HW#4 Report

-Calculation about electrical parameters of NMOS-

◆ **Reference : "Effects of high-K dielectrics with metal gate for electrical characteristics of 18nm NMOS device", Norani Bte Atan, Ibrahim Bin Ahmad, ICSE2014, 27-29 Aug. 2014. (DOI : 10.1109/SMELEC.2014.6920794)**

◆ **Purpose**

We will understand the electrical characteristics of NMOS for several dielectrics. Additionally, there are no mention about the width(W) of NMOS in this reference. Thus, we'll calculate the value of W by using the saturation mode I_D equation.

◆ **Parameters**

- L = 18nm
- temperature = 25℃
- dielectric thickness = 130Å
- dielectric material = Al_2O_3(k~9), HfO_2(k~25), TiO_2(k~85)

◆ **I_D-V_D, I_D-V_G characteristics**

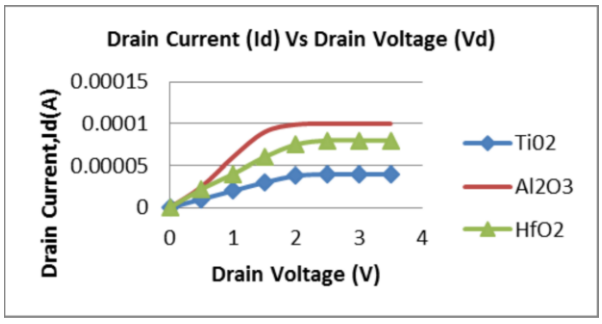

Figure 1. I_D-V_D characteristic at V_{GS}=2.6V

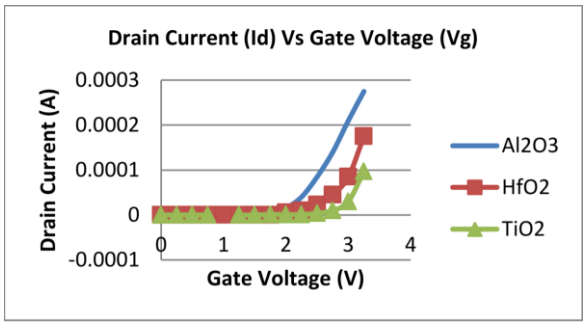

Figure 2. I_D-V_G characteristic at V_{DS}=1.4V

◆ I_{ON}, I_{OFF} characteristics

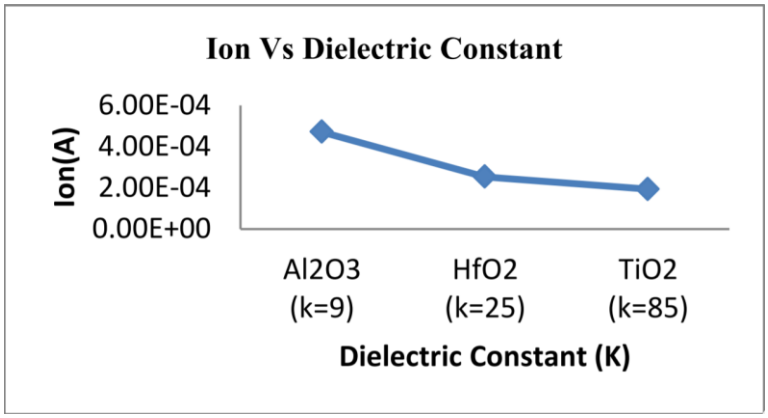

Figure 3. I_{ON} for each dielectrics

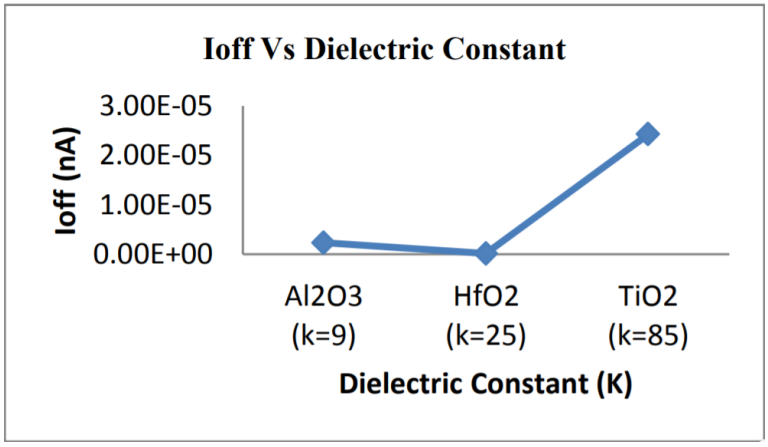

Figure 4. I_{off} for each dielectrics(V_{GS}=0V, V_{DS}=V_{DD})

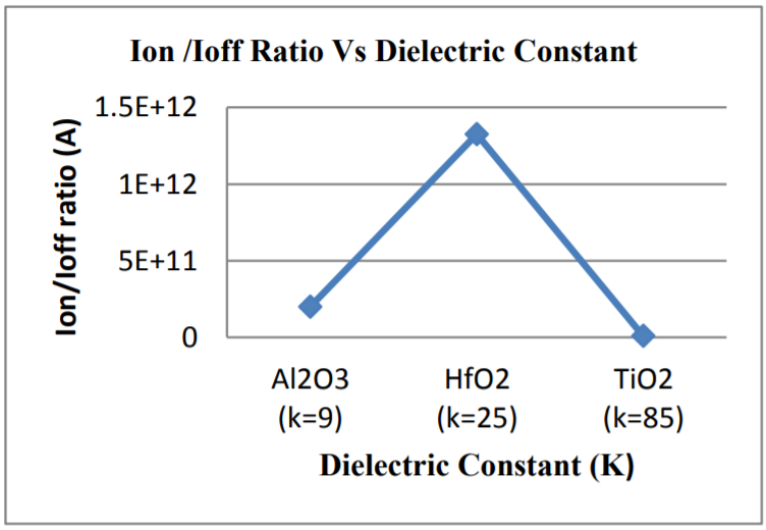

Figure 5. I_{ON} / I_{OFF} ratio for each dielectrics

- We will analyze the electrical characteristics for only Al_2O_3 case.

Parameter	Al_2O_3
V_{th} (V)	0.302651
I_{ON} (A/μm)	$4.721x10^{-4}$
I_{OFF} (A/μm)	$2.365x10^{-15}$
I_{ON} / I_{OFF}	$1.996x10^{11}$

Table 1. Specific values for Al_2O_3 case (I fixed the value of I_{ON}, I_{OFF})

The I_{OFF} value of Al_2O_3 is $2.365x10^{-6}$ nA/μm and the I_{OFF} value of our text book Fig. 2.20, oxide case, is 27nA/μm. I think that there is something wrong calculation with the I_{OFF} value of this paper because it's much smaller than our text book value. Of course the temperature of our text book is 70℃, and the temperature of this reference is 25℃, so the leakage current of our text book should be higher than this reference. However, even with this in mind, this difference is too huge. Thus, this value should be modified.

◆ **C_{ox} calculation**

$$C_{Al_2O_3} = \frac{\varepsilon_{Al_2O_3}}{t_{Al_2O_3}} = \frac{9.34 \times 8.85 \times 10^{-12}}{130 \times 10^{-10}} = 6.358 \ \mathrm{fF/\mu m^2}$$

◆ μ_{eff-n} calculation

- We will use Eq. 2.23 from our text book to evaluate the μ_{eff-n}, value with the conditions from **Figure 1.** ; V_{GS}=2.6V, V_{th} = 0.3026V, t_{Al2O3}=13nm.

$$\mu_{eff-n} = \frac{540}{1 + \left(\frac{2.6 + 0.3026}{0.54 \times 13}\right)^{1.85}} = 451.8 \frac{cm^2}{V \cdot s} = 451.8 \times 10^8 \frac{\mu m^2}{V \cdot s}$$

Of course, this equation is valid for oxide interface, but we'll use this equation for convenience.

◆ W calculation

- From **Figure 1.**, we can know that I_D=0.0001A at V_{GS}=2.6V. Thus, we can calculate width of this NMOS device by those parameters.

$$W = \frac{2LI_D}{\mu_{eff,n} C_{Al_2O_3} V_{ov}^2} = 2.369 \text{ nm}$$

Thus, we can calculate the width of this NMOS device to 2.369 nm. Although there are some assumptions for Al_2O_3 dielectric, but our result may near with the real width because the result has nm scale.