MEDWIN PUBLISHERS
Committed to Create Value for Researchers

International Journal of Forensic Sciences
ISSN: 2573-1734

A Review on Nanomaterials for Developing Latent Fingerprint

Kar AK*

Department of Forensic Science, Adamas University, India

***Corresponding author:** Dr. Aditya Kumar Kar, Department of Forensic Science, Adamas University, Barasat, Kolkata, West Bengal, 700126, India, Email: adi4658kar@gmail.com

Mini Review
Volume 7 Issue 3
Received Date: June 30, 2022
Published Date: July 18, 2022
DOI: 10.23880/ijfsc-16000268

Abstract

Forensics has become a more interesting scientific topic to investigate with the advancement in science and technology in which nanomaterials have attracted a lot of attention in the field of nano-forensic research. Fingerprints are important evidence in any crime scene, and nano-based techniques have a lot of potential in fingerprint investigations in the future. Fingerprints have often been and still are considered one of the most valuable types of physical evidence for personal identification. The prints left behind at a crime scene are usually latent (invisible) fingerprints and thus, the distinct ridge details of fingerprints can be obtained by applying different nanoparticles such as silver, zinc oxide, silicon dioxide, aluminium oxide, gold, carbon and silica on a variety of object surfaces, with gold being the most commonly used. The use of nanoparticles can improve the quality and stability of latent fingerprints. As a result, this review study focuses on the use of various nanomaterials in the development and detection of latent fingerprints.

Keywords: Nanomaterials; Latent fingerprint; Forensic science

Introduction

Nanotechnology is making a significant impact in every field as it is concerned with the study of nanoscale materials. It is a commonly utilised method due to its capacity to alter and characterise matter at the level of single atoms and small atoms. The word "nano" is derived from the ancient Greek "Nanos," which means "dwarf," and refers to one billionth (10^{-9}) mean about nanometer (nm). Generally, 1nm is about 3-10 atoms wide or 40,000 times smaller than the width of human hair. It is concerned with new materials or devices at a scale that ranges between 1 to 100 nanometers [1]. As a result, this universal technology has a wide range of applications in forensic science. Nano-Forensics is a brand-new forensic science discipline that combines nanotechnology and forensic science. It aids in the identification and examination of evidence at the nanoscale level, where previously, essential evidence analysis was difficult due to the instrument's detection limit. Nano analysis is altering the investigative process by making it more precise, faster, and sensitive [2]. Nanotechnology is becoming increasingly appealing for latent fingerprint detection applications. Nanoparticles improves the general and particular properties of fingerprints such as detail minute information and the arrangement of pores. Nanomaterials were employed to produce latent fingerprints because they enhance latent prints better. It improves the disparity and finger impressions by increasing the superficial interaction with the endogenic material present on the elevations of fingerprints [3].

Fingerprints have been used by criminal justice to identify individuals for over 100 years. It is one of the most important evidence due to their uniqueness.and immutability for personal identification [4]. The study of fingerprints as a means of identification, called Dactylography is one of the fundamental science in criminal investigations whereas the scientific study of frictional ridge patterns found on the fingers, palms of hands, toes, and soles of feet is known as dermatoglyphics [5]. A fingerprint is an impression left behind by the skin found on the inner surface of the fingers. The skin on this area is called friction ridge skin and hence fingerprints are the result of minute ridges and valleys found on the hand of every person [6]. This friction skin is found on the fingertips, fingers, palms, and feet of humans, and it is unique to each individual in the world as well as permanent in the arrangement. This ridge detail contains a variety of various chemicals that come from natural excretions as well as other toxins that a human can take up as they contact random surfaces, providing distinctive features that can be left behind at a crime scene [7]. The ridges form before birth, as the foetus develops in the womb, and barring a deep-seated injury which penetrates through epidermal layer of skin, their arrangement will remain unchanged until after death [6].

The two general categories to describe the fingerprint evidence that may be found at a crime scene are visible fingermarks and latent fingermarks. Visible fingermarks are visible without any particular treatment and it may be positive, negative and indented. The latent fingermark is the most common form of fingerprint evidence as it is present but invisible. The latent fingermark, deposited by the ridge of the finger or palm, is a complex mixture of natural secretions and contaminants from the environment. The three types of glands which are responsible for the natural secretions of the skin are sudoriferous eccrine, apocrine glands and sebaceous glands [8]. Sweat contains water (>98%), minerals (0.5%), and organic compounds (0.5%). Eccrine sweat consists of proteins, urea, amino acids, uric acid, lactic acid, sugars, creatinine, and choline, while sebaceous sweat consists of glycerides, fatty acids, wax esters, squalene, and sterol esters [9]. Most of the time, the fingerprints are undetectable and require the use of physical or chemical reagents for visualization [8]. Thus, the identification of latent friction skin from evidence collected at the crime scene is crucial to solving many crimes. Physical method involves physical interaction with impression deposits to create latent finger impressions whereas chemical method develops latent fingerprints by chemical reaction taking place in between the developers and the constituents of sweat [10]. Powder dusting is a "physical" form of enhancement that relies on fingerprint powder particles adhering to the moisture and oily components of skin ridge deposits mechanically. Regular, luminescent, metallic, and thermoplastic are four classes of fingerprint powders [9]. Some of the chemical methods to develop latent prints are iodine fuming process, ninhydrin method, silver-nitrate method and cyanoacrylate method depending upon the types of surfaces. On the other hand optical technologies are nondestructive and use electromagnetic light of appropriate wavelengths to visualise latent finger-marks [10].

However, with the passage of time, both technology and criminality have advanced. As a result, traditional techniques have been proven to be less successful in detecting ancient fingerprints, their stability, and contrast that diminishes over time. As a result, different types nanomaterials are being used in order to improve fingerprint visibility and the traditional method that has been in use since 19th century. Nano-fingerprinting is a new field of forensic science that has emerged [11].

Nanomaterials for Fingerprint Detection

Nanoparticles have recently showed considerable potential in the production of nano-fingerprints i.e. the next generation of fingerprint development procedures. Nanomaterials have a large surface area, small size, optical properties, and have the ability to easily modify the surface using various capping agents. These qualities interact well with diverse non-porous and porous substrates on fingerprint residues. Due to hydrophilic attractions on fingerprint components of substrates, nanomaterials provides better fingerprint images, clearer ridge patterns, and less background interference. Nanomaterials have the advantage of being able to detect both fresh and old fingerprints on a variety of substrates [12]. The different types of nanoparticles in developing latent fingerprints are discussed below.

Silica Nanoparticles

Silica nanoparticles were produced to detect invisible finger impressions on non-absorbent surfaces. The average diameter of SiO_2 nanoparticles is 70 nm [3]. In the formation of latent fingerprints, silica nanoparticles are being utilised as a labelling agent because of the coating ability of silica nanoparticles and their simplicity of production [11]. Varied mass ratios of silica and 4-(chloromethyl) phenyltrichlorosilane with 700 nm of silicon dioxide nanoparticles were used to make silica nanoparticles. Due to the creation of hydrogen bonds and electrostatic attractions with amino acids, proteins, and lipids on fingerprint residues applied to diverse substrates, silica nanoparticles are easily coated with dyes to facilitate latent fingerprint detection. Because of an amide bond formed between the negative charge of the silica nanoparticles and the positive charge of the amine functional group on the fingerprint residue, fingerprints were formed by a new interaction between the fingerprint substrate and amine groups functionalized on silica nanoparticles. The best latent fingerprint detection was achieved with a ratio of (50:1) SiO_2 : 4-(chloromethyl) phenyltrichlorosilane as well as on non-porous substrates, these nanoparticles showed the best result [12]. Thus, the amphiphilic based silica nanoparticle has an affinity towards amino acids which is the basic component of fingerprint residue and due to this it was applied for the detection of latent fingerprint.

Nanocarbon Powder

Carbon nanoparticles have low cytotoxicity, water solubility, chemical inertness, and good biocompatibility [13,14]. It can be used as pigments, fillers, supercapacitors, bioimaging dye, photocatalysis, optoelectronics, bio diagnostics, high-performance electrode material in batteries, and optical sensing [15]. It can also be used for water treatment, catalyst carriers, electrode materials, and hydrogen storage in the form of activated carbon. In the industrial sector, coal is commonly used as a precursor for carbon nanoparticle synthesis, although biomass such as shells, cork powder, wood, bamboo, and plant waste can also be transformed into activated carbon [16]. According to previous research, nanocarbon powder (NP) generated from acid digestion of rice husk had the capacity to develop latent fingermark on a light background [17]. Thus, nanocarbon powder is very effective for detecting latent fingermarks on a variety of non-porous and semi-porous surfaces and it interacts selectively with fingermark residue, resulting in clear and sharp pictures of fingermark ridges [18]. On the other hand carbon nanoparticles loses its fluorescence in a solid state, it is combined with starch powder to make it flexible. The addition of starch powder to fluorescent carbon nanoparticles gives them a long-lasting colour. The above combo has a lot of potential when it comes to fingerprint recognition. According to a recent study, this combination acts as a fluorescent marker in the development of latent fingerprints on non-porous item surfaces, resulting in a fluorescent image of the fingerprint when exposed to UV light [11].

Silver Nanoparticles

Silver nanoparticles have gained attention in the field of nano-forensic fingerprinting because of their remarkable ability to stick to fingerprint residue. Silver nanoparticles were able to develop distinct ridge details and were found to be stable for more than a month. By using a lower concentration of silver nitrate, the silver nanoparticles shows good visibility and stability, and it can be used instead of the traditional silver nitrate method [19]. The physical developer (PD) reagent contains silver nitrate, which is an important component [20]. The silver nanoparticles range in size from 1 to 200 nanometers. The main component of silver physical developers is silver ions and a reducing (developing) agent as the colloidal silver has an affinity towards organic components of the fingerprint residual. It was made for developing latent images on photosensitive materials such as photographic emulsions [21]. The physical developer (Ag-PD) method develops fingerprints on surfaces that have been exposed to bright sunlight for several hours. In this technique, an iron salt reduces an aqueous solution of silver nitrate to metallic silver, which involves an oxidation–reduction couple. The silver nanoparticles generated during the reaction interact with the fingerprint residue, and the impression can be seen on the paper surface as a dark grey or black silver picture due to the presence of an electric force of attraction between positively charged fingerprint residue and negatively charged silver colloids [22]. The silver physical developer method is appropriate for porous surfaces because it visualised the prints on moistened samples. The visibility of the prints is inadequate. As a result, before dealing with a silver physical developer, the prints were treated with gold nanoparticles and citrate ions as a stabiliser [23]. The persistence of silver nanoparticles in the form of reagent (Ag-PD) from earlier times to more modern times has been found to be particularly successful in the establishment of latent fingerprints on negatively charged silver colloids on paper surfaces [11]. This method is costly, time-consuming, unstable and the process is damaging, leaving lasting traces on the documents.

Zinc Oxide Nanoparticles

Zinc oxide nanopowders are used to enhance the old hidden finer impressions on impermeable exteriors. It aided in the development of distinctive fingerprint ridge details that fluoresced under UV light [3]. The properties of ZnO includes a wide band gap (3.37 eV), a high excitation binding energy (60 MeV) that allows it to transition even at room temperature, and an additional adhesive property that allows interaction with the lipids and proteins in the fingerprint residue at ambient temperatures. Under wet conditions ZnO nano-powders naturally fluoresce in UV light. The ZnO nanopowder has a mean particle size of 1–3 um as determined by TEM images. The procedure is effective for creating both new and old fingerprints left on nonporous surfaces [23]. A mixture of nanopowder ZnO and SiO_2 has been discovered to be successful in producing latent fingerprints on a variety of nonporous surfaces [24]. Using aluminium and zinc particles, the Vacuum Metal Deposition technique has been used to generate a latent finger impression on plastic surfaces [3]. Under vacuum, gold is evaporated to form a very thin film of metal on the surface being examined (this layer is invisible to the naked eye). In the same way, a second coating of zinc (the latter is rarely employed due to its toxicity) is deposited. The gold film is evenly deposited to the sample's surface and penetrates the fingerprint deposit. Zinc is deposited on the exposed gold first, but it does not penetrate the fingermark deposit. As a result, the ridges are left translucent, while the background is plated with zinc. This method produces excellent fingermark detail, with the greatest results coming from nonporous materials like plastic and glass. This technique has also been used to create fresh fingermarks (48 hours old) on fabric and paper banknotes [8].

Gold Nanoparticles

Gold nanoparticle (AuNPs) plays an important role in developing latent fingerprints due to their inert nature, great selectivity, sensitivity, and properties that allows the developed fingerprints to be stored for a long time. The nanoparticles are typically electrostatically adsorbed or have their surfaces changed to boost affinity for sweat components [25]. Owing to these properties, the gold nanoparticles were used to enhance the visibility of the latent fingerprints.The average size of the gold nanoparticles is 2–3 nm (spherical shape). While using the gold nanoparticle solution on porous surfaces, the single metal deposition (SMD) produces good results (distinct ridge features) in a single step whereas the multi metal deposition (MMD) requires many bath steps in a restricted pH range [23]. However, multimetal deposition (MMD) was invented by Saunders in 1989, a new process for improving latent fingermarks based on colloidal gold deposition followed by silver reinforcement [26]. The multi-metal deposition (MMD) method uses gold and silver to develop latent fingerprints which involves immersing the fingerprint in an aqueous gold solution at low pH levels, followed by contrast enhancement using physical developer. The physical developer solution comprises silver ions, which are reduced to silver metal on gold nucleating sites in the presence of a reducing agent. Due to the electrostatic interaction between the cationic charged finger impression residue and anionic charged gold nanoparticles, a silver picture of the dormant unique finger impression is acquired [3]. For enhancement, the silver/reducing agent bath utilised in the multi-metal deposition (MMD) approach is replaced with a single gold/reducing agent bath in the single-metal deposition (SMD) technique. Gold colloids deposited on fingerprints act as catalysts, causing metallic gold to precipitate from the gold/reducing agent solution, resulting in larger gold colloids. After development, this procedure leaves reddish fingermarks [25]. In this method, the object bearing the fingerprints requires to be bathed in an aqueous solution of the gold nanoparticles [23]. The entire process is dependent on the fingerprints' sebaceous secretion, which successfully hides them beneath the paper, and the gold nanoparticles lead to the production of latent prints [23]. Thus multi metal deposition (MMD) is a technique for detecting latent fingerprints on porous and non-porous surfaces based on colloidal gold biolabeling [27,28].

Aluminium Oxide Nanoparticles

Aluminium oxide nanoparticles range in size from 30 to 60 nanometers and maintains its stability over time [23]. For the recognition of latent fingerprints, a harmless, environmentally friendly nanopowder was produced. Eco-friendly binders such as aluminium oxide nanoparticles covered with a naturally coloured dye (eosin yellow) and hydrophobic seed extract were used to make the nano-powder. The seed extract of *Cyamopsis tetragonoloba* (guar bean) acted as a hydrophobic material, repelling water molecules and allowing the small powder particles to attach to the latent fingerprints' oily contents [29]. The use of nanopowder in the development of latent fingerprints not only allows for clear visibility on a variety of porous and nonporous surfaces, but also allows for the identification of faded latent fingerprints. Furthermore, the combination's elements are environmentally beneficial and the procedure is both costly and time-consuming [23].

S. No.	Nanoparticles In fingerprint development	Method	Reference
1	Poly(p-phenylenevinylene) (PPV) Nanoparticles	Immersing	[30]
2	Silica Nanoparticle	Dusting and Spray	[31]
3	CdSe nanoparticles	Dusting method	[32]
4	Aluminium oxide nanoparticles	Dusting Method	[23]
5	Organosilicone fluorescent nanoparticles	Spray Method	[33]
6	Oligomer/silica hybrid nanoparticles	Spray	[34]

Table 1: Summary of some of the nanoparticles used in development of latent fingerprint.

Conclusion

Forensic science includes several disciplines and has a wide range of sub-specialties that use techniques adopted from the natural sciences to produce criminal or legal evidences that aids in criminal identification. With the advancement in science and technology, forensics has become a more intriguing scientific discipline to investigate, and thus, nanotechnology is playing an increasingly essential role in this field. Nanotechnology is rapidly evolving as a powerful instrument, and it has the ability to enhance and modify the concept of trace analysis. Nanoparticles are being used in the discovery of various aspects that are used in investigations as a result of nanotechnological advances in the area of forensic science.

Fingerprint is one of the most important pieces of evidence when it comes to determining a suspect's identify. As fingerprints are unique, they portray the person. No two people have the same fingerprints. Apart from enhancing the properties of fingerprints with appropriate techniques, DNA can be extracted from them. The new approaches for developing latent fingerprints by nanoparticles are far superior than the conventional ones that are already in use. These particles can simply be used to reveal fingerprints on a variety of surfaces and also have tremendous potential for more precise finger ridge details. This is due to nanoparticles superior discernibility over commercially available traditional fingerprinting materials. This approach of latent fingerprinting has greatly increased the use of nanoparticles in the field of forensic science and made sample analysis considerably easier and more accurate. Metal nanoparticles such as silica, silver, and gold nanoparticles have recently shown significant potential in fingerprint analysis on a variety of surfaces. Furthermore, due to their high adhesive nature with fingerprint residue, silica and gold nanoparticles coated with bi-functional reagent have been found to be particularly successful in developing fingerprints on non-porous and porous surfaces. In contrast, the fingerprint on the paper surface was better when silver nanoparticles were utilised as a reagent in physical developer method. Gold nanoparticles are more widely used for latent fingerprint detection than other materials due to its enhanced visibility of fingerprint pictures, ridge patterns, and sweat pores. With the advancement of nanotechnology, forensic experts will be confronted with a variety of nanoscale evidence in the future. Hence, nanotechnology has a great potential for the development and detection of latent fingerprint which helps in criminal identification.

References

1. Lodha AS, Pandya A, Shukla RK (2016) Nonotechnology: an applied and robust approach for forensic investigation. Forensic Research & Criminology International Journal 2(1): 35-37.

2. Chauhan V, Singh V, Tiwari A (2017) Applications of Nanotechnology in Forensic Investigation. International Journal of Life-Sciences Scientific Research 3(3): 1047-1051.

3. Bhati K, Tripathy DB (2020) Role of Nanoparticles in Latent Fingerprinting: An Update. Letters in Applied NanoBioScience 9(3): 1427-1443.

4. Thomas GL, Reynoldson TE (1975) Some Observations on Fingerprint Deposits. Journal of Physics D: Applied Physics 8: 724-729.

5. Indira SS, Singh J, Sodhi GS (2019) Dermatoglyphics - A Morphological Biomarker in Human Ailments: A Review. International Journal of Forensic Sciences 4(4): 000176.

6. Houck MM (2016) Forensic Fingerprints (Advanced Forensic Science Series) 1st (Edn.). Academic Press.

7. Fulton M (2017) Latent Chemistry: The Development of Fngerprints.

8. Champod C, Lennard C, Margot P, Stoilovic M (2004) Fingerprints and Other Ridge Skin Impressions, first edition. CRC Press, USA.

9. Lee HC, Gaensslen RE (2001) Advances in Fingerprint Technology. 2nd (Edn.). CRC Press LLC.

10. Bumbrah GS, Sharma RM, Jasuja OP (2016) Emerging Latent Fingerprint Technologies: A Review. Research and Reports in Forensic Medical Science 6: 39-50.

11. Prasad V, Prasad L, Chandravanshi LP, Lukose S, Agrawal P (2020) The Emerging Role of Nanoparticles in Forensic Fingerprinting. Journal of Seybold Report 15(9): 2124-2131.

12. Prabakaran E, Pillay K (2021) Nanomaterials for latent fingerprint detection: a review. Journal of Materials Research and Technology 12: 1856-1885.

13. Peng H, Sejdic JT (2009) Simple Aqueous Solution Route to Luminescent Carbogenic Dots from Carbohydrates. Chemistry of Materials Communication 21(23): 5563-5565.

14. Ngu PZZ, Chia SPP, Fong JFY, Ng SM (2016) Synthesis of carbon nanoparticles from waste rice husk used for the optical sensing of metal ions. New Carbon Materials 31(2): 135-143.

15. Meiling TT, Cywinski PJ, Bald I (2016) White carbon: Fluorescent carbon nanoparticles with tunable quantum yield in a reproducible green synthesis. Scientific Reports 6: 28557.

16. Song X, Zhang Y, Chang C (2012) Novel Method for Preparing Activated Carbons with High Specific Surface Area from Rice Husk. Industrial & Engineering Chemistry Research 51(46): 15075-15081.

17. Rajan R, Zakaria Y, Shamsuddin S, Hassan NFN (2018) Synthesis of carbon nanoparticle from Rice husk by acid digestion for fingermark dusting application. Malaysian Journal of Forensic Sciences 8(1): 7-13.

18. Rajan R, Zakaria Y, Shamsuddin S, Hassan NFN (2018) Nanocarbon powder for latent fingermark development:

a green chemistry approach. Egyptian Journal of Forensic Sciences 8: 60.

19. Prasad V, Prasad L, Lukose S, Agrawal P (2021) Latent fingerprint development by using silver nanoparticles and silver nitrate – A comparative study. Journal of Forensic Sciences 66(3): 1065-1074.

20. Coppes A, Ramotowski RS, Jones BA, Manna ME, Chervinsky EV, et al. (2018) Silver Nitrate Grade and its Effect on Physical Developer Performance – A Validation Study. Journal of Forensic Identification 68(1): 11-27.

21. Cantu AA (2001) Silver Physical Developers for the visualization of Latent prints on paper. Forensic Science Review 13(1): 29-64.

22. Sodhi GS, Kaur J (2015) Physical developer method for detection of latent fingerprints: A review. Egyptian Journal of Forensic Sciences 6(2): 44-47.

23. Prasad V, Lukose S, Agrawal P, Prasad L (2019) Role of Nanomaterials for Forensic Investigation and Latent Fingerprinting- A Review. Journal of Forensic Sciences 65(1): 26-36.

24. Arshad A, Farrukh MA, Ali S, K-ur-Rahman M, Tahir MA (2015) Development of Latent Fingermarks on Various Surfaces using ZnO-SiO2 Nanopowder. Journal of Forensic Sciences 60(5): 1182-1187.

25. Mohamed AA (2011) Gold is going forensic. Gold Bulletin 44: 71-77.

26. Stauffer E, Becue A, Singh KV, Thampi KR, Champod C, et al. (2007) Single-metal deposition (SMD) as a latent fingermark enhancement technique: An alternative to multimetal deposition (MMD). Forensic Science International 168(1): e5-e9.

27. Becue A, Champod C, Margot P (2007) Use of gold nanoparticles as molecular intermediates for the detection of fingermarkss. Forensic Science International 168(2-3): 169-176.

28. You W, Zhao YB, Xu SL, Tian SS (2021) Visualization of latent fingermarks on fabric using MMD – A preliminary study Forensic Science International 327: 110981.

29. Sodhi GS, Kaur J (2014) Fngerprint Developing Comoposition and Method Thereof. Indian Patents.

30. Chen H, Ma RL, Chen Y, Fan LJ (2017) Fluorescence Development of Latent Fingerprint with Conjugated Polymer Nanoparticles in Aqueous Colloidal Solution. ACS Appl Mater Interfaces 9(5): 4908-4915.

31. Zhang M, Ou Y, Du X, Li X, Huang H, et al. (2017) Systematic study of dye loaded small mesoporous silica nanoparticles for detecting latent fingerprints on various substrates. J Porous Mater 24: 13-20.

32. Algarra M, Radotić K, Kalauzi A, Mutavdžić D, Savić A, et al. (2014) Fingerprint detection and using intercalated CdSe nanoparticles on non-porous surfaces. Analytica Chimica Acta 812: 228-235.

33. Zhanga H, You J, Nie C, Wang J, Dong X, et al. (2019) Non-conjugated organosilicone fluorescent nanoparticles for latent fingerprint detection. Journal of Luminescence 215: 116582.

34. Yang Y, Liu R, Cui Q, Xu W, Peng R, et al. (2019) Red-emissive conjugated oligomer/silica hybrid nanoparticles with high affinity and application for latent fingerprint detection, Colloids and Surfaces A: Physicochemical and Engineering Aspects 565: 118-130.