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Application of nanotechnology in criminology and forensic Sciences

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Abstract:
Nanotechnology being a new discipline of the research has many advances. Due to its properties nanostructures are involved in revealing many evidences and cases. Nanostructures play an important part in forensic study and criminology. It is evident that gold and silver nanostructures are greatly used in fingerprint detection. However different nanotechniques are employed to detect trace materials from the crime scene. Fragmentation of DNA, amplification and cooperation is taken place by using nanoparticles with the help of PCR technique. Nanostructures can act as sensors for a variety of chemical and biological components, including explosives, according to contemporary studies on nanomaterial research and development. Nano-gold (Au-NPs), nano-silver, and nano-titanium dioxide (TiO2) particles along with capillary electrophoresis, SEM, TEM, and FTIR are used in forensic toxicology. Inculcation of nanostructures in saliva and nerve agent detection is also observed. In the realm of forensic science, nanotechnology is projected to play a significant role in the future by bringing more specialised and sensitive methods of case detection and revelation, as well as flawless evidence. In this review article all the aspects were nanostructures are applied in forensic sciences are studied in detail.
Key words: Nanotechnology, Forensics, nanoparticles, toxicology, nanotechniques

1. Introduction

Nanotechnology is growing rapidly with the application of various fields like physical sciences, natural sciences and computational and biological sciences. Nanotechnology is the controlled development of structures at atomic, molecular and macromolecular level with in the length scale ranging from 1- 100 nanometer. These materials are known as "nanostructures" which are unique in their properties and functionality. They are actually of small size, easily soluble, multifunctional and surface tailorable [1] Owning to their properties they are applied in various fields. An important and significant approach of the nanotechnology is their benefit in criminology and forensic sciences as their use disclosed significant evidences which proves significant in criminal investigation [2].

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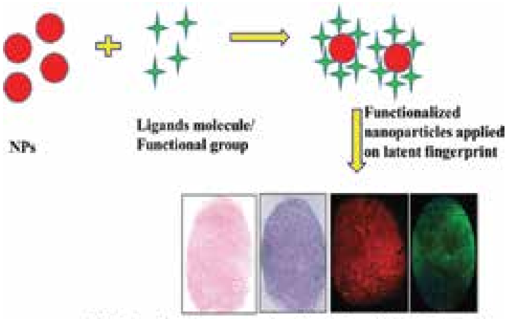
Many areas in forensic nanotechnology are covered which comprises of forensic toxicology, nanosensors, sequencing of DNA, scanning probe microscopy, nerve gas detection, saliva detection, latent fingerprint detection, fiber and hair analysis, analysis of drug detection and trace evidence analysis [3].

2. Application of nanotechnology in forensic sciences

2.1 Fingerprint detection

To ensure the safety of the person defense industries introduced the finger print detection. Fingerprints are of three kinds: visible, indented, or latent. Visible fingerprints can be seen explicitly. Indented fingerprints are those obtained from malleable materials. Latent fingerprints are invisible and more difficult to detect to detect latent fingerprints fluorescent nanoparticles or quantum dots can be used. Due to their small size, nanoparticles have the capability to recognize smaller with more accuracy. For instance, gold and silver nanostructures are utilize in latent finger detection. Titanium oxide or zinc oxide nanostructures are able to detect fingerprints on surfaces. When used as nanocrystals or nanocomposites, metal sulphide nanoparticles are very effective at locating fingerprints on aluminium foil and soft drink cans [4].



Colorimetric /Fluorescence based detection of latent Fingerprint

In forensic science, the study of fingerprints serves as the primary proof of individualization. The traditional methods for developing fingerprints don't have the sensitivity or dependability to work on a variety of surfaces or older prints. For the development of latent fingerprints, nanotechniques are used [5].

In addition to producing superior prints and being naturally UV fluorescent, 20 nm zinc oxide particles can function in wet environments, which is something that traditional micron-sized powders cannot. In order to enhance the creation of fingerprints, other researchers have been employing particles smaller than 10 nm that also glow under UV light. They have been creating nanopowders with special engineering that will allow them to work with SALDI-TOF2-MS. This implies that when a fingerprint is created with these powders, the chemicals—both those ejected and those left behind after coming into touch with other materials—that make up the fingerprint may be examined and identified [6].

2.2 Trace evidence material analysis:

Minute quantities that are present at crime scene known to be trace evidence. Nanostructures play a vital role in analyzing these materials. Trace evidence include hair, fibers, paint, glass, gunshot residue (GSR), and explosives [7].

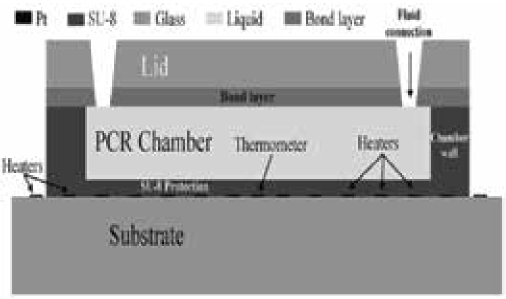
For trace evidence analysis atomic force microscopy is applied. Due to its capacity to discriminate between various environmental exposures or forced damages to fibres, AFM is a very effective instrument in the forensic investigation of fibre evidence.

2.3 DNA Analysis:

DNA extraction and amplification are made more effective by the use of nanoparticles (NPs). Gold nanoparticles significantly increase the polymerase chain reaction (PCR) [5].

In contrast to the traditional sieving mechanism and the transitory mechanism, new separation methodologies for DNA analysis employing nanostructures have been devised [9].

The polymerase chain reaction (PCR) is a popular technique for making duplicates of particular DNA fragments. A single DNA molecule is quickly multiplied into many billions of molecules using PCR. Consequently, PCR is a useful technology in forensic DNA analysis that can be used to identify an individual or a group of individuals. Gold nanoparticles have been found to significantly increase the polymerase chain reaction's (PCR) effectiveness. The reaction time is shortened and the heating/cooling thermal cycle rates are raised when 0.7 nm of 13 nm Au-NPs are added to the PCR reagent. As a result, significant increases in PCR efficiency are attributed to Au nanoparticles' excellent heat transfer properties [10].



Silver and gold nanoparticles, for example, scatter light in a size-dependent manner, and the absorbance and emission spectra of semiconductor quantum dots are size-tunable. These characteristics make it easier for them to be used in multitarget assays, as does the capacity to affix almost any biologic recognition element to the particle surfaces. For instance, using size-dependent features as just one example, both quantum dots and metal nanoparticles can be coupled to either DNA sequences or proteins so that fluorescence or light scattering, respectively, can be used as an output signal [11].

2.4 Nanosensors

Modern studies on nanomaterial research and development have shown that nanostructures can serve as sensors for many chemical and biological components consisting of explosives. One of the fundamental promises of the nanosensor sector is the development of ultra-small devices with powerful sensing capabilities. The most promising nanosensor ideas for trace explosive detection include electronic noses, nanocurcumin-based probes, lasing plasmonnano cavities, nanowire/nanotube, and nanomechanical devices [12].

Nanoparticles can be utilised in detectors and collectors that have a target warfare weapon recognition site. The target, which might be chemical, physical, or biological, determines the parameters for choosing the nanoparticles. There are a number of nerve agents, such as sarin and sulphur mustard, that only last a short time in the environment and may also be volatile, but others, such as ricin, VX, and others, are toxic nerve agents that need to be addressed and can be done so with the help of nanoparticle detectors with nanostructured recognition sites [13]. A very sensitive (1 nM) and selective (over other nitro explosives) ultrasensitive nanocurcumin-based nanomaterials surface energy transfer (NSET) sensor is designed for the detection of tiny amounts of

Trinitrotoluene (TNT), and we discovered the highest fluorescence enhancement for sensing TNT to date (up to 800 times) [14].

Barcodes and trackers are employed to stop crime. Injecting the inmates with nano trackers makes it easier to find them if they manage to escape. Nano trackers make it possible to keep tabs on prisoners after their release [10].

2.5 Nanostructures in toxicology and drug analysis

The effective use of current nanotechnology in forensic toxicology includes the identification and quantification of various poisonous substances from a wide range of forensic evidence, including blood, hair, saliva, urine, vitreous humour, fingerprints, and skeletal remains. The development uses nano-gold (Au-NPs), nano-silver, and nano-titanium dioxide (TiO_2) particles along with capillary electrophoresis, SEM, TEM, and FTIR [15].

Using nano-techniques like HPLC, FT-IR, XPS, and Tof-MS, a wide variety of both legal medications (like paracetamol and loratadine) and illegal substances (like cocaine and ecstasy) are regularly detected and identified. Nano-grams of pharmaceuticals and drug formulations can now be found in a variety of media, including blood, urine, and hair, thanks to modern advancements in these procedures. Modern forensic investigators now have access to a multitude of data on drugs, paraphernalia, and excipients, including information on morphology, chemical composition, and surface stiffness, because of advances made in these procedures [16].

2.6 Saliva detection analysis

Forensic saliva identification is a useful supplemental tool in criminal investigations. Techniques for detecting salivary bacteria have been found to be effective ways to determine the presence of saliva. The creation of SiC nanoparticles that have been stabilised by bovine serum albumin (SiC-BSA NPs) is described as a one-pot process. To enable the fluorometric detection and imaging of bacteria in saliva, SiC@BSA NPs were coupled to the antimicrobial peptide GH12. More specifically, the oral bacteria S. salivarius levels were detected using a nanoprobe having fluorescent excitation/emission maxima at 320/410 nm. The assay can be completed in 40 minutes, and the detection limit is 25 cfu/mL/1. Blood, urine, and semen were among the forensic body fluids in which the nanoprobe was employed to identify microorganisms [17].

A quick and affordable smartphone-based bacteria sensor that tests for two oral bacteria in actual samples of saliva is developed. In order to create a series of test strips for this bacterium sensor, blue-emitting silicon carbide quantum dots (SiC Qds) and red-emitting gold nanoclusters (AuNCs) were used. This technique has good sensitivity for the selective detection of two types of oral bacteria, S. salivarius and S. sanguinis. The test strips were exposed to bacterium solutions, which encouraged the evolution of dose-sensitive colours under a 365 nm UV lamp, which were captured by a smartphone camera and assessed using a colour detector APP [18].

2.7 Nerve agent detection

Forensic and clinical examination of the very lethal nerve toxin VX requires a screening approach. An effective method for VX detection with the human eye was devised utilising a straightforward colorimetric technique using gold nanoparticles (AuNPs). When VX was added to the AuNPs under mildly acidic circumstances, the AuNPs turned from bright red to deep blue [19]. The creation of straightforward techniques for the quick and effective detection of these dangerous compounds is essential because organophosphorus nerve agents (OPNAs), such as Sarin (GB), Tabun (GA), Soman (GD), and VX, would be extremely harmful in military and terrorist strikes. AgNPs that have been functionalized and immobilised with acetylcholinesterase (AChE) and 5,5′-dithiobis-(2-nitrobenzoic acid) are used to create the detection substrate (DTNB). Acetylthiocholine (ATCh) is hydrolyzed by AChE in the absence of OPs to create thiocholine (TCh), which continues to interact swiftly with DTNB to create the extremely sensitive Raman probe molecule TNB [20].

3. Conclusion

Nanostrucutures play signinficant role in the field of science and technology. Hence, with their enhanced properties its demand is increasing. In forensic sciences they are used in almost every matter from security measures to crime scene investigation. This article covers alomost every aspect in which nanoparticles are utilized. In future, they are also implanted in robotics and polymer sciences.

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