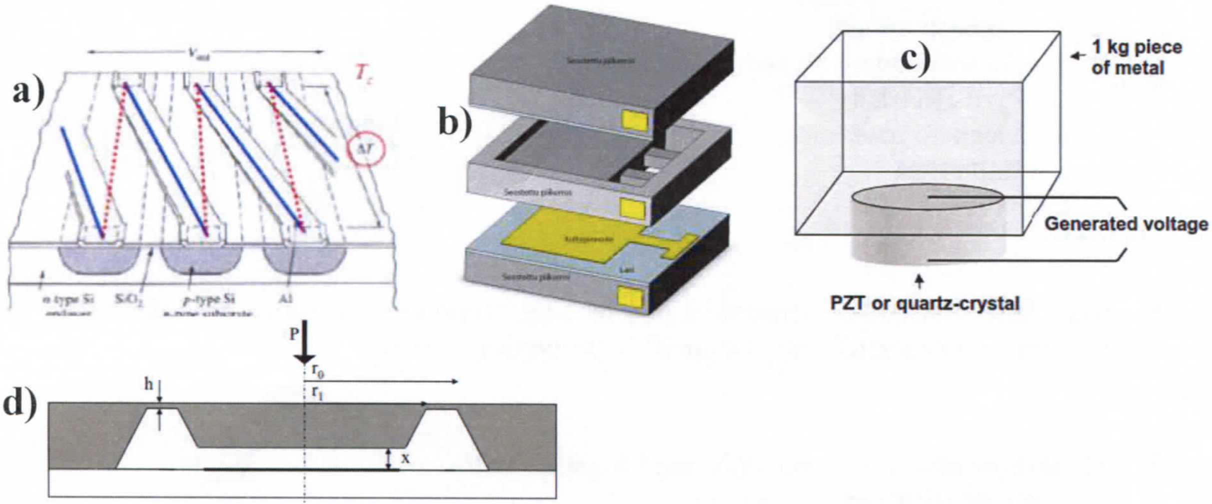
ASE-3036 Microsensors

Exam on Mon 13.3.2017 at 17:00-20:00 at TB103
Exam responsible: Jukka Lekkala

No written material is allowed.
All calculator types can be used.

Answer only to six (6) questions. If you have answered to more than six questions, only the six answers that have given the least amount of points will be considered.

1. Sensors can be classified or categorized at least in three different way. How would you classify the sensors shown below.



2. A photodiode of an optical fiber receiver is used in reverse biased mode in order to increase its frequency band. The dark current of the diode with 10 V reverse voltage is $I_D(-10\ V) = 30$ nA and the internal shunt resistant of the diode was measured to be 10 MΩ:n. The wavelength of the light used in the optical communication is 900 nm. The quantum efficiency QE of the diode for that wave length is 80 %.
    a. What is the total RMS noise current in 1 GHz measurement bandwidth (hard stop, brick wall) at room temperature? (2 p)
    b. What is the sensitivity of the receiver at the given wavelength? (2 p)
    c. What is the NEP (Noise Equivalent Power) for the diode at room temperature when the measurement band width is 1 GHz? (2 p)

   Shot noise produced by the dark current is calculated as $i_s = \sqrt{2ei_dB}$ and the thermal noise current as $i_j = \sqrt{\frac{4kTB}{R}}$. $QE = \frac{S}{\lambda} \cdot \frac{h \cdot c}{e}$. Boltzmann constant = 1.3806*10^{-23} J/K, speed of light = 3*10^{8} m/s, Planck constant = 4.136^{-15} eVs. The unit of sensitivity S is A/W. NEP $= \frac{i_n}{S}$.

   Note! Even though we are talking about noise equivalent power, it is usually given as power density W/√Hz.

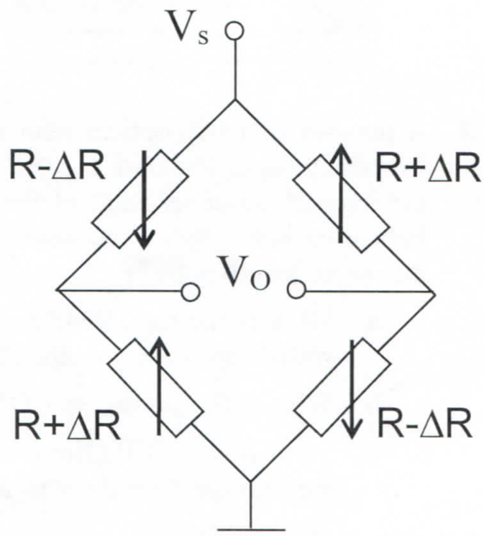
3. a) Explain how a diode (pn-junction) can be used to measure light. (2 p)
   b) What phenomena limit the useful wavelength range? (2 p)
   c) Draw also an electronic circuit diagram for the measurement of a photodiode. (2 p)

4. Briefly explain the terms listed below (1 p each)
   a. Bulk micromachining
   b. Epitaxial silicon
   c. Fused quartz
   d. Polysilicon
   e. Quartz
   f. Surface micromachining

5. Explain shortly: (1 p each)
   a. Seebeck effect
   b. Photoconductivity and photoresistor
   c. Pyro electricity
   d. Magneto resistance
   e. Hall effect
   f. PTAT

6. Thin- and thick-film sensors. Consider e.g. following aspects: manufacturing processes, materials, dimensions, sensor examples, properties,... (6 p)

7. Wheatstone bridge is commonly used together with piezo resistive sensing elements.
   a. What makes Wheatstone bridge convenient and useful? (2 p)
   b. Which kind of sensors it is commonly used with? (1 p)
   c. Derive the equation for the output voltage V_O of the Wheatstone bridge shown below. (3 p)



8. a) What is the minimum diameter of a monocrystalline silicon wire that will support a weight of a 65 kg person? (2 p)
   b) What is the maximum strain of the monocrystalline silicon before it breaks? (1 p)
   c) How long wire of some material can you hang in earth's gravity field ($g=9.81\ m/s^2$) before it breaks under its own weight? Write your answer in terms of material properties i.e. derive an equation for the maximum length. (2 p)
   d) What is the maximum length in the case of silicon? (1 p)

   Assume 160 GPa for the Young's modulus and 6.5 GPa for the maximum tensile stress (yield strength) of silicon. $E = \frac{F \cdot l}{\Delta l \cdot A}$, $\sigma = F/A$