MSE 6412 – Structures of Materials

School of Materials Science and Engineering
Georgia Institute of Technology

Fall Semester 2016

Course Objective	To provide students with a fundamental understanding of structural features of materials, including point and space groups, representative crystal structures, quasi-crystals, amorphous and rubbery states, liquid crystals, colloids, solutions, and effect of symmetry on materials properties
Lecture	11:05-11:55 T, Th in Love 299
Instructors	Meilin Liu, Karl Jacob, and Paul Russo
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Office Hour	Tu, Th 3-4:30
Teaching assistant	TBD
Homework	Problems will be assigned periodically and solutions will be posted a week later. Homework will not be collected or graded.
Exam/grading	4 Exams, 25% each Exam 1 – Symmetry, point and space groups Exam 2 – Crystalline structures and properties Exam 3 – Amorphous/rebury states, liquid crystals Exam 4 – Colloids and solutions
Learning Objectives:	Upon completion of this course, students will be able to: 1. Deduce point groups of simple crystal structures and geometric figures. 2. Understand space group notations and all symmetry elements associated with each space group. 3. Become familiar with structural features of all class of materials, including hard and soft materials. 4. Understand the inherent correlation between structure and properties of materials

Academic Integrity	Students are reminded of the obligations and expectations associated with the Georgia Tech Academic Honor Code and Student Code of Conduct, available online at www.honor.gatech.edu. Academic dishonesty will not be tolerated, including cheating, lying about course matters, plagiarism, or helping others commit a violation of the Honor Code.
Learning Accommodations:	For students with documented disabilities, we will make classroom accommodations in accordance with the ADAPTS office (http://www.adapts.gatech.edu). However, this must be arranged in advance.

References

1. Lecture notes – to be posted on T-Square or Dropbox
2. Physical Ceramics, Y. M. Chiang, D. Birnie, and W. D. Kinggery, Wiley, 1997.
3. Crystallography, Walter Borchardt-Ott, Springer-Verlag, 1993, QD 905.2.B713
4. Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry, 2nd Edition
5. Introduction to Physical Polymer Science, 4th Edition, L. H. Sperling, Wiley, 2006
6. Liquid Crystal Fundamentals, Shri Singh, World Scientific Publishing, 2002
7. Liquid Crystals, L Liebert, Elsevier, 2012

Topical Outline - Structure of Materials

1. Introduction (1/2 week)
   - Overview of the course
   - Structural features of materials and their impact on properties
2. Symmetry in crystallography (1 week)
   - Geometric arrangement of atoms: Lattice and unit cells
   - Transformation of coordinate systems
   - Symmetry operations: rotations, inversion, reflection, translation, etc...
   - Magnetic symmetry: time reversal and axial quantities
3. Point and space groups (2 week)
   - Crystallographic point groups (2D and 3D)
   - Magnetic (color) point groups (color, charge, & time reversal)
   - Space groups
   - Non-crystallographic point groups: Curie (limiting) groups (symmetry of force fields, physical properties)
4. Effect of **crystal symmetry** on properties of materials (1 week)
   - Neumann's principles
   - Number of independent components of tensor properties in different crystals
   - Ferro-electricity, Ferrimagnetism, and other physical interactions
5. Representative **crystal structures** (& unique properties) of materials (2 week)
   - Metals, alloys, semiconductors
   - Folded chain model, extended chain crystals
   - Effect of hydrogen bonding
   - Ceramics/Ionic crystals (AX, AX_2, ABX_3, AB_2X_4 compounds: e.g., Fluorite, Perovskite, Spinel, Garnet, etc.); Pauling rules
6. Quasi-crystals (1/2 week)
   - polygonal (dihedral) quasicrystals (8-, 10-, 12- fold local symmetry)
   - Icosahedral quasicrystals (aperiodic in all directions)

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7. Amorphous structure (1 week)
   - Structure of amorphous state – Glassy, Rubbery and Melt states
   - Hermanns orientation
   - Amorphous orientation
   - Oriented mesophase
   - Glassy state: examples from soft (PMMA) and hard (silica) materials
   - Characteristics of glassy state (eg. optical) – contact lenses, window glass, etc.
8. Combination of crystalline and amorphous states (1/2 week)
   - Organization of crystallites and non-crystalline regions

- Grain/grain boundary
- Spherulites
- Switchboard model
- Fringed micelle model
- Shish-kebab morphologies
- Structure vs properties (eg. conductive/insulative) vs structure

9. Rubbery State (1 week)
   - Structure of rubbery state
   - Polymer network
   - Interpenetrating network (IPN)
   - Gels
   - Semi-crystalline polymers & rubbery state
10. Liquid Crystals (2 weeks)
    - Lyotropic & Metallotropic LCs
    - Nematic, Smectic, Chiral, Discotic LCs
    - Liquid Crystal Textures- optical properties/Schlieren texture
    - Structure transitions
11. Colloids (2 weeks)
    - Molecular interactions, length scales, and position correlation/particle distribution
    - Stability of colloidal systems
    - Tyndall scattering
    - Colloidal self-assembly
    - Colloidal crystals
    - Micelles
    - Liquid crystal colloidal suspensions
12. Solution (1/2 week)
    - Mixtures and solution
    - Structure of gas/Liquid/Solid solutions
    - Coil–globule transition

(14 weeks and exam one week)