

A Novel Atomic Force Microscope with Multi-Mode Scanner

Chun Qin, Haijun Zhang, Rui Xu, Xu Han and Shuying Wang

State Key Laboratory of Modern Optical Instrumentation, Zhejiang University,
Hangzhou 310027, People's Republic of China, Email: zhanghj@zju.edu.cn

Abstract. A new type of atomic force microscope (AFM) with multi-mode scanner is proposed. The AFM system provides more than four scanning modes using a specially designed scanner with three tube piezoelectric ceramics and three stack piezoelectric ceramics. Sample scanning of small range with high resolution can be realized by using tube piezos, meanwhile, large range scanning can be achieved by stack piezos. Furthermore, the combination with tube piezos and stack piezos not only realizes high-resolution scanning of small samples with large-scale fluctuation structure, but also achieves small range area-selecting scanning. Corresponding experiments are carried out in terms of four different scanning modes showing that the AFM is of reliable stability, high resolution and can be widely applied in the fields of micro/nano-technology.

1. Introduction

In recent years, micro and nano technology have become one of the frontier of technological development. Atomic force microscope (AFM) has been proved to be a powerful and versatile tool ^[1] to study the surface of nanomaterials in various research fields ^[2-3]. In an AFM, a micro cantilever with a micro-fabricated tip is used to scan the sample surfaces, and the deflection of the micro cantilever is measured to detect the distance between the tip and the sample surface ^[4-8].

Currently, the majority of conventional AFMs only have a single scanner and a single scanning mode to realize small scanning range of small sample with high resolution ^[9-10], which cannot meet the growing demand. In order to achieve more functions at the same time, in this paper, a new type of AFM with multi-mode scanner is developed. With some special designs, the AFM can provide some different scanning forms. So it can satisfy the specific need of various samples under different situations.

2. Method and Working Principle

2.1. System components

The overall schematic diagram of the AFM with multi-mode scanner is shown in Figure 1. The system consists of an AFM probe, a scanning and feedback controlling circuit, and a personal computer (PC) with AFM software system. The AFM probe is of an elaborate design including cantilever and tip, measured sample, the XYZ scanner and optical paths, etc. The scanner is made up of tube piezos and stack piezos combined in X, Y and Z directions. The AFM employs sample-scan mode with micro-cantilever fixed to realize the given functions.



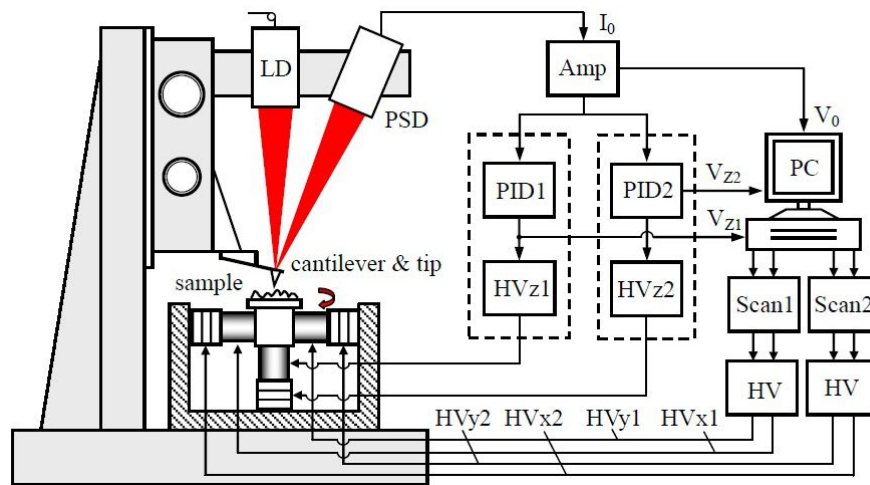


Figure 1. Scheme of the multi-mode scanner AFM

2.2. Working principle

The specially designed AFM can provide at least four scanning forms as shown in Figure 2.

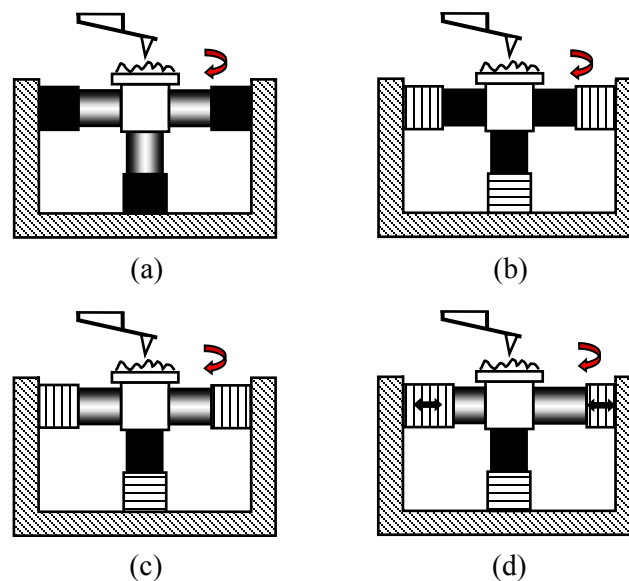


Figure 2. Scanning forms of the multi-mode scanner AFM. (a) small range scanning mode with tube-piezoelectrics, (b) large range scanning mode with stack-piezoelectrics, (c) combined mode with stack-piezoelectric feedback and tube-piezoelectrics scanning, (d) combined mode with stack-piezoelectrics area selecting and tube-piezoelectrics scanning.

The first scanning form is shown in Figure 2 (a), the stack piezos are regarded as rigid body when uncharged. Like most traditional AFMs, the small scanning range of small sample with high resolution and high speed can be realized by using three orthogonal tube piezos for XY scanning and Z feedback control. The resolution can reach 0.2 nm laterally and 0.1 nm vertically.

In Figure 2 (b), the second scanning form can realize a wider range scanning of the sample by using three orthogonal stack piezos for XY scanning and Z feedback control. In this situation, the tube

piezos are rigid body because they are not energized. At the same time, this scanning form can keep a comparatively high resolution both laterally and vertically.

In Figure 2 (c), the third scanning form is a combined one to use stack-piezo for Z feedback and tube-piezoes for XY scanning. This form is suitable for scanning small samples with large-scale fluctuation in height. Meanwhile, as shown in Figure 2 (d), small range area-selecting scanning can be realized using two stack piezos in XY directions. First of all, in order to select the target area, a certain size of voltage is applied in the stack piezos in XY directions according to the requirements and remains unchanged. After that, the small range scanning with high accuracy for target area can be realized by using the tube piezos. Moreover, like the first form, the resolution of this form can also reach nanometer level.

3. Experiment

In order to verify the performance of the multi-mode scanning AFM, corresponding experiments are carried out in terms of four different scanning modes.

For small scanning range of small sample, we choose the first scanning form in Figure 2 to realize high accuracy and high speed. The AFM image of nanoimprint structure on polycarbonate film (shown in Figure 3) is scanned under the first scanning form. The distribution of the sample can be clearly seen.

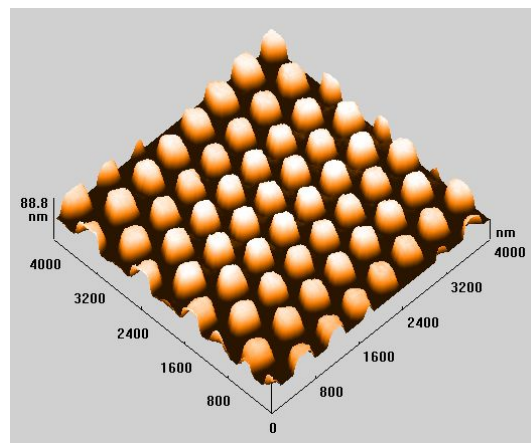


Figure 3. The AFM image of nanoimprint structure on polycarbonate film

When the sample is a larger one and needs greater scanning range, we choose the second scanning form. The AFM image of two-dimensional lattice structure is shown in Figure 4.

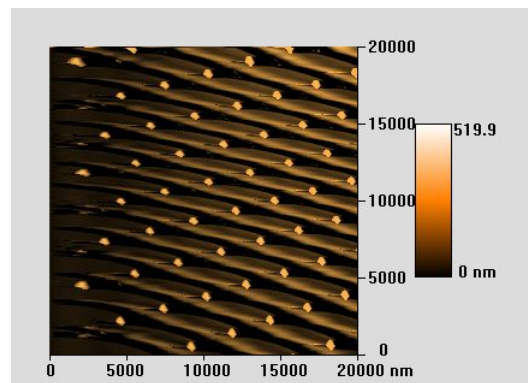


Figure 4. The AFM image of two-dimensional lattice structure

For small sample with large-scale fluctuation structure in height, the third scanning form in Figure 2 can satisfy the requirement. The AFM image of large-scale fluctuation structure on a sapphire glass substrate is shown in Figure 5 (a). In order to see the full image of our interesting area inside the marked squares, the fourth scanning form is selected. As shown in Figure 5 (b), the target area can be seen completely and clearly.

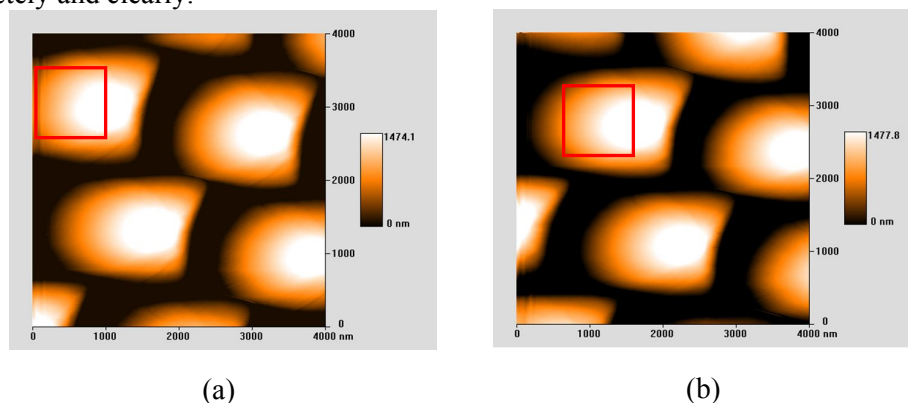


Figure 5. The AFM images of large-scale fluctuation structures on a sapphire glass substrate

4. Conclusion

A new type of AFM with multi-mode scanner is developed, and it can be applied to the scan images of different samples. Experiments show that the AFM is of reliable stability and can provide different scanning forms according to the actual requirements. Compared with the conventional AFMs, the novel AFM owns more optimized performance, better repeatability and has a potential of satisfying much wider applications in various research fields.

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