COE HSC Depth Study Material

Organic semiconductor-based biosensors

How do we integrate biomolecules with electronic devices?

Year 11 Physics	Module 4: Electricity and Magnetism	Electrical circuits	**Year 12 Chemistry**	Module 7: Organic Chemistry	Polymer Chemistry
Year 12 Physics	Module 6: Electromagnetism	Electric fields	**Year 12 Biology**	Module 8: Non-infectious Disease and Disorders	Blood glucose level

Introduction & context

Transistors are electronic devices consisting of three terminals in which electrical current between two of the terminals is controlled by a signal applied at the third. The architecture of a common type of transistor – the thin film transistor (TFT) – is shown in Figure 1. The source and drain electrodes are connected by a semiconductor, and the gate electrode is separated from the semiconductor by an insulating dielectric layer. The signal applied to the gate electrode controls the current flowing between the source and drain electrodes and allows the device to operate as an amplifier or switch. Transistors based on conventional solid state semiconducting materials such as silicon are one of the fundamental components for of modern-day electronics.

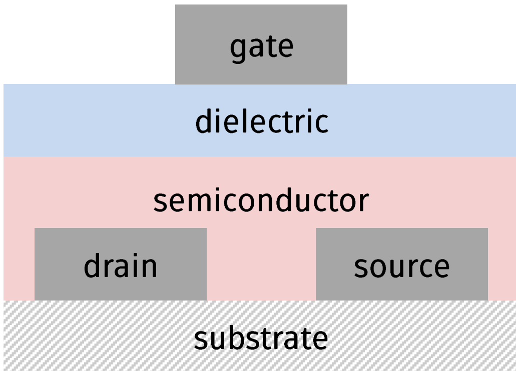

Figure 1 Diagram illustrating the cross section of a thin film transistor.

In more recent years, organic (carbon-based) conducting and semiconducting materials have been used in the fabrication of transistors. Devices with an organic semiconducting layer are generally referred to as "organic transistors" and often take the form of an organic thin-film transistor (OTFT), with the same general structure as the conventional TFT shown in Figure 1. Due to their potential low-cost fabrication on flexible substrates, OTFTs are of particular interest in applications such as flexible integrated circuits or chemical sensors.

These OTFT devices can be modified to include a biological recognition element to form a biosensor. In this case, the enzyme glucose oxidase (GOX) acts as a selective recognition element as part of an OTFT-based glucose sensor. The transistor works by taking advantage of the interaction between glucose and the enzyme, which produces hydrogen peroxide (H_2O_2). The H_2O_2 can in turn be broken down electrochemically into components which can modify the electrical conductivity of the organic semiconductor material poly-3-hexylthiophene (P3HT). It is hoped that this technology can be developed in to a "lickable" glucose test for diabetes management which takes advantage of the correlation between the concentration of glucose in blood and saliva.

Device Operation

The first step of device operation occurs when the glucose which is applied to the top of the device diffuses to the GOX located in or on the Nafion layer as shown in Figure 2. The GOX selectively oxidises glucose with gluconolactone and hydrogen peroxide (H_2O_2) generated as products of the reaction as described in the following equation:

$$Glucose + \ O_2 \xrightarrow{GOX} gluconolactone + H_2O_2$$

Subsequently, when the H_2O_2 in solution is oxidised above a threshold voltage (-0.7 V) by a voltage applied at the electrodes, it breaks down electrochemically into hydrogen (protons), oxygen, and electrons as described in the equation below:

$$H_2O_2 \xrightarrow{\sim 0.7V} O_2 + 2H^+ + 2e^-$$

The net result of these two reactions is that a stoichiometric quantity of protons is liberated which is directly proportional to the number of glucose molecules oxidised by the enzyme.

Once the protons are liberated, they can move (accelerated by an electric field) through the films into the P3HT film changing its electronic properties and hence the current flowing between source and drain.

The next phase of this project involves upscaling the fabrication of these devices to large area roll to roll printing. See the "Printable Electronics" document for more information.

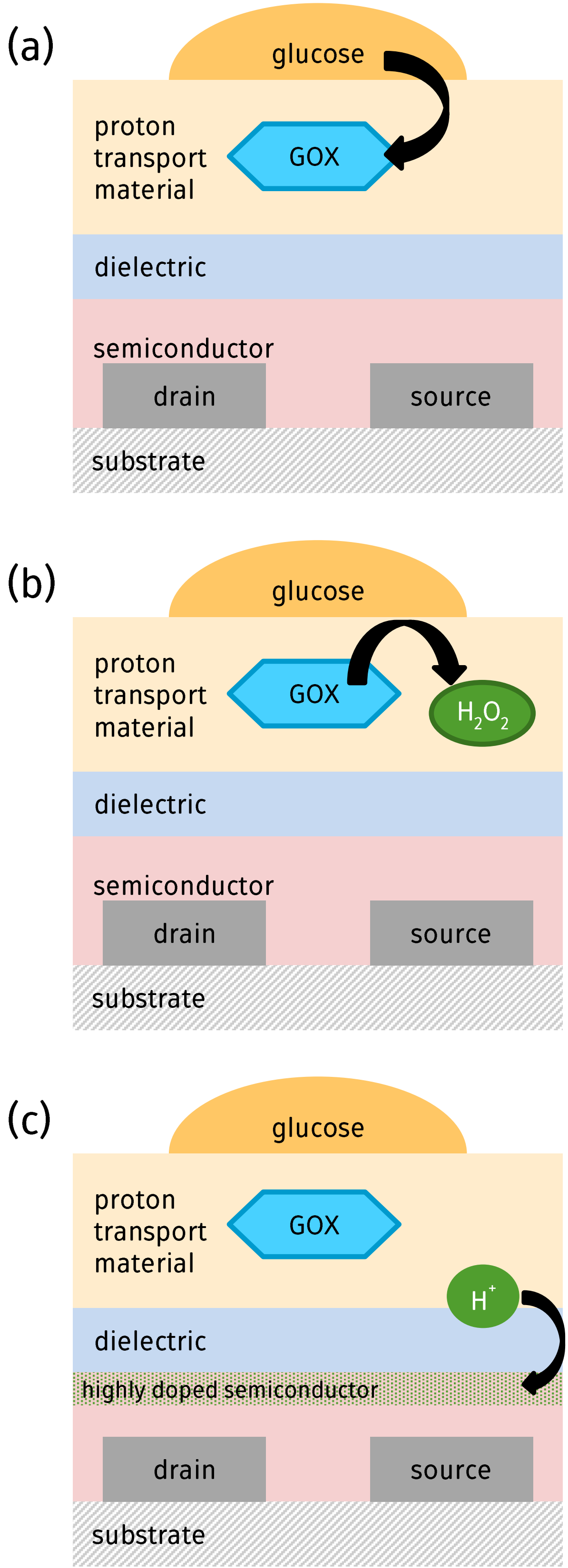

Figure 2 Organic glucose biosensor operation. (a) glucose interaction with GOX (b) H_2O_2 liberation and (c) proton doping of organic semiconductor.

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Related Concepts

Writing Chemical Equations
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Related Questions

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