UNIVERSITI TEKNOLOGI MARA

INTEGRATED SOLID-STATE ELECTRODE FOR EXTENDED-GATE FET pH SENSOR

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ABSTRACT

pH sensors considered as a crucial element in broad applications such as medical, agriculture and industrial. There are several methods used to detect the pH level as simple as a litmus paper to a complicated electronic device. Among them, extended-gate field effect transistor (EGFET) pH sensor is receiving significant attention due to its advantages such as low cost, simple structure and flexible shape. An EGFET system consists of a separated substrate containing sensing material connected to the gate terminal of a FET. The two electrodes that are essential for an EGFET system are sensing electrode (SE) and a reference electrode (RE). The conventional RE is a glass tube containing liquid electrolyte making it bulky and not suitable for miniaturization. To realize miniaturization of an EGFET sensor system, the SE needs to be sensitive and RE needs to be in solid-state form. In addition, these solid-state electrodes also need to be fabricated onto one substrate to allow sensor miniaturization. Among the material used for SE, zinc oxide (ZnO) is a preferable material due to its versatile properties in terms of physical and electrical properties. Other than that, ZnO also was known for its various nanostructure morphologies. Based on the theory, these nanostructure morphologies are able to improve the sensor sensitivity due to the high surface area to volume ratio. In this work, for SE, the nanostructured ZnO deposition using thermal chemical vapor deposition (TCVD) and chemical bath deposition (CBD) methods were explored. Besides deposition methods, the growth condition also was reported influences the ZnO nanostructures quality. In this study, several parameters were varied in order to produce the best ZnO nanostructures for EGFET pH sensor, including TCVD growth temperature, post-deposition heat treatment, CBD immersion time and also ZnO solution concentration. It was found that the TCVD method produced ZnO nanotetrapods whilst CBD method resulted in ZnO nanoparticles. The nanotetrapods were not suitable as SE due to the powder-like physical structure as it will be dissolved when immersed in pH buffer solution. Therefore, the post-deposition heat treatment was applied on ZnO nanostructure produced by TCVD method to improve the adhesion strength. However, this post-deposition treatment also was found to have no effect on ZnO nano tetrapods adhesion strength. Thus, the CBD method with 3 hours deposition time and 0.1 M concentration was chosen. The ZnO nanostructure deposited by CBD method exhibited good pH sensitivity of 52.9 mV/pH with linearity of 0.9947. To address the miniaturization issue, a quasi-solid-state RE (QRE) fabrication was explored by thermal evaporating an Ag layer onto indium tin oxide (ITO) substrate followed by chlorination using $FeCl_3$ by a simple drop technique. It was confirmed that the proposed QRE performed similar transfer curve characteristic with the commercial RE. Then, facile fabrication of an integrated solid-state electrode (ISSE) consisting of ZnO nanostructure SE and solid-state (Ag/AgCl) QRE on a single 2 x 2 cm^2 ITO substrate was studied. The ISSE was then tested in the EGFET pH sensor system and it was found that the sensor sensitivity was 53.4 mV/pH, which is comparable with the measurement using a commercial RE having a sensitivity value of 52.4 mV/pH. Repeatability and reproducibility tests for the ISSE were performed and the variation was less than 10% indicating that the fabrication method was reliable.

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