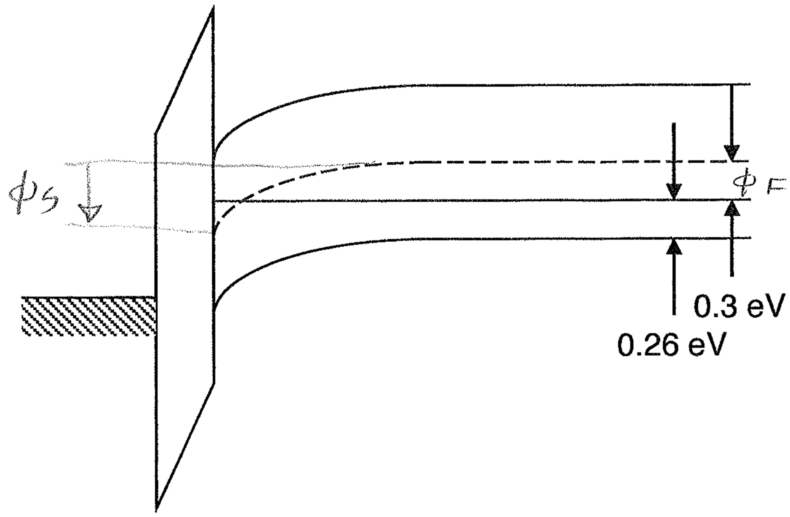
5. An MOS capacitor is biased at the threshold of inversion, as shown in the band diagram below. You may assume that no inversion layer charge is present, and that the structure is "ideal" as defined in class. (The sketch is not drawn exactly to scale. Do not attempt to answer the questions below by "measuring" the diagram.)



A. What is the surface potential?

ABET-5 Question
(5 pts.)

$\phi_S = 2\phi_F = 2(0.3\,V) = \boxed{0.6\,V}$

ϕ_S is the total band bending from the bulk to the surface. At the onset of inversion, we know that $\boxed{\phi_S = 2\phi_F}$. ϕ_F is the Fermi level relative to midgap in the bulk.

B. What is the substrate doping? (5 pts.)

$$N_A = n_i e^{\frac{(E_i - E_F)_{x=\infty}}{kT}} = 10^{10} cm^{-3} e^{\frac{0.3eV}{0.0259eV}}$$

$$N_A = \boxed{1.07 \times 10^{15} cm^{-3}}$$

C. What is the width of the depleted region in the semiconductor? (5 pts.)

$$W = \sqrt{\frac{2K_S\epsilon_0}{q N_A} \phi_S}$$

$$= \sqrt{\frac{2(11.8)(8.85 \times 10^{-14} F/cm)}{(1.6 \times 10^{-19} C)(1.07 \times 10^{15} cm^{-3})} (0.6V)}$$

$$W = \boxed{8.556 \times 10^{-5} cm} \quad (= 0.8556 \mu m)$$

44:00

6. A silicon p-type MOS capacitor is maintained in the dark at room temperature. The substrate doping is $1x10^{17}$ cm^{-3} and the oxide thickness is 20 nm. Assuming the sample is "ideal" (as discussed in class and in the text), calculate the threshold voltage.

ABET-5 Question
(10 pts.)

$V_T = V_g$ when $\phi_s = 2\phi_F$

Since $\boxed{V_g = \phi_s + \sqrt{2V_0\phi_s}}$, we can set

$$\boxed{V_T = (2\phi_F) + \sqrt{2V_0(2\phi_F)}}$$

$$\phi_F = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right) = (0.0259\,v)\ln\left(\frac{1\times10^{17}cm^{-3}}{1\times10^{10}cm^{-3}}\right)$$

$$\boxed{\phi_F = 0.4175\,v}$$

$$V_0 = \frac{q K_s \epsilon_0 N_A}{C_{ox}^2} \qquad C_{ox} = \frac{K_{ox}\epsilon_0}{t_{ox}} = \frac{3.9\,(8.85\times10^{-14}F/cm)}{20\times10^{-7}cm}$$

$$C_{ox} = 1.726\times10^{-7}\,F/cm^2$$

$$V_0 = \frac{(1.6\times10^{-19}C)(11.8)(8.85\times10^{-14}F/cm)(1\times10^{17}cm^{-3})}{(1.726\times10^{-7}F/cm^2)^2}$$

$$\boxed{V_0 = 0.5610\,v}$$

$$\therefore\ V_T = 2(0.4175\,v) + \sqrt{2(0.561v)(2)(0.4175v)}$$

$$\boxed{V_T = 1.803\,v}$$