fluorescent magnetic powder.

7. Green phosphorescent magnetic powder.

Development techniques

To develop a fingerprint, it is necessary to take some powder with an applicator or brush and remove the excess.

Depending on the type of applicator, powder or surface, different techniques can be used for fingerprint development []. One of them is *painting*, with side-to-side motion, which is used on larger surfaces. Another method is *swirling*, making circular movements with the wrist.

Dabbing can be done by leaving small amounts of powder on the surface without generating too much pressure.

Finally, another technique is *twirling*, a method where the powder is deposited directly by rotating the brush on its own axis.

In this investigation it was used the *painting* and *swirling* techniques, which are the most recommended for the magnetic applicator.

Criteria for the analysis of the results

The final objective of a print development is its eventual forensic comparison. In order to evaluate the final results, two important conditions were considered [].

a) **Sharpness:** the prints must be legible, allowing the details and characteristics of the lines to be properly visualized, and there must be contrast between the black of the lines and the white of the spaces.

b) **Integrity:** the prints must have sufficient field for the complete and integral visualization of a good quantity of congenital details of the papillary lines, suitable for comparison.

Procedures

The procedure established for this investigation were the following

1. The donor stamped the same digits over the selected surfaces, controlling the variables described above. As a first step, it was important to make sure that these surfaces did not contain previous fingerprints or residues that could interfere with the investigation.

2. The operator put on the safety elements to avoid possible contamination: mask and nitrile gloves.

3. The magnetic tip of the magnetic applicator was brought close to the pot, creating an irregular star of powder, which would act as brush bristles. The applicator tip was brought close to the known area where the invisible latent print was located, and gently rubbed over it mainly with *painting* and *swirling* techniques.

4. Once the prints were impregnated with powder, the ambient lights were turned off. Subsequently, the development was carried out by illuminating the sample where the print was located with the use of the 12 Ultraviolet LED flashlight.

5. While the Ultraviolet flashlight illuminated the sample, photographs were taken of it, using amber lenses as an Ultraviolet filter.

6. After 30 seconds of illumination, the Ultraviolet flashlight was turned off and a new photographic record was taken. In this way, it was possible to register how both samples were visualized without the illumination source.

7. The results and observations obtained were recorded and compared.

The selected surfaces were labeled in duplicate, as follows:

Numbers for surface, as follows: 1. CD; 2. Photograph; 3. Check; 4. Printed cardboard; 5. Reflective glass.

Letters for powders, as follows: A. Green fluorescent magnetic powder; B. Green phosphorescent magnetic powder.

Hypothesis

As a general hypothesis, it was established that:

"Phosphorescent powder generates better quality fingerprint developments than those generated by fluorescent powders".

As a specific hypothesis, it was stated that:

"On surfaces that react to Ultraviolet light, the phosphorescent powder provides better results than the fluorescent one".

Results

Results obtained on the CD surface

By illuminating with ultraviolet light and using the amber lens (Ultraviolet filters) it could be observed that prints suitable for comparison were obtained using both types of photoluminescent powders.

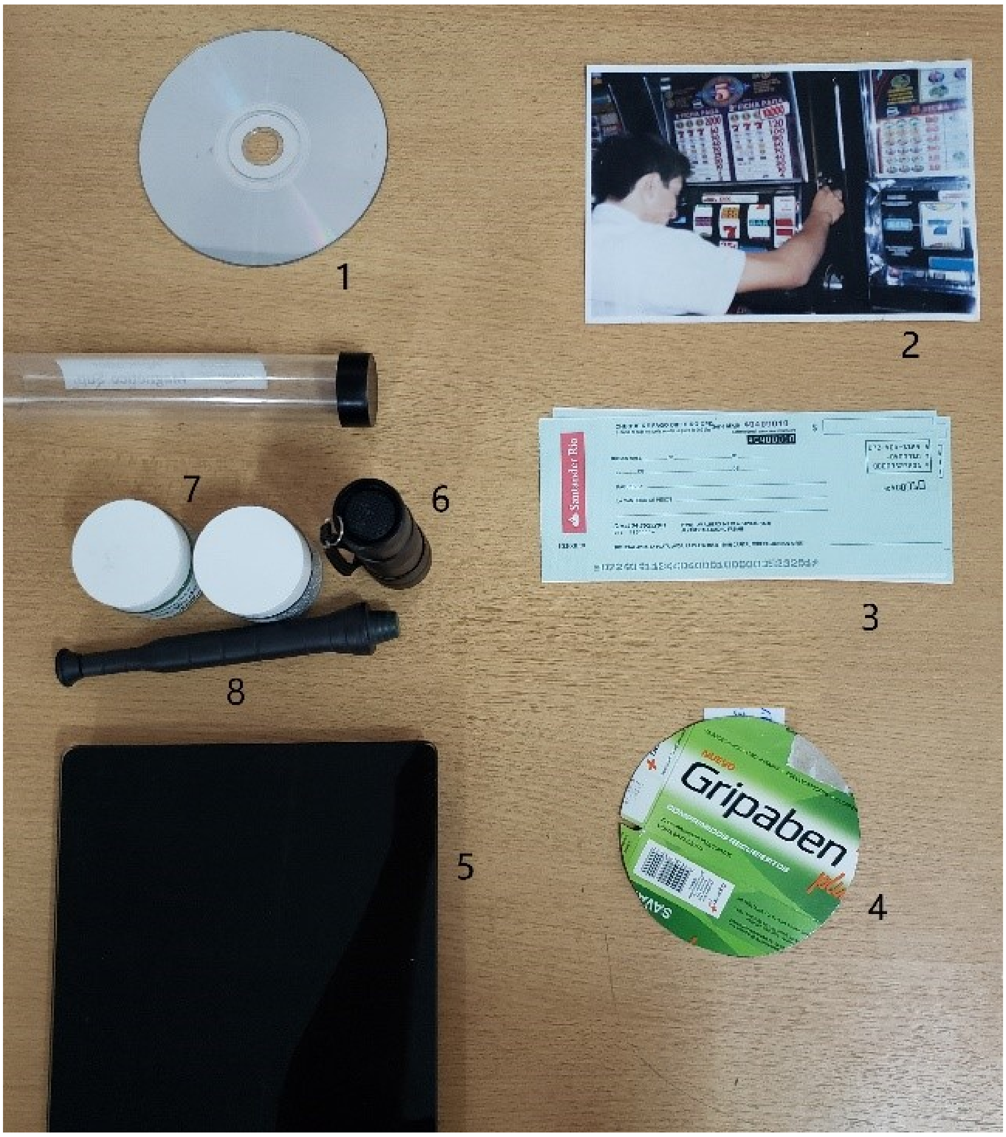

Figure 1: Illustrative image of the instruments and surfaces used: 1. CD; 2. Photograph; 3. Checks; 4. Printed cardboard; 5. Reflective glass; 6. Ultraviolet flashlight; 7. Photoluminescent powders; 8. Magnetic applicator

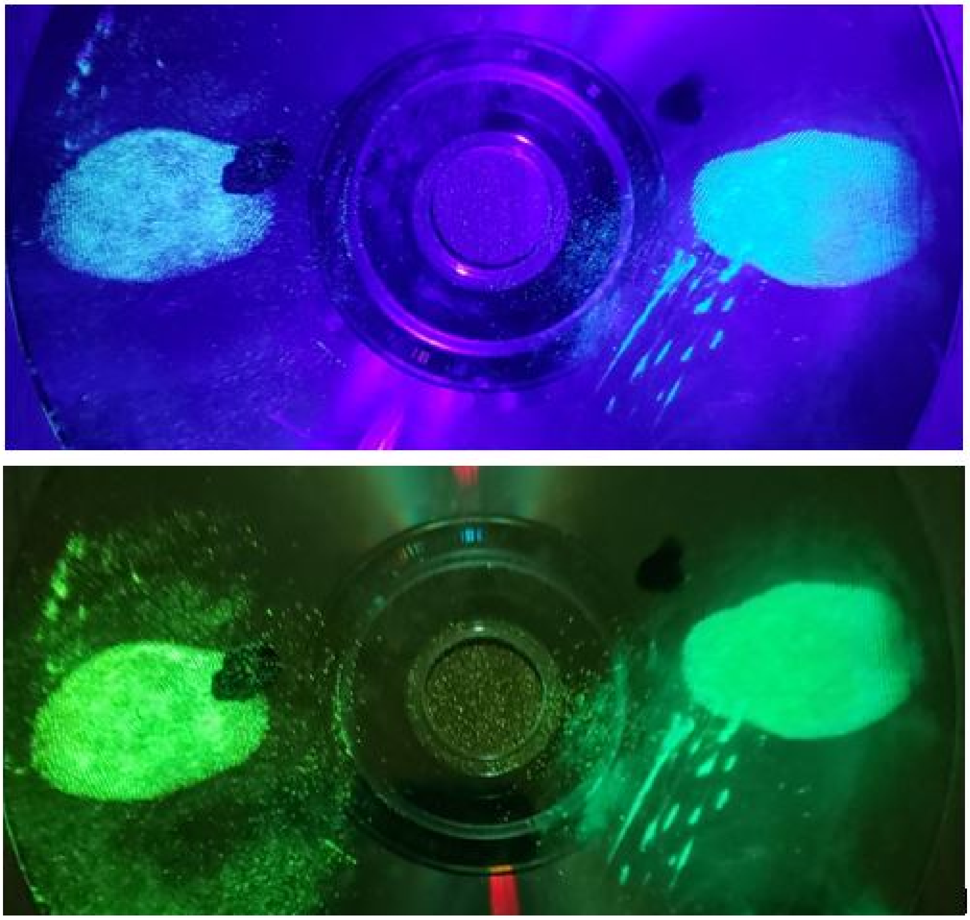

Figure 2 and 3: Fingerprints developed with phosphorescent powder (left) and with fluorescent powder (right), without using ultraviolet filter (above) and using the amber lens (below)

However, when applying such illumination, interferences were generated by the reflectance produced by the CD surface. This generated inconveniences at the time of taking a photograph of the fingerprints.

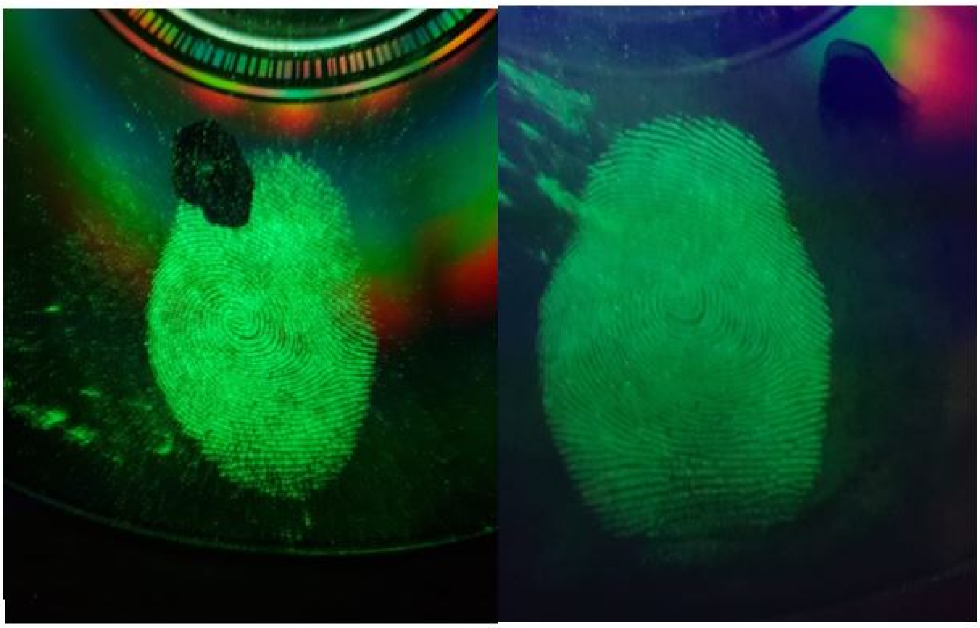

Figure 4 and 5: Reflectance generated in fingerprint developed with phosphorescent powder (left) and fluorescent powder (right), using ultraviolet filter

When the illumination source was turned off, the sample developed with fluorescent stopped generating contrast, while the one developed with phosphorescent continued emitting light, obtaining a better photograph. This way the interference generated by the surface reflectance was avoided.

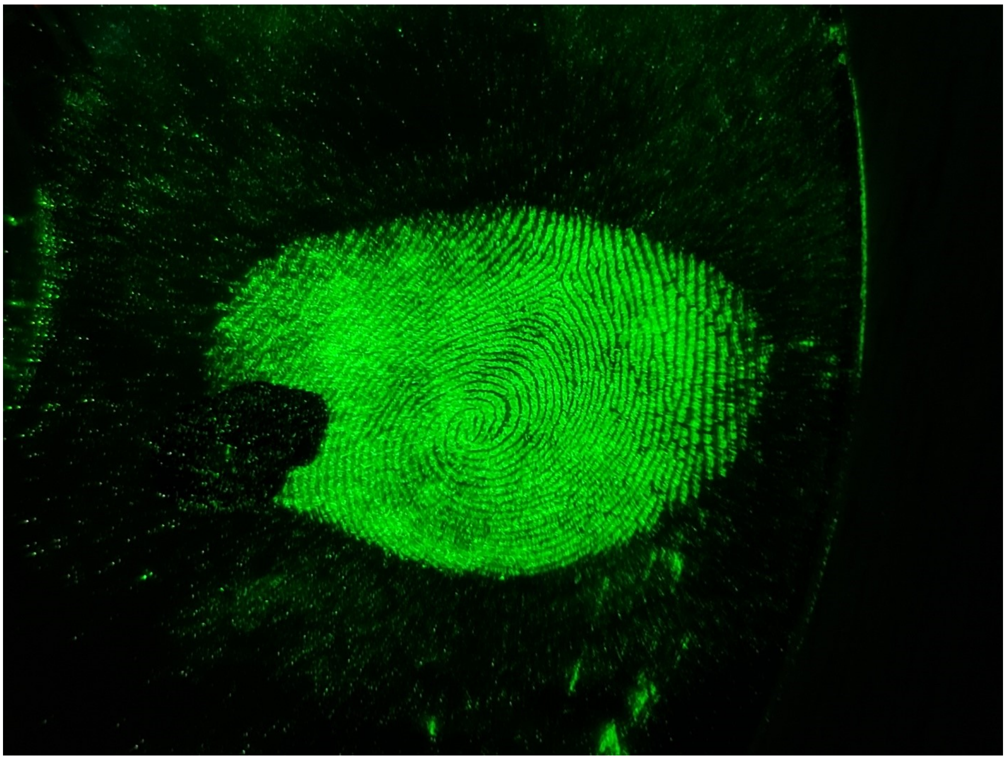

Figure 6: Fingerprint developed with phosphorescent powder once the ultraviolet light source has been turned off

Results obtained on the Surface of the Photograph

Both prints were generated on the same surface (photograph), in which there was color variation (multi-color).

When developing the fingerprints on the photograph, and using ultraviolet illumination, it could be observed that in both cases the contrast was not sufficient for an eventual comparison, even when using the ultraviolet filter. This was mainly due to the reaction of the white present on the surface of the photograph to the ultraviolet illumination.

Figure 7 and 8: Prints developed with phosphorescent (left) and with green fluorescent (right), without using ultraviolet filters (above) and with ultraviolet filter (below)

Therefore, ultraviolet light did not provide an ideal fingerprint in any case, due to the interference generated by the surface reaction. In this way, the sample revealed with phosphorescent powder was the only one that could be visualized correctly, as it can be seen in Figures 9 and 10.

Figure 9: Fingerprint developed with phosphorescent powder (left) and with fluorescent powder (invisible, on the right) once the light source has been turned off

Figure 10: Fingerprint developed with phosphorescent powder (enlargement of the previous figure)

Results obtained on the surface of bank checks

For the experimentation on this type of surface, two bank checks of similar characteristics and correlative numbering were used. The sample subjected to be developed with phosphorescent powder was the check N° 40400009, while the one to be developed with fluorescent powder was used was the N° 40400010.

In both cases three fingerprints were generated in the same areas considered more complex: one print on the bank logo -reactive to ultraviolet light-, another on an area that had the check numbering invisible to natural light, but visible with ultraviolet light; and the last one in a writing field area.

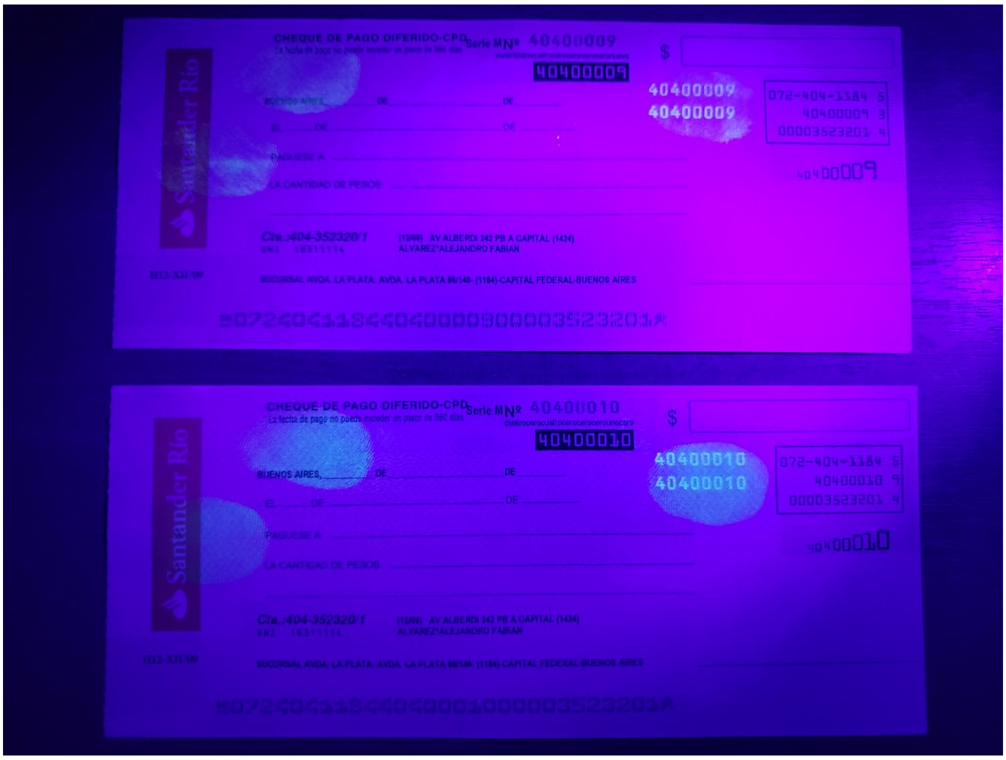

Figure 11: Fingerprints developed with phosphorescent (above) and fluorescent (below) without using ultraviolet filters

In either case, it was not possible to visualize the fingerprint correctly without an ultraviolet filter, since the check paper itself reacted to the ultraviolet light, impeding a correct contrast.

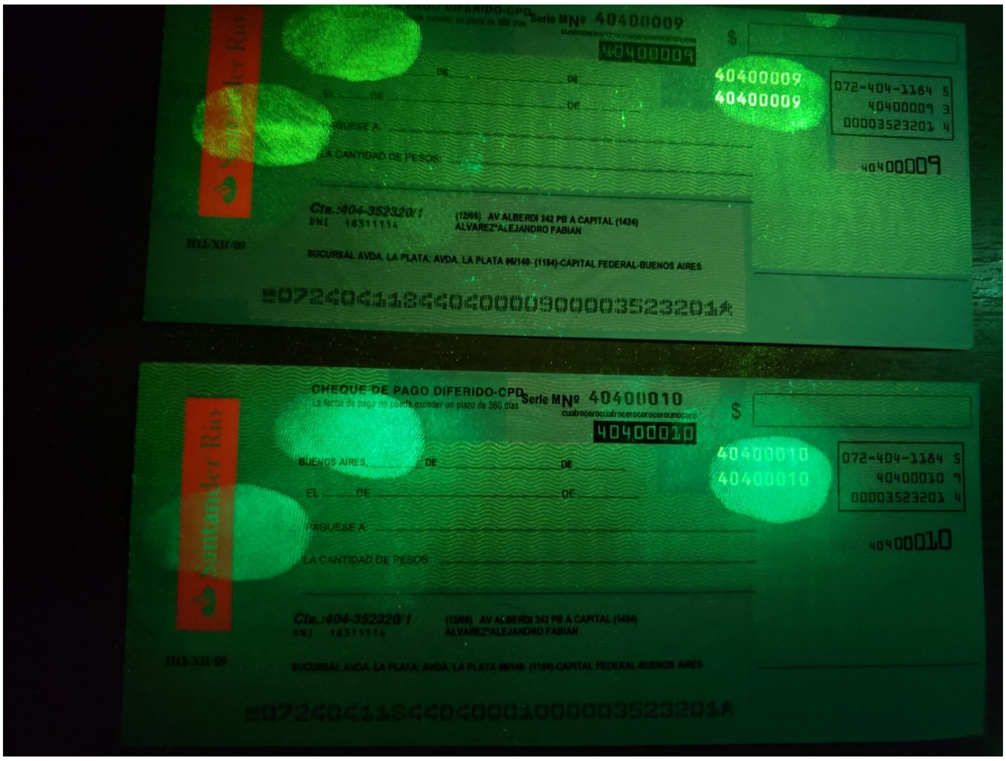

Figure 12: Fingerprints developed with phosphorescent powder (top) and with fluorescent powder (bottom), using an amber lens as ultraviolet filter

The inks used as security elements on the checks such as bank logo, check numbering and security background in the writing area, also generated interferences: they were reactive to the light source, even using the amber lens as a filter. Turning off the ultraviolet flashlight, the surface was completely annulled, with only the fingerprint developed with phosphorescent powder being visible.

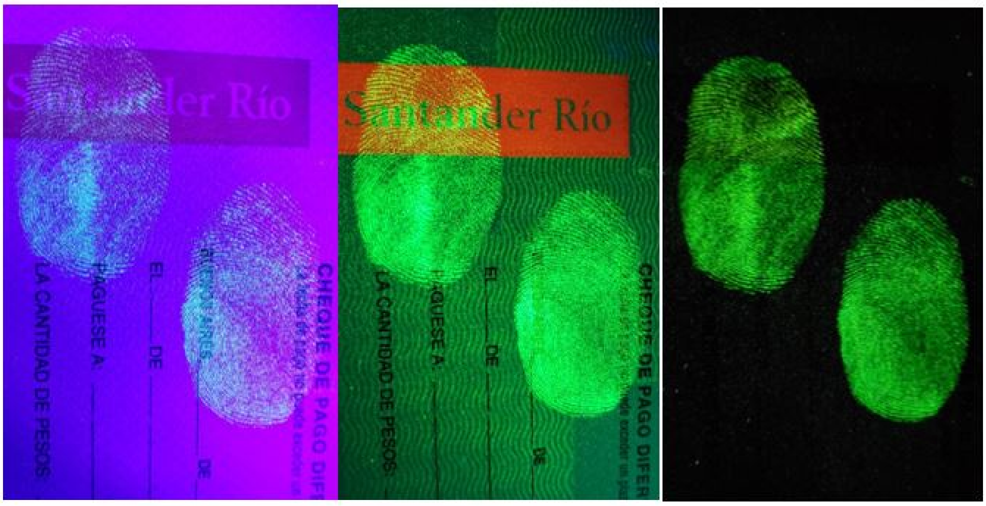

Figure 13: Detail of fingerprints developed with phosphorescent powder using ultraviolet light without filter (left), with ultraviolet filter (middle) and with ultraviolet light turned off (right)

Figure 14: Detail of fingerprints developed with fluorescent powder using ultraviolet light without filter (left) and with ultraviolet filter (right). No contrast was visualized when the light source was turned off

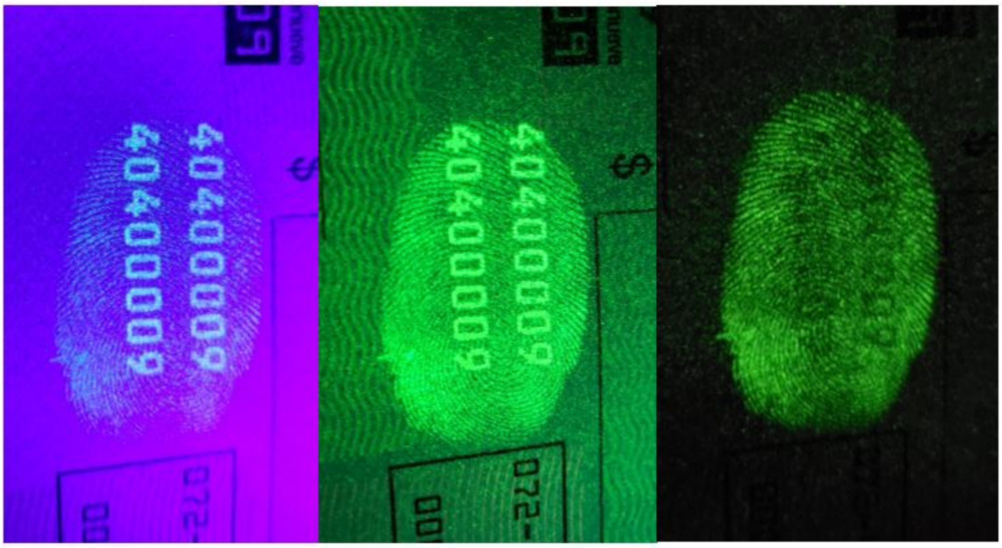

Figure 15: Detail of fingerprint developed with phosphorescent powder using ultraviolet light without filter (left), with ultraviolet filter (middle) and with ultraviolet light turned off (right)

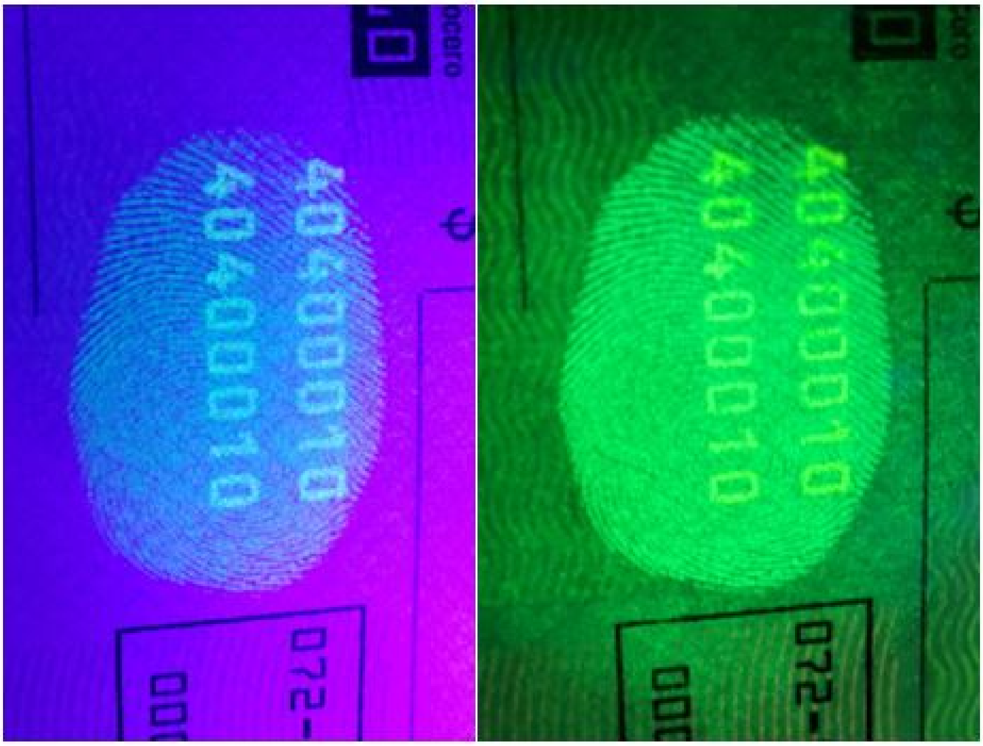

Figure 16: Detail of fingerprint developed with fluorescent powder using ultraviolet light without filter (left) and with ultraviolet filter (right). No contrast was visualized when the light source was turned off

Results Obtained on the Printed Cardboard Surface

Two fingerprints were developed on a multicolor glossy laminated cardboard surface, one of them with phosphorescent powder and the other with fluorescent powder, in sectors with similar characteristics.

Figure 17 and 18: Fingerprints developed with phosphorescent powder (left) and with fluorescent powder (right), without using ultraviolet filters (above) and with ultraviolet filters (below)

In both cases enough contrast was obtained for an eventual comparison. Although it was possible to avoid interferences generated by the surface using the amber lens as an ultraviolet filter.

As in the previous cases, a better contrast was obtained by directly annulling the surface by turning off the ultraviolet light source. In this way, the developer with phosphorescent properties was the only thing that continued to emit light for a short period of time.

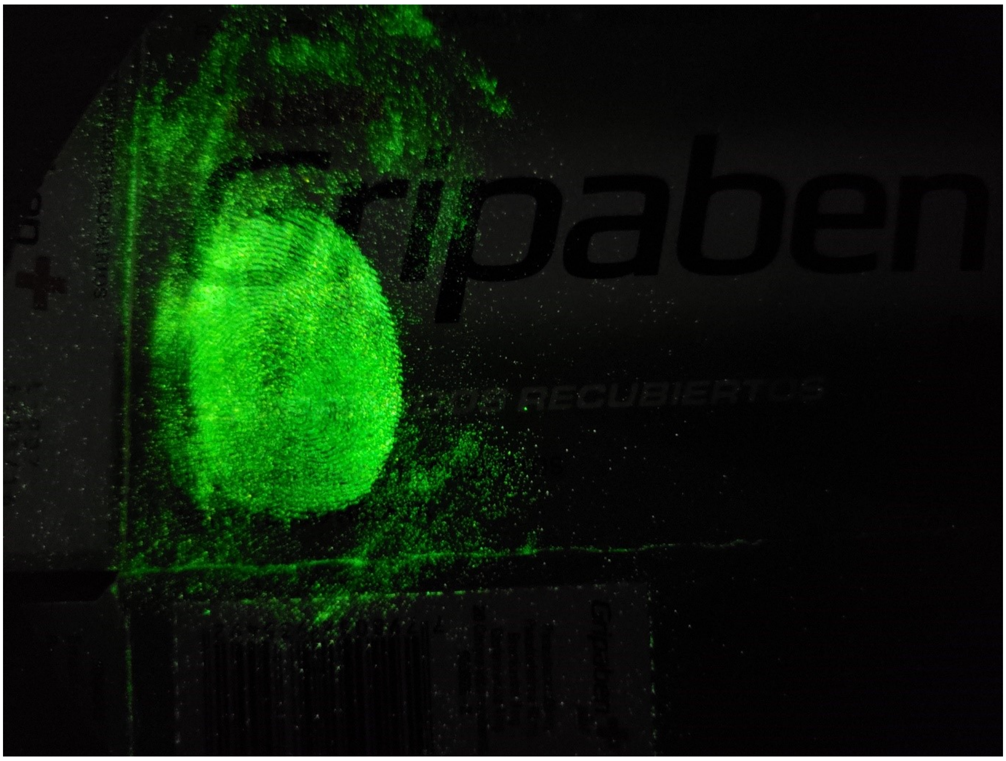

Figure 19: Fingerprints were developed with phosphorescent powder (left) and with fluorescent powder (invisible, on the right) once the light source has been turned off

In the case of the sample developed with phosphorescent powder, it was necessary to generate the fingerprint again, due to a bad impregnation of the powder in the first development. This did not happen with the magnetic fluorescent powder.

One drawback discovered about phosphorescent powder is that it can poorly adhere to the latent fingerprint on smooth surfaces like this laminated cardboard.

Results Obtained on the Glass Surface

Latent fingerprints were generated on two sectors of a dark reflective glass and developed with phosphorescent and fluorescent powder.

In both cases, it was possible to obtain developed fingerprints suitable for comparison (enough contrast), using ultraviolet light with and without ultraviolet filters.

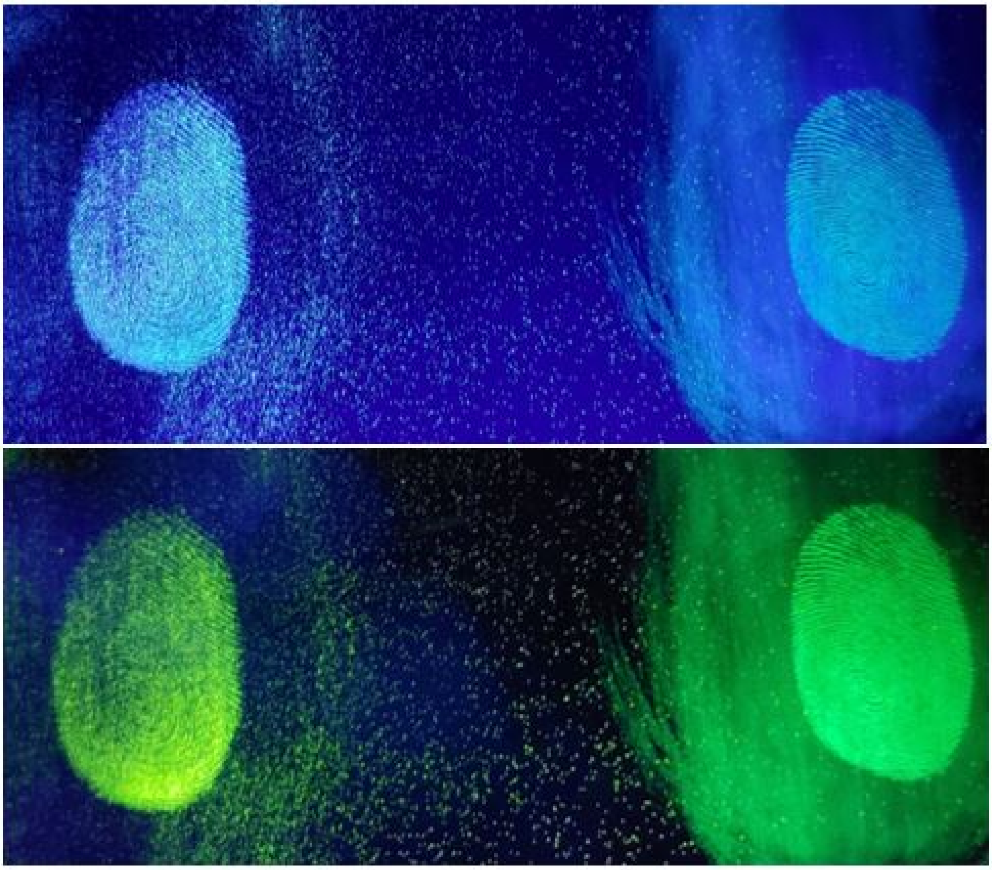

Figure 20 and 21: Fingerprints developed with phosphorescent powder (left) and with fluorescent powder (right), without using ultraviolet filter (above) and with ultraviolet filter (below)

Turning off the light source, the development with phosphorescent powder continued to emit light, but did not generate significant differences as was the case for the previous samples.

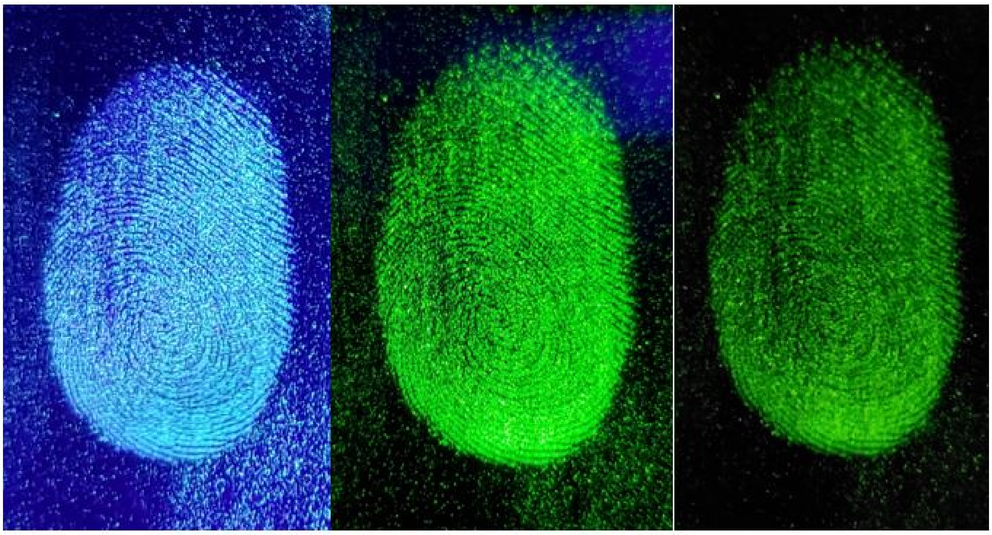

Figure 22: Detail of a fingerprint developed with phosphorescent powder using ultraviolet light without filter (left), with ultraviolet filter (middle) and with ultraviolet light turned off (right)

Also, in this case, the fingerprint quality obtained with the fluorescent powder was superior to that obtained with phosphorescent powder, as can be seen below.

Figure 23: Comparison of fingerprint developed with phosphorescent powder (left) and fingerprint developed with fluorescent powder (right), both using ultraviolet light with filters

Summary of results obtained

The following table summarizes the results obtained in the development on the 5 types of surfaces:

Surface	Developed with ultraviolet light without filter		Developed with ultraviolet light with filter		Ultraviolet light turned off	
	Ph.	Fl.	Ph.	Fl.	Ph.	Fl.
CD						
Photography						
Checks						
Printed cardboard						
Glass						

Table 01: Comparison of the results obtained. References: Red = A correct contrast regarding the surface was not visualized. Yellow = Contrast was visualized, but there were interferences. Green = A correct contrast regarding the surface was obtained. Ph. = Phosphorescent powder. Fl. = Fluorescent powder

Discussion

Scott (2013) performed experiments exploring the potential of phosphorescent powder for the development of fingerprints, comparing it with the results obtained with traditional fluorescent powder.

Initially, Scott [] added ferromagnetic powder to the mixture to create the phosphorescent magnetic powder. But according to him, this generated a heavy mixture that worsened the quality of the development results. That is why he compared fingerprints revealed with regular phosphorescent powder with those developed with fluorescent magnetic powder.

Contrary to what Scott found in his experimentation, it was discovered at the end of the investigation that mixing phosphorescent pigments with magnetic powder is possible to obtain fingerprints suitable for comparison with the fingerprints developed by fluorescent magnetic powder in the 5 cases presented in this work.

But at the same time, it was found out certain drawbacks that could be related to the comment made by Scott regarding the mixture with ferromagnetic powder. Concretely, in the case of the laminated cardboard it was necessary to generate the print again, due to poor adhesion of the powder to the print in the first attempt. Another case was the glass surface, where the quality of the print generated was inferior to that obtained by the fluorescent magnetic powder.

In his article, Scott realized that he only needed ultraviolet filters to photograph fingerprints developed with fluorescent powder. But in this investigation, it was necessary to use the amber lens as an ultraviolet filter to enhance contrast in both cases equally, where interfering surfaces were found (CD, check, cardboard).

One of Scott's conclusions was that the phosphorescent powder generated a perfect contrast to that generated by the traditional fluorescent, since it completely annulled any unwanted luminescence coming from the surface.

The experiments carried out on the selected samples corroborated what Scott mentioned above: the phosphorescent powder was especially useful for those surfaces that presented luminescence (photograph and check).

Finally, Scott recommended the use of phosphorescent powder on reflective surfaces, based on the experience carried out on a CD.

During this investigation, the experience was replicated using magnetic phosphorescent powder and the result obtained was the same: the phosphorescent characteristics of the powder made it possible to turn off the light source, thus avoiding contrast reduction due to the reflective nature of the surface.

In agreement with Scott, the property of persistently emitting light over time without the need for a constant light source, makes the phosphorescent powder a viable alternative. It provides better results than the traditional fluorescent powder, especially on those surfaces defined in this research as ‘complex’.

Conclusions

From the experiments carried out, it was possible to demonstrate the effectiveness of the phosphorescent magnetic powder on the 5 selected surfaces, obtaining suitable prints for comparison in all cases.

The superiority of the phosphorescent powder over the traditional fluorescent powder was evident in the photograph surface.

Furthermore, due to its persistent luminescence over time, the phosphorescent powder provided better contrasts than those obtained with the traditional fluorescent powder in the case of ultraviolet-reactive (check and photograph) and reflective (CD) surfaces.

However, phosphorescent powder has presented drawbacks that were not revealed in the traditional fluorescent one: As the powder did not adhere properly to the print on the first attempt, in the case of the laminated cardboard surface it was necessary to generate the print again. Likewise, the development generated on the glass surface was of lower quality than the generated by the fluorescent powder.

In both cases the type of surface (smooth) is the same, which implies that phosphorescent magnetic powder performs better on porous surfaces.

Recommendations

Although the forensic value of the phosphorescent powder has been demonstrated, it is recommended further research into its sensitivity and specificity to fully understand its scope and limitations.

It would be possible to further investigate the charging time and light emission time of the phosphorescent powder once the light source is turned off, and how this factor varies in the result of the contrast generated.

It is also recommended to investigate the reactions over time, but on the prints themselves: how the photoluminescent powders act on older prints, investigating different periods of time (e.g., 5 hours after stamping, days, weeks, etc.).

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