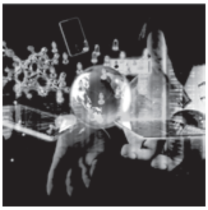

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The role and impact of Aluminium oxide nanoparticles in crime investigation

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Abstract
Nanotechnology is an important and powerful tool in most the areas including medicine, imaging, and forensic sciences. It is rapidly growing region of research with potential in various fields, running from medical care to production and physical science. Nanotechnology has a potential to make significant positive contribution in forensic science in crime detection. Forensic science applies knowledge and methods from natural science in order to identify, individualize, and assess evidence. Hence, with the aid of evidence, crime scenes can be rebuilt, investigations can be directed, and offenders can be prosecuted. Nano-analysis use tools like UV Vis spectroscopy, atomic force microscope (AFM), XRD, EDX, Raman micro spectroscopy (Raman), scanning electron microscope (SEM), and transmission electron microscope (TEM) (Raman). Moreover, in current article, an attempt was made to elucidate how nanotechnologies could be crucial in addressing current forensic investigation issues such as explosive detection, forensic toxicological analysis, finger print analysis, forensic DNA analysis, detection of explosive residue, forensic nano trackers, drug facilitated crime.

Keywords: Nanotechnology, Forensic investigation, Nano trackers, DNA analysis, explosive detection.

1. Introduction

A variety of physical, biological, and chemical disciplines are combined in nanotechnology to explore phenomena at the nanoscale scale (1 nm^{-1} billionth of a meter). One of the main aspect of nanotechnology is the synthesis of metal and metal oxide nanoparticles (McNeil, 2005). The leading method for the synthesis of nanoparticles is green synthetic access to synthesize nanoparticles of assortment of metal and metal oxides are deprecation of hazardous chemicals (Duan, Wang, & Li, 2015). Green synthesis methods has gained attention because of low cost, efficiency and relatively high yield of products. The nanoparticles can be characterized by using UV Vis spectroscopy, Infrared spectroscopy, Scanning electron microscopy, X-ray diffraction spectroscopy and EDX (Jadoun, Arif, Jangid, & Meena, 2021).

Real-time crime scene can benefit from the manufacture of nanosensors and nanotechnical equipment. Nano-forensics is an emerging field of forensic science that focuses on finding explosive gases, biological agents, and residues. (Mandal & Mandal, 2015). Research in forensic science is thought of as the process of examining, gathering, and evaluating trace evidences at the site of a crime using particular procedures and methods. These days, the application of nanotechnologies in forensic science can fundamentally alter the investigative processes by making them quicker, more accurate, more potent, more sensitive, and simpler to use, which clarifies the undeniable significance of these technologies.Identification, investigation of the crime, and making linkages between pieces of evidence and criminals are the core concerns of forensic science (Srividya, 2016).

Now, it become so easy togather, analyse, and find the complicated hidden evidence from the scene of the crime.The application of nanotechnology in forensics has only recently begun but is already showing signs of becoming a game changer (Chen, 2011). Various components of nanotechnology in medicine, genetics, analytical chemistry and forensic sciences can act as catalyst in the speed of evidence analysis in real-time (Tambo & Ablateye, 2020).

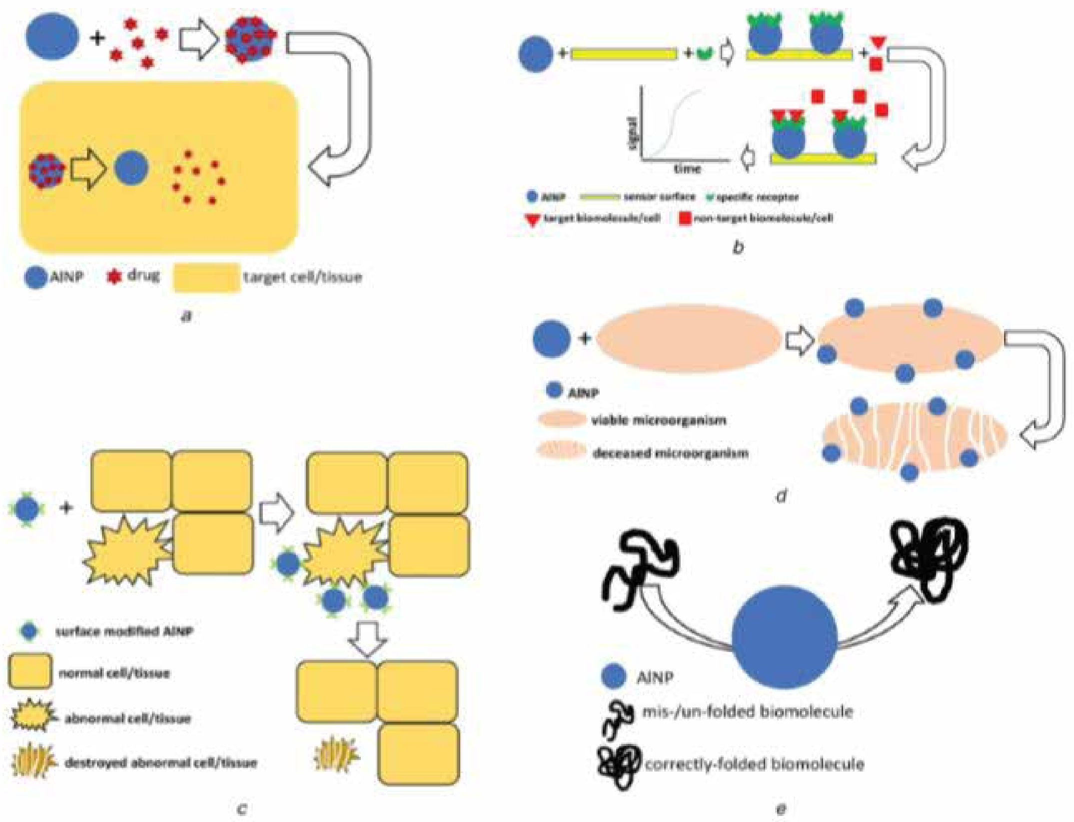
A fascinating topic in nanotechnology over the past ten years has been the development of new synthesis techniques for nanomaterials including metal nanoparticles, carbon nanotubes, quantum dots (QDs), graphene, and its composites. Two distinct fundamental concepts of synthesis i.e. top down and bottom up techniques have been applied to produce nanomaterials with the necessary sizes, shapes, and functions (Saxena, Jain, & Saxena, 2021). Nanocomposites (NCs) are materials with at least one nanoscale phase and a mixture of matrix and filler components (0-100 nm). They are very important to many industrial and technological fields as well as to forensic science. Based on their host matrix, the first NCs are divided into three groups (metal, ceramic, and polymer). They can all be applied in many situations and scenarios (Shah, Dasgupta, Chakraborty, Vadakkekara, & Hajoori, 2014).

Nanotechnology has become an essential tool in many scientific domains. The use of hazardous chemicals in the physical and chemical procedures used to synthesize metal nanoparticles has a negative impact on the environment (Gopi, Amalraj, Haponiuk, & Thomas, 2016). Green synthesis offers an inexpensive and environmentally benign alternative method for creating metal nanoparticles, which aids in limiting the drawbacks of chemical methods. Since nature provides a variety of products in the form of bacteria, fungi, and plant/biopolymers that fulfill the objective in an unharmful manner, green resources such as plant extracts, specific bacteria, fungi, and biopolymers are used to synthesize metal and metal oxide nanoparticles (Saxena et al., 2021). Due to their small size and high surface area to volume ratio, nanomaterials are extensively used in a range of industries, mechanics including medicine, optics, electronics, microbiology, material science, biotechnology, numerous engineering fields and crime investigations (Konjari, Jacob, Jayanthi, Ramalingam, & ETHIRAJ, 2015).

Al_2O_3 Nanoparticles

Aluminum oxide nanoparticle are metal oxide nanoparticles that have a variety of forensic applications due to their exceptional physicochemical/structural types, including resistance to wear, mechanical, and chemical pressures as well as their favorable optical properties/a porous huge surface area (Menaa, 2014). The extensive use of aluminum oxide nanoparticles is partly a result of their inexpensive preparation costs and straightforward handling. As a result, this investigation over analyzed the significance of aluminum oxide nanoparticles (Oliveira-Filho et al., 2016).

One aluminium atom is surrounded by six oxygen atoms, giving aluminium oxide nanoparticles (Al_2O_3NPs), a class of porous nanomaterials that are part of the metal oxide nanomaterials family, a corundum-like structure. Aluminum oxide nanoparticles, like other metal oxide nanoparticles, are easily controlled and accessible (NPs). The enormous surface area, powerful mechanical characteristics, and outstanding chemical resistance to high temperatures and harsh environmental conditions are all features of these competitively economical nanoparticles (Sadiq, Chowdhury, Chandrasekaran, Mukherjee, & Medicine, 2009). The techniques used in the synthesis include solution reduction, decomposition/gas evaporation, mechanical ball milling, laser ablation, bursting wires, and mechnochemical (Ghiuță et al., 2018).



Synthesis of Al_2O_3 NPs (Abdelghany et al., 2018).

Aluminium oxide (Al_2O_3) nanoparticles (NPs) have drawn particular attention because of its distinctive characteristics, such as excellent mechanical strength, high hardness and good chemical stability (Abdelghany et al., 2018). Al_2O_3 NPs can be produced using a variety of methods, such as laser ablation, sputtering, sol-gel, pyrolysis, ball milling, and hydrothermal procedures (Abdelghany et al., 2018).

Metallic oxides (MOs) are regarded as a further fascinating topic with numerous scientific applications. Aluminum oxide nanoparticles are among the suitable types of metallic oxides nanoparticles. Aluminum oxide nanoparticles have a variety of uses in a variety of fields, including forensic sciences (Sivaramakrishnan & Neelakantan, 2014). water remediation, biological applications, catalysts (Mittal, Chisti, & Banerjee, 2013).

Aluminum oxide nanoparticles can be produced by using waste aluminium foil. Aluminum oxide nanoparticles can be created by co-precipitating old aluminium foils at room temperature and mechanically milling. Ultraviolet-visible spectroscopy, infrared and as well as X-ray diffraction can be used to characterize their functional groups and optical activity as well as their particle size and phase (Sharma & Sharma, 2020).

In order to create stabilised zero valent Al_2O_3 nanoparticles that aggregated in a chain with individual particles having a diameter of 20 to 75 nm, ascorbic acid was used in the synthesis process. Ascorbic acid has also been employed in the stabilisation and functionalization of nanoparticles (Babaei Savasari, Shiravi, & Hojati, 2018).

Al_2O_3 nanoparticles can be produced by using the thermal breakdown technique. They employed agarose dextran/gelatin as the building blocks for the polysaccharide. They were able to produce Al_2O_3 crystals with an average size of 10 nm (Magro, Baratella, Bonaiuto, de A Roger, & Vianello, 2018).

Aluminium oxide nanoparticles can be biosynthesized by using tea extract. The extract's polyphenol/caffeine concentration served as a decreasing/capping agent. Magnetite/magnetite nanoparticles with a zero valent iron content were characterized using XRD/FTIR spectroscopy (Herlekar, Barve, & Kumar, 2014).

2. Characterization of Nanoparticles

Size and shape are two of the key elements that can be considered in the description of NPs. It is also possible to determine the size distribution, surface area, surface charge, level of aggregation, and surface chemistry (Minelli, 2016).

As nanoparticle production goes up, more accurate measurement skills will be required. It is necessary to characterize the nanomaterials produced in diverse methods more thoroughly. The description of the nanoparticle core can be important as the surface ligands can influence the physical properties (Peters et al., 2015).

Aluminum oxide nanoparticles synthesized from leaf extract can be characterized from X-ray diffraction spectroscopy (XRD), Energy dispersive X-ray spectroscopy (EDS/EDX), and Fourier transform infrared spectroscopy (FTIR)(Fahmy et al., 2018)

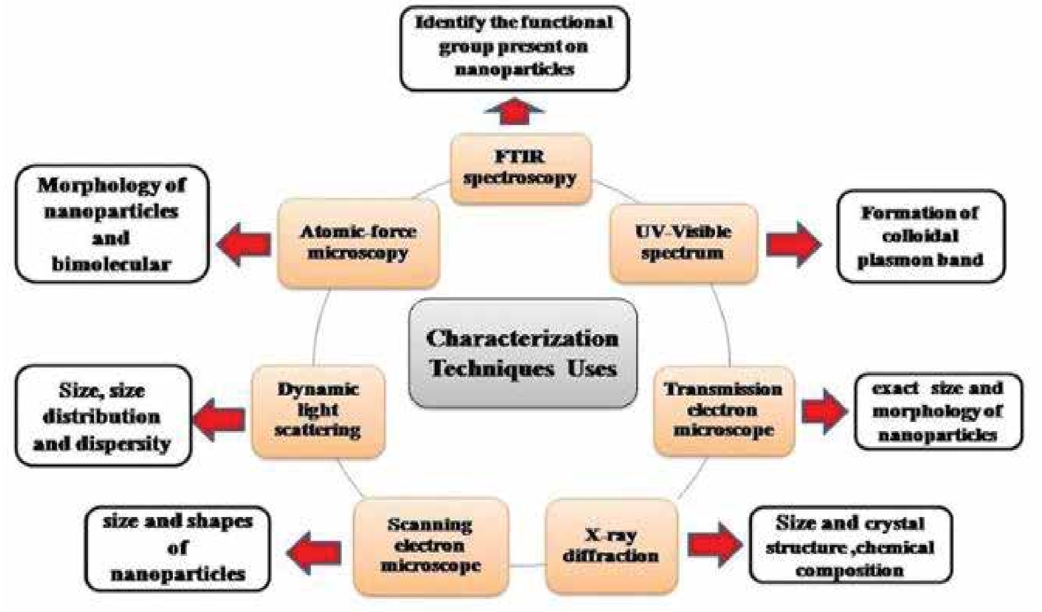


Fig 2.3 Characterization of nanoparticles (Peters et al., 2015).

3. Nanotechnology in Crime Scene Investigation

Forensic Toxicological Analysis

Nanotechnology can be used in forensic toxicology to examine various toxic substances from a variety of significant forensic evidences, including hair, blood, saliva, vitreous humour, and even skeletal remains and samples of fingerprint evidence. To increase the detection limit, gold, silver, and titanium oxide nanoparticles are frequently utilized (Mandal & Mandal, 2015). The low-cost, active, stable, and time-limited nanosensor produced with novel methodologies may be employed as an immediate spot test and a significant replacement for on-the-field testing methods for forensic toxicological drug screening (Reece & Hulse, 2014). The use of forensic nanotechnology on actual samples can successfully demonstrate how well the nanosensors are suited for toxicological investigation (Boumba & Vougiouklakis, 2015).

Fig: Toxicological analysis by nanoparticles

Forensic Fingerprints Analysis

Since the beginning of time, criminologists have employed fingerprints as a distinctive kind of evidence. Latent fingerprints may be created using a variety of coloured materials, such as carbon soot on a light backdrop or aluminium flake on a dark background. However, these products have significant flaws including fuzzy fingerprint pictures. Materials based on nanotechnology are used to tackle this issue. In 1980, latent fingerprints on the surface of porous paper were frequently seen using gold and silver nanoparticles (Prasad, Lukose, Agarwal, & Prasad, 2020). However, over the past 20 years, a number of other nanoparticles have gained popularity for the detection of latent fingerprints on porous and non-porous surfaces, including silicon dioxide, fluorescent starch-based carbon, Eu^{+3}-doped Al_2O_3, aluminium oxide, and CdS (a photoluminescent nanocrystal capped with dioctysulfo-succinate) (Pandya & Shukla, 2018).

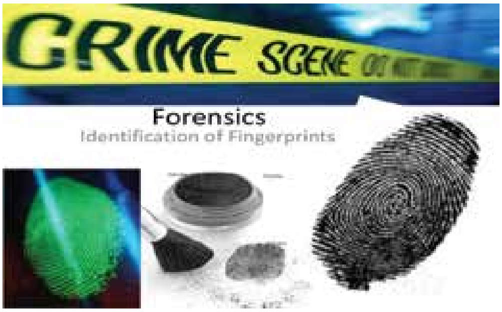


Fig: Identification of finger prints

Forensic DNA Analysis

Forensic DNA analysis is carried in murder cases, rape cases and other crime cases. DNA examination of blood stains, hairs, fibres semen can be carried out. The most latest and cutting-edge tools used for forensic DNA analysis are microfluidic devices (R. K. Singh et al., 2015). These devices have the advantages of quicker inspection times, lower contamination risks, and direct application to crime scenes. Microfluidic chip technology is another crucial advancement that has already shown promise in medical settings, including point-of-care applications (Rakesh, Divya, Vishal, & Shalini, 2015).

Fig: DNA analysis

Detection of Explosive Residue

Nanotechnology can used to determine unfragmented remnant (trace quantity) of the explosive that may stay at the crime scene, the fragmented residues of explosives (bomb explosion) are dispersed far from the actual location of occurrence (Jahangir, 2012). The trace amount of shattered explosives recovered from the crime scene may be easily identified using nanotechnology. Additionally, this technique aids the investigators in finding minute gun powder particles on the shooter's hand (Muro, Doty, Bueno, Halamkova, & Lednev, 2015).

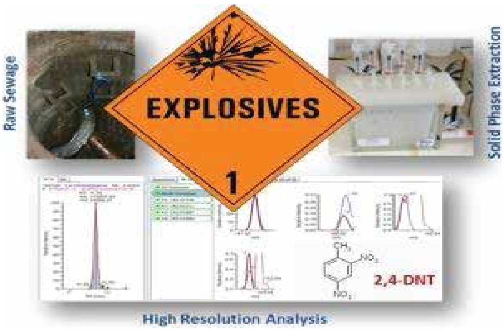


Fig: Explosives analysis

Forensic Explosive Detection

Globally, terrorist actions have escalated, which has boosted interest in finding hidden bombs. Nanomaterials offer the active potential to develop explosives detectors. Systematic and effective finding of explosives concealed in luggage, cars, and other objects. Explosives tracing is a very expensive and challenging task. Nanostructures are utilized as sensors to find various chemical and biological components, including explosives. The ultra-compact gadgets are highly capable of sensing (Sree Satya Bharati, Byram, & Soma, 2018). Dogs can recognize various types of odours including explosives; however, at the moment, dogs have been trained for detecting out hidden explosives which is too expensive and time consuming. To detect conventional bombs, grenades and plastic explosives, advanced nanosensor concept devices such as electronic noses, nanotube, and nanomechanical devices are employed. .As a result, dogs may now readily and disadvantagelessly trace using the electronic nose approach. Typically, an electronic nose has a chemical detection mechanism like an artificial neural network (Muthukumar, 2012).

Forensic Nano Trackers

Nowadays, trackers and barcodes are used to combat the crime. In order to stop people from stealing, trackers are utilized as a preventative strategy in the form of a covert pattern on the merchandise (Murray, 2022). Trackers are not only a preventative measure, but they can also be used to find lost or stolen objects. Trackers can be used for security purposes as well because they can stop prisoners from eluding capture (Lohiya & Shah). Nano trackers are put into the prisoners' bodies in this situation to help catch them if they escape. Nano trackers make it possible to keep tabs on prisoners after their release. If they commit a crime again, nano trackers make it easier to find them (S. Singh & Samal, 2021).

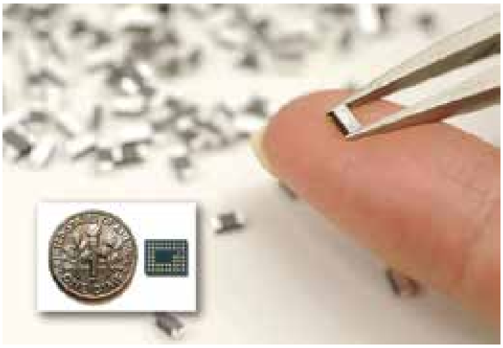


Fig: Forensic nano trackers

Drug-Facilitated Crime (DFC)

DFC, sometimes referred to as "date rape," is the use of psychotropic chemicals that impair one's ability to make decisions or regulate their conduct. These substances are utilized in a variety of criminal activities, including rape and other horrifying sexual assaults against people of all ages (minors to adults). It is also employed in robberies and financial extortion. The sensitivity, cost-effectiveness, and other instrumental constraints that forensic professionals confront when using the current standard procedures for the identification of these types of drugs are significant. Recently, with the use of nanotechnology, researchers created a clever and effective way for identifying these illegal medicines (Pandya & Shukla, 2018). This "smart" approach allows for the rapid qualitative and quantitative detection of codeine sulphate using smartphone cameras and citrate-stabilized gold nanoparticles as a probe. Because of its extreme sensitivity, this approach may accurately and immediately identify very small amounts of codeine sulphate by examining colorimetric changes in the probe. Gold nanoparticles have also proved to be efficient for the detection of trace amounts of clonazepam (S. Singh & Samal, 2021).

4. Using Nanotechnology to Estimate the Time of Death

An important aspect of a criminal investigation is estimating the exact moment of death. To anticipate the time of death in the traditional system, numerous factors are studied. postmortem hypostasis, changes in the eye, contents of the urinary bladder, rigor mortis, changes in decomposition are the various factors. However, traditional approaches can only roughly forecast the time of death. Fluorescent nanoparticles, according to researchers, might be employed in conjunction with flow cytometry to determine the quantity of amino acids (VH) (Andrews et., al 2021).

5. Conclusion

The current review explained the significance of nanotechnology in the field of crime scene investigation. The different techniques of nanotechnology in different stages of criminal investigation have been discussed. Potential of nanotechnology can make a positive social contribution and it would not only help to solve the crime but also prevent the crime. The rapid advancements in forensic science come with technological improvements in nanotechnology. In the near future, nanotechnology may assist as an innovative and preventive tool in the various field of forensic science like virtual autopsy, crime scene investigation, fingerprint identification, questioned document, ballistics, and toxicology.

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