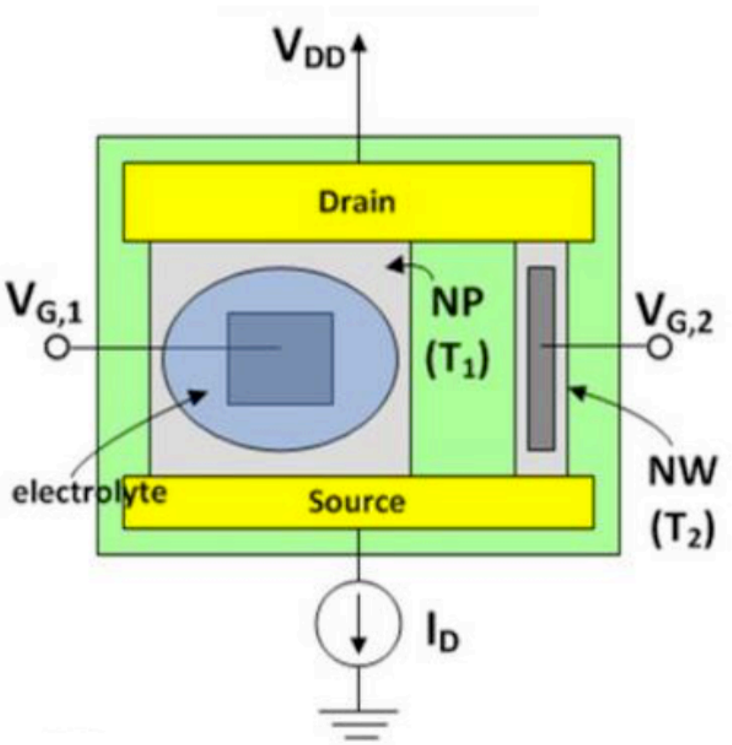
pH sensitivity amplification by a NP-NW sensor

Consider an accumulation-mode NP-NW transistor pair. What is the maximum pH sensitivity for such a device with AlGaN serving as the channel of the planar FET (T1) and Si-NW as the NW-FET (T2) with the following properties?

- AlGaN has a mobility of 2000 $cm^2/V \cdot s$, $T_{Ox} = 45nm$, $W = 1\mu m$ (T1)
- Si-NW has a mobility of 100 $cm^2/V \cdot s$, $T_{Ox} = 15nm$, $W = 50nm$ (T2)
- $L_1 = L_2, V_{DS1} = V_{DS2}$.



Solution:

Accumulation mode operation:

$$\Delta I_{D1} = \mu_1 C_{OX1}\left(\frac{W}{L}\right)_1 V_{DS1}\Delta V_{GS1}$$

$$\Delta I_{D2} = \mu_2 C_{OX2}\left(\frac{W}{L}\right)_2 V_{DS2}\Delta V_{GS2}$$

$$\Delta I_{D1} = \Delta I_{D2}$$

$$\mu_1 C_{OX1}\left(\frac{W}{L}\right)_1 V_{DS1}\Delta V_{GS1} = \mu_2 C_{OX2}\left(\frac{W}{L}\right)_2 V_{DS2}\Delta V_{GS2}$$

$$\frac{\Delta V_{GS2}}{\Delta V_{GS1}} = \frac{\mu_1 C_{OX1}\left(\frac{W}{L}\right)_1 V_{DS1}}{\mu_2 C_{OX2}\left(\frac{W}{L}\right)_2 V_{DS2}} = \frac{\mu_1 C_{OX1}\left(\frac{W}{L}\right)_1}{\mu_2 C_{OX2}\left(\frac{W}{L}\right)_2} = \frac{\mu_1 C_{OX1} W_1}{\mu_2 C_{OX2} W_2} = \frac{C_{OX1}}{C_{OX2}} * \alpha$$

At highest sensitivity, we know that

$$\frac{\Delta V_{G1}}{\Delta pH} = \frac{59mV}{pH}$$

$$\Delta V_{GS2} = \Delta V_{GS1} * \frac{C_{OX1}}{C_{OX2}} * \alpha$$

$$\frac{\Delta V_{GS2}}{\Delta pH} = \frac{\Delta V_{GS1}}{\Delta pH} * \frac{C_{OX1}}{C_{OX2}} * \alpha$$

$$\frac{\Delta V_G^{NP-NW}}{\Delta pH} = 59\frac{mV}{dec}\left(\frac{C_{Ox1}}{C_{Ox2}}\right)\alpha$$

Numerical application:

$$\frac{\Delta V_G^{NP-NW}}{\Delta pH} = 59\frac{mV}{dec}\left(\frac{\mu_1}{\mu_2}\frac{W_1}{W_2}\frac{C_{Ox1}}{C_{Ox2}}\right)$$

$\frac{\mu_1}{\mu_2} = 20;\ \frac{W_1}{W_2} = 20;\ \frac{C_{Ox1}}{C_{Ox2}} = 1/3;$

S=59 mV/pH*20*20/3=8V/pH

pH response is nonlinear.
So be careful!.