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Development Of Latent Fingerprint By Gold Nanoparticles

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Abstract : Nanotechnology and advanced instrumentation have numerous applications in the field of forensic science. Examples include gold nanoparticles used to enhance polymerase chain reaction efficiency and atomic force microscopy for analysing ink and bloodstains. Various nanoparticles can be used for detecting fingerprint and their ridge details on various surfaces , nanoparticles like silver, zinc oxide, silicon dioxide, aluminium oxide, gold (with silver physical developer), europium, fluorescent carbon, and amphiphilic silica but Gold is the most commonly used. Fingerprints are valuable evidence at crime scenes, and nano-based approaches have great potential for future investigations. This paper explores the use of gold nanoparticles to produce and identify latent fingerprints through MMD technique. Multimetal deposition is a versatile technique for identifying latent fingerprints on porous things such as fabric tape, masking tape, and cardboard; semi-porous goods such as expanded polystyrene, latex gloves, waxed paper; and non-porous items such as metals and plastics.

Keywords : Latent fingerprints , Gold nanoparticles , forensic investigation .

1 . Introduction

Every individual has a different pattern of papillary line skin on their feet and hand . From week nine to week twenty-four of embryonic development is when this friction ridge skin develops in mother's womb. The elevated area of the friction ridge skin makes an impression when it comes into touch with fingers. Forensic investigations have utilised this distinct pattern to determine an individual's identify since the late 1800s (1). The patterns seen on human fingerprints are extremely unique to each person and don't change over time, making them the most effective means of identification available (2). The ultimate pattern of the friction ridge skin varies from person to person, even if two identical twins, due to the varying growth and pressure that each embryo endures inside the womb. The elevated area of the friction ridge skin makes its contact impression on fingerprints (1).

Sweat is released and left on the skin's surface through a single row of pores that are present in each skin ridge. There exist three categories of glands in the body that naturally secrete substances, i.e apocrine, sebaceous, and eccrine. Forensic investigations are particularly interested in the makeup of these three secretions. Diffused throughout the body, eccrine sweat glands are most numerous at the palmar and plantar surfaces. 98-99% of eccrine sweat contains a mixture of water and inorganic ions (phosphate, iodide, chloride, bromide, and fluoride) along with organic materials (such as urea, fatty acids, and amino acids). Sebaceous glands are present in the entire body, "with the exception of the hand and foot's friction ridge surfaces. A thick, milky fluid is expelled by the apocrine glands, which are mostly located in the human axillae and anogenital area . Ecrine sweat leaves an imprints of the finger's line arrangements on surfaces as it comes into contact with them, along with oily materials the finger picks up like sebum (1; 2).

1.1 Fingerprints might be classified as follows: Latent, Patent, or Plastic:

- Patent fingerprints are clearly visible to the eye and formed specifically by extraneous materials like blood, paint, or grease.
- Plastic fingerprints are formed when skin comes into contact with soft materials like soap, clay, plaster, cement, wax, and glue.
- Latent fingerprints are fingerprints that cannot be seen through the naked eye and are found on various surfaces because of the physiological secretions or contaminations that people have onto the fingers. Fingerprints are the most common evidence at crime scenes, but they are very difficult to identify. The last type of fingerprints considered the most commonly encountered evidence collected from crime scenes is invisible fingerprints.

1.2 Dactyloscopy : It is the study of fingerprint identification, and Sir Francis Galton gave the classification method that contained three basic pattern types: loops, whorls, and arches. On the other hand, Henry Faulds identified eight classes: whorl, plain arch, right loop, left loop, central pocket, tented arch, twin loop, and accidental whorl. Invisible fingerprints are the type of evidence most commonly detected at crime scenes, but in order to make them visible, development techniques must be used because they are invisible to the human eye. The generated fingerprint images include details at three fundamental ridge pattern levels, as well as fingerprint minutiae (such as ridge terminating, bifurcation, delta, core, crossover, lake, and island features); these details include ridge path deviation, breadth, shape, and pores (3). Fingerprint detection is most commonly used in forensic investigations, Fingerprint analysis demonstrates a number of basic ideas. In forensic science, latent fingerprint identification is the most common approach for identifying individuals. To identify a fingerprint from a crime scene, ridge pattern features are matched and compared to the control fingerprint held on record. Ridge patterns were classified as class 1 (loop, arches , whorl), class 2 (minutiae), or class 3 (sweat pores). Which is shown in fig 1. this review study focused on the method of using gold nanoparticles for the formation of invisible fingerprints. Nanotechnology is therefore developing in forensic research to effortlessly acquire evidence at crime scenes and their surroundings and present this after laboratory analysis in a court of law(4).

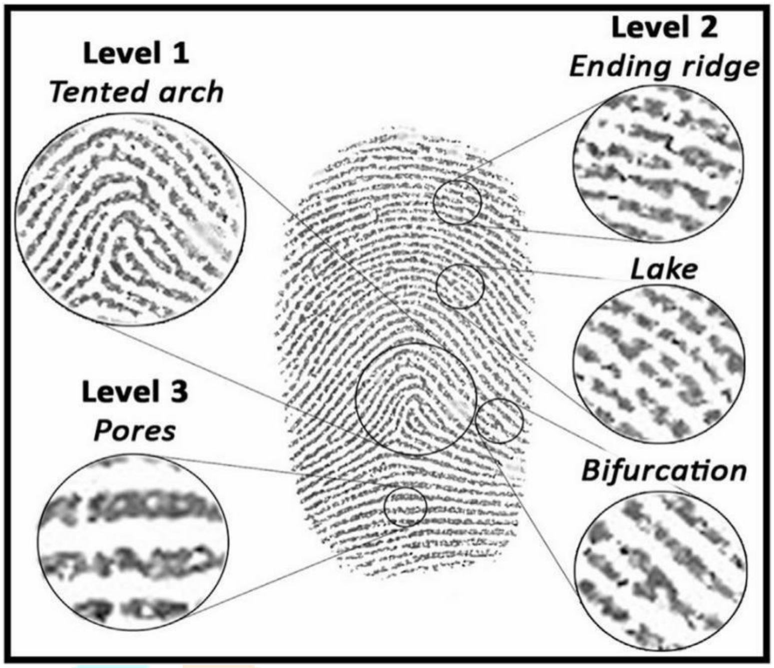

Fig 1 The primary donor's fingerprint were taken in ink.
Fingerprint ridge characteristics include: class 1 (mark tented arch), class 2 (minutiae ending ridge, lake, and bifurcation), and class 3 (pores).

1.2 Forensic Applications of Nanotechnology :

1.3.1 Nanotechnology and Questioned Documents :A nanoscale AFM(Atomic Force Microscopy) has been developed in forensics to investigate materials. This microscope scans the surface of documents to evaluate ink crossing, revealing pen stroke patterns and 3-D surface morphology (6).

1.3.2 Nanotechnology for Bloodstain Age Determination : The age determination of dry bloodstains is one of the many additional significant forensic uses for the AFM (7).

1.3.3 Nanotech and Fingerprints : The application of nanoparticles contain recently demonstrated significant promise in creating nano-fingerprints, the next generation of fingerprint production methods. Fingerprints are among the most crucial pieces of evidence discovered at the crime scene, because they are accepted as universal evidence of human identity (8).

1.3.4 Evaluation of Nanotechnology in forensic fingerprinting :

In 1970, silver nanoparticles was first introduced as a reagent in the silver physical developer technique for creating latent fingerprints on porous paper surfaces (15).

In 1980, by using MDD method gold nanoparticles were added to the silver physical developer procedure to improve the latent fingerprint on porous paper surfaces (16; 17).

A Luminous nanopowder made up of zinc oxide was then created in 2004 to visulalized latent fingerprints on non-porous surfaces (18).

In 2006 , a non toxic powder made of aluminium oxide nanoparticles covered with natural fluorescent colours was utilized to produce latent fingerprints on non-porous surfaces (19).

Gold nanoparticles were first bonded to a porous paper surface in 2012 using a bifunctional reagent to produce fingermarks (20).

In 2012, gold nanoparticles that functioned with antibodies were employed as labelling materials , to identify drug and drug metabolites in fingerprints (21).

In 2013, a technique for visualizing latent fingerprint on nonporous coin surface suing electrodeposition of metal nanopartilces was proposed (22).

Gold nanoparticles were employed as a probe in 2013 to identify cocaine metabolites in latent fingerprints ,produce (23).

Carboxyl functionalized silica nanopartilces was presented in 2014 , to identify the mechanism behind the interaction between silica nanoparticles and fingerprint residue (12).

Carboxyl amhiphilic silica nanopowder was created in 2014 to produce latent fingerprints on smooth , non porous surfaces (9).

In 2016, labelling markers for the development of latent fingerprint on non porous sarfaces like glass slide , were using fluorescent carbon nanoparticles based on starch (24).

By using Eu^{+3} doped AI_2O_3 nanocrystalline powder , latent fingerprint were created on nonporous substrate in 2016 (25)

2 . Literature Review :

1. Nanoparticles are extremely small particles that range in size from one to 100 nanometers (nm). In reference A human hair is roughly 80,000 nm wide. These microscopic particles have distinct features that distinguish them from their bulk counterparts. They can be made of a variety of materials, including metals, semiconductors, and polymers.

Gold nanoparticles (AuNPs) are a form of nanoparticle made of gold atoms. They are especially fascinating since they have various valuable features.

This review study examines how forensic science can identify invisible fingerprints, using nanomaterials and their impact on image quality. Studies on latent fingerprint detection using nanomaterials such as metal nanoparticles. Some nanomaterials employed for invisible fingerprint identification produce low-quality images, highlighting their drawbacks. More research is consequently required to increase the latent fingerprint detection capacities of nanomaterials (4).

2. The detection of latent fingerprints (LFP) is a major goal of forensic science. Latent fingerprints undergo a simple and reliable way to identify individuals. Nanomaterials can enhance fingerprint contrast by interacting with endogenous chemicals on ridges. That is one of the most crucial applications of nanotechnology in LFP Identification, but most of the findings in this area have majorly focused on the physical fingerprint patterns. They did not study the chemical information inherent in LFPs. It is used to visualize and molecular image LFPs via imaging mass spectrometry and specialized gold nanoparticles (AuNP) characteristics. LFP images are captured as blue and pink by different surface plasmon resonance (SPR) bands of gold nanoparticles. Imaging their distributions without affecting the fingerprint patterns has been done. (9).

3. Nanotechnology and modern instruments come with many prospects in forensic science. Various nanoparticles, such as silver, zinc oxide, silicon dioxide, aluminium oxide, gold with silver being physical inventor, europium, fluorescent carbon, and amphiphilic silica, can be applied to develop fingerprint-like ridge details on various surfaces. Gold is the most commonly used. Fingerprinting is valuable testimony in scene of offence ,& nano-based approaches has great ability in future examination. This work focuses on using nanoparticles to produce and identify latent fingerprints (10).

4. The colloidal gold or multimetal deposition method (MMD) is improve to detect latent or invisible fingerprint on permeable & nonpermeable area, demonstrating the technology's potential. It has been demonstrated that managing particle size, pH, reagent, and handling is crucial. The possibilities of MMD are demonstrated with a challenging case study (11).

5. The objective of this effort is to refine the single-metal deposition (SMD) and multimetal deposition (MMD) techniques to make them less automated , more robust, and easier to use. Two significant drawbacks of the MMD/SMD were found to be the labor-intensive process of creating gold nanoparticles and the notable drop in efficiency that occurs when the working solution's pH rises over 3. It is no longer necessary to keep an eye on the temperature during the synthesis process thanks to the simplification of the protocol. When aspartic acid is used in conjunction along with sodium citrate during the manufacture of gold nanoparticles , the efficiency as well increased. In the MMD/SMD(single metal deposition) frame, this increases the pH range for which fingermarks can be detected. Instead of 2–3 , as was the case with the earlier formulations, the operational range is now expanded from 2 to 6.7. Processing substrates that tend to raise the pH of the solution after immersion may be made easier by the technique's enhanced working solution resilience (12).

6. Many non-porous objects have successfully undergone the single-metal nanodeposition method (SND), a straightforward and environmentally benign synthetic procedure for discovering invisible fingerprint. The working solution for detecting latent fingermarks was gold nanoparticles (AuNPs), which were created with glucose present & sodium borohydride acting as a reductant. Conventional MMD procedure requires exactly six baths within a very narrow range of pH values between 2.5-2.8. The SND technique, however, is straightforward in producing a clear ridge feature in one step, being able to cover a wider range of pH values between 2.5-5.0. The SND would make the work of forensic personnel simple in detecting latent fingerprints in a crime scene or laboratory. The SND method significantly reduced the bath steps and produced a clear and sharp development of latent fingermarks without background staining (13).

7) Nanotechnology is the study of matter control at the atomic and molecular levels. The common forensic use of microfluidic devices nowadays is post-polymerase chain reaction (PCR) quantification. Most of the forensic

laboratories are now applying these methods for post-PCR measurement of mitochondrial DNA. Another idea is to assist in the investigation of gun crimes or explosives scene. Even if the case is cleansed and wiped , the fingerprints can be imaged or seen employing a nanoscale developer with an x-ray source. Nanotechnology will enhance the view of virtopsy(Virtopsy is a virtual alternative to a traditional autopsy, carried out utilizing scanning and imaging technology) , crime scene investigation, identification, forensic ballistics, and toxicology (14).

3. Methodology

3.1 Multi-metal deposition Technique :

The popular fingermark detection method called Multi-Metal Deposition (MMD) employs metal nano-particles in solution. Originally suggested in 1989, MMD (now called "MMD-I") uses a twostep process to identify invisible fingerprint on various substrates. Underneath particular experimental settings, the first step is to stimulate the deposition of gold nano-particles on the invisible secretions. The latent fingermarks can then be seen thanks to a silver-based amplification phase that follows. Consequently, the identified fingermarks show up as light marks on dark surfaces and as dark-brown markings on possibly unstained substrates. The foundation of MMD involves the use of "colloidal gold," or tiny gold particles suspended in water. Schnetz & Margot found that the ideal diameter of the particles is approximately 14 nm. It imparts a deep rubyred color to the aqueous colloidal gold. Under particular experimental circumstances, the gold colloids are drawn to certain elements of the fingerprint residual when a sample with a invisible fingerprint is submerged in such a solution (11).

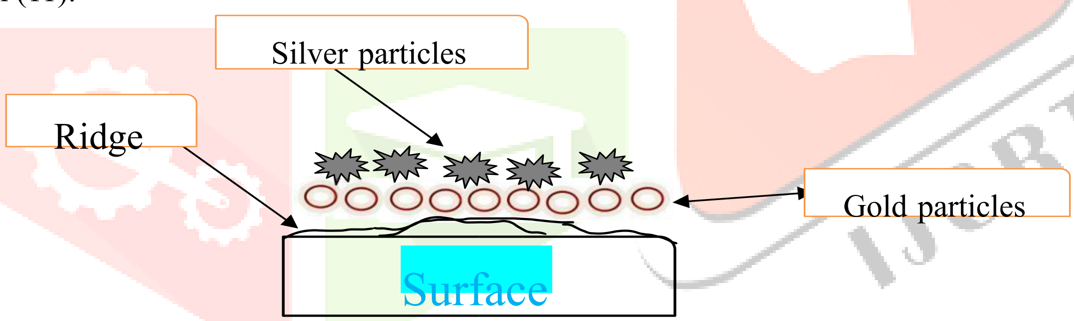

Fig 2. Mechanism of multimetal deposition technique

The generally recognized explanation states that positively charge atom in the fingerprint are electrostatically attracted to the negatively charged gold nanoparticles at low pH values. At this stage, it’s challenging to get a great variation in orderly to see the fingerprint that have been detected because of the tiny size of the gold nanoparticles . As a result, adding a second metal layer to the surface of the gold nanoparticles is required to improve the outcome (9).

Since the required duration is between 30 and 120 minutes, four different immersion times (30, 45, 60, and 95 minutes) of CG1 colloidal gold working solution were investigated in early testing. The best option for allowing gold nanoparticles to fully react with any invisible print while preventing extreme background staining was to immerse them for 45 minutes. This was done in order to develop fingerprint that have been treated with CG1. The washing process of a prototype or dip material for fingerprint detection should have at least two changes of RO-DI water. Afterwards, the wet target was immersed in the gold colloidal working solution for CG1 for 45 min or for CG2 for 18 min while being shaken in an orbit at a speed of 50 revolutions per minute. After the gold deposition process, the fabrics were rinsed in two further changes of RO-DI water to eliminate excess colloidal gold and then placed inside a glass dish that contained a physical developer working solution for only 2 to 3 min until ridge features could be observed clearly. The required submersion period for the secondary enhancement procedure of silver colloid onto the cloth was cut short to 2 to 3 min from 5 to 15 min, based on pre-experiments run in the laboratory. It was determined that soaking for a period of less than 2 min will provide almost no enhancement, whereas soaking for longer than that would lead to the excessive adhesion of silver nanoparticles to the entire fabric piece, completely obscuring the fingermark on substrates colored dark gray. The visualized fingermarks were later recorded by Nikon D7000 Camera using a copy stand (10).

Results & Conclusion :

This review study examines the various nanomaterials and their uses in forensic science. Included is a description of the nanomaterials used in the synthesis and characterization of invisible or latent fingerprints, as well as their actual application for visualization. Long-lasting invisible fingerprints can be created with metallic nanostructures and functionalized for secondary identification using MMD with gold & silver nanoparticles. The establishment of invisible fingermarks with gold nanoparticles (AuNPs) and the Multimetal Deposition (MMD) process has truly become one of the major developments in contemporary forensic science.Researchers have developed a novel reagent using gold nanoparticles that can detect latent or invisible fingerprints and identify drugs or medicine and their metabolites. When gold colloid and bifunctional substance used to a fingerprint-containing paper surface, the paper serves as a substrate & fingerprint help as mask. Gold colloids could be employed as a reagent in the MMD technique to identify sweat proteins & polypeptides in fingerprints. applying AuNPs as a probe has enabled the identification of cocaine metabolites in invisible fingerprints. Electrodeposition of metal nanoparticles can create invisible fingerprints on impermeable coin substrates, revealing intricate ridge patterns. and the review provides a timeline of nanoparticle evolution from 1970 to 2016, emphasizing nanotechnology achievements in forensic fingerprinting.

Case study :

In a professional theft at a luxury jewelry shop , recovering the latent fingerprint from a glass display case and a plastic bag that was discovered at the crime scene was a difficult time for forensic scientists. Standard fingerprinting methods like powder dusting and cyanoacrylate fuming , failed to produce clear ridge features due to weak fingerprint residue and environmental exposure. To address this limitation forensic scientists used the Multimetal Deposition (MMD) technique approach with Gold nanoparticles (AuNPs), a very sensitive method for improving fingerprint visibility on difficult surfaces.

The method began with the application of colloidal gold nanoparticles , which specifically bound to amino acid and fatty residue found in the latent fingerprint . this initial deposition laid the groundwork for future enhancements . A silver solution was then added , which reacted with the gold layer , boosting constrast and making the ridge details more visible . A second gold layer enhanced the fingerprint patterns , making them more clear and well defined. The improved fingerprint were then scanned and examined by the Automated fingerprint identification system (AFIS), which correctly matched them to a known suspect in the police databases.

The application of gold nanoparticles and MMD technique proved to be a game changer in this case , allowing investigators to extract distinct and identifiable fingerprints from non – porous surfaces when other approaches had failed. This critical forensic evidence was instrumental in gaining a conviction , demonstrating the efficacy of nanotechnology-based fingerprint development procedure in modern criminal investigations.

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