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GLUCOSE SENSORS BASED ON ELECTROCHEMICAL PROCESS: A REVIEW

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ABSTRACT

The modes of detection process in glucose sensor mainly rely on three processes namely: electrochemical process, optical process and combination process .Glucose sensors can be made with the help of nanotechnology and it can be useful in sensing the glucose level in pancreatic - β cells .These nanostructured materials and oxides are dugout for the growth of glucose sensors with extra stability and sensitivity. In glucose sensors different types of metal oxides used are ZnO, MnO_2, and TiO_2 etc. In terms of insulin it shows a major role in achievement in normoglycaemic state and rejecting hypoglycemic state. Diabetic mellitus is the major disease caused by the increased level of glucose. So the level of glucose can be sensored by the glucose sensor. This article summarizes the use of glucose sensors and the challenges of the glucose sensors in different stages.

KEYWORDS: glucose biosensor, electrochemical techniques, nanomaterial and oxides, self-examinee of blood glucose, glucose oxidase.

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1. INTRODUCTION

Nowadays Diabetes mellitus is a major problem faced by the people all over the world, spreading as a threat. It is caused by the increased level of glucose in the blood. Pancreatic-βcells produce the insulin and it tightly controls the glucose level in the blood. When pancreas fails to produce the insulin, glucose level in the blood will be raised. Glucose plays a vital role in the stability of the human body. By testing the level of blood glucose in the body for avoiding the emergency caused by the diabetic is a crucial confirmation for efficient treatment. 2.8% of the people in this world are suffering from diabetes mellitus. By latter of this era it will be doubled[1]. Glucose in the blood is controlled and detected by the human body itself. The glucose level in the blood automatically increases after having the food and similarly controlled after 3hours. For the detection of this increasing level of glucose, glucose sensors can be used. Glucose sensors are a self-detecting system. Glucose sensors have a tremendous role in the diagnosis of diabetes mellitus and it is a great growth in the industrial field. Nanostructured materials and oxides are dugout for the growth of glucose sensors with extra stability and sensitivity not only in a healthy medical side and also in a cuisinesindustry[2]. Wide variety of elements of oxides and sensors are used to develop the glucose sensor. Glucose sensors are biosensors which co-operates with different transducers. Mainly 5 types of transducers are used. 1. Electrochemical transducers 2. Piezoelectric transducers 3. Optical transducers 4. Magnetic transducers 5. Thermometric transducers. These transducers are helping in detecting the glucose level by converting one form of energy into other forms[3]. It mainly suits and adapts to maintain the glucose level in an artificial pancreas. Some of these metal oxides possess some electric properties as well as catalytic properties. In glucose sensor different types of process are taking place. Nano scaled sensors are the other major sensors. Nano materials have a great stability than other materials. Electrochemical sensors are other major glucose sensors. It mainly depends on the electrochemical process[4]. These sensors are mainly classified into two 1. Enzymatic sensor 2. Non enzymatic sensor[5]. As per the electrochemical sensor it works over with a different agents and catalyst. Electrodes are main part in the electrochemical sensors. It works on the basic principle of electrochemical process. Due to the use of these electrodes, sometimes corrosion will be occurring. As result of this an unwanted layering will transpire. It will reduce the stability of electrochemical sensor at a great extent. Enzymatic provides a very effective stability and sensitivity. In Non-enzymatic sensors, oxidization take place directly and no enzyme will present there[6, 7]. As a result of this, the sensor provides a very large performance with a nice stability at a very good condition.

2. ELECTROCHEMICAL PROCESS

For the biosensor industry the developing of a perfect glucose sensor is a top issue with great possibilities. Different electrochemical processes are held in the creations of glucose sensors. Enzymatic glucose sensors are containing large selectivity and non-toxicity components[8]. Non-enzymatic sensors are rapidly rising in the industrial field from long term back[9].

2.1ENZYMATIC GLUCOSE SENSORS

In biosensor production, enzymatic glucose sensors are heading mainly in self detection of glucose level. In 1962 enzymatic glucose were firstly announced by Clarke and Lyons[10] in which the consumption of oxygen was monitored in the existence of oxygen based on oxidation catalyst of glucose. Because of this wavering amount of oxygen, oxygen sensors have to be developed for the corrected level of oxygen by Updike and Hicks[11]. Glucose oxidase is the major component used in the enzymatic glucose sensor. Glucose oxidase is also known as “the gold standard of glucose sensing”[10]. In oxidoreductase group, glucose oxidase is illustrative of glucose. According to the mechanism of enzymatic glucose sensors, they mostly rely on three generations. Mainly three types of processes were involved in these three generations. They are:

1. Oxygen arbitrated system

2. Redox arbitrated system
3. Direct electron transfer

2.1.1. FIRST GENERATION OF ENZYMATIC GLUCOSE SENSORS

In this generation, it talks about the oxygen mediated system. Here the enzyme is rehabilitated back to oxidized form by milieu oxygen. As a result of this, the production of hydrogen peroxide will increase in serious manner. It can either produced by the oxidation or through the electrochemical process at electrode. Gluconolactone is another substance formed due to the oxidation method. The key advantage of the hydrogen peroxide type sensors is their simplicity of design and it can be made in small shapes even in the large technology (Wilkins and Atanasov, 1996).

$$\beta\text{- GLUCOSE} + O_2 + {}^{enzyme}H_2O \rightarrow \text{GLUCONIC ACID} + H_2O_2$$

$$H_2O_2 \xrightarrow{catalyst} O_2 + 2H^+ + e^-$$

2.1.2 SECOND GENERATION OF ENZYMATIC GLUCOSE SENSOR

In first generation, the foremost problem is witnessed as the over dependence of oxygen. For avoiding this, surrogatesubstrates were preceded.For expedite the electron transfer, electron accepting intermediaries were needed.Physiological and non-physiological Peace Corps are used in the second generation of the enzymatic glucose sensors. Non physiological parameters used in this generation are

1. Ferrocene spinoffs
2. Ferricyanide
3. Quinones
4. Transition-metal complexes

These mediators can play a major role in enzymatic glucose sensors; they possess some much more aspects and suits for the sensors. All of these mediators having low molecular weight and solubility are very less compared to the natural rate. As a result of these diffusion rate is very high with reversible and irreversible properties[12]. Low potential of reduction process held to avoid the high oxidation of inquisitive kinds of species[13]. Mediators are comparatively small, due to this, maintenance and sticking properties of the intermediaries are pretty difficult to uphold[14]. Intermediaries are highly reactive to enzyme than oxygen. Though the process is taking place, the efficiency and the stability of the system will become lower[15]. It results in the formation hydrogen peroxide. As an effect of these features mediators are well much talent to react with the prying substance and more distress to accuracy and proficiency of diagnostic part of the body[16,17]. Free style of detecting system uses glucose hydrogenase and some enzymes[18].

2.1.3. THIRD GENERATION OF ENZYMATIC GLUCOSE SENSOR

Direct transfer of electron takes place in third generation of glucose sensors. Here no need of enzymes and mediators. The difficulty of electron transfer is much large so the sensitivity and stability of the system will increase gradually. Direct transfer of electron is pretty much difficult between the electrode and reacting enzymes. Because in which the redox entrenched, the thickness of the protein in-between them is comparatively precisely high. Earlier the intermediaries and glucose accessed by means of flow of molecules from higher region to lower region by diffusion and penetration of these molecules will not possible in a perfect electrode. The emerging of nanomaterial and highly reactive material are the reason behind in the sudden growth. When competing with the thawed oxygen, it can be regenerated the enzyme, but bearing power is very small.

2.1.4. MEDIATORS USED IN ENZYMATIC GLUCOSE SENSORS

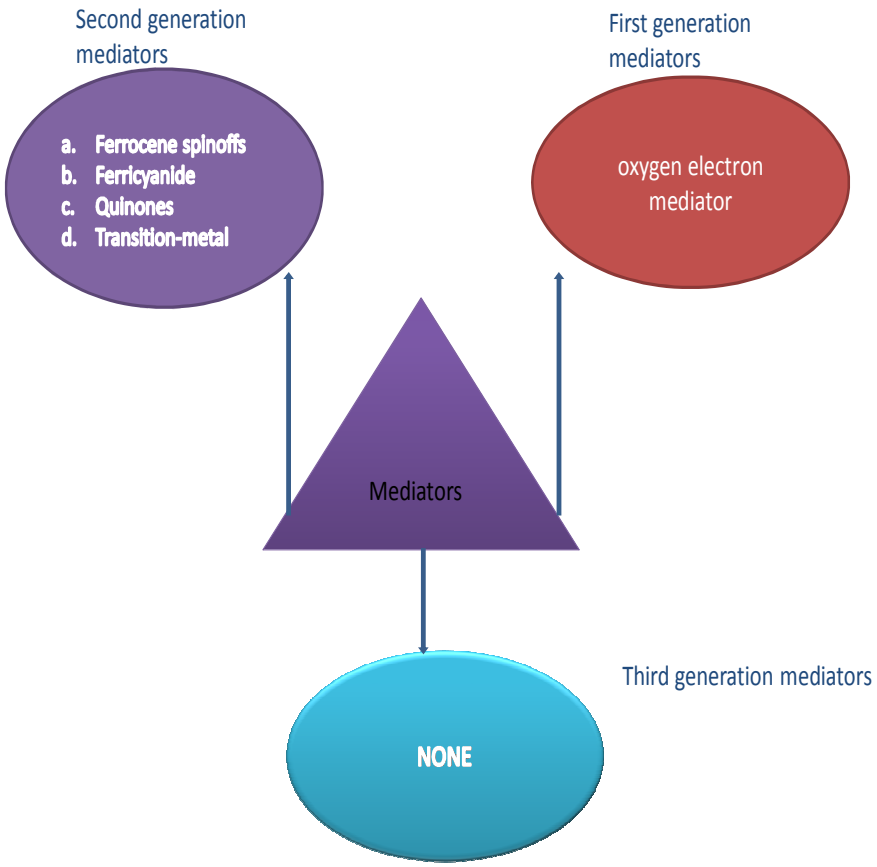

Figure A
Represents the mediators used in enzymatic glucose sensors

2.1.5. ADVANTAGE OF ENZYMATIC GLUCOSE SENSOR

The main advantage of the enzymatic sensor is their stability and efficiency of the system. GOx maintains the pH level at a specific rate at 2-8. Each generation are using different techniques. Numerous mediators are giving the role to the system to gain sensitivity and stability. For ensuring the stability of the system, the fabrication steps have some few processes like electrochemical polymerization chain reaction. Now a day's glucose sensors are unbeatable at the industrial field.

2.2. NON ENZYMATIC GLUCOSE SENSORS

These glucose sensors are also known as the fourth generation of the glucose sensors. They are highly potential comparatively to other generations and enzymatic sensors to diagnose oxidation of glucose. In here oxidation can be done directly in sample itself. This system was initially identified by the Walther Loeb about hundred years ago. Clarke electrode was used at first in the research field of enzymatic glucose sensors.

Chart 1
Electrode composition of materials

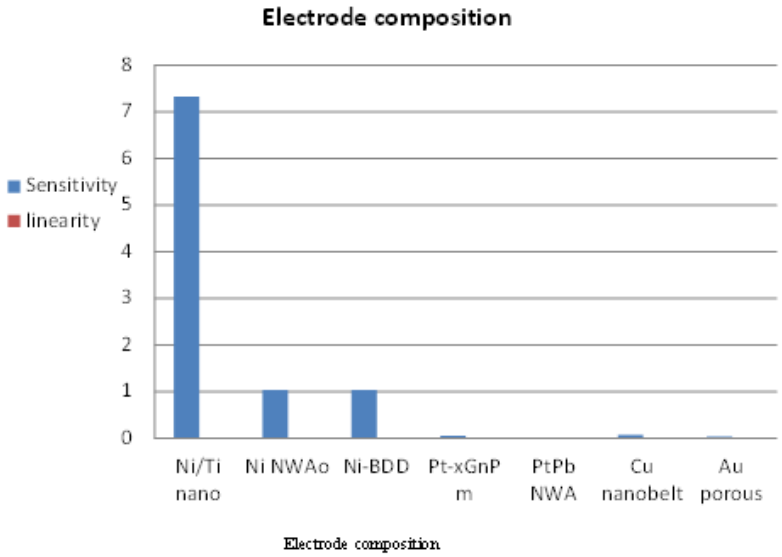

Figure 2.2.1
Chart 1 shows graphical representation of different electrode composite of different materials

This shows composition of electrode with their sensitivity and linearity. It shows the lack of consistence showed by the electrode. Chart 1 represents the diagnostics by the ampereometric examination developed in this generation[19,20]. Sensitivity and linearity changes are according to the physiological parameters [21]. Chart 2 shows said about the polymers and composites[22].

Chart2
Polymers and Composites

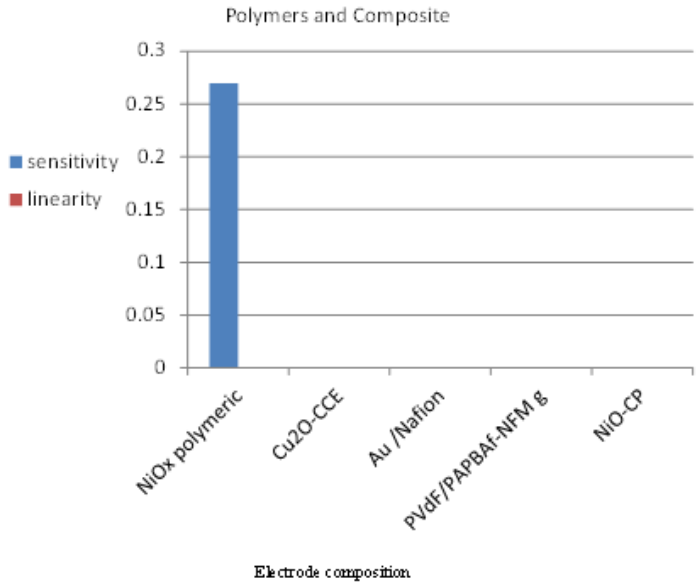

Chart 2 shows graphical *representation of different electrode composite of different polymers and composites*.

Fixed potential are arranged for the non-enzymatic glucose sensors. In chart 1, we can easily find that the frontier of the detection is comparatively low and less extravagant. Non-enzymatic glucose sensors are mainly depends upon the electrode[23]. Different types of electrodes were used in the glucose sensors, some of them are made up of nickel, platinum, gold and carbon electrodes[24]. In latest, the development of glucose sensors causes in the increasing range of Nano materials[25]. The recent developments in this area gyrate around the progress in synthesis of nano materials[26]. Nano porous materials and micro porous materials raised the interest of sensors in this field. The applications of these progress influenced industries such as microelectronics, petroleum areas, sustainable energy etc. The activity of the electrode is often expressed in terms of roughness factor. The surface roughness is directly proportional to the electrochemical activity. Nano based electrode materials provide a very high dynamic apparent area which is greater than symmetrical area. The coming up with carbon nanotubes allowed the compensations, by increasing the apparent area. According to inherent electrodes, through re-developing the planar electrode, the materials coated in planar elecctrodes are highly porous, so in the carbon electrodes, there will be increase in the apparent range of the electrodes and modification in this region is very vast.

3. SYSTEM DESIGNING OF GLUCOSE SENSOR

Glucose sensor mainly made up of different transducers[3]. As we mentioned earlier. These transducers have vital role in the glucose sensors.

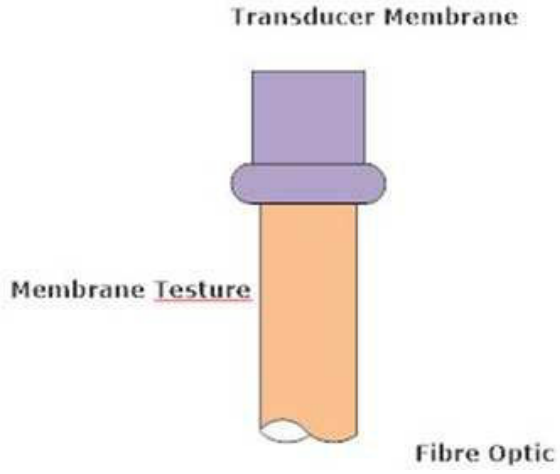

Figure 01
Part of glucose sensor

The figure describes the transducer used inside a glucose sensor. The transducer consists of upper transducer membrane and in the middle layer there will membrane testure with diffusion properties. Fibre optic is placed at the bottom. The main principles of electrochemical process are potentiometric glucose sensors and ampereometric glucose sensors. Figure 3.02 shows the implantable four layered glucose sensors. Which having Gold layer consists of 29mm of thickness, sensing layer mass transport limiting layer possess of 15mm thickness. Bio compatible layers are having 20mm thickness. These four layered glucose sensors are mainly used for continuous detecting of glucose[27].

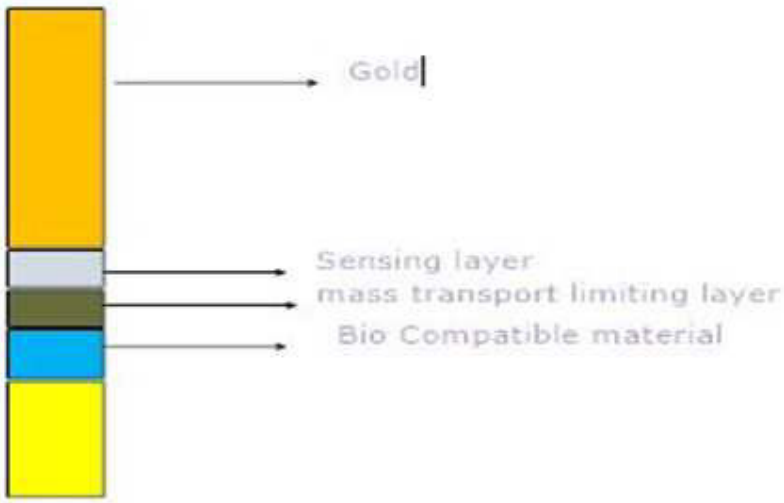

Figure 3.02
Four layered glucose sensor

4. CONCLUSION AND DISCUSSION

It is evident that in the past 8-10 years there was an immense increase in the development and use of CGD, as it place great role in the management of diabetes. In this journal I had discussed mainly about enzymatic and non-enzymatic glucose sensors which work on the principle of electro chemical process. Though the both sensors have its own advantage, the non-enzymatic sensor is much easier and simpler to sense glucose. In the future, we are expecting sophisticated CGD devices, which can make a revolution in both the industrial & health sector. In order to fabricate such advance CGD device, bio-medical engineers together with multidisciplinary team should be needed.

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