Exercise 6

Calculate the depletion layer capacity at a reverse bias \( V_R = 0.5 \) V in a Au/n-Si Schottky diode. Assume the following parameters:

- Au work function: \( \phi_M = 4.80 \) eV
- \( n \)-region: doping density of \( N_D = 1 \times 10^{21} \) m\(^{-3}\)
- Si electron affinity: \( \chi = 4.05 \) eV
- Si Fermi level: \( E_F = E_C - 0.15 \) eV
- Permittivity: \( \varepsilon = \varepsilon_0 \times 12.0 \times 8.854 \times 10^{-12} \) F/m
- and \( q = 1.6 \times 10^{-19} \) C.
The built-in potential can be calculated as

\[ qV_{bi} = \phi_B - (E_C - E_F) \]

For an \( n \)-type contact,

\[ \phi_M < \chi : ( ) \text{ contact} \]
\[ \phi_M > \chi : ( ) \text{ contact with the barrier height of } \phi_B = \phi_M - \chi \]

Hence,

\[ qV_{bi} = \]

By substituting the given parameters,

\[ qV_{bi} = (4.80 - 4.05) - 0.15 = \]

Depletion layer capacity \( C \) is

\[
C = \frac{\varepsilon}{w} = \sqrt{\frac{q\varepsilon N_D}{2(V_{bi} + V_R)}}
\]

\[
= \sqrt{\frac{1.6 \times 10^{-19} \cdot 12.0 \times 8.854 \times 10^{-12} \cdot 1 \times 10^{21}}{2(0.60 + 0.5)}}
\]

\[
= \sqrt{\frac{1.70 \times 10^{-8}}{1.3}} = 1.14 \cdots 10^{-4} [C]
\]

27 Metal Oxide Semiconductor Junction

- Bias application
- Surface space-charge
- MOS FET
Realistic Schottky Barrier

Image force and Shottky barrier:

\[ \frac{q\phi_m}{1} \]

\[ \text{METAL} \]

\[ \text{SEMICONDUCTOR} \]


Metal Oxide Semiconductor Junction

\( n\)-type semiconductor at \( V = 0 \):

\( p\)-type semiconductor at \( V = 0 \):

\[ \frac{q\chi}{1} \]

\[ \frac{q\phi_B}{1} \]

\[ \frac{q\phi_m}{1} \]

\[ E_F \]

\[ E_C \]

\[ E_V \]

\[ E_g/2 \]

\[ q\psi \]

\[ \text{METAL} \]

\[ \text{INSULATOR} \]

\[ \text{SEMICONDUCTOR} \]

Metal Oxide Semiconductor (MOS)

$p$-type Si / SiO$_2$ / poly-Si :

In 2007, Intel introduced $p$-type Si / high-$k$ oxides (HfO$_2$ etc.) / metal.

* http://www.wikipedia.org/

Bias Applications

Reverse bias ( ) :

Forward bias ( ) :

**Surface Space-Charge**

$p$-type semiconductor:


**Space-Charge Variation**

With different surface potentials $\psi_S$:

Charge Distributions

Band diagram of a metal oxide semiconductor junction under an inversion condition:

Electric field distributions:

Charge distributions:

Potential distributions:

MOS Field Effect Transistor (FET)

One of the most popular transistors for amplification and switching:

MOS FET Operation

Current-Voltage characteristics:

Gate functionality:

* http://www.wikipedia.org/

* https://www.youtube.com/watch?v=DquJSQasWG0