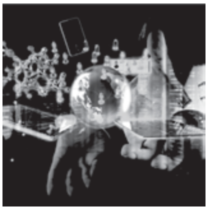

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ZnO Nanoparticles: Synthesis, Characterization and Applications in Forensics

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Abstract:

In most fields, including health, imaging, and forensic sciences, nanotechnology is a significant and potent tool. It is quickly expanding and has potential in a number of areas, including industries, physical science, and medical care. ZnO nanoparticles has potential in advance forensic science and aid in crime detection. Advanced art analytical techniques can be used in characterization of ZnO nanoparticles, such as High-performance liquid chromatography (HPLC), X-ray diffraction spectroscopy, and SEM. Nanotechnology forensic investigations include questioned documents, in estimating the time of death and age of blood. Moreover, nanomaterials can be used for forensic inquiry, such as quantum dots, which can be employed as luminous materials for security features in official and private documents. Therefore, the purpose of this study was to introduce and explain the application of ZnO in forensic science as well as the equipment needed to conduct nano-analysis.

1. Introduction

With the development of nanotechnology, it is now possible to manipulate a substance's atoms and molecules at the atomic and molecular level to create unique materials and devices with a wider range of potential remarkable qualities. The word "Nano" relates to one billionth size, or 10^{-9}, which is equivalent to around one nanometer and denotes little (nm). In other terms, it is 40,000 times thinner than the width of a virus or human hair, or around 3-5 atoms broad (100 nm).Thus, nanotechnology is concerned with new materials that range in size from 1 to 100 nm (Hofmann et al., 2020). The newest and fastest-growing area of innovation that deals with the use of nanotechnology is called nano-forensics (Oh, Park, & Choy, 2011). With the development of nanosensors, huge, heavy instruments have been replaced with considerably smaller chip-based platforms. ZnO nanoparticles substantially facilitates the investigation of crimes and also helps to locate anonymous evidence using a quicker analysis technique of investigation with more sensitivity and precision. ZnO nanoparticles can be characterized by SEM, TEM, XRD, EDX, FTIR spectroscopy and Raman-IR radiation

(Smijs, Galli, & van Asten, 2016). The unique characteristics of nanomaterial aid in the discovery and gathering of crucial data that was previously impossible to get. ZnO nanoparticles can be used in explosives detection, DNA extraction from fingerprint or palm print are a few cutting-edge techniques that make it easier to provide concrete evidence in a court of law. Therefore, an effort has been made in this work to highlight the novel viewpoint or notion of nanotechnology with its applications in several forensic science areas, i.e., nano-forensics.

Nanotechnology

Nanoparticles are the cornerstone of nanotechnology. Nanoparticles range in size from 1to100nm. Different kinds of nanoparticles, including inorganic, organic, ceramic, and carbon-based nanoparticles are important (Kausar, 2020). The top-down strategy and bottom-up approach are two methods used to create the nanoparticles (Ijaz, Gilani, Nazir, & Bukhari, 2020).

Synthesis of Zinc oxide nanoparticles

The two major kinds of ZnO nanoparticle synthesis methods are the bottom-up and top-down approaches. Based on the types of processes involved, the top-down method can be split into 2 broad classes, physical and chemical. Physical Top-down technique encompasses the standard method of metallurgy. The metallurgical synthesis of ZnO nanoparticles is classified into 2 types. The first one is the direct process in which any ore of zinc heated with anthracite for the reduction of zinc .It is followed by the zinc vapour oxidation. It then leads to the ZnO powder formation, It is then followed by indirect(-French)process,where the metallic zinc melts,then vaporization at approximately 910^{0}C to give ZnO nanoparticles takes place (Jamkhande, Ghule, Bamer, & Kalaskar, 2019).

Mechanochemical (or mechanical attrition) production of ZnO nanoparticles is one of the chemical top-down approaches. Figure 3 depicts the usual fabrication process of ZnO nanoparticles using this process. In this process, sodium carbonate(Na_2CO_3) and zinc chloride($ZnCl_2$) are ground in enormous ball mills. Ground (NaCl), a solvent, function is to provide the reaction media,separating the resulted reaction mixture.The mixture is then heated between 170 and 380 degrees Celsius to obtain powdered ZnO.Although the mechanochemical process is a cheap way to create large amounts of ZnO nanoparticles.It may take some time to uniformly grind zinc oxide powder and reduce granules to the necessary size resulting in extended millingtime (Otis, Ejgenberg, & Mastai, 2021).

Bottom up approach includes the green synthesis. With the advent of green chemistry and scientists all over the world are introducing green synthesis techniques to produce nanoparticles. This technique of synthesis does not include the use of chemicals that are toxic, but rather environmentally beneficial resources such as plant parts with biomedical applications (flowers, leaves, roots, etc.) and microbes (fungi, algae, bacteria) (Bandeira, Giovanela, Roesch-Ely, Devine, & da Silva Crespo, 2020). Unlike the chemical technique, this method of synthesis also regulates the creation of hazardous byproducts. In addition to being safe, the advantages of this method over others include cost-effectiveness and manufacturing of impurity-free nanoparticles (Basnet,Chanu,Samanta,&Chatterjee,2018).

ZnO nanostructures can be created using an environmentally friendly method. Natural materials include phytochemicals that serve as both capping and reducing agents, such as polyphenols and terpenoids. The polyphenols (or other phytochemicals) and zinc ions in the solution of the natural extract combine to generate Zn^{+2}, which is a compound. Following this, zinc is hydrolyzed to produce zinc hydroxide ($Zn(OH)_2$), and following calcinations, the complex disintegrates, and aid in the production of ZnO nanostructures (Sana et al., 2020).

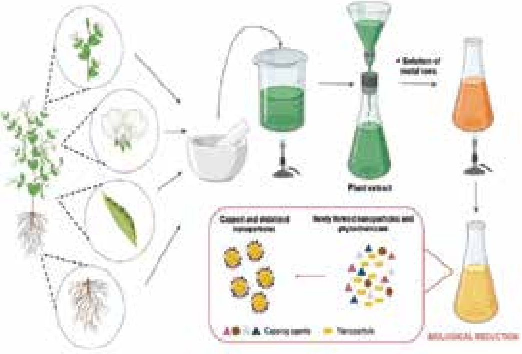

Fig: Green method for ZnO nanoparticles synthesis

Characterization of ZnO Nanoparticles:

Two important characteristics that may be considered important are size and structure of ZnO nanoparticles. Additionally, the particle sizes, surface characteristics and amount of agglomeration may be determined. The common techniques of characterizing ZnO nanoparticles are UV–visible spectrophotometry. Utilizing UV-visible spectrophotometry, distinctive peaks at different absorptions can be observed showing formation of metallic nanoparticles are formed from their respective metallic salts (Noruzi, 2015). Fourier transform infrared spectroscopy (FTIR) is also an important characterizing technique which can effectively analyze the type of the functional groups and their role during bioreduction. To learn more about the functional groups involved for bioreduction, the FTIR spectra of fabricated nanoparticles and virgin plant biomass/extract can typically be compared. (Srinivasan et al., 2019). X-ray diffraction (XRD) is used to study structural data concerning crystalline metallic nanoparticles. The powerful X-rays may penetrate into materials deeply and provide details about their bulk structure (Patil, Ryu, & Kim, 2018). The topography and morphology of the nanoparticles may be learned using scanning electron microscopy.Energy dispersive X-ray spectroscopy may be used to figure out the elemental composition of metallic nanoparticles. Each element has a distinct atomic structure that results in a distinctive collection of peaks on its X-ray spectrum. This allows the elements to be characterized (Thakur et al., 2022).

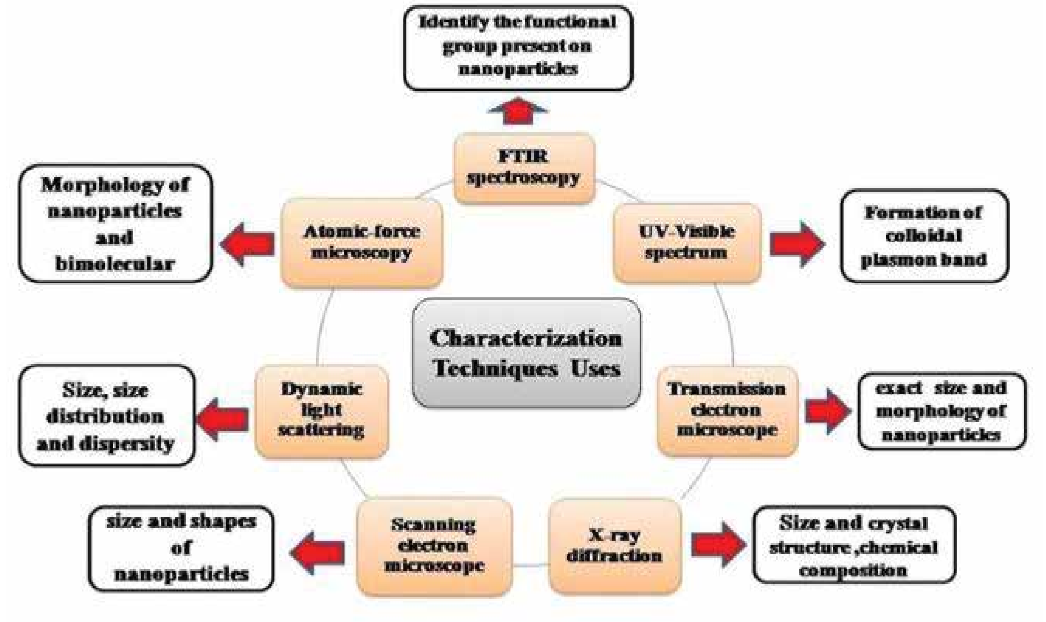

Fig : Characterization of ZnO nanoparticles

2. Applications Of ZnO NPs

Fingerprints Analysis

Fingerprints are regarded as crucial evidence at scene of the crime since they serve as significant physical evidence and may be used to positively identify a suspect. The traditional techniques for developing fingermarks occasionally have drawbacks such limited contrast, low selectivity, strong background interference, and toxicity. (Kesarwani, Parihar, Sankhla, & Kumar, 2020). ZnO is a great material because of its broad bandgap (3.37 eV), high excitation binding energy (60 meV), which allows it to transition at room temperature, and additional adhesive property, which facilitates fingerprint residue interaction with lipids and proteins at ambient temperature. In the form of nanopowder, ZnO nanoparticles were employed to generate aged, LFPs on non-porous surfaces (Deepthi et al., 2018)ZnO nano-powders (20 nm) have recently been discovered by Sydney University researchers to spontaneously glow in UV light when exposed to moisture, in addition to producing clear prints. When lit by long-wave UV light, ZnO nanostructure provides a fine fluorescent image of the LFPs. A team of researchers discovered unique ZnO-SiO_2 nano-powder for the detection of latent fingerprints on diverse surfaces. This nanopowder is extremely effective in visualising the finger ridge in great detail, which is crucial for criminologists (Lodha et al., 2016).

Fig: Finger print analysis by ZnO NPs**DNA**

Analysis

The advancement and improvement of DNA analysis looks to be the most promising use of nanotechnology. DNA may now be extracted, amplified, separated, and sequenced more quickly and conveniently by use of nanotechnology. In addition to revealing the physical characteristics of the owner of the DNA, such as gender, age, the colour of the hair, eyes, and skin, among other things. Nanotechnology is also assisting the detectives in determining the origin of DNA. It does not matter whether the DNA lifted from the crime scene came from saliva, blood skin,s emen, etc. DNA is now extracted from several biological sources, including blood, hair, skin, semen, and saliva, using magnetic nanoparticles. By placing the sample in a carbon nanotube, it is now also able to analyse DNA sequence using AFM (Prasad, Lukose, & Prasad, 2016).

Biosensors

ZnO nanoparticles might be interesting materials for forensic applications as biosensors might be due to their luminescent characteristics, electrocatalytic activity, and excellent performance towards latent fingerprints detection (Naik et al., 2021).

Explosives Detection

Due to several circumstances, detecting explosives is the major problem for law enforcement authorities worldwide. These factors includes the various compounds that have a potential to explode, andthe absence of inexpensive sensors with simultaneous high selectivity and sensitivity. In order to defeat explosives-based terrorism, high sensitivity along with the ability to reduce the costs of sensor production and deployment, are essential (Bhatt, Pandey, Tharmavaram, Rawtani, & Mustansar Hussain, 2020). In addition, various nanosensor devices, including electronic noses, nano-curcumin based probes, lasing plasmon nanocavities, nanowire/nanotube, and nano-mechanical concepts, are used to create workable technological platforms for trace explosive detection (Prasad et al., 2016). Nanotechnology plays a significant role in the study of nerve agents and trace explosives (To, Ben-Jaber, & Parkin, 2020).

3. Conclusion

Applications of nanotechnology for the detection of explosives or dangerous compounds relates to stability, sampling, and accurate calibration. The most promising strategy for the development of advanced solutions appears to be the combination of modern nano sensors with traditional detection platforms.The review paper makes evident the possible applications of nanotechnology, such as fingerprint enhancement, DNA fingerprinting and explosive detection. The different branches of forensic science ,fingerprint enhancement, crime scene investigation, ballistics, and forensic toxicology, will undergo radical change as a result of this technology. For a successful transition from the lab to the real world of tomorrow, it will be important to take into consideration certain patterns.

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