PHY386K Homework Assignment, Sitz section, April 5, 2005)

(1) A security sensor is designed to detect intruders. It consists of parallel plates of metal installed below the floor and above ceiling in a hallway. Estimate the capacitance of such a device, and the change in capacitance induced by the presence of a person. Give a little thought to the dimensions: you want the biggest fractional change in the capacitance, but you want to make sure that an intruder can not go around your sensor. You might also comment on what type of circuit you should use to detect the change in capacitance caused by an intruder.

(2) For a circular membrane, clamped around the rim, the displacement (from flatness) as a function of radial position (r) and pressure (P) is given by:

$$w(r) = \frac{Pa^4}{6D}\left[1 - \left(\frac{r}{a}\right)^2\right]$$

with

$$D = \frac{Eh^3}{12(1-\nu^2)}$$

where the variables are: a the plate radius, h the plate thickness, E is Young's modulus, and ν is Poisson's ratio. Consider a silicon plate with $a = 0.5$ mm and $h = 0.05$ mm. Assume that a piezoelectric resistor is implanted in the silicon radially from the center all the way to the edge. Using this resistor, you can detect a pressure sufficient to produce a strain of 10^{-6}. (The strain is the fraction change in length $\Delta r/r$.) What is the minimum differential pressure that this device can measure?

(3) The figure shows the Auger spectrum of an unknown surface. Use the table of Auger electron energies given in the handout to identify the elements in the sample. What is the material? Hint: this is a commonly used material and is made up of more than one type of atom.

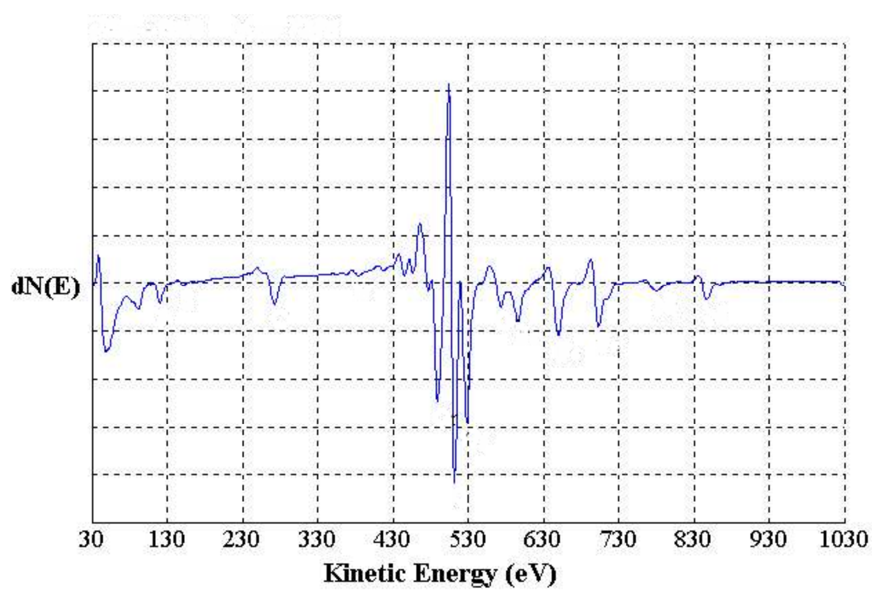


Table 1: Cracking patterns of two gases.

m/q	Compound 1	Compound 2
12	0.9	4.2
13	3.6	1.7
13.5		0.9
14		1.6
24	6.1	
25	23	
26	100	17
27	2.2	100
28		1.6

(4) The table above shows the cracking pattern of two gases measured with a common quadrupole mass spectrometer. Deduce what the two gases are and identify what ion each entry in the table represents. Note: masses lower than 12 are not shown but this does not mean there aren't any. A useful table of isotopic abundances can be found at:

`http://www.sisweb.com/referenc/source/exactmaa.htm`

(5) You need to determine the optimal operating temperature for Pt/SnO_2 based carbon monoxide sensor. Exposure to CO starts to show symptoms at roughly 100 ppm and is lethal at about 3 times this concentration. Design your sensor to trip at 1 ppm to be conservative and assume you can detect a fraction CO coverage of $\theta = 0.25$.

Set the adsorption rate as equal to the impingement rate times the sticking probability, and assume the sticking probability as a function of coverage follows first order Langmurian kinetics:

$$S(\theta) = S_0(1 - \theta)$$

where θ is the fractional coverage and S_0 is the sticking coefficient at zero coverage. Take S_0 to be 0.1.

Equate the adsorption to the first order desorption rate:

$$R = k\sigma[\mathrm{CO}]\mathrm{molecules/cm^2s}$$

where σ[CO] is the surface coverage (in molecules/cm^2) and the desorption rate constant k is given by:

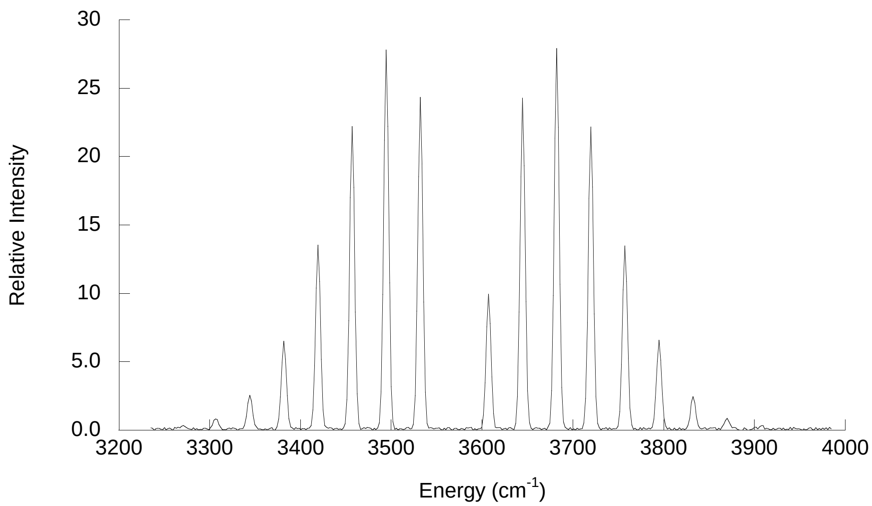
$$k = \nu \exp\left(-E_d/k_B T\right)$$

to find the steady state coverage of CO. Take the binding energy of CO as $E_d = 1.0$ eV/molecule, the pre-exponential to be $\nu_A = 5\mathrm{x}10^{13}$ s^{-1} and assume that the maximum coverage ($\sigma_{\mathrm{saturation}}$) is 2x10^{15} cm^{-2}.

What is the highest temperature your sensor can operate at? What is the recovery time, defined say, as the time it takes for the CO coverage to drop below 1/e of the trip level if the CO concentration is abruptly reduced to zero?

(6) The figure shows the (simulated) absorption spectrum of a diatomic molecule in the gas phase. The data (absorption versus wavenumber) used to generate this plot can be downloaded at: `http://www.ph.utexas.edu/~gositz/Spectrum05.zip`). Assume that the intensity of each spectral feature is proportional to the population of the initial state involved in the transition. Analyze this data and determine: (a) the rotational and vibrational constants for the molecule; (b) the temperature of the gas; (c) the chemical identity of the molecule.

Comments: You need to make an *accurate* determination of the rotational constant to convincingly ID the molecule. To do this, you need to think about how to best determine the position of each line and how to use *all* the line positions to determine the rotational constant. You should also use the intensity of all the lines in your determination of the temperature.



(7) Find a recent publication that is related to kind of sensor technology covered in this quarter of the course: surface or thin film, mass spectroscopy or optical. Good journals to look in are: "Sensors and Actuators," "Journal of Applied Physics," or "Applied Physics Letters. "Science" and "Nature" also occasionally have sensor related article (mostly related to biochemistry). These journals are all available online through the UT library. Submit a copy of the abstract to the article and a critical commentary (imagine that you were refereeing the paper, that is, advising the journal editor whether or not to publish it) addressing issues such as: (1) comparison to previous efforts, (2) potential for practical application (3) overall quality and interest.

Due: 6 pm on Tuesday, April 19, 2005