Abstract

The aim of the studies presented in this thesis was to explore various materials and platforms for the detection of DNA in order to develop a cost-effective, repeatable and reproducible electrical/electrochemical DNA sensor.

Chapter 1 is a review chapter consisting of a comparative study of the fundamental working principle, fabrication process, characteristics and performance of different types of DNA biosensors and a detailed discussion on the progress in the development of DNA biosensors.

The studies described in Chapter 2 focuses on the development of a flexible, label-Free DNA Sensor using Platinum oxide (PtO) as the sensing element. PtO (100nm) deposited using an optimized reactive ion sputtering process revealed p-type semiconducting behaviour with a band-gap of 1.5 eV, resistivity of 0.16 Ω-m and activation energy of 0.22 eV. XPS spectra indicated the presence of PtO phase (32%) along with PtO_2 phase (68%). The XRD spectra indicated the formation of α-PtO_2 phase. Arrays of simple, two terminal sensors were fabricated on transparent, flexible, acetate substrates with platinum oxide thin film forming the active layer (8.0 mm X 60 μm) for DNA detection. The sensor operated on the principle of conductance change resulting from the change in charge carrier density due to attachment of DNA to the platinum oxide surface. The DNA attachment onto platinum oxide was experimentally verified by performing Fourier Transform Infrared Spectroscopy (FTIR) and optical fluorescence measurements. The binding constant of DNA to platinum oxide was found to be 7.35 p.m. for every percentage increase in fluorescence intensity. The sensor arrays showed a DNA concentration-dependent current change that was linear over a large dynamic range and sensitivity down to 0.5 nM. The label-free platinum oxide DNA sensors showed reproducibility with a coefficient of variation (CoV) of less than 10%.

In chapter 2 reactively sputtered Platinum oxide thin film was used as a DNA sensing element. In chapter 3, we subject the reactively sputtered Platinum oxide thin films to an additional RIE step for 3, 6 and 9 minutes and carry out a detailed comparative study of the material and electrical properties of these films. XRD and XPS analysis revealed that when the reactively sputtered Platinum oxide film was subjected to RIE step for longer periods of time, it became progressively α-PtO_2 in nature. Activation energies of 0.24 eV, 0.26 eV, 0.29 eV and 0.31 eV were obtained for the as deposited film and the films subjected to RIE step for 3, 6 and 9 minutes respectively. The Hall mobility of the as deposited Platinum oxide film was found to be 32.15 $cm^2V^{-1}S^{-1}$ at room temperature. However, when the as deposited film was subjected to RIE step for 9 minutes the mobility value rises to as high as 136.13 $cm^2V^{-1}S^{-1}$ at room temperature.

In chapter 4, the development of an electrochemical, sequence specific DNA hybridization sensor using platinum microelectrodes is discussed. A new transduction hybridization pathway obtained by coupling electrochemical adsorption and long-range electron transfer through double-stranded DNA is presented. This property was used to investigate long-range electron transfer properties of synthetic oligonucleotides and plasmids layers. A check complementarity assay of two non-labelled short DNA, without heating or DNA labelling, in a 10 minutes protocol, was in fine established.

In chapter 5, the possibility of DNA sensing using impedance spectroscopy of layer-by-layer self-assembly of weak polyelectrolytes is explored. Interdigitated capacitors (IDCs) with active area of 1X1 mm^2 and electrode spacing of 5 μm are fabricated on acetate sheets for this purpose. Measurement results indicate that there is differential binding of DNA to differently charged polyelectrolyte terminating layer on the IDC surface. The differential binding of DNA to Poly (Allylamine Hydrochloride) (PAH) and Poly (Acrylic acid) was also confirmed using Fluorescence microscopy and FTIR spectroscopy.