IJEAS) ||Volume 2|| ||Issue 2|| ||2016||

Article · January 2016

3 authors:

Vandana Prasad
Sharda University

Sally Lukose

Lalit Prasad
Galgotias University

International Journal of Engineering and Allied Sciences (IJEAS)
||Volume 2|| ||Issue 2|| ||2016||
ISSN: 2455-2054

Emerging Forensic Applications of Nanotechnology

Vandan Prasad[a], Sally Lukose[b], Lalit Prasad[a]*
[a]School of Basic and Applied Sciences, Galgotias University, Greater Noida, Uttar Pradesh, India
[b]College of Traffic Management, IRTE, Faridabad, Haryana, India
*[a]Email : lalit.prasad@galgotiasuniversity.edu.in
[a]pvandanajhs@gmail.com
[b]slukose@irte.com

---ABSTRACT---
This paper reviews the vital application of nanotechnology in the field of forensic science. It highlights the application of a classic tool of nanotechnology, the Atomic Force Microscope (AFM) in diverse field of forensic investigations including questioned documents, in estimation of time of death and age of blood stains, along with it this paper discusses the application other advanced nanotechnology instruments which have been used in forensic investigation such as High-performance liquid chromatography (HPLC), X-ray Photoelectron Spectroscopy (XPS) and Time-of-flight Mass Spectroscopy (Tof-MS) for drug analysis. In addition to this, it illustrates the application of nano-materials which has been applied towards forensic investigation like quantum dots used as luminescent materials for security features in official and confidential documents, Au-NPs used in latent fingerprint development as well as in DNA fingerprinting and nanosensor used in explosive detection. Therefore, this paper aimed at introducing and discussing nanotechnology as applied in forensic science along with instrumentation used in performing nano-analysis.

Keywords- *Nanotechnology, forensic, latent fingerprints.*

I. Introduction

The word 'Nano' comes from a Greek word means dwarf, which refers to billionth (10^9) mean about a nanometer (nm) [1].Therefore nanotechnology deals with emerging materials or devices having a size equal to 100nm or lesser [1]. Thus, nanotechnology is defined as the study and control of matter on an atomic and molecular scale, with structures of the size generally 100nm or smaller [2]. In the current scenario, nanotechnology is making a valuable contribution in various scientific fields in science and technology today including electronics, engineering, physical sciences, and material sciences and also found its application in the field of medical science [1].

Since the advance of nanotechnology used in other fields to study nanomaterials have also been adapted/ modified and found uses in forensic science including High performance liquid chromatography (HPLC), Scanning Probe Microscope (SPM), Infrared Radiation (Fourier Transform Infrared Radiation (FT-IR and Raman-IR), Differential Scanning Calorimetry (modulated DSC), X-ray Photoelectron Spectroscopy (XPS) and Time-of-flight Mass Spectroscopy (Tof-MS), Atomic Force Microscopy (AFM).Recently these instruments have led to the major development in forensics since these can detect and analyze a sample in the nanoscale, critical evidence that could not be collected and analyzed before due to the detection limits of the previous instruments can now be analyzed and used to support the investigations by the help of these instruments [2,3].

In addition, nanomaterials possess novel properties that can assist the collection and detection of evidence which can't be acquired previously. Some examples include trace amounts of gunshot residues, heavy metals, explosives, DNA on fingerprint or palm prints, and so on [2]. Therefore, the degree of explanation of such technology in a 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 is shown in Fig.1.

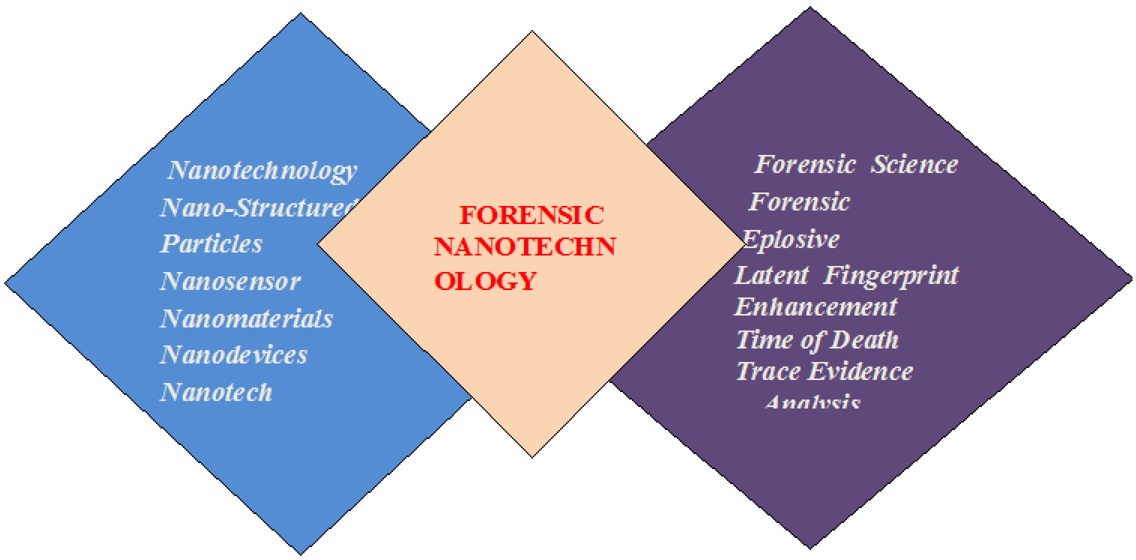

Figure.1 Forensic nanotechnology combines the technologies and approaches of nanotechnology to improve the science of crime detection and analysis

II. EXTENSIVE LITERATURE SURVEY

In the field of forensic science for the investigation, different types of nano- techniques have been used so far. We had gone through various research papers, the methods and the instrumentation used in each work are shown under this section:

2.1. Nanotechnology in explosive detection

In recent years, explosive-based terrorism has grown enormously because explosive-based weapons are simple, easy to deploy, and can cause enormous damage. 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 [1].

Detecting explosives is the major challenge for law enforcement agencies throughout the world as it 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 [1]. Therefore, the modern research and development studies in the nano arena have demonstrated the ability of nanostructures to function as sensors of various chemical and biological compounds including explosives. An example is the use of polymer particles and nanoparticles that, when bound to an explosive molecule, change one of their measurable properties by providing high specificity detection [4] along with this various nanosensor devices such as electronic noses, nano-curcumin based probe, lasing plasmon nanocavity, nanowire/ nanotube, and nano-mechanical concepts are used to form viable technological platforms for trace explosive detection [1]**.**

2.2. Nanotechnology and questioned documents

Technologies to study forensic materials has also moved to the nanoscale (in the order of nm) 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 [2]. The 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. [2 and 3].The depth of ink crossing, amplitude and phase images of ink on paper and crossing sequence can be clearly determined [5].

2.3. Nanotechnology in the 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 antemortem 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 viscoelasticity 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 viscoelavity 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 [5].

2.4. Nanotechnology in the examination of bloodstain

In forensic science, the examination of blood stains represents a major application during crime scene investigation. There exists a lot of reliable methods for the detection and identification of blood spots for the evaluation of suspected bloodstains solutions such as phenolphthalein, tetramethylbenzidine can be used, as they change color when they come into contact with peroxidase or hemoglobin in the blood. However, the determination of the age of a blood spot remains an unsolved problem in forensic routine work [7].

Since (AFM) is a rapidly developing tool introduced into the evaluation of the age of bloodstains, potentially providing legal medical experts useful information for forensic investigations. Therefore it has been used to test the elasticity of blood by recording force-distance curves. The elasticity pattern decreased over time, which is most likely, influenced by the alteration of the bloodstain during the drying and coagulation processes. Once the calibration curve of the elasticity over time is developed by the AFM, the age of bloodstains can be estimated and can further use to assist in criminal investigations [2, 3 and 5].

2.5. Nanotechnology and drug analysis

A wide range of both, legal medicines (e.g. paracetamol and loratadine) and illegal drugs (e.g. cocaine and ecstasy) are routinely detected and identified using nano-techniques such as HPLC, FT-IR, XPS, and Tof-MS. Modern advances in these techniques allow nano-grams of drugs and drug formulations to be identified in a wide range of media including blood, urine, and hair. The progress in these techniques has led to a wealth of information (such as morphology, chemical composition, and surface stiffness) on drugs, paraphernalia and excipients being widely available to modern day forensic investigators. According to a recent study, if a perpetrator or victim of the crime was under the influence of drugs or alcohol, a combination of microextraction by packed sorbent (MEPS) and direct analysis at real time (DART) Tof-MS had been used. These techniques not only improved the speed of extracting drugs from the urine (< 2 minutes)but also the rate of drug detection (< 1 minute). The study leads to the possibility to detect very low levels of drugs, days after consumption in a person's urine. The ability of the technique to quantitate a drug and to be semi-automated could lead to it being used routinely for screening a range of drug metabolites in forensics [2].

2.6. Nanotechnology for enhancement of PCR efficiency

Polymerase chain reaction (PCR) is a common method of creating copies of specific fragments of DNA. PCR rapidly amplifies a single DNA molecule into many billions of molecules. Thus PCR is a valuable tool in forensic DNA analysis used for the identification of one person as well as a group of people. It has been found that gold nanoparticles can be used dramatically to enhance the polymerase chain reaction (PCR) efficiency. When 0.7 nm of 13 nm Au-NPs were added into the PCR reagent the reaction time is decreased while heating/cooling thermal cycle rates are increased. Thus marked improvements in PCR efficiency are attributed to the superb heat transfer property of Au nanoparticles [2 and 5]. In addition, AuNPs have been shown to enhance electro-chemiluminescence (ECL). The technique combined with the isothermal reaction of polymerase and nicking endonuclease. Therefore the AuNPs ECL approach has shown to be sensitive enough to detect approximately 5 attomolar of DNA [8].

2.7. Nanotechnology and 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 [2]. 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 [3].

2.8. Nanotechnology for security features in official and confidential documents

Security of official and confidential documents is always a big issue for a country regarding to their 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 anti-counterfeiting inks. These NPs are not only replacing the ancient fluorescent dyes that can be used in currency notes but also gives more precise and upgrade security features than previously done [9 and 10] .

2.9. Nanotechnology and fingerprints

The use of nanoparticles has recently shown a great potential in producing the next generation of fingerprint development techniques known as nano fingerprints [2]. One of the most important elements of crime scene investigation is the detection of fingerprints as fingerprints are the most widely found evidence in criminal investigations since they are a generalized proof of human identity [11 and 12]. Fingerprints may be latent, patent or plastic in nature. Since the fingerprint is a complex mixture of natural secretions of the body (mostly sweat from a different type of glands) and contaminations from the environment [13]. Therefore the choice of technique for latent fingerprint development is dependent on the composition of latent fingerprints, on the type of substrate and on the ability of the technique to be applied in sequence in the context of the case [11]. Currently, a variety of techniques is being used to develop the latent fingerprints such as iodine fuming, ninhydrin, silver nitrate and cyanoacrylate. However, in the case of additionally aged prints the environment might contaminant the latent fingerprints, to such environments, the fingerprints may suffer from reduced reactivity to detection from these methods. Therefore, over the past few years, nano-scientist have been using increasingly sophisticated techniques to exploit the effects of nanoparticles such as Au-NPs(gold), CdS (cadmium sulphide) and ZnS (zinc sulphide) for the development of latent fingerprints in order to better identify the fingerprints [2, 12 and 14]. Thus Nanotechnology offers the opportunity to develop new fingerprint techniques with superior properties including; improved selectivity, improved contrast with the background and increased sensitivity [2].

III. DISCUSSION

In this review paper, we have discussed the various applications of nanotechnology in the field of forensic science along with the vital application of advanced nanotechnology instruments such AFM in various fields of forensic science such as in questioned documents, in estimation of time of death, in age of blood stains and, in examination of trace evidences with HPLC, XPS, and Tof-MS instruments in drug analysis. This review article also illustrates the potentiality use of nanotechnology in many different forensic investigations like nanosensors for explosive detection, Au-NPs for DNA fingerprinting, quantum dots as luminescent materials for security features in official and confidential documents, Au-NPs(gold), ZnS(zinc sulphide) and CdS-NPs(cadmium sulphide) for fingerprint enhancement along with improved background selectivity etc.

IV. CONCLUSION

In this paper, we have shown various nanotechnology methods and instrumental techniques which can be used in different field of forensic investigations. 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..

V. ACKNOWLEDGEMENT

The authors express their gratitude and thanks to Galgotias University, Greater Noida to publish this review paper.

REFERENCES

[1] A. S. Lodha, A. Pandya, R. K Shukla, *Forensic Research & Criminology International Journal,* 2 (2016) 1-4.

[2] https://www.researchgate.net/publication/305441732_Nanotechnology_in_Forensic_Science.

[3] Y. F. Chen, J. Chin *Chem. Soc.,* 58 (2011) 828-835.

[4] L. Senesac, T. G. Thundat, *J. Mater. Today* 113 (2008) 28-36.

[5] I. Kumar, S. Kumar, M. Singh, K. Kumari, D. Kumar, Y. Ansari, K. Trivedi, S. Rana, S. Sinha, R. Mansuri, G. C Sahoo, M.Dixit, V. N. R Das, K. Pandey, R. K Topno, P. Das, W. J. *Pharmaceut. Res.*, 5 (2016) 266-276.

[6] Y. Wu, Y. Hu, J. Cai, S. Ma, X. Wang, Y. Chen, Y. Pan, *Micron.,* 40 (2009) 359-364.

[7] S. Strasser, A. Zink, G. Kanda, P. Hinterdorfer, O. Peschel, W. M. Heckl, A. G. Nerlich, S. Thalhammer, *Int. J. Forensic. Sci.,* 170 (2007) 8-14.

[8] J. M. Romeika, F. Yan, *J. Forensic Res* S 12 (2013) 1-13
Retrieved From: http://dx.doi.org/10.4172/2157-7145.S12-001

[9] A. A. Cantu, *Proceedings of SPIE-Int. society for optical engineering, Proc. of SPIE.,* 7119 (2008) 71190F 1-8

[10] R. K. Shukla, *Int. J. Forensic Sci. Pattol.,* 1 (2013) 7-10.

[11] M .K. Farrukh, *United State Patent Application Pub. No.*: US 2015/0050495 A1 2013.

[12] J. France, Da Vinci's notebook, 6 (2014)
Retrieved From: davinci.lib.uoguelph.ca/index.php/davinci/article/download/3077/3297.

[13] C. Champod, C. Lennard, P. Margot, M. Stoilovic, Fingerprints, and Other Ridge Skin Impressions book, Chapter-1 Friction ridge skin, New York, (2004) 17-29 CRC Press.

[14] M. Wood, A novel approach to latent fingermark detection using aptamer- based reagents, *Ph.D. thesis, University of Technology Sydney* (2014).
Retrieved From: https://opus.lib.uts.edu.au/bitstream/10453/24200/1/01front.pdf.