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Research Article

Nanoparticles: For The Development Of Latent Fingerprints

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ARTICLE INFO | **ABSTRACT**

The development of latent fingerprints is an essential component of forensic science because, in our day and age, the rate of crime is not declining but rather rising daily. These fingerprints can be used to link suspects to victims and help identify criminals. Lately, nanotechnology has become increasingly important in the development of latent fingerprints; however, as nanotechnology advances, metal nanoparticles have emerged as a potentially useful method to improve latent fingerprint visualization and detection. The use of metal nanoparticles, such as zinc oxide, silver, and gold, in fingerprint development is the only subject of this review paper. It looks at the benefits these nanoparticles have over conventional fingerprint development techniques, how they interact with fingerprint residues, and how to synthesize and apply them. The study also addresses the practical use of nanoparticle-based techniques in forensic settings, including their efficacy on challenging surfaces, as well as their sensitivity and specificity. The review also takes into account the possible effects of employing metal nanoparticles in forensic investigations on human health and the environment. This paper attempts to demonstrate the potential of metal nanoparticles to revolutionize forensic practices and improve the precision and dependability of fingerprint analysis by offering a comprehensive overview of their role in the development of latent fingerprints.

Keywords: Development, Fingerprint, Latent fingerprint, Nanoparticles

Introduction

Fingerprints plays crucial role in forensic science based on Locard's exchange principle, which states that whenever two objects come into contact, trace materials are exchanged between them. For fingerprints, this means that when the ridges of the fingers touch a surface, materials are transferred, leaving behind a print [1]. The friction ridges on the tips of fingers and thumbs leave impressions on surfaces that are recognized as fingerprints. Since each person has a unique fingerprint that does not match anyone else's and does not change over time, they are the perfect way to identify individuals. Even if someone disputes their identity, changes their name, or modifies their appearance as a result of illness, aging, accidents, or self-inflicted cosmetic surgery, their fingerprints can still be used to verify their identity. Dactyloscopy, the process of utilizing fingerprints for identification, is essential to contemporary law enforcement [2]. One of the most common types of evidence discovered at crime scenes are latent fingerprints, which require development techniques to become visible because they are invisible to the unaided eye. The accuracy of identification is determined by the quality of the images produced after the fingerprints are developed. Three different levels of detail are visible in these images: (1) the general ridge patterns (like arches, loops, or whorls); (2) the finer details (like ridge path deviations, widths, shapes, pores, and other specific features) and (3) the minutiae details (like ridge endings, bifurcations, deltas, cores, crossovers, lakes, and islands) [3].
As nanotechnology focuses on the study of materials at the nanoscale, it is having a significant impact on many different fields. This technique is popular because it can alter and examine matter at the atomic level. The word "nano" is derived from the ancient Greek word "Nanos," which means "dwarf." A nanometer (nm) is one billionth (10^{-9}) of a meter. Generally speaking, 1 nm is 40,000 times thinner than a human hair and

measures between three and ten atoms wide. The creation of novel materials or devices with sizes between one and one hundred nanometers is the focus of nanotechnology. There are many uses for this all-encompassing technology, including forensic research. A new field called "NanoForensics" combines forensic science and nanotechnology to identify and analyze evidence at the nanoscale.

The limitations of detection instruments previously made this level of analysis difficult. Investigative procedures are being revolutionized by nano analysis, which improves sensitivity, speed, and precision. Nanoparticles enhance both the general and specific characteristics of fingerprints, such as minute details and pore patterns, which is why nanotechnology is becoming more and more popular for latent fingerprint detection. By enhancing contrast and the interaction between endogenous materials on the fingerprint ridges, nanomaterials improve latent fingerprints, making them more pronounced and detailed [4]. Metal nanoparticles, metallic oxide nanoparticles, semiconductor quantum dots, carbon dots, polymer dots, fluorescent silica nanoparticles, fluorescent mesoporous silica nanoparticles, conjugated polyelectrolyte dots, aggregation induced emission luminogens molecule incorporated nonmaterial, and uncommon earth fluorescence are some of the nanoparticles that can be used to create a latent fingerprint [5]. The use of fingerprint powders and other chemical processes, which are traditional methods for latent fingerprint development, have a number of disadvantages, such as poor visibility, smudging, and ineffectiveness when dealing with old or contaminated prints. Nevertheless, employing nanoparticles successfully resolves these problems. When it comes to creating latent fingerprints on a variety of surfaces, nanoparticles made of gold, silver, zinc oxide, silicon oxide, aluminum oxide, carbon, quantum dots, and rare earth metals have demonstrated significant success [6].

Metal Nanoparticles

Silver nanoparticles used for the development of latent fingerprint

Latent fingerprints detection snapshots are developed using a physical approach that leverages the electrostatic interactions between fingerprint residues, such as amino acids, 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]. The main ingredient used to make metal nanoparticles, specifically silver nanoparticles (AgNPs), is silver nitrate ($AgNO_3$). AgNPs have drawn a lot of interest in nano-forensic fingerprinting because of their unique capacity to stick to fingerprint residues. The use of lower silver nitrate concentrations in a novel technique for producing AgNPs is the main focus of this work. The AgNPs were created by a wet chemical process with different molar concentrations (0.1, 0.01, and 0.001 M) of silver nitrate. A high-resolution transmission electron microscope and an ultraviolet-visible spectrophotometer were used to characterize the AgNPs [8]. Techniques for detecting LFP have been developed to recognize fingerprints on porous, dry, and wet substrates. Creating images on porous materials like paper, clay, and adhesive tape is one way to improve LFP detection. In order to produce images, photographers work with the fingerprints image developer. Redox reagents, like iron salts, are used to create oxidation-reduction reactions in the images. Because iron salts have a reducing property, the film made by the silver nitrate method turns into metallic silver. The latent fingerprint image is thus seen as a black photograph with a dark grey color due to the interaction between metallic silver particles and the lipids and fatty acids in the fingerprint's sweat residue [9].

Forensic science has also used silver nanoparticles to identify fingerprints. They greatly improve the quality of fingerprint images, which makes them superior in this application. On the other hand, fingerprint detection no longer frequently uses metal ions supported on surfaces [10]. As fine powders, silver nanoparticles have been adsorbed onto sweat and oily residues found in fingerprint ridges. When applied to fingerprint residues, silver ink solutions stick to the ridge areas of the finger. However, because of its high cost and the complexity of the necessary equipment, this solution has not proven effective for latent fingerprint detection. The need for a fast, easy way to detect LFP is increasing. As a result, a brand-new method that enhances LFPs image visualization has been created, and it has a wide range of uses in forensic science. As silver nanoparticles have a strong affinity for organic compounds found in fingerprint residues, they have become one of the most effective powders for creating latent fingerprints. For instance, latent fingerprints from 1970 have been found on porous surfaces using silver nanoparticles powder as a physical developer [11]. Because of the oxidation and reduction processes involved, silver was converted into silver nanoparticles during fingerprint detection by employing iron salt as an oxidant. This process produced clear images on porous surfaces. On the porous surfaces, these processes created silver nanoparticles that were dark and gray in color. The electrostatic interaction between the positively charged sweat residues on the finger and the negatively charged silver nanoparticles played a major role in the development of latent fingerprints. Nevertheless, fingerprint images obtained from the solution form of silver nanoparticles were low visibility and of low quality. Applying gold nanoparticles powder before using the silver nanoparticles solution helped to solve this problem [12].

Gold nanoparticles used for the development of latent fingerprints

Selectivity, sensitivity, inertness, and long-term stability are among the critical characteristics of gold nanoparticles that have been demonstrated for fingerprint detection. On non-porous surfaces, they are widely used to find latent fingerprints. The lipophilic attraction of the amine functional groups of gold nanoparticles to the fatty acid compounds found in fingerprint ridges causes them to stick to fingerprint residues [13]. Latent fingerprint (LFP) identification and visualization is the main focus of forensic science research. The finger ridges are the main location where nanomaterials are applied to improve LFP visualization. For the purpose of identifying and imaging LFPs, mass spectrometry has made use of gold nanoparticles [14]. Studies show that the colors blue and pink improve fingerprint recognition and highlight the Plasmon resonance of gold nanoparticles on their surface [15]. The ability of gold nanoparticles (AuNPs) to desorbs and ionizes laser light makes it possible to analyze endogenous and exogenous compounds embedded in latent fingerprints (LFPs) directly and display their distributions without interfering with the fingerprint patterns. In addition to providing proof of individual identity, this simultaneous visualization and molecular imaging aid in the resolution of overlapping fingerprints and the detection of potentially dangerous materials. The method produces uniform images even on non-uniform surfaces by analyzing substances on LFPs using laser desorption/ionization. Additionally, it has been used for forensic investigations to identify small compounds, produce molecular images, and compile data on chemical compounds. During LFP detection, a scanning electron microscope can identify the shape of gold nanoparticles, which function as electrically conductive materials [16].

These particles offer multiple benefits for creating macroscopic, microscopic, and molecular fingerprint images. Because gold nanoparticles are inert, sensitive, and selective, they can improve latent fingerprint (LFP) detection on both porous and non-porous surfaces. These nanoparticles allow for the long-term preservation of LFP images [17]. Gold nanoparticles were utilized in conjunction with multimetal deposition and sol-gel techniques to improve visibility when detecting latent fingerprints (LFPs) on various substrates [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]. Compared to surface substrates treated exclusively with gold nanoparticles solution, fingerprint images of higher quality were obtained as a consequence of multimetal deposition. As a result, in crime scene investigations, these gold nanoparticles are not appropriate for identifying latent fingerprints (LFPs) on porous or non-porous substrates. In order to comprehend the fingerprint detection mechanism, multimetal deposition (MMD) entails coating silica nanoparticles with gold nanoparticles using aqueous techniques. This widely used method for fingerprint development and detection mainly depends on electrostatic interactions between the gold nanoparticles and the sweat from the fingerprint in acidic environments. Here, the crucial chemical interaction is between the amine functional groups of fingerprint sweat and the COOH group of functionalized gold nanoparticles.

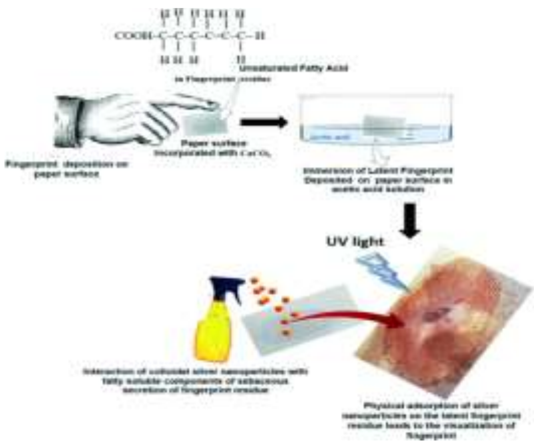

Figure 1:- Development of fingerprint is using silver nanoparticles [22].

Forensic technology has advanced as a result of the improved fingerprint detection performance of these amine-functionalized nanoparticles. Silver nanoparticles have shown comparable results [5].

Conclusion

Metal because they make it easier for latent fingerprints to form, nanoparticles present a promising development in forensic science. Their remarkable characteristics, such as increased sensitivity and specificity, make it possible to clearly and precisely visualize latent prints on a variety of surfaces. Furthermore, novel approaches and formulations have tackled earlier problems in fingerprint detection, like substrate compatibility and background interference. Even though great strides have been made, more research is required to improve these techniques so that they can be used in forensic investigations more widely. In conclusion, the incorporation of metal nanoparticles has the potential to revolutionize fingerprint analysis by offering better methods for forensic analysis and crime scene investigation.

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