



Nanoforensic: An Advanced Perspective in Crime Investigation

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Abstract:

Nano-forensics is the advanced application of nanotechnology-based techniques to resolve cases in forensic science. Forensic science offers scientific methods in criminal investigation. Nano-forensics deals with the development of new approaches for fingerprint visualization, DNA isolation, forensic toxicology, explosive detection, identification of body fluids, gunshot residue analysis, detection of illicit drugs, etc. The nanomaterials used in forensic science are nanocrystals, nanoparticles, quantum dots, nanobelts, nanocomposites, nanoclusters, nanotubes, nanorods, etc. The scope of nanotechnology is very wide.

Key words: nanoforensic, nanotoxicology, forensic science, nanoparticles, nanomaterials

1. Introduction

Nanotechnology is an advanced approach to design, production, manipulation, and application of useful materials, systems, and apparatuses by regulating matter at the nanoscale. It has been used in numerous fields of inquiry, including biomedical sciences, physical sciences, electronic engineering, and many more. First, because nanotechnology can detect and analyses samples at the nanoscale, it allows for the collection and analysis of crucial evidence that was previously impossible.

Second, because it can now analyze samples on a lower scale. Furthermore, nanomaterials have novel features that make it possible to gather and find evidence that was previously impossible to do so. Examples include trace amounts of explosives, DNA on fingerprints, and trace amounts of hazardous metals on palm prints.

Basic researcher and demonstration of chip-based or micro device technology for DNA analysis in forensic application are both included in the DNA Research and Develop-

ment programme. The chemical and biological defense initiative's objective is to develop a wearable, affordable technology that can warn its user of potential chemical and biological threats in time for them to take the necessary safeguards [1].

2. Characterization Of Nanomaterials

Nanomaterials can be characterized by using atomic force microscopy, dynamic light scattering, and Raman micro spectroscopy (Micro-Raman). Since electron beams serve as the light source, electron microscopy can magnify incredibly minute details of nanomaterials with resolution down to the sub-nanometer range. The light source is a cathode that produces a lens-focused high voltage electron

beam. When the beam contacts a photographic plate, phosphor screen, or another light-sensitive sensor, a picture is produced. Through TEM, the internal structure of the materials under study is made visible. Scanning electron microscopy (SEM), which searches for secondary or backscattered electrons, creates images. In comparison to TEM, the process used to create the final images in SEM is very different. SEM scans can show surface shape and produces three-dimensional images [2].

2.1. Atomic Force Microscopy

AFM is very effective tool for assessing nanoparticles. It can determine magnetic forces, chemical bonding, capillary force, electrostatic force, and others. Although SEM and AFM are both capable of producing 3-D images [3].

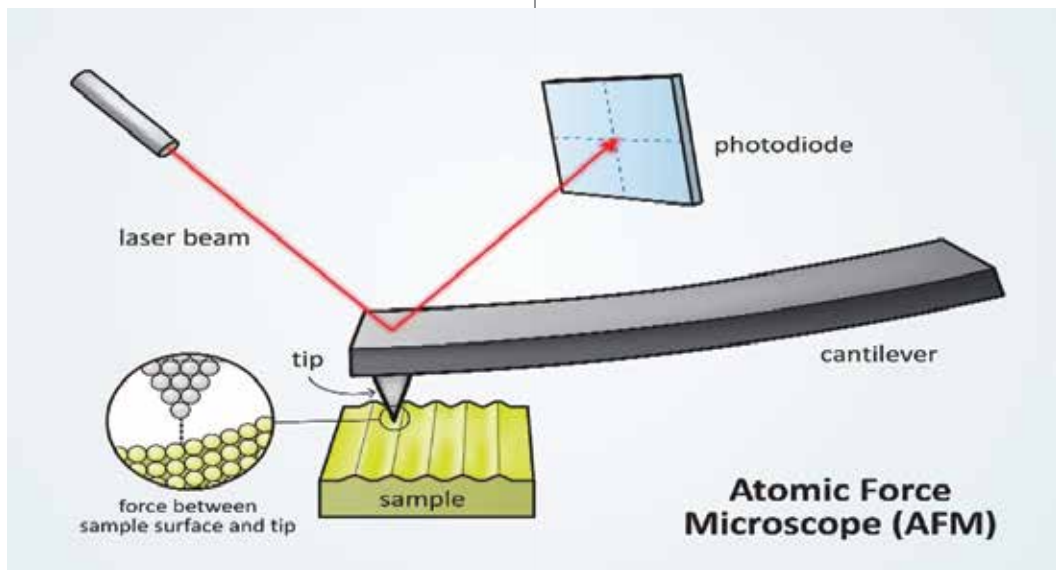


Fig 1: Atomic Force Microscope

2.2. Dynamic Light Scattering

Dynamic light scattering is a well-known technique for estimating particle size in the range from a few nanometers to a few microns

(DLS). DLS is excellent at identifying even trace amounts of aggregated protein. The typical detection window is 0.8 to 6500 nm [4].

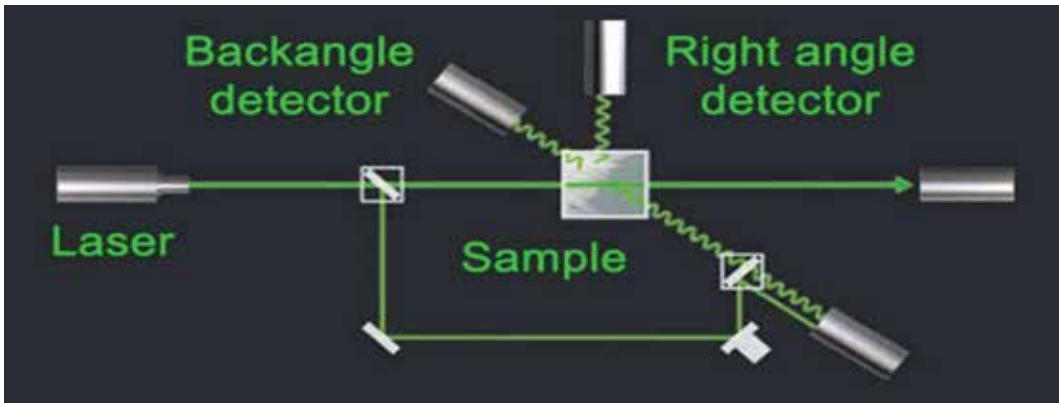


Fig 2: Dynamic Light Scattering

2.3. Raman Micro spectroscopy

Raman spectroscopy, as opposed to focusing on absorption, examines how the sample scatters light. It accomplishes this by counting photons using a charged-coupled device (CCD), a multiple dispersion prism, or a diffraction grating. Filtering removes the wavelength that is near the laser line (Raleigh scattering). The

interference from water to the Raman spectrum is far less than it is for infrared spectroscopy. The study of biological objects like as cells, tissues, peptides, and proteins is thus excellently suitable to it. Extremely specific energy ranges can be connected to the rotational and vibrational motions of particular types of chemical bonds in organic molecules. The fingerprint that can be used to identify the molecule is provided [5].

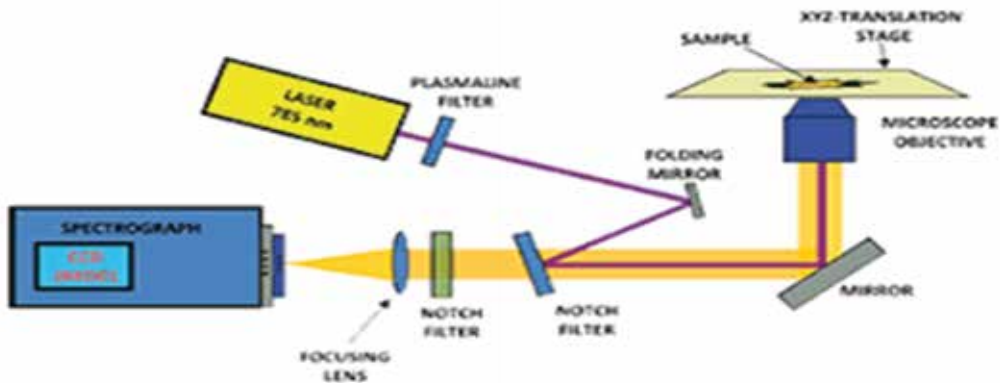


Fig 3: Raman Micro spectroscopy

3. Forensic Applications

The forensic applications of nanotechnology are as follows.

3.1. Latent Fingerprint Enhancement of CdS

Dr. Menzel invented the technique for improving latent fingerprint detection using photoluminescent CdS semiconductor nanocrystals topped with dioctyl sulfosuccinate. His idea was to use fluorescent dye to pre-fume items with cyanoacrylate ester and to paint electrical tape's sticky side with fluorescent dye [6].

3.2. Nano-Fingerprint Residue Visualization

By detecting inorganic elements in the impressions, MXRF produces images of latent fingerprints. The non-destructive analysis and stable inorganic residues make it more advantageous. Fingerprints are saved during processing and might be utilised for further inquiries, such as elemental analysis for gunshot residue. Chloride ions and potassium are the inorganic residues that can be present in fingerprints. MXRF offers an elemental assessment of the inorganic elements present in fingerprints. Additionally, MXRF has the ability to identify chemicals that are not often seen on the hands, such as sweat, saliva, lotion and sunscreen. For instance, MXRF can be used to connect salivary components with food remains in fingerprints to look into situations of missing children [7].

3.3. Gold Nanoparticles to Enhance PCR Efficiency

The effectiveness of the polymerase chain reaction can be considerably enhanced by the use of Au nanoparticles (PCR). The reaction time was found to be reduced while the heating/cooling thermal cycle rates were raised when 0.7nM of 13 nm Au nanoparticles were added to the PCR reagent. The huge increases in PCR efficiency are the result of Au nanoparticles' extraordinary capacity to transmit heat [8].

3.4. AFM and Questioned Documents

For the first time, pen and ink's 3-D surface morphology (AFM) may be studied thanks to a method created by Swiss researchers. They claim that AFM can offer crucial details for comprehending the arrangement of lines produced by ballpoint ink and ribbon dye. They claim that AFM images include the same

level of qualitative data as those obtained using scanning near-infrared microscopy [9].

3.5. AFM and the Time of Death

The morphological changes in blood cells can be utilized to calculate the time of death. The cell and membrane surfaces of unfixed erythrocytes are observed to deform with time. Within a half-day, fissures and cell shrinkage occurred. An early indicator of death is protuberance on erythrocytes, which can be utilized to determine the precise time of death. A study that was published in the journal *Cell Mechanisms of Cells* suggests that there are two potential causes for the development of holes in cells. One is when dehydration causes holes to emerge and hemoglobin in the cytoplasm flows outward; the other is when membrane proteins thin out as a result of dehydration. A group of researchers from the University of Bristol looked into the red blood cells' (RBC) time-dependent surface adhesive force and shape. Their findings imply that AFM is a new potential forensic medicine tool (the estimation of the time of death). RBC cells on mica were noticeably larger in both form and volume than cells on glass, but, surprisingly, their adhesive properties were substrate-independent. On a mica substrate, RBC has the normal biconcave shape, while on a glass substrate, it has a flattened or bicavity shape. In controlled room temperature conditions, changes in the RBC's cell volume and adhesive force were comparable to those in uncontrolled outdoor environmental conditions. To effectively assess blood age, more research is required on a variety of environmental parameters, including humidity, pH value, temperature, and light [10].

3.6. AFM Force Spectroscopy and Bloodstain

In two steps, the nanometer-scale elasticity of

erythrocytes was examined. Red blood cells typically have a "doughnut-like" look, which indicates that they are dry. The modification of the drying and coagulation processes most likely contributed to the changing elasticity pattern over time. It is possible to estimate the age of bloodstains and utilize this information to support criminal investigations once the elasticity of time's calibration curve has been produced [11].

3.7. AFM and Trace Evidence

The surface texture parameters of environmentally problematic materials were quantitatively evaluated using AFM images as a function of exposure time. Three different types of fibres were applied to two distinct soils (town and riverbank) and two distinct types of water during 0, 2, 4, and 6 weeks (ponds and water). The average maximum peak heights (H_{pm}), average maximum heights (H_z), and average maximum valley depths of each sample's surface morphology were assessed (H_{vm}). AFM can differentiate between various environmental exposures or violent damages to fibres, making it an efficient approach for forensic evaluation of fibre evidence.

Criminals frequently use pressure sensitive adhesive (PSA), which can be found in adhesive tapes and packaging. Images illustrating the mechanical characteristics of several PSA tape types, which are frequently used to secure parcels and confine suspects in kidnapping investigations, are displayed. The AFM phase pictures of the three tapes under research show dark and bright regions that, respectively, represent the soft polymer molecules and the rough surfactants. This work is the first to use force mapping and AFM imaging to comprehensively investigate several tapes. According

to a number of studies, AFM has also been applied in criminal investigations in various ways. AFM microcantilever provides the ability to do selective detection as well as surface and image analysis. The study of DNA hybridization, the discovery of two prostate-specific antigen isoforms, C-reactive proteins, *Salmonella enterica*, Vaccinia virus, and explosives like trinitrotoluene (TNT) and PETN are a few examples of applications. It uses the proper coatings on the cantilever surface to identify molecules [12].

4. FUTURE PROSPECTS

Taiwan has the potential and capacity to lead the world in the integration of forensic sciences and nanotechnology. More knowledge in disciplines relating to nanotechnology will be required of forensic scientists. Taiwan's forensic scientists are more qualified and knowledgeable in general than those in most other nations. It is not "mission impossible" to merge forensic science and nanotechnology and create a world-leading environment. It can be accomplished by emphasizing the development of educational research, a competent workforce, and the enabling infrastructure and resources. Additionally, greater forensic lab instrumentation use along with equipment capable of doing nanoscale analysis would be necessary for this [13].

5. CONCLUSION

Real-world criminal cases now have better forensic evidence thanks to analytical chemistry. Many forensic laboratories continue to be understaffed and underfunded, especially at the state and local levels, despite the fact that television programmed have glamorized the field and drawn attention from the general

public and potential students. To address these personnel requirements, formal programmed in forensic chemistry and forensic science education are growing, and there is already a system in place to recognized those that adhere to basic curriculum criteria. The self-evaluation process will surely help the training programmed that opt to pursue accreditation, and in the end, they will generate graduates who are more equipped and future leaders in the forensic science field.

6. References

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