Baghdad Journal of Biochemistry and Applied Biological Sciences
2025, VOL. 6, NO. 4, 238–244, e-ISSN: 2706-9915, p-ISSN: 2706-9907

REVIEW ARTICLE

Comparative Study of Metal Oxide Powders for Revealing Latent Fingerprints on Various Nonporous Surfaces

Dheaa Zageer[1], Evon Akram[1], Raghda Alsayed[2], Suhaib Q. Abdulla[3], Mohammed H. Al-Mashhadani[2], Emad Yousif[2], Shams Ismael[4], Mohammed S.S. Alyami[5], Waled Abdo Ahmed[6]

[1]*Department of Forensic Chemistry, Higher Institute of Forensic Sciences, Al-Nahrain University, Baghdad, Iraq*
[2]*Department of Chemistry, College of Sciences, Al-Nahrain University, Baghdad, Iraq*
[3]*Physics Department, College of Science AL-Nahrain University, Baghdad, Iraq*
[4]*Department of Medical Physics, College of Sciences, Al-Nahrain University, Baghdad, Iraq*
[5]*Department of Science, King Abdulaziz Military College, Riyadh 14514, Saudi Arabia*
[6]*Faculty of Education, Thamar University, Thamar 87246, Yemen*

Article Info.

Keywords:
Fingerprint, Forensic science, Metal oxides, Transparent glass, Black marble, Phone screen

Received: 07.06.2025
Accepted: 30.08.2025
Published online: 01.10.2025
Published: 01.10.2025

Abstract

Latent fingerprints are left behind on various surfaces when a person touches an object, often invisible to the naked eye. The process of detecting these fingerprints and enhancing their visibility is vital for identifying perpetrators in criminal cases. Contrast, resolution, and the ability to see tiny details are all impacted by the different ways in which different agents interact with fingerprint residues and substrates. Surface type, residue composition, environmental variables, and safety issues all influence the best option. Empirical testing is often necessary to determine the most effective reagent for a particular forensic scenario. Several metal oxide powders, including CaO, $ZrSiO_4$, B_2O_3, TiO_2, and CdO, were used in this study to evaluate fingerprint detection on surfaces such phone screens, transparent glass, and black marble. Because of their high adhesion, clarity, and compatibility with various surfaces, $ZrSiO_4$ worked best on glass, B_2O_3 on black marble, and CdO on phone displays.

1. Introduction

One of the most important aspects of forensic science is being able to see latent fingerprints, which are a very useful proof in criminal investigations. These unseen marks, which are made by the natural oils and moisture on our skin, can only be seen with special tools [1]. Powder dusting is still one of the most popular enhancement techniques because it is easy to use and works well, especially on nonporous surfaces like glass [2]. This technique depends on the fine particles' physical attachment to the oils and moisture in the fingerprint residue. However, the sensitivity, contrast, or adaptability needed to detect fingerprints on difficult substrates—particularly clear or dark materials—can occasionally be lacking in conventional black or white powders [3]. Recent developments have addressed these constraints by introducing colored metal oxide powders, which provide enhanced flexibility and contrast on a variety of surface types [4].

The color, particle size, chemical stability, and degree to which the powder sticks to the fingerprint residue are some of the important considerations when selecting a

*Corresponding author: Mohammed H. Al-Mashhadani: mohammed.mashhadani@nahrainuniv.edu.iq
How to cite this article: Zageer, D, et al. Comparative Study of Metal Oxide Powders for Revealing Latent Fingerprints on Various Nonporous Surfaces. Baghdad Journal of Biochemistry and Applied Biological Sciences, 2025, VOL. 6, NO. 4, 238–244. https://doi.org/10.47419/bjbabs.v6i4.428

powder [5]. Iron oxide (FeO_3), titanium dioxide (TiO_2), chromium oxide (CrO_3), copper oxide (CuO), and zinc oxide (ZnO) are frequently investigated oxides that were chosen for their forensic applicability and appearance [6–8], as mentioned in Figure 1.

On light-colored vitreous surfaces, black fingerprint powders—which frequently contain graphite or charcoal—work incredibly well. On the other hand, dark surfaces work better with white powders, which are usually made of ZnO or TiO_2 [9]. More adaptability is offered by some cutting-edge powders, such as silver/red formulations, which provide dual-color contrast, looking silver on dark backgrounds and brilliant red on light ones [10].

The successful application of fingerprint powders on vitreous surfaces requires a delicate touch and a clear understanding of the material's properties [11]. The traditional powder dusting technique remains a common and effective approach for nonporous surfaces like glass [12]. Other techniques and substances are being investigated to improve latent fingerprint development on glass in addition to conventional dusting: magnetic powders, cyanoacrylate fuming, phosphorescent powders, unconventional and natural powders [13,14], as shown in Figure 2.

2. Experiment

2.1. Preparation of Materials and Surface

Before applying, check if all tools (a soft brush, glass rods, ground marble, transparent glass, and phone screen) are clear of contaminants to avoid cross-contamination. Choose a suitable formulation for fingerprint powder that includes the listed compounds (such as TiO_2, which is frequently used in powders because of its high sensitivity on a variety of surfaces, such as CdO, CaO, B2O3, and ZrSiO4, with orange powder),[15] as shown in Table 1 and Figure 3.

To avoid further deposits, gloves should be worn while handling surfaces that may have latent prints. Since latent prints are usually made up of lipids, amino acids, and eccrine secretions that react with the powder, examine the surface in a suitable light to find possible print locations. Figure 4 represents the surfaces of black ground marble and transparent glass.

2.2. Powder Application Process

Apply a small amount of the powder to the bristles with a specific brush (fine fiberglass). This controlled application prevents overuse, which could obscure details. Apply even, gentle pressure while carefully moving the brush in light, circular strokes over the suspected surface. The powder particles will adhere selectively to the latent residues—such as sweat deposits, oils, and other organic materials—causing the fingerprint ridges to become visible. Brushing should continue until the ridge details of the print are well-defined, usually in 10–30 seconds, depending on the type of surface and the thickness of the powder.

Observation and Preservation: Once the latent impression is visible, to improve clarity, stop brushing and gently remove any extra powder with a soft, clean instrument or a light air puff. To verify ridge detail, examine the created print under proper forensic lighting or magnification. For documentation, take a high-resolution photo of the print or transfer it to a different background using adhesive tape [16,17].

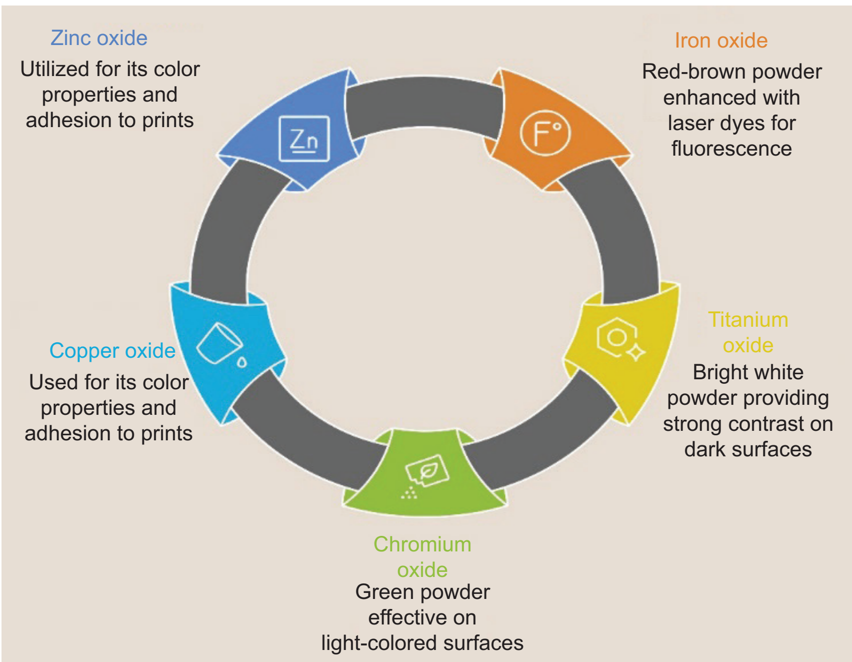

Figure (1): Selected colored metal oxides commonly used in fingerprint development powders, including Fe_2O_3, TiO_2, CuO, ZnO, and Cr_2O_3.

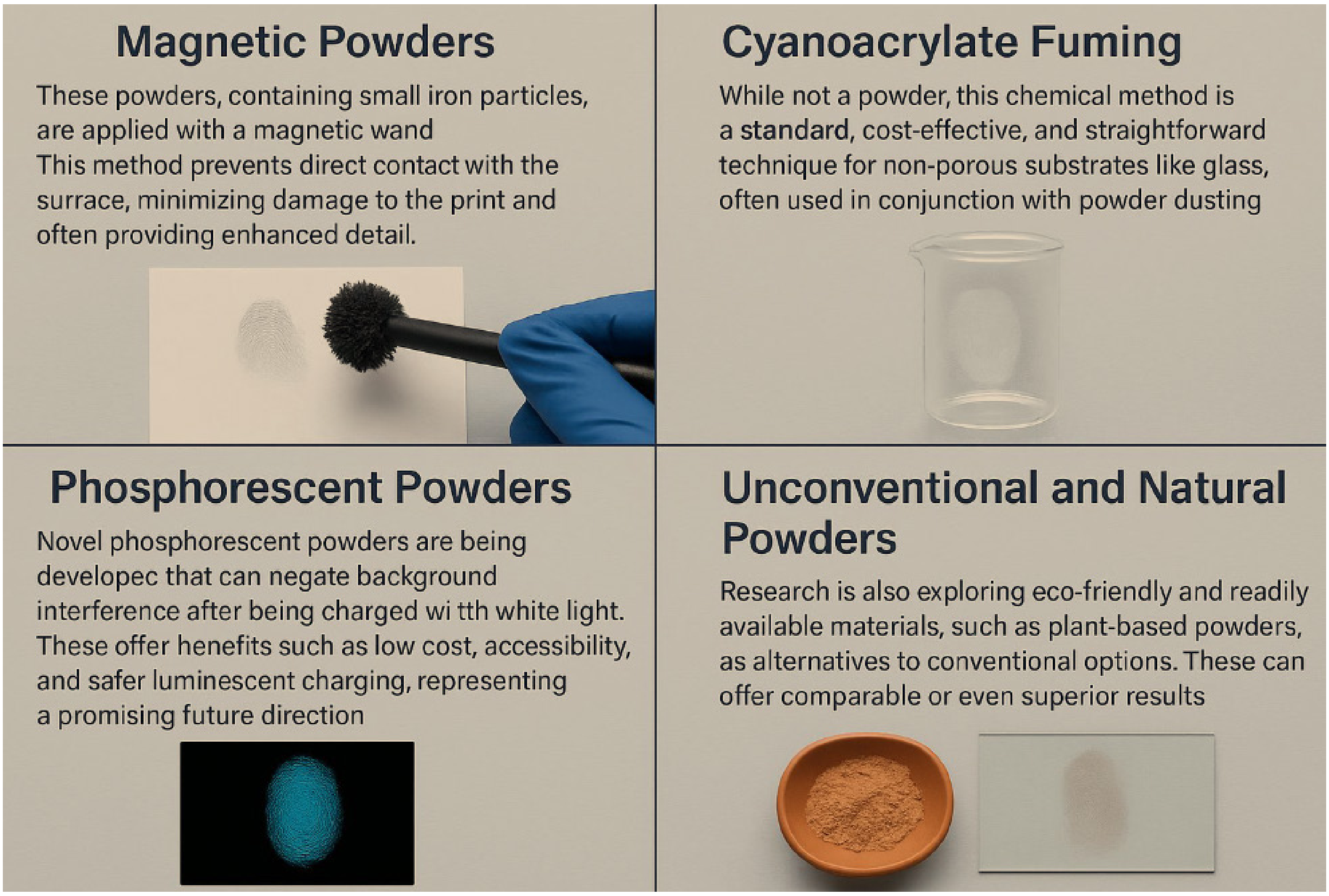

Figure (2): Overview of alternative techniques for latent fingerprint improvement on nonporous surfaces, with magnetic powders, cyanoacrylate fuming, phosphorescent powders, and natural powder.

Table (1): Overview of the compositions and features of fingerprint powder.

Powder	Chemical formula	Color	Particle size	Notable properties
Titanium Dioxide	TiO_2	White	~100–500 nm	High contrast on dark surfaces, safe
Cadmium Oxide	CdO	Reddish-brown	~200–600 nm	High resolution on smooth surfaces, toxic, strong adhesion
Calcium Oxide	CaO	White	~300–700 nm	Reactive, enhances moisture-based residues
Zirconium Silicate	$ZrSiO_4$	Off-white	~400–800 nm	Stable, durable, excellent adhesion on glass
Boron Trioxide	B_2O_3	Transparent-White	~200–400 nm	Adheres well, enhances fine ridge details

Figure (3): Compounds used in the formulation of fingerprint powders, for instance TiO_2, CdO, B_2O_3, CaO, and $ZrSiO_4$.

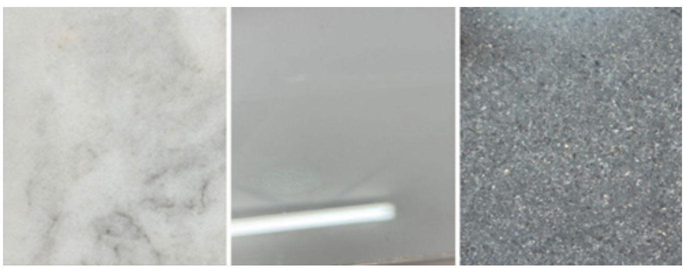

Figure (4): SEM images of various types used for fingerprint analysis: black ground marble and transparent glass.

3. Results and Discussion

3.1. Calcium Oxide (CaO) and Zirconium Silicate ($ZrSiO_4$) on the Surface of the Glass

A fingerprint was documented on a smooth, nonporous surface at two stages: Prior to and following the application of a chemical detection agent.

Pre-Treatment Observation: Before the application of fingerprint powder compounds, the fingerprint was faint and lacked distinctiveness. The major lines and curves, as well as other ridge patterns, were hardly discernible to the naked eye. This restricted visibility highlights the difficulty of examining latent prints that have not been treated and the significance of chemical enhancement methods in forensic fingerprint analysis.

Post-Treatment Observation: Following CaO and $ZrSiO_4$ treatment, the fingerprint becomes more recognizable. Increased ridge detail indicates (CaO and $ZrSiO_4$) affinity for the fingerprint's oily or moist remnants. Nevertheless, some background noise and dispersed particles are also apparent, which could suggest excessive application or nonspecific CaO and $ZrSiO_4$ particles adhesion, as represented in Figure 5. $ZrSiO_4$ produced superior findings based on comparative examination because of its stable adhesion and nondestructive nature, which makes it more appropriate for forensic applications on glass. Faster visibility was offered by CaO; however, there was a risk of particle dispersion and surface abrasion.

Glass: before and after adding CaO and $ZrSiO_4$

The methods and efficacy of CaO and $ZrSiO_4$ for latent fingerprint detection on glass surfaces are very different. CaO, being a basic oxide, interacts readily with moisture and residues left by fingerprints, often enhancing contrast because of its hygroscopic nature, which can help in revealing ridge details. However, sensitive surfaces can be at risk because of its strong reactivity and possible abrasiveness [18]. On the other hand, $ZrSiO_4$ is a ceramic substance that is thermally stable and chemically inert, offering a more durable and safe option for fingerprint development. It works primarily through its ability to adhere finely to fingerprint residues without damaging the substrate, making it particularly suitable for forensic applications involving smooth, nonporous surfaces like glass. $ZrSiO_4$ is typically chosen for its nondestructive characteristics and long-term dependability in forensic investigations, even if CaO might provide faster or more visible results [15,19].

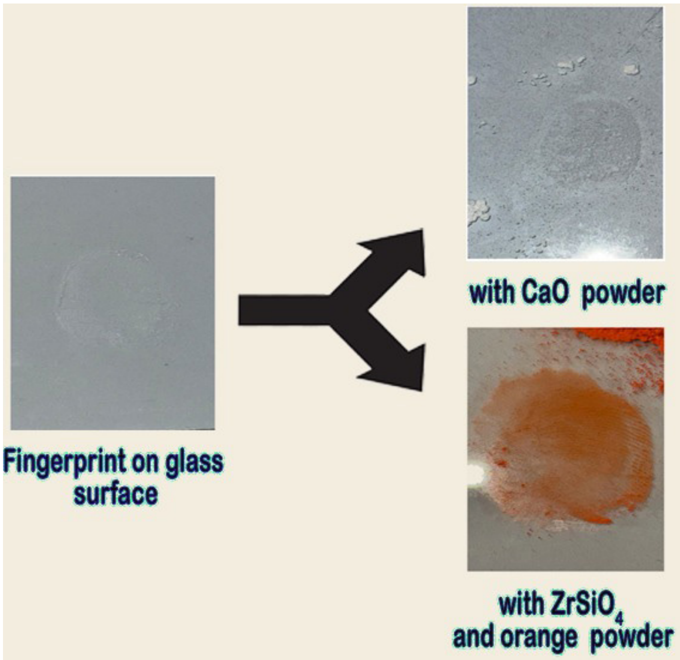

Figure (5): Latent fingerprint on glass surface: post-treatment with CaO, and post-treatment with $ZrSiO_4$.

3.2. Boron Oxide and Titanium Oxide on a Surface of the Black Marble

Pre-Treatment Observations: Upon first examining the untreated granite surface, a very faint latent fingerprint was found. The granite's reflecting qualities and coarse texture significantly reduced the ability to see ridge details. Because of the mostly unidentifiable ridge patterns, the print was not suitable for biometric examination in its initial state.

Post-Treatment Observations: The clarity and contrast of the latent fingerprint significantly improved after boron trioxide (B_2O_3) and TiO_2 was applied. Both primary ridge features and finer details were more clearly visible as a result of the reagent's strong adhesion to the remaining fingerprint constituents. Bifurcations, ridge ends, and other details were well apparent in spite of the substrate's challenging nature. Ridge flow analysis revealed that the fingerprint pattern was an ulnar loop, which is distinguished by ridge lines that enter from the thumb's radial side and curve toward the left hand's ulnar (pinky) side. The overall ridge continuity and the existence of recognized details suggested that the print quality was sufficient for classification and possible identification, as shown in Figure 6.

B_2O_3, with its capability to form a thin, adherent film, works well with the organic residues in latent prints, producing a clear and stable visualization of ridge details even on the greatly polished, nonporous surface of black marble. On dark surfaces, its comparatively low reflectivity also reduces background interference, improving contrast and legibility. The white, highly reflecting powder TiO_2, on the other hand, can produce a striking visual contrast with the black marble's dark background. However, because of its powdery texture and tendency to scatter light, it may obscure fine details or over-deposit in nonprint areas, decreasing clarity [20]. While TiO_2 is useful for quick visual detection because of its brightness, B_2O_3 in general yields better results for detailed fingerprint study on black marble, offering higher fidelity in ridge structure preservation and minimizing false positives from surface irregularities [21].

3.3. Titanium Oxide and Cadmium Oxide (CdO) on the Surface of a Phone Screen

Pre-Treatment Observation: Prior to the application of the reagent, the latent fingerprint looked poorly defined and

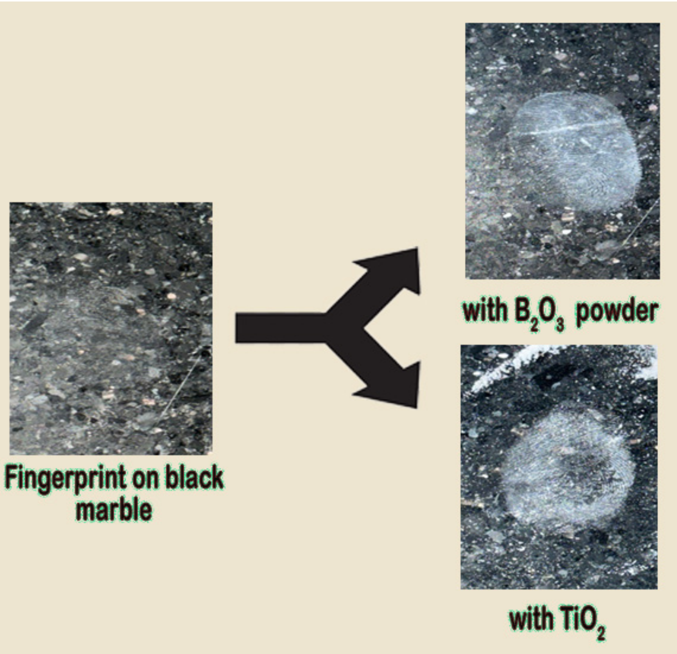

Figure (6): Latent fingerprint on black marble: post-treatment with TiO_2, and post-treatment with B_2O_3.

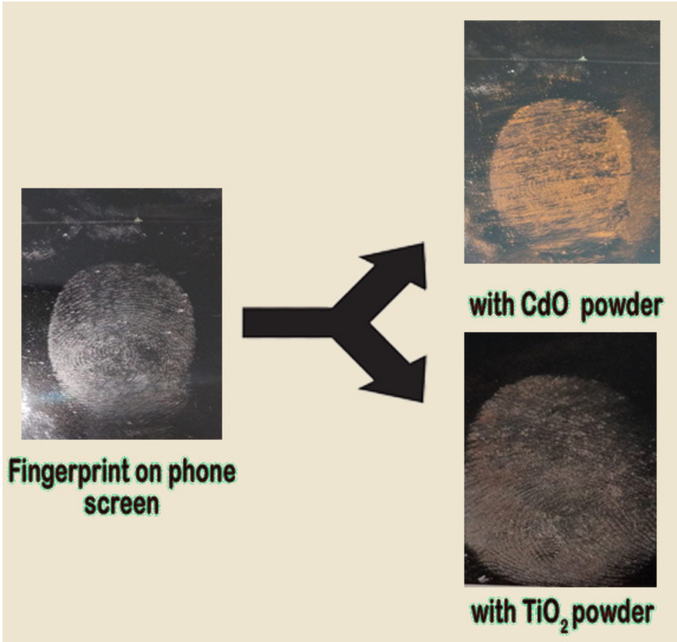

Figure (7): Latent fingerprint on a reflective phone screen: applying TiO_2, and applying CdO.

irregular. Ridge lines were indistinct, and the general pattern lacked enough contrast and resolution for accurate classification or biometric analysis. This limited the ability to identify key features for example ridge endings and bifurcations, presenting considerable challenges for forensic evaluation and pattern recognition.

Post-Treatment Observation: When it comes to latent fingerprint detection on phone screens, CdO and TiO_2 have rather different properties and efficacy, which are typically smooth, reflective, and prone to smudging. TiO_2, a popular white powder with strong light-scattering characteristics, improves fingerprint visibility by contrasting the glossy surface with the print, especially in oblique or ultraviolet (UV) light. Its particle nature, however, can occasionally result in uneven deposition and obscure tiny ridge characteristics, particularly on surfaces like polished screens or glass. In contrast, CdO, though less commonly used because of concerns of toxicity, has been noted for its high sensitivity to latent residues and can produce sharp, high-contrast ridge detail with fine resolution. Because CdO tends to stick to fingerprint residues more selectively, details are easier to see. Nonetheless, its application requires stricter safety protocols. For normal use, TiO_2 is still safer and easier to get, but in controlled settings where ridge pattern analysis is crucial, CdO might provide better resolution, as shown in Figure 7.

TiO_2 performs differently on phone screens compared to black marble as a result of the distinct surface properties of each substrate. On phone screens, which are typically reflective, smooth, and frequently coated with oleophobic layers, by producing a contrast between the print and the glossy background, TiO_2 can improve the visibility of fingerprints. However, unless lighting is well regulated, its reflective surface may produce glare and its small particle nature may result in uneven adherence, potentially hiding finer ridge details [22]. On the other hand, TiO_2 offers a striking visual contrast because of its white color against the dark background of the black marble, a dark, frequently polished stone with slight surface flaws. While this contrast is beneficial, the light-scattering effect of TiO_2 can sometimes result in reduced clarity of fine details, particularly if the powder accumulates in the marble's natural crevices [23,24]. While TiO_2 requires more careful application and lighting control to get clear ridge detail suited for forensic examination on phone screens, it is often more successful on black marble for general contrast [25–27].

According to the results, $ZrSiO_4$ worked best on transparent glass, providing excellent clarity with little interference from the background. On black marble, B_2O_3 + TiO_2 produced outstanding results, particularly because of the film-forming properties of B_2O_3 and the strong contrast of TiO_2. Although CdO + TiO_2 produced high-resolution prints on phone screens, the usage of CdO is less suitable for normal forensic work because of toxicological concerns. CaO, on the other hand, produced findings that were mild, but its higher reactivity resulted in more background noise. A performance summary table was made in order to give an understandable overview of each powder's efficacy on various surfaces (Table 2).

4. Conclusion

The preparation and application of fingerprint development powders using colored metal oxides represent a vital area within forensic science, offering improved capabilities designed for visualizing latent fingerprints

Table (2): Summary of performance by surface and powder.

Powder	Best surface	Contrast	Detail clarity	Background noise	Safety concerns
CaO	glass	medium	moderate	medium	mildly reactive
$ZrSiO_4$	glass	high	high	low	safe
CdO $+TiO_2$	Phone screen	high	very good	medium	toxic (CdO)
B_2O_{3+TiO2}	Black marble	excellent	excellent	low	safe

on surfaces of vitreous material. Using the special properties of metal oxides such as FeO_3, TiO_2, and CrO_3, forensic investigators can obtain exceptional contrast and detail, even on difficult backgrounds. Evidence recovery is being advanced through the continuous development of powder formulations, including the investigation of magnetic and phosphorescent variations, as well as careful application techniques. This study found that B_2O_3 on black marble, zirconium silicate ($ZrSiO_4$) on transparent glass, and CdO on phone screens were the most effective fingerprint powder and surface combinations. On glass surfaces, $ZrSiO_4$ showed excellent stability and clarity, making it appropriate for maintaining delicate ridge details without causing substrate damage. Fingerprint visibility was improved on the dark, polished surface of black marble by B_2O_3, which also reduced background interference and produced outstanding contrast. Because of its strong adherence to latent residues, CdO produced high-resolution ridge patterns on shiny and smooth phone screens in spite of its potential toxicity. These findings highlight how crucial it is to choose fingerprint powders according to the particular surface type in order to achieve the best detection accuracy possible during forensic investigations.

Authors' Contributions

Dheaa Zageer: Conceptualization; Methodology; Evon Akram: Methodology; Data curation; Raghda Alsayed: Investigation; Formal analysis; Suhaib Q. Abdulla: Formal analysis; Validation; Mohammed H. Al-Mashhadani: Supervision; Resources; Project administration; Emad Yousif: Supervision; Project administration; Shams Ismael: Visualization; Software; Mohammed S.S. Alyami: Software; Data interpretation; Waled Abdo Ahmed: Writing—original draft; All authors: Writing—review & editing; Final approval of the manuscript.

Conflict of Interest

The authors declare no conflict of interest with respect to research, authorship and/or publication of this article.

Funding Resources

No funds have been received for this work.

References

[1] Andrade, C.A.; Telles, B.; Sercheli, M.S.; Kawano, N.M.; Soares, R.M.; Vicente, A.N., et al., Road design intervention based on traffic accident dynamics: a forensic intelligence approach. WIT Trans Built Environ, 146: 569–578, 2015. https://doi.org/10.2495/UT150461

[2] Doty, K.C.; Muro, C.K.; Bueno, J.; Halámková, L.; Lednev, I.K. What can Raman spectroscopy do for criminalisties? J Raman Spectrosc, 47(1): 39–50, 2016. https://doi.org/10.1002/jrs.4826

[3] Kumar, I.; Kumar, S.; Singh, M.; Kumari, K.; Kumar, D.; Ansari, K. Application of nanotechnology in forensic DNA and help to investigations on the crime scene analysis. World J Pharm Res, 5(1): 266–276, 2016.

[4] Alyasiri, T.; Hassan, A.; Adil, H.; Alsayed, R.; Makia, R. The antibacterial and antioxidant activities of combined Equisetum arvense extract with TiO nanoparticles in PMAA films. Results Chem, 11: 101829, 2024. https://doi.org/10.1016/j.rechem.2024.101829

[5] Wolfbeis, O.S. Nanoparticle-enhanced fluorescence imaging of latent fingerprints reveals drug abuse. Angew Chem Int Ed, 48(13): 2268–2269,16, 2009. https://doi.org/10.1016/10.1002/anie.200805765

[6] Wang, C.; Zhou, J.; Lulu, L.; Song, Q. Rapid visualization of latent fingerprints with color-tunable solid fluorescent carbon dots. Part Syst Char, 35(3): 1700387, 2018. https://doi.org/10.1002/ppsc.201700387

[7] Singh, K.; Sharma, S.; Garg, R.K. Visualization of latent fingerprints using silica gel G: a new technique. Egypt, J Forensic Sci, 3(1): 20–25, 2013. https://doi.org/10.1016/j.ejfs.2012.09.001

[8] Costa, C.V.; Gama, L.I.; Damasceno, N.O.; Assis, A.M.; Soares, W.M.; Silva, R.C., et al. Bilayer systems based on conjugated polymers for fluorescence development of latent fingerprints on stainless steel. Synth Met, 262: 116347, 2020. https://doi.org/10.1016/j.synthmet.2020.116347

[9] Zhang, X.F.; Liu, Z.G.; Shen, W.; Gurunathan, S. Silver nanoparticles: synthesis, characterization, properties, applications, and therapeutic approaches. Int J Mol Sci, 19(9): 1534, 2016. https://doi.org/10.3390/ijms17091534

[10] Prasad, V.; Lukose, S.; Agarwal, P.; Prasad, L. Role of nanomaterials for forensic investigation and latent fingerprinting—a review. J Forensic Sci, 65(1): 26–36, 2020. https://doi.org/10.3390/ijms17091534

[11] Mansoor, H. S.; Alsayed, R.; Abdallh, M.; Ahmed. D. S.; Bufaroosha, M.; Salihe, N., et al. Polystyrene dopped with Schiff base to reduce outdoor plastic degradation for sustainable environment. SAJCE, 35: 53–59, 2021. https://doi.org/10.1016/j.sajce.2020.11.003

[12] Li, W.; Huo, Z.; Zhang, X.; Zhao, H.; Cui, Z.; Fu, P. et al. New sight for in-situ monitoring of silica growth process: the incorporation of Stöber process and aggregation-induced emission (AIE) technique. Dyes Pigm, 182: 108637, 2020. https://doi.org/10.1016/j.dyepig.2020.108637

[13] Kanodarwala, F.K.; Moret, S.; Spindler, X.; Lennard, C.; Roux, C. Nanoparticles used for fingermark detection—a comprehensive review. WIREs Forensic Sci, 1(5): e1341, 2019. https://doi.org/10.1002/wfs2.1341

[14] Li, J.; Jiao, Z.; Zhang, P.; Wan, X.; Song, C.; Guo, Z., et al. Development of AIEgens–montmorillonite nanocomposite powders for computer-assistant visualization of latent fingermarks. Mater Chem Front, 4(7): 2131–2136, 2020. https://doi.org/10.1039/D0QM00059K

[15] Anderson, D.; Sydor, M.J.; Fletcher, P.; Holian, A. Nanotechnology: the risks and benefits for medical diagnosis and treatment. J Nanomed Nanotechnol, 7: e143, 2016. https://doi.org/10.4172/2157-7439.1000e143

[16] Trujillo, L.E.; Ávalos, R.; Granda, S.; Guerra, L.S.; País-Chanfrau, J.M. Nanotechnology applications for food and bioprocessing industries. Biol Med, 8(3): 1, 2016. https://doi.org/10.4172/0974-8369.1000289

[17] Menaa, F. Genetic engineering and nanotechnology: when science-fiction meets reality. Adv Genet Eng, 4(2): 1000128, 2015. https://doi.org/10.4172/2169-0111.1000128

[18] Hassan, A.A.; Adil, H.; Alyasiri, T.; Alsayed, R.; Makia, R.; Kadhom, M. et al. Nickel oxide nanoparticles with ginger extract: an environmentally sustainable method for antibacterial applications. Results Chem, 9: 2024, p.101617. https://doi.org/10.2478/9788368412031-012

[19] Singh, R.K.; Bansode, F.W.; Sharma, S.; Singh, P.; Bhadauria, S.; Singh, S., et al. Development of a nanotechnology based biomedicine RISUG-M as a female contraceptive in India. J Nanomed Nanotechnol, 6(4): 1, 2015. https://doi.org/10.4172/2157-7439.1000297

[20] Syduzzaman, M.; Patwary, M.S.; Farhana, K.; Ahmed, S. Smart textiles and nano-technology: a general overview. J Textil Sci Eng, 5(1). 2015, 1–7. https://doi.org/10.4172/2165-8064.1000181

[21] Nur Fatin Zulkifli, M.S. Development of natural latent fingerprint powder from durian seeds—a green and effective approach in crime scene. ResearchGate, 2017, 2362–2367. https://doi.org/10.5281/zenodo.845385

[22] Sri Adelila Sari, D.H.N. Development of nail henna (Lawsonia Inermis Linn.) leaf powder as a latent fingerprint visualization on non-porous and porous surfaces. J Med Chem Sci, 2023, 540-552. https://doi.org/10.26655/JMCHEMSCI.2023.3.11

[23] Basavaraj, R.B.; Darshan, G.P.; Prasad, B.D.; Sharma, S.C.; Nagabhushana, H. Rapid visualization of latent fingerprints using novel $CaSiO_3$: Sm^{3+} nanophosphors fabricated via ultrasound route. J Rare Earths, 37(1): 32–44, 2019. https://doi.org/10.1016/j.jre.2018.04.019

[24] Prabakaran, E.; Pillay, K. Synthesis and characterization of fluorescent N-CDs/ZnONPs nanocomposite for latent fingerprint detection by using powder brushing method. Arab J Chem, 13(2): 3817–3835, 2020. https://doi.org/10.1016/j.arabjc.2019.01.004

[25] Prabakaran, E. and Pillay, K., Synthesis and characterization of fluorescent Europium (III) complex based on D-dextrose composite for latent fingerprint detection. Journal of Saudi Chemical Society, 24(8), 584–605, 2020. https://doi.org/10.1016/j.jscs.2020.06.002

[26] Alsayed, R.; Altahan, R.; Al-Mashhadani, M.; Hazim, H.; Kadhom, M.; Zageer, D., et al. Exploring spectroscopic techniques in the forensic examination of synthetic textile fibers. JUAPS, (18), (01):190–196, 2024.

[27] Mahdi, S.A.; Al-Mashhadani, M.H.; Ahmed, A.A.; Yousif, E.; Graisa, A.M.; Moneim, A.E. Advances in the applications of organic materials for fingerprint detection. JUAPS, (17), (2):73–80, 2023.