10 Simple and Effective In-class Experiments and Demonstrations for Materials Educations - An Overview

-A Review of 10 Basic Material Science experiments submitted to the NSF sponsored MatEd project

Activities and Experiments compiled by:
Tom Stoebe
National Resource Center for
Materials Technology Education

Review Preformed by:
Ryan A. Webster
Intern
Edmonds Community College
& Undergraduate
Material Science and Engineering
University of Washington

NSF-Sponsored Advanced Technological Education (ATE) Program
NSF Grant DUE ATE 0501475

Introduction:

"10 Simple and Effective In-class Experiments and Demonstrations for Materials Education- An Overview," is a formal evaluation of 10 basic activities which can be utilized in classrooms from the elementary level through undergraduate. The modules evaluated during this review were compiled by Professor Tom Stoebe, a former Professor of Material Science and Engineering at the University of Washington, and are intended to provide educators with short, introductory demonstrations to Material Science. The 10 activities span a wide range of material classes from metals to polymers, providing students with a brief introduction into an assortment of material science concepts.

Lab 1- "Reactivity of Iron":

The *Reactivity of Iron* is an exceptional activity for demonstrating oxidation and corrosion for students at all levels, from elementary through undergraduate; however, should the activity be utilized as an in-class laboratory it should only be performed by high school students and up. Each portion of the activity was evaluated and the following tips and observations were generated:

The first part of the laboratory provides an eye catching demonstration of the oxidation of steel wool, a common household item. As the steel wool pad is placed into the flame, an elaborate glow is produced (**see Figure 1.0**). Upon completion of the oxidation process, the steel wool's once grayish appearance should turn a green color.

Figure 1.0: For the purpose of this evaluation, a natural gas stovetop was utilized for the completion of the activity; however, as it is called for in the module, a Bunsen burner or propane torch would be more appropriate.

Note: As a safety precaution, any potentially flammable objects should be kept away from the demonstration or laboratory as a result of the hot embers which are emitted during the procedure. Students may also want to wear protective eyewear if performing the activity on their own.

The second portion of the module provides a simple demonstration for the corrosion of iron. As a result of the amount of time required to complete the reaction, the steel wool sample should be submerged in a beaker of water over night to ensure a visible change (**see Figure 2.0**).

Figure 2.0: Over night the water in the beaker should gradually turn a greenish color, providing evidence of the corrosion process. Figure 2.0, provides a look at the sample after approximately 2 weeks of corrosion.

Lab 2- "The Odd Behavior of Rubber Bands":

The Odd Behavior of Rubber Bands, is a slightly more challenging activity designed to introduce students of various academic levels to the elaborate molecular structure of rubber. The experimental procedure described in the module is broken into two segments. The first of these segments provides a simple exploration to demonstrate the rubber bands molecular arrangement.

As outlined in the experimental procedure students will stretch and contract rubber bands, placing them against a sensitive area of the body (i.e. a lip or the forehead). When the rubber band is stretched, students should feel an increase in temperature and a decrease while the rubber band is contracted. As a recommendation, the activity can be performed with a variety of rubber band sizes to further demonstrate this basic activity.

Note: For an explanation as to why the temperature change occurs, please refer to the module

The second activity diagramed in the module is intended to demonstrate the effect of applying heat to rubber bands and observing the phenomenon of hysteresis (**note:** for an in depth explanation of hysteresis, refer to the following article: http://en.wikipedia.org/wiki/Hysteresis). During the evaluation process, a hair dryer was utilized to apply heat to the stretched rubber band for approximately ten minutes (**note:** see **Figure 3.0** for the experimental set-up used during the trial procedure). In addition to the use of a hair dryer as the heating source, a door knob suspended the apparatus via the stretched rubber band and a specific volume of water was utilized as the necessary weight to be added and removed as required by the experimental procedure.

Figure 3.0: Experimental procedure used during the evaluation process of *The Odd Behavior of Rubber Bands* module. **Note:** Heat was applied to the rubber band for approximately 10 minutes.

Upon completion of the of the trial process, the hysteresis was, in fact not observed; however, before abandoning the experimental procedure, it is recommended that various set-ups, weights, and amount of heat applied be varied. Through "tinkering" with the experimental set-up, the activity may prove to be successful and an ideal in-class demonstration of an intriguing concept. Thus, should an instructor elect to utilize this portion of the laboratory, extensive preparation time is necessary to ensure the desired outcome is achieved.

Lab 3- "Fracture-Resistant Ceramics (the Corelle Plate)":

Unlike the previous laboratory, *The Odd Behavior of Rubber Bands*, this module provides students with a quick, simple, and effective demonstration, requiring little or no preparation time by the instructor. The purpose of *Fracture-Resistant Ceramics,* is to introduce remarkably tough ceramic materials through a vivid observation of the astounding properties of a common household item. Upon completion of the experimental procedure, it was discovered that as expected the Corelle plates exhibit amazing strength and as the plate is struck harder against the surface at hand, it provides a sensational demonstration.

Note: If the experimental procedure is being performed with relatively new Corelle plates, demonstrators need not act timidly, and may "bang" the plates with a surprising amount of force onto the lectern or other available surface.

Lab 4- "Plastic Stretch":

Another module requiring very little preparation time is, *Plastic Stretch*, an outstanding in-class activity which further explores common polymer structures. In this demonstration, a "dog bone" shaped piece of polyethylene is cut from a large sheet (**note:** a sheet of polyethylene can be found at most local hardware stores). The "dog bone" is then gradually stretched by two capable participants. In order to effectively complete the demonstration, both participants will need to be fairly strong and pull at a slow and constant rate to ensure the polyethylene morphs into a crystalline phase, evident by the stretch marks in the direction of the force being applied.

Lab 5- "Metal Corrosion":

The fifth module explores the various methods of corrosion of metals under several different conditions, as well as, materials which have undergone various forms of processing. The corrosion of steel, galvanized steel, aluminum, and copper is to be observed over several weeks. As a result, of the extensive amount of time required to complete the observation of the variety of corrosion specimens, this module was not completely tested; however, the corrosion process should be similar to the one evaluated in the *Reactivity of Iron*.

Lab 6- "Metal Properties and Failure Experiment-the Paper Clip":

In addition to exploring the effect of various corrosive environments on metals, *Metal Properties and Failure Experiment-the Paper Clip* is an excellent in-class activity aimed at analyzing a variety of paper clips, noting the amount of fatigue required for each type to fail. Upon completion of the evaluation, it was discovered that the jumbo paper clips required more bending to reach failure, in comparison to the standard size paper clips. If available, the activity should also be completed with paper clips composed of other materials or paper clips subjected to different processing techniques. The utilization of a variety of paper clips will provide students with an idea of the strength of several different materials in comparison to one another, and how various processing techniques influence mechanical properties.

Note: During the evaluation process, it was discovered that the jumbo sized paper clips were much easier to bend and could with stand an average of 2 to 3 bends before failure, while the standard size paper clips withstood only a single bend on average.

Lab 7- "Phase Change Experiment: Nitinol and Bobby Pins":

The seventh module, like previous experiments, can be an effective supplement for analyzing the mechanical properties of metals. However, unlike previous demonstrations, module 7 allows students to observe the change in mechanical properties of materials after the samples have undergone a change in phase. Nitinol, an alloy known for its shape memory abilities, and bobby pins are both excellent materials for demonstrating phase transitions (**note:** for background information regarding the mechanisms for the phase transitions which occur in both materials, the instructor background portion of module 7 is an effective resource).

After completing the bobby pin activity, it was observed that the control, or the unaltered bobby pins were capable of withstanding about 7 bends before failure, while the quenched (i.e. bobby pins heated and then immediately plunged into cold water) could withstand only 1 bend (**see Figure 4.0**). In contrast to the quenched specimens, the annealed samples (bobby pins heated until red hot and then allowed to air cool) were capable of being bent up to 18 times. Finally, the tempered bobby pins, or bobby pins which were heated, quenched, reheated, and air-cooled, could be bent approximately 16 times before failure.

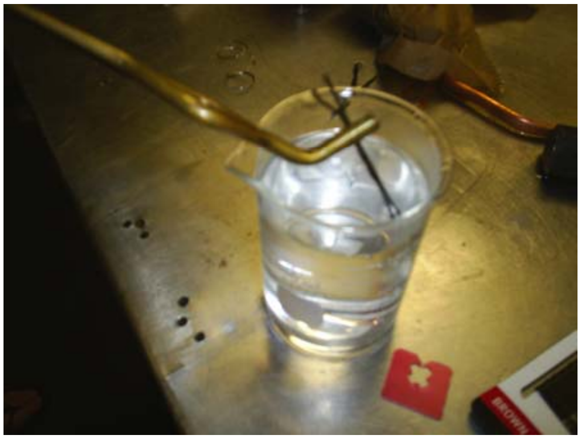

Figure 4.0: Example of a bobby pin being rapidly quenched in cold water immediately after the heating process.

Like the bobby pin activity, the second experimental procedure diagrammed in module 7 effectively demonstrates the mechanical changes in Nitinol (**note:** depending on the availability of nitinol, it may be necessary to perform this portion of the experimental as an in-class demonstration, as opposed to a group laboratory) during a phase transition. After completing the evaluation, it was discovered that a piece of nitinol could be coiled (**see Figure 5.0**) and then dropped into a container of boiling water. Upon contact with the boiling water, the deformed nitinol instantly sprang back to its unaltered form, evident of the occurrence of a phase transition (**see Figure 6.0**).

Figure 5.0: Nitinol sample before being placed into the boiling water.

Figure 6.0: Nitinol specimen immediately after being removed from the boiling water, as evident by the image, the sample sprang back to its previously unreformed state.

Note: For a further and more in depth explanation of both the bobby pin and nitinol transitions, Material Science and Engineering An Introduction by William D. Callister Jr. is a brilliant resource for describing the phase transitions, making it an excellent discussion aid in more advanced classrooms.

Lab 8- "Work Hardening and Annealing of Metals":

The eighth module evaluated, further explores the annealing concept briefly observed in the bobby pin activity in module 7, as well as provides a short introduction to work hardening. As expressed in the experimental procedure, during the evaluation process the copper wire can initially be bent rather easily; however, after further deformation it was observed that as the wire was continually "worked" it become incredibly stiff and no further bending could occur. This increase in strength provides evidence that work hardening had occurred.

The second experimental procedure found in module 8 describes an activity which can be utilized to return the copper sample to a malleable state through the process of annealing. However; do to the unavailability of a proper annealing oven; the evaluation was carried out utilizing an open flame (an acceptable solution from the experimental procedure). After carrying out the revised procedure, it was discovered that because of the rather lengthy amount of time necessary to complete the annealing process, the copper specimen must be subjected to heat source for an extended period of time, producing a potential fire hazard. Also, while utilizing an open flame, it was observed that the copper wire underwent oxidation, as evident by the green surface which gradually appeared across the wire (**see Figure 7.0**). The reaction between the copper specimen and air (oxidation), may inadvertently effect the outcome of the experimental procedure, and thus it is recommended that if available an annealing oven should be used for this portion of module 8 (**note:** because of the extended period of time necessary to complete the annealing process and the lack of a proper annealing apparatus, the final piece of the experimental procedure was not effectively assessed during this evaluation).

Figure 7.0: Length of copper wire utilized during the annealing process with the visible green oxide layer. **Note:** A gas stove top was used to provide the necessary open flame.

<u>Lab 9- "Polymer Processing Demonstration: Happy/Sad and Other Balls":</u>

Happy/Sad Balls and Other Balls provides students with an expanded experimental procedure of a previously developed activity produced by Flinn Scientific Inc. The first portion of the in-class demonstration closely follows the procedure outlined by Flinn Scientific, in which two similar looking polymer balls are bounced. The "happy" ball quickly recoils upward, while the "sad" ball remains placidly in place. This effortless demonstration presents an opportunity to elaborate on the difference in the processing between the two remarkably similar balls (**note:** For more background information alluding to the difference between in the "happy" and "sad" balls, refer to the instructors notes located within the module).

In addition to the Happy/Sad ball demonstration, the module also suggests further exploring the properties of other balls; such as, racquetballs and golf balls. Although the specifics regarding the processing of each type of ball is not explicitly eluded to, further study would allow for a more in depth classroom discussion. Overall, *Happy/Sad and Other Balls* is a solid demonstration, requiring very little preparation time, with exception of additional research for the second portion of the activity.

Lab 10- "Composite Materials":

The final module included in the assortment of simple in-class activities, *Composite Materials*, is the only demonstration provided which explores the interesting characteristics of composite materials. The importance of elaborating on this unique material class is becoming ever increasingly more relevant as composites appear more and more in our everyday lives. In particular, the design and pending production of Boeing's new and revolutionary 787-Dreamliner eludes to just one example of how composite materials are impacting the world (1).

For the composite demonstration outlined in this final module, simple tongue depressors or Popsicle sticks and glue are utilized to fabricate composite beams wielding remarkable strength. Although the composite apparatus may seem rather elementary, it provides an exceptional example for discussing key concepts related to composite structures (i.e. the roles of the matrix and reinforcement fiber constituents). Furthermore, with the exception of the lengthy drying time associated with the fabrication of these simple composites, they can be quickly prepared overnight and utilized in the classroom the following day.

Conclusion:

Although the amount of preparation time and depth of the accompanying in-class discussion may vary by module, the assortment of modules provided should allow for an exceptional introduction to each of the various material classes. Thus, depending on the available preparation time or student level, these ten modules provide educators with a variety of choices for each material class, from metals to composites. The simple set-ups and apparatuses allow for quick and effective utilization in classrooms at the elementary through undergraduate level. Furthermore, the use of the variety of experimental procedures, along with this short overview will allow for an outstanding introduction to the wonderful discipline of material science.

References:

1.) Wikipedia.org. (2007, August). *Boeing 787*. Retrieved August 6, 2007 from http://en.wikipedia.org/wiki/Boeing_787.

Further Recommendations:

As stated in the evaluation of *Phase Change Experiment: Nitinol and Bobby Pins*, Material Science and Engineering an Introduction by William D. Callister Jr. is a great resource for gathering more information on material science related concepts brought about through each module. Another insightful reference is Wikipedia.org, the free online encyclopedia, which contains an assortment of articles suitable for providing more in depth information behind each activity. Both suggested resources should allow for intellectual and dynamic class discussions.