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# Atomic Force Microscopy

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## I. INTRODUCTION AND BACKGROUND

Scanning tunneling microscopy (STM) and atomic force microscopy (AFM) are powerful tools for the examination of surfaces. The research, development, and application of the STM and AFM methods are currently making rapid progress [1].

In 1986, Gerd Binnig and Heinrich Rohrer won the Nobel Prize in Physics for the invention of the scanning tunneling microscope (STM) and the fact that it could achieve atomic resolution [2]. Later the AFM was invented and became very promising because it can be used to image a huge variety of samples which do not need to be electrical conductors.

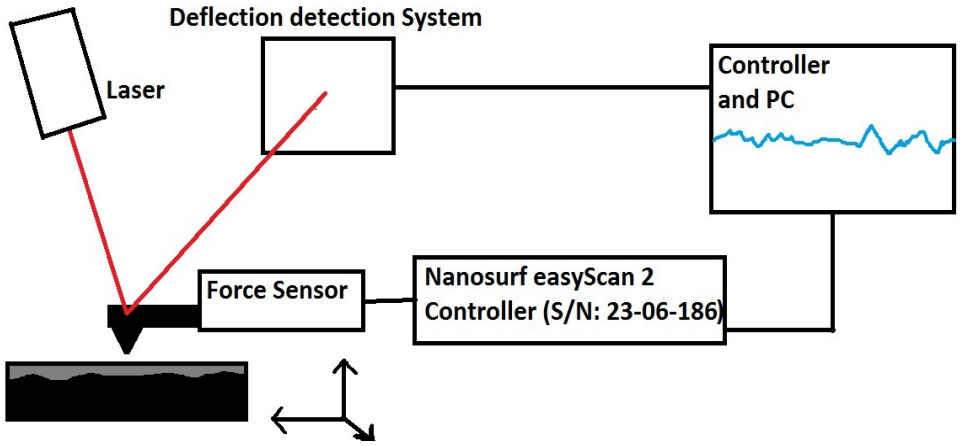
The AFM detects the force interaction between a sample and a very tiny tip mounted on a cantilever. The force interaction between the sample and tip is related to the deflection of the cantilever, so the more the tip presses into the sample the greater the deflection of the cantilever and the greater the force exercised on the sample.

## II. EXPERIMENTAL METHODS

The samples that will be viewed are a chip structure in silicon a.k.a. RAM, a CD stamper gold clusters, and nanotubes. All of these samples are in an extended kit that came with the Nanosurf software.

The AFM uses atomic forces to detect the surface of the sample. The AFM detects the force interaction between a sample and a very tiny tip mounted on a cantilever. Atomic forces attract the tip which causes the cantilever to bend, as illustrated in the setup diagram. The force interaction between the sample and tip is related to the deflection of the cantilever. A feedback system keeps the deflection constant as the tip scans over the sample surface.

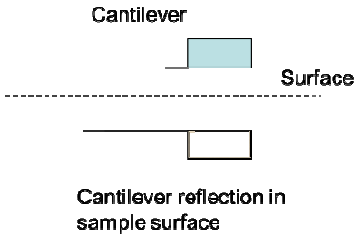
**Setup of AFM experiment:**




Start up the easyScan 2 or a similar program that is used with the AFM. Be sure to load proper parameters otherwise the images produced will not come out clear. Be sure to ground the AFM sample mount if that option is available. Wear gloves when necessary. Also make sure the AFM is level before and during the duration of the experiment.

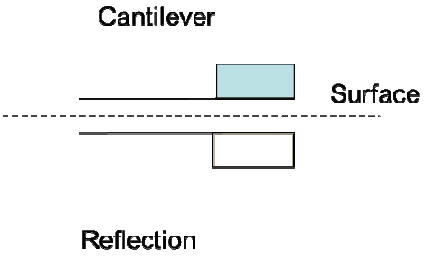
Place the sample on to the sample mount, and carefully slide it under the AFM. Positioning the tip above the sample is the next step. There are two different modes the AFM can operate in: static mode and dynamic mode. Static mode is when the probe tip is always in contact with the sample and the deflection of the cantilever is set by the user. Dynamic mode is when the probe tip is

Figure 1




oscillated and makes intermittent contact with the surface; in some cases, not touching the surface at all. In this particular experiment, dynamic mode was used

2



so as to not break the tip off the cantilever. Next, use the software to prepare the tip to approach the sample. After that, get as close to the sample as you can manually using the side view on the AFM. See figure 1 and figure 2. In figure 1, looking through the side view lens, you can estimate the position of the sample surface. It is half way between the cantilever and its reflection. Advance the tip until the cantilever is close to, but not touching the surface. See figure 2. If the tip touches the surface, the tip might break, and then it must be replaced. This process may vary depending on what AFM and mode is used.

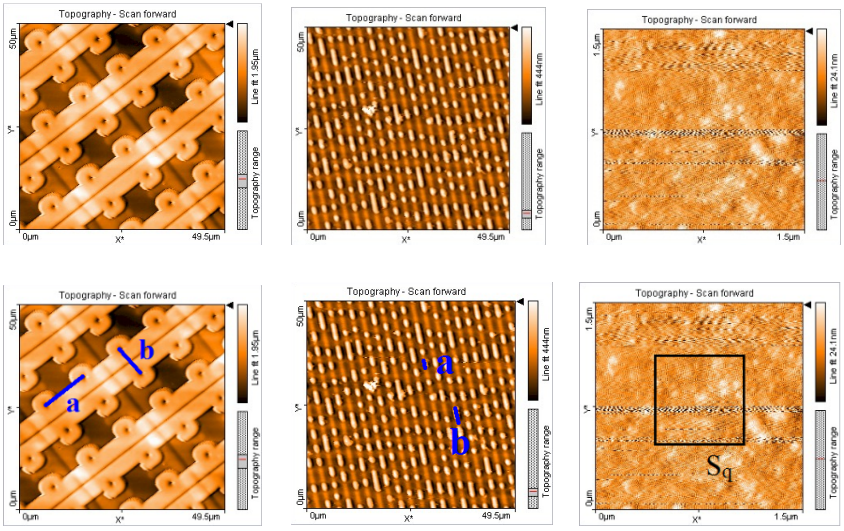
After the tip is in position, click the "approach" button. This will automatically lower the tip closer to the sample at a safe distance to begin the imaging process. Once the image is complete, stop the AFM and click "retract" to raise the tip high enough to remove and view a different sample. Again, this may be different for different software programs that work with an AFM. Save the image as a .nid file, otherwise it will not be saved so measurements can be taken. Repeat the above steps for each sample for the imaging process.

If any problems arise, read the manuals of the AFM and of the easyScan 2 or the software used in this experiment.

## III. RESULTS

The results are as follows:

***RAM*** ***CD*** ***Gold Clusters***




The measurements were made using the built in features of the Nanosurf software.

The RAM had two parts measured: the distance between the "dots" across from it and the distance to the next set of "dots". These are labeled 'a' and 'b' on the previous page.

The CD also had two measurements: the first was the length of a "short bump" and the second was the length of a "long bump". Again, these are labeled 'a' and 'b' on the previous page.

For the gold clusters, the Root-Mean-Square (RMS) roughness, $S_q$, was measured over different areas of the sample image.

There were no nanotubes found on the sample they were supposed to be on. Hence no images of the nanotubes are shown in this report. Table 1 shows the measurements and final values for each sample.

The final values are as follows:

| Sample | Final Experimental Value |
|---|---|
| RAM length a | 12.5±0.2μm |
| RAM length b | 7.1±0.2μm |
| CD length a | 3.5±0.2μm |
| CD length b | 2.5±0.3μm |
| Gold clusters | 5.1±0.8nm |
| Nanotubes | N/A |

Finally these results were compared to the different "companies" on page 36 of the lab manual to determine which company made these samples.

## IV. CONCLUSION

The results strongly support that the samples were "made" by Company #4. The following table shows the experimental results vs. the results presented by Company #4:

| Sample | Final Experimental Value | Company #4 |
|---|---|---|
| RAM length a | 12.5±0.2μm | 10.0±0.3 μm |
| RAM length b | 7.1±0.2μm | 7.2±0.7μm |
| CD length a | 3.5±0.2μm | 3.5±0.3μm |
| CD length b | 2.5±0.3μm | 2.5±0.7μm |
| Gold clusters | 5.1±0.8nm | 5.2±2.3nm |
| Nanotubes | N/A | 25-30nm |

From the table above, the only measurement really in question is the RAM length a. This may be due to the fact that the judgment of where the center of each

"dot" was is different for each person. The measured value was greater than all possible choices listed by the companies, but the closest value of all the companies was Company #4.

If the measured value with its uncertainty overlapped and could potentially be one of the values from the lab manual of one of the "companies", it was declared in agreement with that company, otherwise it was in disagreement. Again, RAM length a, was the only sample in disagreement with Company #4, but every other measured sample was in agreement. The data overall strongly supports that Company #4 was the "creator" of the samples.

## V. APPENDIX.

Table 1 shows the measurements and the uncertainty. The uncertainty of each measurement was calculated by taking the average of the lengths, and then taking the standard deviation of the those same lengths. So the final value reads the average ± standard deviation.

**Table 1:**

| **Measurements of AFM Samples and Standard Deviation with final value as Average±Standard Dev. (Uncertainty Measurements)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **sample 1** | **RAM (micrometers)** | | | | | | **Average** | **Standard Dev.** | | **Final Value** |
| **length a** | 12.6 | 12.75 | 12.56 | 12.37 | 12.33 | | 12.522 | 0.1728 | | 12.5±0.2μm |
| **length b** | 6.989 | 7.182 | 7.416 | 7.008 | 6.782 | | 7.0754 | 0.2374 | | 7.1±0.2μm |
| | | | | | | | | | | |
| **sample 2** | **CD (micrometers)** | | | | | | | | | |
| **length a** | 3.339 | 3.44 | 3.582 | 3.438 | 3.849 | | 3.5296 | 0.1984 | | 3.5±0.2μm |
| **length b** | 2.262 | 2.369 | 2.614 | 2.342 | 3.024 | | 2.5222 | 0.3098 | | 2.5±0.3μm |
| | | | | | | | | | | |
| **sample 3** | **Gold clusters** | | | | | | | | | |
| **Sq** | 4.438 | 5.5377 | 4.7194 | 4.5351 | 6.2068 | | 5.0874 | 0.7612 | | 5.1±0.8nm |

In calculating these uncertainties, page 100 from Taylor was used as a reference for the standard deviations.

## REFERENCES

[1] Magonov, Dr. Sergei N., and Dr. Myung-Hwan Whangbo. "Frontmatter." In *Surface Analysis with STM and AFM*, Wiley-VCH Verlag GmbH, p. I–XII. http://onlinelibrary.wiley.com/doi/10.1002/9783527615117.fmatter/summary?systemMessage=Wiley+Online+Library+will+be+disrupted+24+March+from+10-14+GMT+%2806-10+EDT%29+for+essential+maintenance (Accessed March 21, 2012).

[2] Physics Lab Manual: Experimental Physics II. "Physics 306, spring 2012." p.32-114. Minnesota State University Moorhead Physics Department, 2012.

[3] Taylor, John Robert. *An introduction to error analysis: the study of uncertainties in physical measurements*. University Science Books, 1997. Print.