Biosensor Developments: Application in crime detection

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***Abstract*— Biosensors act as analytical devices to detect biological materials. The wide use of enzymes, proteins, nucleic acids and other such biomolecules makes it possible. The main aim is to detect whether a particular chemical, compound, microbe or any such component is present or not in the given sample. This helps a lot in various detection procedures including those of toxic compounds in the environment, food, drugs and also nowadays in forensic sciences, used as a tool for crime detection. Forensics is making use of the biosensors for detecting the biomolecules and biological components found at the crime scenes which may play a great role in identifying the suspect and even reaching the criminal. Different components like fingerprints, blood samples, odour act as a detecting elements for biosensors. Biosensors are also used in lie detection procedures, to know whether the suspect is telling the truth or not. All these detection processes involve use of different and specific type of biosensors which are discussed here.**

***Index Terms*— Biosensor, Crime detection, Forensics, Biodetectors, Immunosensors.**

I. Introduction

Biological sensors, biosensors or biodetectors are defined as analytical devices incorporating abiological material like enzyme, microorganisms, insects, tissue, antibodies, plant partsor synthetic receptors intimately associated with or integrated within a physicochemical detector or transducer which may be optical, electrochemical, thermometric, piezoelectric, magnetic or micromechanical [1]. Biosensors usually yield an electronic signal which is proportional to the concentration of a specific or group of analyses. Biosensors have been applied to a wide variety of analytical problems including medicine [2], biomedical research [3], drug discovery [4], environment [5], food, process industries [6], security and defense. Most of these biological sensors are used for their intrinsic properties, but scientists also produce genetically modified organisms as biodetectors. Because of their exceptional capabilities, including high specificity and sensitivity, rapid response, low cost, relatively compact size and user-friendlyoperation, biosensors have become an important tool for detection of chemical and biological components for clinical, food, law and environmental monitoring.

Forensic sciences are the application of a broad spectrum of sciences to answer questions of interest to a legal system. This may be in relation to a crime or a civil action. Forensic sciences include several under divisions like forensic entomology, forensic toxicology, forensic anthropology, DNA analysis, criminalistics, and aim to analyze criminal evidences. The results are further presented as accurately and precisely as possible in a court of law [7]. Forensic sciences do not use only chemical technologies to solve a crime; they also use vertebrates or invertebrates as chemical detectors. This use is based on the olfactory capacities of vertebrates and invertebrates to detect volatiles from a human, narcotics or explosives. In the field of forensic sciences, law enforcement agencies and rescue teams worldwide use biosensors including dogs and honeybees to locate corpses, drugs or explosives.

II. Different biosensor approaches used in crime detection:

A. Prostate-specific antigen (PSA) detection in forensic samples:

Prostate-specific antigen is the best serummarker currently available for the detection of prostate cancer and is the forensic marker of choice for determining the presence of azoospermic semen in some sexual assault cases.The detection of PSA has also become the method of choice for the forensic determination of the presence of semen, in the absence of sperm, in sexual assault cases. However, the detection of PSA in forensic samples necessitates different assay requirements than its detection in clinical samples. First, it is not the determination of absolute PSA levels that is important in forensic science, rather the ability to detect PSA in what are invariably ‘dirty’ samples: contamination with otherbodyfluids or dirt, scarcity of thesample, the need for extraction from different types of fabric –leading to low extraction efficiencies–and the decomposition of samples in cadavers or following laundering of fabrics are all common challenges toPSAdetectionin forensicsamples[8].Second, owing to low concentrations of PSA being naturally present in the tissues and body fluids of some females, PSA assays for forensic use require only limited sensitivity to avoid the danger of false-positive results.

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B. Miniaturization ofSurface Plasmon Resonance(SPR) Immunosensors:

Antigen-antibody reactions are now widely used not only for medical diagnostics but also for environmental analysis, forensic medicine and so on. On the other hand, the commercialsuccess of the card-type glucose sensorfor personal uses showed the new possibilities of biosensor applications [9]. Comparing with enzyme sensors, immunosensors have wider application fields since they can detect various substances from bacteria to environmental pollutants. And the same principle could be applied to DNA sensing. So that development of miniature and portable immunosensor systems are strongly required. The miniature immunosensors have many application possibilities, such as in-home medical diagnosis, environmental field monitoring, scientific crime detection, quality check in small food factory, etc. Many types ofimmunosensors have been developed [10], but only SPR immunosensors made commercial success, e.g. BIAcore system. Although SPR phenomenon had been initially used for the characterization of thin metal film [11],the group of Linkoping University have applied SPR to gas [12] and biochemical sensing [13].These studies were bound to the development of BIAcore system. BIAcore system [14-16]realized label-free, real time monitoring, affinity monitoring of biochemical reactions such as antibody [17], DNA [18], receptors [19] and so on.

C. Multi-Metal-Deposition Detection of Biomolecules:

As nanoparticles show unique optical electromagnetic &catalytical properties & have excellent biocompatibility, these are used as signal amplifier for the detection of DNA, RNA, Antibodies & antigen proteins by using different optical & electrochemical techniques [20, 21].Recently, metallic colloid nanoparticles (e.g. gold and silver colloids) have been successfully applied to the progress of both chemical and biological sensing because of their easily controllable size distribution and long-term stability [22].Silver enhancement treatment, i.e.silver deposition on gold nanoparticles, is generally used to visualize proteinor DNA conjugated particles both in electron microscopy studies and electrochemical detection [23, 24].The application of gold colloid to the field of forensic sciences was introduced by Saunders [25], as a method for the detection of latent fingerprints.

The gold nanoparticles stabilized by citrate ions adhere to the fingerprint residue and catalyze the precipitation of the Ag^+ ions to metallic silver (Ag^0) from the aqueous solution on the ridges, thus the auto metallographic silver deposition procedure significantly enhance the developed fingerprints as a result of enlarging the size and darkening the color of the particles. It is a process known as ‘Multi-Metal-Deposition’(MMD). The gold adherence to the fingerprint material is explained by an electrostatic interaction between the negatively charged gold colloids and the positively charged components of the fingerprint residue.

D. Microbial Biosensors:

In case of forensic identification by using microbial biosensor, there is recognition of fine physical feature of object which will distinguish it from other object of the same kind [26, 27]. Body fluid containing valuable evidence of DNA &miRNA are collected from crime scenes & are used for forensic identification [28, 29]. The conventional methods for forensic identification are complicated and time-consuming, & show many difficulties towards solving a criminal case, hence microbial biosensors may be used for forensic identification.

E. Thermal Analyzer Enables Improved Lie Detection in Criminal-Suspect Interrogations:

The lie detector or conventional polygraph are used for criminal suspects & also in case of job interviews. The polygraph analyzes person’s involuntary psycho physiological responses to questions. The sensors are placed on person's arm, fingers, abdomen and chest. The signals produced from sensors detect changes in variables such as breathing and pulse rates, blood pressure, and perspiration and stored digitally. The nervous and innocent individual can fail the polygraph test. The system can be cheated by cleaver individual and hence more truth worthy lie detection methods are required for highly desirable results.Thermal imaging is a promising technology in case of lie detection. Thermal analyzer for deception detection (TAD) analyses far-IR data obtained remotely from a suspect's periorbital (around the eyes) and nostril areas during interrogation. A measured change in skin temperature from the two periorbital areas is converted to a relative blood-flow velocity[30]. The system also detect the person's respiration pattern from measured temperature changes around the nostrils.

F. Chemical Sensors:

Chemical sensors detect odor molecules based on the reaction between the odormolecules and the target sensing materials on the sensor surface. This reaction triggers a certainchange in mass, volume, or other physical properties. The change is then converted to anelectronic signal by a transducer[31]. There are different types of transducers for chemical sensors: optical, electrochemical, heat-sensitive, and mass-sensitive. The mostcommon chemical sensors usedare surface acoustic wave sensor, quartz crystalmicrobalance sensor, metal oxide semiconductor sensor, polymer composite-based sensor and E-noses.

G. Surface Acoustic Wave (SAW) Sensors:

The SAW sensor transducer is mass sensitive. The sensor is composed of a substrate ofquartz that is cut at a crystalline angle to support a surface wave, as well as a chemicallysensitive thin film that is coated on the quartz surface. Since the quartz is a piezoelectricmaterial, it converts surface acoustic waves to electric signals. When the chemically sensitivethin film adsorbs specific molecules, the mass of the film increases, thus causing the acousticwaves to travel more slowly. This change can be detected by the sensor microelectronics oncethe acoustic wave is converted to an electric signal.Since the oscillation frequency of a quartz substrate typically falls within a certain range,it is expected that the sensor will only be able to detect very limited numbers of target molecules. The SAW mini-CAD from MSA is a portable sensor system that canbe designed for chemical warfare agent detection. The system was developed and calibrated todetect a few target chemicals, and thus appears limited in its use for detecting other VOCs.

H. Quartz Crystal Microbalance (QCM) Sensors:

Quartz crystal microbalance (QCM) is another type of microbalance mass sensor.Similar to the SAW sensor, the transducer for the QCM sensor is also mass-sensitive. The majordifference between SAW and QCM is that the former employs a surface acoustic wave sensorwhile the latter uses a bulk acoustic wave sensor. Its sensing mechanism is based on the shift inthe quartz crystal (QC) resonant frequency due to the adsorption of gas molecules onto thesensing films. Film-coated QCM sensors have enabled the detection of a variety of individualpollutants[32-34] and the sensing ofvolatile organic compoundsVOCs [35-38]. The sensors used for the latter are typicallycoated with PVC blended lipids,syndiotactic polystyrene (s-PS) semicrystalline,carbon nanotubes, and molecular imprinted polymers. These films can collect targetVOC molecules and trigger a shift in the QC resonance frequency. Recently, modifications infilm composition have been reported to improve the sensitivity and specificity in gas identification[39, 40].The operation ofthe sensor requires temperature and humidity control because the QC resonant frequency isaffected by variation in temperature and humidity, and thus affects how the frequency shiftsduring gas molecule collection. Therefore the robustness of QCM sensor systems could be anissue for real-time detection of VOCs.

I. E-Nose:

An electronic nose (E-Nose) is an instrument that is designed to mimic the function of thenatural nose. By definition, it uses a sensor array to not only detect but also discriminate amongcomplex odors[41-43]. The sensor array typically consists of a group of non-specific chemical sensors that respond to odors. The detection and identification of a particular odorantis based on a unique combined response pattern from all sensors rather than a response patternfrom a particular sensor. In addition to the sensor array, the response pattern recognitionalgorithm is another key component in an E-nose system that determines how well the E-noseidentifies VOCs.

III. Conclusion:

Biosensors can play a great role in enhancing the procedures of crime detection. The field of forensic sciences will have a new way to detect and find out the criminal in a more efficient and accurate manner. The use of various different biosensors for detecting different types of biological components generally found at crime scenes will help to get good results in less time. More biosensors may also be developed keeping in mind, the expected samples and their complement molecules so that it can be detected in an efficient manner.

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