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Investigation on adhesion properties of gold, silicon and mica by Atomic Force Microscopy

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ABSTRACT

Atomic Force Microscope, based on the strong distance-dependent interaction between a sharp tip and a sample, uses the atomic forces to build an image of the sample surface. It is also possible to obtain the force-distance curve i.e. tip-sample interaction force as a function of their distance. The resulted data can then be used to study adhesion properties of various materials. In this research, silicon tip is employed and force-distance curves were recorded in five different points on the surface of gold, silicon and mica. Measurements are conducted two times per each point. Adhesion forces are then calculated in every single curve and the final data which is the mean of ten different curves are discussed.

Keywords: Atomic Force Microscopy, Force Spectroscopy, Gold, Silicon, Mica

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1. INTRODUCTION

The probe of Atomic Force Microscope (AFM) consists of a cantilever with a sharp tip. The atoms at the end of the tip come to close vicinity of atoms on the surface of a sample when scanning the specimen surface. The cantilever is typically made of silicon or silicon nitride with a tip radius of curvature on the order of nanometers. When the tip is brought into proximity of a sample surface, forces between the tip and the sample lead to a deflection of the cantilever according to Hooke's law. Depending on the situation, forces that are measured in AFM include mechanical contact force, Van der Waals forces, capillary forces, chemical bonding, electrostatic forces, magnetic forces, Casimir forces, solvation forces, etc. Typically, the deflection is measured using a laser spot reflected from the top surface of the cantilever into an array of photodiodes [1-3].

Besides imaging, another major application of AFM is Force Spectroscopy. The direct measurement of tip-sample interaction forces as a function of the gap between the tip and sample results in a force-distance curve. In this mode of AFM, depending on the force direction, the tip is attracted towards or retracted from the surface. Accordingly, the deflection of the cantilever represents the interaction force and the vertical movement in z-piezo stands for displacement. These measurements have been used to measure nanoscale contact forces, atomic bonding forces, Van der-Waals forces, Casimir forces, dissolution forces in liquids and rupture forces [1, 4-6].

In the present study, force-displacement curves are obtained by atomic force microscopy using gold, silicon and mica samples.

2. EXPERIMENTAL

2.1. Materials

Gold and silicon from Anfatec Company and mica film from Plano GmbH (Wetzlar, Germany) were used as the samples.

2.2. Methods

A. Topography

Prior to performing Force Spectroscopy analysis, a surface image of the sample is acquired in order to choose proper points for obtaining force-displacement curves. All experiments were conducted in air and in the ambient temperature. The imaging is gained in contact mode and the CSC17 silicon probe (from Mikromasch Company) with a typical force constant of 0.1 N/m and resonance frequency of 13 kHz is employed.

B. Force Spectroscopy

After getting image from samples, the relatively more flat points without dust particles were chosen by software to do Force Spectroscopy analysis.

Force Spectroscopy was performed by ARA-AFM, an Iranian made AFM (manufactured by Ara-Research Company in Tehran).

Figure 1: Atomic Force Microscope made in Iran, modeled ARA-AFM, used in Force Spectroscopy.

The related window for Force Spectroscopy is shown in Figure 2. Various parameters such as starting point, final point, tip movement direction, delay times, etc. can be adjusted.

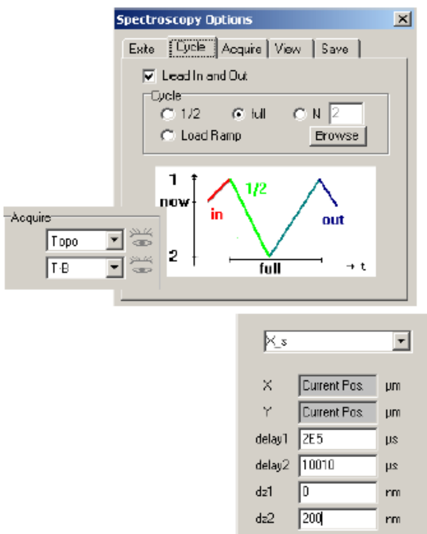


Figure 2: Force Spectroscopy window in ARA-AFM software.

A schematic of typical curve for force-displacement and its different stages is shown in Figure 3.

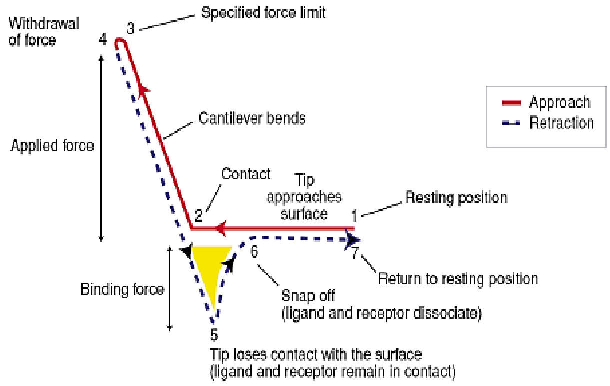


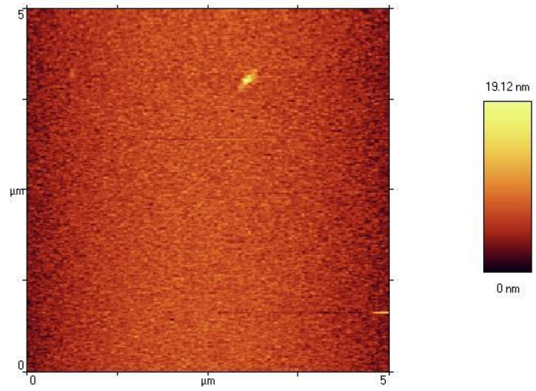
Figure 3: A typical force-displacement curve.

C. Adhesion force measurements

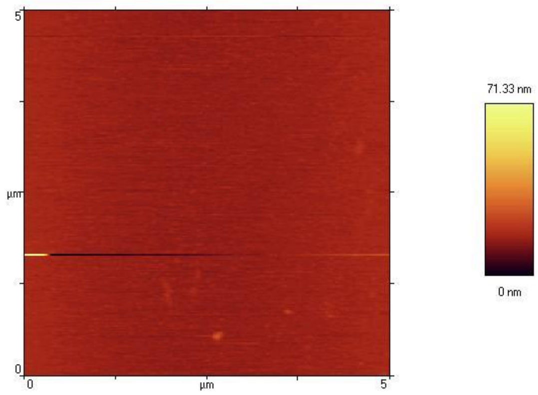
The jump-off-contact occurs during withdrawal of the sample. It is seen that the cantilever elastic constant is larger than the gradient of tip-sample adhesive forces. The height differences between approach and retract curve consider as a criterion for adhesion force. Force Spectroscopy is done in 5 different points of each sample and repeated 2 times. Adhesion force is measured in all 10 curves and the mean value is reported.

3. Results and Discussion

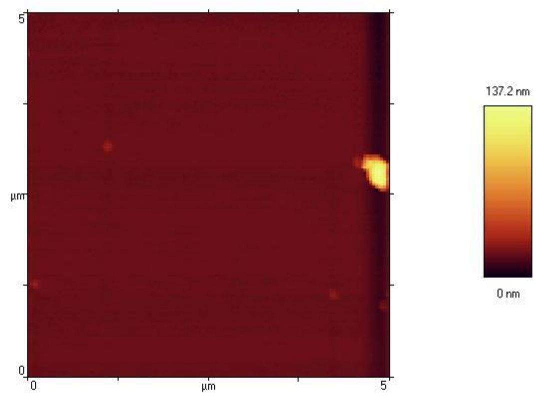
Topography images of the samples and a typical force-displacement curve for gold are available in Figure 4 and 5, respectively.



(a)



(b)



(c)

Figure 4: Topography images of a) gold, b) silicon and c) mica.

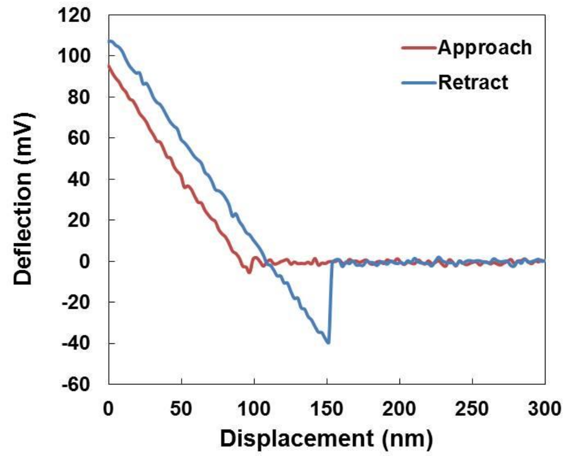


Figure 5: The typical force-displacement analysis of gold.

The mean adhesion forces of samples are summarized in Table 1. As it is obvious, the adhesion force between silicon tip and gold is much lower than silicon and mica samples.

Table 1: The mean adhesion force between the silicon tip and different samples.

Sample	Deflection (mV)	Adhesion force (nN)
Gold	44.7	6.7
Silicon	95.3	14.2
Mica	472.1	70.4

4. Conclusion

Force Spectroscopy by Atomic force Microscope (AFM) is a method to detect numerous forces. In this way, the adhesion force between silicon tip and samples including gold, silicon and mica are measured. The results show that the adhesion force of tip-gold is much lower than the others.

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