Body effect : Background information

Theory

We know that the channel (also referred as inversion layer) is induced in the substrate, under the oxide layer(Tox) when a voltage V_{GS} is applied ($V_{GS} \geq V_t$). This channel can be thought of as conducting N-type/P-type (depending on the type of transistor) film. This film, forms a capacitor with the gate. The SiO_2 layer acts as dielectric. When there is no potential difference between source and body(V_{SB}=0),the inversion charge is given by,

$$Q_{inv} = -C_{ox}(V_{GS} - V_{t0}) \tag{1}$$

The voltage is applied at gate but charge is measured at substrate and hence the negative sign.

However, if there exists a potential difference between the source and the body such that the source-body junction is reverse biased, another capacitor is formed between the channel and the body with the depletion region (W_{dmax}) being the dielectric. This is illustrated in Fig.1 for an N channel MOSFET.

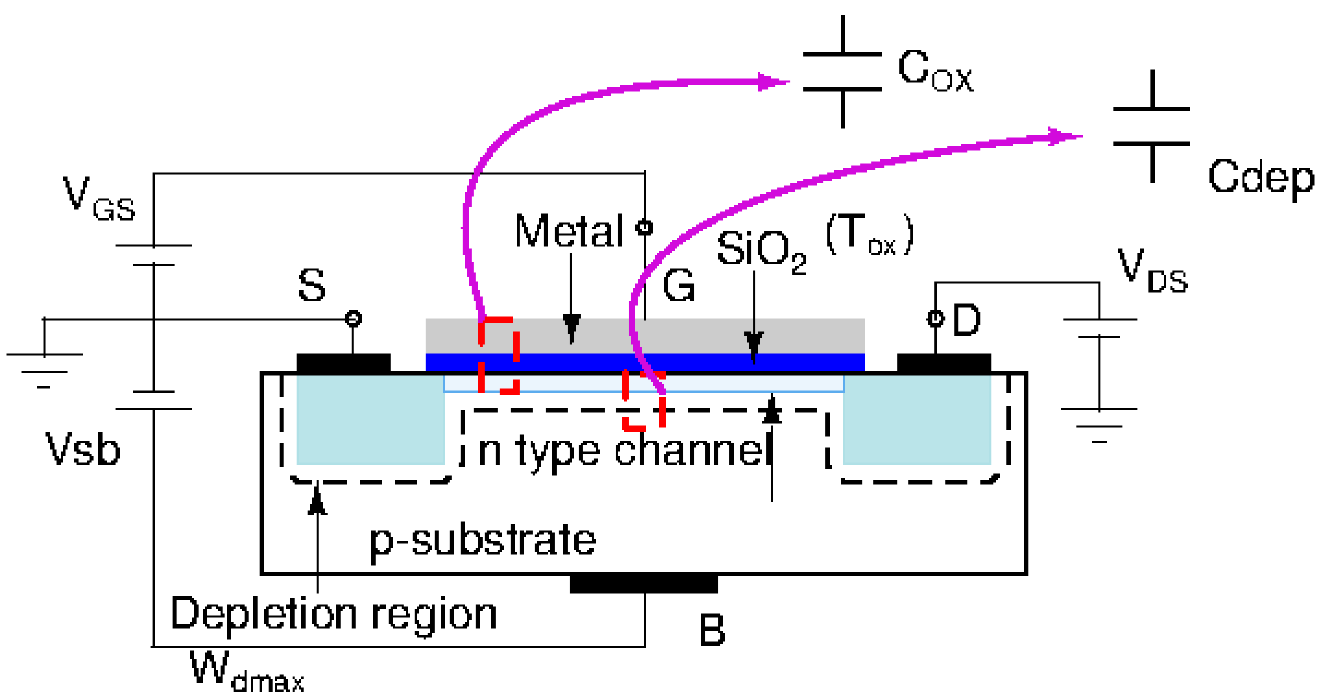


Figure 1: NMOS transistor with body bias illustrating the capacitances C_{dep} and C_{ox}

In this case, the inversion layer charge is coupled to the body through the depletion layer capacitance and

$$Q_{inv} = -C_{ox}(V_{gs} - V_{t0}) + C_{dep}V_{sb} \tag{2}$$

where C_{dep} is the depletion layer capacitance and V_{sb} the difference in voltage between the body and the source.

If we rewrite Eq.2 in the form of Eq.1,

$$Q_{inv} = -C_{ox}\left(V_{gs} - \left(V_{t0} - \frac{C_{dep}V_{sb}}{C_{ox}}\right)\right) \tag{3}$$

$$Q_{inv} = -C_{ox}(V_{gs} - V_t)$$

where

$$V_t = V_{t0} - \alpha V_{sb} \tag{4}$$

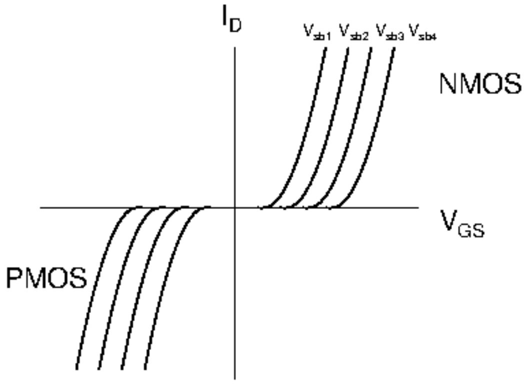
α is called the body effect coefficient defined as C_{dep}/ C_{ox}

Remember, body source junction is always reverse biased. This dependence of V_t on body bias (through α) is called body effect.

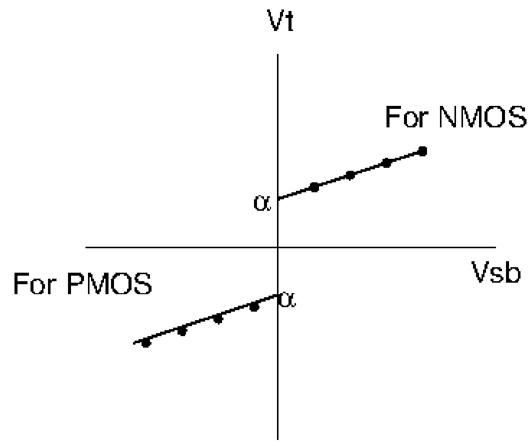
This becomes important when many MOSFETS are on the same piece of silicon and connected in series, the source voltages are all different and some transistors sourcebody junctions could be reversed biased. This raises their V_t and reduces I_d and the circuit speed. This is the undesirable effect for circuit designers. Circuits therefore perform better the body effect is minimized. This can be accomplished by minimizing the T_{ox}/W_{dmax} ratio.

How to extract α

We will bias the transistor in linear region. For each value of V_{SB}, we will get one I_D v/s V_{GS} curve from which one can find V_t for each curve. (V_t can be obtained by biasing the transistor in saturation region also as done in the last experiment.) By plotting V_t v/s V_{SB} which is a straight line as shown in Fig.2b, α is obtained as the slope of the straight line.



(a) : Effect of body bias: $V_{SB}1 < V_{SB}2 < V_{SB}3 < V_{SB}4$



(b) Body Coefficient extraction

Note: for PMOS, as compared to NMOS, we have to reverse the polarity of the voltages. $\mathbf{V_{GS}} \leq \mathbf{V_t}$ and $\mathbf{V_{DS}} \leq \mathbf{V_{GS}}$-$\mathbf{V_t}$. To see body bias effect, we maintain a positive potential difference between Source and Body .i.e. $\mathbf{V_{SB}} > \mathbf{0}$