UNIVERSITI TEKNOLOGI MARA

DEVICE MODIFICATION OF FIELD-EFFECT TRANSISTOR PH SENSOR TOWARDS IMPROVED SENSITIVITY

KHAIRUL AIMI BINTI YUSOF

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ABSTRACT

This thesis presents the device modification of FET based pH sensors, namely ion-sensitive FET (ISFET) and extended-gate FET (EGFET) based sensors, to achieve good device performance. The first part of this research focused to improve the light sensitivity effect of ISFET. Two approaches of layout design modifications have been designed, fabricated, and measured. The first approach was designing a layout and fabrication of three different source-drain metal shield. The findings revealed that by implementing the metal shield layer modification, a good reduction of light sensitivity effect reduced to around 50% and the percentage of leakage current also decreased for about 52.29 % compared to without metal shield at source-drain area. Meanwhile, the source-drain metal shield paired with LOCOS isolation modification has been presented for the second approach. The results successfully indicated excellent reduction on the light sensitivity effect down to 96 % and the leakage current also reduce to 95.21 % compared to that of without metal shield at source-drain area and LOCOS. Then, completed packaged sensor with reduction techniques revealed that the pH sensitivity and linearity at dark environment were 50.17 mV/pH and 0.99997, respectively, whereas, at light environment were obtained at 50.83 mV/pH and 0.99997 respectively. Hence, it proves that the light sensitivity effect reduction technique which the layout of source-drain metal shield with LOCOS isolation modification that imply at this pH sensor managed to overcome the light effect issue. Next, to further improve the sensor sensitivity, the alternative materials were studied, namely TiO_2 and Ta_2O_5 by implementing EGFET configuration due to simple and easy in fabrication and packaging of the sensing membrane part. EGFET pH sensor performances were studied using different materials of sensing films, different fabrication techniques, and also testing and characterization of EGFET pH sensor. The overall findings in studies of exploring suitable materials and fabrication techniques revealed that Ta_2O_5 sensing film prepared at lower RF power of 100 W gives excellent pH sensing properties with higher pH sensitivity (58.70 mV/pH), good linearity (0.99673), smaller hysteresis voltage for both acid and alkaline pH loops (1.24 mV and 3.45 mV), and a lower drift rate (0.1935 mV/h), relative to those of the system that had been subjected to other materials. Then, the best parameter of Ta_2O_5 thin film with higher pH sensitivity was applied in order to further extend the investigation of the semiconductor device characterizations. The results showed that the sputtered thin film gives higher pH sensitivity and linearity, small hysteresis and drift, and good repeatability, and reproducibility.

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CHAPTER ONE
INTRODUCTION

1.1 Research Overview

In 1909, Soren Peter Lauritz Sorensen the Danish biochemist has originally defined pH as a logarithmic measure of hydrogen (H^+) ion concentration in a solution and is important in numerous fields of applications. The slight changes in pH value of a solution can have a significant effect on chemical processes. Hence, both the measurement and control of pH is important such as in medical and biomedical analysis, aquaculture and agriculture, food processing technology, and environment monitoring [1–3]. For example, determining the right pH value in the food and beverage products can ensure its taste and safety. Therefore, there are many tools that been introduced for pH measuring at widely usage [4–6].

Litmus paper and pH glass electrode are some common traditional tools that been used for pH measuring methods because of simple and quick measurement results [7, 8]. Litmus paper is an indicator paper to determine the acidic and basic solutions in an easiest way. It only provides the basic information; color as an indication either it is acidic or basic solution. Hence, it is not practical for people with color blind disability. In addition, litmus paper also cannot be reused after each used. Meanwhile, pH glass electrode is commonly used tool for pH measurement due to good sensitivity and selectivity, wide operating range, and long term stability [9–11]. However, the glass electrode still own certain disadvantages including difficult to integrate with electrical circuit, fragile, large size, temperature dependent, and also requires frequent monitoring maintenance [12–14]. Hence, there are many other pH sensors that have been proposed.

Incorporating silicon technology with sensors has been started since 1970 and among the most well-known example is the ion sensitive field effect transistor (ISFET) introduced by Bergveld [15]. It is a type of electrochemical sensor that converts from chemical information into the electrical signal. ISFET essentially been developed to measure ion concentration (H^+ or OH^-) in a solution causing an interfacial potential on the gate insulator [16]. ISFET being introduced for an alternative way for previous problems. ISFET is continuously being developed to measure pH and other types of ions because of the small size, fast response, and as well as being easy for mass