MSE 423 – Ceramics Processing Laboratory
Fall 2015

Instructor: Laura Nagel

Teaching Assistant:

Lecture: 122 Kiln House, Monday and Wednesday 1:00-1:50 pm
Laboratory: 203 Kiln House, Tuesday and Thursday 2:00-4:50 pm

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Course Website: Compass

Text and References (not required):
1. M. N. Rahaman, *Ceramics Processing*, CRC Press, Taylor & Francis Group: New York (2007)
2. A. J. Moulson, J. M. Herbert, *Electroceramics*, 1st Ed., Wiley: New York (2003).
3. W. D. Kingery, H. K. Bowen, D. R. Uhlman, *Introduction to Ceramics*, 2nd Ed., Wiley: New York (1976).
4. Y.-M. Chiang, D. Birnie, III, W. D. Kingery, *Physical Ceramics*, Wiley: New York (1997).

Prerequisites

According to the UIUC course catalog, MSE 421 is a prerequisite for this course. Due to changes in the overall course schedule, however, MSE 421 is taught during the same semester as MSE 423. It is recommended that students have completed MSE 420 and be registered in MSE 421 concurrent with or have completed MSE 421 prior to taking MSE 423. This course will assume knowledge from MSE 420 and will provide additional material complementary to topics in MSE 421. If there is space available in the course, students from outside MatSE can take MSE 423, but are wholly responsible for the additional materials required to keep up with the course.

Class Description and Objectives

The objective of this course is to provide students with a practical understanding and working knowledge of ceramics properties and processing. This course is a practical, hands-on extension of the topics covered in MSE 420 and 421 and will include experiments and demonstrations involving a wide range of modern ceramic processing methods. These experiments are designed to highlight the relationships between raw materials, processing methods, microstructural development, and physical properties in the diverse class of materials known as ceramics. This laboratory-based practical experience emphasizes the development of an understanding of the underlying physics and chemistry of processing and the design of processing routes to achieve the desired material properties. This will be accomplished through small-group laboratory exercises and written and oral reports.

As part of this course, a range of practical processing methods will be taught. Students will be given the freedom to explore aspects of ceramic powders preparation, powder characterization, forming methods, thermal processing, and physical property characterization. In the first part of the course, students will learn the basics of a number of classic processing methods as applied to traditional materials. This work will provide a foundation upon which the second portion of the class will build. In the second portion of the course, students will be asked to apply their knowledge to produce high-quality functional ceramics. Throughout the course, students will explore the interplay between crystal, electronic, chemical, and microstructural degrees of freedom in ceramics.

The course includes a weekly 50-minute lecture, two 170-minute lab sessions, and a discretionary 50-minute period. The course is a fluid and evolving subject that will be amended throughout the semester as needed. A proposed class outline and schedule are included below.

Module I – Powder and Slurry Preparation and Characterization (2 weeks)

- *Logistics – Laboratory Safety and Expectations Overview*
  - Review course objectives, safety, and laboratory expectations
- *SEM Powder Characterization*
  - Learn basic characterization methods – scanning electron microscopy, helium pycnometry
- *Slurry Preparation and Characterization*
  - Investigate methods for the preparation of stable colloidal ceramic oxide particle suspensions
  - Explore stabilization mechanisms, polyelectrolyte surface coverage, rheology, zeta potential
- *Porosity and Density Characterization*
  - Analyze porosity and density of premade porous samples
- *Deliverable*
  - *Submit as a group*
    - A one-page executive summary
    - A written laboratory report
  - *Submit individually*
    - Theory questions

Module II – Forming and Thermal Processing of Ceramics (5 weeks)

- *Methods for Forming Ceramics*
  - Study forming methods to prepare ceramic oxide parts by slip casting, tape casting and pressing spray-dried powders
- *Thermal Processing*
  - *Drying, calcining, sintering*
- *Mechanical Properties*
  - Assess the bulk mechanical properties of the green bodies and fired ceramics
- *Deliverables*
  - *Submit as a group*
    - A one-page executive summary
    - A written laboratory report
  - *Submit individually*
    - Theory questions

Module III – Selected Advanced Topics (2.5 weeks)

- *Advanced Precursor Synthesis*
- *Ball Milling for Size Reduction*
- *Dielectric and Ferroelectric Properties*
- *Sample Polishing and Etching*
- *Deliverables*
  - *Submit as a group*
    - A one-page executive summary
    - A written laboratory report
  - *Submit individually*
    - Theory questions

Module IV – Custom Project (4.5 weeks)

- Apply knowledge and skills in bulk processing from Modules I - III to the production of a functional ceramic oxide system
- Characterize the structure, quality and physical and mechanical properties of these materials
- Explore the effect of at least one variable – chemistry, processing, sintering, binder, etc. – on the property evolution of this material
- *Deliverables—Submit as a group*
  - A one-page executive summary for the laboratory
  - 20 minute professional research presentation that discusses the scientific motivation, experimental variables, and findings of your work. Pull from the published literature to support your presentation.

Class Schedule

	Class date		Class Topic	Assignments Due
MODULE I	Mon.	24-Aug	Lecture: Introduction and Safety Overview	
	Tues.	25-Aug	Laboratory: Module I	
	Wed.	26-Aug	Lecture: Module I	
	Thurs.	27-Aug	Laboratory: Module I	
	Mon.	31-Aug	Laboratory: Module I	
	Tues.	1-Sept	Laboratory: Module I	
	Wed.	2-Sept	Lecture: Module I	
	Thurs.	3-Sept	Laboratory: Module I	
	Mon.	7-Sept	NO CLASS – Labor Day	
	Tues.	8-Sept	Laboratory: Module II	**Theory Questions for Module I due**
	Wed.	9-Sept	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	10-Sept	Laboratory: Module II	
	Mon.	14-Sept	Lecture: Module II	**Module I Report and Exec. Summary due**
	Tues.	15-Sept	Laboratory: Module II	
	Wed.	16-Sept	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	17-Sept	Laboratory: Module II	
MODULE II	Mon.	21-Sept	Lecture: Module II	
	Tues.	22-Sept	Laboratory: Module II	
	Wed.	23-Sept	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	24-Sept	Laboratory: Module II	
	Mon.	28-Sept	Lecture: Module II	
	Tues.	29-Sept	Laboratory: Module II	
	Wed.	30-Sept	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	1-Oct	Laboratory: Module II	
	Mon.	5-Oct	Lecture: Module II	
	Tues.	6-Oct	Laboratory: Module II	
	Wed.	7-Oct	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	8-Oct	Laboratory: Module II	
	Mon.	12-Oct	Lecture: Module III	**Theory Questions for Module II due**
	Tues.	13-Oct	Laboratory: Module III	
	Wed.	14-Oct	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	15-Oct	Laboratory: Module III	
	Mon.	19-Oct	Lecture: Module III	**Module II Report and Exec. Summary due**
	Tues.	20-Oct	Laboratory: Module III	
	Wed.	21-Oct	Discretionary (Lecture or Laboratory as needed)	**Module IV Proposals due**
	Thurs.	22-Oct	Laboratory: Module III	
	Mon.	26-Oct	Lecture: Module III	
	Tues.	27-Oct	Laboratory: Module III	
	Wed.	28-Oct	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	29-Oct	Laboratory: Module IV	

MODULE III	Mon.	2-Nov.	Discretionary (Lecture or Laboratory as needed)	**Theory Questions for Module III due**
	Tues.	3-Nov	Laboratory: Module IV	
	Wed.	4-Nov	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	5Nov	Laboratory: Module IV	
	Mon.	9-Nov	Discretionary (Lecture or Laboratory as needed)	**Module III Report and Exec. Summary due**
	Tues.	10-Nov	Laboratory: Module IV	
	Wed.	11-Nov	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	12-Nov	Laboratory: Module IV	
	Mon.	16-Nov	Discretionary (Lecture or Laboratory as needed)	
	Tues.	17-Nov	Laboratory: Module IV	
	Wed.	18-Nov	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	19-Nov	Laboratory: Module IV	
	Nov. 23 – 27 – NO CLASS – Thanksgiving Break			
	Mon.	30-Nov	Discretionary (Lecture or Laboratory as needed)	
	Tues.	1-Dec	Laboratory: Module IV	
	Wed.	2-Dec	Discretionary (Lecture or Laboratory as needed)	
	Thurs.	3-Dec	Laboratory: Module IV	
	Mon.	7-Dec	Discretionary (Lecture or Laboratory as needed)	
	Tues.	8-Dec	**Module IV Presentations and Exec. Summary due**	
	Wed.	9-Dec	Last Day of Classes – No Classes	

Laboratory Logistics

- The laboratory will be made available during the above listed times (i.e., those noted in the official schedule for the class) to support the progress of MSE 423.
- Students can only access the laboratory facilities during business hours and under the supervision of Nicole Robards or the TA (Daniel Roper).
- Students should pace themselves and their experimental discovery appropriately within the allotted times for each laboratory Module. Additional times outside the scheduled course slots require that students plan with Nicole Robards or Daniel Roper to be present in the laboratory during their work outside of the scheduled times. Neither Ms. Robards nor Mr. Roper are required to accommodate these requests.

Grading Policies

Student learning and growth will be assessed based on the following assignments:

- **Laboratory Safety, Best Practices, Peer Evaluations (10% of total grade)**
  - Students will be expected to follow a set of stringent laboratory safety and best practices. Failure to do so will result in a loss of points.
  - Laboratory work carries with it a number of safety protocols designed to protect you and your fellow students. These protocols include, but are not limited to, adhering to the dress code, the use of personal protective equipment (PPE), and other experiment-specific safety requirements.
  - Students ***cannot*** work on an experiment alone. Your laboratory partner must be present or you must arrange to work with another group. Additionally, at least one instructor must be present in the laboratory during your work.
  - Attendance of all laboratory sections is not mandatory, but is strongly suggested. The due dates for reports are clearly listed and are not flexible. Students are responsible for getting their work done in a timely fashion in order to complete the assignments at these predetermined dates. Note that extra, discretionary times are scheduled and that students can potentially gain additional access through coordination with the instructors.

- Laboratory cleanliness will be closely policed. Students are to leave the laboratory looking better than they found it. This means cleaning up after yourself, returning items to where you found them, and generally maintaining a clean and orderly work environment. The instructors, the TA, and Ms. Robards will be noting any failures herein.
- Students are required to provide and maintain a neat, orderly, and comprehensive laboratory notebook. These notebooks are extremely important and can be used in litigation to establish intellectual property, the design of multi-million dollar processes, and much more. Laboratory notebooks will be subject to period inspection by the instructors. Details on the expectations for your laboratory notebook are provided in ***Appendix A*** below.

- **Theory Questions (20% of total grade)**
  - Each student must answer a set of theory questions relevant to the topics covered in the module. Theory questions are individual assignments.
  - Module I – Due Tuesday, Sept. 8, by 1:00 PM (Electronic Submission)
  - Module II – Due Monday, Oct. 12, by 1:00 PM (Electronic Submission)
  - Module III – Due Monday, Nov. 2, by 1:00 PM (Electronic Submission)
  - Module IV – Due Tuesday, Dec. 8, by 1:00 PM (Electronic Submission)

- **Laboratory Executive Summaries (10% of total grade)**
  - Each group must produce a 1-page executive summary for each lab module. Details of the requirements are provided in ***Appendix B***.
  - Module I – Due Monday, Sept. 14, by 1:00 PM (Electronic Submission)
  - Module II – Due Monday, Oct. 19, by 1:00 PM (Electronic Submission)
  - Module III – Due Monday, Nov. 9, by 1:00 PM (Electronic Submission)
  - Module IV – Due Tuesday, Dec. 8, by 1:00 PM (Electronic Submission)

- **Laboratory Reports (40% of total grade)**
  - Each group must produce a written report for each lab module. Details of the requirements are provided in ***Appendix C***. Because each module includes multiple experiments, care must be taken to organize the report appropriately.
  - Module I – 10% of total grade, Due Monday, Sept. 14, by 1:00 PM (Electronic Submission)
  - Module II – 20% of total grade, Due Monday, Oct. 19, by 1:00 PM (Electronic Submission)
  - Module III – 10% of total grade, Due Monday, Nov. 9, by 1:00 PM (Electronic Submission)

- **Laboratory Presentation (20% of total grade)**
  - Each group will make a presentation on Module IV on Tuesday, December 8 from 2-5 pm.
  - Students will present in their laboratory groups. Presentations will be 20 minutes long.
  - Each group will submit their PowerPoint presentation electronically and bring 2 printed notes copies of the PowerPoint to the presentation.
  - Additional details concerning the subject matter, grading, and expectations are provided in ***Appendix D***.

Late Assignments

- **Late assignments will not be accepted unless prior arrangements are made with the instructor.**
- If you have concerns I am happy to discuss with you about your specific situation and clarify any questions you have.

Academic Code of Conduct

- This course will execute a “zero-tolerance” policy concerning cheating and plagiarism.
- Students are referred to the University of Illinois, Urbana-Champaign Student Code for complete details on the Student Code. Special attention should be given to Part 4 of Article 1 http://studentcode.illinois.edu/index.html).
- Cheating and plagiarism will be dealt with according to established campus policy. Students caught cheating will receive a failing grade for the assignment.

APPENDIX A – Laboratory Notebook Overview

In an attempt to bring uniformity and consistency to your laboratory experience, we will be adopting a uniform laboratory report format and procedure. The following is adapted with permission from the new electronic book produced by **Matt Sherburne**, **Nicole Robards**, and **Angus Rockett** for use in **MSE 307**.

The following outlines the expectations for the laboratory notebook in MSE 423.

The Laboratory Notebook

The purpose of a laboratory notebook is to record what you did in sufficient detail that you can reproduce what you did (for example through a detailed description of the apparatus and the procedures used to acquire the data), explain problems with the data based on information you recorded in the lab notebook, record any events that might have affected the data, record things that went well, etc.

Suppose that the data looks good but the values change suddenly in the middle of the experimental run. You find that if it were not for the sudden change, your data would have explained the behavior you observed very well. What caused the sudden change? Referring to the lab notebook, you find that you bumped the lab bench between those two measurements. Conclusion: the change in the data was due to bumping the table. You may be able to correct for that change and show that the data works.

Suppose that the position of the sample in the apparatus matters? If you write down where you placed the sample in the apparatus you can reproduce the behavior. At least all samples will be measured at the same position.

Suppose that you and another group run the same experiment but get different results. How do you account for the difference? You refer to your lab notebook and they refer to theirs and you find that the difference was the heating rate (so the experiments in fact were not the same). So the difference in the results may be due to the different heating rate. Now you have learned not only what you set out to learn but also what the effect of heating rate is.

NOTE: the purpose of the lab notebook is NOT to record only your successes. Indeed, it is most important to record the things that went wrong as these are most likely to affect your results. Experiments almost never go completely right. Consequently, you are often faced with how to deal with bad data. If you always insist that all data agree with a trend you will never succeed. You also cannot just ignore data points that do not fit your idea of what the trend should be. However, if you can sort through your data and figure out what the problem was, you may be able to correct for it, determine what to change about the experiment, and possibly show which data is reliable and why.

Elements of the Laboratory Notebook

The following outlines the expectations for your laboratory notebook and what should be included in it for each laboratory portion of the course:

- Your laboratory notebook needs to be either of a stitched or glued type of binding. A three ring binder and/or loose paper will not be acceptable for this class, nor are they acceptable in the real world once you are employed. The three ring binder and loose paper will get you a 0% on the lab notebook portion of your grade.
- The size of the notebook you use is a personal choice; just remember that if you choose a notebook that is small, drawing detailed figures will not be easy. A notebook that is standard page size allows you to easily print out figures or data and go back and glue it into your notebook next to the original figure or data.
- Your pages will need to be numbered; whether you number them or the notebook comes numbered is up to you.
- Every page should be dated. If you start a new experiment or start a new day of work begin a new page in the notebook.
- A sketch or photographs of the apparatus should be included in the notebook along with a description of how the apparatus was connected together (as appropriate). If you measured out a sample, record how the sample was prepared.
- For example, 10 mg of camphor was measured out from the reagent bottle onto a glass slide. Next 15 mg of succinonitrile was measured out from the reagent bottle onto the same glass slide. Both materials

were white powders. The two measured samples were mixed on the glass slide with a spatula. After mixing the combined sample weighted 24 g (1 g apparently was lost, perhaps due to adhesion to the spatula).

- On the outside of your notebook you should put your name, course number, instructors name and your email address.
- If your laboratory notebook does not have a prelabeled section for the table of contents then you should reserve several pages at the front of your laboratory notebook for your table of contents.
- Electronic/digital notebooks are not acceptable for this course. The main reason for this is that their veracity has not been tested in patent litigation cases. Until a legal standard exists for the use of digital notebooks they will not be allowed.
- All writing should be done using permanent ink. What tends to work best is the classic ballpoint pen, as these cannot be erased and do not smear. Other pens work but tend to smear either by your hand running across the writing prior to its drying or from an accidental spill. Pencil is never acceptable.
- If you make a mistake, and you will, do not attempt to ease or apply white out to the mistake. Simply put a line or an “X” through the error and continue on from that point. Draw an “X” in any large empty are of your notebook. This way data cannot be inserted into the space later.
- Your notebook needs to be recorded in chronological order.
- Make notes with small written sections about anything that is odd, out of place, or could potentially impact the outcome of the experiment. For example, note that you bumped the table or something of this type.

Practical Aspects

The following outlines some practical aspects that should be kept in mind when working on your experiments and filling in your laboratory notebook.

- Record your raw data immediately, do not wait and get distracted, or think that I will remember it. You can very easily transpose digits or just forget the correct number if interrupted. Without the correct data it will be much more difficult to write up your lab report.
- Your lab notebook is not to try to carry lab equipment on and should not be used to carry anything around the lab. It is too easy for you to drop and break the items you are carrying.
- Make every effort to keep your lab notebook away from any liquid such as the sink, or other spills which may occur in the lab. While water may not make your ballpoint pen ink run it does make it difficult to write on wet pages.
- Include more detail in your notes than you think you actually need. This will help when you are attempting to write up your lab report. This means record anything and everything you observe in your experiment.
- If it matters in what order devices were connected or turned on then you should record that. It is better to write too much than too little.
- Record how you did the experiment. In what order did you make measurements? What were the values you set the apparatus controls to and in what order? Did you observe any effect of this sequence? Record as much of what you did as reasonable. The more you write down the more likely you are to be able to diagnose problems with the results.
- Any experimental values not recorded by a computer should be written in the lab notebook. (What was the gas flow rate? What voltage did you set the power supply to? Etc.)
- If possible/reasonable, capture your results in a printed form and incorporate them into the lab notebook. When practical, print out the data and tape it or glue it into the notebook. Paper can always be read somehow. Electronic data gets lost, deleted, or becomes obsolete.
- Make notes of things that did or might have gone wrong. If you don't notice anything go wrong during the measurement write that down. That way you know that you did not notice anything strange about the measurement.
- Remember: there are few things in science more annoying than trying to write up an experimental result and realizing that the observation does not fit the theory but you did not write down some key experimental procedure that would have allowed you to at least know why the results did not agree with expectations.

APPENDIX B – Executive Summary Overview

Overview

An executive summary is typically required for business, engineering and scientific reports or proposals. Writing and perfecting these documents will be an aspect of your future career in pretty much any field you pursue. The executive summary is a fully developed mini-version or overview of the report – it is not merely an introduction. The executive summary aims to provide a brief overview of the whole report so that executives or managers (who are very busy) could read the executive summary alone without the accompanying report. It should allow the reader to quickly understand the information contained in the report and should persuade the reader that the document is worthy of being read in detail. It should provide concise, complete, specific, and self-sufficient information such that it can be understood in isolation from the rest of the document. The executive summary should briefly outline the subject matter, the background problem, the scope of the investigation, the method(s) of analysis, the important findings and important issues raised in the discussion, and provide the conclusion and recommendations in just one page. The executive summary should not just be an outline of the points to be covered in the report with no detail of the analysis that has taken place or conclusions that have been reached.

Overall the executive summary stands as an overview at the front of the report but it is also designed to be read alone without the accompanying report (this would often occur in the workplace). The executive summary should be no more than 1 page long and achieve all of these goals.

Writing an Executive Summary

The executive summary should be written in your own words, using a formal writing style. Avoid using jargon and informal language. Early in the document, *clearly articulate the purpose/aim/goal of the report* – using emphasized texted as needed. Briefly provide a context for why this work is timely, important, and necessary. Throughout the executive summary one might:

- Describe the procedure that was used including the methodology or analytical process used to process the data collected.
- Provide a clear, concise summary of the results of the study. The summation of the major findings may include a number of sentences or bullet points.
- Include recommendations for improvement, aspects that were particularly challenging, and roadblocks that kept one from achieving an overall goal as needed.
- Edit the summary to remove minor points. Use your judgment to ensure that the summary is concise and to the point.
- Remove unnecessary words and sentences. Check the accuracy of grammar, spelling, sentence and paragraph structures so that things flow nicely.
- Use formatting and graphics to highlight the message as needed. Clarity of the summary can be improved through usage of bullet points and subtitles in the organizational structure. This will also make it easier for the reader to skim read.

Process involved in writing an Executive Summary

The executive summary is normally not more than a page in length and should provide an adequate representation of the entire document in a shortened form. The executive summary is provided on a separate page at the beginning of the report. An impersonal writing style is used so as to ensure that the report remains formal especially if the audience is your manager or supervisor. At least one sentence is provided for each main section of the report. The key points in the executive summary should be presented in the identical order as they appear in the report so as to encourage logical flow and cohesion. It may be useful to write the executive summary after you have written the whole report so that it more accurately reflects the content of the report. Avoid recycling sentences or paragraphs from the body of the report as this can be repetitious for the reader.

An example layout and formatting instructions for the executive summary are provided on the next page.

FirstName1 LastName1 & FirstName2 LastName 2 (Group #) Month Date, 2015

Experiment and Document Title

Project Overview

For all executive summaries, the text should be Arial size 10 or Times New Roman size 11 font. In all cases the text should be single-spaced and fully justified. There should be a simple heading like that provided here including the names of your group members and your group number, the date, and the document title.

This section should be a short, concise paragraph that establishes and summarizes the work that was done, the context in which this work is important, what the major goals/aims/objectives of this work are, and briefly summarizes the philosophy of how it was done and what was achieved.

Project Methodology

This section should describe the work that was done, the specific techniques, why those approaches are used and appropriate, and any deviations or important aspects the reader needs to know about your approach to the experimental work.

Project Findings and Implications

This section subsequently summarizes the major findings of your work and the implications of your work for the overall course goals and your developing understanding. In this section one can also include a summary of challenges or roadblocks that kept you from achieving your goals, recommendations or how to improve the work in the future, and context for how your work informs the design and processing of future materials.

The document should be self-contained and no more than 1 page long. It should be attached in front of your main laboratory report.

APPENDIX C – Laboratory Report Overview

In an attempt to bring uniformity and consistency to your laboratory experience, we will be adopting a uniform laboratory report format and procedure. The following is adapted with permission from the new electronic book produced by **Matt Sherburne**, **Nicole Robards**, and **Angus Rockett** for use in **MSE 307**.

The following outlines the expectations for the laboratory reports in MSE 423.

The Laboratory Report

In this section a general style guide is given along with a detailed discussion of the parts of the lab report. This is the style that the TA will be using for grading.

Your Laboratory Report must:

- Be typed using a word processing software such as Microsoft Word, LaTeX, or otherwise.
- Be double-spaced.
- Use an appropriate professional font and font size
- Have 1-inch margins on all sides of the page.
- Have numbered pages.
- Have a header that includes the names of your group members and the experiment title (smaller fonts are allowed here to keep the margins at 1 inch).
- Not be longer than it needs to be.

In addition to these formatting requirements, your laboratory report must also include the following structural sections in this order:

- **Title & Cover Page**
  - Your Title should briefly describe the contents of the report and be one line in length if possible. Avoid fluff, qualitative words and acronyms. It is best to use descriptive words that lets the reader know what your reports contents are to be. The cover page should include the due date of your report, the lab group you are in and your lab partners' names. You and your lab partners should have their institutional affiliations listed, double-spaced from and centered below the title. When more than two authors, the names are separated by commas and "and" as necessary.

- **Executive summary** – see Appendix A above

- **Introduction**
  - The introduction establishes the context of your experiment and gives any background information that might help the reader understand the importance of this work. Also included is a statement of the purpose of the work, such as, your hypothesis or at least the questions you investigated. Explain the rationale and approaches and the outcomes your study revealed. When writing the introduction you should use the active voice as much as possible. Avoid first-person references if possible.
  - In general you would like the introduction to answer the following set of well-established questions:
    - What did you study?
    - Why is it important to understand this topic?
    - What did you know about this before you studied it?
    - How has the study advanced your knowledge?
  - The introduction section should be well referenced – including appropriate texts and peer reviewed and review literature.

- **Materials and Methods**
  - In this section you explain "clearly" how you carried out the experiments in your study. Describe your experimental design clearly, including the actual experimental procedures you used. In this section you should also discuss how your data was analyzed. How the data is summarized and how you are reporting the data: means, percentages, standard deviations, etc. Any statistical tests

you used to analyze your data need to be discussed here as will any other numerical or graphical techniques you applied to your data.
- Ideally this should read as if you are verbally describing your processes for the experiments. Using the active voice is allowed, but the third person, passive is the preferred approach. Avoid writing in the first person in this section. Also remember to write in the past tense.

- **Results and Discussion**
  - In this section you need to write concisely and objectively. This section's function is to present your results in an objective manner. The presentation should be in a logical manner, generally sequentially using both Tables and Figures along with the text. If you take the time to generate high quality Tables and Figures the results section can be organized around these. You should (in this course) report your negative results as well. In writing this section you will most likely notice the passive voice dominating, use the active voice as much as you can work it into your write up. Again you have already done the work so this should be written in the past tense. It is easy to start writing paragraphs that all look and sound alike in the section, make an effort to avoid repetitive paragraph structures.
  - Some common mistakes to avoid:
    - Do not reiterate each and every value from your Tables and Figures. Only the key results need to be presented.
    - Do not make a Table of data and then plot this same data in a Figure. You need to make a decision on the best way to present the data. I would generally represent things as graphs, given enough data and that it makes sense to do so.
    - Do not tell your reader all about the raw data. You went through the time and effort to do the statistics so this is what you need to present.
  - You should compare your results to know actual values and determine the % difference. Just presenting the two numbers without any thought to how your results compare to the real world is not sufficient. Include what may have caused the difference and how you can improve the experiment if you were to redo it. Discuss any potential applications of these materials.
  - Figures and tables should be incorporated into the text at this point and aligned in professional, non-intrusive manner. All figures and tables MUST have a caption.

- **Conclusion**
  - Start by restating the objectives of your experiments, generally from your introduction and relate these to your results. Summarize the content of your report and highlight any successes or failures of your experiments. It is also appropriate to suggest future experiments or improvements to you would recommend.

- **References**
  - Referencing is a standardized way of acknowledging the sources of information and ideas that you have used in your document. A list of ALL the references used in the text must be written. Do not use footnotes in your report. List the references in chronological order as they appear in the text.
  - References should be done in the AIP Format. Here are some examples:
    - Generic: A. B. Author1, D. C. Author2, E. F. Author3, *Journ. Title Abb.* **Vol#**, PageStart (Year).
    - Specific: Z. W. Shan, G. Adesso, A. Cabot, M. P. Sherburne, S. A. Syed Asif, O. L. Warren, D. C. Chrzan, A. M. Minor, A. P. Alivisatos, *Nature Mater.* **7**, 947 (2008).

Producing Tables

Tables are one of the most used objects in scientific publications. Tables are assigned numbers independently from figures and are assigned the numbers in the order in which they appear in the text. The first Table is Table 1, the next Table 2.... The legends go above the Table; tables are read from the top down. The typeset of tables should be based on the following rules: 1) Never use vertical lines; 2) Avoid double lines; 3) Place the units in the heading of the table (instead of the body); 4) Do not use quotation marks to repeat the content of cells.

Producing Figures

Figures help you relay your message to the reader and are often easier to understand for a reader than the actual text, for these reasons you should take some time and care when generating your figures. Figures are numbered chronologically as they appear in the text. The first figure is Figure 1 and the next is Figure 2.... The caption for a figure goes below the figure.

Further Stylistic Points

Avoid the use of First or Second person to describe what occurred in the lab – such as "I did" or "You did." Instead say "This was done."

The Passive Voice – The passive voice is used to describe the experiment. This is done to reinforce that the experiment and results are ultimately what the report is about. "The sample was heated for 15 minutes at 200°C." instead of "The investigator heated the sample for 15 minutes at 200°C."

Lab Report Grading Rubric

Required components (contributions to the lab report grade shown in red). At a minimum start a new section for each item in red. The title page and executive summary should be on separate pages. Double space your report, margins one inch, figures must be clear and readable, references sufficient to determine sources.

- Title page – 5%
- Executive summary – Graded separately, see above (each one is 3% of total grade)
- Introduction and background – 15%
  - Motivation for the experiment – 7.5%
  - Background theory – 7.5%
- Materials and Methods – 15%
  - Description of apparatus – 5%
  - Procedures used to conduct the measurements – 5%
  - Experimental variables tested (and not tested, as appropriate) and why – 5%
- Results – 40%
  - Groups that appear to have failed to use their time effectively may lose credit for not making a reasonable number of measurements.
  - The 40% is divided evenly by the measurement descriptions. There should be a separate measurement description for each variable tested.
  - Discuss the results of your findings. Compare your values with the actual values (these values you can find online) and determine the % error. Include what may cause this error and how you can improve the experiment if you were to redo it.
  - Discuss (potential) applications of these materials and implications of your findings for applications or processing routes.
- Conclusions – 10%
  - What information did you obtain from the data – 5%
  - How does this relate to the motivation & theory – 5%
- Writing, Formatting, and Professionalism – 15%
  - Spelling, grammar, organization, use of space, references, formatting, figure quality, etc.
  - Overall effectiveness and clarity of the report.
  - Poor or inadequate references, failure to reference the right types of materials, etc.
  - Failure to acknowledge the source for any data used that is not obtained by you including the names of the persons who obtained that data, the approximate time period when the data was measured.
  - Use concise and proper language.
  - **Do not plagiarize – this includes reproducing text from papers, texts, other class members, etc. This will result in an immediate "0" score for the assignment**.

APPENDIX D – Laboratory Presentation Overview

Format

- Groups of 2-4 students (same as your laboratory research team) - All students must speak in equal proportions
- 20 minute presentation + 5 minutes for questions – I will moderate appropriately
- Presentations must be done in PowerPoint (an electronic copy must be submitted and two paper copies printed in "Note Pages" format should be brought on the day of the presentation)
- Groups will only attend their timeslot on the day of the presentations.

Description

This assignment is meant to test your overall knowledge of the topics of this course as related to ceramics processing as well as your knowledge of the scientific aspects of Module III.

Presentations should do the following:

1) Identify and clearly articulate the relative importance of the functional material that is being studied, why people are interested in these materials, and provide a brief introduction to the core phenomena of interest. Your presentation should provide an introduction to the science and engineering of this topic.
2) Your presentations should provide a description of the experimental variable(s) to be studied, the methodology of that study, and the results of your experimentation.
3) Presentations should also include a small introduction to applications (both realized and/or potential) for these materials and phenomena and provide a brief summary of how one would design a device based on this material. This includes delineation of figures of merit, design criteria, and design/performance trade-offs that might have to be made in utilizing these materials. Provide some context for how your experiments inform this idea.

For example, in a 15 slide presentation (not counting title slide and references), one would expect to see approximately 3-4 slides on the science of the core materials/phenomena, 7-8 slides on experimental details and observations, and 3 slides on the applications and design aspects. Grading (below) is distributed accordingly.

Grading – The Laboratory Presentation is 20% of the overall course grade

- **Scientific Content (25%)**
  - Students will be graded on the scientific details and accuracy of their presentation.
  - This includes the ability to answer reasonable questions following the talk.
- **Experimental Details and Observations (50%)**
  - Students will be graded on their application of the principles of ceramics processing to the Module III techniques. Special consideration will be given for the design of a systematic experiment and subsequent implementation of that experiment to understand some aspect of the effect of processing on properties. Key to this is providing scientific explanations for how the processing impacts the properties.
  - Utilization of basic characterization methods is a must and students who find ways to extend characterization beyond standard methods will be rewarded.
- **Applications and Design Aspects (15%)**
  - Students will be graded on the introduction and description of applications of the materials/phenomena in question.
  - Students will be graded on their analysis and description of how one would design a device and what factors or design criteria are most important in this process.
  - Is there a figure of merit for your material/phenomena? If one were to design an optimum material what would be the balance of properties?
- **Presentation Quality/References/Presentation Style (10%)**
  - Students will be graded on the overall quality of their presentation. Misspellings, poor formatting, lack of effort and attention to detail will result in a loss of points. Presentations are an essential part of the life of scientists and researchers. Too often we do not spend the appropriate time on these

endeavors. Please select a professional slide template, appropriate fonts, and spend the time and effort to construct your presentation professionally.

- All figures and information outside of public knowledge to you and your peers in this class should be referenced.
  - Figures should be referenced directly below the figure on each slide
  - Generic references for works should be used when appropriate
  - Provide a final slide that lists all works cited in order of appearance
  - Please use the Reference Style used in the journal *Applied Physics Letters*.
- Presentation Style is a "catch-all-category" that includes presentation delivery, formatting, coherence, and even distribution of materials amongst team members.