MSE-702: Defects in (Crystalline) Solids

Instructor: Professor J. Narayan (Spring 2016)

Course Objectives and Justification

Defects play a critical role in controlling the properties of solids, which are needed for new functionality and reliability of solid-state devices and systems. The defects in solids can be generally classified into thermodynamic equilibrium (mostly point defects) and nonequilibrium defects (such as dislocations, stacking faults, grain boundaries etc.). This course starts with nature and properties of these defects and generation of point defects (by electron, photon and ion irradiation) and their clustering to form dislocation loops with and without faults. The course covers characteristics of defects in metals, ceramics and semiconductors and correlations of defect structures with mobility (diffusion) and annealing processes. Since control of defects and annealing processes are critical to the success of ion implantation, which is a well-established technique for doping and alloying of semiconductor and other materials, this course covers ion implantation processes to create p-n junctions and two-dimensional materials for next-generation solid-state devices. This course draws parallel with plastic deformation processes in metals, ceramics and semiconductors, and covers the nature of dislocations and properties in each class of materials. Generation of dislocations during processing of thin film heterostructures are covered with an aim to improve the properties of solid-state devices.

Grading: 65% Exams; 20% Homework; and 15% Term Paper

Reference Text Books and Instructor Notes:

(1) Elementary Dislocation Theory (J. Weertman and J. R. Weertman, Oxford University Press, 1992)
(2) Defects in Solids (Richard J. D. Dilley, John Wiley and Sons, 2008)

MSE-702: Syllabus
I. **Fundamentals of point defects and dislocations: 8 lectures (75 min)**
   
a) Introduction to defects and their influence on properties  
b) Perfect crystalline structures  
c) Vacancies and interstitials and dislocations (neutral defects) in metals  
d) Vacancies and interstitials and dislocations (neutral and charged defects) in semiconductors  
e) Defects and dislocations (charged) in ionic solids

II. **Generation of defects and annealing processes: 8 lectures (75 min)**
   
a) Thermodynamic equilibrium generation (thermal heating)  
b) Electron and photon (laser) irradiation (nonequilibrium)  
c) Ion implantation (nonequilibrium)  
d) Clustering of defects into dislocation loops and their annealing  
e) Diffusion mechanisms and mobility of defects and annealing

III. **Defects in thin films and annealing processes: 9 lectures (75 min)**
   
a) Relaxation of stresses and strains and generation of dislocations  
b) Atomic structure and properties of dislocations  
c) Dislocation interactions and reaction mechanisms  
d) Point-defect, impurity and dislocation interactions  
e) Effect of pressure on diffusion and annealing