Lab work N2: Atomic Force Microscope in Contact Mode

This practical is focused on the atomic force microscope (AFM) in contact mode. It is divided into two parts: the first concerning the AFM as a topography measurement tool and the second presenting an application of the AFM for nano-fabrication.

The objectives of this practical are: to understand how an AFM works in contact mode, to learn how to use it in order to obtain correct images, to analyze the images obtained and to use it as a nano-fabrication tool.

I. Introduction

The AFM belongs to the family of Scanning Probe Microscopy (SPM) where a sharp probe is scanned across a surface and some probe – sample interaction or interactions are monitored. In the AFM, the interactions monitored are the atomic forces that appear between the surface atoms and the atoms of the tip (probe). The AFM can operate in contact mode or in intermittent mode. During this practical only the contact mode is used.

II. Functioning principle of an AFM in contact mode

An AFM in contact mode operates by scanning a tip* attached to the end of a cantilever across the sample surface while monitoring the change in the cantilever deflection with a split photodiode detector (as shown in Figure 1). A feedback loop ensures a constant distance between the tip and the sample by vertically moving the scanner (tip) at each (x,y) data point to hold a "**setpoint**" deflection. By maintaining a constant cantilever deflection, the force between the tip and the sample remains constant. The scanner moves vertically at each (x,y) data point and the corresponding distance z is stored by the computer to form the topographic image of the sample surface.

The force range due to the interaction between the tip and the sample can be estimated by using the Hooke's law: $F=-kx$ where F = Force, k = spring constant, x = cantilever deflection. The spring constant usually range from 0.01 to 1.0 N/m, resulting in forces ranging from nN to µN in an ambient atmosphere.

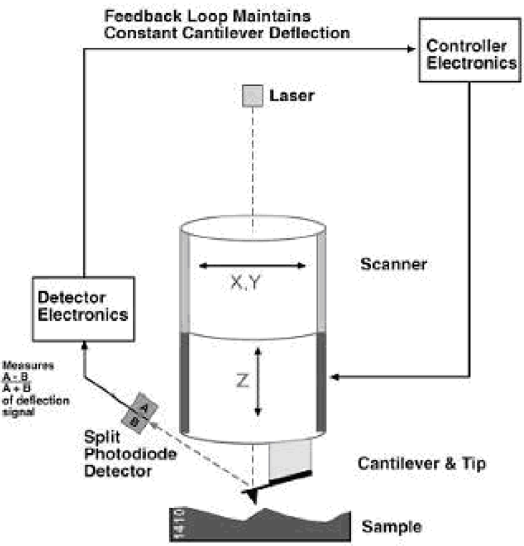

Figure 1: *The principle of AFM functioning.*

* *other AFM instruments use stage scanners (x,y,z) to move the sample, or scan the sample (x,y) and the tip (z)*

III. Experimental work:

III.1 Capturing the images and parameters extraction

☞ Place the sample (**wafer with MOS transistors**) onto the microscope and put the tip into contact with the sample. Optimize the scan parameters in order to obtain a good image of the gate of the MOS transistor. (For this task a teacher **MUST** assist you.)

☞ Perform all the image treatment necessary and extract parameters such as the height and the width of the gate.

☞ Compare the width of the gate on the transistor with that measured on the oxide and with the length which is on the mask. Explain the results.

☞ Zoom on the gate in order to see the roughness of the polycrystalline silicon. Extract the mean dimensions of the grains of monocrystalline silicon.

III.2 Approach retract curves

☞ Withdraw the tip and remove this sample from the microscope. Instead, put the **Si wafer** on the AFM stage. Approach the tip and start imaging this sample. (For this task a teacher **MUST** assist you.) Adapt the scanning parameters in order to obtain a stable image.

☞ Realize a force curve and explain it.

☞ Apply a positive voltage between the tip and the sample while realizing the force curve (for example, 10V). Explain voltage effect on the force curves.

☞ Change the position of the tip and realize a new force curve with -10V bias between the tip and the sample.

☞ Return to the image mode and scan the surface. How can you explain the topography changes?

III.3 Nanofabrication

The AFM can be used for the fabrication of nano-devices. In this part you will see an example of nano-oxydation by the polarized tip of the AFM.

☞ In the image mode, start an image of 3x3μm^2, with 128 lines. Apply -10V bias while the tip is scanning the first line and then skip to line 30. Apply -7V while the tip is scanning this line. Skip to line 60 and scan it with -5V bias voltage between the tip and the sample. Skip to line 120 and scan it with -3V bias voltage on the tip.

☞ Enlarge the scanning area to 4x4μm^2 and scan it at 90°. Comment on the results obtained in this topography image.