**Exam "Technology" (191210730)**

**17th of January, 2011**

***General instructions***

1) The total time given for this examination is 3 hours.
2) Read the complete exam questions before starting, to avoid time problems in the end.
3) It is not allowed to use reference material such as handouts, books, calculators or communicating devices (laptops, mobile phones or pda's) during the exam.
4) Your answers can be given in English or Dutch.
5) Please pay attention to clear writing, the answers should be readable without significant efforts.
6) Students are expected to give detailed and motivated answers. Only complete, long answers with clear drawings qualify for the maximum score.

Good luck!

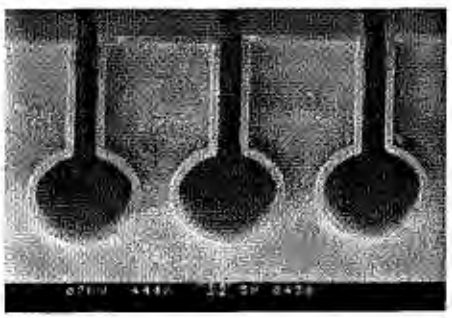
**Question 1: Lithography (20 points max)**

a) Draw the graph that illustrates the relative resist thickness ($t/t_0$) as a function of the exposure dose, for a negative resist. Indicate if the scales are linear or logarithmic and explain what is seen.
b) Explain the four terms in equation $L = k \lambda / NA$
c) Explain what is needed technically to:
- Reduce k
- Reduce $\lambda$
- Increase NA

(In all three cases, you can describe how these variables were improved in the past years.)
d) Describe the proximity effect, what is the cause, and what is the result. How can the proximity effect be suppressed?
e) Name and explain two advantages of a laser light source (for the purpose of lithography) as compared to the high pressure arc lamp.

**Question 2: CMOS & MEMS (20 points max)**

a) What is Moore's Law? (phrase as literally as you can).
b) Draw a cross section of CMOS, including an NMOS and a PMOS transistor, and the N-well and P-well contacts. Clearly indicate what is what.
c) Old CMOS technologies were made with very high temperatures, often up to 1200 °C. Deep-submicron technologies require lower maximum temperatures and so-called "rapid thermal processing". Why?
d) Explain what is meant by surface micromachining and bulk micromachining.
e) Explain (with sketches and text) how the MST structure below can be made by microtechnology.



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**Question 3: Film Deposition and Etching (20 points max)**

a) Briefly characterize and compare the following 6 types of CVD: APCVD, LPCVD, PECVD, LECVD, ALD, and PEALD.
b) Give a definition and purpose of epitaxy. Explain the meaning of selective epitaxial growth as well as matched and mismatched growth.
c) Describe the lift-off process in detail for the formation of gold dots on silicon.
d) Wet etching versus Dry etching: a comparison (name and explain main advantages and disadvantages of both techniques).
e) Explain, using $SiO_2$/Si layer system as an example, what are the means to influence the selectivity to $SiO_2$ over Si or selectivity to Si over $SiO_2$ in case of dry plasma etching.

Fusing oxygen hydrogen

**Question 4. True or False? Motivate your answer (10 points max).**

a) Contact lithography has a better resolution than proximity lithography.
b) A mask is made using optical lithography. e-beam
c) Dry etching is cleaner than wet etching, but it is done at very high temperature.
d) A plasma is used to increase the reactivity of the gas.
e) A light-emitting diode is made without lithography.
f) III-V semiconductors cannot be grown epitaxially on silicon wafers.
g) Electroplating is only possible on a conducting material.

**Question 5. Lab-on-a-chip devices (20 points max)**

a) What is the definition of a LOC device? Mention 3 advantages brought by LOC devices for environmental or medical analysis.
b) Materials. While conventional materials such as silicon and glass have originally only been used to fabricate LOC devices, polymer materials are now predominant for some classes of applications. One example of polymer is PDMS or polydimethylsiloxane.

- What is the fabrication process employed to produce PDMS microfluidic devices? How does the fabrication proceed?
- What are the advantages of PDMS that account for its popularity?
- What are the drawbacks and limitations of this material with respect to other polymer materials?
- Which polymers are also popular, especially for cell studies? How are they processed to fabricate LOC devices? PS

For the fabrication process, please illustrate your answer with a drawing.

**Question 6. Microreactors (10 points max)**

a) Give at least three fundamental reasons why chemical production benefits from a microfluidic format. Also specify what elements/components (concepts) should be minimized in order to achieve these benefits. laminar flow, no mixing (high diffusion)
b) What is the main reason for the use of micromachined elements in liquid chromatography? Also indicate which micromachining / microtechnological processes are essential to achieve the optimal chromatographic performance for liquid chromatography on a chip, and make a schematic drawing of how you would design the fabrication process for a liquid chromatography chip.