IMAGING AT NANO SCALE
USING AFM & SEM

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INTRODUCTION:

Everything on Earth is made up of atoms— the food we eat, the clothes we wear, the buildings and houses we live in and our own bodies. But something as small as atoms are impossible to see with naked eye.

Scientists have been studying and working with nano particles for centuries, but the effectiveness of their work has been hampered by their inability to see the structure of nano particles. In recent decades development of microscopes capable of displaying particles as small as atoms has allowed scientists to see what they are working with. The microscopes needed to see things at nano scale are invented relatively recently about 30 years ago.

Once scientists had the right tools, such as scanning electron microscope (SEM) and the atomic force microscope (AFM) the effective age of nanotechnology started, scientists began to see things at nano scale. But what’s so special about nano scale?

The main interesting fact is that at nano scale the properties of material change significantly. Properties such as melting point, optical property, electrical conductivity, magnetic property, and chemical reactivity change. Accordingly nanotechnology draws significant attention to the scientific community. However to deal with nano dimension it is important to visualize and manipulate the materials/devices having nano dimension. Accordingly there is a need of powerful microscopes capable of visualizing nano dimension.

OPTICAL MICROSCOPE:

Microscope is used to see small objects which can’t be seen with naked eye. In science it is used as an instrument to investigate objects with dimension less than 0.1 mm. The common type of microscope is optical microscope. The main principle of this microscope is magnification of small object through series of lenses. The magnification of a optical microscope with visible light is about 1250× and theoretical limit of resolution is 250 nanometres.

LIMITATION OF OPTICAL MICROSCOPE:

Any object which is smaller than half of the wavelength of light which is used in an optical microscope, could not be visible by the optical microscope. In an optical or light microscope visible light is used to see the object. Visible light has fixed range of wavelengths. The range of the visible light is 400nm-700nm. So for an object below the length of 200nm, the optical microscope is not useful. To study and visualize smaller object less than 200nm, special arrangement is required.
Atomic force microscopy (AFM) is a very high resolution type of microscopy, with demonstrated resolution of the order of fractions of a nanometer, more than 1000 times better than the optical diffraction limit. It was invented by IBM scientist Gerd Bining in 1982.

The AFM has three major abilities- force measurement, imaging and manipulation at nano dimension.

In force measurements, AFMs can be used to measure the forces between the probe and the sample as a function of their mutual separation. This can be applied to perform force spectroscopy to measure the mechanical properties of a sample, such as at nanoscale.

For imaging, it can be used to form an image of three dimensional topography of a sample surface with high resolution. The image taken is reconstructed in the computer screen. This is

### FIG 1: RESOLVING POWER

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For imaging, it can be used to form an image of three dimensional topography of a sample surface with high resolution. The image taken is reconstructed in the computer screen. This is
achieved by scanning the position of the sample with respect to the tip and recording the height of the probe. The surface topography is commonly displayed as pseudo color i.e., false color plot.

In manipulation, the forces between tip and sample can also be used to change the properties of the sample.

Also other properties of the sample can be measured locally and displayed as an image. For example, mechanical properties like stiffness or adhesion strength and electrical properties like conductivity or surface potential, etc.

PRINCIPLE:

Atomic Force Microscope consists of many parts. One of the important part is cantilever with a tip on its head. To study and image the topological surface of a material, the tip of the cantilever is fixed with the material, which have different modes, and a constant force hold the cantilever. As the tip touches the surface of the sample it goes up and down or oscillates due to some changes on surface of the sample. When cantilever bent for the rough surface of the sample then the force on the cantilever also changes accordingly.

A laser beam is reflected from the surface of the cantilever to a mirror. Due to the changes on surface of material when cantilever bents the reflected laser beam also changes its previous position. From the reflected laser beam one can compute the topological picture through imaging techniques of it.

FIG 2: BLOCK DIAGRAM OF AFM
CONFIGURATION:

Atomic force microscope consists of few parts. Those are—piezoelectric element, cantilever with a tip, laser, photodiode, detector.

Piezoelectric Element:- This part is used here to hold the cantilever. It is made of ceramic material. Its size is in micrometer order. It is used to hold the cantilever near the sample to touch the sample surface with the tip of it and complete the imaging process of the sample used.

Cantilever: - This part holds the tip or probe. It carries the tip part to sample surface and helps the probe in imaging process with different mode of touching. Its size is generally in micrometer order. It is made of soft material which can be bent accordingly with the surface of the material used.

Tip: - This is the short part which is attached with cantilever and in generally it has size from few nm to tens nm. This part is made of silicate, borosilicate or silicon nitride. This part helps us to scan the surface of the material used. This part contacts with the surface of material with different modes and helps in imaging.

Laser: - It is a source of incoherent monochromatic light. Here it falls on the top of cantilever. When the tip of cantilever touches the surface of sample or it vibrate from its mean position then the laser light reflects to another position from the previous one and it makes different curve of showing its properties.

Photodiode Detector: - The reflected laser beam falls on it and it detects the change in the intensity and position of the reflected beam. According to this data the information about the properties of the sample is collected.
**DETECTION**: The process of detection of the surface of the sample with the tip of the cantilever and detection of the reflected beam is discussed here. It has three type of mode for detection. The modes are: contact mode, non-contact mode and tapping mode.

**Contact mode**: When the tip of cantilever is in contact with the sample and deflection of cantilever is kept constant, then it is contact mode. In case of low stiffness and low spring constant of the tip these mode is used. As here the tip gets very close to the surface in case of strong attractive force of the sample, tip can interact with the sample. So where the overall force on sample is repulsive there it can be used i.e, for solid surface.

**Non-Contact mode**: In this mode the cantilever does not touch the sample surface. Here the cantilever oscillates with a resonant frequency of amplitude of few nano metre to pico metre or just above the sample. In those cases where the Van der waals force is strong or any other attractive force is present also above the surface of the sample there this mode is used. Here for the presence of this force change in oscillating frequency of the cantilever is occurred and this also changes the tip to sample distance. By measuring tip to sample distance for each point the topographic image is produced.

**Tapping mode**: In ambient condition many sample makes a meniscus layer. In contact mode, to detect the surface of the sample the tip of the probe can stick into for strong attractive force. In this situation to overcome this problem dynamic contact mode or tapping mode is introduced.

In tapping mode the cantilever oscillates with its resonant frequency. When it gets closer to the surface of the sample it gets affected by the forces of the sample like Van der waals force,
electrostatic forces, dipole-dipole interactions. Due the presence of this forces the amplitude and frequency of the oscillation of cantilever gets changed. The AFM image is produced by imaging force of the intermittent contacts with the tip of the probe and the surface of the sample.

In tapping mode the damage is much less compared to the contact mode. Because in this process the time of touching the sample is much less and applied force is much less over time. Due to this reason this is also applicable for imaging of monolayer or bi-layer substances.

**IMAGE FORMATION:**

Using the laser ray which is reflected from the surface of the cantilever, image is formed. The difference in force of the cantilever and on the surface of the sample is measured here for AFM imaging. This force is not measured directly but calculated knowing the stiffness of the cantilever.

From Hooke’s law we know \( F = -KZ \), where \( F \) is the force, \( K \) is the stiffness and \( Z \) is the distance of the bent of the cantilever is bent.

![Force vs Probe Distance Curve](image)

**FIG 5: FORCE VS PROBE DISTANCE CURVE**

To get the topographic image feedback loop is used here to fix the position of cantilever to its initial position and measuring its actual displacement. When the cantilever’s probe touches the surface it is effected by the attractive surface force. Then more potential energy is applied on it and the tip comes to its initial position. By the change of its position we get reflected laser beam at another position from its initial one and we can draw the graph of force vs probe position or distance. From this graph we can compute many properties of the sample.
Applications in the field of physics include (a) the identification of atoms at a surface, (b) the evaluation of interactions between a specific atom and its neighbouring atoms, and (c) the study of changes in physical properties arising from changes in an atomic arrangement through atomic manipulation.

There are several applications using advanced imaging modes that are used for measuring various properties of a material. For example – MFM, EFM, SThM, C-AFM, FMM, SCM etc. A brief description of these application modes are given below.

1. **Topographic imaging:** Now a days 90% of the scientists use AFM to study the surface morphology of a material. It can be used for high resolution imaging of thin film of clay, ionic domains, crystal morphology, etc.
   We have done topographic imaging of thin film of hectorite clay mixed with methanol using AFM.

2. **Magnetic Force Microscopy (MFM):** In MFM the probe tip is coated with ferromagnetic thin film. While scanning it is the magnetic force that induces changes in the cantilever resonance frequency or phase. MFM is secondary imaging mode where two properties-topography and another selected property (magnetic force, electric force etc.) are measured separately. During the 1\textsuperscript{st} pass the topographical information is obtained. During the second pass the topographical information is used to move the probe tip along the same track but keep it at a constant height above the sample surface as determined during the 1\textsuperscript{st} pass.
   A group of 17 researchers has used MFM technique to study the magnetic properties of materials and systems of biological and biomedical interests like magnetoferritin, magnetic nano particles etc in cells\textsuperscript{(1)}
3. **Electrostatic force microscopy (EFM):** In EFM, a voltage bias is applied to the probe tip. While scanning the cantilever resonance frequency or phase is influenced by the ‘tip to sample separation’. The influence of electrostatic force is measured using the principle of force gradient detection.

EFM is also a secondary imaging mode derived from Tapping Mode imaging and performed using two pass technique. The 1st scan measures the Van der Walls forces that are always present between the tip and the sample, and it enables the basic topography of the surface to be mapped. When there is an interaction, the change in the position of the cantilever is recorded by a laser beam deflecting off the cantilever onto a position-sensitive photodiode (PSPD). This position location mechanism is also present throughout the second scan (to locate the different interactions) to enable the topography of the surface and areas of intermolecular attraction/repulsion to be mapped and correlated.

Shaohua Xu and Mortan F. Arndorf from University of Chicago used EFM for probing surface charges in aqueous solutions. Lysozymes, DEAE- Sephadex beads, 3-propyltriethoxysilane - treated glass and mica were imaged in water or phosphate buffer with electrostatic force microscopy. (2)
4. **Scanning Thermal Microscope (SThM):** The scanning thermal microscopy is an imaging mode which provides the capability of imaging thermal conductivity using conductivity contrast mode) and sample temperature (using temperature contrast mode). The principal component of SThM package is a thermal probe with resistive element. Thermal monitoring and control are done by the Thermal Control Unit(TCU).

In conductivity contrast mode the thermal probe is kept at a constant temperature. Changes in sample thermal conductivity affect the heat flow between the self heating probe and sample. This heat is monitored by measuring the voltage necessary to maintain a constant probe temperature.

In temperature contrast mode temperature is monitored using a bridge circuit to measure the probe resistance.

Facundo Ruiz, W.D. Sun and Fred H. Pollak determined the thermal conductivity of diamond like nanocomposite films deposited on Si substrate using a scanning thermal microscope. \(^{(3)}\)

5. **Conductive AFM(C-AFM):** It is a secondary imaging mode derived from Contact Mode that characterizes conductivity variations across semiconducting materials and across conducting or semiconducting material covered with a thin dielectric layer (on the order of a nanometer). C-AFM employs a conductive probe tip. Typically a DC bias is applied between the tip and the sample.
While the Z feedback signal is used to generate a normal contact mode topography image, the current passing between the tip and sample is measured to generate the conductive AFM image which shows the conductivity variations of the materials undertest. Onofrio Pirrotta, Luca Larcher, Mario Lanza, Andrea Padovani, Marc Porti, Montserrat Nafr and Gennadi Bersuker investigate the role of grains and grain boundaries (GBs) in the electron transport through poly-crystalline HfO$_2$ by means of conductive atomic force microscopy (CAFM) measurements. CAFM experiments demonstrate that the leakage current through a thin dielectric film preferentially flows via the GBs.\(^{(4)}\)

**FIG 9: 500 nm x 500 nm topographic map on the polycrystalline HfO$_2$ stack**

**SAMPLE EXPERIMENT PERFORMED DURING THIS PROJECT WORK:**

**Preparation:**
1. We take a coverslip and clean it with chloroform.
2. We take a petridish and firstly wash it with detergent. Then we wash the petridish by putting chromic acid in it for 10 minutes.
3. Now we keep the petridish and a small beaker in the oven at 100°C for 24 hours to dry.

**Sample preparation:** we measure 1mg of hectorite clay using spring balance. Then we mix the hectorite clay with 100ml methanol (10ppm). Then we put the prepared sample in a magnetic stirrer for 24 hours so that the clay mixes with Methanol properly.

**Film deposition:** we put the coverslip in the spin coating instrument and pour the prepared sample drop by drop using a dropper. The coverslip spins and forms a thin layer of the sample. We repeat this technique again and again to form a thin film of the hectorite clay on the coverslip. The coverslip rotates inside the instrument in a particular speed for a
particular time (say speed = 100rpm, Time = 60 sec) which is set by us. Then the imaging is done under AFM.

**FIG: IMAGES TAKEN USING AFM**
**DISADVANTAGES:**

The few disadvantages of AFM are as follows:

1. The AFM can only image an area of about 150 X 150 micrometers and a maximum height of 10-20 micrometers. Compared to SEM which we will study in the next chapter, it can image an area of square millimetres.

2. The AFM takes several meaning for a single scan. The slow rate of scanning during AFM imaging often leads to thermal drift in the image making the AFM less suited for measuring accurate distances between topographical features on the image.

3. Sensitivity of ~0.01 Å, but extremely sensitive to surface conditions.
SCANNING ELECTRON MICROSCOPE (SEM)

OVERVIEW OF ELECTRON MICROSCOPE:

An electron microscope is a microscope that uses a beam of accelerated electrons as a source of illuminating radiation to create an image of the target. It has much higher magnification or resolving power than normal light microscope. A few things that are different in electron microscopes than ordinary microscopes are-

- The light source is replaced by a beam of very fast moving electrons.
- The specimen usually has to be specially prepared and held inside a vacuum chamber from which the air has been pumped out (because electrons do not travel very far in air).
- The lenses are replaced by a series of coil-shaped electromagnets through which the electron beam travels. In an ordinary microscope, the glass lenses refract the light beams passing through them to produce magnification. In an electron microscope, the coils bend the electron beams the same way.
- The image is formed as a photograph (electron micrograph).

There are two main types of electron microscope – The transmission EM (TEM) and the scanning EM (SEM). The transmission electron microscope is used to view tissue sections, molecules, etc through which electrons can pass generating a projection image. The TEM is analogous in many ways to the compound light microscope. TEM is used to image the interior of cells, the structure of protein molecules, the organization of molecules in virus, and the arrangement of protein molecules in cell membranes, etc.

Scanning electron microscopy depends on the emission of secondary electrons from the surface of a specimen. Because of its great depth of focus a SEM provides detailed image of the surfaces of cells and whole organisms that are not possible by TEM. In the next sections we will study SEM in details.

ABOUT SEM:

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The electron beam is scanned and the position of the beam is combined with the intensity of the detected signal to produce an image. Since the wavelength of electron is much smaller than the wavelength of light, the resolution of SEMs is
better to that of a light microscope. Specimens are observed in high vacuum in a conventional SEM.

**Fig10: Schematic diagram of scanning electron microscope**

**CONFIGURATION:**

A scanning electron microscope is a complicated instrument. It takes a high amount of precision to manipulate a beam of electrons to create these detailed magnified images. However, as complicated as the microscope is, it can be broken down into several parts:

**Electron Gun:** The first part of the SEM is the electron gun. An electron gun fires electrons at the sample which is to be magnified. The electrons can be created a few different ways, but the most common method heats up a tungsten wire to produce the electrons.

**Condenser Lens:** The second part of an SEM is the condenser lens. This is used to narrow the electron beam given off by the electron gun. It is a lens made of coils of wire that create an electromagnetic field which compresses the electrons as they travel through it.

**Apertures:** Apertures allow you to control the diameter of the electron beam being passed through them. The aperture consists of a metal rod with different size holes cut into it. The diameter of the electron beam is controlled by changing which hole it travels through. The aperture also blocks off any extra electrons that didn't get fully condensed into the beam from hitting the sample.
Objective Lens and Sample Chamber: After the apertures is another electromagnetic lens called the objective lens. This is the final lens that focuses the electron beam down onto the sample.

Once passing through the objective lens, the electron beam passes into the sample chamber. This chamber holds the sample under a vacuum to eliminate interference of unwanted particles. The target itself needs to be conductive to prevent charging, and allow for better image quality. If the target isn't made of a naturally conductive material it can be coated in one, such as gold.

Detectors: Finally, there are the detectors. These are used to create magnified images, and collect other data. What they detect are the various signals given off by the sample as it is struck by electrons from the beam scanning over it. These signals include secondary electrons, backscattered electrons, and x-rays among others.
**PRINCIPLE:**

The basic principle is that a beam of electrons is generated by a suitable source, typically a tungsten filament or a field emission gun. The electron beam is accelerated through a high voltage and pass through a system of aperture and electromagnetic lenses to produce a thin beam of electrons.

When the accelerated primary electrons strikes the sample, then the surface of the specimen it produces secondary electrons. These secondary electrons are collected by a positive charged electron detector which in turn gives a 3-dimensional image of the sample.

**SCANNING PROCESS AND IMAGE FORMATION:**

In SEM, an electron beam is emitted from an electron gun fitted with a tungsten filament cathode. Tungsten is normally used because it has the highest melting point and lowest vapor pressure of all metals, thereby allowing it to be electrically heated for electron emission. The electron beam, which almost has an energy ranging from 0.2 keV to 40 keV, is focused by one or two condenser lenses to a spot about 0.4 nm to 5 nm in diameter. The beam passes through pairs of scanning coils or pairs of deflector plates in the electron column, typically in the final lens, which deflect the beam in the x and y axes so that it scans in a raster fashion over a rectangular area of the sample surface.

When the primary electron beam interacts with the sample, the electrons lose energy by repeated random scattering and absorption within a teardrop-shaped volume of the specimen known as the interaction volume, which extends from less than 100 nm to approximately 5 µm into the surface. The size of the interaction volume depends on the electron's landing energy, the atomic number of the specimen and the specimen's density. The energy exchange between the electron beam and the sample results in the reflection of high-energy electrons by elastic scattering, emission of secondary electrons by inelastic scattering and the emission of electromagnetic radiation, each of which can be detected by specialized detectors.

The beam current absorbed by the specimen can also be detected and used to create images of the distribution of specimen current. Electronic amplifiers of various types are used to amplify the signals, which are displayed as variations in brightness on a computer monitor. Each pixel of computer video memory is synchronized with the position of the beam on the specimen in the microscope, and the resulting image is a distribution map of the intensity of the signal being emitted from the scanned area of the specimen. Older microscopes captured images on film, but most modern instrument collect digital images.
DETECTION AND MAGNIFICATION:

Detection:

When the electron beam interacts with a sample in a scanning electron microscope, multiple events happen. Different detectors are needed to distinguish secondary electrons, backscattered electrons, or characteristic x-rays. Depending upon the accelerating voltage and sample density the signals come from different penetration depths.

After Auger electrons, the secondary electrons come from the next most shallow penetration depth. A secondary electron detector (SED) is used to produce a topographic SEM image. SED images have high resolution that are independent of the material and is acquired from scattered electrons close to the surface. No material composition information is available.

Backscatter electron detector (BSD):

In scanning electron microscopy (SEM), samples are imaged using a focused electron beam that is scanned across a surface. Different types of electrons are emitted from samples. A backscatter electron detector (BSD) detects elastically scattered electrons. These electrons are higher in energy from atoms below the sample surface. Using a BSD allows for lower vacuum levels, reducing sample preparation requirements and minimizing beam damage.

Backscattered electrons vary in their amount and direction due to the composition and topography of the specimen. The contrast of the backscattered electron image depends on multiple factors, including the atomic number (Z) of the sample material, the acceleration voltage of the primary beam and the specimen angle (tilt) with relation to the primary beam.

Materials with elements composed of a higher atomic number (Z) yield more backscattered electrons than lower Z elements.

Energy dispersive spectroscopy:

In scanning electron microscopy, an x-ray is emitted when the electron beam displaces an inner shell electron that is replaced by an outer shell electron. Because each element has a unique energy difference between outer and inner electron shells, the x-rays that are detected yield an elemental identification. EDS data can be obtained at a point, along with a line or mapped over an area.

Sample structures can be physically examined and their elemental composition determined. Viewing three-dimensional images of microscopic structures only solves half the problem when analyzing samples. It is often necessary to collect more than imaging data to be able to identify
the different elements in a specimen. Using EDS with SEM addresses this need for elemental analysis.

**Secondary electron detector (SED):**
A secondary electron detector (SED) for scanning electron microscopy offers images with resolution independent of the material. An SED image uses the in-elastically-scattered electrons close to the sample surface for topographical information.

- **Magnification:**

No optical transformation is responsible for image magnification in the SEM. Magnification is achieved by scanning an area on the specimen which is smaller than the display. Since the monitor length is fixed increase or decrease in magnification is achieved by respectively reducing or increasing the length of the scan on the specimen. For accurate magnification measurements a calibration is necessary.

Magnification in the SEM depends only on the excitation of the scan coils and not on the excitation of the objective lens, which determines the focus of the beam. The magnification of the SEM image is changed by adjusting the length of the scan on the specimen ($L_{\text{spec}}$) for a constant length of scan of the monitor ($L_{\text{mon}}$), which gives the linear magnification of the image ($M$). The numerical value of magnification is determined by the ratio of length of the scan on the sample,

$$M = \frac{L_{\text{mon}}}{L_{\text{spec}}}$$
**APPLICATIONS:**

In Scanning Electron Microscope, strong electron beam is used for high resolution of 3D imaging of a sample. It provides some information of sample like- Topography, Morphology, Composition.

- **Forensic Investigation-** Scanning Electron Microscopy is used in large area of forensic sciences. It is used to examine fibres, nail, hair, paint, metal particle etc, which is found in the crime region. SEM with X-ray detector is used to provide and compute the analytical data of the topographical details of the postmortem samples.

![FIG12: SEM IMAGE OF CABLE](image)

- **Biological Science-** In scanning electron microscope, various modes of specimen signal of acquisition is present here. So we get the morphological and analytical studies of the sample used. The advantages of SEM is the enriched information we get from the image and its high resolution. From the paper of scientist P.echlin we can tell that the simple preparative technique involved coupled with the versatility and controlled sensitivity of the stage modules allows rapid visualization of the specimens. (6)

![FIG 13: SOME IMAGES USING SEM](image)
o **Soil and Rock Sampling-**

Scanning electron microscope is also used for identification of heavy metals in crystals of sand and silts fraction of soils. Araína Hulmnn Batista, Vander Freitas Melo, Robert Gilkes and Malcolm Roberts studies that heavy metals are concentrates in clay fractions but coarser fractions of the soils are significant source of heavy metals. They aim to evaluate the occurrence of heavy metals in the structure of minerals in the sand and in the silts fractions of the soils.\(^{(7)}\)

![FIG 14: SEM IMAGE OF ROCKS SAMPLE](image-url)

o **Medical Sciences-**

1) EDS part of SEM shows the variation in chemical composition acquiring chemical maps or spot the chemical analyses.

2) Here we can use fully hydrated, unfixed microbes for 3D imaging without proper conventional sample preparation methods. The images have high resolution and area of the images also high.

3) According to scientist Pedro Mestres –\(^{(8)}\)

The relation to adhesion of bacteria with surfaces in ultra-structure of flagella is much discussed topic nowadays. The formation of proteinaceous is also observed with SEM. The attachment of cells to the surface and in a cell cycle the changes of the cell with the variation of cell adhesion can be observed with SEM precisely.

The renowned neurologist Jeff Lichtman proved with SEM the synaptic competition within brain by which one can generate the direction and branching of the synapse in which the information passes.
Entomology and taxonomy-

From the research paper of U.G.A.I. Sirisena, G.W. Watson, K.S. Hemachandra, O. Sage and H.N.P. Wijayagunasekara--- \(^9\)

SEM is used to study accurate morphological structure of very small cuticle of insects. On a research paper about bug species different wax secretion pores is observed through SEM. By preparing the each type of insects of the species and examining it the differences can be showed. With this detailed information of the morphology and wax glands of the species, bug taxonomy is enriched.
**DISADVANTAGES:**

1) The space of the chamber of SEM is limited. So some material does not fit inside it. The maximum horizontal size of it is of the order 10cm and vertical dimension is of the order of few milimeter (40 mm).

2) EDS detector in SEM can’t detect very light element like H, He, Li etc.

3) The sample which is used must be electrically insulated. So the sample is applied to electrically conductive coating unless the instrument is capable of operation in low vacuum mode.

4) Most SEM use solid state X-ray detector which is very fast and easy to utilize. But they have poor energy resolution and sensitivity to element present in low abundances.

**CONCLUSION:**

In this project we have studied about the two imaging instruments AFM & SEM, which is used to observe substances at nano dimension. We have also deposited a thin film of clay-hectorite using spin coating technique and produce images under AFM. So far we have seen that both AFM & SEM, beyond measuring sample topography, SEM can measure the chemical composition and morphology of the sample with high resolution and can generate 3D imaging of the sample. AFM can also measure surface physical properties such as magnetic field, surface potential, surface temperature, friction and many other physical properties. As ordinary optical microscope has many limitation on imaging at nano scale so these instruments are so powerful tools in this regime. These are extremely useful for scientists and researchers from all over the world and in many different branches (medical, forensic, biological, industrial work) who wants to measure incredibly small samples with great degree of accuracy.
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