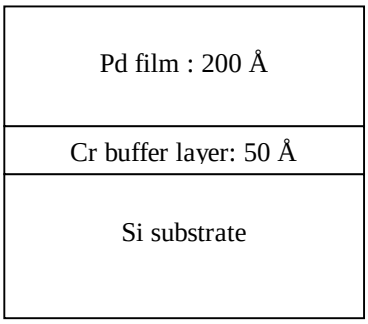
Problems set : Reflectivity

Detlef Smilgies (dms79@cornell.edu) due date: March 29

A 200 Å palladium film was deposited on a silicon wafer including a 50 Å buffer layer of chromium, as determined by a quartz monitor with an accuracy of about 10%. X-ray reflectivity was used to determine the exact layer thickness using a photon energy of 10.45 keV at CHESS F3 station.



a) Calculate the reflectivity of this two-layer system using the matrix method. Hint: use software that can handle complex numbers, for instance FORTRAN, MathCAD, Mathematica, Maple, Matlab… Submit your code as part of the solution. Optical constants for the materials can be found at the CXRO database. Compare your calculated curve to the Fresnel reflectivities of Pd, Cr, and Si. The solution should fall off like the Pd reflectivity. Use a logarithmic scale to see all detail. Plot your curve versus the scattering vector $q_z=2k_z$ - this is the representations of reflectivity curves found usually in literature.
b) The data set contains three columns, the first is q_z in $Å^{-1}$, the second the reflectivity R, and the third the raw signal on the detector. The x-ray beam used for the measurements was too wide below the critical angle, hence only part of the beam was reflected and the measured reflectivity appears too low, so ignore this part of the data. I only roughly normalized the curve, so you are allowed to multiply the curve with a scale factor to make it fit better, if you wish.
c) The calculated curves will fall off somewhat slower than the experimental data, since interface roughness was not included in the theory. A crude roughness model is to multiply R by $\exp(-\sigma^2 q_z^2)$ where σ is an overall root-mean-square roughness. What size of σ do you get ?
d) Compare your calculated reflectivity curve to the data set. Do the layer thicknesses have to be refined? Hint: redo your calculation with thicknesses off by +/-10% for the Pd and the Cr layers and analyze, how the oscillations are influenced. What looks best?