## ELEC-E3230 Nanotechnology (5 cr), Exam 09.05.2022, 16:30-19:30

*The exam consists of questions on 2 pages, with 80 points in total for the questions. Answer briefly enough by considering the exam duration.*

*Please answer in either English or Finnish.* Please contact harri.lipsanen@aalto.fi if you have any problems or questions.

*Answer in by attaching answers as a .pdf or .docx or as photos or scanned versions of hand-written notes and figures. If possible, compile your answers to a single pdf or doc/docx document that you submit into the MyCourses box.*

1. a) The output of a mercury lamp used for photolithography has a spectral line at 365 nm. To decrease feature size using photolithographic techniques, the "obvious" strategy is to use a light source with a shorter wavelength. Why? What challenges make the transition into the deep UV difficult in universities? (4 p)

   b) Extreme ultraviolet lithography is an ultimate photon-based technology. Explain the technical problems associated with it. (4 p)

2. a) Compare graphene to carbon nanotubes as a possible material for integrated circuits in terms of fabrication and material properties. (4 p)

   b) Block co-polymers can be used to create very dense features across an entire wafer that would take days to define using an EBL system. However, block co-polymers are not much used in nanolithography, explain why (4 p)

3. a) In nanostructures, the increased surface-to-volume ratio is often cited as an important property. What effects can the increased surface-to-volume ratio have for the physical, chemical, mechanical, or biological response of the nanostructures? (4 p)

   b) Quantum dots are used in some new TVs to give bright colors. Explain how quantum dots can emit different colors (4 p)

4. a) Give three examples of biomimetic optical nanostructures and explain briefly how they work. (4 p)

   b) Describe nanoimprint lithography simply in your own words. (4 p).

5. a) What makes FinFET structure so successful in following Moore's law in microelectronics industry? (4 p)

   b) What are the main differences between metamaterials and photonic crystals (4 p)

6. a) Explain giant magnetoresonance and its use in hard disk readout. (4 p)

   b) How would you quite simply measure conductivity of a single thiol molecule (or few molecules) in a typical university research laboratory? (4 p)

7. a) Explain by your own words and simply how a quantum computer works. (4 p)

   b) Making a quantum computer having tens to hundreds of qubits is extremely challenging. List problems that cause this. (4 p)

8. a) Explain why GaAs nanowires are potential nanostructures for solar cells. (4 p)

   b) What is the reason for different colors in some natural opal crystals? (4 p)

9. a) When is optical microscopy better than scanning electron microscopy? Can both methods sometimes give equivalent information? Give examples. (4 p)

   b) There are two transparent bottles of fullerenes, which contain either $C_{60}$ or $C_{70}$ in a solution. How can you tell quickly just by eye which one contains $C_{60}$? (4 p)

10. a) Compare atomic force microscopy to scanning tunneling microscopy in practical measurements. (4 p)

    b) Explain briefly the process for atomic layer deposition (ALD) of aluminum oxide. Why ALD is an attractive deposition method for very thin layers? (4 p)