

# A REVIEW ON NANO FORENSICS

## Abstract

Forensic science pertains to the lawful examination of criminal activity, encompassing the application of biological and technological expertise to identify and analyse evidence. The collection, detection, and identification of evidence are of paramount significance. The field of forensic science is significantly impacted by the advancements in nanotechnology. The recent breakthroughs in nanotechnology have demonstrated the potential of sensor technology in detecting minute traces of substances, including explosives and poisons. The study of body fluids holds significant importance in forensic investigations, requiring prompt attention. In this regard, the utilisation of nanotechnology-based lateral flow assays (LFAs) has emerged as a valuable tool, offering both rapidity and sensitivity in detection. Forensic material characterization encompasses the utilisation of atomic force microscopy (AFM) at the nanoscale level to conduct a comprehensive study. The utilisation of atomic force microscopy in questioned document analysis offers a means to analyse the three-dimensional (3D) surface morphology of paper, which becomes valuable in the detection and characterization of ink crossing and pen strokes. Fingerprint analysis holds significant value in the field of forensic science as it serves as crucial evidence for the purpose of individualization. The sensitivity and reliability of conventional fingerprint production processes are insufficient when it comes to dealing with a wide range of substrates and old prints. Nanotechniques are employed for the enhancement of latent fingerprints. The field of forensic biology primarily focuses on the process of identifying and distinguishing individuals, both victims and perpetrators, through the examination of DNA. Nanoparticles, also referred to as NPs, are employed in order to

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enhance the efficacy of DNA extraction and amplification processes. Gold nanoparticles have been found to significantly enhance the performance of the polymerase chain reaction (PCR). The present chapter centres on the synthesis methodology of nanoparticles and the extensive utilisation of nanotechnology in the field of forensic science.

## I. INTRODUCTION

Nanotechnology is the molecular or atomic-level manipulation of materials. It concentrates on things having at least one dimension between one and one hundred nanometers. Three to five atoms make up the breadth of a nanometer. It contains both organic and artificial items. We can create materials and technologies with remarkable qualities thanks to nanotechnology. Numerous academic fields, including biology, engineering, chemistry, and physics, can profit from it.

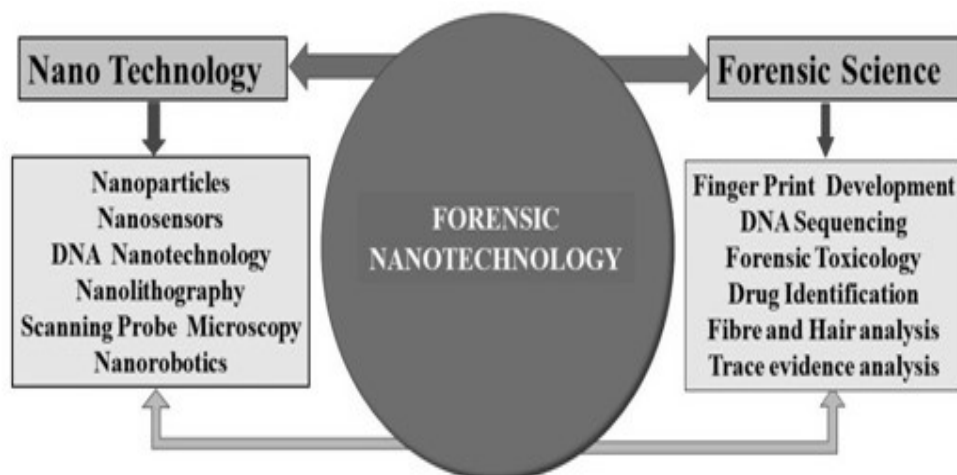
Nanotechnology is used in many fields, including engineering, electrical engineering, and medicine (1). Because its most evolved iteration will significantly affect almost all fields, industries, and facets of society, nanotechnology is sometimes referred to be a universal technology (2). This is because it has several uses and benefits across a wide range of disciplines. Nano-forensics is a brand-new area of forensic science that focuses on finding explosive gases, biological agents, and residues as a result of the development of nano-sensors and nanotechnological techniques for real-time crime scene investigation and investigations of terrorist activity (3). To gather evidence for criminal and other legal actions, many forensic science subdisciplines modify natural science methods (4). Nanotechnology is starting to have an impact on evidence handling at crime scenes, lab analysis, and courtroom presentation. The use of nanotechnology is likely to improve the ability to identify forensic evidence, toxic compounds, and soil in tissue.

## II. FORENSIC NANOTECHNOLOGY

Nanotechnology is the manipulation of substances at the molecular or atomic level. It focuses on objects with at least one dimension between 1 and 100 nanometers in length. The width of a nanometer is three to five atoms. It includes both natural and manmade objects. Utilizing nanotechnology, we are able to produce materials and devices with exceptional properties. It can benefit numerous disciplines, including biology, engineering, chemistry, and physics. Numerous industries, including the engineering, electrical, and medical sectors, employ nanotechnology (1).

Nanotechnology is sometimes referred to as a universal technology because its most advanced iteration will have a significant impact on virtually every field, industry, and aspect of society (4). This is due to its many applications and advantages across many disciplines. Due to the development of nano-sensors and nanotechnological approaches for real-time crime scene investigation and investigations of terrorist activity, nano-forensics is a brand-new field of forensic science that focuses on detecting explosive gases, biological agents, and residues (5). Diverse subdisciplines of forensic science use modified natural science techniques to collect evidence for criminal and other legal proceedings (5).

The management of evidence at crime scenes, laboratory analysis, and courtroom presentation are beginning to be influenced by nanotechnology. The application of nanotechnology is likely to enhance the capacity to detect soil, hazardous substances, and forensic evidence in tissue. **(Figure 1).**



**Figure 1:** Flowchart for Forensic Nanotechnology

### III. APPLICATIONS OF FORENSIC NANOTECHNOLOGY

- 1. Forensic Toxicological Analysis:** As it involves the discovery and identification of poisons and drugs in biological samples taken from crime scenes or from people involved in criminal activity, forensic toxicological analysis is a crucial part of forensic science. Numerous benefits come from using nanotechnology in forensic toxicological analysis. These developments in nanotechnology have the potential to greatly increase the sensitivity and precision of recognizing and locating medications and poisons in biological samples. Forensic toxicologists can improve their analytical methods, get around problems with sample size or degradation, and speed up analysis by using nanomaterials and instruments based on nanotechnology (6). Additionally, nanotechnology can make it possible to identify poisons and drugs at lower concentrations, providing a more thorough comprehension of the forensic evidence. Additionally, the use of nanotechnology in forensic research can help with the characterization and identification of illegal narcotics.
- 2. Forensic DNA Analysis:** Forensic DNA analysis plays a crucial role in criminal investigations by providing valuable scientific evidence that can link individuals to crime scenes or exclude them as suspects. The term 'corpus delict' is often used in forensic case works and legal proceedings to refer to the establishment of events or linkage to the crime (7). During the investigation process, DNA evidence has proven to be a vital tool in determining guilt or innocence. DNA analysis has been at the forefront of forensic science since its introduction in the 1980s. Prior to the use of DNA testing, forensic investigations relied heavily on conventional methods such as fingerprints, dental records, and blood splatter analysis. However, these methods had limitations in terms of accuracy and reliability. With the advent of DNA testing, forensic investigations have been revolutionized. DNA profiling, additionally referred to as DNA fingerprinting, as a process that examines specific sections of a person's DNA to generate a unique genetic profile. To see if it matches, this profile can be matched to DNA recovered at a crime scene or on evidence.

- 3. Forensic DNA Typing:** For forensic DNA typing, a high-quality PCR (polymerase chain reaction) extraction is required. To extract high-quality PCR-ready DNA samples from skeletal remains and suggestive bodily fluids obtained for forensic inquiry, copper, silica-based magnetic nanoparticles, and magnetic nanoparticles are used. As adsorbents for PCR amplification, magnetite nanoparticles containing carboxylic chemicals are employed to isolate DNA (8).

**Table 1: Role of Nanoparticles in Forensic Science**

SI. No	A large area	Use	Nanoparticles	Mode of Function
1.	Fingerprinting	Latent Fingerprint Identification	SiO <sub>2</sub>	Functionalized SiO <sub>2</sub> particles with optical fingerprint detection capabilities
2.	Fingerprinting	Latent Fingerprint Development	Luminescent Dots CdS capped with ZnS and functionalized with Octadecane	Latent fingerprints can be revealed via fluorescence from the lipid fraction found in fingerprint residue.
3.	Fingerprinting	Development of Latent Fingerprint	Colloidal gold with octa decanethiol, dissolved in petroleum ether	Prints of the fingers appeared on both porous and nonporous materials.
4.	Fingerprinting	Development Latent Fingerprint	AgNPs	Physical fingerprint development with silver developer.
5.	Fingerprinting	Latent Fingerprint Development	AuNPs	Developing covert fingerprinting using MMD SMD
6.	Toxicology	Identification of drugs in fingerprint residues using specific targets	Au (10nm and 30 nm), Ag	Anticotinine-functionalized gold nanoparticles can use their fluorescence to detect the presence of cotinine.
7.	Finger Printing	Development of latent fingerprint	Cds	CdS nanocrystals coated in dioctyl sulfosuccinate are used in place of fragrance in cyanoacrylate-scented products and in place of fragrance in the adhesive ends of electrical tape.
8.	Finger Printing	Development of latent Fingerprint	CdSe/Zns	Developed fingerprints on nonporous surfaces glow when exposed to UV light.
9.	Fingerprint	Latent-aged	Exfoliated Egyptian	NIR (near-infrared)

		fingerprint development	blue NPs	luminescence is used to detect fingerprints.
10.	Fingerprinting	Latent Fingerprint Development	ZnS capped with CdS nanocrystal	It has an effect on the FP residue's amino acids.
11.	DNA	Enhancement of PCR efficiency	Au (0.7nm of 13 nmAu) NPs	In real time PCR, the sensitivity of PCR is increased by a factor of about 10,000.
12.	Question Document	Secret Writing	AuNPs and AgNPs (5mg each)	Doubles as an erasable media and erasable ink
13.	Security Purpose	Radio frequency identification Tag (RFID)	AuNPs	Alkanethiol-encapsulated gold nanoparticle ink is used to create military identification tags and barcodes.
14.	Toxicology	Drug Identification tag	Melamine modified AuNPs	Used as nanosensors to detect Clonazepam (the medication used in date rapes) in bodily fluids and bone fragments.
15.	DNA	Quantification of PCR	Carboxylated magnetic NPs, Silica based magnetics NPs and CuNPs	High-Quality PCR (DNA) Isolation
16.	Forensic Toxicology	Drug Identification	Citrate stabilized AuNPs	Codeine sulphate detection and quantitation using a mobile phone app

#### IV. NANOTECHNOLOGY AND FINGERPRINTS DETECTION

Frictional ridges in the skin at the tips of our fingers create a distinctive pattern of ridges and valleys that can be used to identify an individual by fingerprint. Forensic scientists have come to rely heavily on fingerprints since each person has a distinct fingerprint pattern that remains constant throughout his or her life; even identical twins have slightly different prints. The use of nanotechnology in the creation of hidden fingerprints has resulted in fingerprints with greater selectivity, background contrast, and sensitivity. Following this introduction, we will go on to explore the various nanoparticle types and how they can be used to uncover hidden fingerprints. Since 1970, latent fingerprints on porous paper surfaces have been visualised using the Silver Physical Developer (Ag-PD) method, which employs metallic silver nanoparticles as a reagent. The oxidation-reduction couple reaction produces silver nanoparticles (1nm-200 nm) that combine with organic components of the fingerprint residue via electrostatic force of attraction, allowing the impression to be seen as a dark grey or black silver image on the paper surface. If there is any CaCO<sub>3</sub> filler on the print bearing surface, it must be removed prior to printing. In order to increase the fingerprint's visibility, gold nanoparticles stabilised with acierate ion were first put to the print. Because of their

inertness, high selectivity, and sensitivity (8), gold nanoparticles (AuNPs) play a crucial role in the creation of latent fingerprints. When the pH is low enough, colloidal gold (Au) with a particle size of 14 nm or 30 nm has the same effect.

Fingerprints can be developed on both porous and nonporous surfaces by using colloidal gold that has been functionalized with a long chain hydrophobic molecule (octa decanethiol) in a petroleum ether carrier. The carboxylic acid functionalities of finger-mark ingredients are the focus of the amine-functionalized Europium oxide nanoparticles. The SPR method is utilised, initially including an incubation period before moving on to photoluminescent detection. Due to its high luminescence property (8), Al<sub>2</sub>O<sub>3</sub>: Eu<sup>3+</sup> can serve as the best option for fingerprint formation in compared to regular luminous powders. After being fumed with cyanoacrylate ester, soft drink cans and aluminium foil became fingerprinted by Cds nanocrystals coated with dioctyl sulfosuccinate in heptane's/mixture of hexanes. The generated prints are stabilised by octadecane amine, and CdSe ZnS-capped, together with ZnS nanocrystals, can be covalently attached to amino acid components of finger-mark residue on non-porous surfaces. Metallic oxide nanoparticles, including TiO<sub>2</sub> and ZnO, and CdS luminous quantum dots are used for the formation of latent fingerprints.

## V. NANOTECHNOLOGY AND DRUG DETECTION

Due to their diminutive size, nanoparticles can engage with a broader variety of active sites. Evidence-worthy detection and quantification of numerous dangerous compounds can be accomplished with samples of blood, saliva, hair, vitreous humour, skeletal remains, and even fingerprints. Forensic drug testing often falls into two categories: screening and confirmation. Nano sensors' amplified signals can be used in a wide variety of chemical and biological sensing applications because of their distinct optical, electrical, thermal, and catalytic properties. The molecules that make up a nano sensor's receptors serve as forms for the measured chemical. Various receptor materials are available. Using Au nanoparticles functionalized with anti-cotinine, a cotinine antibody, fingerprint residue can be used to infer a person's smoking status.

Fluorescent agent and anti-cotinine nanoparticle conjugates were pipetted onto fingerprints and then incubated (9). Fingerprints of people who don't smoke were made, too, but it was easy to tell that they didn't smoke since their prints didn't glow. Ag (20 nm), Au (10 nm and 30 nm), and TiO<sub>2</sub> (15 nm) can all be used to enhance fingerprint drug detection. Using melamine-modified gold nanoparticles as nano sensors, clonazepam may be detected in both physiological fluids and bone fragments. We use citrate-stabilized AuNPs as a probe and nano sensors containing melamine-modified gold nanoparticles to detect clonazepam (the drug of choice for date rape victims) in bodily fluids and bone fragments. For speedy detection and quantification of codeine sulphate, a citrate-stabilized AuNP probe is employed in conjunction with a smartphone camera for analysis. Lidocaine hydrochloride in vitreous humour postmortem drug testing using a mobile application. Morphine can be determined by voltammetry using a Nafion-modified Carbon Paste Electrode (CPE). The SPR immunosensor is capable of detecting methamphetamine. Detection of drugs using nanochips is already a reality for substances like gamma-hydroxybutyrate, benzoylecgonine, and cocaine. Multiplex drug detection makes use of nanoparticles that can be activated magnetically or optically.

## VI. NANOTECHNOLOGY AND QUESTIONED DOCUMENTS

The formulation of writing and printing ink includes the addition of nanoparticles. The elemental profile and morphological characterization of pigments contained in writing and printing ink can be obtained from scanning electron microscopy (SEM) pictures of the ink at several magnifications. To aid in keeping secret and secure documents secret, self-erasing medium and ink have been developed. Nanoparticles of gold and silver, each 5 nm in size, are used to make these. When exposed to UV radiation, these nanoparticles cluster and change colour. However, when exposed to sunlight, these clusters disintegrate, causing the ink to vanish. The gold or silver nanoparticles in their self-erasing solvent are placed in an organic gel layer. The ink used to make the barcodes utilised for military security is a closely guarded secret. Ink containing gold nanoparticles encased in an alkanethiol is used to create Radio Frequency Identification Tags.

Atomic force microscopy (AFM) can examine the nanomaterials embedded in the paper. It provides qualitative details about a document, such as the crossing sequence, the amplitude and phase variations of the ink on paper, and the depth of the ink crossing. Important data for figuring out the order of lines drawn with a ballpoint pen and a ribbon dye (10-12). To prevent forgery, security documents can be embedded with nanosized luminescent phosphors and up converters, or luminescent nanoparticles like quantum dots.

## VII. NANOTECHNOLOGY AND DNA QUANTIFICATION

First, Lin and his colleagues used gold nanoparticles (0.7 nm of 13 m Au) to boost PCR performance. The heat transfer and Electro Chemiluminescence (ECL) boosting properties of AuNPs are exceptional. As a result, the rate is increased while heating or cooling the thermal cycle since the reaction time is reduced. Using these nanoparticles raises the sensitivity of traditional methods by a factor of 5-10, and by more than 10,000 in real time PCR. Quantification following Polymerase Chain Reaction (PCR) can be performed using a microfluidic system. In about 30 minutes, using a readily available commercial tool called an Agilent 2100 bioanalyzer, DNA samples of any volume, down to the nanolitre range, can be accurately measured. Many forensic science labs can now use this technique for mitochondrial DNA measurement. Copper nanoparticles, magnetic nanoparticles based on silica, and magnetic nanoparticles are all available for high-quality PCR extraction using magnetic nanoparticles. Gold nanoparticle-based polymerase chain reaction (PCR) was observed to have a hot-start-like effect, suggesting its potential utility in nano biological and medicinal research. Urine DNA is extracted with organic chemicals, and the isolated DNA is then purified utilising carboxylate magnetic nanoparticles as solid phase adsorbents for PCR amplification. Nanotechnology for detecting explosives Nanostructures is being examined for use in explosives detection due to their potential as sensors of a wide variety of chemical and biological components. Low quantities of unexploded explosives, contaminated samples, and variations in sample collecting methods are just a few of the obstacles that make detecting small levels of explosives a difficult process. Nanocurcumin-based probes, lasing ionised air, and electronic noses the most promising nano sensor concepts for developing into practical technical platforms for trace explosive detection including plasmon nanocavities, nanowires/nanotubes, and nanomechanical devices. Nanoparticles and polymer particles, for instance, can provide very specific detection of explosives since they undergo a quantifiable



change when linked to an explosive molecule. Antibodies against explosives like Penta Erythritol Tetra Nitrate (PETN) have recently been created. The presence of GSR residues can be detected through the use of nano tagging. Gunshot residue can be identified using high-resolution Scanning Electron Microscope (SEM) imaging, which, when combined with X-ray spectroscopy, can assist detect the elemental elements of the residue. Researchers in 2012 found that a highly selective and ultrasensitive fluorescent probe based on curcumin nanoparticles could be employed for the detection of Trinitrotoluene (TNT) down to the 1 nm level in aqueous solution (13). Label-free and selective detection of 2,4,6-trinitrotoluene (TNT) from 10<sup>-12</sup> to 10<sup>-4</sup> M using amine-terminated nanoparticles was proposed in a 2015 study (Table 1).

## VIII. DISCUSSION

Analytical Applications Based on Nanotechnology Transmission electron microscopy (TEM), scanning electron microscopy (SEM), Raman microspectroscopy, the micro-X-ray fluorescence (MXRF) technology, and atomic force microscopy (AFM) can all be used to identify and analyse materials on the nanoscale. When it comes to analysing forensic evidence, AFM is one of the most versatile methods available. Selective detection is performed with the aid of an AFM microcantilever. It examines ink crossings in documents to establish the order of pen strokes by studying the 3-D surface morphology. The morphological alterations of blood cells are analysed using AFM to provide a quantitative assessment of the estimated time since death. Unfixed erythrocytes show surface cell and membrane deformation over time (14,15). By analysing nanoscale variations in the elasticity of erythrocytes and recording these changes using a force-distance curve, the age of a dried bloodstain can be calculated. Over time, the elasticity pattern weakens. With AFM, researchers may objectively measure the surface texture parameters of traces like textile fibres and pressure-sensitive adhesives in order to draw conclusions about their origins and significance.

## IX. CONCLUSION

Using nanoparticles to shrink traditionally large equipment down to chip-based systems speeds up the analytical process, allowing for more sensitive, fast, and appropriate research. Nano trackers and barcodes are utilised in today's fight against crime. The future may potentially hold several opportunities for devices based on nanomaterials to be used in the investigation of crimes, the monitoring of public spaces, and the recovery of lost or stolen property. The potential benefits of using nanotechnology in forensic research must be weighed against any potential drawbacks. The toxicological effects of nanoparticle translocation in human organs from prolonged occupational exposure are well-documented. DNA degradation can be attributed to a number of different processes, including bacterial decomposition, cross-linking, oxidation, deamination, and the release of nucleases from a putrefying cell. Virtual autopsies, crime scene investigations, and new developments in fingerprint recognition questioned documents, ballistics, and toxicology are just some of the areas where nanotechnology may soon play a role as an innovative and preventative tool.

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