ECE 617 – Thin Film Electronics
Fall 2020
Homework 1 - Solutions
Due Monday October 5th at 2:00pm

Question 1 [3 marks]:
  a) A field-effect transistor (FET) is an electronic switch. Typically, the current that flows through the source and drain electrodes is used to drive some device (e.g. a light emitting diode). State the purpose of gate electrode in an FET.[1 mark]

        It is used to modulate the conductivity of the semiconductor, and hence the current that flows between the source and drain electrodes.

  b) Give a reason why can we not use single crystal silicon wafers for transistor backplanes in televisions / monitors.[1 mark]

        The wafer diameters are too small.

  c) Give a reason why crystalline silicon wafers are not generally being explored for ubiquitous flexible electronics.[1 mark]

        Any of the below (or any other reasonable explanation):
        1) Silicon wafers are not mechanically flexible.
        2) The high temperatures associated with silicon processing are not compatible with flexible substrates.
        3) The cost per device would be too high for certain applications (food packaging etc).

Question 2 [7 marks]:

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

(1)

Where:

- \( I_D \) is the source-drain current.
- \( W \) is the channel width.

Figure 1 Example transfer characteristics of an example thin-film transistor.
• $L$ 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) Are thin film transistors generally depletion mode devices or accumulation mode devices? [1 mark]

Accumulation mode. Some exceptions exist in bioelectronics, such as organic electrochemical transistors.

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

The applied voltages are negative, so this is a p-type transistor.

c) State what is meant by an ambipolar (sometimes called bipolar) thin film transistor.[1 mark]

An ambipolar thin-film transistor is capable of injecting and transporting both holes and electrons.

d) The speed at which information can be transmitted and processed, depends on the time taken for electrons or holes to traverse certain devices. Briefly explain why we generally characterize thin film transistors in terms of charge carrier mobility, rather than charge carrier velocity.[2 marks]

In steady state, the velocity ($v$) of charge carriers is linearly proportional to the electric field ($E$) they are in:

$$v = \mu E$$

We measure and use TFTs at a range of different voltages. Therefore the velocity at which electrons / holes move will depend on the biasing conditions. The field experienced, for a certain set of voltages, will also heavily depend on device design / geometry. These factors make it difficult to compare velocities between devices. For this reason, the mobility ($\mu$), a material property of the semiconductor, is typically evaluated and used as a metric for device performance.

e) 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 portable thin-film electronics.[2 marks]

In Equation 1 we see that the source-drain current is directly proportional to mobility. This means that the current that the transistor can output will increase as mobility increases. Certain devices require a lower threshold of current to drive them (for example light-emitting diodes), so the ability to drive devices is strongly dependent on the charge carrier mobility in TFTs. Additionally, it is clear from Equation 1 that when you reduce applied voltages from ~20V
(mains devices) to ~2V (battery-powered devices) you would need a higher mobility to produce the same current.