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Chloride-sensitivity improvements by Nitrogen plasma immersion ion implantation on Samarium oxide membrane

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The first ion sensitive field-effect transistor (ISFET) with SiO_2 gate as sensing material for bio-medical applications was invented by P. Bergveld in 1970 [1] . Compared with ISFET, the capacitive electrolyte-insulator-semiconductors (EIS) sensor exhibits great potential as a sensing device such as simple structure, easy processes, low cost, and convenient detection system. Over the past few years, to obtain better pH sensing performance, many high-dielectric constant (high-k) materials, such as Ta_2O_5 and HfO_2 [2,3], with high pH sensitivity and stability have been proposed as sensitive layers. But in this high-k sensing materials, to sensing anion ions, such as chloride ions, are difficult. To monitor the changes in concentration in real time, many types of sensors have been proposed.

In this study, the Sm_2O_3 sensing membrane is proposed. To improve sensing properties, nitrogen ion was incorporated into Sm_2O_3 by nitrogen plasma immersion ion implantation (PIII) technique. The PIII technique is an abundant and efficient implantation treatment. We can control the implantation fabriated voltage and time on the different position and concentration of implanted nitrogen ions. Finally, in KCl solution, we get difference sensing properties for nitrogenized sample. Without the nitrogen PIII treatment, we can only sense potassium ions. On the other hand, these samples get pCl sensitive property with the nitrogen PIII treatment. The nitrogen incorporation was done on Sm_2O_3 sensing film by PIII system at 1, 3,5 kV for 3 minutes. The conditions were called as without, 1 kV, 3 kV, and 5 kV, respectively. Different times were taken to distribute nitrogen atoms in different concentration of samarium oxide. Subsequently, they were treated with rapid thermal annealing (RTA) under N_2 ambient for 30 s at 700 ^{o}C. All samples were immersed in reversed osmosis (RO) water for 12 hours to get steady pK/pCl sensitivity response. The pK sensitivity was decreased accompanied with the PIII time increased. This outcome could be attributed to the incorporation of more positive charges in Sm_2O_3 during nitrogen PIII treatment. Because the V_{FB} of the sample with PIII nitrogen treatment was shift to negative than without treatment under the same buffer value, the sensing membrane has more positive charges, as shown in Fig. 1. This result also caused the reduction of the sensitivity, because potassium ions were repelled from the membrane. In the meantime, the chloride ions were attracted with the positive charges. Finally, the sensitivity was changed from positive to negative with nitrogen PIII treatment, so we confirmed the samples were sensed by the chloride ions. In Fig. 1, the properties of the samples under different KCl buffer solution is shown. The Fig. 1 demonstrates the pK and pCl sensitivity of the samples without and with different PIII time. The optimum sensitivity of the sample with nitrogen PIII treatment for 3 min was 47.92 mV/pCl. For the results of nitrogenize-Sm_2O_3 EIS structure, the obvious changes as a function of potassium and chloride ions concentration were observed during titration.

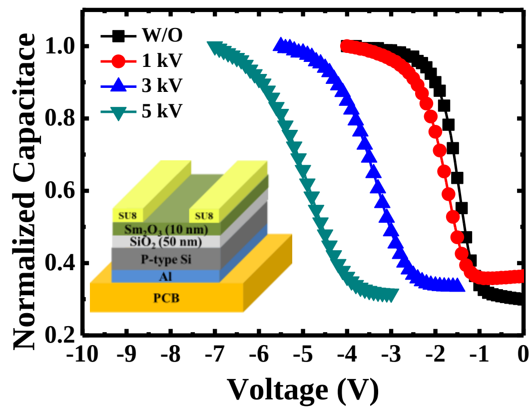

Fig. 1 The C-V curve of all samples is shown in the 10^{-4} M KCl solution.

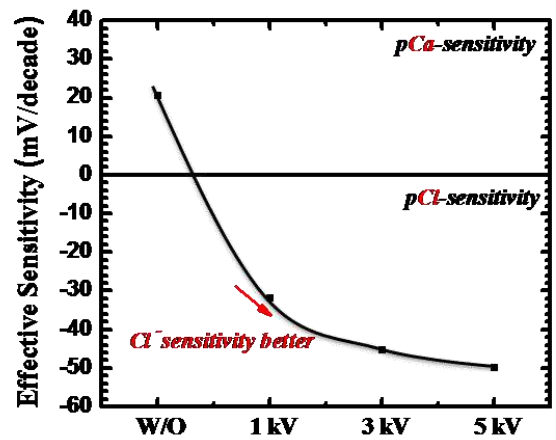

Fig. 2 pKCl-sensitivity of nitrogen PIII on Sm_2O_3 EIS structure.

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