

Research and development of group-work “tutorials” for the introductory materials course.

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Integrated research on emergent materials and phenomena in magnetoelectronics

Initial Focuses:

1. Development of a Materials Concept Inventory
2. Development and evaluation of tutorial like group-work activities for recitations.
3. Assessment and Improvement of the Teaching Assistants' content and pedagogical knowledge.

MSE 205: Introduction to Materials Science

- Approx. 500 students/year
- Freshmen – seniors
- Primarily engineering majors
- Approx. 10% of class are materials science majors

Two Examples of Student Difficulties with Mechanical Properties

A metal is permanently elongated by an applied tensile stress, and then the stress is removed. Which of the following is true?

29% a) Atoms are rearranged compared to before the elongation.

11% b) The atomic bonds are stretched compared to before the elongation.

60% c) Both a) and b) will happen

The two pieces shown below were cut from the same piece of metal. Nothing else has been done to the pieces. Compare the yield strength of the pieces.



58% a) A has a higher yield strength than B

11% b) B has a higher yield strength than A

31% c) A and B have the same yield strength

Two Examples of Student Difficulties with Phase Diagrams

At point b2 what is the fraction of the alloy that is α ? (picture to the right was given.)

19% a) 6%

48% b) 25%

11% c) 28%

21% d) 72%

2% e) 94%

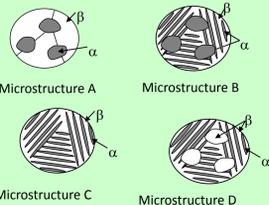
Which of the following sketches best illustrates the microstructure that will develop when the 30 wt% Ag alloy is cooled slowly from 1000°C to 250°C? (Refer to the above diagram)

9% a) A

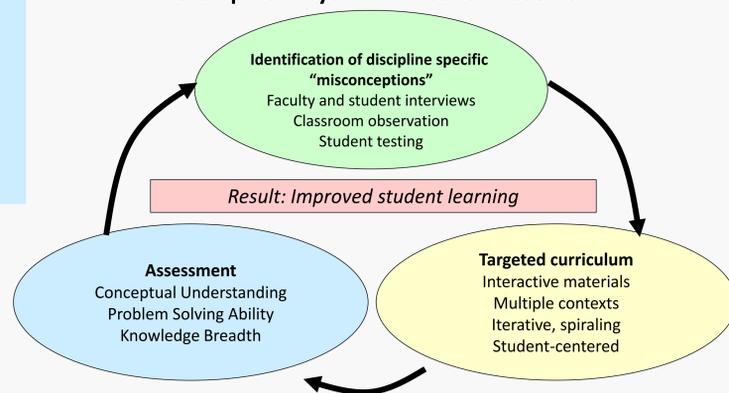
73% b) B

7% c) C

11% d) D



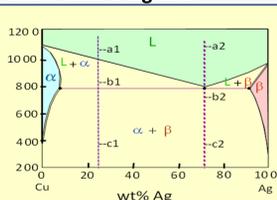
Development Cycle in Education Research



An Example of part of a Worksheet Addressing Student Difficulties with Strength and Plastic Deformation.

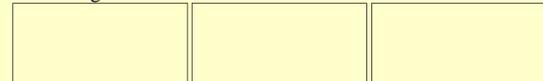
1. How is the strength of a metal defined? (Please give description that a 2nd year engineering student who has not taken this class yet would understand.)
2. What is the difference between yield strength and tensile strength?
3. A tensile stress is applied to a metal bar such that it deforms **plastically**. Draw a sample of atoms in the bar
 - a) Before deformation
 - b) During deformation while under stress
 - c) After the stress is released
4. After the stress is released, is the bar's volume different than before being deformed? Explain.
5. Does the density change after plastic deformation? If so, how?

An Example of part of a Worksheet Addressing Student Difficulties with Phase Diagrams

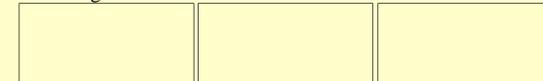


Draw pictures of the microstructure of this Copper-Silver alloy as you slowly cool the solution.

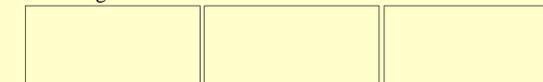
At 24% Ag



At 72% Ag



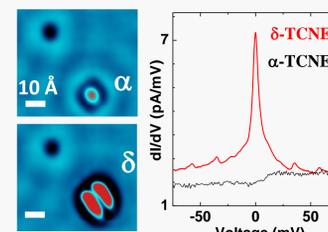
At 97% Ag



Conclusions:

- Use of group-work “tutorials” in the Materials Science course does not lead to better attendance in the none mandatory recitations.
- Students who attend did even better on the recitation related questions on the final exam than would be expected from those students over all better performance.
- Weekly TA training sessions are important to remind and fill in any content knowledge that is necessary for the “tutorial” and to inform the TAs of areas of difficulty that the students will have.

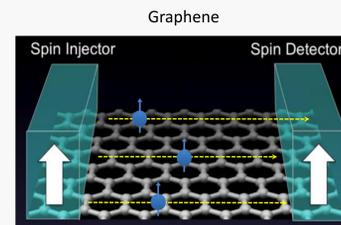
IRG-1: Towards Spin-Preserving, Heterogeneous Spin Networks



STM images of TCNE, tetracyanoethylene (C₆N₄), on a Cu(111) surface acquired at low temperatures (5 K or -268 ° C).

By applying a voltage pulse with the STM tip, it is observed that a single TCNE molecule can be reversibly switched between the nonmagnetic α and magnetic δ states.

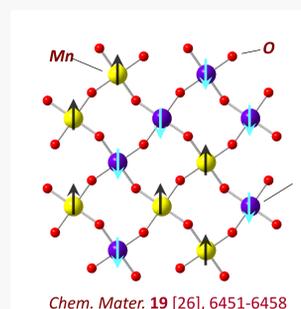
This kind of multistability has recently been proposed for massively parallel computing on the nanometer scale. --Arthur Epstein and Jay Gupta



Fabrication of graphene spin valves with ultrathin magnesium oxide (MgO) tunnel barrier.

This breakthrough enables the development of a graphene spin computer, that can integrate logic and memory for much greater computing power. --Roland Kawakami

IRG-2: Double Perovskite Interfaces and Heterostructures



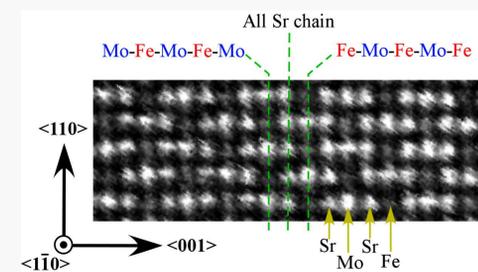
Chem. Mater. 19 [26], 6451-6458

Discovering new magnetic properties in Ca₂MnRuO₆, where the Mn and Ru ions order ferrimagnetically at room temperature, despite the fact that they are randomly distributed in the lattice.

Chemically substituting La³⁺ for Ca²⁺ tunes the conductivity from metallic to semiconducting while retaining the ferrimagnetism.

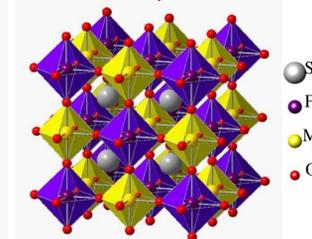
Understanding this unique behavior may hold important clues for magnetism and half-metallic transport in the broader class of double perovskites. --Patrick Woodward

Depositing highly ordered, single crystalline films of Sr₂FeMoO₆ that retain their magnetism to temperatures over 227°C.



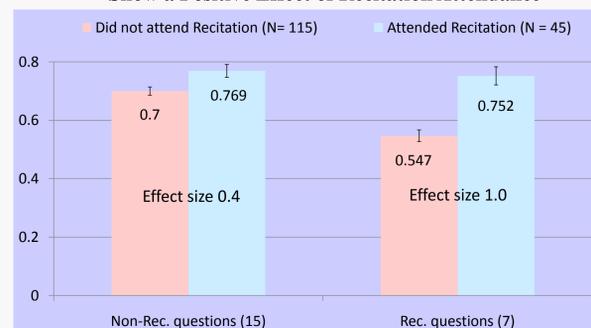
Scanning transmission electron microscope image of an Sr₂FeMoO₆ film

Double perovskite lattice

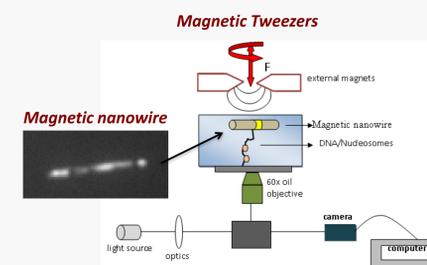


Ordered double perovskites, such as Sr₂FeMoO₆, are among the very few materials that allow electrons of one spin direction to move through them as though they were passing through a normal metal, while blocking electrons of the opposite spin. --Hamish Fraser and Fengyuan Yang

Au 2009 Final Exam Scores Show a Positive Effect of Recitation Attendance



Seed Funding: This program complements the IRGs, and it is aimed at supporting new materials research ideas with the potential for transformative impact on science and technology.



Developing micron- and nanometer magnetic particles for single biomolecule torque and force measurements. Providing new molecular insight into gene expression, replication and repair. --Michael Poirier