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Introduction to Nanotechnology & Its Applications in Forensic Investigation & Analysis

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ABSTRACT

Nanotechnology is the growing field of scientific research & technology. Nanotechnology has vast applications specially in the field of forensic science. It helps in diagnosing and examining samples at the nano- scale level that was earlier difficult due to detection limits of instruments. Nanotechnology has already shown immense potential in many fields of research like medicine, molecular biology, genetics, material science & it also has a promising potential even in the fields of forensic science. This area of research has its own significant interest as the advances in the field of nanotechnology are being incorporated in the field of forensic science. For revealing the secrets of forensic science, nanotechnology is being used quite extensively. In forensic nanotechnology minute chip materials are used instead of bulky instruments which reduces the steps of methods of analysis to make investigation purpose accurate, precise and less time consuming.. An important advantage of using nanotechnology in the field of forensic science is that it reveals the hidden evidences, which can prove to be helpful for the forensic scientists to give an outcome to their investigation. This review aims to discuss role of nanotechnology in forensic analysis and detection of crime scene.

KEYWORD: *Nanotechnology, Crime detection, Forensic Expert, Forensic science, Fingerprint analysis*

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INTRODUCTION

Today the era of dreaming big is over. Now the idea is that small is good. Based on this principle, scientists are developing nanoscience, commonly referred to as Nanotechnology (NT). This technology is emerging as an 'industrial force' worldwide. It has the potential to reduce costs with its multiple applications and the inherent ability to produce new materials like non-corroding and flexible iron and many more. Nanotechnology is a rapid growing field which sets new horizons in the field of science and technology As nanotechnology is still evolving, there doesn't seem to be any one definition that everybody agrees on. Nano deals with matter on a very small scale and also matter at the nano scale behaves differently than bulk matter. But beyond that, different individuals and groups focus on different aspects of nanotechnology as a discipline. The word nano is a scientific prefix that stands for 10-9 or one-billionth & the word itself comes from the Greek word nanos which means dwarf.

Nanotechnology is the study and use of structures between 1 nanometer (nm) and 100 nanometers in size. The Foresight Institute gave a definition as:

"Nanotechnology is the study of phenomena and fine-tuning of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale."

The European Commission offers this definition as**:** **"Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications."**

This definition from the National Nanotechnology Initiative adds the fact that nanotechnology involves certain activities, such as measuring and manipulating nano-scale matter.

The definition of nanotechnology by Thomas Theis, director of physical sciences at the IBM Watson Research Center, offers a broader and interesting perspective of the role and value of nanotechnology in our world.

"Nanotechnology is an upcoming economic, business, and social phenomenon. Nano-advocates argue it will revolutionize the way we live, work and communicate."

APPLICATIONS OF NANOTECHNOLOGY

The ability to see nano-sized materials has opened up a world of possibilities in a variety of industries and scientific areas. As nanotechnology is essentially a set of techniques that allow measurements of properties at a very small scale, it has many applications, some of them are listed below.

1. Drug delivery:

Today, most harmful side effects of treatments such as chemotherapy are a result of drug delivery methods that do not target their intended target cells accurately. Researchers at Harvard and MIT have attached special RNA strands of about 10 nm in diameter to nanoparticles and filled the nanoparticles with chemotherapy drug. These RNA strands are attracted to cancer cells. When the nanoparticle encounters a cancer cell it adheres to it and releases the drug

into the cancer cell. This directed method of drug delivery has great potential for treating cancer patients while producing less harmful side effects than conventional chemotherapy.

2. Nano – forensics:

Nano-forensics, a completely new area of forensic science associated with the development of nano-sensors, nanotechnical methods for real-time crime scene investigation and terrorist activity investigations, determining the presence of explosive gases, biological agents and residues. [1-4]

3. Forensic Science:

Forensic Science is a broad field of subspecialties which uses techniques adopted from the natural sciences to obtain criminal or other legal evidences. [5-9] Nanotechnology is having an impact on the handling of evidence at crime scenes, its analysis in the laboratory and its presentation in the court room. Application of nanotechnology is likely to enhance the capacity to toxic materials, forensic evidence in tissue, materials and soil. [10-13]

Forensic science mainly deals with identification, evaluation, investigation of the crime, finding connections between pieces of evidence and perpetrators. Nano-analysis is commonly used in the nanotechnology detection of crimes. Some of these analyses techniques are Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Dynamic Light Scattering, and Raman Microscopy. [14-16] These techniques assist forensic scientists firstly by making it possible to analyze nano-scaled samples and secondly by making use of the specific effects of nanomaterial to identify and collect evidence, which would not have been possible by previous techniques. DNA extraction from palm-prints, fingerprints, gun residues, explosives and heavy metals are some of the novel approaches that ease the way for forensic scientists to provide conclusive evidence [17-21] (Figure 1).

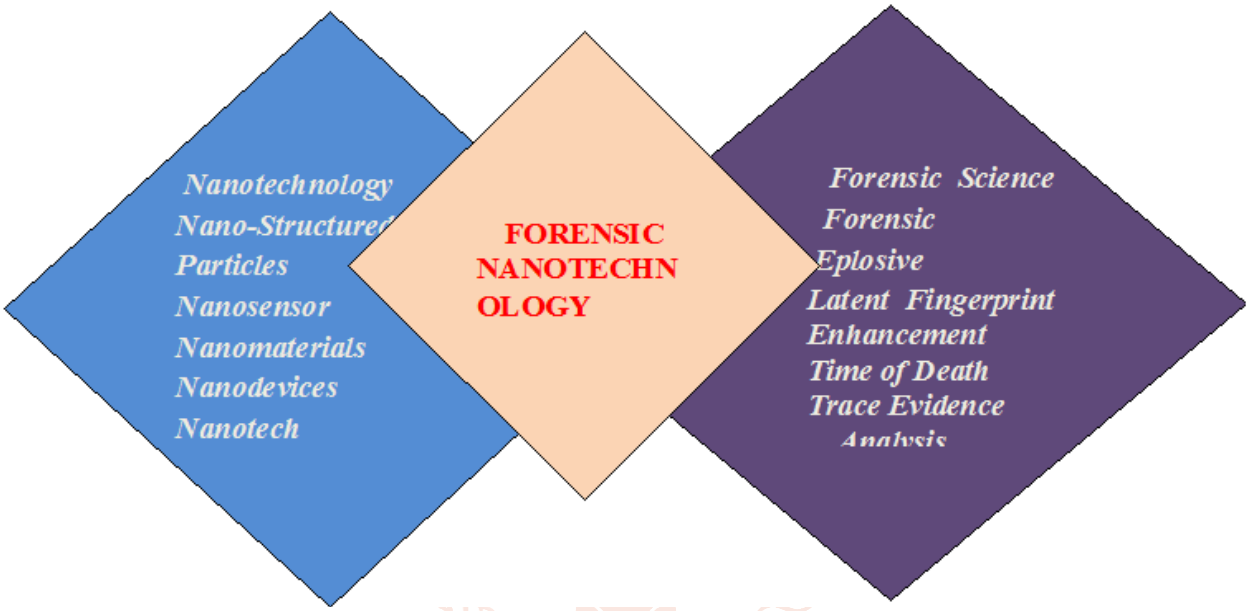

Figure.1 Forensic nanotechnology combines the technologies and approaches of nanotechnology to improve the scene of crime detection and analysis.

Nanotechnology assist forensic scientists in following areas of forensic science:

3.1. Forensic toxicological analysis :

Nano technology is effectively used in the discipline of forensic toxicology for examination of different toxic materials from numerous important forensic evidences like hair, blood, saliva, vitreous humor and even from remains of body skeleton and samples of evidences of fingerprints. Gold nanoparticles, silver nanoparticles and Titanium oxide nanoparticles are commonly used to enhance the detection limit. [22-26]

3.2. Finger print analysis:

Distinctive lines and swirls at the end of our fingers give a unique pattern of ridges and valleys to each individual, known as fingerprints or Frictional Ridge Skin (FRS). Owing to the fact that this pattern is unique to each individual and doesn't change throughout a person's life, it has been used as a biometric identifier by the criminologists and law enforcement officers in forensic investigations since late 19th century [38]. Apart from the scars which originated from any accidents, fingerprints remain same throughout a person's life. Even identical twins with identical DNA have different fingerprints [39]. Fingerprint formation begins, when the baby is still in the womb at about 10th week.. Fingerprints are fully formed at about seven months of foetus development. [40,41] If appropriately gathered and accurately analysed, fingerprints are impeccable and can serve crime fighters with invaluable knowledge to identify the criminals [42]. Interestingly, fingerprints not only reveal identity, it can also hint about a person's profession as well as substances touched and secretions from a person's body.

Traditionally, fingerprint analysis was mostly performed by powdering method, for which different types of commercially available powders including magnetic powder, aluminium flake powder, luminescent powder and iron flake powder are used. [38] Techniques such as mass spectroscopy in addition to chromatography are used to identify the molecular ion of explosive residues or prohibited drugs important for forensic detection. [43] Other methods used for fingerprint analysis are Surface Assisted Laser Desorption/ Ionization (SALDI) coupled with mass spectroscopy [44],

Desorption Electro spray Ionization (DESI) mass spectroscopy [45], Matrix Assisted Laser Desorption/ Ionization mass spectroscopy (MALDI) [46], Raman spectroscopy, Infrared spectroscopy. [38]

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Patent finger marks can be seen with naked eyes and thus can be used directly but clarity of the latent fingerprints can be enhanced by using gold nanoparticles bound with long hydrocarbon chains which form hydrophobic interactions with the sweat residues along with silver physical developer. [47]

3.3. Forensic DNA analysis:

Forensic DNA analysis is carried in murder cases, rape cases and other crime cases. DNA analysis of blood stains, hairs, fibres semen can be carried out. Micro-fluidic devices are the recent advanced devices used for forensic DNA analysis. The advantages of these devices are shorter examination time, risk of contamination is less and directly applicable at the crime scene. Another most important technology is micro-fluidic chip technology has already proven to be useful and effective within medical applications, such as for point-of-care use. [27-32]

3.4. Forensic explosive detection:

Global terrorism is increasing now-a-days due to more and more terrorist activities. So, greater drawn attention is drawn for the detection of hidden explosives. Nano materials provide a active potential to create sensors for detection of explosives.. Tracing of explosives is a very costly and complicated task. Nanostructures are used as sensors for detection of different chemical and biological compounds including explosives. To trace the explosives, advanced nanosensor concept devices like electronic noses, nanotube and nanomechanical devices are used detect the conventional bombs, plastic explosives and grenades .[4-9]

3.5. Gunshot residue analysis : Nanotechnology can be applied for detecting the analysis of gunshot residue. Microscopic particles of gunshot residues are often present on the hands of a shooter, following discharge of a firearm.High-resolution SEM imaging is used in the GSR analysis to locate residue particles, and X-ray spectrometry to determine their composition of the elements. [33-37]

3.6 Questioned documents analysis:

Technologies to study forensic materials has also moved to the nanoscale with techniques and machines which are now capable of manipulating molecules on the nanoscale. One such technique is the AFM which allows visualizing and manipulating materials at the level of individual molecules [48]. The Atomic Force Microscopy (AFM) can examine the ink crossing in documents to determine the sequence of pen strokes and 3-D surface morphology, which provides essential information for determining the sequence of lines made by ball pen ink and ribbon dye. [48 , 49] The depth of ink crossing, amplitude and phase images of ink on paper and crossing sequence can be clearly determined [50].

3.7. Estimation of the time of death:

Estimation of the time of death is one of the most important problems for forensic medicine and law. Physical and chemical postmortem changes are evaluated together while estimating the time of death. The pattern analysis of ante mortem and postmortem bloodstains is one of the important parameters for forensic science, and cellular changes of blood cells can be useful for the quantitative assessment of the time of death. Recently it was reported that the application AFM can resolve one of the most crucial issues in forensic science the estimation of the time of death. Since (AFM) is a rapidly developing tool introduced into the evaluation of the age of bloodstains, potentially providing legal medical experts useful information for the forensic investigation. Therefore the AFM detections on the time-dependent, substrate type-dependent, environment (temperature/humidity)-dependent changes in morphology and surface visco-elasticity of RBC imply a potential application in forensic medicine or investigations, e.g., estimating age of bloodstain or death time[6]. As it is a new potential tool in forensic medicine the time-dependent surface adhesive force and morphology of red blood cells (RBC), and cellular visco-elasticity vs. distance curve under 1) controlled, room temperature (temp: 25 ^{0}C, humidity: 76%); 2) uncontrolled, outdoor-environmental (temp: 21.2–33.7 ^{0}C, humidity: 38.4–87.3%) and controlled, low-temperature (temp: 4^{0}C, humidity: 62%) conditioned by AFM [50].

3.8. Trace evidence:

An important aspect of any crime scene investigation is to detect, secure and analyze trace evidence. Atomic force microscopy (AFM) is a nanotechnology tool that can be used to generate forensic information on a various range of trace evidence including the measurement of cuticle step heights in hair, the morphological and elastic properties of hairs and fibers, and the density with structural properties of bone and enamel. [48] According to a recent study on the fiber, it was reported that AFM is a very powerful tool in the forensic examination of fiber evidence due to its capability to distinguish between different environmental exposures or forced damages to fibers [49].

4. Security features in official and confidential documents:

Security of official and confidential documents is always a big issue for a country regarding to its national security. Therefore there are many ways of making or attempting to make a document secure and counterfeit proof. These include watermarks, fluorescent inks, security fibers, optical variable ink, plan chettes, and holograms. However, if one wants to mark (tag) a document with an invisible code that is luminescent, one normally uses inorganic luminescent phosphors or organic luminescent fluorophors. This is where the attention in using nanoparticles as security features comes in, particularly, luminescent nanoparticles such as quantum dots or nano-sized luminescent phorphors and up-converters. Thus quantum dots and other nanoparticles are

being considered as luminescent materials. Recently, various types of nanoparticles are developed that can be used for a new generation of anticounterfeiting inks. These NPs are not only replacing the ancient fluorescent dyes that can be used in currency notes but also gives more précis and upgrade security features than previously done [52,53] .

5. Nanotechnology and its military usage:

NT often acts as an enabling means that enhances applications in exhilarating ways. Defence applications for NT are numerous, ranging from sensing Weapons of Mass Destruction (WMD), combatant protection kits (smart armour, active camouflage), and medical aid (infection control), to self-healing materials and nano-electronics. At the same time, NT is more of an evolving technology and many applications in the military realm are actually theoretical possibilities and demand more in-depth research and development.

Future aspects of Nanotechnology in Forensic Science

The integration of these scientific areas shows advantages in the development of nanotechnology in various areas of forensic science, health sciences and various areas of automotive engineering as well. By combining the most advanced chemical and physical technologies with the needs of modern applications of biomedical and forensic research. The growing demand of nanotechnology today has enabled most of the scientist and analyst to go in the efficient strategic objectives and sound skills in the field of nanotechnology.

CONCLUSION

Nanotechnology has a potential to make significant contribution in forensic science & in crime detection. Various applications of nanotechnology in the area of forensic science has been discussed in this review. So, nanotechnology serves as a important tool in the field of forensic science. In this paper, various nanotechnology methods and instrumental techniques which can be used in different field of forensic investigations have been shown. These mentioned methods conclude that the nanotechnology is fast and accurate for more reliable and secure system affiliated in forensic investigation. Therefore, nanotechnology is likely to play a major role in the future to deliver more selective and more sensitive ways which can help the investigators to solve the cases with more success.

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