Exam Nanomaterials Research

Master Nanotechnology

Module/course code: 201900042
Date: 18-9-2019
Time: 13:45 – 16:45 *(+25% for students who may use extra time)*
Course-coordinators: Wesley van den Beld and Roald Tiggelaar

Type of test:

- Closed book

Allowed aids during the test:

- (Scientific) calculator

Not allowed during the test:

- Mobile phones
- Laptops
- Notes or other study material

Read all exam questions before starting, to avoid time problems at the end.

Write your answers on the separate exam paper. Please pay attention to clear writing, the answers should be readable without significant efforts.

You are expected to give a detailed and motivated answer. Only a complete answer will qualify for the maximum score. This maximum achievable score is based on the associated learning goals.

Good luck!

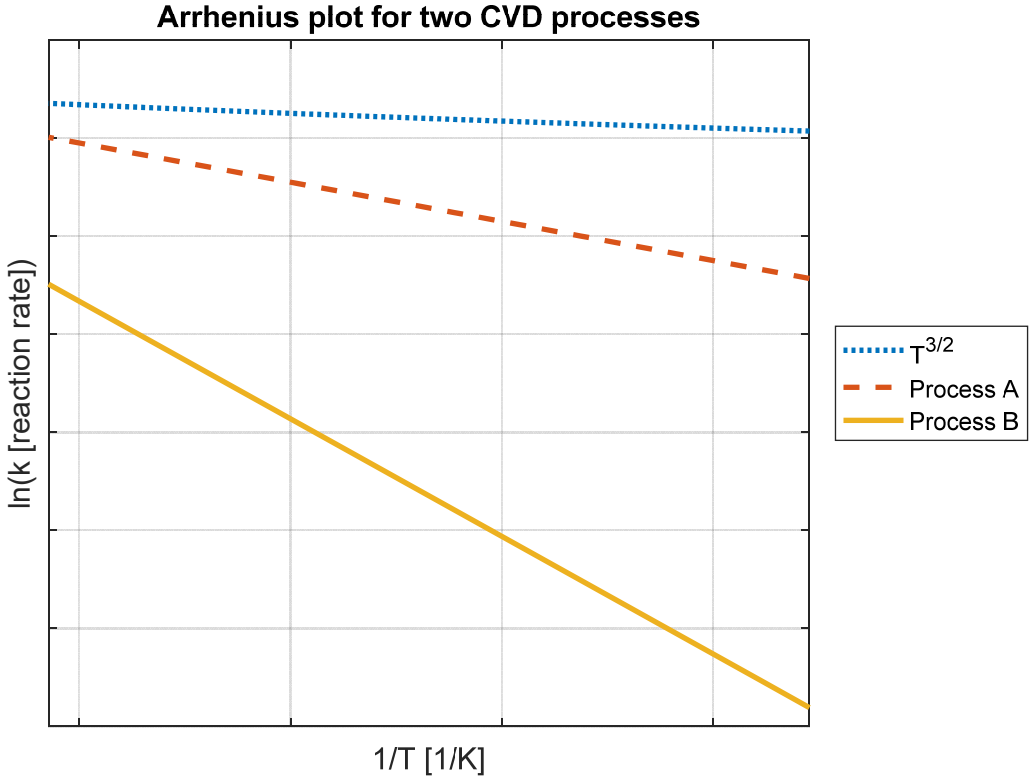
Question 1

TCOater system which allows sputter deposition of various materials

For fabrication of a waveguide device in integrated optics research, high quality layers are deposited by sputter deposition in the TCOater system. In order to have desired waveguide mode propagation, the thickness of the deposited film is crucial. To characterize the thicknesses of deposited films usually spectroscopy ellipsometry and X-ray reflectometry are used, which are both non-destructive analysis methods that rely on reflection to analyse a thin layer of nanomaterial.

a) As waveguide core, TiO_2 is deposed using reactive sputtering with oxygen. Which method is most suited for determining the thickness of this TiO_2 film and why? *(1 point)*
b) For a metal contact layer Ru will be deposited. Which method is most suited for determining the thickness of this Ru film and why? *(1 point)*
c) Why is a cleanroom required for the fabrication of nanomaterial-based devices? *(1 point)*

Question 2



Two Chemical Vapour Deposition (CVD) processes, process A and process B, are compared by varying the deposition temperature, while all other deposition parameters are kept constant. The results are displayed in the Arrhenius plot above. Use this plot to answer the following questions.

a) Why is it convenient to plot a $T^{3/2}$ line in the Arrhenius plot? Explain your answer. *(2 points)*
b) In which CVD regime does process A operate? And what about process B? *(1 point)*
c) Which process has the highest activation energy? *(1 point)*
d) Which process has the highest deposition rate within the plotted temperature range? *(1 point)*

Question 3

Furnace system for the growth of a CVD layer at high temperature

Generally, for thermal CVD processes high temperatures in combination with controlled gas conditions are required. To achieve this, dedicated furnace systems are available in the Nanolab cleanroom. For a certain CVD process for the enthalpy and the entropy energy terms hold: $\Delta H = 75\ \mathrm{kJ/mol}$ and $\Delta S = 75\ \mathrm{J/(mol\ K)}$.

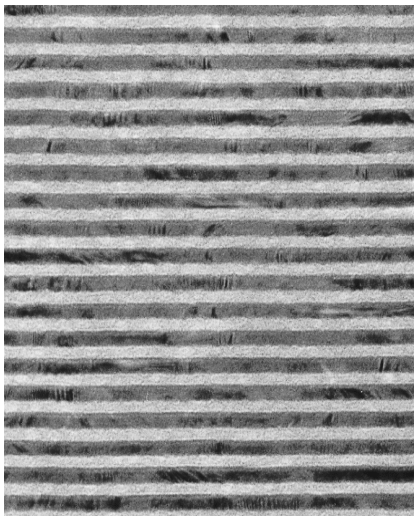
a) What is the Gibbs free energy as function of temperature? Please make a sketch. *(1 point)*
b) For which temperature range a workable deposition rate can be obtained? *(1 point)*
c) Which type of CVD could enable deposition at lower temperatures? Explain your answer. *(2 points)*

Question 4

For power transistors a material for contact electrodes is being studied. The aim of the research is to have low resistivity wiring for carrying large currents towards the power transistors.

a) What requirements of the nanomaterial can you mention for this research application? Name at least 2. *(2 points)*
b) Suppose we want to sputter deposit this film for high-throughput industrial application. Which sputter parameters would you change/optimize in order to achieve a high deposition rate? *(2 points)*

Question 5



Mo/Si multilayer mirrors for EUV

For extreme ultraviolet (EUV) lithography applications multilayer mirrors are used for projecting the mask image to the photoresist on the wafer. For these mirrors generally a stack of silicon and a metal is used. To obtain a high reflectivity, sharp interfaces are required between these two materials.

What deposition method would you choose to deposited this multilayer of nanomaterial? And what would be the advantages and disadvantages of this deposition method? *(2 points)*

Question 6

Multilayers (ML) composed of Cu and Ni are interesting because of the gigantic magneto-resistance (GMR) effect, a characteristic for thin-layered ferromagnetic/non-magnetic material systems. Suppose you have deposited a Cu/Ni ML on a Si substrate of 3 x 3 cm^2 by DC magnetron sputtering. During deposition of each layer, your sample is located right below the corresponding 10 cm diameter target. The following settings are used: target-substrate distance of 7 cm, power of 50 W (350 V), krypton as sputter gas, low deposition pressure (ca. 10^{-4} mbar) and no substrate rotation.

a) The deposited Cu/Ni multilayer shows high roughness at the interfaces. What extra technique(s) can be introduced or parameters can be changed during magnetron sputtering deposition to reduce the interfacial roughness? Name at least 2. *(2 points)*

b) Suppose you want to apply magnetron sputtering to deposit a new sample with layers of lower density. Which of the five mentioned settings would you change and how? Justify your answer. *(1 point)*

c) Now you will deposit the same multilayer using e-beam method. Describe how and why you would expect the following properties to change or not: density, purity, roughness and layers intermixing. *(1 point)*