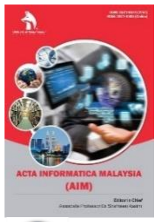
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0874 (Print)
ISSN: 2521-0505 (Online)
CODEN: AIMCCO

Acta Informatica Malaysia (AIM)

DOI: http://doi.org/10.26480/aim.01.2025.26.28



CrossMark

REVIEW ARTICLE

RESTORATION OF NANO SCALE IMAGES EMPLOYED A WEIGHT FUNCTION TO COMBINE THE HEIGHT IMAGE WITH THE DEFLECTION IMAGE

Ahmed Ahtaiba

Electrical and Electronic Engineering Department, Sirte University
****Corresponding Author Email: amaa_1973@yahoo.com***

ARTICLE DETAILS

Article History:

Received 11 April 2025
Revised 21 May 2025
Accepted 17 June 2025
Available online 23 July 2025

ABSTRACT

Atomic force microscopy works by mounting a probing tip on the free end of a micro mechanical cantilever and then scanning an item with that tip. Cantilever deflection occurs during horizontal scanning of the sample. Several ways exist for sensing the cantilever's deflection. For example, this approach is commonly employed in optical beam deflection due to its simplicity. It compares the observed deflection to the set point deflection while scanning the sample stage. The next step is to reduce the error signal, which is the set point deflection minus the detected deflection, by advancing the sample stage in the Z-direction. This closed-loop feedback mechanism may sustain the cantilever deflection and, by extension, the force exerted by the contact between the tip and the sample, up to a certain point value. This causes the sample stage to move in three dimensions, which roughly follows the contours of the sample. As a result, the topographic picture is often generated from the Z-direction electrical impulses that drive the sample stage scanner. To create the AFM topographic picture, the authors in this study employed a weight function close to 3 to combine the height image, which is used to drive the Z-scanner, with the deflection image. By means of trial and error, the value of has been ascertained experimentally. A more accurate topographic picture is produced by this technique.

KEYWORDS

height image; scanning speed; deflection image; image restoration.

1. INTRODUCTION

Among the many valuable tools available, the AFM allows for measurements of materials down to the nanometer scale (Ahtaiba,2025; Ahtaiba, 2023; Ahtaiba et al., 2017). In contrast to scanning tunneling microscopy (STM) and electron microscopy, the Atomic Force Microscope can image inorganic samples with unprecedented clarity and provide high-resolution images of biological samples. Air applications include surface characterization, lithography, and data storage; it also possesses the unusual capability of seeing things in liquids on the nanometer scale.

Scanning an item with a probing tip attached to the free end of a micromechanical cantilever is the basic concept of an atomic force microscope. When scanning an item, the tip probes its surface using one of two modes: contact mode, in which the tip remains in constant touch with the object, or tapping mode, in which the tip oscillates at the resonance frequency of the cantilever (Binnig et al., 1986; Hansma et al., 1988; Sarid, 1994). Using contact mode allows for sub-nanometer precision in measuring the cantilever's deflection. Adjusting the sample's or cantilever's location in the Z-axis in response to changes in the probing force. Hence, the feedback controller's output stands in for the topographical data (Zhong et al., 1993). An accurately defined and calibrated positioning system in the Z-direction, as well as a high-performance feedback loop, are necessary for this task. Minimizing changes of the imaging force and avoiding damage to the tip and sample are both made possible by this criterion. Imaging soft biological samples requires a continuous and minimal tip-sample contact force. Scanning speeds of existing AFM systems are constrained by the specific microscope's dynamic behavior. The input bandwidth of the feedback loop that regulates the force-sample interaction, the scanning unit's dynamic behavior, the force sensor's reaction time, and the data collection system's speed are the primary constraints.

2. PRINCIPLE

A common method of interaction In Figure 1, we can see an AFM system that measures height using an optical cantilever technology. Assuming the scan speed is kept low enough to provide sufficient reaction time by the feedback unit, the feedback system functions as intended. In order to keep the cantilever signal level at a set-point value (, S-0.), the piezo tube is regulated by the feedback signal; the signal F represents the topography. Scan speed determines the frequency component of the surface topography-derived cantilever signal (Schitter et al., 2001). When there is insufficient feedback bandwidth, the feedback signal (F) and the cantilever signal (**O**) diverge from, F-0 and, S-0, respectively, because to the increased scanning rates. The discrepancies between the feedback signal F and F-0, as well as the cantilever signal **O** and S-0, are supplied by

$$\partial C = C - S_0 \quad (1)$$

$$\partial F = F - F_0 \quad (2)$$

The two equations given above suggest that the discrepancies σa and σF have a distinct connection. In cases when the feedback bandwidth is inadequate, the signal C-0., representing the topography of the sample surface, can be derived from the F and C signals. The cantilever signal derived from σF is represented by the parameter σ0, and since the feedback bandwidth of F is equal to $F0$. The displacement of the piezotube follows a linear relationship with the signal. In other words,

Quick Response Code	Access this article online	
	Website: www.actainformaticamalaysia.com	**DOI:** 10.26480/aim.01.2025.26.28

Cite The Article: Ahmed Ahtaiba (2025). Restoration Of Nano Scale Images Employed A Weight Function To Combine The Height Image With The Deflection Image. *Acta Informatica Malaysia, 9(1): 26-28.*

$$\partial C = \propto \partial F \tag{3}$$

Here, the coefficient $\propto$ is determined experimentally.

F_0 can be written from equations (1), (2), and (3) as follows:

$$F_0 = F - C/\propto + S_0/\propto \tag{4}$$

S-0 and ∘ are constants in this context. This means that the following equation may be used to determine the surface topography from the cantilever signal and the feedback signal, which corresponds to the fluctuation of $C0$.

$$T = F - C/\propto \tag{5}$$

Where T is the surface topography.

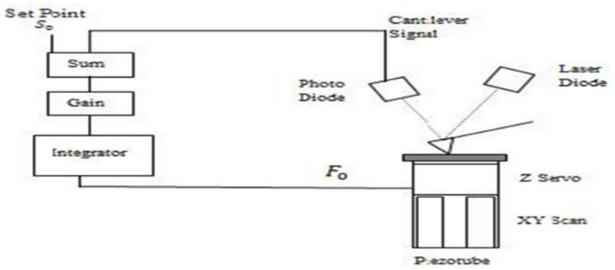


Figure 1: Shows a contact mode AFM system.

3. Feedback Control

A common feedback control unit utilized in AFM imaging is depicted in figure 2 as a schematic block diagram. The cantilever tip of the atomic force microscope is moved horizontally over the surface of the sample. Maintaining a consistent cantilever deflection is achieved by using the Z piezo actuator to adjust the cantilever's vertical position (Yumoto et al., 1999). One important factor affecting picture quality is the feedback servo mechanism that regulates the cantilever deflection. Attractive Van der Waals and repulsive Pauli forces keep the cantilever tip in a certain position with respect to the sample surface (Schitter, 2007; Stack et al., 2004). The Z-piezo moves the sample surface so that the tip may probe it. The controller ensures that the cantilever's deflection remains relatively consistent. This causes the tip to exert a consistent push on the sample. As the set point of the controller is directly proportional to the force put on the sample, it is preferable to use a minimal force to prevent injuring soft samples or the tip. Figure 2 shows that the controller output is used to generate the topographical picture, while the cantilever deflection value is used to form the deflection image.

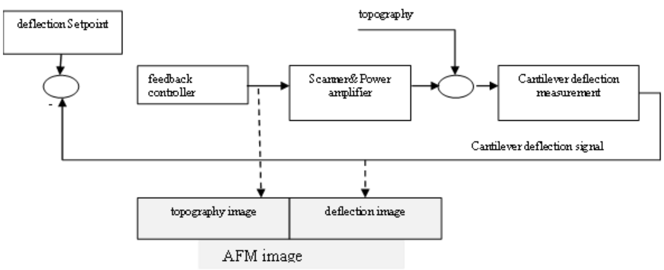


Figure 2: Shows a schematic block diagram used in AFM imaging

4. Results

By touching the surface of the sample with a pointed tip that is connected to the free end of a cantilever, the Atomic Force Microscope creates an image when operating in contact mode. Cantilever deflection occurs during horizontal scanning of the sample. There are a number of ways to detect the cantilever's deflection. To feel the cantilever deflection, for example, one common and straightforward way is optical beam deflection. The sample is scanned with the purpose of comparing the observed deflection to the set point deflection value. Then, by adjusting the sample stage in the Z-direction, we may reduce the error signal, which is defined as the difference between the detected and set point deflection values. This closed-loop feedback mechanism may keep the cantilever deflection and, by extension, the force interacting between the tip and the sample, constant at a certain point value. This causes the sample stage to move in three dimensions, which roughly follows the contours of the sample. Consequently, the Z-direction electrical impulses used to operate the sample stage scanner may often be utilized to produce the topographic image.This chapter explains how to build the AFM topography picture. The values are taken from the topographical height image, which is used to drive the Z-scanner, and the deflection image. The weight function, represented by the parameter, is near to 3 for this gadget. Here, we use a trial-and-error method to empirically find the value of. Compared to the previous approach, this one produces a more accurate topographic picture (see Figure 1).

An AFM measurement scheme utilizing the cantilever-feedback signal combination approach is shown in Figure 3. This chapter defines the x-axis as the scan direction and the y-axis as the perpendicular to this. If the cantilever signal is sent via a low pass filter into the feedback loop to limit the bandwidth of the feedback, the piezotube will react linearly and instantaneously to the feedback signal. Here, we utilise three distinct scanning speeds—2 Hz, 6 Hz, and 9 Hz—to get picture data in the specified scan line direction. An example of this would be the acquisition of a single 512*512 pixel picture in 1.5 minutes at a scan speed of 6 Hz in the specified scan line direction, with a measurement point frequency of about 6 KHz. Changing the piezotube length to meet the criteria in Equation (3) is necessary for this combination approach. On the other hand, linear hysteresis is nearly visible in the piezotube. Since there is hysteresis between the F signal and the altered form of the piezotube and the C signal reacts linearly to the surface height, the influence of piezotube hysteresis on the picture is shown in Equation (5) through F. At higher frequencies in the F signal, where the piezotube exhibits numerous small hysteresis loops, local picture distortion becomes more pronounced.

The combination process, as described by Equation (5), requires experimental determination of the coefficient. In the case of this AFM type, the coefficient is 3.

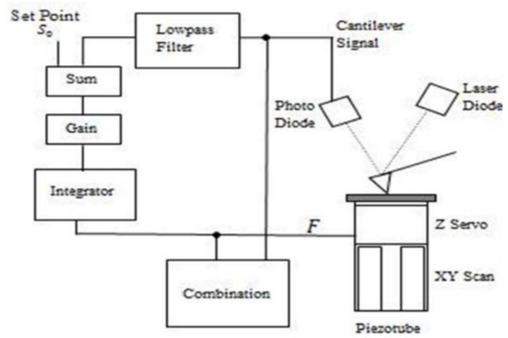


Figure 3: Illustrates the schematic of AFM

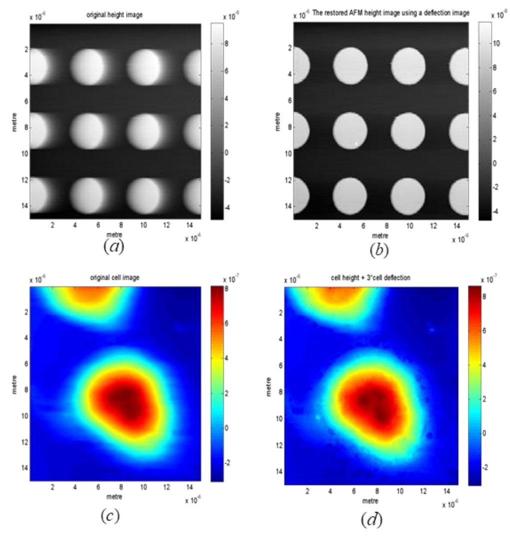


Figure 4: Displays the experimental outcomes for the suggested method of merging processes at a 2 Hz scanning speed. (a) The high-resolution original image of the silicon-based standard sample; (b) The combined image of the silicon-based standard sample; (c) The original image of the cell sample; and (d) The combined image of the cell sample.

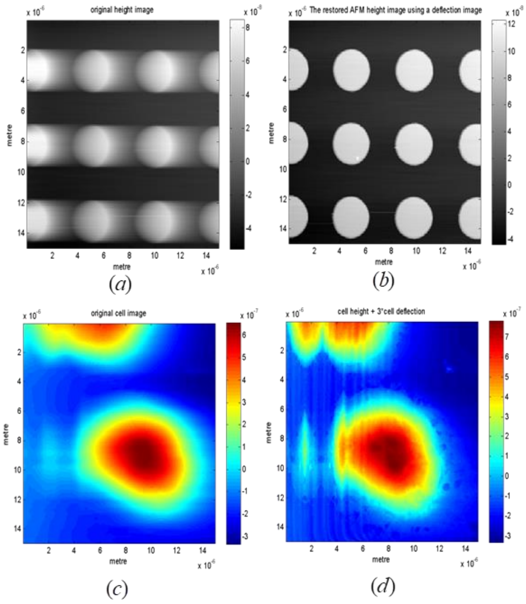


Figure 5: Displays, at a 6 Hz scanning rate, the experimental outcomes for the suggested combining process method. (a) The high-resolution original image of the silicon-based standard sample; (b) The combined image of the silicon-based standard sample; (c) The original image of the cell sample; and (d) The combined image of the cell sample.

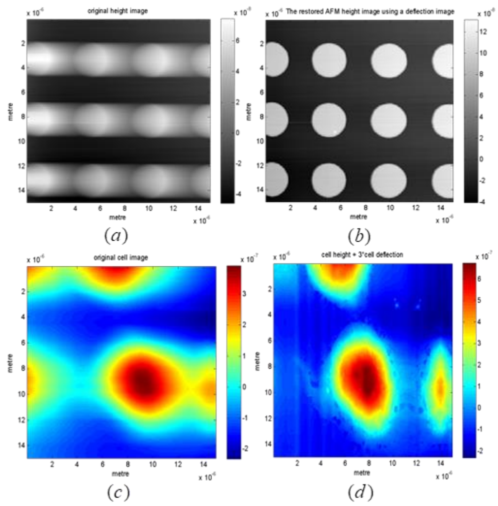


Figure 6: Displays the experimental outcomes for the suggested method of merging processes at a 9 Hz scanning speed. (a) The high-resolution original image of the silicon-based standard sample; (b) The combined image of the silicon-based standard sample; (c) The original image of the cell sample; and (d) The combined image of the cell sample.

5. Conclusion

This study explains how a deflection picture may be used to create a restoration AFM height image. It has also been demonstrated how this method was utilized for imaging at greater scan rates at various dynamic scanning speeds. A typical SPM calibration sample made of a 2D array of little elevated columns and the surface of a live cell were used as examples of the two samples that were seen in order to do this. The surface measurement findings for contact mode AFM were then compared. This method is based on multiplying the AFM height picture with the AFM deflection image after applying a consistent number of weights to the former. The initial height image was distorted by the instrument's dynamic frequency response while scanning at higher rates, but the new image is far clearer and more precise.

Refernces

Ahtaiba, A., 2025. Testing and comparing the original image with the restored image that was obtained by using the erosion and of the dilated image by the AFM tip. Acta Scientific Computer Sciences, 7, Pp. 23–28.

Ahtaiba, A., 2023. The improvement in the AFM image after applying a Lucy-Richardson deconvolution algorithm using a new technique for estimating the AFM tip shape from the square sample. WSEAS Transactions on Signal Processing, 19, Pp. 103–107.

Ahtaiba, A., Abdulhadi, A., Amreiz, H., Imrayed, O., Darwish, M., 2017, September. Restoration of an AFM height image using a deflection image at different scanning speeds. Proceedings of the International Conference on Advanced Computing (ICAC), Pp. 1–4.

Binnig, G., Quate, C. F., Gerber, C., 1986. Atomic force microscope. Physical Review Letters, 56, Pp. 930–933.

Hansma, P. K., Elings, V. B., Marti, O., Bracker, C. E., 1988. Scanning tunnelling microscopy and atomic force microscopy: Application to biology and technology. Science, 242, Pp. 209–216.

Sarid, D., 1994. Scanning force microscopy. Oxford University Press.

Zhong, Q., Inniss, D., Kjoller, K., Elings, V. B., 1993. Fractured polymer/silica fiber surface studied by tapping mode atomic force microscopy. Surface Science Letters, 290, L688–L692.

Schitter, G., Menold, P., Knapp, H. F., Allgöwer, F., Stemmer, A., 2001. High performance feedback for fast scanning atomic force microscopes. Review of Scientific Instruments, 72, Pp. 3320–3327.

Yumoto, S., Ookubo, N., 1999. Fast imaging combining cantilever and feedback signals in contact-mode atomic force microscopy. Applied Physics, 69, Pp. 51–54.

Schitter, G., 2007. Design and modelling of a high-speed AFM scanner. IEEE Transactions on Control Systems Technology, 15, Pp. 906–915.

Stack, R., Schitter, G., Stark, M., Stemmer, A., 2004. State-space model of freely vibrating and surface-coupled cantilever dynamics in atomic force microscopy. Physical Review, 69, Pp. 1–9.