Mittuniversitetet
MID SWEDEN UNIVERSITY

Försättsblad Prov Original

Kurskod	Provkod	Tentamensdatum
EL041A	T201	2019-01-16

Kursnamn	Elektronik AV, Sensorer och instrumentering
Provnamn	Teori del 2: Skriftlig tentamen
Ort	Sundsvall
Termin	
Ämne	

6895642268

Utskriven 2019-01-14 kl. 15:34:15

Sensors and Instrumentation

Written examination on theory part 2, 3.0 hp

The 16th of January 2019, HT 2018

All answers to the questions and solutions to the mathematical problems should be written in an "easy to read and easy to follow" fashion. Mention and motivate, if you make an assumption. Try to be precise and coherent in formulating your answers. Irrelevant and/or unnecessarily long text might cost you points. Figures and plots, if needed, should be drawn with proper labels, units and axes.

- Course codes
  - EL041A, EL046A
- Aid:
  - Calculator,
  - If relevant, a dictionary or electronic dictionary between English and the students home language.

- Time: 5 hours.
- Maximum points: 60.
- Minimum points to pass: 30.

Grading scale:

60	Max
54	A
48	B
42	C
36	D
30	E
28	Fx
0-27.5	F

Section A: 7 x 6 = 42 points

(1) One of the processing steps in the cleanroom lab was titled "Loading doping furnace, 950 °C, 1 hour". Explain the physical purpose of this step as detailed you can.

(2) During the process step "Oxide growth, wet 1050 °C, 1 hour", a silicon dioxide layer was grown on you sample. What is the purpose of the silicon dioxide in the electrical design of the sensor? Explain the growth process.

(3) Describe the IV and CV measurements of the semiconductor sensor samples manufactured during the cleanroom lab. Draw the expected diagrams for the measurements and explain how to interpret them.

(4) Describe the basic operating principles of CCD and CMOS imaging sensors. Compare these sensors by listing their advantages and disadvantages.

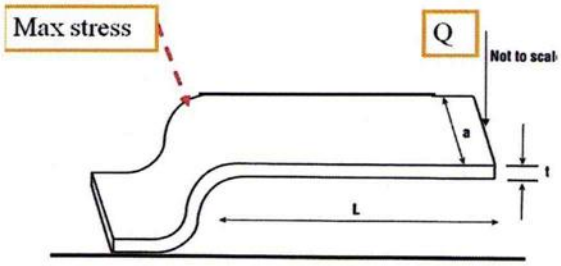
(5) Design two sensors, one capacitive and one resistive, to sense humidity and moisture. Explain the functionality of your sensors.

(6) Explain these force and pressure sensors
   a. Explain with physics, how the conductivity increases when a pressure sensitive film of piezoresistive ink is subjected to force?
   b. Explain the functionality of a pressure sensor using Mercury.

(7) A monomer (one chemical unit) such as ethylene is reacted with other monomer molecules to form long chains of repeating ethylene units, forming the polymer polyethylene. Explain this process. Use drawings to clarify.

Section B: 8 points

(1) When stress is applied to a semiconductor resistor, having initial resistance R, the piezoresistive effect results in change in the resistance ΔR.



A p-type silicon cantilever beam with a piezoresistor located at the point of maximum stress is subjected to a point load Q at the end of the beam. Q is 20 μN, the length of the beam is 800 μm and the beam thickness is 3 μm. Calculate the beam width that results in a 5 % resistance change for the piezoresistor due to the load Q.

Help:

Mechanics for cantilever beams:

$$\text{Deflection } W(P,x) = \frac{Qx^2}{6EI}(3L-x)$$

$$\text{Max stress } \sigma = QLt/2I$$

Stress: σ=Force/Area $\quad I = \frac{at^2}{12}$

Resistance change due to longitudinal and transverse stresses:
Longitudinal stress σ_l and longitudinal piezoresistance coefficient π_l
Transverse stress σ_t and transverse piezoresistance coefficient π_t

$$\frac{\Delta R}{R} = \pi_l\sigma_l + \pi_t\sigma_t$$

$$\approx \frac{\pi_{44}}{2}(\sigma_l - \sigma_t)$$

You can neglect the influence of transverse stress since the beam lies perpendicular to the silicon <110> lattice direction.

A typical room-temperature piezoresistance coefficient for n-type silicon is $\pi_{44} = 1.4 \cdot 10^{-9}$ Pa^{-1}.

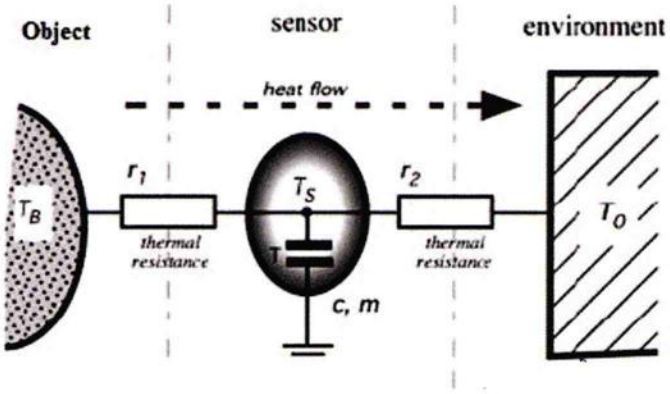
Section C: 10 x 1 = 10 points

Find the most correct answer.

(1) The purpose of spin casting is

(a) To cast signal unto a spinning angular velocity sensor
(b) To apply a thin layer of a resist that will later be patterned.
(c) To gain precision control of the thickness for thin layer deposition.
(d) Both (b) and (c)
(e) None of the above.

(2) What is desired in this thermal circuit to minimize the measurement error



(a) $r_1 \to 0$ and $r_2 \to \infty$.
(b) $r_1 \to \infty$ and $r_2 \to 0$.
(c) $r_1 \to 0$ and $r_2 \to 0$.
(d) $r_1 \to \infty$ and $r_2 \to \infty$.

(3) Flow rate of a liquid or a gas inside a tube is

(a) The ratio between the average velocity and the cross-sectional area of the tube.
(b) Equal to the average velocity.
(c) The ratio between the average velocity and time.
(d) The product of the average velocity and the cross-sectional area of the tube.

(4) Silicon does not possess the

(a) Pyroelectric effect.
(b) Piezoresistive effect
(c) Piezoelectric effect
(d) Both (a) and (b)

(6) While nano-technology referred to dimensions of a device on a nanometer scale, most of the sub-miniature elements have sizes in a micrometer range.

(a) True
(b) False

(7) In an ionic smoke detector

(a) Alpha particles generates charges if smoke is present
(b) Alpha particles are positive ions which charges the smoke particles so they generate charge to the sensor
(c) The absence of alpha particles indicates the presence of smoke.

(8) In a whispering gallery mode (WGM) resonator, a complete round trip in an integer multiple of the light wavelengths causes optical resonances.

(a) True
(b) False

(9) The main idea in an ultrasonic flow sensor is the detection of frequency or phase shift caused by flowing medium.

(a) True
(b) False

(10) The definition "the mass m of water vapor per unit volume V of wet gas" refers to

(a) Humidity ratio
(b) Absolute humidity
(c) Relative humidity