University of Southern California

Department of Materials Science and Engineering

MASC 535L E. Goo

Transmission Electron Microscopy

Spring 2013

Lecturer : Edward Goo

602 VHE

x04426

ekgoo@usc.edu

Lab Instructor: John Curulli

101B CEM

x01990

curulli@usc.edu

Text - *Transmission Electron Microscopy: A Textbook for Materials Science,* D.B. Williams and C.B. Carter, Springer, 2009 2nd Edition, ISBN 978-0387765020

References

1. *Scanning Electron Microscopy and X-ray Microanalysis*, edited by J. I. Goldstein, D. E. Newbury, P. Echlin, D. C. Joy, C. Fiori and E. Lifshin, Plenum Press 1981, QH 212, S3 S29

2. *The Operation of Transmission and Scanning Electron Microscopes*, D. Chescoe and P. J. Goodhew, Oxford 1990, QH212 S3 C44

3. *Electron Microscopy of Thin Crystal*, P. B. Hirsch et al., QD 921, H55 1977

4. *Transmission Electron Microscopy: Physics of Image Formation and Microanalysis*, L. Reimer, QH 212, T7R43 1989

5. *Transmission Electron Microscopy of Materials*, G. Thomas and M. Goringe, TA 417.23, T48

6. *Practical Electron Microscopy in Materials Science*, J. W. Edington, QD 906.7, E37E34 1976

7. *Practical Analytical Electron Microscopy*, D. B. Williams, TA 417.23, W55 1984

University of Southern California

Department of Materials Science and Engineering

MASC 535L E. Goo

Course Syllabus

The numbers after each main topic refer to the chapters in William and Carter that are relevant to that topic.

I. Overview of TEM - 1

II. Electron Sources – 5

- A. Tungsten Filament
- B. LaB_6 Crystal
- C. Field Emission Source

III. Vacuum Equipment and Specimen Holders - 8

IV. Electron Lenses, Aperatures and Resolution - 6

- A. Magnetic Lenses
- B. Lens Aberrations
- C. Formation of Electron Probe

V. Electron Beam - Specimen Interactions – 2 to 4

- A. Elastic Electron Scattering
- B. Inelastic Electron Scattering
- C. Beam Damage
- D. Backscattered Electrons
- E. Secondary Electron Emission
- F. Characteristic X-rays

VI. Electron Diffraction – 11, 12, 16 to 19

- A. Crystal Geometry
- B. Diffraction Theory
- C. Finite crystal
- D. Ewald sphere construction
- E. Indexing Electron Diffraction Patterns

F. Higher Order Laue Zones

G. Double Diffraction

H. Kikuchi Lines

I. Diffuse Scattering

J. Convergent Beam Electron Diffraction

VII. Transmission Electron Microscope - 9

A. Ray Diagram

B. Objective Lens

C. Selected Area Diffraction Patterns

D. Bright-field and Dark-field

E. Displaced Aperture vs. Tilted Beam Dark Field Images

F. Two-beam BF-DF Pair

G. Rotation Calibration

H. Projector Lens

I. Scanning Transmission Electron Microscope

VIII. Image Collection and Processing - 7

A. Cameras

B. Digital Image Acquisition

C. Image Processing

IX. Specimen Preparation - 10

X. X-ray Microanalysis – 32 to 35

A. Detection Systems

B. Qualitative Analysis

C. Quantitative Analysis

D. ALCHEMI

XI.Convergent Beam Electron Diffraction – 20 and 21

XII.Defect Analysis

A. Burgers Vector – 26

B. Stacking Faults – 25

C. Weak Beam Imaging – 27

XIII. Moiré Fringes – 23

XIV. Lorentz Microscopy – 29

XV. High Resolution Electron Microscopy – 28

XVI. Electron Energy Loss Spectroscopy – 37 to 40

- A. Plasmon Peaks
- B. Detection System
- C. Quantitation

XVII. Theory of Image Formation in a Transmission Electron Microscope – 13 to 15

- A. Kinematical Theory of Image Formation
  1. Perfect Crystal
  2. Imperfect Crystal
- B. Dynamical Theory of Image Formation

XVIII. Advanced Topics in TEM Image Formation

- A. Matrix Formulation
- B. Quantum Mechanical Approach
- C. Many-beam Theory
- D. Multi-slice Approach

Text book - Transmission Electron Microscopy: A Textbook for Materials Science (4 Vol set) by David B. Williams and C. Barry Carter 2nd edition – this is a require text. It is a four volume text and is available in paperback for $66 from Amazon.

Lab – There will be a weekly lab where you will learn to operate the transmission electron microscope. We will schedule the labs in the first lecture. Typically it will be a three hour lab session with three students per lab session. The tentative schedule of the labs is given below. It is not unusual for the transmission electron microscope to be down for maintenance or repair. Eleven weeks are listed on the schedule but more weeks may be available.

Laboratory Schedule

1st week: - Starting up the Akashi, specimen insertion and alignment – January 21

2nd week: - Bright-field imaging, focusing and stigmation – January 28

3rd week: - High resolution imaging - February 4

4th week: - Project #1 - High resolution imaging of graphitized carbon – February 11

5th week: - Project #1 - High resolution imaging of graphitized carbon – February 18

6th week: - Project #1 - High resolution imaging of graphitized carbon – February 25

7th week: - Starting up JEOL, specimen insertion and alignment – March 4

8th week: - Energy dispersive X-ray spectroscopy – March 11

9th week: - Project #2 - High resolution imaging of gold particles – March 25

10th week: - Project #2 - High resolution imaging of gold particles – April 1

11th week: - Project #2 - High resolution imaging of gold particles – April 8

Exams - There will be a midterm and a final. The midterms will be on February 27th, Wednesday and April 10th, Wednesday. The midterms will be in class on these days. The final is on May 13th, Monday 2:00 - 4:00 pm

Grading
Homework(six homework assignments) – graded credit/no credit - 10 %
Lab Performance - 25 %
Midterm I - 20 %
Midterm II - 20 %
Final – 25%

Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. Website and contact information for DSP: http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html, (213) 740-0776 (Phone), (213) 740-6948 (TDD only), (213) 740-8216 (FAX) ability@usc.edu.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. SCampus, the Student Guidebook, (www.usc.edu/scampus or http://scampus.usc.edu) contains the University Student Conduct Code (see University Governance, Section 11.00), while the recommended sanctions are located in Appendix A.

Emergency Preparedness/Course Continuity in a Crisis

In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of Blackboard, teleconferencing, and other technologies.