non-degenerate state.

Example:

For $n_x = 3;\ n_y = 3\ ;\ n_z = 3$

$$E_{333} = \frac{27\,h^2}{8\,ma^2} \text{ and } \Psi_{333} = \sqrt{\frac{8}{a^3}} \sin\frac{3\pi x}{a} \sin\frac{3\pi y}{a} \sin\frac{3\pi z}{a}$$

3.16 MICROSCOPE

Microscope is an instrument used to view the magnified image of a smaller object. Generally microscopes are classified into simple and compound microscopes. In a simple microscope only one lens is used but in compound microscope two or more lenses are used.

Further they are classified into metallurgical microscope, electron microscope, ultraviolet microscope, etc.

Basic definitions of microscope

(i) Magnifying Power

The magnifying power (M) of a microscope is defined as the ratio between the angles subtended by the final image at the eye to the angle subtended by the object at eye placed at the near point.

$$M = \frac{\text{Angle subtended by the final image at eye } (\beta)}{\text{Angle subtended by the object at eye placed at the near point } (\alpha)}$$

$$M = \frac{\beta}{\alpha}$$

(ii) Resolving Power

It is the ability of an optical instrument to form distinct and separable images of the two point objects which are close to each other.

If *'d'* is the least distance between two close point objects then we can write

$$d = \frac{\lambda}{2\ N.A}$$

$$\text{Resolving power} \quad \frac{1}{d} = \frac{2\ N.A}{\lambda}$$

Where N.A. is the Numerical Aperture of the microscope and λ is the wavelength of light through vacuum.

An optical microscope can resolve only a few hundreds of nanometer separation and the magnification is about 2000x.

3.17 ELECTRON MICROSCOPE

It is an instrument that uses highly energetic electron beam to examine a very small specimen.

Principle: The high energy electron beam is allowed to fall over the specimen and image formed due to the transmitted electron beam from the specimen is examined.

Construction

Essential parts of the electron microscope

i) An electron source
ii) Electro magnetic lenses
iii) Metal aperture
iv) Object holder
v) Screen

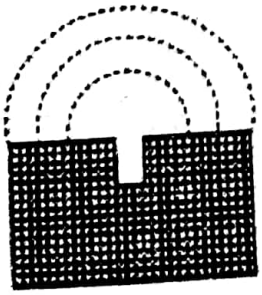

Fig. 3.13

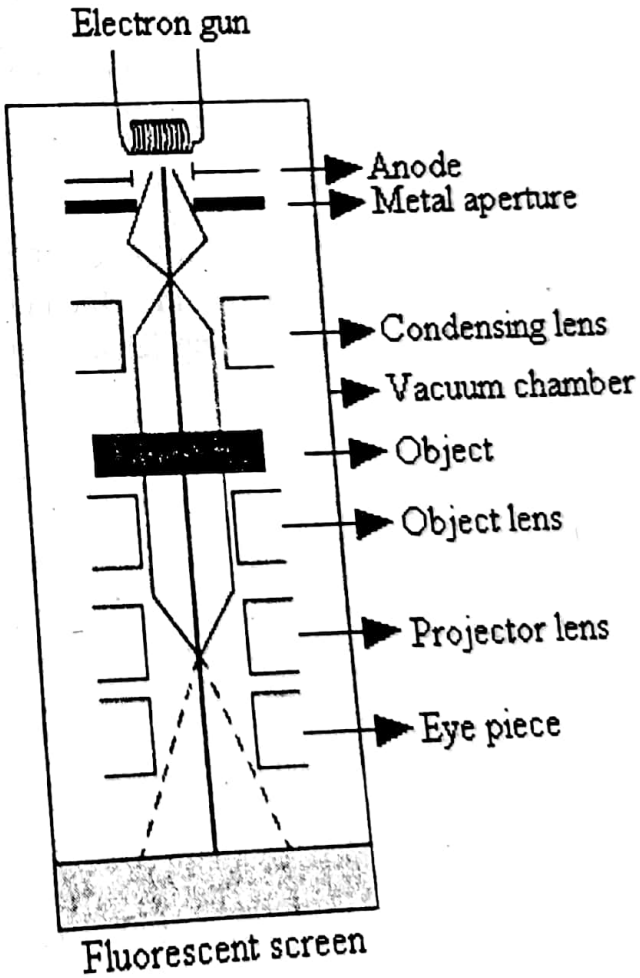

Fig. 3.14

Description

Electron gun is made of tungsten filament. Electrons which are emitted due to thermionic emission by the filament are accelerated by a large potential applied to the electrodes of the electron gun.

Electro magnetic lenses are made of coils enclosed inside the iron shield which has a gap at the middle as shown in the Fig. 3.13. If the gaps of the two electromagnetic lenses are faced with each other uniform magnetic field is produced. Similarly if the gaps of the two electromagnetic lenses are slightly disturbed non-uniform magnetic field is produced. Electron beam can be focused by the electromagnetic lens.

In this system we have three magnetic lenses.

i) Condensing lens which is used to condense the electron beam.

ii) Objective lens which is used to resolve the structures of the object.

iii) Projector lens which is used to enlarge the object.

Metal aperture is used to get a narrow beam and object holder holds the object. Enlarged image of the object is seen through the fluorescent screen.

The whole arrangement is kept inside a vacuum chamber as shown in the Fig. 3.14.

Working

Streams of electrons from the electron gun are accelerated by the positive anode potential. The electron beam is then confined to a narrow beam by the metal aperture (slit) and the condensing lens. Then the electron beam is passed through the object.

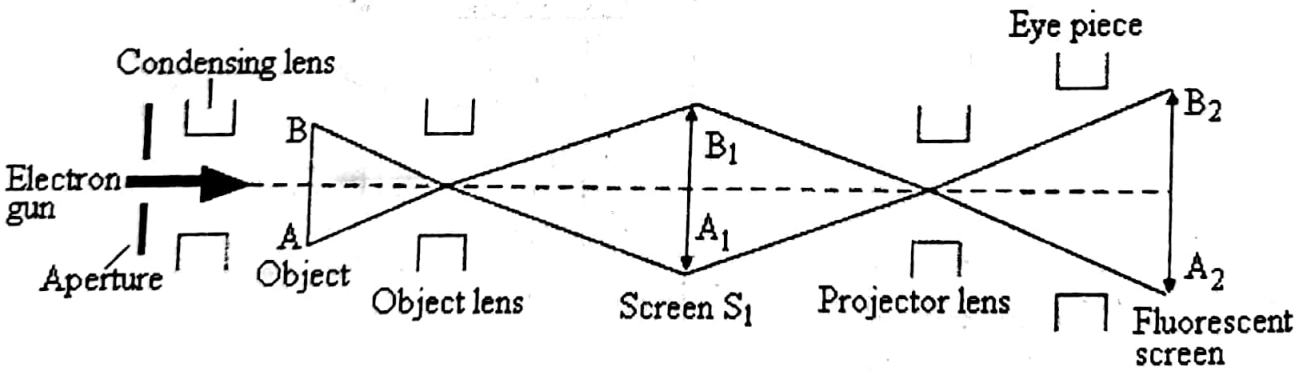

Fig. 3.15

An interaction between the electron beam and the object occurs and the transmitted electron beam carries the image of the object. Then it is passed through the magnifying objective lens as shown in Fig. 3.15. This lens magnifies

the images of the object more than 100 times. Then the image is made to fall on the screen S_1 and the electron beam is passed through the magnifying projector lens. It also magnifies the image of the object again more than 10 times. Finally the image of the object is made to fall on a fluorescent screen. The image formed on the fluorescent screen is viewed through an optical lens which is attached with the eyepiece. It also magnifies the image 10 times. Therefore total magnification in the order of more than 10^5 times is achieved.

Merits

i) The magnification is 100000X.

ii) Focal length of the microscope can be varied.

Applications

i) It is used to determine the complicated structure of the crystal.

ii) It is used to study the disease due to virus and bacteria.

iii) It is used to study and analysis of colloidal particles.

iv) It is used to study the composition of papers, paints etc.

3.18 DIFFERENCES BETWEEN TELESCOPE AND MICROSCOPE

S.No.	Telescope	Microscope
1	We get the magnified image of the distant object.	We get the magnified image of the very small object.
2	Eye piece is small.	Eye piece is large.
3	Object is large.	Object is small.
4	Permanent record is not possible.	Permanent record is possible

3.19 DIFFERENCES BETWEEN OPTICAL MICROSCOPE AND ELECTRON MICROSCOPE

S.No.	Optical microscope	Electron microscope
1	Light source is used	Source is an electron gun
2	Optical lens system is used	Electro magnetic lens system is used
3	Vacuum is not necessary for the operation.	Vacuum is necessary for the operation.
4	Magnification is 2000 X	Magnification is 100000 X

3.20 TYPES OF ELECTRON MICROSCOPES

Electron microscopes are classified into three types. They are

i) Scanning Electron Microscope (SEM)
ii) Transmission Electron Microscope (TEM)
iii) Scanning Transmission Electron Microscope (STEM)

3.21 SCANNING ELECTRON MICROSCOPE (SEM)

Principle

Electron beam is made to fall on the various portions of the specimen by the scanning coils for scanning the sample. From the secondary electrons or back scattered electrons or x-rays that are produced by the incoming incident electrons are used to get the information about the specimen's surface, topography, composition etc.

Construction

The schematic diagram of the SEM is shown in the Fig. 3.16. It consists of an electron gun to produce high energy electron beam. Metal aperture is used to get a narrow beam and a magnetic condensing lenses are used to condense the electron beam. A beam deflector is placed between magnetic condensing lens and the magnetic objective lens. A set of scanning coils are placed inside the objective lens to scan the sample. The electron detector (scintillator) is used to collect the secondary electrons and can be converted into electrical signals by the detector (photomultiplier tube). These signals containing information about the scanned sample are then passed into the CRO. Finally the image is viewed on the CRO screen (image viewing screen).

Working

Streams of electrons are produced by the electron gun. These electrons are accelerated by the anode. These accelerated electron beams are confined to a narrow beam by the metal aperture and the first magnetic condensing lens. It is then passed through the second condenser lens to get thin, light coherent electron beam. Beam deflector effectively focuses the electron beam on the desired portion of the specimen. Again it is passed through the objective lens which focuses the coherent electron beam on the object. When electron beam strikes the specimen the specimen is scanned and the specimen-beam interactions can take place as shown in the Fig. 3.17.

In SEM the secondary electrons from the specimen are selectively attracted towards the detector. Detector consists of a positive potential at the front and scintillating coating at the back. Hence the secondary electrons are attracted towards the positive potential and finally converted into light pulses by the scintillating coating.

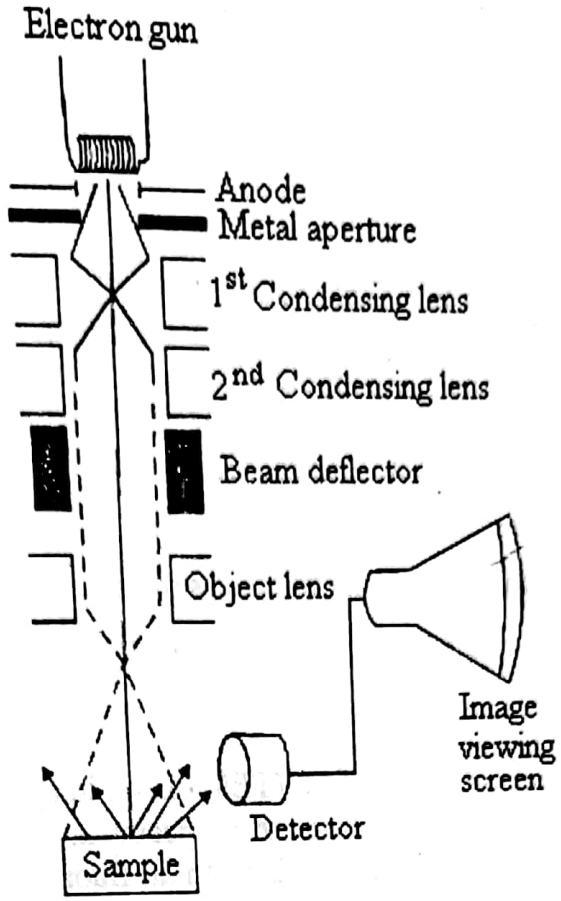

Fig. 3.16

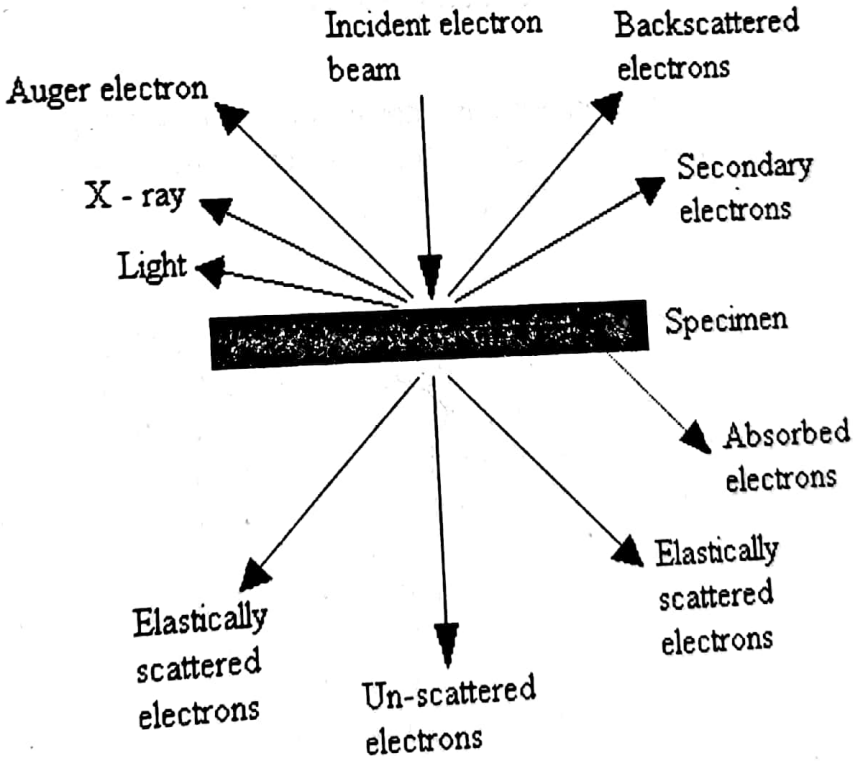

Fig. 3.17

The photomultiplier tube in the detector converts the light pulses into voltage signals. This voltage signal is then processed and amplified by an electronic circuit to get a point of brightness on the screen of the CRO. Thus the image is built up simply by scanning the electron beam across the specimen.

Advantages

i) Magnification is 300000X.
ii) It has large depth of focus.

Applications

i) It is used to study the disease causing agent like virus and bacteria.
ii) Used in microstructure analysis of ceramic materials.
iii) It is used to measure the thickness of thin coating.

3.22 TRANSMISSION ELECTRON MICROSCOPE (TEM)

Principle

Transmission electron microscope (TEM) is an imaging technique whereby a beam of electrons is transmitted through a specimen. Then an image is formed, magnified and directed to appear either on a fluorescent screen or layer of photographic film or to be detected by a sensor such as a CCD camera.

The first practical transmission electron microscope was built by Albert Prebus and James Hillier at the University of Toronto in 1938.

Description

The transmission electron microscope consists of an electron gun, condenser lenses, sample holder, objective lens, projector lens, apertures and phosphor screen. The arrangement is shown in Fig. 3.18.

Working

1. The electron gun produces a stream of monochromatic electrons.
2. This stream is focused to a small, thin, coherent beam by the use of condenser lenses 1 and 2. The first lens usually controls the spot size and the second lens usually controls the intensity or brightness.
3. The beam is restricted by the condenser aperture knocking out high angle electrons.
4. The beam strikes the specimen and a part of it is transmitted. The transmitted beam contains the information about the electron density, phase and periodicity that are used to form an image.
5. This transmitted portion is focused by the objective lens.
6. Optional objective and selected area metal apertures can restrict the beam that is the objective aperture enhancing contrast by blocking out high-angle diffracted electrons, the selected area aperture enabling the user to examine

the periodic diffraction of electrons by ordered arrangements of atoms in the sample.

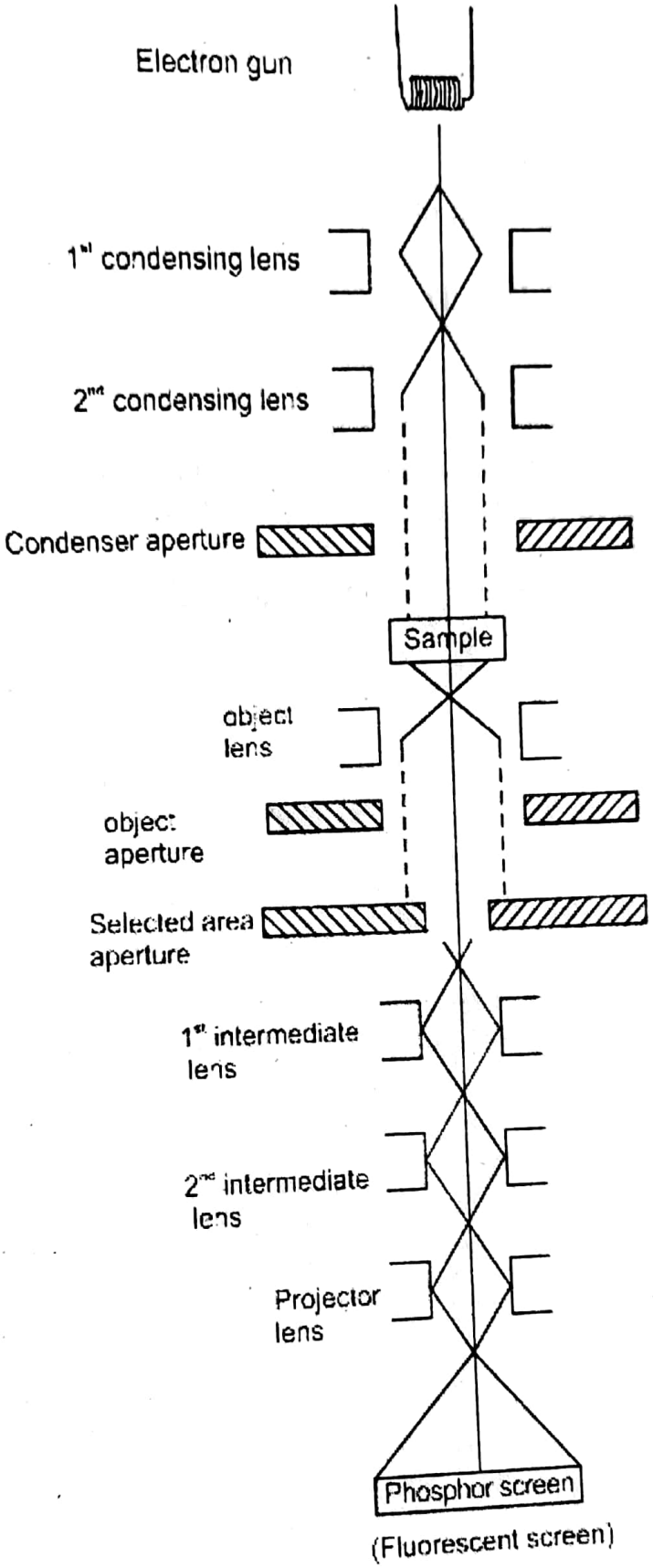

Fig. 3.18

7. The beam is passed down the column through the intermediate and projector lenses.
8. The beam of the specimen strikes the phosphor image screen and light is generated and forms the image of the object.

Limitations

1. Sample preparation is tedious.
2. During the preparation of the sample the structure of the sample may be altered.
3. In the case of biological samples electron beams my damage the sample.

Applications

1. It is used to find the composition of the sample.
2. It is used to find the arrangement of atoms in the specimen.
3. TEM is used to get image of internal body structures of animals, viruses and DNA.
4. It is used to determine the size, shape of the particles which forms the specimen.