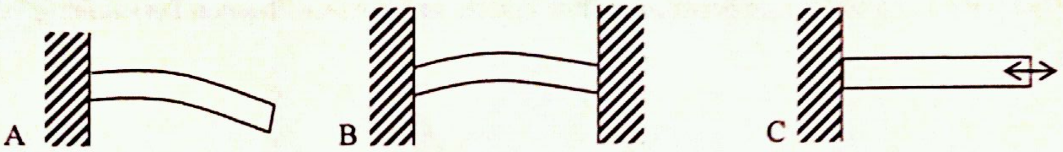
Microsystems technology S-129.3210 (5 cr)

Exam 14.12. 2011 Ilkka Tittonen/Tuomas Rossi

Answer all 5 questions. Each question 6 points.

1. Micromechanics

a)



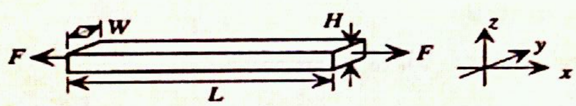
D $m_{eff} \approx 0.41 \cdot m$

E $m_{eff} \approx 0.38 \cdot m$

F $m_{eff} \approx 0.24 \cdot m$

You have 3 different simple beam configurations (A, B and C), where the shaded area corresponds to the stationary support. You have three different values for effective mass (D, E and F). Which effective mass belongs to which configuration and why? If m = density times mass, why are all the effective masses smaller? (Correct pairs 1p, explanations 1p)

b) Assume, that you try to pull a beam from its ends.



$L = 200\mu m$

$H = 4\mu m$

$W = 3\mu m$

$E_{silicon} = 160 GPa$

If you apply a force F of 50N, what is the stress in the beam? What is the corresponding change in length? (1p)

c) In capacitive RF MEMS, dc bias voltage is used. What is its role? (1p)

d) In capacitive RF MEMS, the resonance is affected by losses, in which way? (1p)

e) In capacitive RF MEMS, what is the basic effect or mechanism to make any micromechanical MEMS device move at its resonance frequency? (1p)

2. Thermoelectrics

a) Explain what is the physical effect (not only the name, but how it really works) that can be used to convert waste heat into some useful form? In order to improve efficiency, what should be developed? (2p)

b) What kind of materials are needed for that? Give some examples. (2p)

c) What are the physical reasons and challenges for micro/nanoengineering to improve this conversion? (2p)

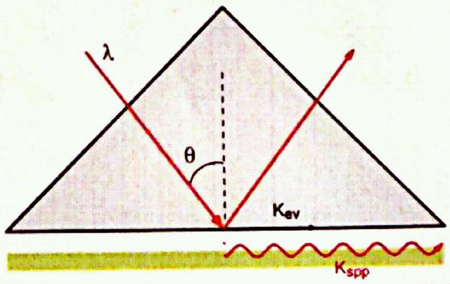
3. BioMEMS

a) Design a cell capture device in which fluid moves, cells are captured and finally released. Make a drawing with some approximate measures and explain how it works. (3p)

b) Design a device for copying DNA (PCR chip). Explain how it works. (3p)

4. Plasmonics

a) What is the main difference between electric current and Surface Plasmon Polaritons (SPP)?



b) Figure above shows the excitation of SPP via the evanescent field generated upon total internal reflection (TIR) in optical prism setup. For such an excitation, the evanescent field and SPP wavevectors (K_{ev} and K_{spp} respectively) have to be matched. Find the angle required to excite SPP with $K_{spp} = 10^7$ (1/m) with the light of 632nm wavelength? (refractive index of the prism material n = 1.45)

$$Kev = \frac{\omega}{c} n \sin\theta$$

c) What physical phenomenon limits the minimal K_{spp} that could be excited?

5. Answer shortly to each questions (1p each)

a) What materials are usable in micromechanics at temperatures that are many hundred degrees C?

b) Of what material and how you would make piezoelectric coatings?

c) How is the pull-in voltage determined in capacitive MEMS?

d) What can you say about silicon as a heat conductor?

e) What can you say about silicon as a piezoelectric material?

f) What are the dissipation processes in micromechanical motion, elasticity, in fluidistics and in the electric field?