研究速報

Making Five Atomic Force Microscope for 200,000 yen each

— A student project —

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1. Introduction

At the Graduate School of University of Tokyo, a lecture and technical training course was newly opened from the summer term of year 2003. Its aim was acquisition of the basics of scientific instrumentation, circuitry and programming. Eighteen students supervised by four professors built five atomic force microscopes with a budget of just under 200,000 yen per microscope. The paper describes the details of the microscope, how the course was organized, and what was achieved.

2. Purposes

The atomic force microscope (AFM) can acquire images by scanning the tip and measuring the displacement of the cantilever caused by atomic force between the tip of the cantilever and the sample surface (Fig. 1). The AFM can also be applied to insulators, is an advantage over the scanning tunneling microscope.

This course's purpose was to learn the principles of AFM, analog circuitry, programming by C-language and basis of microcomputer control.

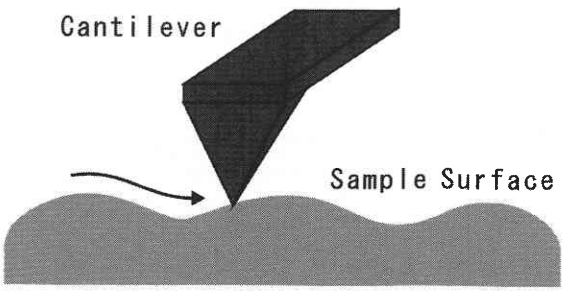

Fig. 1 Schismatic of principle of AFM.

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3. Instrumentation

Operational mode of conventional AFM

Can be classified as follows,

(1) Contact mode[1] -Tips contact surfaces of samples and figures of surfaces are measured by displacement of cantilevers.

(2) Tapping mode[2] -Tips contact surfaces of samples periodically and figures of surfaces are measured by amplitude shift of cantilevers.

(3) Non-contact mode[3] -Tips are vibrated close to surfaces of samples and figures of surfaces are measured by frequency shift of cantilevers.

We applied contact mode as the operation mode of AFM that we made, because contact mode AFM is the basic mode and is easy to implement.

We applied an optical lever method[4] to measure displacement of cantilevers. We show the schematic of an optical lever method in Fig. 2. An optical lever method is the measuring way of cantilever's behaviors by irradiating the back of the cantilever with a laser and detecting the reflection with a photodetector. The spot of reflection moves with the cantilever's displacement caused by sur-

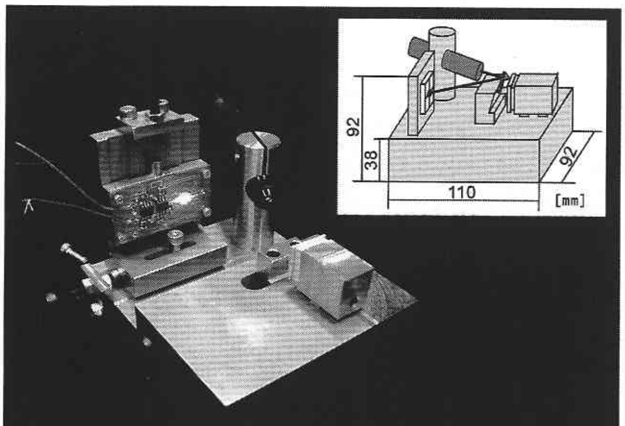

Fig. 2 The AFM head composed in the class.

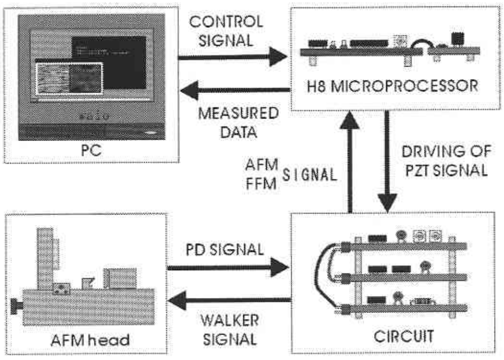

Fig. 3 Schematic of the system.

face topography. Thus the output power of a photodetector changes, and the surface corrugation could be obtained.

In this way, the principle and the composition of the optical lever method is simple and can be low-cost. We applied a four-segment photodiode as a photodetector.

We show the entire composition of the AFM which we made in Fig. 3. The analog circuit processes the signals from AFM head and the H8 microprocessor receives the signals and sends them to PC. The rough and fine positoneres of AFM head are composed of piezoelectric element and are controlled by the H8 microprocessor via the analog circuit.

In this course, the parts which students made are,

(1) Data acquisition and scanning control programs: We made data acquisition programs based on sample programs given by professor. The program for PC saves signals which are sent from H8 microprocessor. And, the program for H8 microprocessor interfaces signal-processing circuit with PC and controls driving of piezoelectric element on AFM head.

(2) Signal processing circuit: This circuit calculates 4-segment photodiode signals to deflection (AFM) and friction (FFM) signals. The circuits adapt the signal voltage for PC. The compositions are I/V converters, adding operators, an integrator, and amplifiers.

(3) AFM head: This is a main component of this AFM unit.

(4) Samples: We made micro-patterns on Si chips by etching Au deposited Si wafers. The mask is SAM (Self assembly monolayer) with a PDMS stamp. Cleaved mica was used for atomic level imaging.

4. Course contents and cost

This class was held 180min a week, a total of 14 times. Fig. 4 shows the course content and its flow. The class was divided into 5 groups which consisted of three to five students. Each group made one AFM. Fig. 5 is the scene of the class.

Total cost was 200,000 yen each AFM including PC, machine parts, electrical circuits, etc. Its approximative breakdown is shown in Table 1.

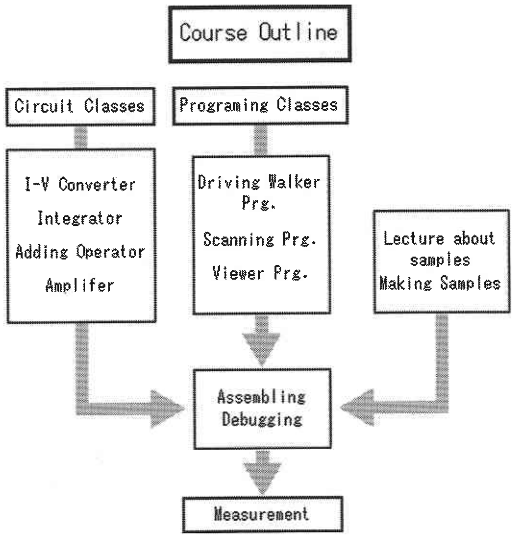

Fig. 4 The outline of the class.

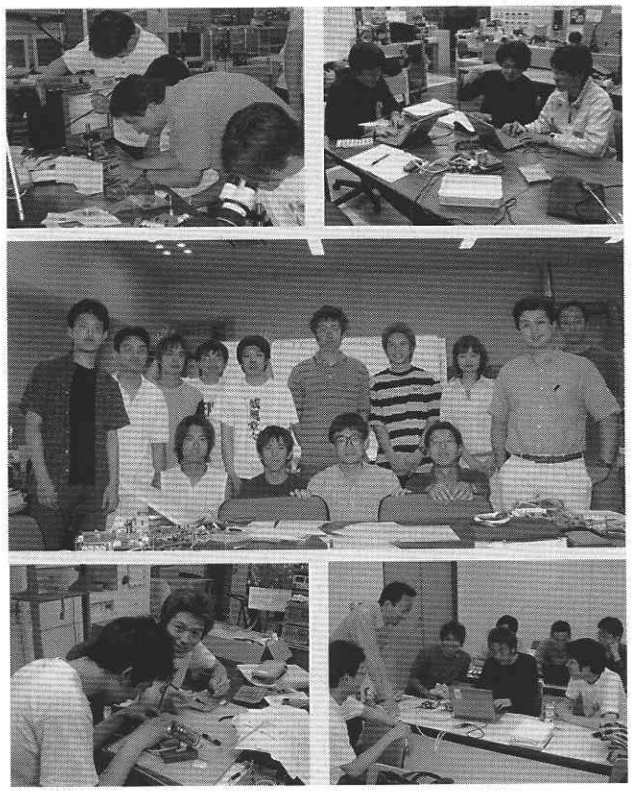

Fig. 5 Scene of the class and group photo.

Table 1 Approximative breakdown.

Item	Price[¥]
PC	50,000
H8 Microcomputr Kit	5,000
Signal processing circuit	28,450
Walker driver circuit	17,443
AFM head	97,152
Sampled	1,840
Total	199,885

5. Results

We observed surface of samples with AFM we made. Au deposited on silicon wafer, crystal plane of mica and SAM were used as samples. The results of observation on Au deposited and mica are shown in Fig. 6 and Fig. 7 respectively.

The scan area size was 300nm × 300nm in Au observation. We could confirm typical gold corrugations.

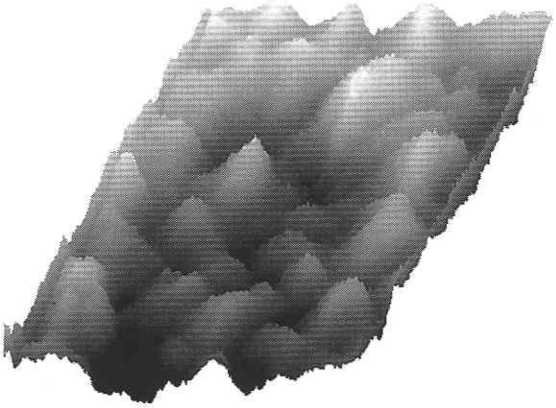

Fig. 6 Au deposited (300 nm × 300 nm).

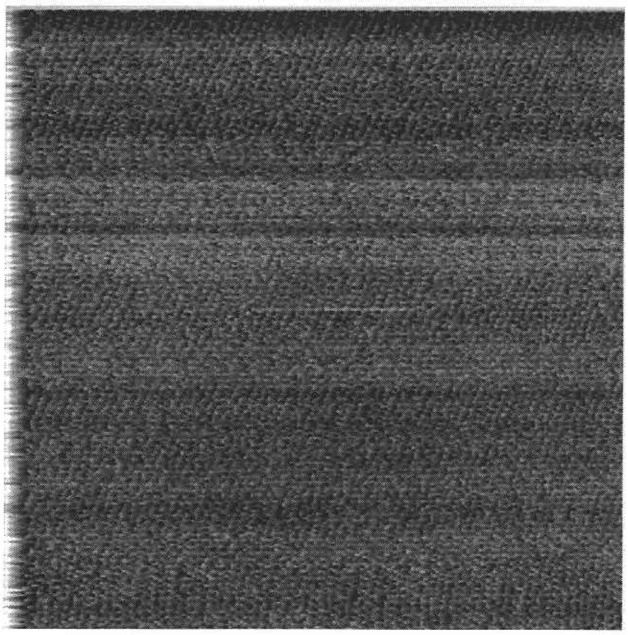

Fig. 7 Cleaved mica (30 nm × 30 nm).

We observed cleaved mica surface with attenuator to narrow scan area. It was 30nm × 30nm. This narrowing was done to use the greatest dynamic range of the AFM considering D/A output of H8 microcomputer is 8 bit. D/A output was used as driving voltage of the stage so that it moves in 256 steps. Hence it is necessary to narrow the scan area when we observe smaller patterns with this AFM. In Fig. 7, there are 63 light and shade patterns in single horizontal row. Number of the patterns should be 60 when scan was done 30nm × 30nm area because crystal distance of mica is 0.5nm. Therefore, we considered that crystal face of mica could be observed.

It was difficult to observe SAM because of PZT driving voltage, dynamic range, etc. scanning rougher plane, lager area is an issue in the future.

6. Conclusion

For the purpose of learning principles of scientific instruments, a class of technical exercises including mechanics, optics, electronics, measurements and control was held at the graduate school, the University of Tokyo. A contact mode AFM was chosen as the system to be implemented. Au deposited on silicon wafer and cleaved mica were observed. The class was held three hours a week, a total of 14 times, conducted with four professors and eighteen students. The total cost was just under 200,000 yen per AFM. Five AFMs were made in total. Good mechanical design and optics made the low-cost AFM highly performant. It was an effective course where students learned about teamwork, leadership and rewarding moments. Class recommences April 2004.

Acknowledgement

We thank TODAI SEIKEN-KAI for financial support.

(Manuscript received, November 17, 2003)

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