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Array of Ion-Sensitive Field Effect Transistors based pH sensors using SiN_x/SiO_xN_y Stacked Layer Gate Dielectric

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Abstract – In this work, arrays of Ion Sensitive Field Effect Transistors – ISFETs based pH sensors have been fabricated and characterized. These ISFETs are used as chemical and biochemical detection devices, and have as gate dielectric a silicon nitride/silicon oxynitride stacked layer, which is the sensor element. Furthermore, our ISFET process fabrication is fully compatible with a standard CMOS technology. ISFETs electro-chemical characterization with (V_{GS}=1.5V) reference gate electrode was carried out. In this characterization, analyte solutions with different pH values were dropped on the gate. Operating in the saturation region with V_{GS}=1.5V, an absolute pH response (S) of about 1.162 mA/pH with a correlation coefficient (R) 0.9939 for pH values of 4, 6, 8 and 9 were obtained. This electrical parameter variation in related to pH values demonstrates the viability of the use of these devices on the chemical and biochemical detection.

Environmental control, agriculture and industrial processes, and clinical analyses can be performed in real time using chemical and biochemical detection devices based on ISFETs [1]. These devices present low cost and small size, because can be fabricated by standard CMOS process.

In this work, n-channel ISFET arrays have been fabricated on p-type silicon substrate (Fig 1). Our ISFET process fabrication is fully compatible with a standard CMOS technology. In these ISFETS, the gate dielectric is the chemical sensor element. This dielectric is a silicon nitride/silicon oxynitride stacked layer. It is important to notice that this kind of SiN_x/SiO_xN_y stack layer as gate dielectric of ISFETs, previously, has not been investigated by literature. The silicon oxynitride (SiO_xN_y) was grown on Si substrate using an ECR (Electron Cyclotron Resonance) plasma system, and the silicon nitride (SiN_x) was deposited on SiO_xN_y/Si structure by LPCVD (Low Pressure Chemical Vapor Deposition)

ISFETs electro-chemical characterization was carried out using analyte solutions with different pH values dropped on the gate dielectric. The analyte is considered the ISFETs gate electrode. Thus, current-voltage characteristic curves with reference gate electrode, in related to different pH values were obtained. The $I_{DS}xV_{DS}$ curves (Fig.2), where I_{DS}, V_{DS} and V_{GS} are drain-source current and voltage, and gate-source voltage, respectively, were obtained using a reference voltage electrode positioned on analyte dropped on gate dielectric. In reference electrode, which must be in contact to analyte, was applied one V_{GS} voltage of 1.5V. Fig. 2 shows an typical families of pH response curves for the SiN_x/SiO_xN_y stacked layer gate ISFET operated in the saturation region (V_{GS}=1.5V), an absolute pH response (S) of about 1.162 mA/pH with a correlation coefficient (R) 0.9939 for pH values of 4, 6, 8 and 9 were obtained. The pH response is excellent in linearity by means of the correlation coefficient. These results are better than the results from the reference 2, which fabricated ISFETs based pH sensors using nano self-assembled multilayer films. Therefore, the silicon nitride/silicon oxynitride stacked layer used in this work as sensor element, are suitable for enhance ISFET application.

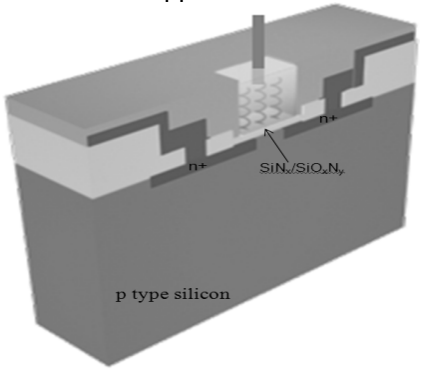

Fig. 1 – The schematic diagram of the SiN_x/SiO_xN_y stacked layer gate ISFET.

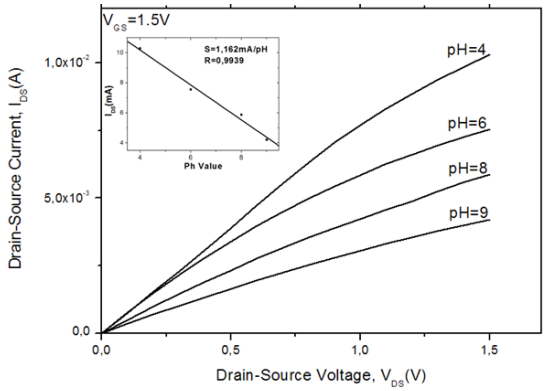

Fig. 2 – Typical families of pH response curves for the SiN_x/SiO_xN_y stacked layer gate ISFET and pH response.

References

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