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Multi-Analyte Indium Gallium Zinc Oxide-Based Dielectric Electrolyte-Insulator-Semiconductor Sensing Membranes

Authors : Chyuan Haur Kao, Hsiang Chen, Yu Sheng Tsai, Chen Hao Hung, Yu Shan Lee

Abstract : Dielectric electrolyte-insulator-semiconductor sensing membranes-based biosensors have been intensively investigated because of their simple fabrication, low cost, and fast response. However, to enhance their sensing performance, it is worthwhile to explore alternative materials, distinct processes, and novel treatments. An ISFET can be viewed as a variation of MOSFET with the dielectric oxide layer as the sensing membrane. Then, modulation on the work function of the gate caused by electrolytes in various ion concentrations could be used to calculate the ion concentrations. Recently, owing to the advancement of CMOS technology, some high dielectric materials substrates as the sensing membranes of electrolyte-insulator-semiconductor (EIS) structures. The EIS with a stacked-layer of SiO_2 layer between the sensing membrane and the silicon substrate exhibited a high pH sensitivity and good long-term stability. IGZO is a wide-bandgap (~3.15eV) semiconductor of the III-VI semiconductor group with several preferable properties, including good transparency, high electron mobility, wide band gap, and comparable with CMOS technology. IGZO was sputtered by reactive radio frequency (RF) on a p-type silicon wafer with various gas ratios of $Ar:O_2$ and was treated with rapid thermal annealing in O_2 ambient. The sensing performance, including sensitivity, hysteresis, and drift rate was measured and XRD, XPS, and AFM analyses were also used to study the material properties of the IGZO membrane. Moreover, IGZO was used as a sensing membrane in dielectric EIS bio-sensor structures. In addition to traditional pH sensing capability, detection for concentrations of Na+, K+, urea, glucose, and creatinine was performed. Moreover, post rapid thermal annealing (RTA) treatment was confirmed to improve the material properties and enhance the multi-analyte sensing capability for various ions or chemicals in solutions. In this study, the IGZO sensing membrane with annealing in O_2 ambient exhibited a higher sensitivity, higher linearity, higher H+ selectivity, lower hysteresis voltage and lower drift rate. Results indicate that the IGZO dielectric sensing membrane on the EIS structure is promising for future bio-medical device applications.

Keywords : dielectric sensing membrane, IGZO, hydrogen ion, plasma, rapid thermal annealing
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