Homework No. 4

Fundamentals of AFM: Part I

Lectures: P1_Wk4_L1 - P1_Wk4_L6

Problem 1: Specifying the dimensions of a microcantilever

Suppose you want to design a microcantilever from Si that deflects 1 nm when 1nN of force is applied at the end.

Q1.1. Most (if not all) Si cantilevers are made from <100> oriented Si wafers. What is a reasonable estimate for the appropriate Young's modulus for cantilevers made from a <100> oriented Si wafer?

a) about 0.13 GPa
b) about 1.3 GPa
c) about 13 GPa
d) about 130 GPa

Q1.2. Suppose you already have a reliable fabrication process to produce cantilevers that are 30 □m wide. What should be the ratio of the thickness to the length of the microcantilever to achieve the desired performance?

a) 0.01
b) 3.14
c) 0.12
d) 0.0092

Q1.3. If the minimum thickness of the cantilever you can reliably fabricate is 2 □m, what should be the length of cantilever to meet the desired specification?

a) 300 □m
b) 0.32 □m
c) 200 □m
d) 22 □m

Q1.4. Due to fabrication issues, if the uncertainty in the thickness of the cantilever is ±10%, what is the corresponding uncertainty in the spring constant?

a) ±40%
b) ±30%
c) ±20%
d) ±10%

Q1.5. What is the resonant frequency (in kHz) of the cantilever?

a) 28.6 kHz
b) 10.2 kHz
c) 61.5 kHz
d) 367 kHz

Problem 2: Measuring the Hamaker constant

Assume a tip with radius 10 nm interacts with a flat substrate only through van der Waals forces. The tip is located at the end of a cantilever with a spring constant of 2 N/m. When the tip-substrate gap is determined to be 0.5 nm, the cantilever deflection is measured to be 0.25 nm.

Q2.1. Estimate what must be the Hamaker constant?

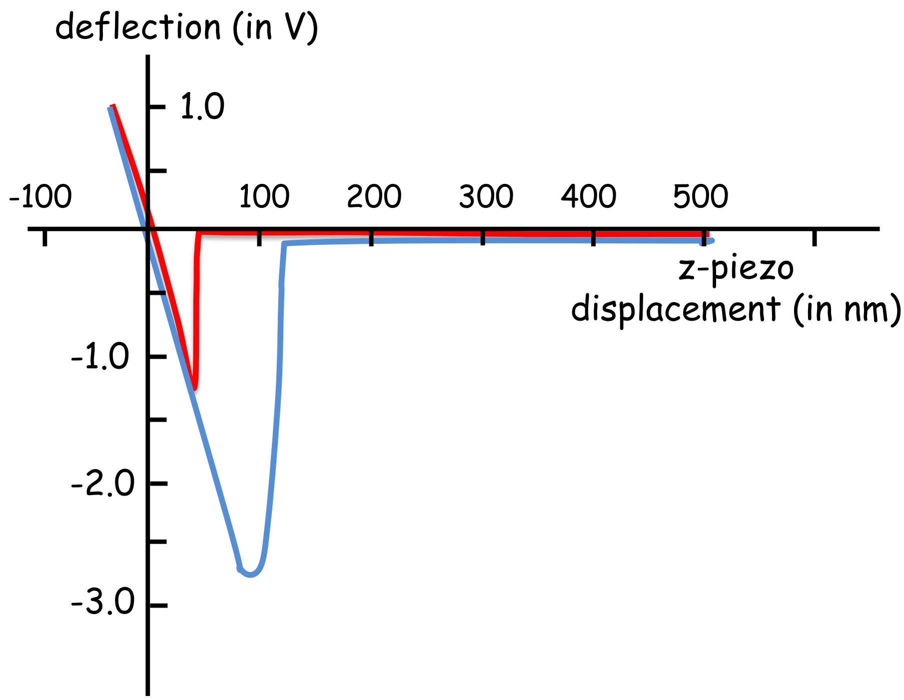
a) 0.5×10^{-19} J
b) 1.0×10^{-20} J
c) 2.0×10^{-19} J
d) 7.5×10^{-20} J

Q2.2. Estimate the minimum cantilever spring constant k to avoid jump to contact? Assume a_o = 0.3 nm.

a) 1.0 N/m
b) 2.0 N/m
c) 9.3 N/m
d) 15.3 N/m

Problem 3. Force vs. distance experiment

Below is a plot of typical data from an AFM deflection vs. displacement experiment. Use this plot to answer the questions that follow below.



Q3.1. From an examination of this data, which curve represents the <u>approach</u> of the tip to the substrate?

a) Blue
b) Red

Q3.2. From an examination of this data, is there any compelling evidence for long range van der Waals forces acting between the tip and substrate?

a) Yes
b) No

Q3.3. The zero for the z-piezo displacement is determined by

a) the location determined by the jump to contact
b) the location determined by the pull-off
c) the location when the cantilever returns to its original, undeflected position after contact with the sample
d) the location at which the set point force is reached

Q3.4. Suppose this data were taken by indenting a hard tip into a hard substrate. From an examination of this data, estimate roughly the optical sensitivity of the position sensitive detector?

a) 2 nm/V
b) 5 nm/V
c) 20 nm/V
d) 50 nm/V

Q3.5. If a cantilever with a spring constant of 0.75 N/m was used when this data was acquired, estimate the set point force.

a) 5 nN
b) 18 nN
c) 37 nN
d) 125 nN

Q3.6. From an examination of this data, can you estimate the pull-off force?

a) 50 nN
b) 100 nN
c) 150 nN
d) Can't make a judgment from the data provided