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Transistor	W [µm]	L [µm]
T1	10	10
T2	0.21	0.085
T4	10	0.085

For this experiment our aim is to investigate the STS and the $DIBL$ effect on some LV transistor. In order to do that, we biased the drain voltage at different value of $V_{DS} = 0.5\,V, 0.75\,V, 1\,V$, and we swept the gate voltage within a range of $0V - 1V$. We chose these values of V_{DS}, higher of some $\frac{kT}{q}$, so we can neglect the dependence of the subthreshold current on this parameter.

For our analysis we decided to use three different transistors, T1, T2 and T4, whose dimension are in the table.

Since the STS is the slope of the $log_{10}I_{DS} - V_{GS}$ curve in the subthreshold regime, knowing that $t_{ox} = 2.2\,nm$, $N_a = 1.5 *\ 10^{18}cm^{-3}$, $\varepsilon_{ox} = 3.9\varepsilon_0$, we proceeded to calculate the V_T.

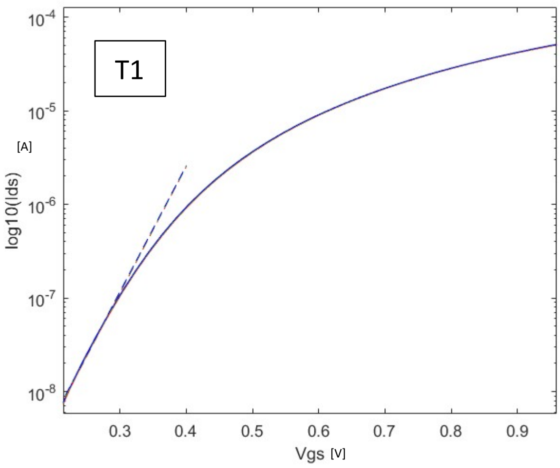
$$V_T = V_{FB} + 2|\Phi_B| + \frac{\sqrt{2\varepsilon_{Si}qN_a2|\Phi_B|}}{C_{ox}}$$

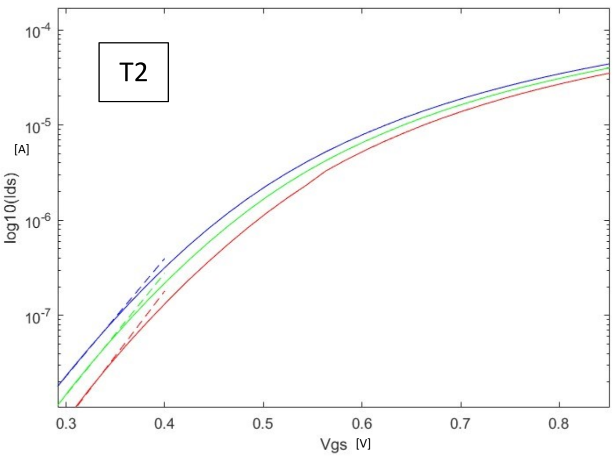
Assuming that the Fermi level of the metal is aligned to the conduction band of the silicon, we can easily calculate $V_{FB} = -\left(\frac{E_{GAP}}{2q} + \frac{kT}{q}\ln\left(\frac{N_a}{n_i}\right)\right) = -1V$, $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = 1.57\,\frac{\mu F}{cm^2}$, which lead to $V_T \cong 0.37$.

Moreover, since we want to compare the theorical STS_{tho} with the experimental lab, we proceed to calculate the $C_{dep} = \frac{\varepsilon_{Si}}{W_d^{max}} = \frac{\varepsilon_{Si}}{\sqrt{\frac{2\varepsilon_{Si}}{qN_a}2|\Phi_B|}} = 0.36\,\frac{\mu F}{cm^2}$, $m = 1 + \frac{C_{dep}}{C_{ox}} = 1.22$.

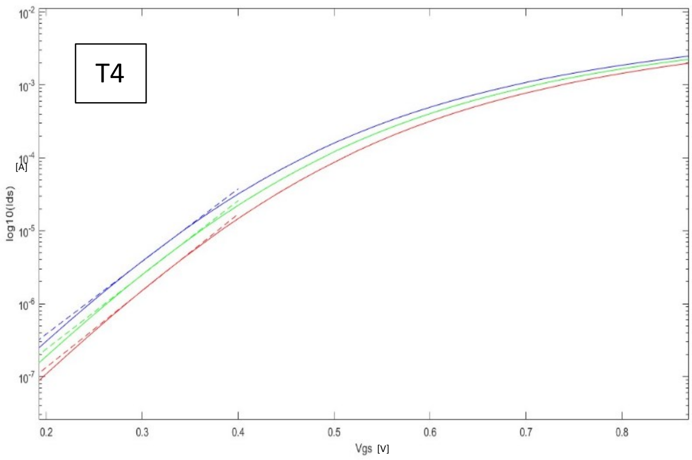
With these values, we obtain $STS = \frac{kT}{q}\ln(10)\,m = 73\,\frac{mV}{dec}$.

Experimentally, the following $log_{10}I_{DS} - V_{GS}$ curves were obtained.





(For each figure, the solid blue line is for $V_{DS} = 1V$, the solid green line for $V_{DS} = 0.75V$ and the solid red one for $V_{DS} = 0.5V$. Meanwhile the dashed lines represent the polynomial interpolant of grade 1 in the subthreshold regime for each V_{DS})



Using the polyval function on Matlab we obtained the value of the coefficients of the interpolant straight line and so we can calculate the slope, so it's STS, as shown in the table.

T1	$74\,mv/dec$
T2	$78\,mv/dec$
T4	$95\,mv/dec$

We can see that the experimental value is slightly more than the theorical one.

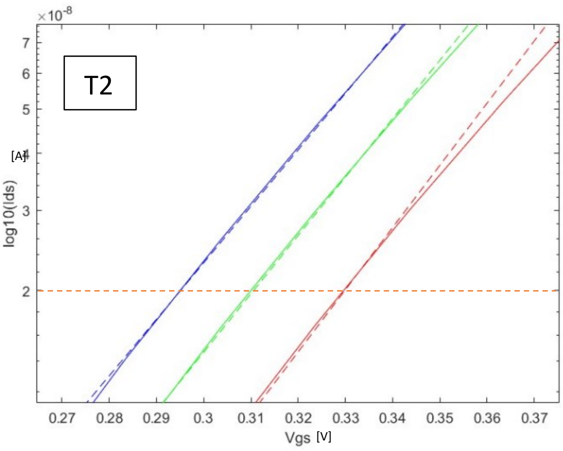
Since $\frac{kT}{q}\ln(10)$ is a constant, the difference between the real and the theoretical STS should be reconduct to m and so C_{dep}: this difference can be related to the depletion approximation and to some 2-D electrostatic effects coming from the source and the drain regions that affects C_{dep}.

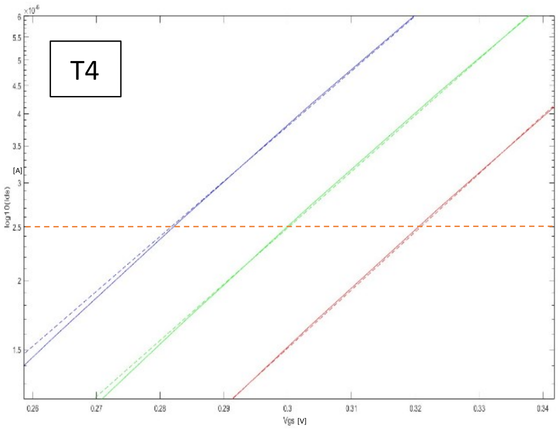
Finally, we can proceed to evaluate the DIBL.

First of all, since $W_d^{max} = \sqrt{\frac{2\varepsilon_{Si}}{qN_a}2|\Phi_B|} = 28.9\,nm$, $t_{ox} = 2.2\,nm$ and $2(W_d^{max} + 3t_{ox}) = 71\,nm$, since for the T1 transistor $L \gg\ 2(W_d^{max} + 3t_{ox})$, it is a long channel transistor, so it is not affected by the $DIBL$ and so there is not a dependence of V_T on the V_{DS}. This is clear considering that all the curves for the different V_{DS} overlap and they can't be distinguished.

Meanwhile, for T2 and T4, since L is comparable to $2(W_d^{max} + 3t_{ox})$, they are short channel transistor, meaning that their electrostatic is a 2-D one and depends on V_{DS} too. Thus, the $DIBL$ effect can be seen, since, due the dependence of V_T on the V_{DS}, we have translated curves for the different values of V_{DS} in the left direction. This translation on V_T is the same variation that affect the V_{GS} needed to reach a particular value of I_{DS}.

So, we can evaluate the dependence of V_T on V_{DS}, considering a constant value of current and the V_{GS} needed to reach that value for each curve.





What we obtained is reported in the following tables.

T2

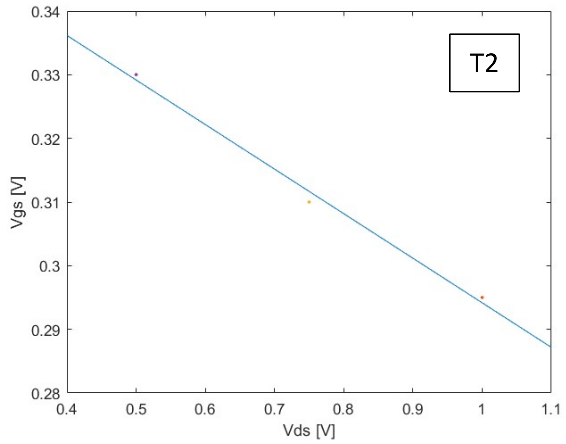
V_{GS}	1V	0.75V	0.5V
V_{DS}	0.295V	0.31V	0.33V

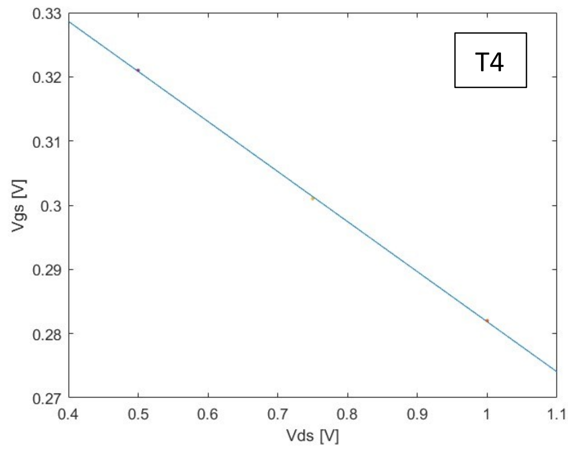
T4

V_{GS}	1V	0.75V	0.5V
V_{DS}	0.282V	0.301V	0.321V

Then we can plot the $V_{GS} - V_{DS}$ curve for these points, whose slope is the same of the $V_T - V_{DS}$ curve. This slope, in $\frac{mV}{V}$ is the $DIBL$ coefficient.

In order to do that we used the polyval function to obtain a straight line and measure the slope.





Thanks to that, we calculate the following $DIBL$ coefficient.

T2	$-70\frac{mV}{V}$
T4	$-78\frac{mV}{V}$