EGN 3365: Materials in Engineering - Introduction

Course Objective...

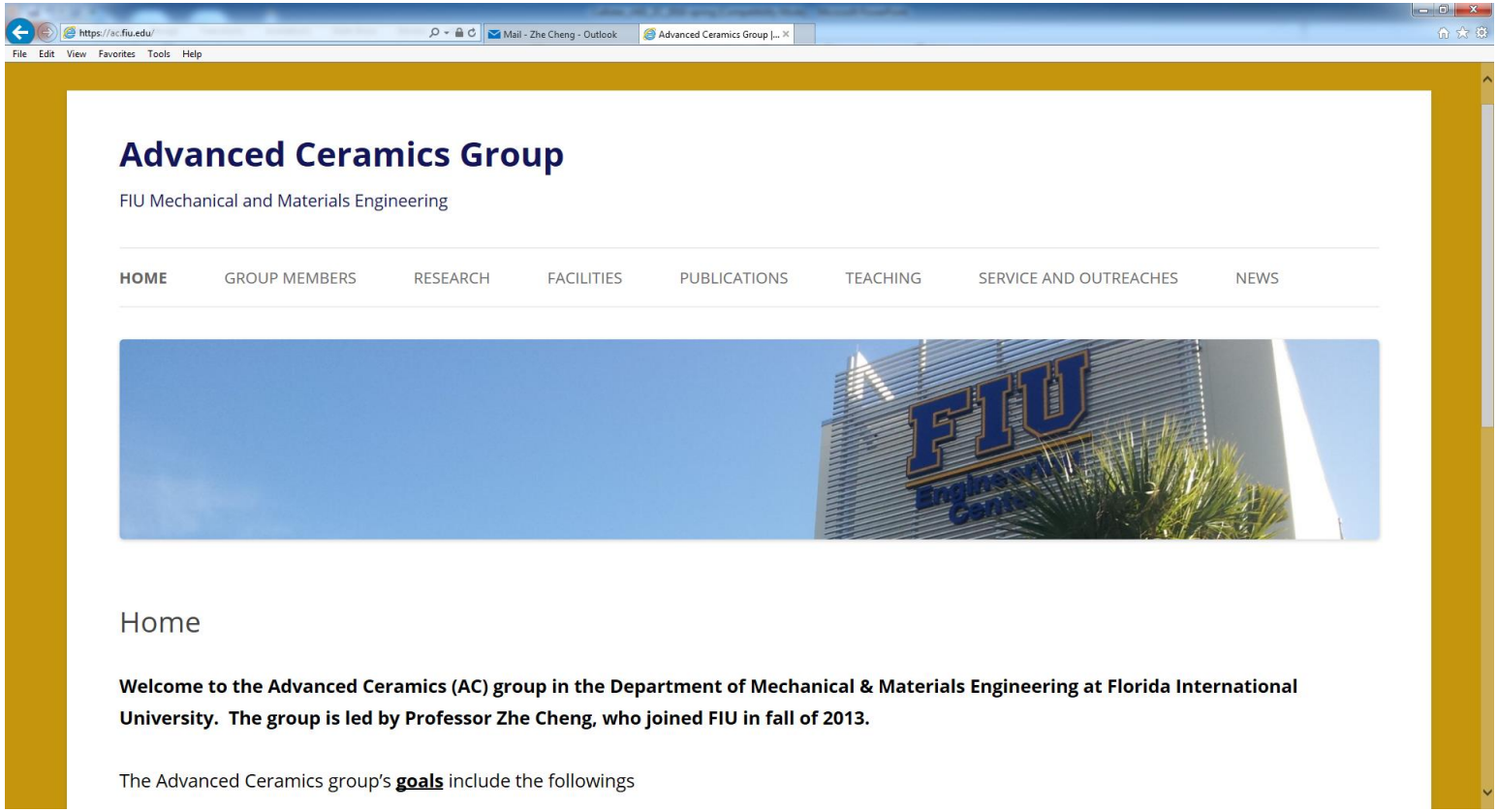
Introduce fundamental concepts and methods in materials engineering (and science)

- **Instructor: Dr. Zhe Cheng**
  - **Phone: 305-348-1973**
  - **Email: zhcheng@fiu.edu**
  - **Office: EC3172**
- **Course website (for lecture slides and review information):**
  https://ac.fiu.edu/teaching/egn3365/
- **Instagram chat group:**

- **Prerequisites:**
  - **CHEM1045 General Chemistry I;**
  - **MAC 2311 Calculus I;**
  - **PHY 2048 Physics with Calculus I**

More About Dr. Zhe Cheng

- **Education & Experiences:**
  - **PhD in Materials Science & Engineering, Georgia Tech 2008**
  - **Research scientist at DuPont 2008-2013**
- **Research group website: https://ac.fiu.edu**



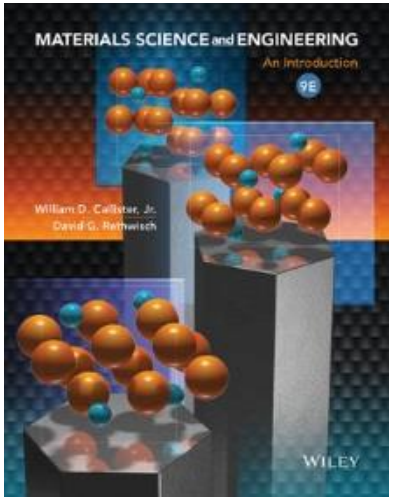
Course Feature

- **Interdisciplinary & broad**
- **Raising awareness & common sense**
- **Not exactly a specific tool/skill based course**
- **Every material/application is unique**

This course will help you to know:

- basic concepts in materials engineering
- major categories of materials
- considerations in materials selection/design/processing

Textbook & Other Materials



- **Materials Science and Engineering**
  An Introduction,
  William D. Callister, Jr. and David G Rethwisch,
  John Wiley & Sons Inc, 9th ed. (2013)

Any other earlier versions are OK!

- **Wiley links for book purchase/rental**
  http://www.wiley.com/WileyCDA/WileyTitle/productCd-EHEP002505.html
- **CourseSmart online e-text rental:**
  http://www.coursesmart.com//9781118324578
- **Lecture notes for students and other supplemental information available through Wiley *student companion site***
  http://bcs.wiley.com/he-bcs/Books?action=index&itemId=1118324579&bcsId=8580

Wiley Student Companion Site

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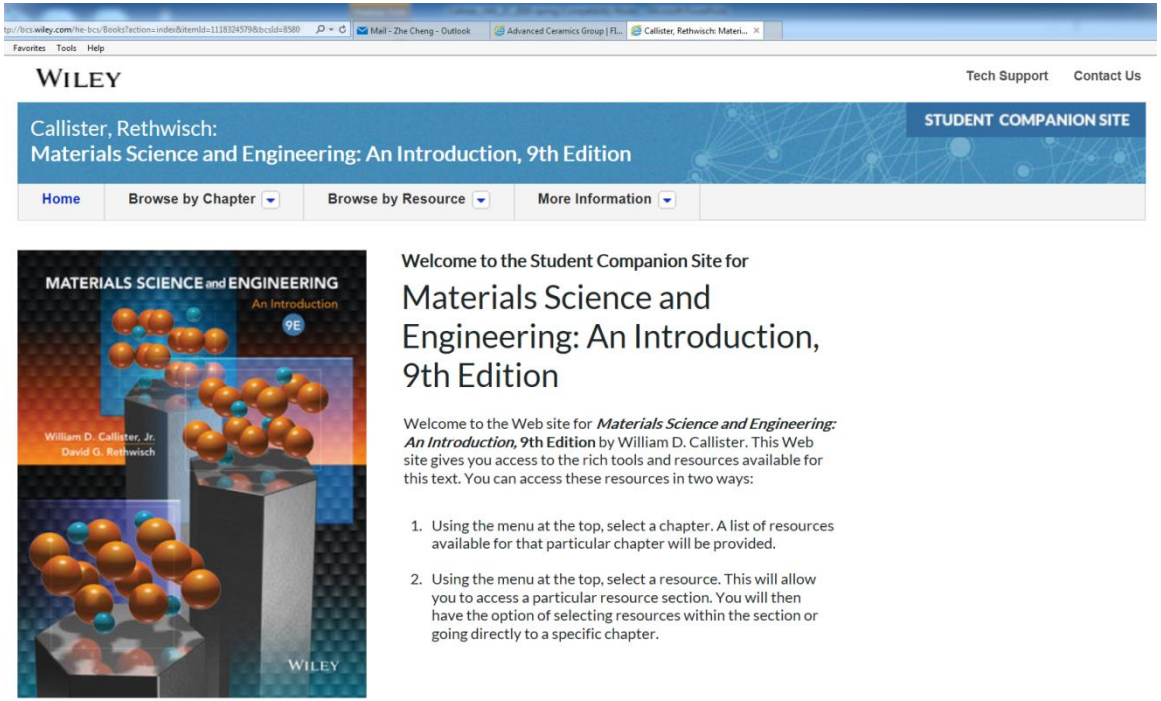
- **Extra contents:**
  - **Concept check answers**
  - **Virtual Materials Science & Engineering (VMSE)**
    - **Users can manipulate molecules and crystals to better visualize atomic structures of crystals**
    - **Polymer repeat units and molecules**
    - **Diffusion computations**
  - **Student Lecture Slides**
  - **Case Studies**



Grading

- Homework (10 points)
- Attendance (8 points, in the form of class exercises)
- Group presentation (7 points)
- Three closed-book exams (25 points each for each)
- Final Grades:
  - A:>=90; A-:87-89.9;
  - B+:84-86.9; B:80-83.9; B-:77-79.9;
  - C+:74-76.9; C:67-73.9;
  - D: 60-66.9;
  - F: <60

  Past statistics
  - 2017 spring: Median: 78.3; Standard deviation: 18.0; Highest: 96.8
  - 2016 fall: Median: 77.3; Standard deviation: 17.1; Highest: 98.1
  - 2016 spring: Median: 74.8; Standard deviation: 12.2; Highest: 97.0
  - 2015 fall: Median: 80.1; Standard deviation: 19.1; Highest: 94.5
  - 2015 summer: Median: 81.8; Standard deviation: 11.6; Highest: 95.1
  - 2015 spring: Median: 73.6; Standard deviation: 21.3; Highest: 91.7
  - 2014 Fall: Median: 76.7; Standard deviation: 9.1; Highest: 90.8

Course Policy

- **Attendance required, checked in the form of class exercise**
- **Cell phones and other device on silent mode**
- **Can discuss homework problems, but must independently finish them**
- **Exams will be closed-book, 1 letter page (2-sided OK) formula/concept sheet allowed**
- **Grade discrepancies – resolve within the next business day**
- **"Make-up" exams only for real, life-threatening emergency with valid proof**
- **Accommodate disability/religious holidays**
- **NO cheating or plagiarizing in ANY form**

Guidelines on Group Presentation

- **A 12 min max presentation (~12 slides) about materials evolution/development of interest to you**
  - **It should be based on <u>one</u> of the two formats below:**
    - **The evolution/development of a SPECIFIC <u>MATERIAL</u> (e.g., man-made diamond), or**
    - **The evolution of materials used for a SPECIFIC <u>APPLICATION</u> (e.g., materials for solar cell light absorber)**
  - **It should have most of the following (but NOT necessary all)**
    - **Introduction**
    - **Materials development (may have multiple generations)**
      - **The original material and/or application and its limitations**
      - **New materials or processing used in practice (i.e., in manufacturing) and how and why it exceed original materials**
      - **Limitations with the new materials/processing, if any**
    - **Conclusions and/or directions for future R&D for that material or application**
    - **Contribution of each member (e.g., literature survey, PowerPoint file preparation, others)**
- **Dates:**
  - **Date 1 (after 2nd exam): Group presentation topics due**
  - **Date 2 (last week of semester): oral presentation**
- **Grouping: each group should have 3 or 4 students, form group on your own**
- **Grading: 7 points maximum and all group members get the same grades**
- **<u>It needs to be at the COLLEGE LEVEL, quantitative, showing the concepts/knowledge learned in this class and not remaining at the middle-school or even primary school level!</u>**

Contents Covered

- **Fundamental Concepts (chapter 1-5, 9, 10)**
  - Structure
  - Diffusion
  - Phase and phase transformation
- **Properties (Chapter 6-8, 17)**
  - Mechanical
  - Corrosion/degradation
- **Categories of materials (Chapter 10-16)**
  - Metals, Ceramics/Glass, Polymer, Composites: their processing and applications
- **Interrelationships between different aspects**

Types of Materials – By Chemistry/Composition

- Metals: Pure elements or compounds consist of metallic elements
  - Metallic bond
  - High thermal & electrical conductivity
  - Opaque, reflective
- Ceramics: – mostly solid compounds consists of at least one non-metallic elements (oxides, carbides, nitrides, sulfides)
  - Ionic or covalent bonding (refractory)
- Polymers: Large molecules contain carbon C as well as other elements such as H, O, N, Si, S, etc.
  - Usually covalent bond between atoms
  - Soft, ductile, low strength, low density, low melting point
- Composites: Consisting at least two distinctly different materials to realize optimized properties that combines the advantages of each components

Types of Materials – Other Classifications

By **application** or function

- Structural materials
- Electronic materials: Conductors; Semiconductors; Dielectrics
- Optical materials
- Magnetic materials
- Biomaterials
- …

By certain **property**

- Electrical: conductor; insulator; semiconductor
- Hardness: hard versus “soft”
- Toughness: brittle versus ductile
- …

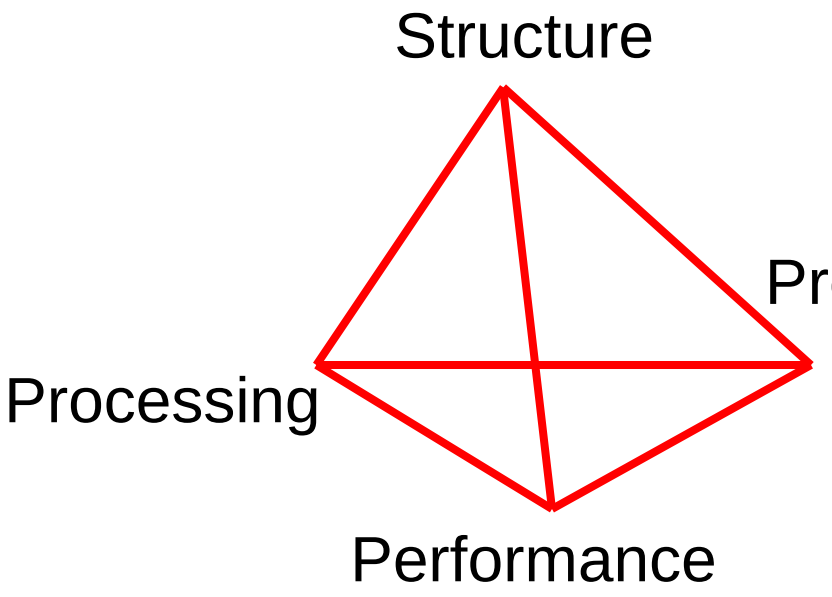
By **source**

- Natural materials
- Man-made

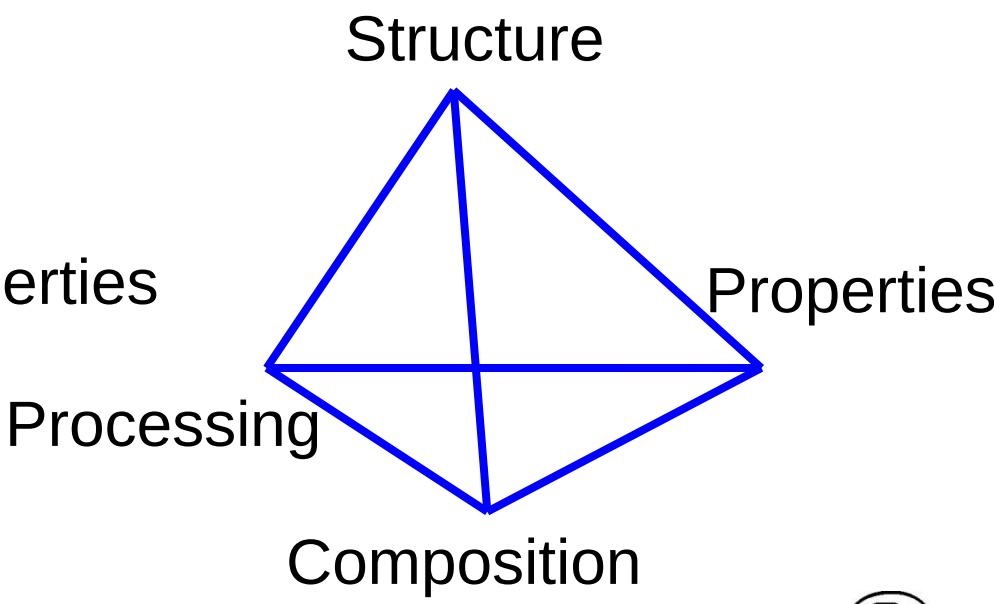
Materials Tetrahedron

- **Basic "aspects" of materials engineering and their inter-relationships**

Common "Materials" Tetrahedron



Dr. Cheng's version of "Materials" Tetrahedron



Materials Composition

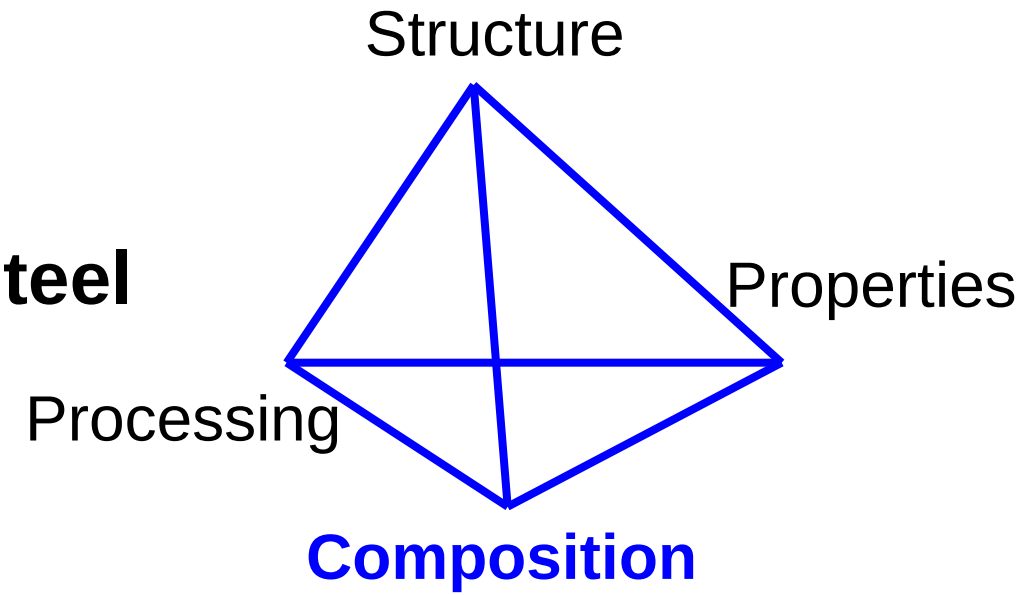
Chemistry

- **Al vs. Ti vs. Fe**
- **Metal vs. Polymer**
- **…**

Concentration

- **C content in iron & steel**
- **B or P content in Si**
- **…**

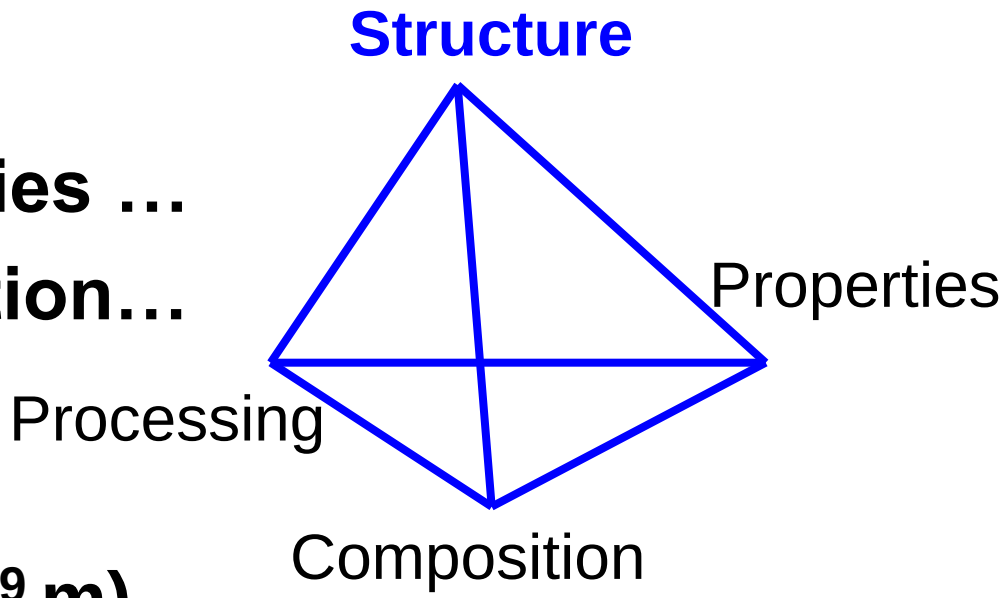
Dr. Cheng's version of "Materials" Tetrahedron



Materials Structure

- **Macro-scale (e.g., millimeter, ~10^{-3} m and above)**
  - **Bar, sheet, fiber…**
- **Micro-scale (e.g., micron, ~10^{-6} m)**
  - **Grain and boundaries …**
  - **Pores and distribution…**
- **Atomic scale (e.g., nanometer, ~10^{-9} m)**
  - **Crystal (or lattice) structure**

Dr. Cheng's version of "Materials" Tetrahedron



Materials Processing

Heat

- **Casting**
- **Sintering**
- **Annealing**
- **…**

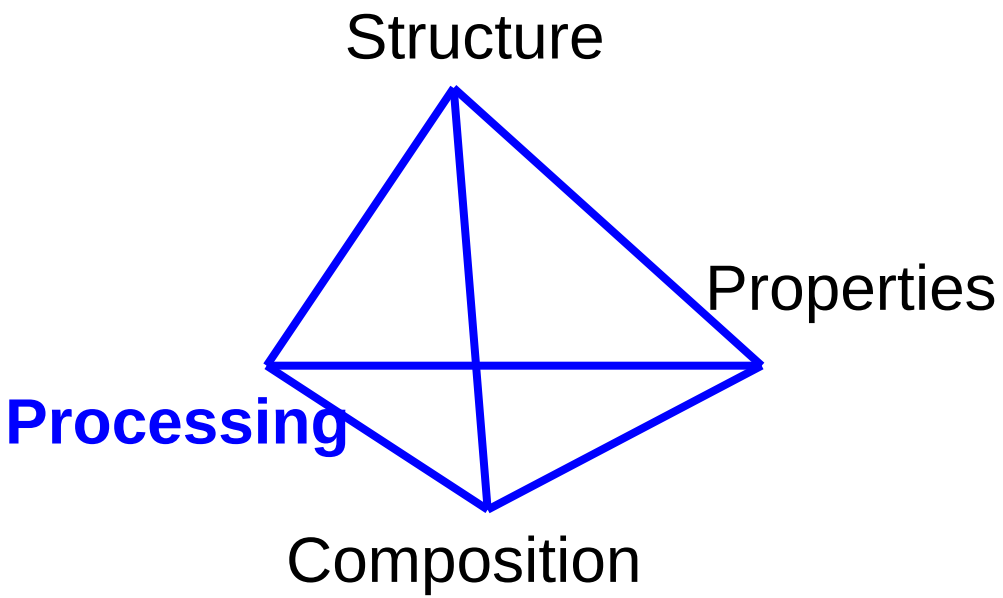
Mechanical

- **Rolling**
- **Cutting and grinding**
- **…**

Other (Chemical, Electrical, etc.)

- **Sputtering**
- **Electrodeposition**
- **…**

Dr. Cheng's version of "Materials" Tetrahedron



Materials Properties

Mechanical

Electrical

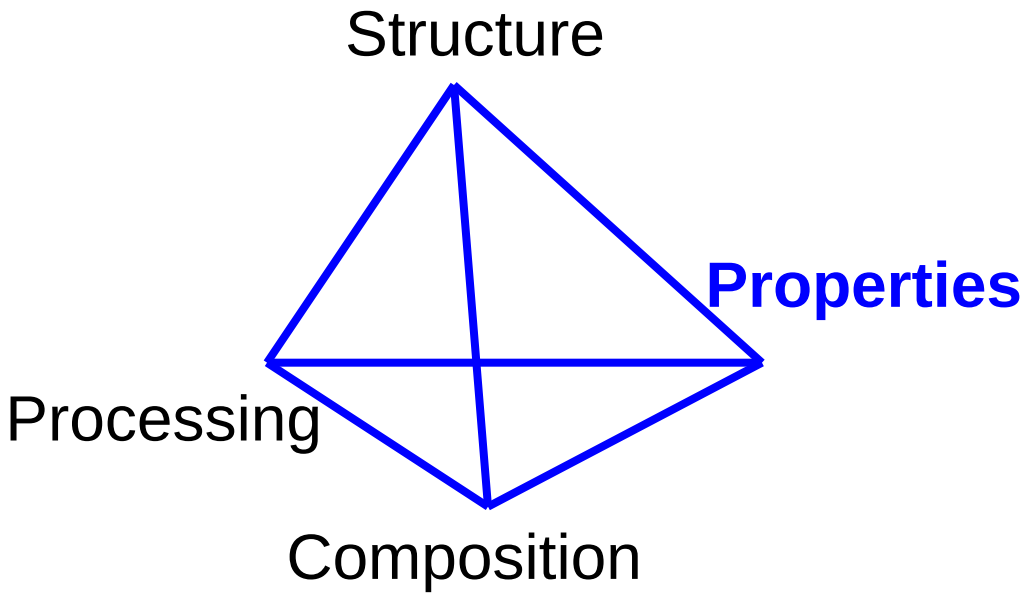
Thermal

Optical

Magnetic

Other

Dr. Cheng's version
"Materials" Tetrahedron



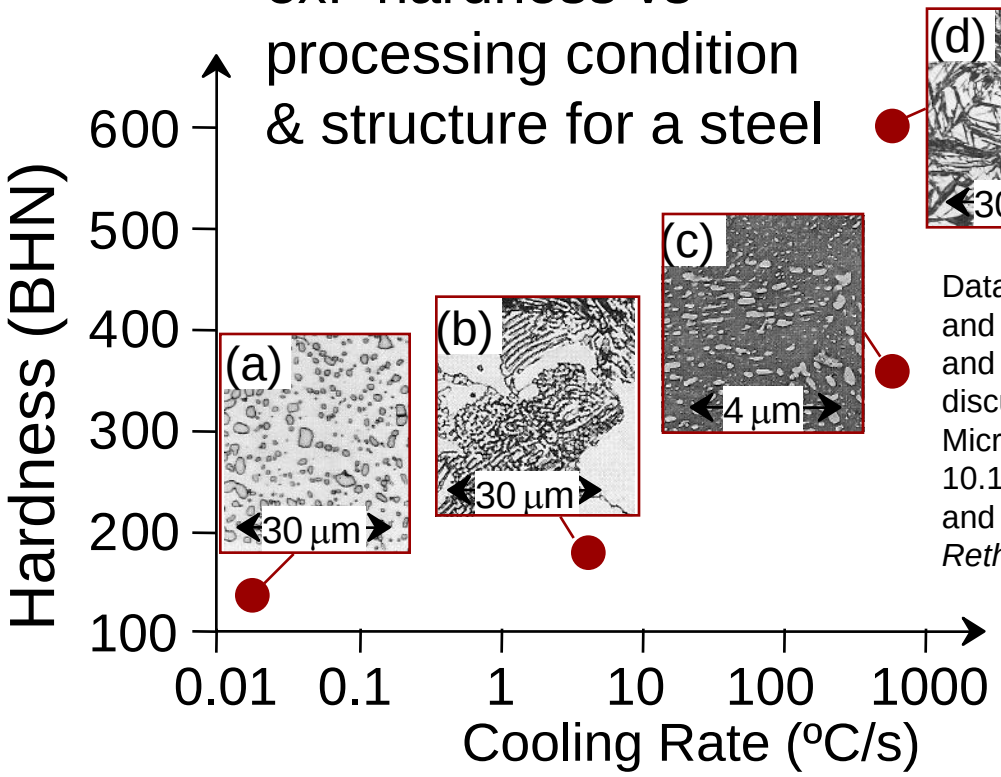
Composition – Structure – Processing – Properties Relationships

- Properties largely depends on composition

  ex: hardness of aluminum vs. diamond; steel vs. pure iron

- Once composition fixed, properties is also influenced by (micro)structure

ex: hardness vs processing condition & structure for a steel



Data obtained from Figs. 10.30(a) and 10.32 with 4 wt% C composition, and from Fig. 11.14 and associated discussion, *Callister & Rethwisch 8e*. Micrographs adapted from (a) Fig. 10.19; (b) Fig. 9.30;(c) Fig. 10.33; and (d) Fig. 10.21, *Callister & Rethwisch 8e*.

- Processing can change structure (and sometimes composition) and resulting properties

"Evolution" of Material Choice for a Particular Application

1. Pick an application ⟶ Determine required Properties

   Properties: mechanical, electrical, thermal, magnetic, optical, deteriorative.

2. Properties ⟶ Identify/discover candidate Material(s)

   Material: composition & structure

3. Material ⟶ Identify required Processing

   Processing: changes *structure* and overall *shape*
   ex: casting, sintering, vapor deposition, doping
   forming, joining, annealing.

Material of choice for a specific application may change/evolve overtime

"Evolution" of a Particular Material

1. Pick a material → Determine intrinsic Properties
   Copper

2. Applications → Identify possible (new) applications
   Mechanical tool; Weapon; Housewares and sculptures;
   Structural elements such as tubings; Lead wires for currents;
   Interconnect in seminconductor device

3. Processing → Identify required Processing

   Processing: changes *structure* and overall *shape*
   ex: Metallurgy, electrodeposition, casting, joining, annealing, polishing,

Application & processing evolve overtime for a given material

Class Exercise

Materials selection

- **Picks a specific engineering application and discuss the potential materials that might be used for that particular application:**
  - ***Example: lamp post: wood, concrete, steel, aluminum…***

Or

Materials evolution

- **Pick a specific material and discuss its current and potential future applications**
  - **Example: gold: coin, decoration/ jewelry, reactor, electrical wiring…**

SUMMARY

Course Goals:

- Understand the basic ways of classification of engineering materials

- Be aware of the different aspects (i.e, composition, properties, structure, and processing.) in material selection/design/manufacturing considerations

- Understand the concept of “evolution” for materials

Homework #1

- **Read Chapters 1 and then give a statement in your homework confirming you finished the required reading**
- **>100 word short write-up describing a specific material or an application (for which material is the limiting factor) that interests you and explain why**