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ROLE OF ELECTROCHEMISTRY IN DIABETIC SYSTEM AND ORGANIC SPECTROSCOPY- A REVIEW

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Abstract

Diabetes is a condition in which the body either does not produce enough, or does not properly respond to, insulin, a hormone produced in the pancreas that enables cells to absorb glucose in order to turn it into energy. In diabetes, the body either fails to make enough insulin (Type 1 diabetes), or does not properly respond to its own insulin (Type 2 diabetes). This causes glucose to accumulate in the blood, leading to complications of the eyes, kidney, heart and circulatory system, among others. Much of this burden may be reduced or eliminated by early detection and improved self-care than with poorly-controlled subjects. This good control is enabled by frequent, consistent and accurate self-testing of blood glucose to optimize therapy. Electrochemistry found useful in disease detection. A disposable polymer microchip promises to make medical diagnostics easier and more convenient. Electrochemistry based sensors offer sensitivity selectivity and low cost for the detection of selected DNA sequences or mutated genes associated with human diseases. Electrochemical Impedance Spectroscopy (EIS) or AC impedance methods have seen tremendous increase in popularity in recent years. Electrochemical impedance spectroscopy has become a mature and well-understood technique. It is now possible to acquire, validate, and quantitatively interpret the experimental impedances.

Key Words: Electrochemistry, Diabetes, AAS.

Introduction

Electrochemistry is a branch of chemistry that studies chemical reactions which take place in a solution at the interface of an electron conductor (a metal or a semiconductor) and an ionic conductor (the electrolyte), and which involve electron transfer between the electrode and the electrolyte or species in solution[1].

Electrochemistry in general and electrochemical technology in particular has over recent decades evolved from an art to an exact science. This development is seen as the main reason for the constantly growing number and widening types of applications of this practical science/engineering. Means and methods of electrochemical technology provide the essential components of modern macro and microelectronics, optoelectronics, optics, sensors of most types and many more. Industries from the automobile to the high-tech industries have adopted methods of electrochemical technology, even where other methods such as evaporation, sputtering, chemical vapor deposition (CVD) are an option, for reasons of economy and/or convenience[2].

There are various extremely important electrochemical processes in both nature and industry, like the coating of objects with metals or metal oxides through electrodeposition and the detection of alcohol in drunken drivers through the redox reaction of ethanol. The generation of chemical energy through photosynthesis is inherently an electrochemical process, as is production of metals like aluminum and titanium from their ores. Certain diabetes blood sugar meters measure the amount of glucose in the blood through its redox potential. The nervous impulses in neurons are based on electric current generated by the movement of sodium and potassium ions into and out of cells, and certain animals like eels can generate a powerful voltage from certain cells that can disable much larger animals.

Electrochemistry found in useful in disease detective like A disposable polymer microchip promises to make medical diagnostics easier and more convenient, Immunoassay is the workhorse tool of biomedical diagnostics. Annual sales for immunoassay reagents and supplies are currently ca $7000m (>£4000m) worldwide and ca $2000m in the US[3].

In medicine, immunoassay is used in two general classes of applications: for identifying the organism responsible for a disease (diagnosis), and for monitoring disease treatment. Despite its success, however, immunoassay does have drawbacks. In particular long assay times, complex and expensive equipment, and the need for trained technicians have restricted its use mainly to centralized laboratories. But things look set to change. In this competitive market-place, medical diagnostic companies are already looking at new technologies that allow fast, quantitative and portable assays with simplified instrumentation. Lab-on-a-chip systems capable of analyzing minute volumes of sample currently offer the best hope. Microchips should not only greatly simplify the process of immunoassay, but could also allow diagnosis to be carried out in local analytical laboratories, A&E departments, doctors' surgeries or even pharmacies. In this way, they may one day be used by all health professionals at 'point of care' regardless of location, and ultimately even by patients in the home.

Electrochemistry based sensors offer sensitivity selectivity and low cost for the detection of selected DNA sequences or mutated genes associated with human diseases. DNA based electrochemical sensors exploit a range of different chemistries, but all take advantage of nanoscale interaction between the target in solution, the recogtion layer and a solid electrode surface. Numerous approaches to electrochemical detection have been developed, including direct electrochemistry of DNA, electrochemistry at polymer-modified electrode, electrochemistry of DNA-specific redox reporters, electrochemical amplification with nanoparticals and electrochemical devices based on DNA modified charge transport chemistry[4].

Electrochemistry for Diabetes Management

a) Electronic Meter[5]

(Measurement, storage and communication device)

Applies potential differences in a programmed sequence to the sensor collects biamperometric current data Records and displays results

- rate
- amperes
- flow rate pressure
- volts
- average electron energy
- electrode
- electrolyte sample
- electrode potential

Example:-

Just as water will flow if a pressure difference exists between two points in a pipe, will flow if exists between two points in a conductor. Similarly, as flow increases with pressure in a pipe, current increases in a conductor as the potential difference is increased.

1. Electronically using a meter or,

2. Chemically.

If an electrode can match its electron energy with ions in solution, those ions may define the electrode potential. Consider the (electron addition) of potassium ferricyanide (M) to potassium ferrocyanide (M). This is a simple:

$Fe(CN)_6^{3-} + e^- = Fe(CN)$

$M_{ox} + e^{-+} = M$

Since M_{ox} and M_{red} each has different electron energies, by using the Nernst equation to define the solution potential (the average energy of electrons in thermal solution)

$E=E^0+0.059/n \log[M_{ox}/M_{red}]$[10]

An extremely useful method is-

- Current potential difference
- Potentiostat
- Nernst equation
- Amperometry
- Cottrell equation

b) Mediators[6,7]

A well-known mediator is potassium ferricynide. The reaction process-

a) Glucose first reacts with the enzyme glucose dehydrogenase. Glucose is oxidized to gluconic acid and enzyme is temporarily reduced by the enzyme.

b) The reduced enzyme next reacts with M_{ox} transferring a single electron to each of two mediator's ions. The enzyme is returned to its original state and the two M_{ox} are reduced to M_{red}:

c) Fericynide and ferrocynide are capable of rapidly transferring electrons with an electrode. The electrons may thus be transferred between glucose and the electrode via enzyme and mediator.

The biosensors reagents are actually more complex containing a number of other active ingredients e.g., stabilizers, processing aids etc

Electrochemical Impedance Spectroscopy (EIS) or AC impedance methods have seen tremendous increase in popularity in recent years. Initially applied to the determination of the double-layer capacitance1-4 and in ac polarography, 5-7 they are now applied to the characterization of electrode processes and complex interfaces. EIS studies the system response to the application of a periodic small amplitude ac signal. These measurements are carried out at different ac frequencies and, thus, the name impedance spectroscopy was later adopted. Analysis of the system response contains information about the interface, its structure and reactions taking place there However, EIS is a very sensitive technique and it must be used with great care. It is not always well understood. This may be connected with the fact that existing reviews on EIS are very often difficult to understand by non-specialists and, frequently, they do not show the complete mathematical developments of equations connecting the impedance with the physico-chemical parameters[8]. It should be stressed that EIS cannot give all the answers. It is a complementary technique and other methods must also be used to elucidate the interfacial processes. The EIS Theory Primer presents an introduction to Electrochemical Impedance Spectroscopy (EIS) theory. This application note has been kept as free from mathematics and electrical theory as is possible. If you still find the material presented here difficult to understand, don't stop reading. You will get useful information from this application note even if you don't follow all of the discussions. Electrochemical impedance spectroscopy has become a mature and well-understood technique. It is now possible to acquire, validate, and quantitatively interpret the experimental impedances. This chapter has been addressed to understanding the fundamental processes of diffusion and faradic reaction at electrodes. However, the most difficult problem in EIS is modeling the electrode processes, which is where most of the problems and errors arise. There is an almost infinite variety of different reactions and interfaces that can be studied (corrosion, coatings, conducting polymers, batteries and fuel cells, semiconductors, electro catalytic reactions, chemical reactions coupled with faradic processes, etc.) and the main effort is now being applied to understanding and analyzing these processes.

CONCLUSION

In electrochemical DNA sensing some important hurdles remain. The first depends upon the electrode probe themselves and their fabrication into useful arrays. Array sizes of the order of 10 have thus far been demonstrated but more typically array of 50-100 sequence will be needed for clinical application. For example, genetic screening for cystic fibrosis carriers testing for 25 different mutation plus positive and negative controls. Although it is not the fashion electrode pads with reproducible dimensions of a micron or less the electrode readout requires, mechanical connections to each individual. Accu-Chek Advantage illustrates many fundamental chemical and electrochemical reaction concepts. Although we have only skimmed the science and engineering considerations, the system illustrates elements of enzymatic and charge transfer reactions, potentiometry, amperometry and diffusion. By carefully optimizing a design based on fundamental principles, this handheld device provides a robust electrochemical system for blood glucose measurement.

Atomic absorption spectroscopy can be used to determine some metals, which are capable of giving solution of the metals concerned in either an aqueous or organic solvent. Atomic absorption spectroscopy is an ideal candidate for this type of studies.

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