Principles of Semiconductor Devices

Chapter 7: MOS Field-Effect-Transistors

7.1. Introduction

The *n*-type Metal-Oxide-Semiconductor Field-Effect-Transistor (nMOSFET) consists of a source and a drain, two highly conducting *n*-type semiconductor regions, which are isolated from the *p*-type substrate by reversed-biased p-n diodes. A metal or poly-crystalline gate covers the region between source and drain. The gate is separated from the semiconductor by the gate oxide. The basic structure of an *n*-type MOSFET and the corresponding circuit symbol are shown in Figure 7.1.1.

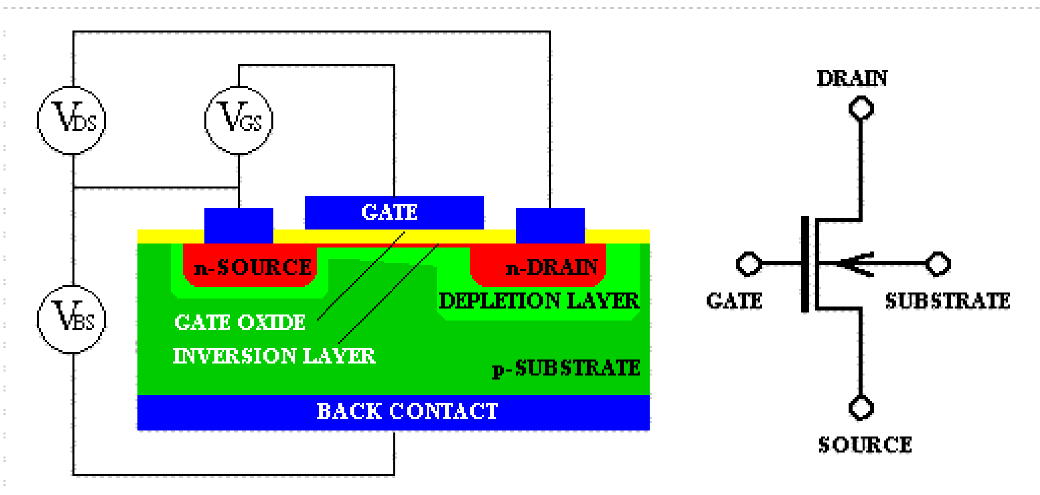

Figure 7.1.1 : Cross-section and circuit symbol of an *n*-type Metal-Oxide-Semiconductor-Field-Effect-Transistor (MOSFET)

As can be seen on the figure the source and drain regions are identical. It is the applied voltages, which determine which *n*-type region provides the electrons and becomes the source, while the other *n*-type region receives the electrons and becomes the drain. The voltages applied to the drain and gate electrode as well as to the substrate, by means of a back contact, are referred to the source potential, as also indicated Figure 7.1.1.

A conceptually similar structure was proposed and patented independently by Lilienfeld and Heil in 1930, but the MOSFET was not successfully demonstrated until 1960. The main technological problem was the control and reduction of the surface states at the oxide-semiconductor interface.

Initially, it was only possible to deplete an existing *n*-type channel by applying a negative voltage to the gate. Such devices have a conducting channel between source and drain even when no gate voltage is applied. They are called "depletion-mode" devices.

A reduction of the surface states enabled the fabrication of devices, which do not have a conducting channel unless a positive voltage is applied. Such devices are referred to as "enhancement-mode" devices. The electrons at the oxide-semiconductor interface are concentrated in a thin (~10 nm thick) "inversion" layer. By now, most MOSFETs are "enhancement-mode" devices.

While a minimum requirement for amplification of electrical signals is power gain, one finds that a device with both voltage and current gain is a highly desirable circuit element. The MOSFET provides current and voltage gain yielding an output current into an external load, which exceeds the input current, and an output voltage across that external load which exceeds the input voltage.

The current gain capability of a Field-Effect-Transistor (FET) is easily explained by the fact that no gate current is required to maintain the inversion layer and the resulting current between drain and source. The device has therefore an infinite current gain in dc. The current gain is inversely proportional to the signal frequency, reaching unity current gain at the transit frequency.

The voltage gain of the MOSFET is caused by the current saturation at higher drain-source voltages, so that a small drain-current variation can cause a large drain voltage variation.

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