ROHINI
COLLEGE OF ENGINEERING AND TECHNOLOGY
Approved by AICTE and affiliated to Anna University Chennai (An ISO Certified Institution)
Accredited by NAAC with A+ Grade

DEPARTMENT OF BIOMEDICAL ENGINEERING

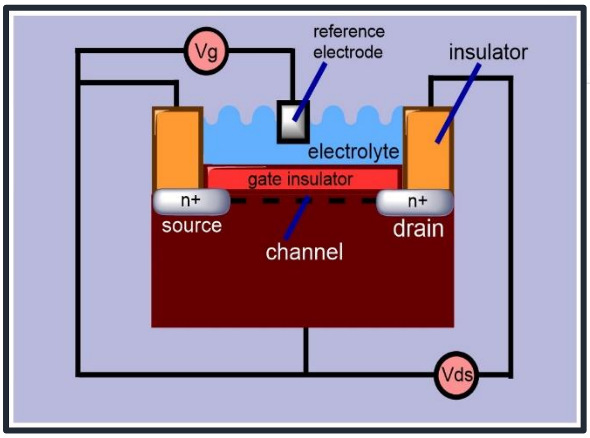
BM3491 Biomedical Instrumentation

UNIT- V BIOCHEMICAL MEASUREMENTS

5.2 Ion selective FET (ISFET), Immunologically sensitive FET (IMFET)

5.2.1 Ion selective Field Effect Transistor (ISFET):

- An ion-selective field-effect transistor (ISFET) is a type of sensor used to *measure ion concentrations* in a solution.
- It operates on the principle of a *field-effect transistor*, where the conductance between two terminals is controlled by an electric field.
- However, in an ISFET, the gate of the transistor is a reference electrode coated with a selective membrane that responds specifically to the ions of interest.



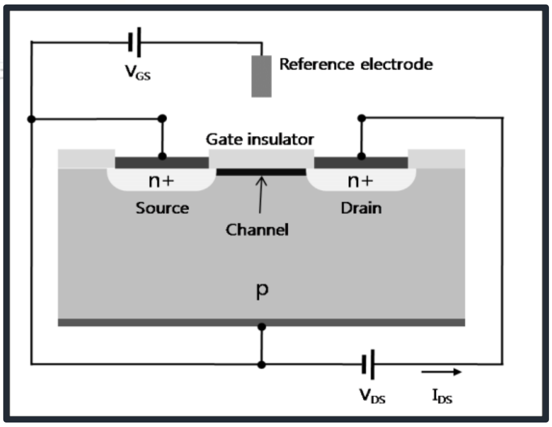


Fig. 5.2.1 Ion selective Field Effect Transistor

- Ion Sensitive Field Effect Transistor (ISFET) is in fact a *Metal Oxide Semiconductor Field Effect Transistor (MOSFET)* in which *metal gate* is *replaced by a complex structure* sensitive to hydrogen ion concentration.

- It is obvious that ISFET is obtained by replacing the standard metal gate of a MOSFET with a reference electrode, a chemically sensitive insulator between which presents a measured electrolyte.

- *The gate voltage is applied to the reference electrode* and the electrolyte closes the electric Gate-Source circuit.

- ISFET is therefore fundamentally a MOSFET and hence the theoretical description of MOSFET is essential to describe ISFET's theory.

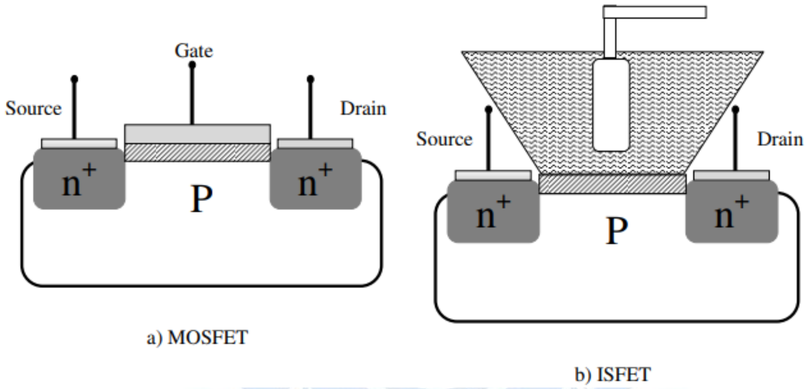
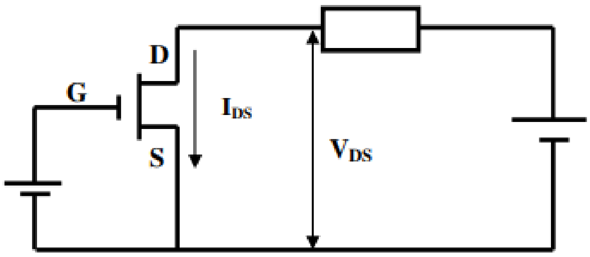


Fig. 5.2.2. *Schematic representation of (a) MOSFET, (b) ISFET*



(c) Electronic diagram

- ISFETs have a structure that is comparable to MOSFETs, and a reference electrode and electrolyte gate replace the metal gate; consequently, the signal transfer mechanism is comparable.

- The sensitive film is applied to the oxide layer to detect other types of ions and molecules. The solution is connected directly with the oxide and achieves linear detection of ions.
- The working of ISFET is explained in the following Steps
  1. **Selective Membrane**: The gate of the transistor is coated with a selective membrane that allows only specific ions to pass through. This membrane can be tailored to be selective to certain ions, such as hydrogen ions (H^+), sodium ions (Na^+), potassium ions (K^+), or others.
  2. **Ion Interaction**: When the solution containing ions comes into contact with the selective membrane, ions in the solution interact with the membrane. Depending on their charge and size, some ions will permeate through the membrane while others will be repelled.
  3. **Change in Potential**: The interaction between the ions and the selective membrane causes a change in the electric potential at the gate of the transistor.
  4. **Transistor Response**: This change in potential alters the conductivity of the transistor channel, which can be measured as a change in current between the source and drain terminals.
  5. **Ion Concentration Measurement**: By measuring the change in current, the concentration of ions in the solution can be determined. The greater the concentration of ions, the larger the change in current.

Applications of Ion selective field effect transistor:

1. **pH Sensing:**
   One of the most common applications of ISFETs is in pH sensing. ISFETs can determine the pH level accurately.
2. **Biomedical Applications**:
   ISFETs are used in various biomedical applications such as biosensors for monitoring glucose levels, detecting biomarkers in bodily fluids, and studying ion channel activity in cells. They are also utilized in the development of implantable devices for continuous monitoring of physiological parameters.
3. **Chemical Analysis**: ISFETs are used in chemical analysis techniques such as ion chromatography and ion-selective electrode potentiometry.

4. Biotechnology and Pharmaceutical Research:

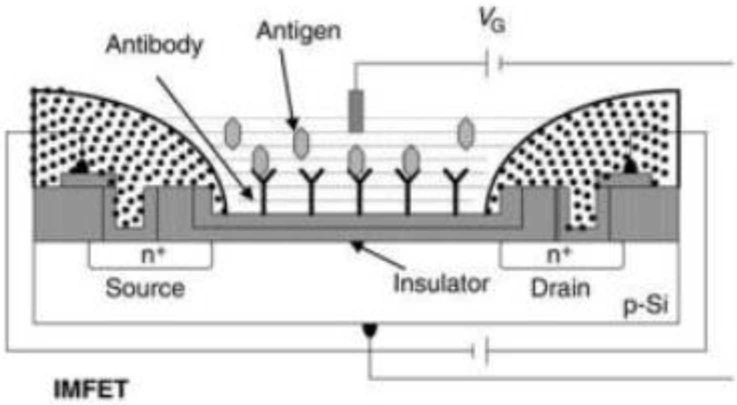
ISFETs play a significant role in biotechnology and pharmaceutical research by enabling the real-time monitoring of biochemical reactions, enzymatic processes, and drug interactions.

5.2.2 Immunologically Sensitive Field Effect Transistor (IMFET):

Structure and Operation of IMFETs:

1. **Field Effect Transistor (FET) Basics**:
    - **Source**: The terminal through which carriers enter the channel.
    - **Drain**: The terminal through which carriers leave the channel.
    - **Gate**: The control terminal that modulates the channel's conductivity.
    - **Substrate**: The body of the transistor, typically made of a semiconductor material.
2. **Immunological Layer**:
    - **Immobilization**: Antibodies or antigens are immobilized on the gate surface of the FET.
    - **Specific Binding**: The immobilized molecules specifically bind to their target antigens or antibodies from the sample.
3. **Detection Mechanism**:
    - **Binding Event**: When the target molecule binds to the immobilized antibody/antigen, it induces a change in the local electric field.
    - **Signal Transduction**: This change in the electric field affects the surface potential and modulates the current flowing through the FET.

- **Measurement**: The change in current or voltage is measured and is proportional to the concentration of the target molecule.



Applications of IMFETs:

1. **Medical Diagnostics**:
   - **Disease Biomarkers**: Detection of specific proteins or antibodies related to diseases such as cancer, HIV, and cardiovascular diseases.
   - **Point-of-Care Testing**: Rapid diagnostics at the patient's side without the need for extensive laboratory equipment.
2. **Environmental Monitoring**:
   - **Pollutants and Toxins**: Detection of hazardous substances such as heavy metals, pesticides, and pathogenic microorganisms in air, water, and soil.
   - **Real-Time Monitoring**: Continuous surveillance of environmental samples for immediate detection of contaminants.
3. **Food Safety**:
   - **Pathogen Detection**: Identifying contamination by bacteria, viruses, and toxins in food products.
   - **Quality Control**: Ensuring the safety and quality of food during production and before consumption.
4. **Biotechnological Research**:
   - **Protein-Protein Interactions**: Studying interactions between various proteins to understand biological pathways.

- **Drug Discovery**: Screening potential drug candidates by detecting their interaction with target biomolecules.

Advantages of IMFETs:

1. **High Sensitivity**:
    - Capable of detecting very low concentrations of target molecules due to the amplification effect of the FET.
2. **Specificity**:
    - Utilizes highly specific antigen-antibody interactions, reducing the likelihood of false positives.
3. **Rapid Response**:
    - Provides real-time monitoring and fast response times, ideal for point-of-care diagnostics.
4. **Miniaturization**:
    - Potential for miniaturization, allowing for the development of portable and compact devices.

Challenges and Considerations:

1. **Stability**:
    - Ensuring the stability of the immobilized biomolecules over time to maintain consistent performance.
2. **Non-Specific Binding**:
    - Minimizing interference from non-specific binding or other environmental factors that could affect accuracy.
3. **Manufacturing Complexity**:
    - Fabricating IMFETs with consistent quality and performance can be challenging and may involve complex processes.

****