

Exercise 3.6-1

All Class Exercises and Quick Questions to

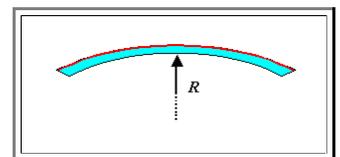
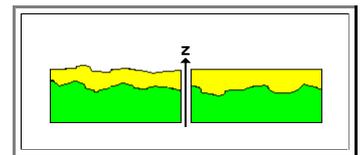
3. Thin Films

Subchapter 3.1: Thin Films - General

- Interference causes the color of a thin film and betrays its thickness? *Explain!*
- Give examples of what "thin" could mean in relation to *intrinsic* length scales. Provide (and discuss briefly) some intrinsic lengths, in particular with respect to semiconductors
- Give a few numbers for the meaning of "thin":
 - Thickness of a human hair $\approx \approx$ **????**
 - Thickness of a gate oxide in an integrated transistor $\approx \approx$ **????**
 - Thickness of antireflection layers of optical lenses $\approx \approx$ **????**
 - Thickness of a thin film solar cell $\approx \approx$ **????**
 - Other examples you can come up with **???**
- Give some examples of thin film applications outside of semiconductor technology.
- Give the equation for the capacity **C** of a parallel plate capacitor with plate area **A** for a maximum voltage of **10 V**. How can you achieve maximum capacity and what are the limits? Hint: Consider field strength and relevant intrinsic length scales.

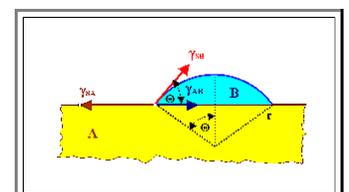
Subchapter 3.2: Mechanical Properties

- How would you define the roughness of the two thin films shown? Give an equation if possible and differentiate between the two cases.
- Give examples for a thin layer of material **B** on substrate **A** for which you would expect good or bad adhesion, respectively: Give reasons for your expectation.
- The "surface" energy of glass is around $\gamma(\text{Glas})$ **300 mJ/m²**, for a metal we might have $\gamma(\text{Metal}) \approx$ **2100 mJ/m²**. You deposit a noble metal. On which substrate would you expect better adhesion?
- Give an example of how one could measure the adhesion strength of a thin film.
- The red thin layer (thickness d_B) on the blue circular **Si** wafer substrate (thickness $d_A \gg d_B$) is under compressive stress σ ; the wafer thus is warped with a radius of curvature = **R**. What would **R** be proportional to?
Hint: It is a two-dimensional problem.



Subchapter 3.3: Nucleation and Growth

- What happens when the first incoming atom hits the surface of the substrate? Give at least 4 different possibilities.
- Where would you expect the first incoming atoms to be solidly bound? Use the proper terminology.
- Define "sticking coefficient". Discuss the dependence of the sticking coefficient for a given system on the precise substrate condition for a given substrate.
- Explain briefly the major methods for investigations of the nucleation of thin films on substrates.
- Explain how you get from interface energies to forces, and from forces to the wetting angle Θ
- Discuss and name the two major growth modes following from extreme values of Θ
- Discuss and name a third major growth mode



Subchapter 3.4: Structure, Interface and Some Properties

- What is epitaxial growth? Consider the possibility of epitaxial growth; giving possible conditions (e.g. with respect to structures, lattice constants, ...) and use simple pictures:
 - A on A.
 - A (fcc) on B (fcc).
 - A (fcc) on C (hex).
 - A (fcc) on B (fcc) with intermediate layer.
 -
- B (fcc; (100)) with lattice constant a_B is deposited on A (fcc; (100)) with $a_B = 0.95 a_A$. Sketch the structure for
 - Thickness of B only a few atomic layers.
 - Thickness of B > 50 nm
- *Difficult!* Sketch a pure edge misfit dislocation network on a {100} interface plane for a misfit of 10 % for the case of
 - Burgers vector of the dislocations is $\underline{b} = a\langle 100 \rangle$.
 - Burgers vector of the dislocations is $\underline{b} = a/2\langle 110 \rangle$.
- *Difficult!* What would happen if the (square) network of misfit dislocations on a {100} type interface would be changed from edge dislocations to screw dislocations?
- What are the energetic reasons for introducing misfit dislocations into epitaxial interface if the layer thickness is larger than a critical thickness? What determines the critical thickness?
- Sketch the curve for the critical thickness d_{crit} in a d_{crit} - misfit diagram, Try to give approximate numbers.
- Enumerate and discuss *structures* obtainable with thin films but not (easily) with bulk materials. Give examples for applications.
- Give reasons why thin film properties can be quite different from bulk properties; give examples.
- Name some technologically extremely important special thin film properties; discuss with actual numbers.