Nanotechnology – An introduction

This lesson is to initiate and encourage interest in the technology of the future, nanotechnology. Admittedly, the world is moving towards smaller and faster. In 1959, Richard Feynman posed an interesting question at the American Physicists society-meeting. **What would happen if we could arrange atoms, one by one, the way we needed?**

Nanotechnology is all about engineering at the atomic level. It is about manipulating atoms and molecules to build new materials with new properties. With nanotechnology comes the ability to build nano robots which could make the process of replicating so simple and efficient that it becomes easy to build or assemble machines at minimal cost and very efficient speed. Nanotechnology has diversified applications in the field of medicine, space science, industry, computers, etc. The future of nanotechnology depends on our understanding of the materials and their properties at the atomic level. To this extent the STM and other scanning probe microscopy devices have been used to study the properties of materials at the atomic level. This lesson plan will provide the opportunity for the learner to become familiar with dimensions in the nano world and the instrumentation techniques to study the structure and behavior of materials at the atomic level.

**Problem:** How do we see what we cannot see? Is it possible to engineer devices atom by atom at all? What are the techniques used to map out surfaces atom by atom? What is the need to study individual molecules and atoms when we already know the behavior of bulk matter? Is physics any different at the nanolevel?

**Abstract:**

Introduction to dimensions in the nano world and to simulate scanning force microscopy techniques to map out the topography of a surface. Using scanning techniques to build models which show variation of electrical properties on the surface and design a probe meter to measure the gradient and transform it into a readable map.
Alignment with national and state standards
Georgia standards
SCSh3. Students will be able to use tools and instruments for observing, measuring, and manipulating objects in scientific activities.
   c. Develop and use systematic procedures for recording and organizing information.
SCSh4. Students will be able to use the ideas of system, model, change, and scale in exploring scientific and technological matters.
   a. Apply the concept of a system to the analysis of how things work and the design of solutions to problems. Specify the system’s boundaries and subsystems, its relation to other systems, and its input and output.

SCSh5. Students will be able to communicate scientific ideas and activities clearly.
   a. Write clear, coherent accounts of scientific activities, including possible analyses and alternative interpretations of the results.
   b. Choose appropriate summary statistics to describe group differences, always indicating the spread of the data as well as the data’s central tendencies.
   c. Make and use tables, charts, graphs, and scale drawings to make scientific arguments and claims in oral and written presentations.
   d. Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.

AP Physics : Electric field, electric potential, current electricity topics

Objectives:
The overall objective is to gain knowledge of investigative techniques used to study properties of materials at the nano level.

Specific objectives:
To get familiar with the dimensions involved in the nano world
To understand the principle of atomic force microscopy techniques and use simulated models to study the topography of surfaces
To use the knowledge of electric field and equipotential surfaces to map unknown charge distributions and to use it to understand electric force microscopy techniques.
**Anticipated learner outcomes:**
The students will get to know the importance of nano technology as one of the future technologies. Students will understand basic principle and operation of scanning probe microscopy techniques. Students will be able to appreciate the importance of measurement as a fundamental tool in increasing knowledge about scientific phenomena.

**Background**
Scanning process in Television
Van der waals forces and graph of force Vs separation
http://www.chemguide.co.uk/atoms/bonding/vdw.html
Spring constants and cantilevers
http://en.wikipedia.org/wiki/Cantilever
Resolution of image

**Materials & Supplies**
shoe box model of surfaces, grid sheets , straws, Velcro hooks and loops , rulers, color pens etc.,
Project supplies: multimeter, aluminum foil, electrodes (bars, pointed and circular metal electrodes) , resistance paper, metallic paint

**Plan**
**Warm up** : 10 minutes
**Introducing the dimensions of nano world**
The term nano is derived from the Greek word meaning dwarf and represents the SI prefix 10\(^{-9}\) m.
Arrange the following dimensions from the largest to the smallest. Which of them is in the order of a nano meter ?

Length of a foot ball field, diameter of a proton, radius of the nucleus, mean distance between sun and earth, size of a cell in living organism, height of a geostationary satellite, size of virus, size of an atom , thickness of human hair, size of the pupil, wavelength of light, thickness of paper

- How many times smaller is a nanometer as compared to the thickness of human hair ?
- If you can split human hair into two halves, how many times do you have to divide it before you reach a nanometer ?
**Mapping an unknown surface**

The students will be divided into groups and each group will be given an unknown surface to map. The object is a topographically varying surface, which will be built to resemble the step structure of atomic surfaces with surface defects like holes, trenches and projections. It will also have pieces of Velcro attached to it to simulate atomic sites. The probe will be a straw at the end of which is attached a small piece of Velcro. The idea is to map the surface topographically investigating variations in height and variations in the adhesive force acting on the probe. The variations in the height can be studied by calibrating the probe and by simply measuring the length of extended part above a reference line. The probe should be moved across the surface in raster fashion just like reading a textbook. The grid will be provided to them, which will determine the no. of data points on each line of scan and the total no. of scan lines in the given area. A hole is made in the center of each square of the grid to insert the probe to make the measurement. The group will then construct the topographic surface two dimensionally on the given grid map of the same dimensions of the surface. They can use a color scheme to map out the variations in height. They can also map out the atomic sites by using their own key. They should be also able to use excel software in generating a 3d topographic image of the surface with their own key.

**Analysis Questions :**

A class period on discussion of actual AFM techniques can be done using videos and images of AFM in action. Better still, a field trip to gatech to visit some of the labs where scanning probe microscopy is used to get a working experience of the same is advised. After an introduction to AFM, the following analysis questions can be completed by discussion within their groups.

1. How well does the topography map created compare with the actual surface topography ?

2. To produce a more accurate image map of the surface, what can be done ?
3. What is the force between the probe and the surface in reality as compared to the adhesive forces between the Velcro surfaces on the probe and the atomic sites in the model?

4. How does this force vary with the separation between atoms?

5. If we use a fine spring to measure this force, what should be the spring constant of the spring to be able to respond to changes in force of that magnitude and measure it?

6. What is the rough distance between atoms in a material?

7. Does the size of the probe tip affect the resolution of the image?

8. If you want to actually scan a surface and produce atomic level resolution images, how should your probeware be?

**Assessment and Project**

Scanning probe microscopy can also measure changes in other local properties like conductivity, electric potential or charge distribution, etc. Design a 2-D surface model which shows a gradient of one of the electrical properties as mentioned above. Use strips of aluminum foil to make your design if you are studying conductivity. Use different shapes of electrodes given if you are studying electric potential distribution. Design a suitable probe to measure the change in property and test the model and probe and summarize your results. Follow the assessment grading rubric for making the best possible design of the surface and the probe.

**Project Guidelines:**

Use A4 size surface to do the electric field mapping
Choose shape and orientation of electrodes for which you can clearly visualize the electric field pattern.
Use metallic paint to draw your electrodes and suitable values of potential.
Start with a plan of action for designing your surface with gradient in electric potential
characteristics and the method of data collection.

**Assessment rubric**

**Project: Design and mapping equipotential lines and electric field**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
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<tbody>
<tr>
<td><strong>Scientific Knowledge</strong></td>
<td>Explanations by all group members indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.</td>
<td>Explanations by all group members indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.</td>
<td>Explanations by most group members indicate relatively accurate understanding of scientific principles underlying the construction and modifications.</td>
<td>Explanations by several members of the group do not illustrate much understanding of scientific principles underlying the construction and modifications.</td>
</tr>
<tr>
<td><strong>Plan</strong></td>
<td>Plan is neat with indication of choice of electrodes and their positioning and potential applied.</td>
<td>Plan is neat with a rough indication of choice of electrodes and their positioning and potential applied.</td>
<td>Some evidence of a plan is available but not clear on the choice of electrodes and their positioning and potential applied.</td>
<td>No evidence of prior planning relative to the choice of electrodes and their positioning and potential applied.</td>
</tr>
<tr>
<td><strong>Construction - Materials</strong></td>
<td>Appropriate materials were selected and creatively modified in ways that made them even better.</td>
<td>Appropriate materials were selected and there was an attempt at creative modification to make them even better.</td>
<td>Appropriate materials were selected.</td>
<td>Inappropriate materials were selected and contributed to a product that performed poorly.</td>
</tr>
<tr>
<td><strong>Data Collection</strong></td>
<td>Data taken several times in a careful, reliable manner. Several equipotential lines traced so as to make electric field mapping easy and as accurate as possible.</td>
<td>Data taken twice in a careful, reliable manner. Enough equipotential lines traced so as to make electric field mapping possible.</td>
<td>Data taken once in a careful, reliable manner. Equipotential lines traced correctly but not enough to map out electric fields.</td>
<td>Data not taken carefully OR not taken in a reliable manner. Equipotential lines not traced correctly enough to make electric field mapping possible,</td>
</tr>
<tr>
<td><strong>Modification/Testing</strong></td>
<td>Clear evidence of troubleshooting, testing, and refinements based on data or scientific principles.</td>
<td>Clear evidence of troubleshooting, testing and refinements.</td>
<td>Some evidence of troubleshooting, testing and refinements.</td>
<td>Little evidence of troubleshooting, testing or refinement.</td>
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Summary:
The hands on experience in scaling the topography with the first model, the field trip and the discussion and analysis will acquaint the learner with a good knowledge of the fundamental principles of scanning probe microscopy. Problem solving and getting to design the model in the project using given guidelines will help them think and trouble shoot on their own to work on extending the principles of surface analysis.

Internet research on future applications of nanotechnology and ethics in this field can be assigned as homework followed by classroom discussion on the same.