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Review Article

Multifarious applications of atomic force microscopy in forensic science investigations

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ABSTRACT

Forensic science is a wide field comprising of several subspecialties and uses methods derived from natural sciences for finding criminals and other evidence valid in a legal court. A relatively new area; Nano-forensics brings a new era of investigation in forensic science in which instantaneous results can be produced that determine various agents such as explosive gasses, biological agents and residues in different crime scenes and terrorist activity investigations. This can be achieved by applying Nanotechnology and its associated characterization techniques in forensic sciences. Several characterization techniques exist in Nanotechnology and nano-analysis is one such technique that is used in forensic science which includes Electron microscopes (EM) like Transmission (TEM) and Scanning (SEM), Raman microscopy (Micro -Raman) and Scanning Probe Microscopes (SPMs) like Atomic Force Microscope (AFM).

Atomic force microscopy enables surface characterization of different materials by examining their morphology and mechanical properties. Materials that are immeasurable such as hair, body fluids, textile fibers, documents, polymers, pressure sensitive adhesives (PSAs), etc. are often encountered during forensic investigations. This review article will mainly focus on the use of AFM in the examination of different evidence such as blood stains, forged documents, human hair samples, ammunitions, explosives, and other such applications in the field of Forensic Science.

Contents

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1. Introduction

Forensic science is a broad field and consists of several subspecialties and uses different techniques that find its roots in natural sciences in the guilty and other lawful evidence. It can also be defined as a wide and multidisciplinary field that comprises of different branches such as geology, physics, chemistry, biology, and mathematics and uses them to examine and analyze different physical pieces of evidence obtained in a crime scene. Nano-forensics is a new field in which nanosensors are developed to acquire immediate results during the investigations of evidence at a crime scene. Terrorist activities investigations demand immediate results to confirm the existence of explosive gasses, biological agents, and residues and benefit from nanosensors. This is made possible through the implementation of Nanotechnology and its characterization techniques in forensic sciences.

Nanotechnology can be defined as a field that involves designing, creating, synthesizing and manipulating materials and systems by controlling the energy and matter at the nanometer scale for various applications in different fields. A major focus has been towards the manufacturing of novel materials and studying their properties and the changes in properties brought by a different particle shape, size, and distribution [1]. In the past decade, Nanotechnology has caused major breakthroughs in electronics [2], material science [3], biotechnology [4] as well as in the field of regenerative medicine [5,6]. Many fabrication methods have been developed for the synthesis of objects through a control of sub-micrometric or nanometer size features [7]. Nanotechnology's input in forensic sciences can be summarized in 2 ways. In one way, it helps in the collection of various evidence from crime scenes like gunshot residues, DNA, fingerprints or palm prints, heavy metals and explosives through the usage of nanomaterials synthesized through various Nanotechnology routes. These nanomaterials possess unique properties due to their small size (ranging in nanometers) like the large surface area and roughness which assist in the easy collection of evidence. In another way, Nanotechnology helps in detecting and analyzing samples at the nanoscale level, more specifically the evidence that is important for examination but could not be collected due to detection limits of the instruments and thus enhance the investigation levels [8]. This can be done by using advanced microscopic techniques such as Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and Scanning Tunneling Microscopy (STM).

Characterization of the fabricated materials in Nanotechnology requires tools that are capable of multiscale imaging. Among various microscopy techniques available, the Scanning Probe Microscope (SPM) has played a critical role [9] in the advancement of nanotechnology. Atomic Force Microscopy (AFM) is a type of high-resolution scanning probe microscopy and has been a highly effective technique to analyze different types of nanomaterials. It was developed by Binning et al. [10] in 1986. It provides a 3D topographical image of any type of material with sub- nanometer vertical resolution and nanometer lateral resolution without any prior sample preparation through a probe with a nanometer size tip that is scanned throughout the substrate [11–14].

The basic components of AFM include a micro-cantilever with a very sharp probe (tip) at the end to scan the sample surface as shown in Fig. 1. It also shows the various areas of forensic science that deal with the usage of AFM as a characterization technique.

The cantilever is typically made up of silicon or silicon nitride. Depending upon the usage, the cantilever can be coated with a very thin layer of gold or other metals with the tip radius of about several nm. AFM's image generation is based on the deflection of the forces between the cantilever tip and sample surface when brought into contact. Even though both AFM and SEM can produce 3D images, AFM has additional advantages over SEM. AFM can

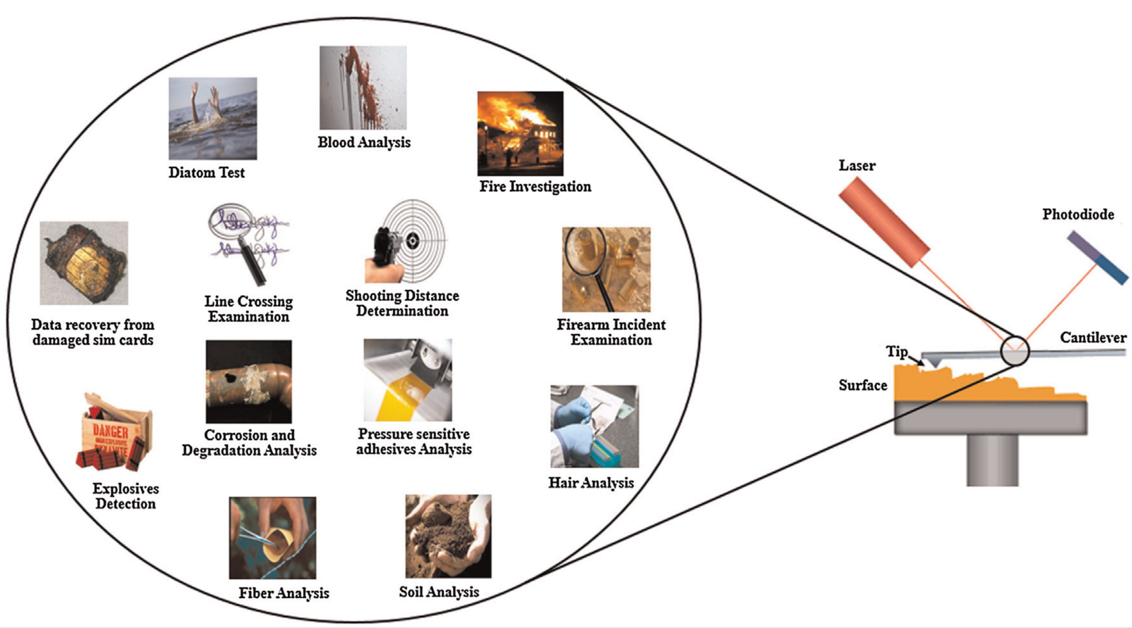

Fig. 1. Diagrammatic representation of instrumentation of AFM and its applications in forensic science.