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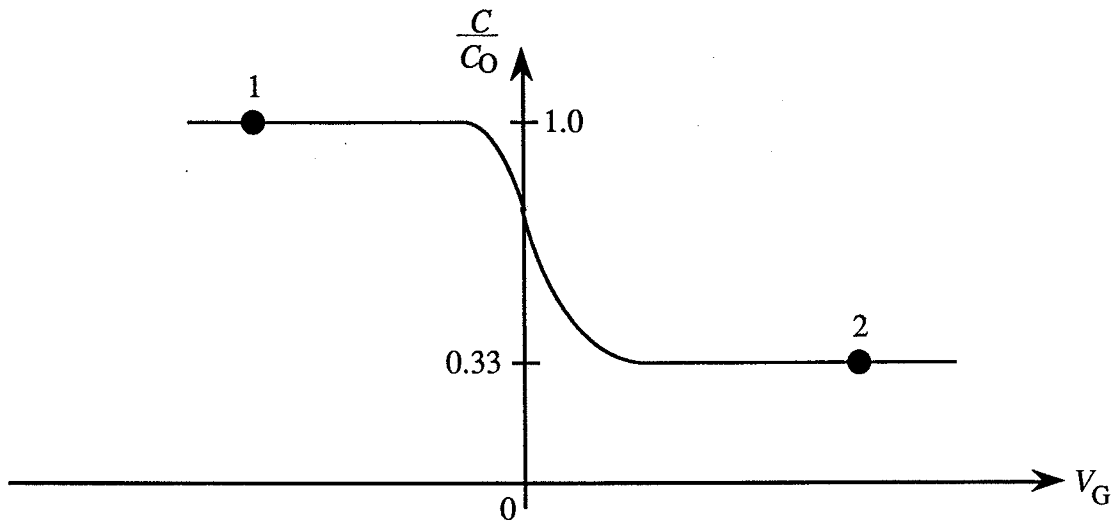
| **Course:** | **Semiconductor Device Fundamentals** |
| **Level:** | **Undergraduate** |
| **Module:** | **C** |
| **Test:** | **C6** |
| **Type:** | ***Open* Book, *Open* Notes** |

**Problem Weighting---** **F-1...35 (5 each part)**
**F-2...25**
**F-3...40 (8 each part)**

**F - 1**

The high-frequency *C–V* characteristic exhibited by an IDEAL MOS-C is sketched below. Answer the questions that follow assuming $x_o = 0.1\mu m$ and $T = 300K$.




(a) Identify the flat-band point on the curve. {Place a dot (●) at the appropriate point and write "FB" next to it on the curve.]

(b) Identify the point corresponding to $V_T$ on the curve.

(c) Sketch the *low-frequency C–V* characteristic to be expected from the device. (Superimpose your labeled sketch on the above figure.)

(d) Sketch the *total-deep-depletion C-V* characteristic to be expect from the device. (Superimpose your labeled sketch on the above figure.)

(e) Is the semiconductor component of the MOS-C doped *n*- or *p*-type? Explain.

(f) *Based on the δ-depletion approximation*, what is the surface potential ($\phi_S$) at point 1 on the curve.

(g) Based on the δ-depletion theory, what is the depletion width (*W*) inside the semiconductor at the point 2 on the curve. (A *numerical* answer is required.)

**F - 2**

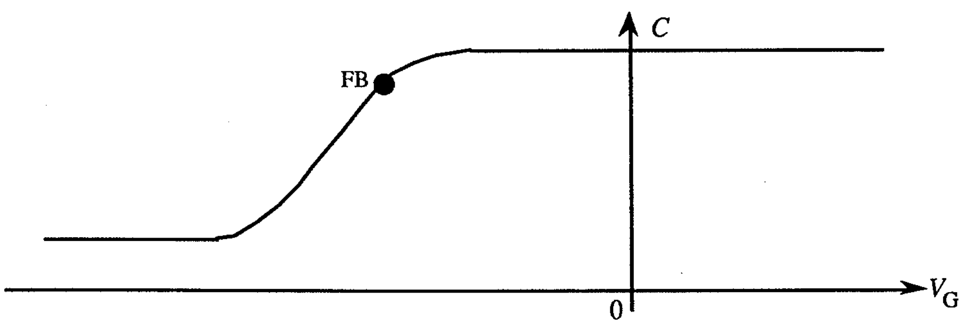
By definition, $\phi(y)$ is the potential at the point $y$ in the MOSFET channel. The channel runs from $y = 0$ at the source to $y = L$ at the drain. Correspondingly, $\phi = 0$ at the source and $\phi = V_D$ at the drain. Employing a square-law type analysis, derive an expression for the voltage $\phi(y)$ that exists at an arbitrary point $y$ in the MOSFET channel. (Your answer should be expressed in terms of $y$, $I_D$, $V_G - V_T$, and $Z\bar{\mu}_n C_o$.)

HINT: You must modify the $I_D$–$V_D$ Square-Law derivation to obtain a relationship involving $y$ and $\phi(y)$ instead of the $L$ and $V_D$ appearing in the usual below-pinch-off result.

F - 3

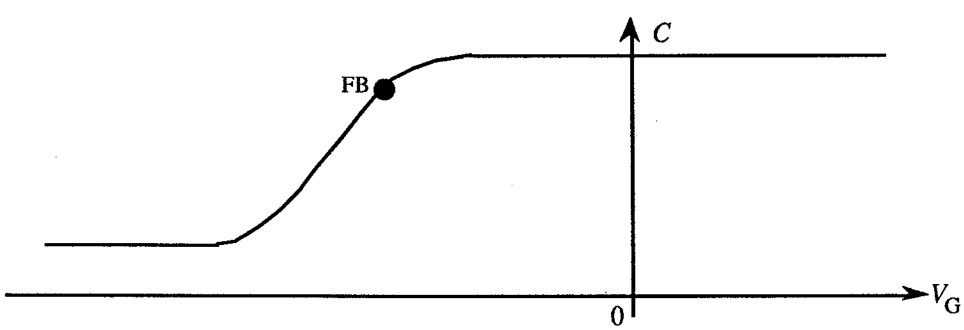
An MOS-C is known to contain a $\phi_{MS} \neq 0$, $Q_F \neq 0$, $Q_M \neq 0$ distributed throughout the oxide, and a significant number of *donor-like* interface states. The *C–V* characteristic exhibited by the device is repeated in each part of the problem below. Indicate how each of the operations specified in parts (a)-(e), TAKEN SEPARATELY, will affect the observed characteristic. **In each case, sketch the *C–V* characteristic to be expected after the operation AND explain how you arrived at the revised characteristic. (There will be no credit for a sketch without an acceptable explanation.)**

(a) An anneal in performed which totally eliminates the interface states.



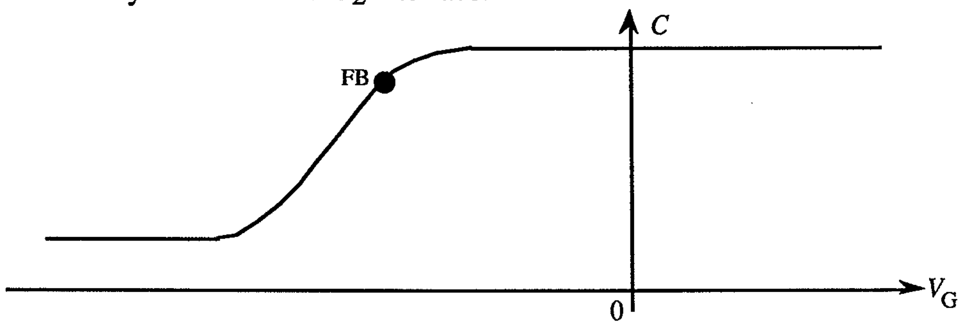

EXPLANATION:

(b) An anneal is performed which reduces $Q_F$.



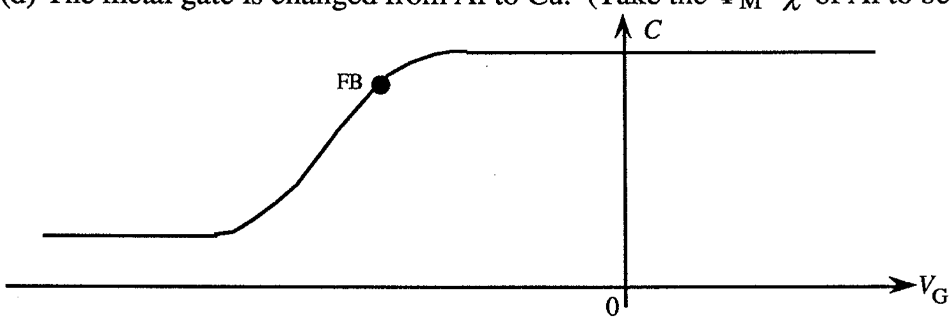

EXPLANATION:

(c) Phosphorus gettering is performed so that the mobile ions are trapped in the top 10% of the oxide away from the $Si$-$SiO_2$ interface.



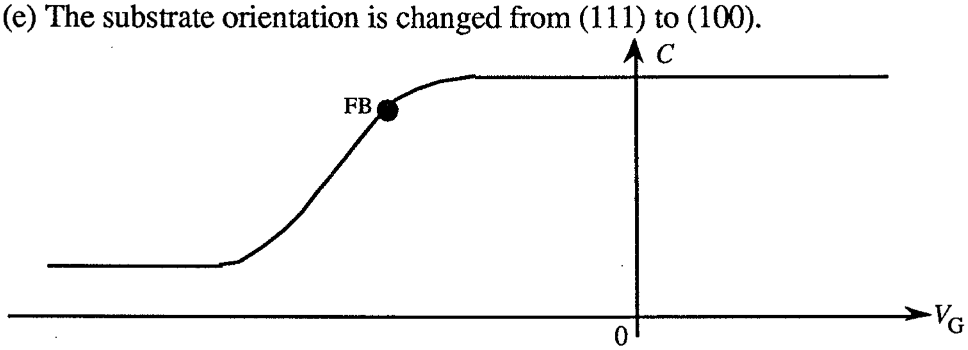

EXPLANATION:

(d) The metal gate is changed from Al to Cu. (Take the $\Phi_M'-\chi'$ of Al to be –0.03eV.)




EXPLANATION:

(e) The substrate orientation is changed from (111) to (100).




EXPLANATION: