DOCUMENT RESUME

ED 118 447 SE 020 302

AUTHOR	Hirschhorn, J. S.; And Others
TITLE	Classroom Demonstrations in Materials Science/Engineering.
PUB DATE	Jun 75
NOTE	11p.; Paper presented at the Annual Meeting of the American Society for Engineering Education (Ft. Collins, Colorado, June 16-19, 1975)
EDRS PRICE	MF-$0.83 HC-$1.67 Plus Postage
DESCRIPTORS	College Science; *Demonstrations (Educational); Engineering; *Engineering Education; *Higher Education; *Instruction; Science Education
IDENTIFIERS	Materials Science; University of Wisconsin

ABSTRACT

Examples are given of demonstrations used at the University of Wisconsin in a materials science course for nontechnical students. Topics include crystal models, thermal properties, light, and corrosion. (MLH)

Event Number 2588

American Society for Engineering Education
Annual Conference, June 16-19, 1975
Colorado State University
Ft. Collins, CO 80521

Title of Paper

Classroom Demonstrations in Materials Science/Engineering

Name of Authors

J. S. Hirschhorn, G. M. Maxwell and F. J. Worzala

Title and Address of Authors

Professor and Associate Professors

Department of Metallurgical and Mineral Engineering
1509 University Avenue
Madison, Wisconsin 53706

CLASSROOM DEMONSTRATIONS IN MATERIALS SCIENCE/ENGINEERING

I. Introduction

For the past two and a half years the Metallurgical and Mineral Engineering Department of the University of Wisconsin-Madison has been teaching a course in materials science for non-technical students. It has been found that the students are very receptive to classroom demonstrations, much more so than engineering and science students. This is believed to be due in part to the non-technical students fear of technical subjects. The demonstrations presented seem to alleviate the fear and motivate the students in that they can actually see what is taking place. In general, there are no mysterious "black boxes" that suggest that science is only for those with mystic powers. The demonstrations have been selected with a mind to materials and equipment that are somewhat common and if the students are truly interested, suggestions are made as to how the experiments can be slightly modified and carried out by the students themselves.

II. Typical Experiments

Many different demonstrations, using both commercially available equipment and our own "Rube Goldberg" devices, have been used. The demonstrations to be described are those which have been most accepted by the students.

Crystal Models

Commercially available wire and wooden ball models are used to demonstrate the common crystalline structures, i.e., BCC, FCC and HCP.

hese models have been especially useful in showing why FCC structures are more ductile than HCP. The FCC can be rotated slightly, bringing other similar slip planes into view, while the same operation with the HCP model clearly shows an absence of additional slip planes.

Styrofoam balls which have been glued together to form large sheets are used to show the stacking sequence in FCC and HCP structures. The students are encouraged to use pennies and imagine they are spheres to build their own models of the structures by first forming a close packed sheet of pennies and then adding subsequent layers over the holes left in the underlying sheets.

The Atomix Model (Emotion Products Inc., P.O. Box 282, Montreal 215, P Q Canada) is very useful for simulating grain boundaries, point defects, dislocation flow, grain growth and vapor pressure above a solid. The 5" x 5" model consists of 6000 small stainless steel balls enclosed between two sheets of clear acrylic. The model can be passed around the class or used with an overhead projector. A fine grained metal can be duplicated by vibrating the model in a horizontal plane and quickly turning the model slightly up so that the balls flow to the bottom (quenching). Within the grains the balls arrange themselves in a close packed structure. Grain growth can be duplicated by mechanically tapping the model in a slightly raised position (the students are told the tapping duplicates an increase in temperature). Point defects and clusters of defects also occur throughout the structure, oftentimes with stacking faults radiating out from the imperfections. "Dislocation motion" can also be seen during the mechanical agitation.

Mechanical Properties

The idea of elastic and plastic behavior is first demonstrated with a coat hanger and a long piece of glass tubing. The elastic properties of the metal and glass are demonstrated by bending the two slightly. The plastic nature of the coat hanger is then demonstrated and compared to the negligible plastic deformation of the glass rod. Later the students are introduced to the concept of fatigue by asking them how it would be possible to break a coat hanger by hand. The coat hanger is cycled and fractured and the students are then introduced to S-N curves.

The concept of elastic modulus is introduced to the students by passing around two metal cans, one made of aluminum and one of a mild steel. The students are asked to estimate the thickness of the aluminum can, given the thickness of the steel can. The students usually estimate that the aluminum is half as thick as the steel where, in fact, they are only one or two mils different. The students are then introduced to elastic modulus and Hooke's Law and it is explained what they probably measured in the cans is the strength of bonding of the atoms or the elastic modulus. This is followed up by hanging two bending loads on two identical strips of aluminum and steel and showing the amount of deformation.

Stress concentrations are shown by breaking glass tubing which is scratched and unscratched. Another technique used to show stress concentrations is to place a notched piece of plastic between two pieces of polarizing film. The fringes clearly radiate from the notched area of the plastic. The assembly can be taped together with scotch tape and passed around the class for the students to compress and note the stress concentration lines.

Creep phenomena can be demonstrated with a length of soft solder (50 Pb - 50 Sn). A 50" length of .062" diameter solder is pinned to the blackboard at the beginning of the class period with a three pound weight hanging on the end. The bottom of the wire is marked on the blackboard and a few readings taken during the class period. At the end of the period the wire has generally stretched three or four inches. Different stresses (which can be calculated and used to give real meaning to the class) can be applied on subsequent days and the effects noted and compared.

The effects of cold working can be readily shown using a paper clip and a powerstat. Several paper clips are distributed to the class and they are asked to open them up into a "square u" shape. They are then asked to twist the paper clip and count the number of full twists before the paper clip fails--generally about fifteen. A similar paper clip is then hooked up to a powerstat and the temperature increased until the paper clip turns a red-yellow. The paper clip is then quenched in water. One of the students is then asked to twist the paper clip until it fails. Generally it will fail in thirty to forty turns. The class is then asked to explain what operation the paper clip might have been exposed to during its fabrication and what occurred during the heating operation.

Thermal Properties

The thermal conductivity of materials is demonstrated with a propane torch and similar cross sections of silver, aluminum, copper, steel, stainless steel and glass. A student is asked to come to the front of the class and hold on to one end of a piece of each material and place the other end in the propane flame. Another student is asked to measure the amount of time the student can hold on to the piece before he must drop it. The times are then related to the material's thermal conductivity and heat capacity.

The thermal expansion of materials is demonstrated with butyl alcohol and a long piece of iron wire. The alcohol is heated in a small florence flask with a long neck and the expansion noted. Another technique is to suspend a 4' length of iron wire from a portable frame with the lower end hooked to a swiveled pointer system. The pointer itself is approximately 2' long and extends over to a portable 2' scale. Electrical leads from a powerstat are hooked to the top and bottom of the wire. On heating the wire with the powerstat, it expands and allows the pointer system to drop. The pointer will move one or two feet over the scale. The same system is used to show the phase transformation of pure iron from FCC to BCC on cooling.

Thermal shock is demonstrated by heating soda-lime glass to a temperature just below its melting point and quenching it in water. The same operation is performed on vycor tubing. The difference in thermal shock is explained in terms of thermal expansion coefficient, thermal diffusivity, elastic modulus and yield strength.

Electrical Properties

The generation of electricity is first shown with a coil of copper wire and a 2,000 gauss magnet. A flashlight bulb is hooked up to the wire and the light bulb is lit by passing the wire back and forth through the magnetic field. Different types of wire are then substituted for the original copper and the brightness of the light compared to the original oil. This is explained in terms of the movement of electrons through the wire. Motor action can be simulated with the same arrangement and a battery. Laying the coil on top of one pole of the magnet and touching the battery with the leads will cause the coil to be "spit away" from the magnet, while reversing the connections will cause the coil to be drawn into the magnet.

Comparison between the changes in properties of semiconductors and metals with changes in temperature have been made, but it has not been too well received because of the "black boxes" which must be used to demonstrate the phenomenon.

Magnetic Properties

The magnetic properties of transformer cores are shown by connecting a small coil of wire to a battery and moving the coil underneath some iron filings. The coil has little or no effect on the filings. An iron core is then inserted into the coil and the operation repeated. The coil-core assembly now has a significant effect on the iron filings.

To distinguish between electromagnetism and ferromagnetism, several different specimens are suspended from a stand between the poles of a large magnet. A piece of lucite is first suspended from two pieces of string between the poles of the magnet, with no visible interaction. The plastic is then swung through the poles with again no interaction. A solid piece of aluminum is then suspended between the poles with no obvious interaction. On swinging the aluminum, however, the oscillation are obviously dampened out. Another piece of aluminum with several slits cut approximately three-fourths the width of the aluminum is tested with little or no interaction. A similar sheet of aluminum with slits cut only in the middle width is tested, with very noted interaction when it is moving. This is explained in terms of the ability of the material to sustain circulating electrical current.

Light

The wave like nature of light is explained by using the polarizing film referred to in the mechanical properties section. The two pieces of film are rotated relative to each other until the light is blacked off.

The students are encouraged to perform their own experiment on refractive index by taping a penny to the bottom of a paper cup and positioning of the head so that the edge of the penny can barely be seen over the rim of the cup. On pouring water into the cup and holding the head still, the penny will come into partial or full view.

Corrosion

The corrosion action and formation of protective films can be demonstrated with mercury and a piece of pure aluminum. A thin layer of mercury is applied to the surface of an aluminum sheet by rubbing. This creates a flakey, non-adherent oxide of mercury and aluminum, which grows rapidly. In a matter of minutes, the surface of the aluminum is completely covered with a thick layer of white oxide.

On the first class in corrosion, iron nails can be placed in paper cups. In a matter of a few days, the head and point of the nails will be covered with rust. Bent nails will also show a large accumulation of rust at the strained areas.

Metals

The allotropic transformation of iron can be shown using the apparatus described in the thermal expansion of iron. The iron is heated up to a red-yellow heat with the powerstat. The transformation from the BCC to FCC is not mentioned at this time since it is difficult to rule out dimensional changes which could be attributed to uneven changes in the powerstat. On reaching the 1800°F range, the powerstat is very quickly set back to zero. The wire will contract with decreasing temperature until it reaches 1670°F, where the pointer will suddenly drop one or two inches with the expansion of wire accompanying the transformation of the iron from the FCC to BCC arrangement.

The non-equilibrium structure of iron can be demonstrated by making a small coiled spring. A one foot length of piano wire of approximately 48 mils diameter is heated up into the austenite range with a powerstat and allowed to cool slowly into the equilibrium structure. The wire is then wound into the shape of a small spring using a 3/4" mandrel. The coil is then reheated to the austenite range and quenched very quickly in water to form martensite. Half of the spring is then broken off and subsequently crushed. The remaining half of the spring is reheated to a blue-purple color to obtain tempered martensite. The spring is now very springy and capable of absorbing energy elastically.

Ceramics-Glass

The inert sheet structure of clays is demonstrated using a piece of mica. It is first shown that the mica is very difficult to cut perpendicular to the sheet structure, but is relatively easy to cut parallel to the sheets. This is explained in terms of silicate tetrahedrons coming together in such a way as to satisfy the bonding requirements of the oxygen in the tetrahedron.

The properties of tempered glass are shown by comparing an untreated soda-lime glass to a tempered glass cup. The untreated glass can be borken rather easily by dropping it on a table. The shock resistance of the treated cup is demonstrated by pounding a nail into soft wood using the cup as a hammer.

III. Summary

Classroom demonstrations have become an important part of the materials course for non-engineering students. As a technique for stimulating student interest, the demonstration is very helpful. As a method for teaching technical concepts to non-technical students, the classroom demonstration is invaluable.

Course and instructor evaluations over the last few years invariably refer very favorably to the classroom demonstrations. The evaluations are in the form of multiple choice, but in approximately 40% of the evaluations, students have taken the time to comment on the demonstrations. It is recognized that classroom demonstrations can be carried to the point where they simply become entertainment with little instructional value, however, almost all of the feedback is stated in such a way that there can be little doubt the classroom demonstrations are very effective tools in teaching technical concepts to non-technical students.