Journal of Advances in Applied Sciences and Technology
ISSN : 2393-8188 (print)
2393-8196 (online)
www.milliyasrcollege.org.journal.php

THE MICROSCOPY CHARACTERIZATION TECHNIQUES FOR NANOMATERIALS

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ABSTRACT:

The nanotechnology is considered to be the key technology for current century. It also shows promising applications in the field like biology, physics, material science, chemistry and earth science. The challenges to scientists and technologists are characterizing these nano size materials. This paper discusses the basic theory of the characterization techniques such electron microscopy (SEM/TEM/STM) in the field of nanotechnology.

KEYWORDS: Nanotechnology, electron microscopy, nano size materials.

1. INTRODUCTION

The nanotechnology can be defined as the manipulation, precision-placement, modeling and manufacture of material at the nanometer scale (10^{-9})[1]. Hence nanotechnology is also called the science of making things very small. The electron microscopy has been a valuable tool in the development of scientific theory. Electron Microscopes are scientific instruments that use a beam of highly energetic electrons to examine objects on a very fine scale. This examination can yield information about the topography (surface features of an object), morphology (shape and size of the particles making up the object), composition (the elements and compounds that the object is composed of and the relative amounts of them) and crystallographic information (how the atoms are arranged in the object). Electron microscopy were developed due to the limitations of light microscopes. The Transmission Electron Microscope (TEM) was the first type of Electron Microscope to be developed and is patterned exactly on the Light Transmission Microscope except that a focused beam of electrons is used instead of light to "see through" the specimen.

Though the principles of all techniques (SEM/TEM) are different but one common thing is that they produce high magnified image of the surface or bulk of the sample. The nonmaterial’s can only be observed through these imaging techniques as human eye as well as optical microscope cannot be used to see dimensions at nano level.

2.CHARACTERIZATION BY MICROSCOPY

2.1 SCANNING ELECTRON MICROSCOPY (SEM)

The scanning electron microscope[2] shown in fig.1 is an electron microscope that images the sample surface by scanning it with a high energy beam of electrons. Conventional light microscopes use a series of glass lenses to bend light waves and create a magnified image while the scanning electron microscope creates the magnified images by using electrons instead of light waves.

2.1.1 BASIC THEORY

In SEM, a source of electrons is focused in vacuum into a fine probe that is rastered over the surface of the specimen. The electron beam passes through scan coils and objective lens that deflect horizontally and vertically so that the beam scans the surface of the sample. As the electrons penetrate the surface, a number of interactions occur that can result in the emission of electrons or photons from or through the surface. A reasonable fraction of the electrons emitted can be collected by appropriate detectors, and the output can be used to modulate the brightness of a cathode ray tube (CRT) whose x- and y- inputs are driven in synchronism with the x-y voltages rastering the electron beam. In this way an image is produced on the CRT; every point that the beam strikes on the sample is mapped directly onto a corresponding point on the screen[3]. As a result, the magnification system is simple and linear magnification is calculated by the equation:

$$M = L / l$$

where L is the raster's length of the CRT monitor and l the raster's length on the surface of the sample.

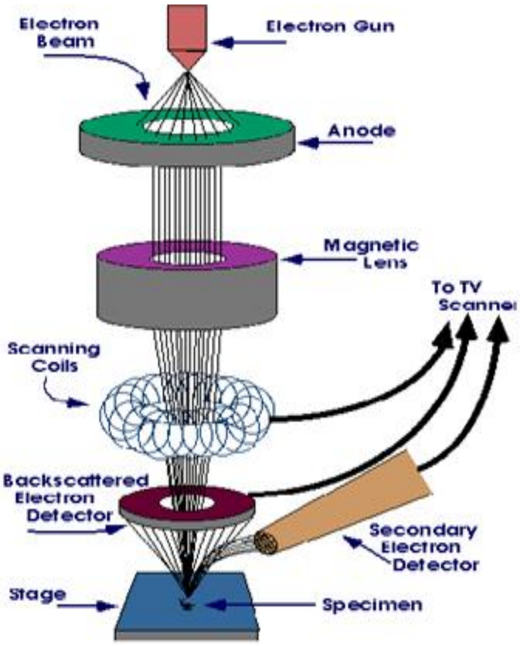

Fig.1. *Geometry of SEM*

SEM works on a voltage between 2 to 50kV and its beam diameter that scans the specimen is 5nm-2µm. The principle images produced in SEM are of three types: secondary electron images, backscattered electron images and elemental X-ray maps. Secondary and backscattered electrons are conventionally separated according to their energies. When the energy of the emitted electron is less than about 50eV, it is referred as a secondary electron and backscattered electrons are considered to be the electrons that exit the specimen with an energy greater than 50eV[4].Detectors of each type of electrons are placed in the microscope in proper positions to collect them.

2.2 TRANSMISSION ELECTRON MICROSCOPY (TEM)

The transmission electron microscope is shown in Fig.2. is a technique where an electron beam interacts and passes through a specimen. An image is formed from the electron transmitted though the specimen magnified and focused by an objective lens and appears on an imaging screen.

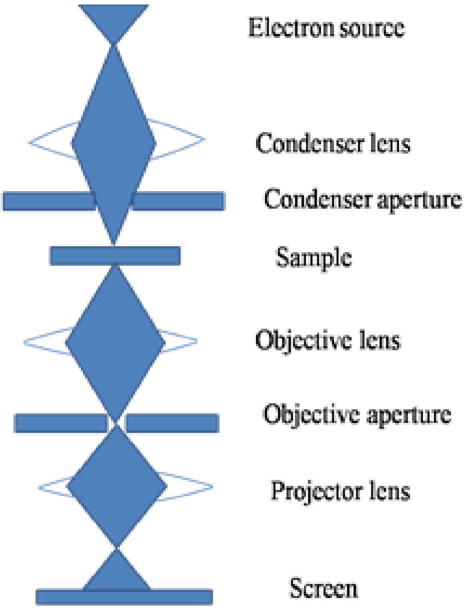

Fig.2. *Transmission Electron Microscope with all of its components.*

2.2.1 BASIC THEORY

The electron beam is confined by the two condenser lenses which also control the brightness of the beam, passes the condenser aperture and "hits" the sample surface. The electrons that are elastically scattered consist the transmitted beams, which pass through the objective lens. The objective lens forms the image display and the following apertures, the objective and selected area aperture are used to choose of the elastically scattered electrons that will form the image of the microscope. Finally, the beam goes to the magnifying system that is consisted of three lenses, the first and second intermediate lenses which control the magnification of the image and the projector lens. The formed image is shown either on a fluorescent screen or in monitor or both and is printed on a photographic film.

2.3 SCANNING TUNNELING MICROSCOPY (STM)

Scanning tunneling microscopy[5] is an instrument for producing surface images with atomic scale lateral resolution, in which a fine probe tip is scanned over the surface of conducting specimen, with the help of piezoelectric crystal at a distance of 0.5 to 1 nm, and resulting tunneling current or the position of the tip required to maintain a constant tunneling current is monitored.

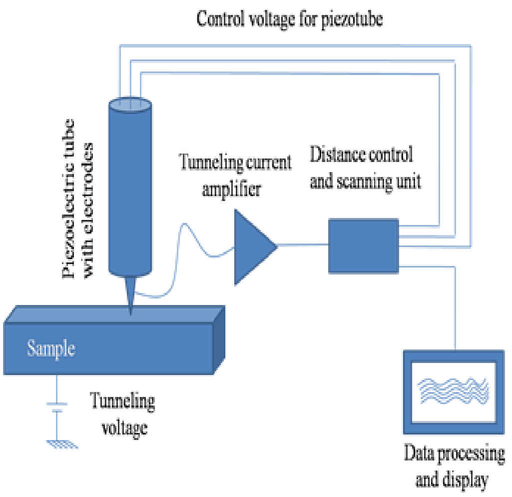

Fig.3. *Scanning Tunnelling Microscopy*

2.3.1 BASIC THEORY

The STM principle is based on the concept of quantum tunneling. When conducing tip is brought very near to metallic or semiconducting surface, a bias between two can allow electrons to tunnel through the vaccum between them. For low voltages, this tunneling current is a function of the local density of states at the Fermi level of the sample. Variations in current as the probe passes over the surface are translated into an image. For STM, 0.1 nm lateral resolution and 0.001 nm depth resolution is considered as good resolution. Normally images generated by holding the current between the tipoff the electrode and the specimen at some constant value by using a piezoelectric crystal to adjust the distance between the tip and the specimen surface. The STM can be used not only in ultra high vacuum but also in air and various other liquid or gas, at ambient and wide range of temperatures. Also it requires extremely clean surface and sharp tips.

3. CONCLUSION

The quality and information derived through these techniques depends on understanding of the user, sample preparation accuracy. The characterization techniques for nanomaterials are very efficient. The SEM shown image at much high magnified as compared to light microscope. The SEM techniques can also be used to view dispersion of nanoparticles. The Tem is used widely both in material science and biological science. STM is a powerful tool in nanotechnology and nanoscience providing facilities for characterization and modification of variety of materials. Also this is used to detect and characterize the materials.

ACKNOWLEDGEMENT

The authors would like to thank their respective societies for encouragement.

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