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แบบจำลองการใช้งานกล้องจุลทรรศน์แรงอะตอมแบบ Noncontact

The Noncontact Atomic Force Microscopy Model (NC-AFM)

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บทคัดย่อ

แบบจำลองการทำงานของกล้องจุลทรรศน์แรงอะตอมแบบ noncontact (NC-AFM) เพื่อส่งเสริมนักศึกษาได้มีความรู้ความเข้าใจเกี่ยวกับหลักการทำงานของกล้องจุลทรรศน์แรงอะตอม โดยแบบจำลองดังกล่าวจะแสดงให้นักศึกษาได้เข้าใจเกี่ยวกับเครื่องมือที่ใช้ในการวิจัยด้านนาโนเทคโนโลยี ซึ่งเครื่องมือดังกล่าวจะใช้หลักการของอันตรกิริยา แวน เดอร์ วาลล์ (Van der Waals interactions) หรือแรงอย่างเข้ม (strong force) ที่เกิดในระดับอะตอมเพื่อการตรวจสอบคุณสมบัติและการจัดเรียงโมเลกุลของอนุภาคที่อยู่ในระดับขนาดนาโน

ABSTRACT

Modeling a noncontact atomic force microscope (NC-AFM) to enhance the college students' understanding of how the AFM operates. The model introduces the students' comprehension of how to use the nanotechnology tool for research. The NC-AFM senses nanoparticles by measuring Van der Waals interactions (strong force) which will happen at the atomic scale for evaluating properties and manipulating nanoparticles.

คำสำคัญ: กล้องจุลทรรศน์แรงอะตอม การจัดเรียงอนุภาคนาโน การเรียนรู้เรื่องเครื่องมือนาโนเทคโนโลยี

Keywords: Atomic force microscopy, Manipulating nanoparticles, Learning of nanotechnology tool

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Introduction

Learning nanoscience and nanotechhnology was introduced to 38 college students who have no experience in learning nanoscience and nanotechnology. Our classroom started with the simple questions "What is nanomaterial?" and "How do scientists study nanoparticles?" After that the Atomic Force Microscope (AFM) was introduced to the students as a tool to study the nanoscale. There are two basics modes of operation of the AFM, contact and non-contact modes. Phuapaiboon et al. (2009), reported hands-on activities that provided Thai learners opportunities in learning how contact mode AFM works. In this study to have students learn another mode, a non-contact mode AFM (NC-AFM), a simple model was designed in order to show how the tip oscillates along a vertical axis while scanning over a sample surface. The NC-AFM was developed by Martin et al (1987). In NC-AFM, as the tip approaches a sample, the van der Waals attractive force between the tip and the sample acts which causes changes in the amplitude of the cantilever vibration (Hutter and Bechhoefer,1993).

Atomic Force Microscopes (AFMs) are most often used for high-resolution imaging and detailed surface characterization, but soon after their invention it was recognized that they could also be used to change, interact with, and control nanoscale matter. The development of tools and techniques for the manipulation of nanoscale objects, such as nanoparticles, nanotubes, or nanowires, is crucial for advances in nanoscience and nanotechnology. Manipulation of nano-objects has been achieved by picking them up from the substrate and placing them to a different location (Custance et al., 2009). An AFM tip can be used via different mechanisms to modify surfaces with nanometer resolution. The AFM tip can serve as a robotic hand to precisely position nano-objects and assemble them under computer control.

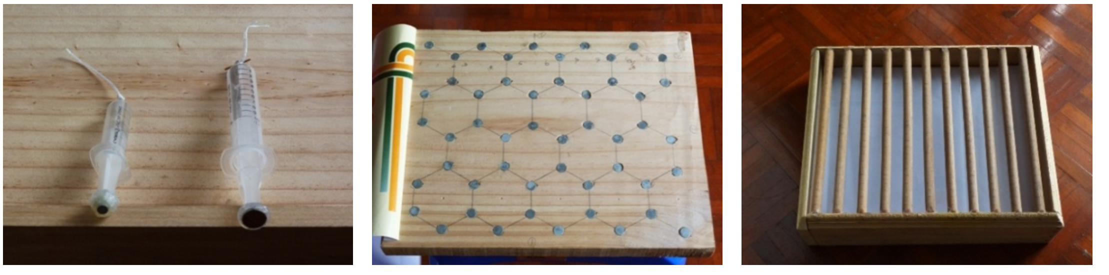
Research Methodology

1. The NC-AFM model

Materials: This paper built a NC-AFM model. The NC-AFM tip was represented by a syringe with a magnet glued at the end of the syringe's rod. Two differently sized syringes (5 ml and 10 ml) and magnets (∅5 mm and 12 mm) were used. The syringe's rod had its rubber removed and was tied with the syringe using a tiny string, shown in Figure 1(a). Three different sample surfaces were provided by using different sized magnets (∅10, 12 and 15 mm). They were fixed in the wood plates shown in Figure 1(b). As an unknown sample, the sample surfaces were covered with a piece of paper and then put in the wood (paper) box. Then the sample surfaces were scanned by using the tip of the syringe to follow gridlines (columns) of the box lid, as shown in Figure 2. So when the syringe's magnet was placed on the sample surface's magnet, the attractive force pulled the tip (syringe rod) to move down. Hence magnetic force represented the van der Waals force between the tip and the sample; similar to the NC-AFM model created by Planinsic and Kovac (2008).

2. Manipulating Nanoparticles

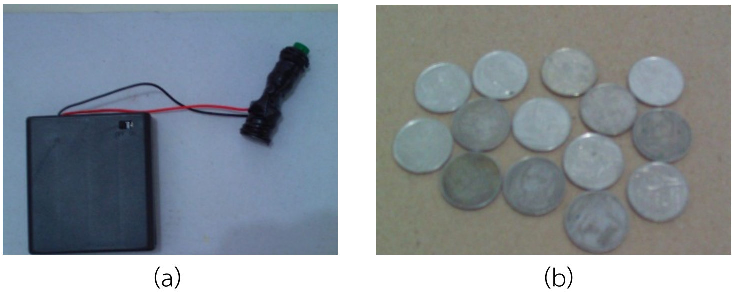
Materials: Simple materials, an electromagnet and one-baht coins, were used. There are two versions of one baht coins, the previous version is made of silver, but the newer version is made of iron coated *nickel*. However there is no visible difference between these two versions.



(a) (b) (c)

Figure 1. (a) The AFM probe, (b) sample surface and (c) sample surface in the wood box covered by paper

Figure 2. The AFM tip probing the unknown sample surface



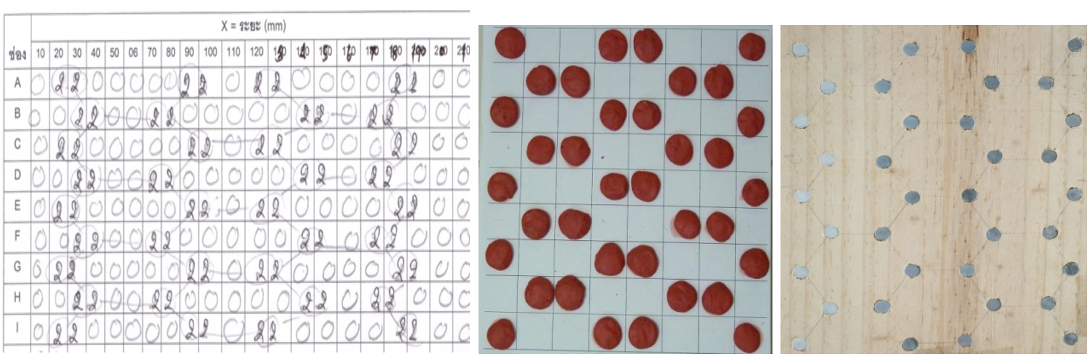
(a) (b)

Figure 3. (a) an electromagnet (b) one-baht coins

Results

The NC-AFM model

As a game, the high school students were asked to predict the structure of the unknown sample surface. The students worked in groups of four to scan and record the vertical position change of the syringe's rod when it moved up or down while scanning the sample surface, as shown in Figure 4a. Two different sizes of syringe tips were provided for each group. The students revealed that use of syringe tips in scanning an unknown surface let them feel the attractive force between the tip and the surface; it helped them to imagine the figure/structure of the sample surface that they were working on. After that, students were asked to construct a plasticine model of the sample surface following their recorded data (Figure 4b). All students were also asked to match the components of the real AFM with the AFM model and explain operations of the AFM non-contact modes (Figure 5).



(a) (b) (c)

Figure 4. The comparison between the student models of a simple surface

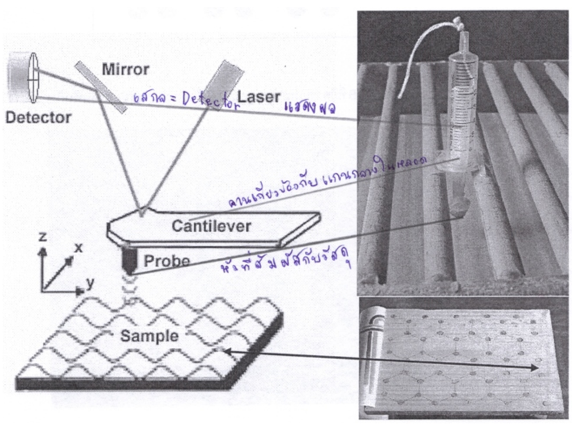


Figure 5. The student comparison of the AFM

Manipulating Nanoparticles

A very interesting question posed by Richard Feynman, "Whether, ultimately—in the great future—we can arrange the atoms the way we want; the very *atoms*, all the way down! What would the properties of materials be (if we had this capability) and what would happen if we could arrange the atoms one by one?" was discussed before doing a hands-on activity. To learn how AFM manipulation can be a tool for the fabrication of nanoparticles' patterns, the model was introduced that an AFM can be used to arrange and manipulate nanoparticles, see in Figure 6. The AFM tip is represented by an electromagnet and the specific nanoparticles were represented by iron one-baht coins, while the silver coins represented another type of nanopaticle that could not be picked up by using this electromagnet (tip). After that, an example of manipulation of randomly deposited gold particles on a mica substrate was discussed. The 15 nm diameter gold particles were pushed from an initial random position to form the IL logo (Figure 7). So students learned that tasks such as pushing and pulling or cutting and indenting can be performed, and nanoscale objects can be mechanically moved by the AFM probe tip.

(a) (b)

Figure 6. A hands-on activity of manipulating atoms (coins) using AFM tip (an electromagnet).

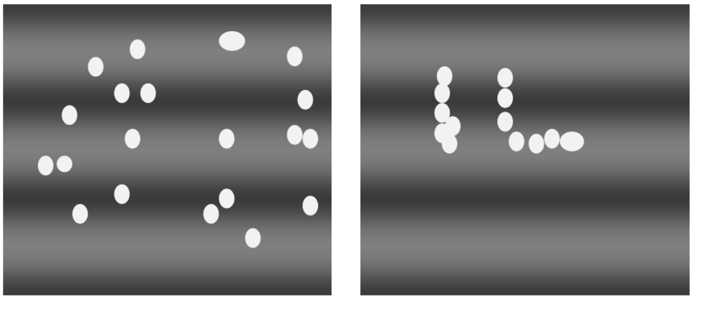


Figure 7. A random pattern of 15 nm gold balls was converted into the "IL" logo pattern.

Discussion and Conclusion

After the learning activity, the classroom discussed about the picture's quality when using different sizes of the tip. When compared to the understanding of AFM's achieving atomic resolution.

If the physical probe used in AFM imaging is not ideally sharp then an AFM image will not reflect the true sample topography, but rather will represent the interaction of the probe with the sample surface, see Figure 8.

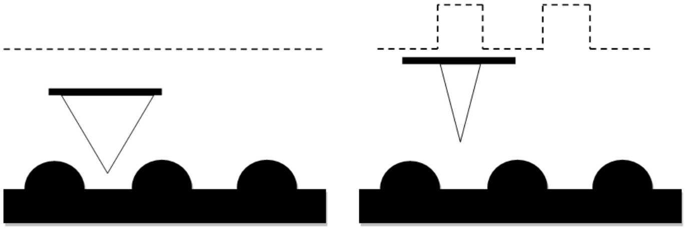


Figure 8. Ideally a tip with a high aspect ratio will give the best resolution, the radii of magnets influence the resolution.

The advantage in our models was that students were allowed to compare similarities and differences between real NC-AFM and the models they constructed, as well as learning the process of how the NC-AFM works through very simple activities performed in a relatively short time. However, in the real situation, AFM works by bringing an atomically sharp tip close to a surface. There is an interactive force between the tip and the surface. As the probe tip scans back and forth over the surface, the tip will rise and fall with the different features on the surface. Since this is going on at a very small scale, we cannot watch the tip directly. The NC-AFM models help us to see how the probe tip interacts with the surface and the magnetic force is represented to the van der Waals force in the real NC-AFM.

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