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EE290D  
Spring 1999

Handout #49  
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**HOMEWORK ASSIGNMENT #5 SOLUTIONS**

**Problem 1: FED Technology**

- a) A fundamental problem with an array of emitters is the nonuniformity in tip sharpness, emitter height and work function across the array. This variation results in tip-to-tip variation in turn-on voltage and consequently variation in emission current as a function of drive voltage. To improve the pixel-to-pixel uniformity of the emission current, a large number of emitters ( $>1000/\text{pixel}$ ) is employed (for better statistical uniformity). (Note that the use of “ballast” resistors between the emitters and emitter electrodes also greatly improves the emission current uniformity.) The high degree of redundancy also results in a robust design whereby processing yield is increased due to relative insensitivity to particulate contamination.
- b) Residual gases such as oxygen ( $\text{O}_2$ ), water vapor ( $\text{H}_2\text{O}$ ), carbon monoxide ( $\text{CO}$ ) and carbon dioxide ( $\text{CO}_2$ ) will react with (*i.e.* oxidize) the emitters, affecting (increasing) their surface work function and thereby degrading their emission current. Because of the high electric fields and high-density electron beams within an FED, residual gas molecules can be ionized; the ions can sputter the emitters, altering their topology and thereby reducing emission current.
- c) Advantages of low anode voltage:
1. Small cathode-to-anode spacing can be used; this simplifies the spacer formation process.
  2. Arcing is not a significant problem due to the low voltages. (There is minimal charging of the spacers by secondary electron emission.)
  3. Because a relatively small cathode-to-anode spacing can be used, focusing electrodes are not needed (to limit electron-beam spread) in order to achieve high color purity.
  4. Field-sequential color selection can be used, to reduce the number of column drivers by a factor of 3, with resultant lower driver cost and easier (less critical) anode-to-cathode alignment.

Disadvantages of low anode voltage:

1. Phosphors are less efficient at low voltages, so low-voltage operation results in lower display brightness. In order to achieve high brightness, high current must be used, resulting in reduced lifetime (accelerated Coulomb aging of phosphors). Note: High drive voltages are needed to provide high current, so driver cost is high; this disadvantage is offset by the reduction in the number of drivers (for the field-sequential color selection scheme).
2. Color phosphor materials are still under development (for improved efficiency and lifetime). Differential phosphor aging is presently a barrier to the commercial introduction of LVFED color displays.

**Problem 2: FED Cathode Design**

- a) Low-voltage ( $\sim 10$  V) operation permits the use of low-cost display-driver integrated circuits (implemented in standard CMOS technology); it also reduces power consumption (proportional to  $V^2$ ). Low gate voltages are also desirable to minimize the degradation of emitters in ambients containing oxygenic gases.
- b) Approaches to decreasing the operating voltage of a field emitter array:
1. Decrease the surface work function of the emitter.
  2. Decrease the electrode spacing by using a triode (gated emitter) structure with small gate aperture.
  3. Decrease the radius of curvature of the emitter tip (to achieve a larger field-enhancement factor  $\beta$ ).
  4. Increase the number of emitters per pixel, to lower the required current per emitter.
  5. Improve the phosphor efficiency, to lower the required current per emitter.

**Problem 3: Plasma Display Technology**

- a)  $\text{Ne}^+$  ions bombard the cathode (coated with  $\text{MgO}$ ) to produce secondary electrons and thereby induce (avalanche) breakdown. Xe atoms excited by the electrons in the plasma radiate vacuum ultraviolet (VUV) light upon relaxation to the ground state. The VUV light is converted to visible radiation by the phosphor.
- b) The screen printing technique is much simpler (and hence is much lower in cost) than photolithographic techniques. The disadvantages of screen printing are that it cannot be used with very thin films and that its resolution -- as well as layer-to-layer alignment accuracy -- is limited (e.g.  $>10\ \mu\text{m}$  minimum feature size).

**Problem 4: Plasma Display Driving Scheme**

- a) In an AC-PDP, charges are deposited on the cell walls of an ON pixel; these charges increase the electric field across the gap, so that a lower applied voltage can be used to ignite a discharge. In a DC-PDP, a discharge-stabilizing resistor is connected in series with the plasma cell of each pixel; because of the voltage which is dropped across this resistor, a larger applied voltage is required.
- b) In a conventionally driven AC-PDP, each address electrode requires a separate driver and each scan electrode requires a separate driver as well. The sustain electrodes for all of the cells are connected and driven together. For an HDTV ( $1920 \times 1080$  pixels) display, 1920 data drivers are required, and 1081 scan+sustain drivers are required.
- c) By employing AND logic in addressing the cells, every  $n$ th "scan" electrode can be connected to a common terminal while every  $n$  "sustain" electrodes in sequence is connected to a common terminal; therefore, the number of scan drivers in an HDTV ACPDP can be reduced to  $\sqrt{1080} = 33$ . Each of the "scan" and "sustain" drivers would be connected to 33 electrodes. (The last scan driver and sustain driver would each be connected to only 24 electrodes.)

Alternatively, every 30th "scan" electrode can be connected together (so that 30 scan drivers would be required, each connected to 36 electrodes) while every 36th "sustain" electrode is connected to a common terminal (so that 36 sustain drivers would be required, each connected to 30 electrodes).