DESIGN METHODOLOGY OF BACKSIDE CONTACTED ISFETs USING DEEP DIFFUSION

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ABSTRACT:-

Design approach of the fabrication method for Ion-Sensitive Field-Effect Transistor (ISFET) structures with contact pads located at back–passive side of the device is presented. In this approach, FET structure will be constructed on the front face of the chip. The connections between the source and the drain diffusion and the back contacts will be achieved by diffusing impurities from both sides of the wafer. The front surface has an insulating surface where the chemically active gate is placed. The device thus acts as a chemical sensor. This contrasts with traditional devices where the gate and the contacts are placed on the front surface of the transistor. This device will feature anisotropically etched cavities from the back side of the wafer to ensure electrical connections through the silicon wafer. These sensors will be more compact, easily mounted and will not have encapsulation problem; however, the fabrication technology will be more complex.

KEYWORDS:- *ISFETs, Back Contacts, Deep Diffusion.*

INTRODUCTION:-

The concept of assembling of Ion Sensitive Field Effect Transistor (ISFET) structures with contact pads located at the back – passive side of the structure, facilitates considerably protection of the structure against chemically aggressive environment and makes exchange of the structure in field condition much easier. This approach, however, poses difficult technological requirements. To ensure the electrical connection throughout the silicon wafer thickness, around 500μm deep cavity has to be formed to reach in close vicinity of the active side of the device followed by deep diffusion throughout remaining silicon membrane. Next, this deep cavity has to be effectively coated with continuous metal film which forms a contact pad to external connector. Coating and structuring of such 3-D structures requires special technological endeavors. A cross-section of an ISFET with backside contacts is shown in Fig.1.

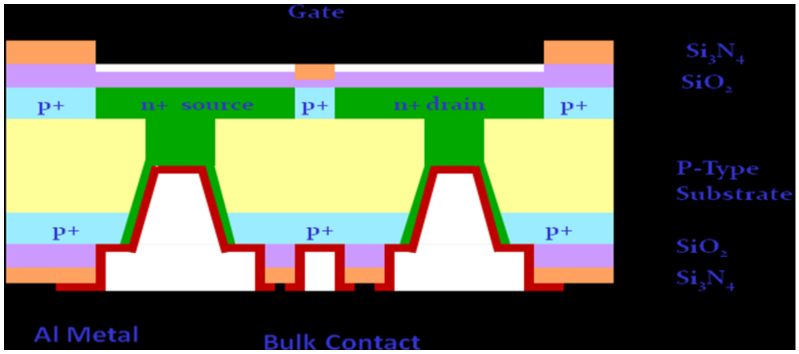

Fig.1 The cross sectional view of the BSC ISFET with source, drain & bulk Al contacts.

BACKGROUND:-

Since Bergveld introduced the first ion-sensitive field- effect transistor (ISFET) in 1970 [1], many different geometries, encapsulation approaches and mounting techniques have been proposed and developed [2-5]. The common aim of these developments was the production of chemical sensors that are low cost and reliable. Most of these devices were fabricated using a planar technology where the drain, the source and the gate, represented by the ion-sensitive area, are placed on the same face of the chip.

Encapsulation has posed non-trivial problems that have hindered the full impact of semiconductor chemical sensors in analytical and medical applications.

Encapsulates often suffer from liftoff, allowing the aqueous electrolytic solution to touch the metallic contacts, producing a short circuit and the appearance of sizable leakage currents. When leakage occurs, the ISFET is no longer functional, and if used *in vivo*, it might be unsafe as well. Additionally, encapsulation has to be an automatic process that permits ISFETs to express their potential as inexpensive sensors [6].

An ISFET featuring back contacts has a lengthened distance between the exposed gate and the encapsulated electrical connections. There is a larger obstacle for the onset of leakage currents. Furthermore, encapsulation is easier to automatize as less precision is required for the deposition of encapsulate materials. Micromachining techniques, based on the selective anisotropic etching of silicon, have been used to produce ISFETs with back contacts. These efforts have been the subject of a review by Edwald et al. [7]. A pit etched on the back face of the chip provides electrical access to the drain and source diffusions. A free ionsensing area is left on the front face of the chip. Micromachining of pits for back contacts presents several problems. A great depth of field is required in wafer aligners and other optical tools in order to focus the wafer surface and the pit bottoms simultaneously. The main anisotropic etchants that will be used are TMAH, hydrazine, ethylene-diamine-pyrocatechol (EDP) and potassium hydroxide (KOH) [8]. These chemicals pose several handling and safety problems [9]. Hydrazine is an explosive and hazardous substance. EDP is highly toxic and carcinonogenic. The potassium ions present in KOH solutions pose a grave pollution risk to clean-room facilities. These problems call for a separate etching facility apart from clean-room installations [10].

In the present paper, a novel technique is presented where back contacts are achieved by deep diffusions, providing clean and flat surfaces on the device. It can be implemented in a standard silicon fabrication facility where planar technologies are used. No special separate facilities are required.

The present design relates to chemical or electrochemical sensors based on Si FET technology for the measurement of hydrogen ions (pH) and other ion activity in solution. In the proposed ISFET structure, the electrical contact to the source and drain regions is made through individual holes etched from the back up to the source and drain regions with sidewall isolation being provided in the holes and metallization covering the surface of sidewalls and extending to contact pads on the back of the ISFET.

This ISFET will be fabricated by using a silicon substrate with a (100) orientation. An orientation dependent etch will be used to etch the holes to the source and drain regions where the presence of an etch stop halts the etching process. A doped region is then created in the sidewalls of the holes to provide the isolation from the substrate and the metallization is then laid on the sidewalls to provide the external contacts.

PROCEDURE:-

Double-side polished silicon wafers (4”, P-type, <100> oriented, 10-20Ω cm resistivity and 500-550microns thick) will be used to fabricate the device.

The source (n+) is short-circuited with the p-type substrate by the metallization for proper device biasing. To form the holes, an anisotropic etching of silicon in TMAH solution shall be performed at the back side of the wafer as one of the first technological steps. This etching is performed leaving 5-6 micron thick membranes.

Next, the membranes are n+ doped from its both sides by the deep phosphorus diffusion to make good electric contacts to the source and drain areas of the device. It has to be noted, that due to the fact, that formation of the backside contact cavity and diffusion connection requires both (consecutive), aggressive chemical and long-term high temperature treatments, it has to be performed before fabricating the ISFET structure. Thus, special precautions have to be undertaken to protect the silicon wafers with delicate, thin silicon membranes during the rest of the processing sequence. The main ISFET structure is built at the front side (Fig.2) of the wafer by applying ion implantations (n+ -doped source and drain areas, p+ doped channel gate, p+-doped channel stoppers), 8 photolithography levels, silicon dioxide and silicon nitride layers depositions and thermal oxidations, as commonly used in MOS technology.

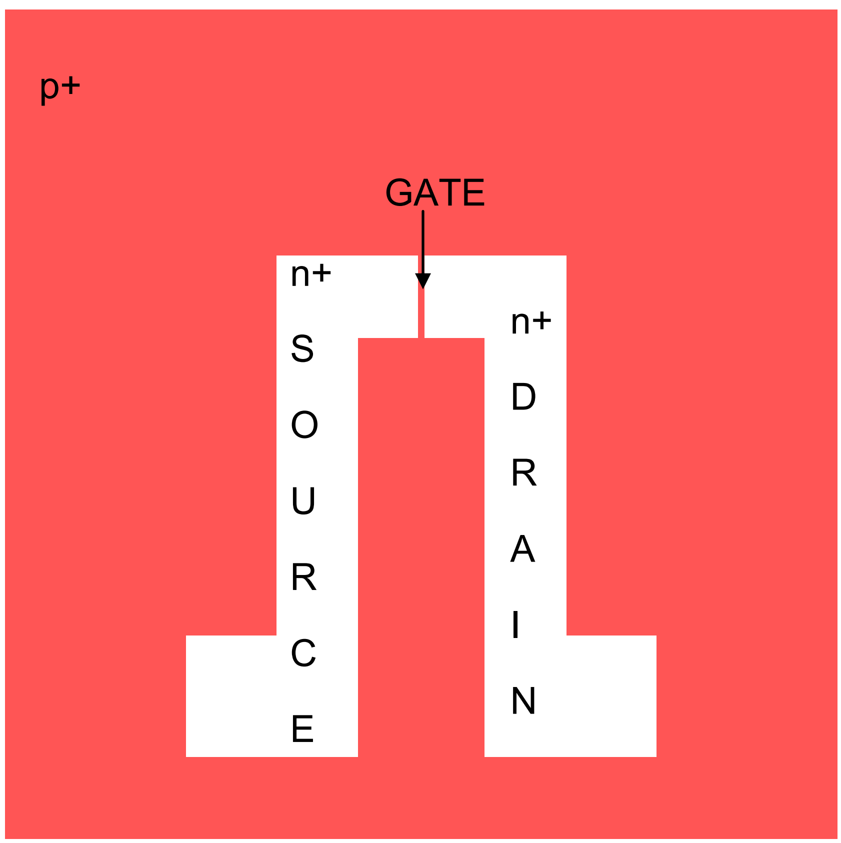

Fig. 2 Pattern showing source, drain and gate

The dielectric gate (ion detection area) is composed of thin silicon oxide and silicon nitride layers. The ISFET structure with such a gate may be directly used for pH measurement in the range 1-12 pH.

The mask designing is done using L-Edit version 8.30 and the complete mask layout is shown in Fig. 3.

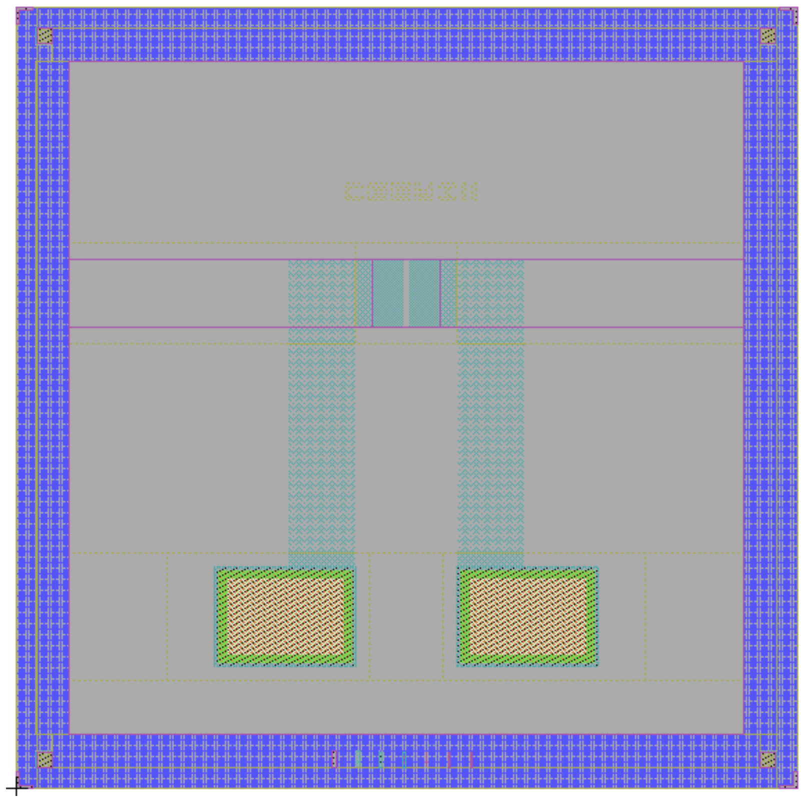

Fig. 3 Combined Photo-mask showing the final pattern

CONCLUSIONS:-

The above proposed design of an Ion Sensitive Field-Effect Transistor (ISFET) having electrical connections at the back-passive side of the chip has been planned using a standard planar technology in which the back contacts would be formed using deep diffusion technique. These chemical sensors will overcome the problem of encapsulation that hindered the potential of conventional chemical sensors having all electrical connections of source, drain and gate on the front face of the chip. The new chemical sensors will be easier to encapsulate, more reliable and more compact; however, the technology involved in its fabrication will be more complex.

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