Experimental Techniques in Materials MATE 515

Physical Methods for Materials Characterization:
Lecture 4
Electron Microscopy Intro
Course materials:
http://in.materials.drexel.edu/blogs/515_experimental_techniques/

Instructor : Peter Finkel

MATE 515 Laboratory Demonstration Schedule

Facility	Supervisor	Location	Times /Date	
OM	Superuser	MCF	Week 5	Oct 26-27
XRD	Zhorro Nikolov	MCF	Week 6	Oct 31
SEM/ESEM	Dee Breger	MCF	Week 7	Nov 6
WDS/EDS	Superuser	MCF	Week 8	Nov 14
OIM/EBSD	Superuser	MCF	Week 9	Nov 22
Magnetic	Peter Finkel	525 Bossone	Week 10	TBD

- Exact time of these demonstrations is to be confirmed one week in advance basis in agreement with the MCF staff for and will be offered at least 4 times /week for 4 groups. In general, they are optional, but will undoubtedly be helpful for your exams and, more importantly, your research.

Outline Electron Microscopy Introduction

- Principles:
- Lenses, defects and resolution
- Comparison of SEM and TEM
- Electron/Sample interactions
  - Scattering
  - Diffraction

Introduction

Transmission Electron Microscope (TEM) versus Transmission Optical Microscope (TOM)

	TEM	TOM
Source	100-400 kV electron gun high current densities: 5 x 10^4 Am^{-2} for tungsten filament 1 x 10^6 Am^{-2} for field-emission source	Light source
Condenser lens	Electromagnetic lens, focus adjusted by controlling the lens current	Glass lens, focus adjusted by lens position
Specimen stage	Allows for specimen tilt as well as some z-adjustment	Allows for specimen tilt as well as some z-adjustment
Objective lens	Fine focusing of the image by adjusting the lens current	Fine focusing by adjusting the position of the specimen and the objective lens
Final imaging system	Employs electromagnetic lenses to produce image on a fluorescent screen	Eye piece forming image for direct viewing
Recording system	Computer monitor or TV	Normal viewing or photographic films
Experimental set-up in	Vacuum, better than 10^{-6} torr	Air, at atmospheric pressure

Electron Microscopy

- Major components are the electron column consisting of an electron gun and the electron lenses, and the control console consisting of a cathode ray tube viewing screen and the scanning and control electronics for the electron beam.
- The three dimensional appearance of the image is due to the large depth of field.
- A scanning electron microscope (SEM) employs a probe lens to focus the electron beam into a fine probe and scanning coils are used to scan the probe over the sample.
- Resolution of the SEM is controlled by the probe lens. It is the inelastically scattered electrons that provide information. Usually < 30 keV electrons are used in SEM.
- In optical microscopy and TEM, information is collected continuously over the full field of view (from all image points simultaneously) and focused by suitable lenses to form a magnified image. In SEM, information is collected sequentially.

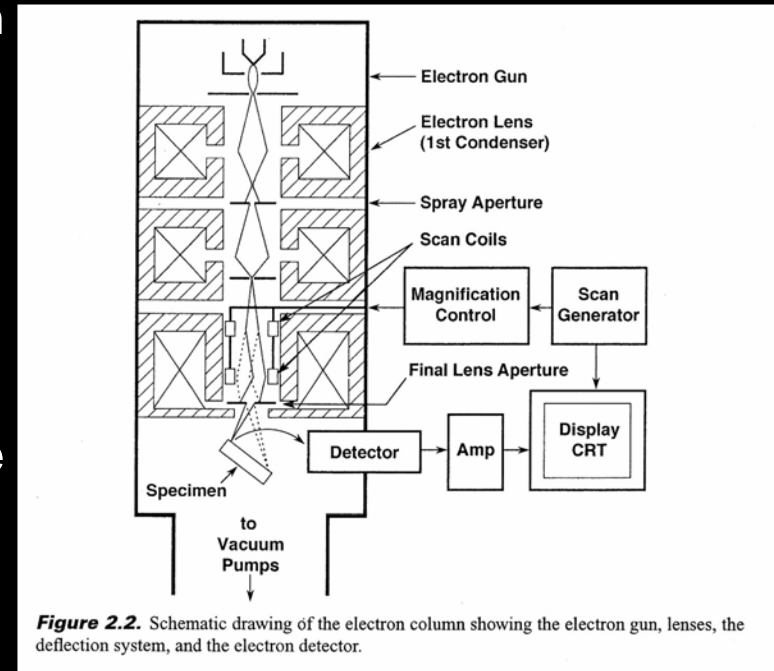


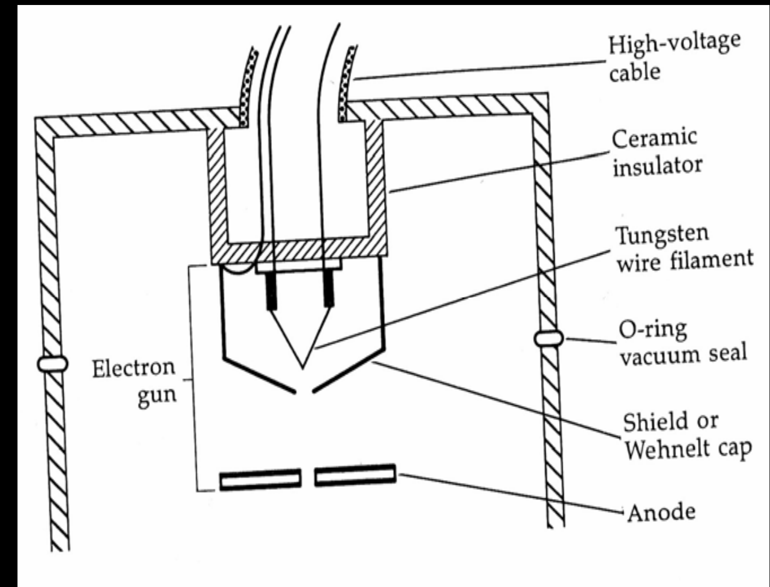
Figure 2.2. Schematic drawing of the electron column showing the electron gun, lenses, the deflection system, and the electron detector.

Electron gun

- The filament is resistively heated to 2000 – 2700K by applying a high voltage and a small amount of current to a point that valence electrons are released from its tip in what is called a space charge cloud. The amount of energy needed to cause electrons to leave the filament is called the **work function**.
- The electrons are released in all directions. The Wehnelt cap/grid has a slight negative potential (charge) - or excess of electrons - to create negative lines of force that focus the emitted electrons and control their emission.
- The filament or **cathode** is supplied with a high negative voltage, e.g. -20,000 volts. The **anode**, a metal plate with a hole in it, is at ground potential (0 volts) and is greatly positive with respect to the cathode. This potential difference accelerates the electrons toward the anode.

Electron gun

- Along the route from the cathode to the anode, the paths of the individual electrons cross each other. This is called the point of **crossover** with diameter d0**.** It is considered the **real source** in the electron gun, and its image is projected onto the specimen surface. After the crossover, the electron beam diverges with a divergence angle a0. The condenser and objective lenses then produce a demagnified image of the crossover on the specimen with an image diameter dp.
- The **anode** has a hole in it. This hole allows only a fraction of the electrons to continue down the column toward the lenses. The remaining electrons are collected on the anode and returned via the ground to the voltage supply.



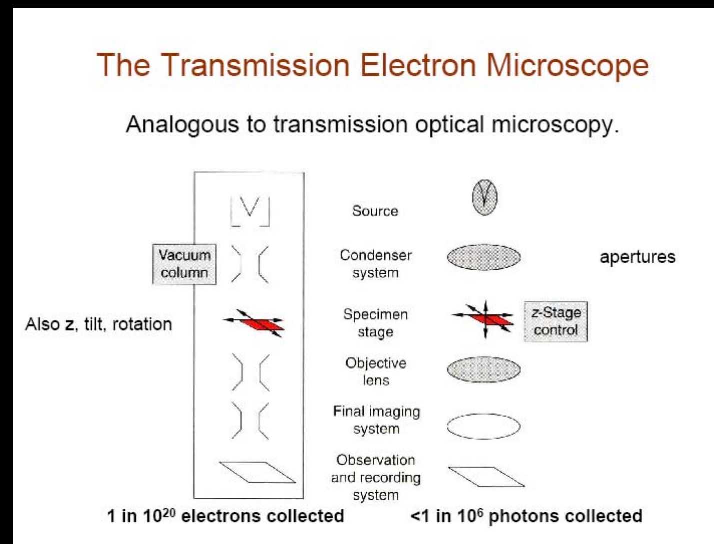
Electron Sources

- Hot Cathode Guns: Tungsten filaments and Lab-six – LaB_6 crystals, producing thermionic emission of electrons.
- Thermionic emission formula:
- Current density $I = AT^2 \exp(-E/kT)$
- A = Richardson's constant depending on the source material,
- T = emission temperature K (C+273),
- E = work function or the energy required to escape from the filament into the vacuum, k = Boltzman's constant.

Tungsten:	**LaB_6:**
stable beam current	stable beam current
short life	10 times longer life
large tip	smaller tip
large emitting area (probe diameter)	smaller emitting area (probe diameter)
low brightness	higher brightness (10 times higher current)
high work function	lower work function
high evaporation rate	medium evaporation rate
lower vacuum (10-6 Torr)	higher vacuum (10-7 Torr)
low resolution	higher resolution (due to thinner beam)
2700 K	1700 K

Review Electron Microscopy

- MATE 515 Brandon Ch 4.pdf



http://www.colorado.edu/physics/2000/tv/moving_electrons.html