2006 Qual Exam Questions

Prof. H.-S. Philip Wong

1. Consider a semiconductor with a bandgap of 0.5 eV. Draw the energy band diagram of the semiconductor if it is intrinsically doped. Indicate the workfunction of the semiconductor in the band diagram.

2. If a metal with a workfunction that is the same as the semiconductor is brought in contact with the semiconductor, draw the energy band diagram again.

3. If the workfunction of the metal is smaller, draw the band diagram.

4. If the workfunction of the metal is larger, draw the band diagram.

5. Now, focus on the case in which the workfunction of the metal is larger. Assume we make a MOSFET with the source and drain with the metal directly in contact with the semiconductor. Draw the Id vs Vds curve (with different Vgs) for this transistor. Explain the features of the IV curve and contrast this with a conventional MOSFET.

6. How can you improve the IV characteristics of this transistor? What is the physics behind your solution?

7. Now, draw the Id vs Vgs curve (at high Vds) of the unmodified transistor. Explain the features of the IV curve and contrast this with a conventional MOSFET.

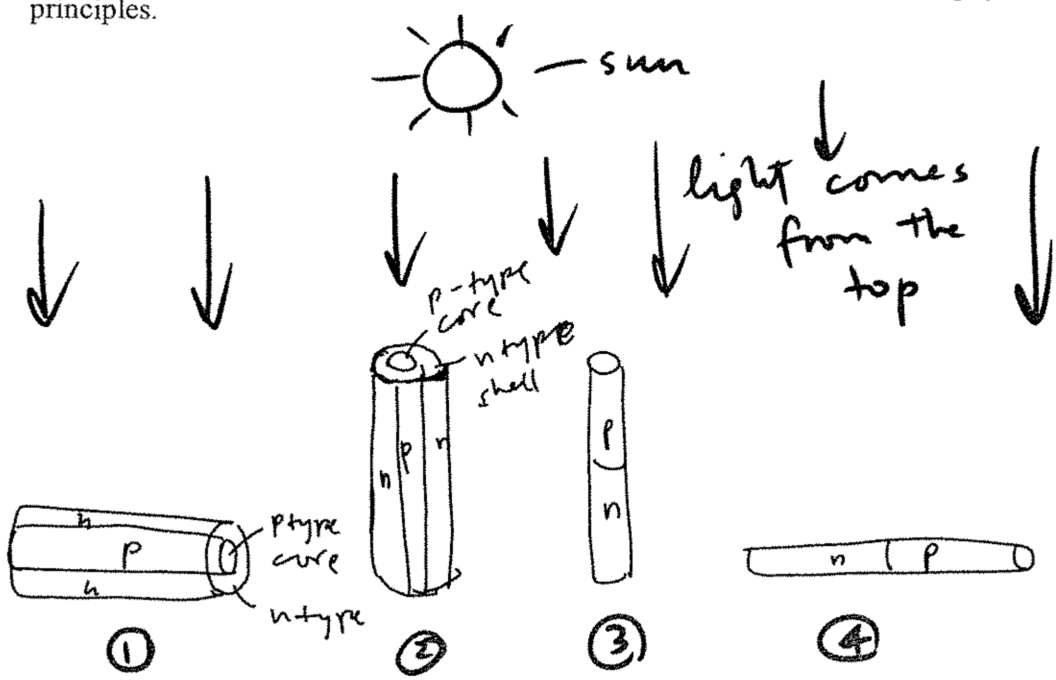
8. Can we use this ambipolar transistor in conventional CMOS circuit families? Which circuit types will not work with the ambipolar transistors?

9. Draw the circuit diagram of a 2–input CMOS NAND gate. Will this circuit work if the transistor is made of the ambipolar transistor above?

2008 Qual Exam Questions

Prof. H.-S. Philip Wong

1. Tell me how a semiconductor solar cell works.
2. Show the I-V characteristics.
3. Show the band diagram of a silicon pn-junction solar cell with and without light illumination. Show where the Fermi levels are and where the conduction band and valence band is. Explain how you would determine the Fermi level.
4. Consider a semiconductor pn-junction nanowire of diameter 30 nm and about 1 um long. Which one of the following four device configurations will give you the best solar cell? Light is coming from the top. Explain your answers using device physics principles.

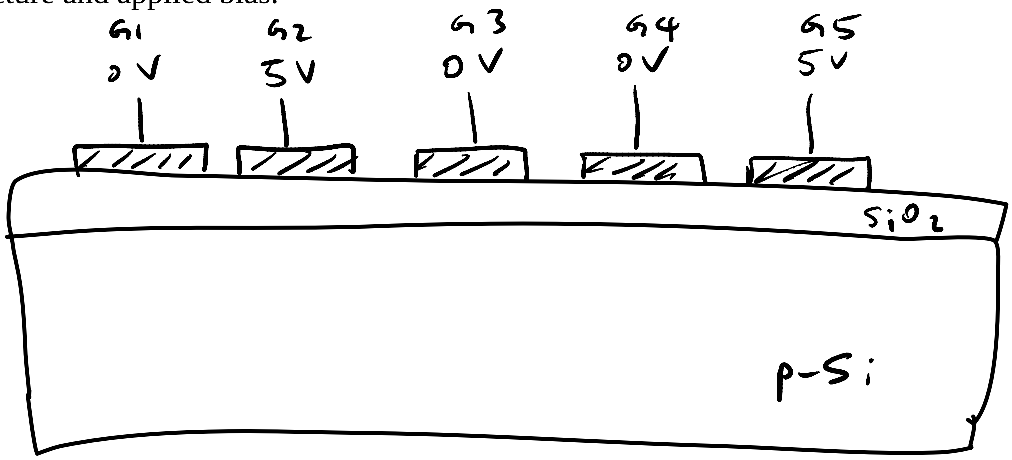


5. If you are allowed to change the device configuration, how would you change it to improve this solar cell?

2010 Qual Exam Questions

Prof. H.-S. Philip Wong

1. Do you know how a Charge-Coupled Device (CCD) works?
2. Draw the energy band diagram along the SiO2/Si interface for the following device structure and applied bias.



3. Assume some electrons are collected under G2. Now, we want to move the electrons to the right under G3. What biases would you apply to the gates G1 to G5?
4. What are the forces acting on the electrons that move the charges from G2 to G3?
5. If we want to move the electrons faster, what would you do? You can change anything you want, including (but not limited to) applied biases, device structure, doping, and the materials of the device.
6. If there is an n+ doping in the p-Si in between the gates, how does the band diagram look like and how does it affect the charge transfer?

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Prof. H.-S. Philip Wong

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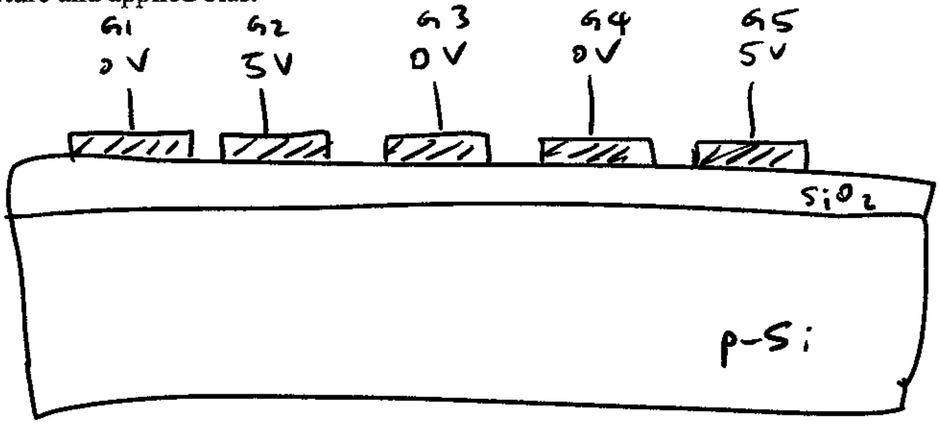

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2012 Qual Exam Questions

Prof. H.-S. Philip Wong

1. Consider an n-channel MOSFET designed for 1V operation with a metal to semiconductor source/drain contact (sometimes, this is called a Schottky barrier FET). Draw the band diagram in the direction normal to the Si/SiO2 interface.
2. Next, draw the band diagram from the source to the drain assuming the nMOSFET is above the (small, positive, say 0.4V) threshold voltage and the drain voltage is small compared to the applied gate bias.
3. Now, if there is a gap between the edge of the gate and the source and drain metal to semiconductor junction, draw the band diagram again. Assume the gate dielectric extends across the ungated gap region.
4. If I now insert a dielectric layer on top of the gate dielectric. This gate dielectric has a dielectric constant of 20 and there are trapped positive charges between this 2nd gate dielectric and the original gate dielectric. Draw the band diagram again.
5. What does the band diagram look like if instead of isolated positive charges, there are electric dipoles (+ve on the 2nd gate dielectric side and –ve on the 1st gate dielectric side).
6. Sketch the Id vs Vgs and Id vs Vds curves for case #4 and case 5 above.

The more questions you can answer, the more points you will get in the exam.

2013 Qual Exam Questions

Prof. H.-S. Philip Wong

I would like to have a solid-state imaging device that takes a picture of the room in the visible wavelengths, in color.

You are given the following materials and the use of a semiconductor fabrication facility: Si, Ge, SiO_2, Si_3N_4, TiO_2, HfO_2, Al_2O_3, Al, Cu, W.

Would you please make a proposal for such a COLOR solid-state imaging device using only those materials listed above? Trace elements such as dopants of semiconductors can be assumed to be available.

Please explain the physics and the operation principles of the proposed device.