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Mini Review

Nanotechnology: an applied and robust approach for forensic investigation

Abstract

Nanotechnology, the manipulation of matter at the atomic and molecular level to form novel materials with unusually diverse and unique properties, is a quickly expanding area of research with immense potential in several fields, ranging from health care to production and physical science. In forensic science it promises to revolutionize the applicability of micro-fluidic systems in post-polymerase chain reaction (PCR) quantification, DNA extraction media, fingerprint visualization using nano-powder. In general, Forensic Nanotechnology will transform the bulky instruments into small chip-based platforms, and shorten analysis methods to make investigations, sensitive, timely, and applicable.

Keywords: nanotechnology, forensic, fingerprint, dna, micro fluidic system

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Anand S Lodha,[1,2] Alok Pandya,[1] Ritesh K Shukla[1]

[1]Ahmedabad University, India
[2]Department of Forensic Science, Gujarat University, India

Correspondence: Ritesh K Shukla, Institute of Life Sciences, Ahmedabad University, Ahmedabad- 380009, India, Tel 91-79-26302414-18, Email ritesh.shukla@ahduni.edu.in

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Abbreviations

PCR, polymerase chain reaction; PETN, pentaerythritol tetranitrate; Ag-PD, silver physical developer; PSMA-b-PS, poly (Styrene-alt-maleic anhydride)-b-polystyrene; GNP, gold nanoparticles

Introduction

The advent of nanotechnology is taking control of atoms and molecules individually, modifying and placing them to use with an extraordinary degree of accuracy. The word 'Nano' comes from Greek word means dwarf, which refers to one billionth (10-9) mean about nanometer (nm). In general, to understand one nanometer is about 3-5 atoms wide or 40,000 times smaller than the width of human hair or a virus that typically 100 nm in size. It deals with emerging material or devices having size equal to 100 nm or lesser. Nanomaterials are applying in different areas including electronics, engineering, physical sciences, materials sciences and also found its application in the field of medical science.[1] Its application starts from the production of UV protective sunscreen to advanced drug delivery systems, cancer therapeutics, and nano-based devices. This new paradigm of medical science has been termed as 'Nanomedicine'.[2] Nanotechnology is sometimes referred as a universal purpose technology since in its advanced version it will have substantial impact on almost all industries and all areas of civilization.[3] Therefore, degree of expansion of such technology in forensic investigation is plentiful and here, in this paper an attempt was made to discuss the role of nanotechnology with respect to its application in different fields of forensic science, shown in Figure 1.

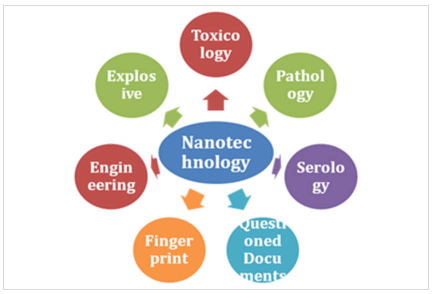

Figure 1 Application of nanotechnology in the various field of forensic science.

Forensic toxicological analysis

In current scenario nano technology most effectively applied in the field of forensic toxicology for detection and quantification of different toxic substances from various forensically important evidences like, blood, saliva, hair, vitreous humor and even from skeletal remains and fingerprint samples. Recently Hou 2015 has explored the spectroscopic properties of the nanoparticles and their potential application to identify the illicit drug like cocaine in fingerprint samples. For identification purpose gold nanoparticle (10 nm & 30 nm), silver nanoparticles (20 nm), and titanium oxide nanoparticles (15 nm) have been used and claimed that these nanoparticles enhance the detection limit of the illicit drugs in fingerprint samples.[4] Furthermore, Lodha et al.,[5] have developed a sensor to identify the drug clonazepam (date rape drug) using melamine modified gold nanoparticles from blood and skeletal remains samples.

In addition codeine sulphate, a narcotic substance were investigated with smart phone application as new approach in on spot crime scene forensic examination of illicit drugs from skeletal remains which claims the portability in future investigation with the help of gold nanoparticles.[6] Similarly lidocaine hydrochloride were investigated from vitreous humor as alternative body fluid for on spot, portable, lab on phone approach of postmortem drug screening which another advancement to provide the advance platform for the future investigations based on forensic nanotechnology.[7] The sensors developed with this novel approaches might be used as a preliminary spot test and a good substitute means for on-field test, low-cost, rapid, reliable and real time screening methods for forensic toxicological drug screening. Forensic nanotechnology was successfully applied to real samples to illustrate the applicability of the developed nano sensor for toxicological investigation.

Forensic DNA typing

At present the quantification of post-PCR (polymerase chain reaction) is the utmost extensive forensic nanotechnology application of the micro fluidic systems. In a very short period of time i.e., within 30 minutes DNA samples can be quantified even in nanoliter range using commercially available Agilent 2100 bioanalyzer. These systems are presently being used to quantify mitochondrial DNA in many forensic science laboratories. Due to their small size, the prospective of such devices being used at the scene of crime is extensively specified. Furthermore, these small devices are performed rapid, disposable that necessitates minimal cleanup and maintenance that will edge the technology.[8] It is also very crucial in Forensic DNA typing to extract the good quality PCR ready DNA samples for DNA typing and many authors used magnetic nanoparticles, silica based magnetic nanoparticles and copper nanoparticles for extraction of good quality PCR ready DNA samples from different forensically significant body fluids and skeletal remains samples.[9] Nanoparticles have received considerable attention in biology and medicine because of their promising applications. Pan et al.,[10] apprehended hot start-like effect in gold nanoparticle-based PCR, which has promising applications in nanobiological and biomedical studies. DNA extracted from urine using organic reagents while carboxylated magnetic nanoparticlesare used as solid phase adsorbents to isolateintact DNA for PCR amplification.[11]

i. Forensic explosive detection

From the last two decade, terrorist activities increased globally and it has drawn attention to detect hidden explosives and needs to call for new advanced technologies to combat such type of activities and protect the public. There are more than 4400 of a total of 12000 terrorist attacks were undertaken using explosives. Over 20000 people were killed worldwide and more than 30000 were injured as a result of these attacks.[12] The number of suicide bombings has increased by almost 60% since 2005.[12] Efficient detection of hidden explosives in luggage, mail, vehicles, aircraft, toothpaste as well as on suspects is the major challenge for law enforcement agencies throughout the world. Currently, trace based explosives detection systems in use which have limitations in selectivity, sensitivity, size, and certainly cost. Miniaturization of systems to bench top or even handheld levels has immense potential, especially for trace explosive detection. Detecting explosives is a very intricate and costly task because of a number of factors, such as the wide variety of compounds that can be used as explosives, the vast number of deployment, and the lack of inexpensive sensors providing high sensitivity and selectivity simultaneously.

Hence, high sensitivity and selectivity, combined with the ability to lower the production and deployment costs of sensors, is indispensable in winning the battle on explosives-based terrorism. The modern research and development studies in the area of nanomaterials have demonstrated the ability of nanostructures to function as sensors of various chemical and biological compounds including explosives. Ultra-small devices with high sensing capabilities are among the key promises of the nanosensor domain. Electronic noses, nanocurcumin based probe, lasing plasmonnanocavity, nanowire/ nanotube and nano mechanical devices are nanosensor concepts with the strongest potential to form viable technological platforms for trace explosive detection.[13–17] Recently, an antibody was developed against the explosive pentaerythritol tetranitrate (PETN).[18] At present, dogs have been trained and used successfully for sniffing out hidden explosives; however, dogs are costly to train and are easily tired. The electronic nose technique can mimic the bomb-sniffing dogs without their drawbacks. Overall, nanotechnology based sensors have strong potential for meeting all the requirements for an effective solution for the trace detection of explosives.

ii. Forensic fingerprint visualization

The impressions left by the friction ridges of the finger, most often referred to as finger marks. These finger marks are not only exhibit contact with the surface/articles but also enable to identify the person. Mostly three types of fingerprints are found i.e., latent, patent and plastic. Almost every crime scene carries latent prints which are not easily visible to naked eyes and need further processing. To decipher the latent fingermarks, a range of physical and chemical methods has been developed. Powder methods are most common to develop latent fingermarks. The best fingerprint powder will stick or adhere to the sweat residues left by the finger, which give rise to the characteristic patterns that make latent print to coloured or fluorescent visible print based on type of powder used. Various common materials adhere to the background, making a clear identification considerably tougher to achieve. To overcome such problems and for more preciseness nanotechnology is being used to develop fingerprint. To decipher the fingerprint pattern nanoscale powders have been used. Various studies have been reported in which nanopowders help to decipher the fingerprint and recently one of them reported that Zinc Oxide powders with 20 nm size that give better prints and UV fluorescent compare to others.[19] Moreover their developed methods work on wet condition too where traditional powders cannot to do so. Mike[19] has developed a novel approach which opens a new paradigm in forensic science to solve gunshot/firing cases.

In this study using a nanoscale developer and an X-ray source a technique has been developed that can be able to visualize the imprinted fingerprints even if the casing has been rubbed or washed based on the fact that when someone leaves those finger impression on the bullet casing.[19] Moreover, a study replaced the traditional gold solution with a more stable equivalent gold nanoparticles bristle with long hydrocarbon chains suspended in petrol ether. The result revealed that gold nanoparticles adhere to the surface with sweat residues through hydrophobic interactions which can be then developed with silver physical developer (Ag-PD), producing dark impression of ridge detail that not only improve the quality of the developed print but also the clarity of the print.[17] Similar group has also developed another method of fingerprint enhancement using cadmium selenide/zinc sulfide nanoparticles (CdSe/ZnS NPs) suspension for non-porous surfaces. CdSe/ZnS nanoparticles have potential to give fluorescence under UV light.

Therefore, fingerprint developed with the help of these NPs can be observed directly and no additional method of fingerprint development is required.[20] Fernandes et al.,[21] have reported that the use of hybrid nanopowders can improved the visualization of latent fingerprints on multi-coloured or patterned backgrounds. Song K et al.,[22] described a general approach integrates the merits of both colorimetric imaging and photoacoustic imaging for Latent Fingerprint visualization using poly (styrene-alt-maleic anhydride)-b-polystyrene (PSMA-b-PS) functionalized gold nanoparticles (GNPs). These incredible successes in the field of latent fingerprint development attract the forensic scientist and researcher towards fingerprint development using nanotechnology.

Conclusion

Challenges to unlock the potential of the nano-technology for viable explosive or toxic substances detection applications relate to providing stability, sampling and reliable calibration. Use of nanosensors with advances along with conventional detection platforms (e.g. electronic nose concept) seems to be the most promising approach for the development of advanced solutions. In addition to technical challenges for developing novel nano enabled detection methods there are several overarching operational and policy considerations impacting the deployment of these technologies for protecting public from terrorism threats. This review article shows clearly the potentiality use of nanotechnology like nanosensors for explosive detection, DNA fingerprinting, fingerprint enhancement. Before it comes into the regular applications in the field of forensic science, many other things needs to be addressed for the future perspectives like efficiency, cost cutting, accuracy of amalgamation of technology and safety aspects of health and environmental.

Nevertheless, the routine use of nanotechnology in the forensic practice is still limited, probably as a consequence of that many of the reported developments were not applied to samples with the grade of complexity that is required. Therefore, major research efforts should be made in the near future to ensure use of nanotechnology better equipped for these samples, in order to enhance the robustness and reliability necessary for a real applicability to this field. This technology is going to transform the various fields of forensic science including molecular biology, virtopsy, crime scene investigation, fingerprint enhancement, ballistics and forensic toxicology. In future, it will clear trends to be taken into account for an effective translation of the laboratory to the real world.

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Conflicts of interest

The author declares that there are no conflicts of interest.

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