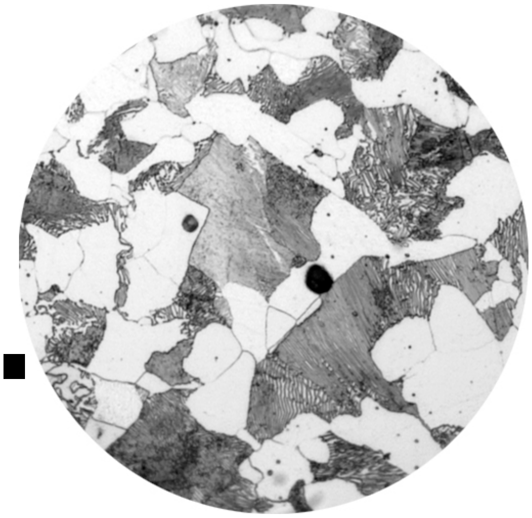
SCI 1410: materials science & solid state chemistry

PROJECT TWO.

processing, microstructure, and properties of metals and alloys



OVERVIEW

For Project 2, your team will explore microstructure-processing-property connections in modern alloy systems. Your team will select an alloy system (e.g., 6061 aluminum, 4140 alloy steel, Ti-6Al-4V, cartridge brass, lead-free solder, ancient bronze, cast zinc, superalloys) and a fabrication or processing technique (e.g., welding, precipitation hardening, rolling, casting, soldering, sintering, tempering), and you will design experiments and use modern laboratory equipment to answer a question of technical significance in modern materials applications. You will learn materials theory related to phase diagrams, phase transformations, strengthening mechanisms in metals, thermal and mechanical processing, and applications of different alloys. By the end of this project, you will understand how to control, modify, and predict material properties and microstructure; you will be able to increase the strength, decrease the brittleness, refine the grain size, and change the microstructural features of alloy systems while humming the theme song from *The Magnificent Seven*. As a result of your experiences, your hands will smell like oxidized metal, and you will long for the warmth of the heat treating furnaces. By the end of Project 2, you will love metals. Oh yes, this is guaranteed.

LEARNING OBJECTIVES

Project 2 will help you develop your learning in these areas:

- Design and management experiments to explore relationships among structure, processing, properties, and performance in metals or alloys.
- Safe and effective use of laboratory equipment for metals processing and analysis.
- Use of phase diagrams to analyze and predict microstructure and properties.
- Explanation and prediction of microstructural and property changes that result from compositional modification, and mechanical and thermal processing.
- Specification of processing techniques to achieve particular microstructures or a specific set of properties in metallic materials.
- Explanation of the environmental and societal impacts of metal ore extraction and processing, metallic materials production, and metals recycling.
- Honing of collaboration skills and positive teaming interactions.
- Application and development of self-regulated learning strategies, and self-motivation in open-ended projects.

HOMEWORK AND EXAMS

Assignments in this phase of the course will include:

Homework. Part 2 will include homework assignments that emphasize development of your analysis, communication (graphical and written) and diagnosis skills. Homework assignments will include readings and problems on the following topics:

1. Diffusion
2. Phase Diagrams
3. Dislocations and Strengthening Mechanisms
4. Nucleation and Growth, Transformation Kinetics

Exam Problems. Two open-book exams will be assigned during this phase of the course.

PROJECT

The second project provides an opportunity for you to explore connections among material microstructure, processing, and or performance characteristics. You will learn material processing methods, and some new analytical and laboratory techniques. As in Project 1, you will design a set of experiments to determine properties and characteristics of a material system, but this time you will actually process the materials prior to analysis, and you will explain how your processing variables affect your alloy microstructures. The details of Project 2 are largely up to your team, but the primary goal of the project is to build connections and understand the interrelationships among processing, microstructure, properties, and broader context and impacts.

A general framework for the project is provided on the following page.

Laboratory Experiment

1. Form a project team and select an alloy system or systems of interest. Pick something with a meaningful technical and societal context, e.g., cast aluminum alloys in automotive components, quenched and tempered steel in machine parts, heat treated titanium in biomedical applications, lead-free solder alloys in modern electronics, structural steel in buildings, etc.
2. Select a processing method or methods (e.g., rolling, drawing, casting, tempering, sintering, heat treating). Note that not all processes are relevant to all alloy systems, so do some research and ask your instructors lots of questions.
3. Select a general project approach. For example, your team could conduct a comparison of various alloys that are processed in the same way, you could analyze the effects of a particular process such as tempering on the properties of a single alloy, or your could explore the effects of composition on a particular property of an alloy system. There are lots of possibilities here, so try to generate a list of potential project directions, and then converge on the idea that is most exciting, motivating, or interesting to your team.
4. Design your project experiments. State a hypothesis, or identify the question or questions you would like to answer. Identify your experimental controls and variables. Determine an appropriate set of properties or characteristics to test or examine. Select appropriate materials science laboratory tools for the analyses.
5. Implement your experiment. Process your metal or alloy. Measure properties and characteristics. Observe your microstructures.
6. Analyze your data, and build connections among microstructure, processing, and properties. How does it all fit together?
7. Contextualize your project experiments, i.e., identify the significance of your findings...make it real!
8. Explore the environmental or social impacts of your metals and alloys. As in the first project, the specific environmental or social impact analytical angle is up to your team, but the start of life sustainability issues of metals may be particularly interesting to examine. Some examples of sustainability angles you may consider:
   a. MINING. Where are the ore reserves? What are the naturally occurring concentrations for the metal? Are the raw materials readily available, or are our natural resources highly depleted? Who is doing the mining? Are the mines small-scale or large-scale operations? What are the energy inputs for ore extraction and pre-treatment of the ore? What waste streams are produced during extraction, and where does the waste go? What are the toxicity levels of chemicals used in extraction and of the waste streams? How do these substances impact the local ecosystem? How does mining positively and negatively impact people or communities? How do the mining company perspectives differ from those of other groups such as the local community, government, or non-governmental organizations (NGOs)?
   b. MINERAL PROCESSING. How is the metal refined? What are the chemical reactions that occur during refining? What are the energy inputs for separation of the metal from its ore? What waste streams are associated with processing, and where does the waste go? What are the toxicity levels of chemicals used in and waste produced by processing? How do these substances impact the local ecosystem? Who is doing the processing, and how are these people affected by their work?
   c. ALLOY PROCESSING. How is your metal transformed from the pure state to a useful alloy? What are the energy inputs for these processes? Are any harmful chemicals used during processing, or are any toxic waste streams produced during processing? If so, what are the impacts of these on people and the environment?
   d. FUTURE OUTLOOK. What advances in sustainable mining/production or reuse/recycling are being explored or implemented? Are we generally moving in the right direction, or are there major problems still to solve? How's the long-term outlook for your metal? Are there lower-impact replacement materials available for your metal or alloy? Are there lower impact processes available?
   e. END OF LIFE. Examine the recyclability of your material or component. Analyze issues related to the disposal of the material/product, e.g., toxicity, reactivity, biodegradation

   These are only a few ideas for examining the environmental impacts of your materials. Feel free to suggest other interesting analytical angles. Find something of interest to you and your teammates.

Project Deliverables

A. Proposal

Length: around half a page (can be longer if it helps you)

Due: Tuesday, March 3, end of class. Please send a copy to Jon via email.

The proposal gives you the opportunity to outline a project plan and receive feedback on your approaches. Briefly answer the following questions:

1. Who are the members of your team? What is the name of your team? Do you have a motto, logo, sponsor, or product endorsements?

2. What metal alloy or alloys will you study? What modern applications for these materials are of interest to your team? Why are they of interest to you?
3. What materials did you (or do you need to) order for your study? Please specify the form of the material, as well as the vendors, part numbers, and costs.
4. How will you process your alloys? What experimental variables will you change to study the effects of your processing? What equipment will you use? How much time will it take to implement your processing plan?
5. Which material properties will you investigate? Why are these properties important to the object's use, performance, or manufacturing? What equipment will you use? How much time will your testing and analyses take?
6. What microstructural features will you explore? How might you connect microstructure, processing, and properties, and how will you explain these connections with materials science theory? How much time will your microstructural analyses take?
7. What questions related to environmental or societal impacts will you explore? What aspects of the metal life cycle are the most interesting to your team, or the most relevant for your alloy? What research will you conduct to answer these questions?
8. Do you need any specialized supplies, resources, or processing or testing setups for your project? If so, what are these, and how will we get them?
9. What information resources will you use to support your investigation?

B. Presentation

Length: 10 minutes per team, plus 5 minutes for Q&A

Due: Tuesday, April 7, class time

This presentation is more formal than the Project 1 presentation. Make some slides, prepare your talk, and focus on the analyses and conclusions of your project. Teach your peers something interesting!

C. Written Report

Due: Wednesday, April 8, 11:59 pm

Your report should include the sort of information typically found in technical report:

- a one-paragarph abstract that summarizes the report
- a clear introduction that sets background and explains your goals or motivations
- brief descriptions of your experimental methods (don't spend too much real estate on this)
- clear presentation of data and analyses of results,
- awesome supporting graphs of your data,
- clear, annotated micrographs and other figures (e.g., phase diagrams),
- clear conclusions that are well-supported by your analyses, and
- formal citations of your sources.

Support your analyses and conclusions with high quality figures and graphics, and don't forget to include some micrographs of your processed alloys. We'll go with an IEEE paper template for this report (details to follow).

This paper will be assessed according to the following competencies:

- Communication
- Qualitative analysis
- Quantitative analysis
- Diagnosis and experimental inquiry

The project report grading rubric on the web site provides a detailed breakdown of each of these competency areas.