MATE 6110
Transmission Electron Microscopy

Objective:
To introduce the kinematical electron scattering theory, optics in TEM, diffraction contrast imaging of crystals containing defects, and dynamical electron diffraction effects. To introduce the concept of reciprocal space, basis for indexing electron diffraction patterns, and diffraction from twinned crystals. To introduce the theory, techniques and applications of high-resolution transmission electron microscopy (HRTEM) in materials research. To describe chemical microanalysis using EDS

Text: Functional and Smart Materials - structural evolution and structure analysis
by Z.L. Wang and Z.C. Kang (Plenum Press, 1997)

Reference book: Elastic and Inelastic Scattering in Electron Diffraction and Imaging
by Z.L. Wang (Plenum Press, 1997)

Home work 4 assignments

Exams Middle term and final

Grade 30% Home work
35% Middle term exam
35% Final exam

Content:

1) Introduction,
2) Interaction between electron and matter:
   Single electron scattering model
   Wave property of electron
   Plane wave
   Electron scattering by statistic potential
   Electron scattering by a single atom
   Kinematical diffraction from a single crystal
3) Reciprocal space
   Definition
   Miller index
   Ewald sphere
   Some mathematics for diffraction physics
      Delta function
      Fourier transform
      Convolution
4) Optics in TEM
   Electron gun
   Lens

Ray diagram of TEM
Illumination system

5) Index diffraction patterns
Structure factor and extinction rules
Shape factor
Two methods to index the SAD patterns
    Guess the zone axis [uvw]
    Index the pattern, and then get the [uvw]
Camera length
Laue circles
Kikuchi patterns
Double diffraction
Convergent beam electron diffraction (CBED)

6) TEM diffraction contrast
Bright-field and dark-field images
Diffraction contrast
Kinematic diffraction from imperfect crystal
Special defects in crystals
    Stacking faults
    Dislocations
Thickness fringes

7) Sample preparation
Nanoparticles, nanowires/nanobelts
Planar-view sample preparation
Cross-section view sample preparation
    Traditional polishing method
    Ultramicrotome
    FIB

8) Phase contrast
Phase object approximation (POA)
Abbe's imaging theory
Information transfer of optic system
    Spherical aberration
    Chromatical aberration
    Defocus
Image resolution
    The contrast transfer function
    Scherzer defocus
    Envelope function
        Spread of focus
        Beam convergence effect
        Source coherence
Diffractogram
HRTEM image simulation
    Dynamical scattering theory of image simulation
    Multislice theory

9) TEM applications:
   Characterization of nanoparticles
   Surface structure determination by profile TEM images
   Planar defects in nanomaterials
   New phase identification
10) X-ray Energy-dispersive spectroscopy
   Inelastic scattering
   Principle of XEDS
   Detectors
   Energy resolution
   Dead Time
   Qualitative and quantitative XEDS
11) Electron energy-loss spectroscopy (EELS)
   Zero loss
   Plasmon
   ELNES
   EXELFS
12) Introduction on scanning transmission electron microscopy