MSE 7210 – DISLOCATIONS, DEFORMATION, AND STRENGTHENING MECHANISMS

Spring 2024 - Tu & Th 9:30 to 11:30 (Love 299)

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LEARNING OBJECTIVE: Application of dislocation theory for understanding of the plastic deformation of crystalline solids and their strengthening mechanisms based on interactions of dislocations with point defects (solute atoms), line defects (dislocations), planar defects (grain/phase boundaries), and volume defects (precipitates & dispersoids), as well as effects under high strain rates. The focus will be on fundamental concepts used to build models describing the various strengthening mechanisms. Understanding of the fundamental concepts is essential for predicting material performance, as well as for alloy design and their processing.

CATALOG DESCRIPTION: This course emphasizes the understanding of the role of dislocations on plastic deformation mechanisms and their interactions with defects resulting in strengthening, dislocation dynamics, and their correlations relevant to engineered structural materials.

REFERENCES: Class notes (copies of slides) will be posted on Canvas ahead of the class. While class notes provided will be quite detailed, additional references for each topic are included in the outline.

GRADING POLICY: Two Exams (70 points) and Final Group Presentation (30%). Instructions will be provided for the presentations during the course of the semester.

ATTENDANCE: Essential to encourage discussions on range of topics of interest to students

COURSE EXPECTATIONS & GUIDELINES

Academic Integrity: Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on GT Academic Honor Code, visit http://www.catalog.gatech.edu/policies/honor-code/. Any student suspected of cheating or plagiarizing will be reported to the Office of Student Integrity.

Accommodations for Individuals with Disabilities: If you are a student with learning needs that requires special accommodation, contact the Office of Disability Services at http://disabilityservices.gatech.edu/, or (404)894-2563 as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me asap in order to set up a time to discuss your learning needs.

Student Use of Mobile Devices: Please silence all mobile devices at the beginning of class.

Student-Faculty Expectations: At Georgia Tech we believe that it is important to continually strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for basic expectations that you can have of me, and that I have of you. Simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. I encourage you to be committed to these ideals while in this class.

COURSE OUTLINE:

INTRODUCTION AND COURSE OVERVIEW

[1] PLASTIC DEFORMATION MECHANISMS

1. Basics of Dislocation Theory (Type, motion, forces, stresses, etc.)
2. Deformation by Slip & Alternate Mechanisms (Twinning, Martensitic Transformation)

Refs: - Introduction of Dislocations, D. Hull and D.J. Bacon, Pergamon Press
Elementary Dislocation Theory, Weertman and Weetman, Oxford University Press
Defects in Crystals, Prof. Dr. Helmut Föll - https://www.tf.uni-kiel.de/matwis/amat/def_en/

[2] SOLID SOLUTION STRENGTHENING

1. Solute-dislocation interactions
2. Mechanical effects of interactions

Refs: - D. Peckner, Strengthening of Metals, Rienhold, 1967. p. 93.
- A. Kelly, R.B. Nicholson, eds., "Strengthening Methods in Crystals," J. Wiley, 1977, p. 17.
- M.A. Meyers and K.K. Chawla, "Mechanical Metallurgy," Prentice Hall, 1984, p.383.
- U.F. Kocks, "Kinetics of Solution Hardening," Symposium on the 50th Anniversary of "Introduction of Dislocations," in Metall. Transactions Symposium Series, Vol. 16A(12), 1985, pp.2109.

[3] PRECIPITATION & DISPERSION STRENGTHENING

1. Dislocation-precipitate interactions (Mott and Nabarro, Orowan)
2. Advanced theory of precipitation strengthening – Friedel Statistics
3. Ashby's theory of dislocation-dispersoid interactions – SSDs and GNDs

Refs:- D. Peckner, Strengthening of Metals, Rienhold, 1967. p. 142.
- M.A. Meyers and K.K. Chawla, "Mechanical Metallurgy," Prentice Hall, 1984, p.402.
- A.J. Ardell, "Precipitation Hardening, Symposium on the 50th Anniversary of "Introduction of Dislocations," in Metall. Trans. Symposium Series, Vol. 16A (12), 1985, p.2131

[4] WORK HARDENING IN SINGLE CRYSTALS

1. Conventional theories (Taylor, Mott)
2. Kuhlmann-Wilsdorf and Seeger's theories

Refs: - M.A. Meyers and K.K. Chawla, "Mechanical Metallurgy," Prentice Hall, 1984,P.353.
- D. Kuhlsmann-Wilsdorff, "Theory of Work Hardening" in Symposium of the 50th Anniversary of "Introduction of Dislocations," in Metall. Transactions Symposium Series, Vol. 16A(12), 1985, pp.2131.

[5] POLYCRYSTALLINE HARDENING

1. Inhomogeneities in Deformation Due to Grain Boundaries
2. Conventional Theories of Grain Size Effects
3. Recent Theories of Strengthening in Nanomaterials

Refs: - C.Y. Chin, "Relation Between Single Crystal and Polycrystal Hardening in Work Hardening in Tension and Fatigue, TMS Publication, 1977; pp. 45-66
- A.W. Thompson, "Polycrystalline Hardening," ibid, pp. 89-126

[6] HIGH-STRAIN-RATE STRENGTHENING

1. Effects of High-Strain-Rate on Deformation Mechanisms
2. Strain Rate Dependence on Mechanical Properties and Constitutive Relations
5. Deformation Localization – Adiabatic Shear Banding

Refs: - M.A. Meyers, "Dynamic Behavior of Materials," J. Wiley, 1994.