SCI 1410: materials science & solid state chemistry

PROJECT ONE.

structure, bonding, properties, and impacts of everyday products

OVERVIEW

The primary goals of the first project are to (1) characterize properties of materials used in common products, (2) use theory to explain why the materials exhibit certain properties, and (3) connect your project findings to the broader technical (performance) and societal (impact) contexts. As you progress through the project, you will learn about the chemistry and structure of solids, thermal and mechanical behavior of materials, and basic analytical and measurement methods. You will get an introduction to lab safety, and just-in-time training on testing equipment and experimental methods. By the end of the first project, you will have measured a variety of material properties such as strength, hardness, and melting point, and you will be able to explain and predict material properties based on your understanding of the chemical composition and arrangements of atoms or molecules in the materials.

LEARNING OBJECTIVES

The first phase of the course will help you develop your learning in these areas:

- Preparation of samples for testing and analysis; and safe and effective use of lab instrumentation for measurement of composition, structure, and properties. [Experimental design and diagnosis]
- Interpretation of data on material composition, structure, and properties [Quantitative and qualitative analysis].
- Explanation of connections among chemical composition, atomic structure and bonding, and material properties
- Exploration of materials selection and performance in a specific context [Quantitative and qualitative analysis]
- Analysis of the environmental or societal effects of the processing, use, or disposal of materials. [Quantitative and qualitative analysis]
- Personal goal setting, and planning, and management of team projects. [Teaming, Lifelong Learning]

ASSIGNMENTS

The assignments in the first phase of the course include:

Homework. This project phase will include several homework assignments that emphasize basic materials science analytical skills. Homework assignments will include readings and problems that cover the following topics:

1. Mechanical Properties
2. Atomic Structure and Bonding, Thermal Properties
3. Crystallography and Defects in Solids
4. Life cycle of materials and environmental impacts

Exam Problems. You'll have several open book exams over the next few weeks. These problems will help me evaluate your understanding of various matsci concepts, and your ability to synthesize various topics from the homework, readings, and project work. Exam problems are individual assignments, except as noted.

Project. This is what you've been waiting to see! The first project provides an opportunity for you to explore connections among material composition, atomic and molecular structure, and thermal, mechanical, environmental, and other properties of materials. In the project, you will learn to use a variety of laboratory instruments, develop a project plan, analyze material property data, and design experiments to determine properties and characteristics of a real system. The details of this project are largely up to your team, but the general goals of the project are:

(i) identification of the materials used for various components of your object (What atoms, ions, and molecules are there?);

(ii) identification of the structure or lack of structure in your materials (How are the atoms, ions, or molecules arranged?);

(iii) measurement of the material properties of the object components (How do these materials behave, and what does this mean for performance?),

(iv) examination of material selection for the design (Why were these materials chosen?),

(v) exploration of the environmental impacts of your materials, and (vi) building connections among composition, structure, properties, and performance.

Think "reverse engineering" and "product testing," with an eye toward environmental and societal impacts.

LABORATORY EXPERIMENT

A general framework for the project is as follows:

1. Form a project team and select a consumer product that interests all of you.
2. Explore the components of your product. Identify properties or characteristics of the product that are of interest to your team, or relevant to the product's manufacture or performance. Identify questions you would like to answer.
3. Based on your list of questions and the capabilities of equipment in our labs, design a set of experiments to explore your materials. Identify other ways you could characterize your material(s) by research. Try to measure several attributes of your material(s), and consider ways in which you may build connections between structure-composition, properties, performance, and context (Figure 1). Some things you could measure or research:
   - Crystal structure (or lack of structure)
   - Chemical (atomic or molecular) composition
   - Density
   - Melting temperature
   - Glass transition temperature (polymers)
   - Percent crystallinity (polymers)
   - Degradation or oxidation temperature
   - Thermal expansion coefficient
   - Chemical reactivity
   - Recyclability or reusability
   - Toxicity (of the material or its processing)
   - Viscoelastic properties
   - Ductile to brittle transition
   - Strength (compressive, yield, tensile, flexural, shear)
   - Young's modulus
   - Ductility
   - Impact resistance
   - Energy absorption or toughness
   - Hardness
   - Fracture mode
   - Electrical conductivity
   - Optical properties
   - Surface energy

   Note that your textbook does not describe many of these techniques, so you may need to do some research to gain understanding of various measurement techniques.
4. Consider the environmental implications of your material or product. Select an interesting angle from which to analyze your product. For example,
   - Examine the recyclability of a material in your product.
   - Analyze issues related to the disposal of the material/product, e.g., toxicity, reactivity, biodegradation.
   - Examine the availability or depletion of the raw material(s) in your product.
   - Explore replacement materials for use in your product, with the goal of reduced environmental impact.
   - Conduct a life cycle analysis of your product.

   These are only a few ideas for examining the environmental impacts of your materials. Feel free to suggest other interesting analytical angles.

   As you consider different environmental or societal impact analysis angles, it may be helpful to think about specific questions your team is interested in answering, e.g., *What particular component or material of this product has the most significant environmental impact? What phase of the product life cycle offers the most opportunity for improvement? Where do the raw materials originate, and who is involved in the extraction of these raw materials? Are more benign materials available to replace those used in this product? How is this material recycled, and what are the costs of recycling – energy, water, waste, performance loss, etc.? How do biological systems interact with this material, or with waste from the processing of this material?*
5. Design a set of experiments to measure your selected properties. Test your components. Analyze your data. Connect your analyses with materials science theory. Your instructor and the course assistants are good resources for assisting with your experimental design and analyses, so please explore ideas with them.

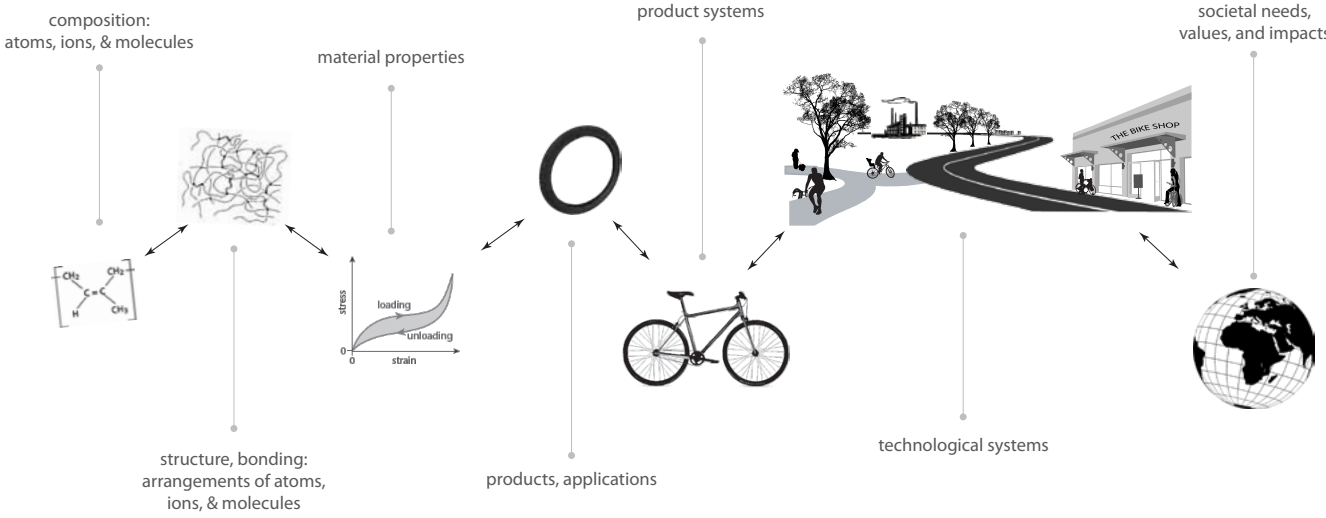

Figure 1. Your goal in this project: Start with a product or product system (middle), and explore the small-scale atomic structure and bonding (left), properties and technical performance (middle), and larger societal contexts and impacts of its materials (right).

PROJECT DELIVERABLES

I. PROPOSAL

Format: two options here – written or graphical/visual. If you opt for a written document, send me about a page of text. If you opt for the graphical/visual, I recommend using the poster template from the in-class practice activity.

Due: Wednesday, January 21, end of class period

The goal here is to create a draft project plan and receive feedback. Briefly answer the following questions:

1. Who are the members of your team? What is the name of your team? Do you have an official motto, logo, sponsor, or product endorsements?
2. What product are you studying? Why does it interest you?
3. Which material properties would you like to investigate? Why are these properties important to the object's use, function/performance, or manufacturing?
4. How might you connect the properties to atomic-scale chemistry and structure, and explain these connections with materials science theory?
5. What do you know about the modern usage of this artifact? Who makes it, who uses it, how popular is it, what societal impacts does it have, what values do people assign to it? What interesting environmental issues or questions arise when considering your artifact?
6. What specific questions will you attempt to answer in the next few weeks? What are your strategies for answering your questions?
7. Given your experimental strategies, what outputs will you produce (e.g., graphs, statistics, text, models, sketches), and how will you present your findings in your poster?
8. Do you have any questions or concerns?

II. Poster

Size: 28" x 42" maximum – vertical or horizontal orientation

Due: Wednesday, February 25, by midnight. Email a pdf version of your poster to me, or place a copy on a public drive and send me the link. In addition, please print a hard copy, and hang it in the AC hallway before the due date and time.

The specific poster format is up to your team, but it should include information typically found in technical poster: clear introduction that sets background and explains your goals or motivations, brief descriptions of your experiments, clear presentation of your data and analyses of your results, and some solid conclusions that you can draw from your analyses. Readers should walk away from your poster understanding WHAT you are studying and why, HOW your materials behave (properties), WHY they behave that way (connect properties to structure, bonding, and composition), and WHY WE CARE (the context-specific significance of your findings). Some questions or topics you should consider when developing your poster:

- What materials make up your product? What are the compositions of your materials? What type of structure and bonding do these materials have?
- How do your materials behave? You can get this information via experiments or research. For experimental data, be sure to use reference values from the literature to verify/check your lab data.
- Why were particular materials selected for the design, i.e., what led the designers to the choice of different materials? How do your materials address the performance requirements of your product components?
- How can you use materials science theory to explain your materials' behaviors?
- How can you connect the various properties to each other, e.g., is strength explained by atomic bonding? How can you support your conclusions?
- What effects do your materials have on the world? Are there particular societal or environmental impacts that are important to consider when creating, processing, transporting, using, or disposing of your materials?

You cannot address all the properties and all the property-structure connections for your product's materials in one poster, so do your best to organize your paper around a structured analysis that combines evidence with solid logical reasoning. Note that it is easy to illustrate HOW your materials behave, e.g., *this alloy has high ductility.* It's much more challenging to explain WHY, e.g., *the high ductility arises from the metal's structure and bonding…this alloy has a face-centered cubic structure, and relatively weak an non-directional metallic bonds. This allows for easy motion, or "slip," of dislocations in response to applied stress, causing the material to plastically deform.* **Don't forget to answer the WHY questions – this is the "science" part of materials science.**

Your team's poster will be assessed according to the following competencies:

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

Detailed grading rubrics for each of these competency areas will be posted on the web site. Check them out ahead of time, so there are no surprises.

III. Brief presentation

Length: Eight minutes per group (not counting questions)

Due: Tuesday, February 24, in class

Present the most interesting, most exciting, or most valuable aspect of your project to the rest of the class. Do not try to present everything you did in the project. I'm thinking one to three slides, and a well-practiced talk. Your presentation should include the following:

1. a significant technical analysis component that explains a material property or behavior based on structure, bonding, and composition, and
2. a meaningful analysis of a societal or environmental impact of your material or product.