Exam for Surfaces and Interfaces **Spring 2012, term IIa**

02. 04. 2012

Write your name and student number on each sheet and number the sheets.
Use for each question a different sheet.

Name: _____

Student number: _____

Question	1	2	3	4	5	6	7	8	9	10	11	Σ
Points												

1. Vacuum (6 points)

a) What is the impingement rate for nitrogen molecules on the inner surface of a vacuum vessel having a pressure of $5*10^{-6}$ mbar and a temperature of 25°C? What is the impingement rate for the same system at $5*10^{-9}$ mbar?

b) A reactive sample is to be stored in a UHV chamber for 8h. In this amount of time, a maximum coverage of 0.1 ML of gas is allowed to be adsorbed on the sample surface. Which maximum pressure in the chamber is acceptable in order to fulfill this request? A sticking coefficient of 1 and a partial pressure of 100% for the reactive gas are assumed. Assume that the gas is water and 1 monolayer is equivalent to 10^{15} /cm^2. Avogadro's constant: $6.022*10^{23}$ /mol.

c) For a simple vacuum system, calculate the pumping speed at the chamber if the pump has a speed of 200 L/s, the pressure at the vacuum pump is $5*10^{-6}$ mbar and the conductance element is a tube with a diameter of 40 mm and a length of 80 cm.

d) 1 ML of N_2 (assume that 1 ML is equal to 10^{15}/cm^2) is adsorbed at the inner walls of a cooled cube having an edge length of 10 cm. Through annealing the cube at 300 K, all the adsorbed N_2 gas is desorbed from the walls. How much does the pressure increase inside the cube?
The Boltzmann constant is $k = 1.38*10^{-23}$ J/K.

2. AES (3 points)

a) Explain why in AES the work function of a specimen analyzed does not have any influence on the kinetic energy of the detected peaks. (from Gilmore)

b) Can you imagine using an X-ray source to excite Auger electrons? (from Vickerman)

c) Is there any chemical information available in Auger spectra? (from Vickerman)

3. XPS (2 points)

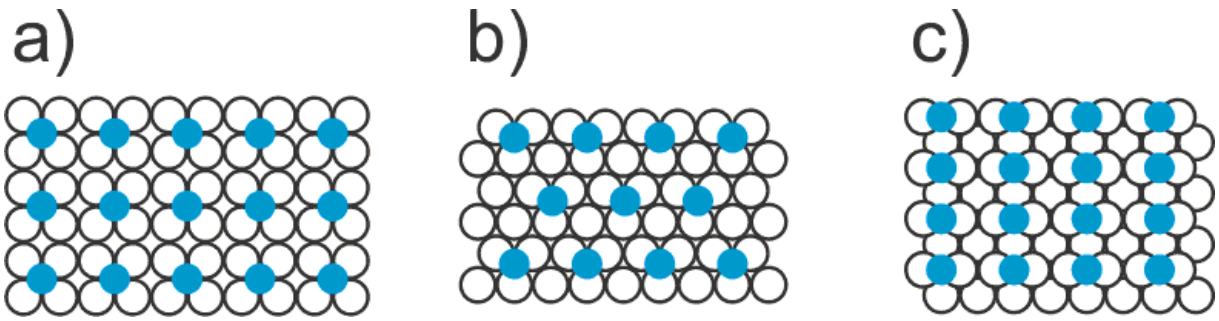
The Si 2p3/2 binding energy is 99.0 eV in elemental Si. When Si is oxidized to SiO_2, a chemical shift of 4.0 eV is observed.

a) What is the sign of the chemical shift and why?

b) If you were able to measure the binding energy of the Si 1s level, would you expect the chemical shift to be the same, larger or smaller than 4.0 eV? Why?

4. Surface structure and LEED (6 points)

Classify the structures shown below in both Wood's notation and matrix notation. Additionally, determine the associated LEED patterns.



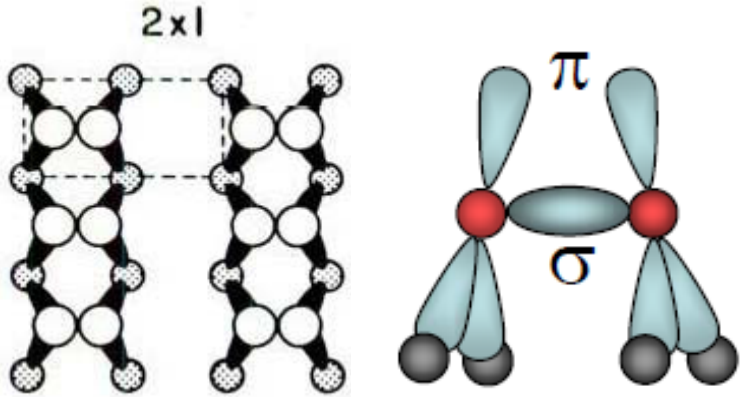
5. Work function (1 point)

The work function of Pt(111) is 5.93 eV. A Ru film has a work function of 4.71 eV. If Ru islands are deposited on a Pt(111) surface, in which direction does electron transfer occur and why?

6. Activation energy (2 points)
A diatomic gas is chemisorbed dissociatively on a metal surface via a physisorbed precursor state. The activation energies for desorption from the chemisorbed and precursor physisorbed states are 1.3 eV and 0.2 eV, respectively. The barrier between the chemisorbed and physisorbed states is 0.1 eV. Estimate the equilibrium coverage in both adsorption states if p = 10^{-5} mbar and T = 400 K. Assume that all rate constants are 10^{13} Hz and $n_0 = 10^{15}$ cm^{-2}.

7. Diffusion (2 points)
After deposition of equal amounts of aluminum at the same deposition rate onto a Si surface, the number density of Al islands was found to be 10^{10} cm^{-2} at 350°C and 10^{12} cm^{-2} at 80°C. Estimate the activation energy for the surface diffusion of Al adatoms.

8. STM (2 points)
The dimer unit on a Si(100) surface (see images below) has a bonding orbital just below E_F and an antibonding orbital just above E_F. Make a prediction about STM images that are taken at positive compared with negative voltages. Do the images look the same and, if not, how do they differ?



9. AFM (3 points)
A cantilever with a force constant of 0.1 Nm^{-1} is scanned across a surface in constant height mode. What will be the change in force as it passes over a bump of height 100 nm?

a) For a silicon nitride AFM probe of radius 50 nm, calculate the contact area at zero load, the pull-off force and the contact area at separation of the tip from the surface, assuming that JKR mechanics are obeyed and that the interfacial free energy (γ) is 40 mN/m. The elastic modulus of silicon nitride is 64 GPa.

10. Methods for structure determination (3 points)
Outline two methods for the determination of the structure of surfaces, identifying the key physical principles on which the structural sensitivity is based. In particular, describe one method relying on long-range order, and one requiring short-range order only, and highlight the complementary aspects of these methods and their information content.

11. ARPES and STS (4 points)
Compare ARPES and STS to each other.

a) Describe shortly how both techniques work.
b) Which information can be accessed by ARPES but cannot be accessed by STS?
c) Which information can be accessed by STS but cannot be accessed by ARPES?