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# Development of Latent Fingerprints through Nanoparticles: A Review

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**Abstract**

*As we are living in the world where crime rate is not decreasing but increasing day by day for that the development of latent fingerprints is a crucial component of forensic science, providing essential evidence in criminal investigations from linking the suspect to the victim to the catching of the culprit. Recently nanotechnology is playing crucial role in the development of latent fingerprint but the progress in nanotechnology has introduced metal nanoparticles as a promising technique to enhance the visualization and detection of latent fingerprints. This review paper is solely based on the use of metal nanoparticles, including gold, silver, and zinc oxide, in fingerprint development. It explores how these nanoparticles interact with fingerprint residues, the methods for synthesizing and applying these particles, and their benefits over traditional fingerprint development techniques. Additionally, the paper discusses the sensitivity, specificity, and practical application of nanoparticle-based methods in various forensic contexts, including their effectiveness on difficult surfaces. The review also considers the potential health and environmental impacts of using metal nanoparticles and in forensic investigations. By providing a thorough overview of metal nanoparticles in latent fingerprint development, this paper aims to showcase their potential to transform forensic practices and enhance the accuracy and reliability of fingerprint analysis.*

**Keywords:** *fingerprint, Latent fingerprint, nanotechnology,*

## 1. Introduction

Fingerprints are crucial in forensic science based on Locard's exchange principle, which states that whenever two objects come into contact, trace materials are exchanged. For fingerprints, this means that when the ridges of the fingers touch a surface, materials are transferred, leaving behind a print.[1] Fingerprints are impressions left on surfaces by the friction ridges on the tips of fingers and thumbs. They are an ideal method for identifying individuals since each person has unique fingerprints that do not match anyone else's and remain unchanged throughout life. Fingerprints can confirm a person's identity even if they deny it, change their name, or alter their appearance due to age, disease, personal interventions like plastic surgery, or accidents. The practice of using fingerprints for identification is known as dactyloscopy and is crucial for modern law enforcement.[2] Latent fingerprints, which are the most frequent type of evidence found at crime scenes, are invisible to the naked eye and thus necessitate development techniques to make them visible. Once the fingerprints are developed, the quality of the resulting images determines the accuracy of identification. These images exhibit characteristics at three levels: (1) the overall ridge patterns (such as arches, loops, or whorls); (2) minutiae details (including ridge endings, bifurcations, deltas, cores, crossovers, lakes, and islands); and (3) finer details like ridge path deviations, widths, shapes, pores, and other specific features.[3]

Nanotechnology is having a profound impact across various fields due to its focus on studying materials at the nanoscale. This method is widely used because it can modify and analyze matter at the atomic level. The term "nano" originates from the ancient Greek word "Nanos," meaning "dwarf," and refers to one billionth (10^-9) of a meter, or a nanometre (nm). Typically, 1 nm is approximately 3-10 atoms wide and about 40,000 times thinner than a human hair. Nanotechnology deals with creating new materials or devices that range in size from 1 to 100 nanometres. This universal technology has diverse applications, including in forensic science. NanoForensics is an emerging field that merges nanotechnology with forensic science, enabling the identification and examination of evidence at the nanoscale. This level of analysis was previously challenging due to the limitations of detection instruments. Nano analysis is revolutionizing investigative processes by enhancing precision, speed, and sensitivity. Nanotechnology is increasingly favored for latent fingerprint detection, as nanoparticles improve both the general and specific features of fingerprints, such as fine details and pore patterns. Nanomaterials enhance latent fingerprints by improving contrast and the interaction with endogenous materials on the fingerprint ridges, thereby making latent prints more visible and detailed.[4] There are various nanoparticles to develop latent fingerprint which include metal nanoparticles, metallic oxide nanoparticles, semiconductor quantum dots, carbon dots, polymerDots, fluorescent silica nanoparticles, fluorescent mesoporous silica nanoparticles, fluorescent silica nanoparticles, conjugated-polyelectrolyte dots, aggregation induced emission luminogens molecule incorporated nonmaterial and uncommon earth fluorescence.[5] Traditional methods for developing latent fingerprints, such as using fingerprint powders and various chemical techniques, have several drawbacks, including poor visibility, smudging, and ineffectiveness with aged or contaminated prints. However, using nanoparticles addresses these issues effectively. Nanoparticles made from gold, silver, zinc oxide, silicon oxide, aluminium oxide, carbon, quantum dots, and rare earth metals have shown considerable success in developing latent fingerprints on various surfaces.[6]

## 2. Metal Nanoparticles

### 2.1. Silver Nanoparticles for Latent Fingerprint Development

Latent fingerprint (LFP) detection snapshots are developed using a physical approach that leverages the electrostatic interactions between fingerprint residues, such as amino acids and fatty acids, and silver nanoparticles. These colloidal silver particles exhibit a strong affinity for organic compounds, allowing them to easily form LFP images on porous surfaces.[7] Silver nitrate (AgNO3) is the primary substance used in creating metal nanoparticles, specifically silver nanoparticles (AgNPs). Due to their distinctive ability to adhere to fingerprint residues, AgNPs have gained significant attention in nano-forensic fingerprinting. This study primarily explores the use of lower concentrations of silver nitrate in a new method for developing AgNPs. The AgNPs were synthesized using a wet chemical process with varying molar concentrations (0.1, 0.01, and 0.001 M) of silver nitrate, and were characterized using an ultraviolet-visible spectrophotometer and a high-resolution transmission electron microscope.[8] LFP detection techniques have been devised to identify fingerprints on moist, dry, and porous substrates. Enhancements in LFP detection involve developing images on porous materials such as paper, clay, and adhesive tape. Photographers collaborate with fingerprint image developers to create visuals, utilizing redox reagents like iron salts that produce oxidation-reduction reactions in the images. The film, produced by the silver nitrate method, converts to metallic silver due to the reducing properties of iron salts. Consequently, the latent fingerprint image appears as a black photograph, displaying a dark grey colour resulting from the reaction of metallic silver particles with lipids and fatty acids in the sweat residue of the fingerprint.[9]

Silver nanoparticles have also been utilized in forensic science for detecting fingerprints. They are considered superior in this application because they significantly enhance the quality of fingerprint images. In contrast, metal ions supported on substrates are no longer commonly used for fingerprint detection.[10] Silver nanoparticles powders have been adsorbed onto sweat and oily residues within fingerprint ridges, acting as fine powders. The silver ink solution applied to fingerprint residues adheres to the finger’s furrows, highlighting the ridge areas. However, this solution has proven ineffective for latent fingerprint detection due to its high cost and the complexity of the required equipment. There is a growing demand for a quick, simple method for LFP detection. Consequently, a new technique has been developed that improves the visualization of LFP images, with extensive applications in forensic science. Silver nanoparticles have emerged as highly effective powders for developing latent fingerprints due to their strong affinity for organic compounds in fingerprint residues. For instance, silver nanoparticle powder has been used as a physical developer to detect latent fingerprints from 1970 on porous surfaces.[11] During fingerprint detection, silver was transformed into silver nanoparticles using iron salt as an oxidant, resulting in clear images on porous surfaces due to the involved oxidation and reduction processes. These processes produced gray and dark-coloured silver nanoparticles on the porous surfaces. The development of latent fingerprints relied significantly on the electrostatic interaction between the negatively charged silver nanoparticles and the positively charged sweat residues on the finger. However, the solution form of silver nanoparticles yielded fingerprint images with poor quality and low visibility. This issue was resolved by applying gold nanoparticle powder before treating with the silver nanoparticles solution.[12]

### 2.2. Gold Nanoparticles for Development of Latent Fingerprint

Gold nanoparticles have exhibited crucial properties for fingerprint detection, including selectivity, sensitivity, inertness, and long-term stability. They are frequently used for detecting latent fingerprints on non-porous surfaces. The amine functional groups of gold nanoparticles adhere to fingerprint residues due to their lipophilic attraction to the fatty acid compounds present in the fingerprint ridges.[13] Forensic science research focuses on identifying and visualizing latent fingerprints (LFPs). Nanomaterials are primarily applied to the finger ridges to enhance the visualization of LFPs. Gold nanoparticles have been employed in mass spectrometry for the identification and imaging of LFPs.[14] Research indicates that blue and pink colours enhance fingerprint detection, which also demonstrates the surface Plasmon resonance of gold nanoparticles.[15] The laser desorption/ionization property of gold nanoparticles (AuNPs) enables the direct analysis of both endogenous and exogenous compounds embedded in latent fingerprints (LFPs), showing their distributions without disrupting the fingerprint patterns. This simultaneous visualization and molecular imaging provide not only evidence of individual identity but also help resolve overlapping fingerprints and detect hazardous substances. The technique applies laser desorption/ ionization to analyze substances on LFPs, yielding uniform images even on non-uniform surfaces. It has also been utilized to detect small compounds, provide molecular images, and gather chemical compound information for forensic investigations. Gold nanoparticles act as electrically conductive materials, with their shape identified by a scanning electron microscope during LFP detection.[16]

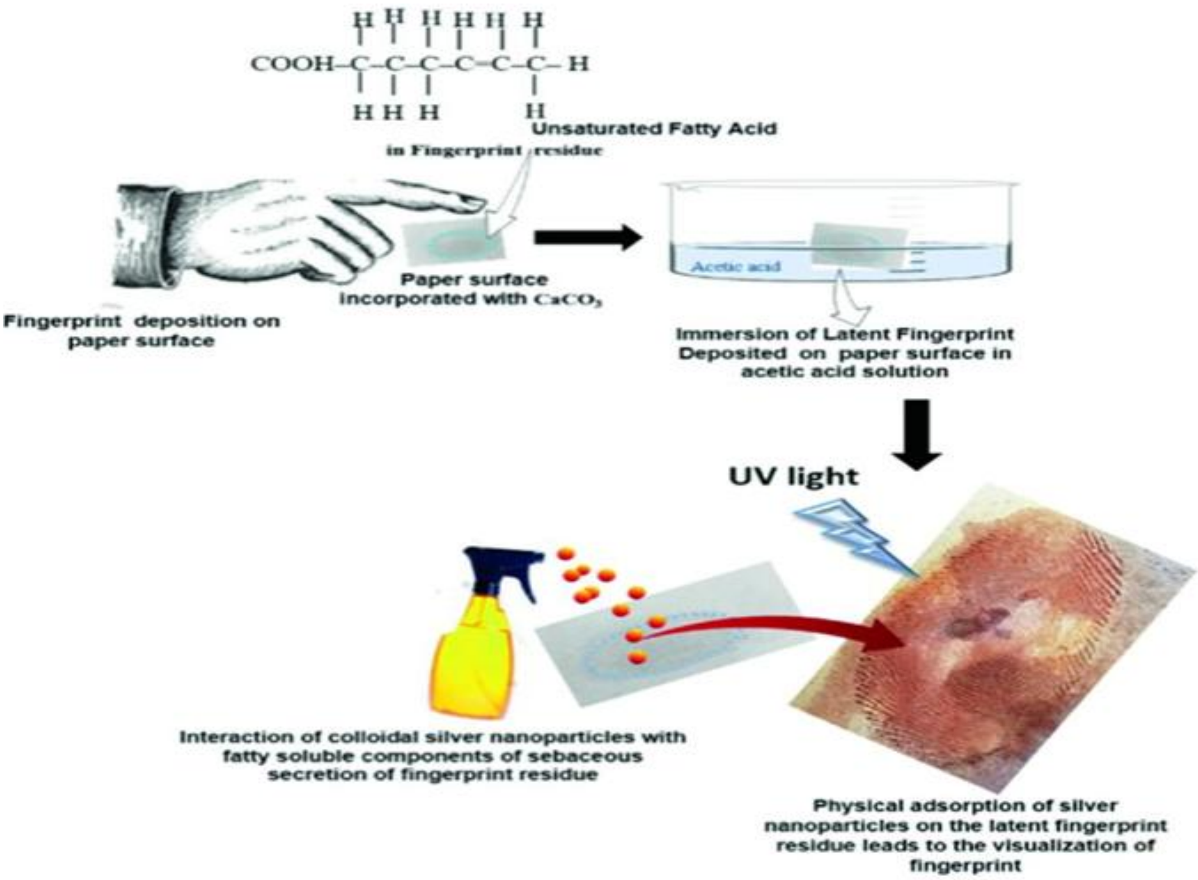


**Figure 1.** *Development of fingerprint using silver nanoparticles [22]*

These particles provide several advantages for developing fingerprint images at macroscopic, microscopic, and molecular levels. Gold nanoparticles are particularly effective for enhancing latent fingerprint (LFP) detection on both non-porous and porous surfaces due to their sensitivity, selectivity, and inert nature. The LFP images developed using these nanoparticles can be preserved for a long time.[17] Gold nanoparticles were employed to detect latent fingerprints (LFPs) on different substrates, enhancing visibility through the use of sol-gel methods alongside multimetal deposition[18] Gold nanoparticles solution and silver nanoparticles solution were applied to the surface of fingerprints to convert silver nanoparticles into metallic silver.[19][20] Clear fingerprint images were observed as a result of enhanced interaction between the negative charge carried by gold nanoparticles and the positive charge found in the sweat pores of fingerprints.[21] As a result of multimetal deposition, fingerprint images of superior quality were obtained compared to surface substrates treated solely with gold nanoparticles solution. Therefore, these gold nanoparticles are not suitable for detecting latent fingerprints (LFPs) on both non-porous and porous substrates in crime scene investigations. Multimetal deposition (MMD) involves coating silica nanoparticles with gold nanoparticles using aqueous techniques to understand the fingerprint detection mechanism. This mechanism primarily relies on electrostatic interactions between the gold nanoparticles and fingerprint sweat in acidic environments, widely applied in fingerprint detection and development. The chemical interaction between the COOH group of functionalized gold nanoparticles and the amine functional groups of fingerprint sweat is crucial here. Such amine-functionalized nanoparticles have demonstrated improved results for fingerprint detection, leading to advancements in forensic technology. Similar outcomes have been observed with silver nanoparticles.[5]

## Conclusion

Metal nanoparticles offer a promising advancement in forensic science by facilitating the development of latent fingerprints. Their exceptional properties, including heightened sensitivity and specificity, allow for the clear and accurate visualization of latent prints across diverse surfaces. Moreover, innovative techniques and formulations have addressed past challenges in fingerprint detection, such as background interference and substrate compatibility. While considerable progress has been achieved, ongoing research is necessary to refine these methods for broader adoption in forensic investigations. In summary, the integration of metal nanoparticles has the potential to transform fingerprint analysis, providing more effective techniques for crime scene investigations and forensic analysis.

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