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Mini Review

Nano-Forensics a Comprehensive Review

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Abstract

Nanotechnology is becoming popular in today's world, with the nano-revolution touching almost in every field. It offers a promising application in electronics, diagnosis, biosensing, drug delivery, and imaging. Nano-Forensic is emerging as a novel discipline in the field of forensic science. Nanotechnology has been utilized extensively in forensic science to detect and analyse evidence at a nanoscale level. Nano analysis is transforming the investigation process by making them more accurate, faster, and more sensitive. As nanomaterials have the property of enhancing the detection limit at nanoscale level it has been widely used to detect fingerprint, explosives, unlawful drugs, toxic substances and DNA samples.

Keywords: Nano-sensors; Forensic science; Nano-forensics; Nano-PCR

Introduction

Nanotechnology is making a valuable contribution in every field. It is a widely used technique because of its ability to manipulate and characterize the matter at a level of single atoms and small atoms [1]. The word "nano" is derived from the ancient Greek "Nanos," meaning "dwarf," which refers to the "billionth" or a factor of 10-9. In general, to understand 1nm is about 3-10 atoms wide. It is very tiny when compared with the standard size encountered day-to-day. E.g., 1nm is 1/1000th the width of human hair. Nanotechnology described the study aspect concerning the science, engineering, and technology conducted at a scale that ranges between 1 to 100 nanometers [2]. The potential of nanotechnology in electronics, diagnostics, biosensing, imaging, optical devices, and drug delivery due to their small size, large surface area, and enhanced reactivity [3-7]. Its multi-purpose application in almost every field has made it a universal purpose technology [2]. Therefore this universal technology has a plentiful of applications in the field of forensic science. Nano-Forensic, an exquisite blend of nanotechnology and forensic science, is entirely a novel discipline in forensic science. Nano-Forensic helps identify and examine evidence at the nanoscale level as earlier, it is impossible to analyze the critical evidence because of the instrument's detection limit. With advancements in the techniques, Nano analysis is transforming the investigation process by making them more accurate, faster, and more sensitive [8,9]. Nano forensic and other technologies have significant fingerprint analysis applications, explosive detection, drug screening, toxic substance analysis, and DNA analysis [10,11]. This review would briefly update how nanotechnology is widely used in forensic analysis of evidence.

Nanomaterials for latent fingerprint analysis

Nanoparticles have been used for decades to develop the latent fingerprint, with silver nanoparticles being used from 1970. The small size of nanoparticles allows them to bind with the minute ridges of a fingerprint, further enhancing the ridge details on fingerprints and

sweat pores. Morris presented that silver nanoparticles can be used as physical developers to visualized latent fingerprints on paper [12]. During the reaction, the silver nanoparticles formed with the organic constituent of fingerprints, which develop the fingerprint in dark grey or black sliver image on the porous surface [13]. Gold nanoparticles are beneficial for latent fingerprint analysis as they are inert, highly selective, and sensitive. It has the advantage that latent print produced by gold nanoparticles can be store for a longer duration. Gold nanoparticles are used to improve latent fingerprints' visibility by multi-metal deposition (MMD) and single metal deposition due to these properties [14,15].

Quantum Dots and fluorescent materials have gained significant attention due to their small size and excellent fluorescent intensity. A study carried out by Dr. Roland Menzel [16] shows that Quantum Dots can visualize [16]. Quantum dots can also be used for the development of bloody fingerprints. Bloody fingerprints have high chances of smearing and contamination, which can damage the ridge details in fingerprints. It was overcome by quantum dots having the fluorescence property used to analyze bloody prints [17]. The study shows that incorporating the minor amount of ZnO-SiO2 nanoparticles in powder increases the visual enhancement of latent print to third-level ridge details of prints [18]. Carbon nano powder has been developing for the visualization of prints against multi-colored or patterned backgrounds [17].

Role of nanoparticles in explosives detection

Explosives-based terrorism has been rising for the last few years. Explosives such as bombs, improvised explosives devices (IEDs), grenades are causing widespread mass destruction [19]. Over the year, various sensing devices have been developed for the detection of trace explosives. Because of nanomaterial's unique electrical and optical properties, it is widely used to develop low-cost sensors. Sensing of the explosives is usually done through biologically based sensors [20]. Immunosensing techniques provide a great sensitivity in detecting the TNT with a detection limit as low as 0.09g/ml [21]. Frances S et al. [22] prepared a capillary immunosensor for the specific TNT detection by using the Anti-TNT antibody [22]. Carbon-based nanomaterials, including carbon nanotubes, graphene, and carbon nanoparticles, have properties like chemically inert, low cytotoxicity, high biocompatibility, and unique electronic properties the applications of these materials as sensors. Chen et al. utilized graphene oxide as an oxidized derivative of graphene to detect nitroaromatic explosives. They constructed the graphene-based sensor and analyzed compounds like dinitro toluene (DNT), dinitrobenzene (DNB), and trinitrobenzene (TNB) [23].

Nanomaterial in DNA analysis

DNA analysis has a tremendous potential benefit for the civil and criminal justice system [24]. It establishes the identity of an individual in forensic investigation. Nowadays, nanoparticle-based methods influence DNA analysis because of their low cost, easy automation, and convenient operation. Precisely, the magnetic nanoparticles are used to extract DNA because of increased sensitivity and high DNA yield. Nongyue He et al. used the Fe3O4 nanoparticles to extract nucleic acid from four different sources such as bacteria, yeast, human blood, and virus. The results showed that using magnetic nanoparticles to extract nucleic acid gives the high yield and relatively high purity of nucleic acids [25].

Sensor-based DNA detection technique has applications in DNA analysis. Mostly the gold nanoparticles are used for sensing mechanisms because of their optothermal property. Cheong, et al. [26] used Au nanorods for the extraction of DNA from the cell. Using the optothermal property researchers transformed the near infra-red energy into the thermal energy in a microfluidic chip that results in lysis of pathogen and eventually in the extraction of DNA [26]. Apart from gold nanoparticles, silica nanoparticle-based assay also detects DNA with the great sensitivity of 10pM [27]. The NanoPCR, a nanoparticle assisted PCR, is gaining considerable attention because of its specificity and reaction speed. Various types of nanoparticles like carbon tubes, quantum dots, and metal nanoparticles are introduced into the PCR technology. These nanoparticles are improving the efficiency and specificity of PCR products [28-30].

Nanoparticles in illicit drug analysis

The demand for illicit drugs is continuously increasing. Cannabis, amphetamine-type substances, cocaine, and heroin continue to be the most prevalent illicit drugs, but comparatively, new psychoactive agents have also been increasing in the market. In criminal investigations, drug analysis is a significant branch of modern analytical chemistry with many legal and socially applicable consequences. With the advancement in technology, sensing devices are used to detect drugs [31]. Sensing using nanoparticles usually takes place through colorimetric, fluorescence, and electrochemical sensors [32,33]. Gandhi, et al. [34] reported the development of dipstick assay based on the AuNP labeled single-chain fragment variable (scFv) antibody for the detection of morphine. The developed dipstick is suitable for analyzing the morphine from different biological fluids like blood, urine, and saliva [34]. Au nanoparticles show a significant Surface Plasmon Resonance phenomenon. It is used in colorimetric sensors. Gao et al. used a colorimetric sensor based on aptamer and molybdenum disulfide (MoS2)-gold nanoparticles (AuNPs) to detect cocaine. This sensor has been found to be rapid, cost-effective, and highly sensitive [35]. Different quantum dots techniques along with the other techniques, are also being used for fluorescence-based sensing because of their excellent quantum yield and fluorescence [36].

Conclusion

The potential of nanotechnology is making a positive contribution to forensic science to solve the crime. Various types of nanoparticles are in use for the detection of various forensic samples. Nano-sensors applications in Nano-forensics are due to high sensitivity. Further, Nano-Forensics has made the investigation process rapid. Nanotechnology can benefit in the future as an advanced and preventive tool in different field of forensic science.

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