Faculty of Electrical and Electronic Engineering Technology

DESIGN OF BIOSENSOR USING COMSOL MULTIPHYSICS

SAGUNDALAI A/P RAJENDRAN

Bachelor of Electronics Engineering Technology with Honours

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DEDICATION

My beloved brothers

and

Supervisor and

My Friends

ABSTRACT

LFBs (lateral flow biosensors) are dominant in biology and medicine, agricultural sectors, culinary, and geoscience because of their cheap rate, accessibility, speed, durability, and mobility. Nowadays, Computer simulation have been an important component of biosensor development. Lately, the COMSOL Multiphysics Simulation has shown to be a powerful virtualization technology, especially in Nanotechnology and, more crucially, in biomedical applications and other activities require fluid and solid processes. The research started with a simulation of a gold nanoparticle-based biosensor created with the COMSOL Multiphysics software package. The simulation was used to describe overall amplitude of something like the turbulent concentration's gradient in the sample, speed area with in capillary streaming, fields related of adsorbate molecules, including averaged proportional surface coverage of absorbed analyte. Just after GNPs was simulated using Multiphysics, far radiation characteristics and thermal performance in gold nanoparticles were investigated. Subsequently, the polypeptide absorption is simulated, and the reactive component intensities vary over time. During five second and thirty seconds, the feature of enzyme B, as well as the velocity field, were discussed. The concentrations of proteins A and B are seen to change with the Gaussian concentration pulse feed inlet, also the behaviour of protein in which the bulk concentration is shown, indicate that the beads at the centre of the column are less accessible for adsorption or that the protein is more rapidly adsorbed at the centre, both phenomena lowering the bulk concentration there. and the velocity field that the porous structure causes a quite distorted velocity field. The exception is at the walls where the 76 flow is less obstructed due to the relatively large gap between beads and wall all of above to increase the accuracy of magnitude of the laminar velocity field in the flow cell ,

concentration distribution in the analyte stream and surface coverage of adsorbed species and Average fractional surface coverage of adsorbed analyte concerned in biosensor model based on gold nanoparticles GNPS in Multiphysics.

ABSTRAK

LFB (biosensor aliran sisi) dominan dalam biologi dan perubatan, sektor pertanian, kulinari dan geosains kerana kadarnya yang murah, kebolehcapaian, kelajuan, ketahanan dan mobiliti. Pada masa kini, simulasi komputer telah menjadi komponen penting dalam pembangunan biosensor. Pakej Perisian Multifizik COMSOL telah menjadi alat yang kuat untuk simulasi dalam dua puluh tahun terakhir, terutama dalam Nanoteknologi dan, lebih penting lagi, dalam aplikasi bioperubatan dan aktiviti lain memerlukan proses yang lancar dan padat. Melaksanakan perisian COMSOL untuk reka bentuk mempunyai kelebihan yang ketara berbanding reka bentuk komponen atau sistem tradisional, termasuk penilaian parameter kritikal yang lebih mudah pada tahap reka bentuk yang berbeza, kapasiti yang lebih besar dan pemantauan serta pengurusan pada harga yang lebih murah dalam tempoh yang lebih singkat. Penyelidikan pertama kali melihat model simulasi biosensor berdasarkan nanopartikel emas (GNP) yang dicipta dengan pakej perisian COMSOL Multiphysics. Penyelidikan terdiri daripada besarnya medan halaju laminar di sel aliran, taburan kepekatan dalam aliran analit dan rangkuman permukaan spesies yang diserap dan liputan permukaan pecahan rata-rata analit yang diserap dibincangkan dari model. Kedua, corak radiasi medan jauh dan kehilangan haba dalam nanopartikel emas dieksplorasi setelah GNP dimodelkan dalam Multifizik. Terakhir, Akhirnya, penjerapan protein dimodelkan dalam COMSOL, dan kepekatan spesies yang bertindak balas berubah dengan masa. Ciri-ciri protein B selepas 5 dan 30 saat, serta medan halaju, telah dibincangkan, dan beberapa cadangan telah dibuat untuk menfungsikan GNP dan meningkatkan ketepatan dan keberkesanan reka bentuk biosensor.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

$COMSOL$	-	Computer solution
$GNPs$	-	Gold Nanoparticles
Nm	-	Nanometre
$Au\ NPs$	-	Gold Nanoparticles
SPR	-	Surface Plasmon Resonance
NPs	-	Nano Particles
FET	-	Field Effect Transistor
$PDEs$	-	Partial Differential Equations
$LFBs$	-	Lateral Flow Biosensors
LF	-	Lateral Flow
SMA	-	Steric Mass Action Approximation
P	-	Analyte molecules
S	-	Surface sites
PS	-	Adsorbed analyte
QS	-	Quenched State
C_P	-	The species concentration
C_{PS}	-	Concentration of surface adsorbed species
DP	-	The diffusion coefficient
U	-	The velocity vector
E	-	Refractive index
Er	-	Relative permittivity
K0	-	The free space wavenumber

CHAPTER 1

INTRODUCTION

1.1 Background

A biosensor, in the broadest sense, is any biological organism designed to detect (either qualitatively or statistically) a respond to an environmental change. Generally, biosensor is a device that combines a biological element (that can cause a disturbance) with a traditional transducer (which is able to generate a measurable signal). Biological elements have primarily been enzymes, antibodies, organs, and microbes, while DNA and cell receptors have also been applied. The extraction of analytical data will be transformed mainly by using biosensors. This will enable for a more in-depth examination or studies or analysis and controlling certain processes automatically, mainly in the areas of clinical diagnosis, microbiology, food science, and sewage management. To be more specific biosensor is a device that can detect an analyte quantitatively and provide a signal that can be measured. The sensors that involve are electrochemical, optical, piezoelectric, or thermal measuring principles. A biosensor is a reasonably simple device to make. However, if models are to be produced, team members who have different type of skills with experts in electronics, mechanical design, and biotechnology are needed. Each type of biosensor must be calculation on the basics of detection limit, selection, trustworthiness, storage stability, flexibility, convenience, and, in certain situations, bioactive components, sanitation, and proper storage are all important factors to consider. Hundreds of biosensors have been described in the specialist research for the measurement of a huge proportion of samples [1].

1.2 Problem Statement

Biosensors have becoming professional in a variety of sectors, particularly engineering and medicine, where a huge estimated number of attempts are required to achieve the accurate results. The production of biosensors necessitates an integrated laboratory with materials, structures, and equipment, which is currently lacking throughout the world. To circumvent this issue, the simulation was created using COMSOL Multiphysics as a medium to finish the model along an estimated outcome.

1.3 Project Objective

The main purpose of this research is to Initial design of Biosensor using COMSOL Multiphysics as modelling tool. Specifically, the objectives are as follows:

a) To design a Gold Nanoparticle biosensor using high accuracy COMSOL Multiphysics Software.

b) To identify the properties of Gold Nanoparticles from the design in COMSOL Multiphysics Software.

c) To study the concentration of the species with time by designing a protein model in COMSOL Multiphysics Software.

1.4 Scope of Project

The scope of this thesis are as follows:

a) Design the Model in COMSOL Multiphysics.

CHAPTER 2

LITERATURE REVIEW

2.1 Nanotechnology

Nanotechnology is the study of matter on a size of one billion of a meter (i.e., $10^{-9}\ m = 1\ nm$) or smaller [2]. Nanotechnology is the relatively close manipulating things in order to build innovative layouts, products, plus technological advances The technique will assist a range of areas, such as healthcare, consumer goods, electricity, supplies, and industrialization. The term "nanotechnology" encompasses all designed constructions, electronics, and methods. Nanomaterials is things having a measurement of one-to-one hundreds of nanometers. At about this dimension, composites start to show their own characteristics., which affect physical, chemical, and biological behaviors. The heart of modern technology is the study, development, and use of these nanotechnology features. Nanotechnology is a collection of guidelines combining biology, physics, and chemistry that results in nano-sized particles that perform specific roles [3].

2.2 Nanoparticles

Nano comes from the Greek word "nanos," meaning indicates "small" or "dwarf." This prefix nano refers to one billionth of a part (10(-9) it's used as a term. Foremost basic component in the creation of a nanomaterials is a nanoparticle. It's much lower than the conventional universe, that is governed by Newton's law, but very greater than just an particle or a basic structure, which is governed by quantum physics.

The size of a nanoscale can range from 1 to 100 nano meters. The qualities of a material alter as its size approaching the molecular dimension. This is attributed to a rise in the number of the total area to pore volume, that enables the surface atoms to have the most influence on the structure's efficiency. Due to their extremely tiny size, nanoparticles have a comparatively large high aspect ratio as comparing to metals including such granules, trays, and films. Nanoparticles can also have unusual visual, physiological, and chemical characteristics since they are small enough just to confine their charged particles and create quantum states [1].

Those nanoparticles have special and increased mechanical / chemical characteristics compared to the pure materials due to their huge reactive and exposed surface area and quantum size impact as a result of electronical architectures. Telecommunications, computational chemistry, microbiology, and biochemistry have all used such nanoparticles extensively [2].

Nanoparticles can be classified into a variety of groups based on characteristics, shapes, and dimensions. Among some of the numerous groupings are nanotubes, metal nanoparticles, ceramic nanoparticles, and polymeric nanoparticles. NPs have unique physical and chemical properties due to their huge surface covering and nanoscale structure. Their optical properties, as per sources, are influenced by their diameter, which outcomes in varying colours due to the absorption in the visible area. Their dimensions, texture, and construction determine their reaction, toughness, as well as other qualities. Because of these characteristics, they are well adapted for a broad range of business and domestic purposes, involving catalyst, scanning, pharmaceutical applications, energy-based research, and environmental monitoring. Heavy nano - particles such as contribute, mercury, and tin are reported to be rigid and sturdy.

Excessive metal nanoparticles such as make a contribution, mercury, and tin are thought to be so hard and resilient that they have been resistant to dissolve, posing a range of biological risks [3].

Metallic nanoparticles (MNPs) are made up of an inorganic metal or metal oxide core encased in an organometallic material or transition metal coating [3].

Physicochemical and biological features of nano particles vary from metallic materials (e.g., low freezing heats, large specific surface areas, unique optical characteristics, major determinants, and unique relatively reliable), making them valuable in a variety of industrial purposes. But in the other hand, the way a nanoparticle is perceived and characterized is significantly reliant just on usage [1].

2.2.1 Gold Nanoparticles

Gold nanoparticles can be used in a variety of fields, the most crucial of which being biomedicine. Because of their high compatibility with the human biology, low toxicity and adjustable stability, compact dimensions, and capacity to interact with a range of chemicals, they are suited for controlled drug delivery, cancer treatment, biomedical imaging, diagnosis, and several other applications. They can also absorb infrared light, which gives them optical characteristics [5].

Latest research has showed that gold nanoparticles can pass the blood-brain barrier, interact with DNA, and cause genotoxic effects. They are frequently employed in photodynamic treatment because of their capacity to produce heat and so target and kill malignancies. Gold nanoparticles can be made in a variety of ways, the most popular of which are biological and chemical. The chemical process, however, has the advantage of being able to regulate the size and structure of the nanoparticles more precisely [5]. Since of their unique electromagnetic field characteristics, gold nanoparticles have received a lot of attention in the field of biological labelling, chemical and biological detecting, microelectronics, photodynamic therapy, biomedical imaging, DNA labelling, microscopy and photoacoustic imaging, surface-enhanced Raman spectroscopy, tracking and drug delivery, catalysis, and cancer therapy

Gold nanoparticles have a wine-red solution, which is distinct from bulk gold, which is an inert yellow solid. Gold nanoparticles come in a variety of sizes and shapes, including cylindrical, semi, octahedral, decahedral, polyhedron multiple twined, multiple twisted, irregular form, tetrahedral, nanotriangles, Nano prisms, hexagonal platelets, and nanorods, with sizes ranging from one nm to eight m [6].

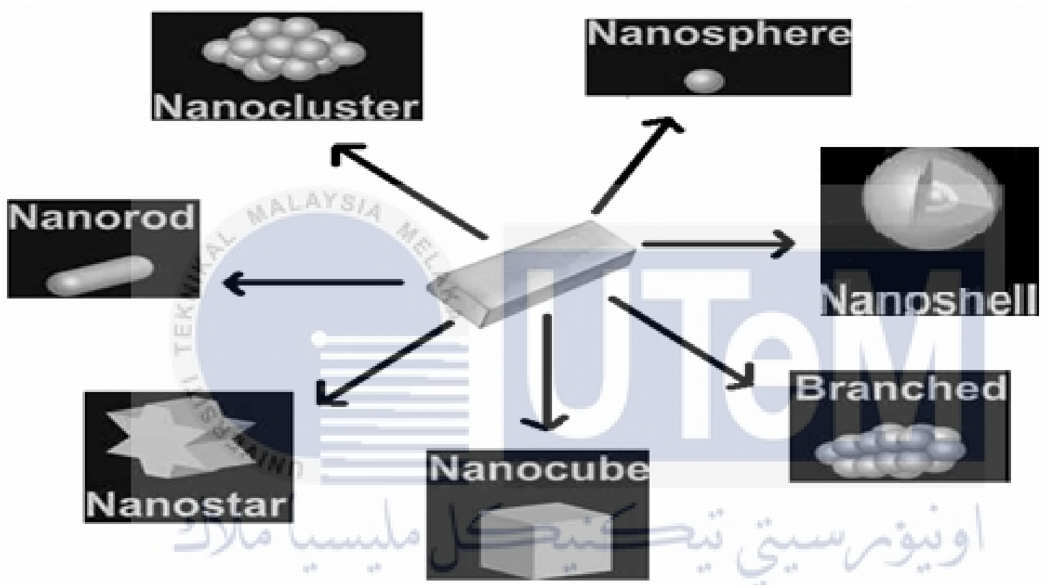

Figure 2.1Gold Nanoparticles in various form

When compared to spherical shaped nanoparticles, triangular shaped nanoparticles have the most appealing optical characteristics. The use of a single active component from a plant extract in the creation of gold nanoparticles is a crucial biosynthetic strategy for purifying gold nanoparticles and researching their medical applications. Gold nanoparticles have long been employed as a radiation booster in the field of radiation treatment.

2.2.1.1 Properties And Application of Gold Nanoparticles

Chemically stable gold nanoparticles have a better biological familiarity, according to their key aspects. Then there's the depend on its ability of gold nanoparticles, such as

Plasmon resonance. Furthermore, these were adaptable due to its simple with which redox interconnections can be adjusted. To analyze cancer cells, gold nanoparticles can be utilized as tiny detectors. Gold nanoparticles deposit in tumor site and have a toxic effect, causing the cell and its sensor to die or be killed. This has a great level of consistency due to the gold-Sulphur interactions. Finally, their light absorption properties can be exploited to disperse medications from afar.

The size, shape, and physical properties of gold nanoparticles are used to divide them into subgroups. The first gold nanoparticles to be studied were gold nanospheres (although not exactly spherical in a strict sense). Since then, nanorods, nano shells, and nanocages have all been characterized. In the following statement, the phrase "gold nanoparticle(s)" will refer to a collection of all of these subtypes, with the subtype of gold nanoparticles used in each study indicated where appropriate. The bulk of these gold nanoparticles can now be manufactured with such a strictly restricted particle diameter and even amazing accuracy [4].

Figure 2.2 Gold Nanoparticles in various shape

There are many applications of gold nanoparticles in recent decade. Nanoparticles have a variety of biological and industrial uses, including illness diagnostics, targeted treatment, and medication administration. Nanoparticles are characterised by their multifunctionality and sub-Micronics size. For site-specific medication delivery and cellular uptake, nanoparticles can be combined with ligands, imaging labels, therapeutic compounds, and other capabilities. The utilisation and manufacturing of gold nanoparticles, the most studied of all metallic nanoparticles, are discussed in this paper. Various anticancer medications are available, but they both drive malignant and normal cells to necrosis [4].

Another application of gold nanoparticles are useful materials that may be used in a wide range of applications. Gold particles were coated with DNA and inserted into plant embryos or cells by researchers. This ensures that some genetic material enters and transforms the cells. Plant plastids are improved by this strategy. Moreover, gold nanoparticles optical-electronic characteristics are being studied extensively for applications in high-tech fields such as sensory probes, electronic conductors, therapeutic agents, organic photovoltaics, drug administration in biological and medical settings, and catalysis.

There really are numerous both these uses for gold nanoparticles, including polymeric materials, surface coating, nanomaterials, as well as fabrics; it acts as a potent, anti-fungal, and anti-microbial agent; applications for nanowires and catalysts; to join resistors, conductors, and other digital integrated circuits elements; and photosensitizing diagnosis (PDT). Types of sensors, including a colorimetric sensor employing gold nanoparticles, can assess if products are fine to consume when a carcinoma harbouring nanoparticle is illuminated, the atoms quickly warm up, eliminating cancer cells. In ‘visible settings, as substrates for measuring the sound waves of covalent bond Spectroscopy is a kind of spectroscopy that employs light to detect dispersed colours in gold nanoparticles, which is now being used in biological imaging applications. It could be used as transmission electron microscopy probes since gold nanoparticles are thick. Genetic markers are used to detect cancers, cardiac conditions, and viral infections. As catalysis in a range of chemical reactions, and then as fuel cell technology.