ECE599 – 002: Special Topics – Thin Film Electronics
Fall 2018
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Homework 1
Due at the beginning of class Tuesday October 9th

Question 1 [10 marks]:

\[ I_D = \frac{W}{L} \mu C_{ox} \left[ (V_G - V_T)V_D - \frac{V_D^2}{2} \right] \] (1)

Where:
- \( I_D \) is the source-drain current.
- \( W \) is the channel width.
- \( L \) is the channel length.
- \( \mu \) is the charge carrier mobility.
- \( C_{ox} \) is the capacitance per unit area.
- \( V_G \) is the applied gate voltage.
- \( V_T \) is the threshold voltage.
- \( V_D \) is the applied drain voltage.

a) Figure 1 shows the transfer characteristics of a thin-film transistor. State whether this transistor is n-type or p-type. [1 mark]

b) Briefly describe what is meant by an ambipolar (sometimes called bipolar) thin film transistor. [1 mark]

c) The main result from the gradual channel approximation is given by Equation 1. Using this equation, explain briefly one of the reasons why a high mobility is generally desirable in thin-film electronics. [2 marks]

d) Say we are measuring a square thin-film transistor (where \( W = L \)). Explain briefly why the gradual channel approximation may not be valid in this case. [1 mark]

e) In deriving Equation 1, mobility was assumed to not be a function of applied field. Instead, consider a TFT where mobility depends on the voltage in the channel via: \( \mu(V) = \mu_0 V \). You can assume the mobility does not depend on gate voltage (\( V_G \)) or threshold voltage (\( V_T \)), only on the voltage in the channel (\( V(x) \)) due to \( V_D \). Evaluate the source-drain current flowing in this TFT if:
- $W = 200 \mu m$.  
- $L = 10 \mu m$.  
- $\mu_0 = 1 \text{ cm}^2/\text{V}^2\text{s}$.  
- $C_{ox} = 200 \text{ nFcm}^2$.  
- $V_D = 10 \text{ V}$.  
- $V_G = 20 \text{ V}$.  
- $V_T = 2 \text{ V}$.  

Hint: you can start with the differential equation at the top of slide 26 Lecture 3.[5 marks]

**Question 2 [15 marks]:**
Figure 2 shows transfer characteristics of a thin-film transistor (TFT), measured at applied drain voltages of $V_D = 10 \text{ V}$, $V_D = 40 \text{ V}$. The transistor width and length are $W = 1 \text{ mm}$ and $L = 50 \mu m$, respectively. The gate oxide capacitance per unit area is $11 \text{ nFcm}^2$. This data is available to download [here](#).

![Figure 2 Transfer characteristics ($I_D$ vs $V_G$) of an example field-effect transistor. This data is available to download here.](#)

a) Provide an estimate of the on/off ratio of this transistor.[1 mark]

b) By numerically differentiating the data when $V_D = 10 \text{ V}$, evaluate the representative **linear field effect mobility** for this data. Show all steps and explain the rationale for your choice of value of $\mu_{\text{lin}}$. Include any relevant graphs. For this analysis assume that threshold voltage is close to $V_T = 0 \text{ V}$. [4 marks]

c) By using either of the approaches described in class, use the data when $V_D = 40 \text{ V}$ to determine a representative **saturation field-effect mobility**. Show all steps and explain the rationale for your choice of value of $\mu_{\text{sat}}$. Include any relevant plots. For this analysis assume that threshold voltage is close to $V_T = 0 \text{ V}$. [4 marks]

d) Using an approach of your choosing, estimate the threshold voltage of this transistor from the data provided. Include any relevant plots. [6 marks]