Journal of Forensic Biomechanics

Kaushik et al., J Forensic Biomed 2017, 8:1
DOI: 10.4172/2090-2697.1000131

Review Article Open Access

DNA Fingerprints: Advances in their Forensic Analysis Using Nanotechnology

Mahima Kaushik[1,2*], **Swati Mahendru**[2], **Swati Chaudhary**[2] **and Shrikant Kukreti**[2]

1Cluster Innovation Centre, University of Delhi, Delhi

2Department of Chemistry, University of Delhi, Delhi

*Corresponding author:** Mahima Kaushik, Cluster Innovation Centre, University of Delhi, Delhi, India, Tel: +91-11-27666702; E-mail: kaushikmahima@yahoo.com

Received date: August 29, 2016; **Accepted date:** February 22, 2017; **Published date:** March 02, 2017

Abstract

For deciphering the secrets of forensic science, nanotechnology has quite extensively been utilized. Generally, for identifying the fingerprints, a lot of combination of different materials and film assemblies have already been utilized. Since the mode of interaction between the nanoparticles and fingerprint marks, is still not clearly understood, fabricating the nanoparticle assemblies for their identification is quite challenging. Complete identification of fingerprint marks which are generally because of a combination of some kind of proteins and fatty acids, is still a difficult task and is only partially being done with the help of different techniques. Nanotechnology has already shown immense potential in many fields like medicine, molecular biology, genetics, material science etc. and it has also marked promising potential even in forensic analysis studies. This review aims to discuss the details of the process of fingerprint formation, their role in forensic analysis along with the latest advances in the field of nanotechnology for their identification. This information may enhance our understanding about the progress in the forensic analysis of fingerprints, which may further be utilized in solving the puzzle of various criminal cases.

Keywords: DNA Fingerprinting; Forensic science; Applications of nanotechnology in forensic science; Techniques of DNA fingerprinting

Introduction

Distinctive lines and swirls at the end of our fingers give a unique pattern of ridges and valleys to each individual, known as fingerprints or Frictional Ridge Skin (FRS). Owing to the fact that this pattern is unique to each individual and doesn't change throughout a person's life, it has been used as a biometric identifier by the criminologists and law enforcement officers in forensic investigations since late 19th century [1]. Apart from the scars which originated from any accidents, fingerprints remain same throughout a person's life. Even identical twins with identical DNA have different fingerprints [2]. Fingerprint formation begins, when the baby is still in the womb at about 10th week. Growth in the size of hands, feet etc. after the embryonic volar pads stop growing trigger the cell differentiation on the fingertip skin. Embryonic volar pads are the raised pads on the fingers, palms and feet due to swelling of mesenchymal tissue, a precursor of blood vessels and connective tissues. Flow of amniotic fluid around the foetus as well as position of foetus during the differentiation process creates a microenvironment responsible for the finer details of the fingerprints. Fingerprints are fully formed at about seven months of foetus development [3,4].

The fingerprints can be collected from practically any solid surface such as porous or non-porous surface, adhesives, metals, fabric, human skin and many others. Depending on the residue composition, they can be classified as patent (visible) or latent (invisible) fingerprints. Patent fingerprints are formed, when they are based on blood, ink, paints, etc. Latent fingerprints are impressions of the fingers ridge pattern formed on the surface, when a finger picks eccrine sweat, together with oily substances such as sebum. Eccrine glands are major sweat glands of human body and eccrine fraction of fingerprints mostly consist with inorganic compounds, amino acids, proteins, lipids and miscellaneous compounds such as lactate, urea, creatine, creatinine, glucose and many others. Sebaceous glands are responsible for waterproofing and lubricating the skin, as they secrete oily or waxy matter. So the sebaceous part of fingerprints comprise of fatty acids, phospholipids, wax esters, sterols, squalene and other organic compounds.

This review would briefly update on the fingerprint formation, various techniques utilized for their identification in forensic analysis and the recent most advances in the nanotechnology field.

Various techniques utilized for forensic analysis of fingerprints

The composition of human sweat and sebum is unique for each individual and depends on a number of factors such as individual's age, health condition, diet etc. The composition of fingerprints already deposited on surface can change with time due to a variety of factors, such as evaporation of volatile components of fingerprints, diffusion of fingerprints into porous surface, exposure to light, temperature and humidity, and many more [1,5]. Even though there are a number of optical, chemical and physical techniques available for fingerprint analysis a considerable portion of the latent fingerprints still escape detection, resulting in inaccurate analysis. If appropriately gathered and accurately analysed, fingerprints are impeccable and can serve crime fighters with invaluable knowledge to identify the criminals [6]. Interestingly, fingerprints not only reveal your identity, it can also hint about a person's profession as well as substances touched and secretions from a person's body. Fingertips of a guitar player are rough with calluses due to plucking and brushing the strings, whereas that of a person who deals with a lot of paper work are often smooth [7]. Various physical traits of an individual can be determined by analysing the components of sebum and sweat present in the fingermarks, as the gland secretions are controlled by the body's hormone system Muramoto et al. [8] demonstrated a novel test sample for the spatially resolved quantification of illicit drugs on the surface of a fingerprint using Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) and Desorption Electrospray Ionization Mass Spectrometry (DESI-MS). Using an ink-jet-printed array of known quantities of drugs, researchers calibrated their mass spectrometry techniques to measure specks of the chemicals. Then, using 3-D printed plastic finger and artificial sebum, drug-tainted fingerprints pressed onto paper or silicon were created, to investigate the effect of matrix and substrate effects on analyte signal response [9].

Traditionally, fingerprint analysis was mostly performed by powdering method, for which different types of commercially available powders including magnetic powder, aluminium flake powder, luminescent powder and iron flake powder are used [1]. Techniques such as mass spectroscopy in addition to chromatography are used to identify the molecular ion of explosive residues or prohibited drugs important for forensic detection [10]. Other methods used for fingerprint analysis are Surface Assisted Laser Desorption/ Ionization (SALDI) coupled with mass spectroscopy [11], Desorption Electrospray Ionization (DESI) mass spectroscopy [12], Matrix Assisted Laser Desorption/ Ionization mass spectroscopy (MALDI) [13], Raman spectroscopy, Infrared spectroscopy [1]. However, with the advent of Nano technological advances in the field of forensics, cutting-edge techniques for fingerprint analysis are being emerging.

Role of nanotechnology in forensic analysis

Nanotechnology has vast application in the field of forensic science. It helps in diagnosing and examining samples at the nano-scale level that was earlier facing difficulty due to the detection limits of machines. Samples including explosives, heavy metals, gunshot residues, DNA fingerprints can be detected using nanotechnology [14]. Nanotechnology is the everyday growing field of scientific research and technology. It can be coined as the technique that works at nanometer scale including choice of materials, analysis, synthesis, measurement through devices, etc. At nanometer scale, materials can be handled at the level of different atoms or molecules. Nanotechnology can also be used to develop productive machines by employing atoms as basic building blocks [15]. At this level, physical as well as chemical properties of a material can be controlled. Many scientific areas such as electronic engineering, biomedical sciences, material sciences and physical sciences have vast application of nanotechnology nowadays. Nanostructures are characterized by greater stability, larger surface area and are considered stronger materials [16]. Different Nanoparticles like gold nanoparticles, Zinc sulfide/ cadmium selenide and various organic-inorganic silica based particles etc. are used to enhance the lucidity of the fingerprints.

Recently, the efficiency of forensic science has increased in various fields. Analysis of DNA by illustration of micro-device or chip-based technologies in forensic science is done by DNA research and development program, whereas chemical and biological defence program involves development of inexpensive or wearable device, which can alert against unexpected biological and chemical threat in a very short time, for the wearer to take powerful constructive measures [17]. Techniques for instance, Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Raman Microspectroscopy (Micro-Raman), and Scanning Probe Microscope (SPM) are used for nanomaterial analysis and they have been effectively modified and applied to the forensic research area. Semiconductor nanomaterials (quantum dots), carbon nanotubes, nanoparticles, and peptide nanotubes are few of the examples of nanomaterials, which are used nowadays in the field of environment engineering, medicine, quantum computer, catalysis, consumer products and communication [18].

Identification and evaluation of toxic substances from different crucial samples, which are considered important for forensic analysis such as hair, blood, saliva, palm-print or fingerprint samples, and skeletal remains, can be done using nanotechnology. Recently, illegal drug such as cocaine found in the fingerprint samples are quantified by exploring the spectroscopic properties of nanoparticles. Detection limit of these prohibited drugs is amplified in the fingerprint samples by employing silver, gold as well as titanium oxide nanoparticles [19]. A nanosensor was developed in order to detect clonazepam drug from the blood and skeletal samples by using melamine altered gold nanoparticles [20]. Similarly, sensors have been developed for the better, rapid and inexpensive on-field test. Commercially available bioanalyzer, Agilent 2100 have the ability to increase the DNA samples even upto nanoliter scale within a very short span of time and thus, are used to quantify mitochondrial DNA samples in forensic research [21]. High quality DNA samples which are amplified by PCR can be extracted from different skeletal remains and body fluids with the help of magnetic nanoparticles, copper nanoparticles, and magnetic nanoparticles involving silica for the purpose of forensic analysis [22].

Role of nanotechnology in fingerprint analysis

Patent fingermarks can be seen with naked eyes and thus can be used directly for investigation process. However, latent fingermarks need to be developed in order to visualize them and for using in investigation process. Integration of nanotechnology with fingerprint analysis has a diverse range of implications, especially in enhancing clarity while developing the fingerprints. Clarity of the latent fingerprints can be enhanced by using gold nanoparticles bound with long hydrocarbon chains which form hydrophobic interactions with the sweat residues along with silver physical developer [23]. Identification of latent fingermarks on paper that has been wetted by water is a challenging task, as the amino acids dissolved in the sweat which are the main substrate for fingerprint enhancement are removed by water. Aqueous solution of silver nanoparticles stabilized by cationic surfactants act as appropriate silver physical developer (Ag-PD) in this case, as silver slowly deposits on the water-insoluble components of the sweat. However, this method suffers from glitches, such as lack of reproducibility, poor contrast, etc. This can be overcome by using Multimetal Deposition (MMD) method, where AuNPs bind to the fingermark residue through ionic interactions between the negatively charged gold colloids and the positively charged components of the fingermark. They further catalyze the precipitation of metallic silver from the Ag-PD solution (Figure 1). Another highly versatile and reproducible approach, where modified gold nanoparticles (AuNPs) are used to bind preferentially to paper through AuNPs–cellulose interactions and forms an invisible coating over the entire paper surface, while leaving the sebaceous ridges uncoated. The AuNPs are bound by bifunctional reagents, whose molecules contain active heads that have a high affinity to the paper, and active tails that can bind to the metallic nanoparticles. So second treatment with conventional Ag-PD solution will result in darkening of the gold coated region by the precipitation of black silver over them (Figure 1) [24]. Hybrid organic-inorganic silica based particles are extremely helpful for latent fingermark analysis. Zinc sulfide/cadmium selenide nanoparticles are developed in order to enhance the fingerprints and these nanoparticles also have tendency to give fluorescence in the presence of UV light so that fingerprints under this system can be directly observed without the need of any additional method [25]. Hybrid cadmium sulfide quantum dots (QDs) nanocomposites assembled in a Porous Phosphate Heterostructures (PPH) functionalized with mercaptopropyl (PPH-SH) and Propionitrile (PPH-CN) tend to be fluorescent in nature that make them potentially useful for fingerprint analysis [26]. On the other hand, latent fingerprints present on patterned or multi-coloured background can be easily visualized by using hybrid Nano powders and gold nanoparticles functionalized by Poly (styrene-altmaleic anhydride)-b-Polystyrene (PSMA-b-PS) [27,28]. A mixture of the magnetically responsive diacetylene (DA) powder and magnetite nanoparticles, applied to a surface containing latent fingermarks, becomes immobilized along the ridge patterns of the fingerprints in presence of a magnetic field. This mixture composite immobilized on the latent fingerprint, on irradiation with UV light results in generation of blue-colored Polydiacetylenes (PDAs). Heat treatment of the blue-colored image promotes a blue-to-red transition as well as fluorescence turn-on which enables efficient visual imaging of a latent fingerprint [29].

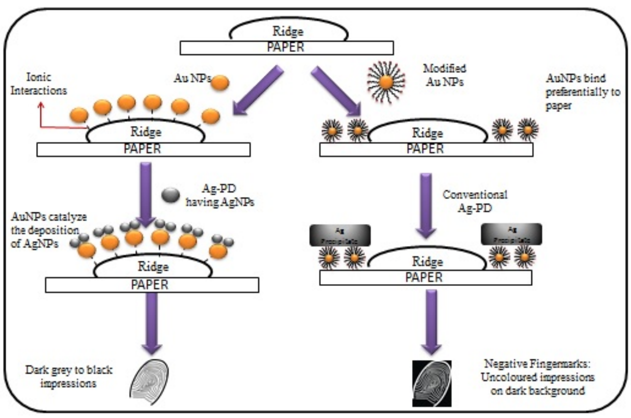

Figure 1: Identification of latent fingerprints on a wet paper using nanotechnology

Outlook and Future Directions

Recently, nanotechnology had been utilized quite extensively in medical field for developing point-of care diagnostics for various diseases like cancer. Nanobiosensors have been explored for their clinical applications as an additional tool in diagnosis of a particular disease or an infectious micro-organism. Likewise, many materials and film assemblies with the aid of nanotechnology had constantly been developed to help in identifying the DNA fingerprints, especially in crime incidences. Enormous efforts have continuously been done for improving upon the sensitivity and specificity of the material in identifying the fingerprints which may be obtained in quite distorted situations. Forensic analysis certainly has a lot of room for improvement in terms of DNA analysis, which may be obtained from serum, saliva, blood or any other cell or tissue at the crime scene. Engineering new nanomaterials with the help of more sensitive and advanced techniques is quite challenging and is need of the hour for performing DNA analysis or identification of fingerprints.

Acknowledgements

Authors would like to acknowledge the research and development grant of University of Delhi, Delhi, India.

References

1. Hazarika P, Russell DA (2012) Advances in fingerprint analysis. Angewandte Chemie International Edition 51: 3524-3531.
2. Daluz HM (2014) Fundamentals of Fingerprint Analysis. CRC Press.
3. (2015) Scientific American Editors Ask the Experts: The Human Body and Mind. Macmillan.
4. Maltoni D, Maio D, Jain A, Prabhakar S (2009) Handbook of fingerprint recognition. Springer Science & Business Media.
5. Leśniewski A (2016) Hybrid organic–inorganic silica based particles for latent fingermarks development: A review Synthetic Metals.
6. Spaulding J (2008) Careers in Fingerprint and Trace Analysis. The Rosen Publishing Group.
7. Hamilton SL (2008) Fingerprint Analysis: Hints from Print. ABDO Publishing Company.
8. Huynh C, Halamek J (2016) Trends in fingerprint analysis. TrAC Trends in Analytical Chemistry.
9. Muramoto S, Forbes TP, van Asten AC, Gillen G (2015) Test Sample for the Spatially Resolved Quantification of Illicit Drugs on Fingerprints Using Imaging Mass Spectrometry. Analytical chemistry 87: 5444-5450.
10. Goucher E, Kicman A, Smith N, Jickells S (2009) The detection and quantification of lorazepam and its 3-O-glucuronide in fingerprint deposits by LC-MS/MS. Journal of separation science 32: 2266-2272.
11. Rowell F, Hudson K, Seviour J (2009) Detection of drugs and their metabolites in dusted latent fingermarks by mass spectrometry. Analyst 134: 701-707.
12. Ifa DR, Jackson AU, Paglia G, Cooks RG (2009) Forensic applications of ambient ionization mass spectrometry. Analytical and bioanalytical chemistry 394: 1995-2008.
13. Wolstenholme R, Bradshaw R, Clench MR, Francese S (2009) Study of latent fingermarks by matrix-assisted laser desorption/ionisation mass spectrometry imaging of endogenous lipids. Rapid communications in mass spectrometry 23: 3031-3039.
14. Chen YF (2011) Forensic Applications of Nanotechnology. Journal of the Chinese Chemical Society 58: 828-835.
15. McCord B (2006) Nanotechnology and its Potential in Forensic DNA Analysis. Profiles in DNA 9: 7-9.
16. Javan GT (2015) Nanotechnology and Its Applications in Forensic and Criminal Cases.
17. Dongre NL Nanotechnology in Forensic Geosciences.
18. Gohil S, Domb AJ, Kumar N (2011) Nanomaterials for regenerative medicine. Nanomedicine 6: 157-181.
19. Harvey JMH (2015) Nanoforensics: Forensic application of nanotechnology in illicit drug detection. J Forensic Res 6: 106.
20. Lodha A, Pandya A, Sutariya PG, Menon SK (2013) Melamine modified gold nanoprobe for "on-spot" colorimetric recognition of clonazepam from biological specimens. Analyst 138: 5411-5416.
21. Hallikeri VR, Bai M, Kumar AV (2012) Nanotechnology-The future armour of forensics: A short review. Journal of the Scientific Society 39: 10.
22. Lodha AS, Pandya A, Shukla RK (2016) Nanotechnology: An Applied and Robust Approach for Forensic Investigation. Forensic Res Criminol Int J 2: 00044.
23. Lang H, Hegner M, Gerber C (2007) Nanomechanical cantilever array sensors. In Springer Handbook of Nanotechnology 427-452.
24. Jaber N, Lesniewski A, Gabizon H, Shenawi S, Mandler D, et al. (2012) Visualization of latent fingermarks by nanotechnology: reversed development on paper-a remedy to the variation in sweat composition. Angewandte Chemie International Edition 51: 12224-122247.

25. Sametband M, Shweky I, Banin U, Mandler D, Almog J, et al. (2007) Application of nanoparticles for the enhancement of latent fingerprints. Chemical Communications 11: 1142-1144.
26. Algarra M, Jiménez-Jiménez J, Moreno-Tost R, Campos BB, da Silva JE, et al. (2011) CdS nanocomposites assembled in porous phosphate heterostructures for fingerprint detection. Optical Materials 33: 893-898.
27. Fernandes D, Krysmann MJ, Kelarakis A (2015) Carbon dot based nanopowders and their application for fingerprint recovery. Chemical Communications 51: 4902-4905.
28. Song K, Huang P, Yi C, Ning B, Hu S, et al. (2015) Photoacoustic and Colorimetric Visualization of Latent Fingerprints. ACS nano 9: 12344-12348.
29. Lee J, Lee CW, Kim JM (2016) A Magnetically Responsive Polydiacetylene Precursor for Latent Fingerprint Analysis. ACS applied materials & interfaces 8: 6245-6251.