Highly pH Sensitive Suspended-Gate Silicon Thin Film Transistor (ISTFT)

F. Bendriaa, F. Le Bihan, A.C. Salaün,
T. Mohammed-Brahim, O. Bonnaud
GM-IETR, UMR CNRS 6164
University of Rennes 1,
Bat.11B, Campus de Beaulieu, F-35042 Rennes Cedex, FRANCE, brahim@univ-rennes1.fr

Field Effect ion – sensitive structure is the well-known Bergveld's Ion Sensitive Field Effect Transistor (ISFET) that is a gateless FET with a sensitive film covering the channel insulator and with a reference electrode diving in the solution and fixing the gate bias. The sensitivity of ISFET is explained from the shift of the threshold voltage induced by the variation of the flat-band voltage, V_{FB}, in presence of charges distributed in the solution, and more especially the H^+ ion concentration that governs the pH of the water solution. Particularly, the surface potential at the insulator-solution interface, which is included in the V_{FB} expression, linearly varies with the value of the pH solution. In this case, the maximum sensitivity, which is the Nernstian sensitivity, is 59 mV/pH at 20°C. So, the sensitivity of all the present ISFET is lower than or close to this maximum.

In this usual ISFET structure, the reference electrode only fixes the potential of the solution, which is homogeneous with a homogeneous distribution of the H^+ ions.

Here, the air-gap TFT structure, for which we published previously the technological process [1] (Figure 1), is used with some improving modifications to measure the pH value in a solution. This new structure is called "Ion Sensitive Thin Film Transistor" (ISTFT). It is fabricated using surface micro-machining technology. The channel is made of non-intentionally doped polycrystalline silicon film, the source and drain of heavily *in-situ* doped polycrystalline silicon film, both deposited by Low Pressure Chemical Vapor Deposition (LPCVD) technique. Also, a heavily *in-situ* doped polycrystalline silicon film deposited by LPCVD is used as suspended gate. Germanium film, deposited by LPCVD but with other deposition parameters, is used as sacrificial layer [2]. Indeed, Germanium is easily etched using H_2O_2 solution with a quasi-infinite selectivity with all other used materials such as deposited silicon dioxide or silicon. Figure 2 shows a SEM micrograph of the airgap TFT structure.

Surface micro-machining is used as a tool to reduce and control the sacrificial layer thickness and then the airgap under the suspended gate. The present structure introduces a new parameter in the functioning of the ISFET, that is a field effect inside the solution occurring in the very thin channel-to-gate gap. The H^+ ion distribution becomes un-homogeneous that increases significantly the sensitivity.

Very high sensitivity in comparison with previous ISFET structures is found by using the air-gap TFT structure thanks to the un-homogeneous distribution of H^+ ions. It is greater than 200 mV/pH, much higher than the Nernstian sensitivity. The field effect depending of the electric field amplitude, it is found of course "airgap" dependent.

References:

[1] H. Mahfoz-Kotb, A.C. Salaün, T. Mohammed-Brahim, O. Bonnaud, IEEE Trans. Electr. Dev. Lett. **24**, 165 (2003)

[2] Mahfoz-Kotb H.; Salaün A-C.; Mohammed-Brahim T.; Le Bihan F.; El-Marssi M.; Thin Solid Films, 427; pp. 422-426 (2003)

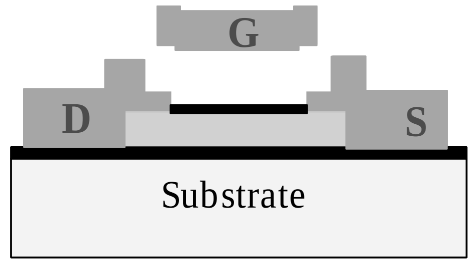

Figure 1 : Air-gap TFT structure [1]

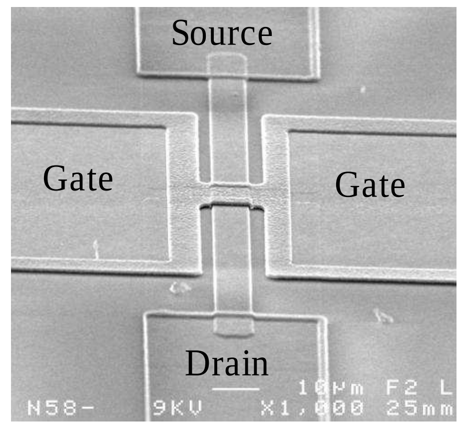

Figure 2 : SEM micrograph of the air-gap TFT structure involved the ISTFT.