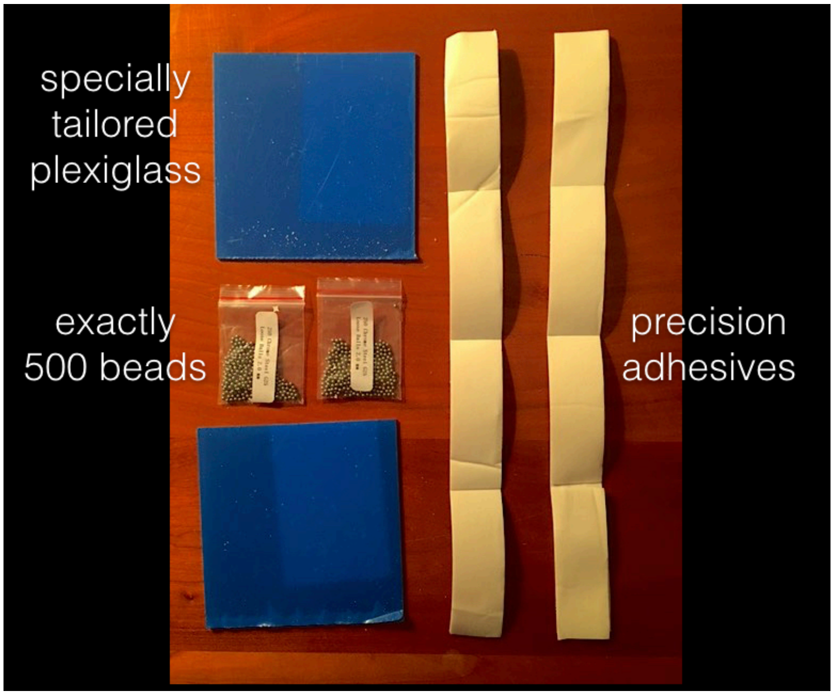
Goodie bag #7: Defects

Handed out on 11.5.18 | Quiz #8 on 11.15.18



Do yourself a solid.

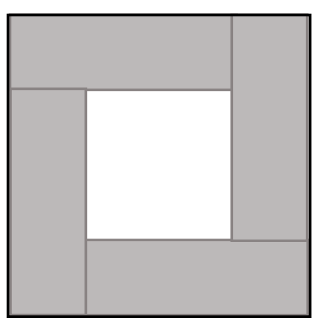
This bag contains:

- 2 plexiglass panels
- 2 bags of 250 beads each
- 8 pieces of double-sided tape

What to bring to the quiz: your built atomic model

Building instructions: see video on the 3.091 Stellar website (under Goodie Bag Problems) for high quality production, step-by-step DIY instructions!

1. Remove the blue protective layer on each side of each plexiglass panel – you should end up with 2 *transparent* panels.
2. Stick 4 pieces of double-sided tape on one of the panels, placed as shown:



3. Remove the protective layer off the top of each of the 4 tape pieces you just used.
4. Place a second piece of tape on top of each of the 4 pieces already on the plexiglass. This makes it so each piece is now a double-layer of two stacked pieces of tape.
5. Remove the protective layer off the top of the second layer of tape pieces.

6. CAREFULLY and SLOWLY pour the 500 beads into the square in the plexiglass middle away from the tape (they will easily bounce away so be careful and slow).
7. CAREFULLY stick the second plexiglass panel on top, thus encapsulating the balls.

Introduction

This goodie bag will explore 1D, 2D and 3D defects in crystalline materials, and the Arrhenius law.

Questions

Question 1: Basic manipulations

Shake your model for a few seconds. Then hold it still and look at it with a light behind it, in order to clearly see the arrangement of the beads.

Identify one 0D defect (vacancy), one 1D defect (line), one 2D defect (grain boundary – actually appears in 1D here).

Question 2: Process simulation

Let's imagine that your model represents a piece of metal such as Aluminum that you want to process in order to get a certain shape.

a) To get the desired shape, the metal will typically go through a combination of extrusion, rolling, and coiling (all of which introduce a significant amount of deformation into the material). Let's simulate this by shaking your model vigorously. Look at your model and list the type(s) of defects that you see, and (roughly) how many of each type you see. Would it be easy to deform your material at this point?

b) A way around this is to perform annealing. Let's simulate this by ***gently*** tapping on the side of your model 3-4 times. Look at your model and list the type(s) of defects that you see, and (roughly) how many of each type you see.

c) Could you fully remove defects by annealing for a very long time (i.e. gently tapping 10 or 20 times or more)? In which part of the model (center, edges, corners…) are defects most present/harder to get rid of?

Question 3: Formation energy

This model being the most accurate model ever built (ed. note: it's not), let's quantify the vacancy formation in this material. Shake the model vigorously for a few seconds, then count the number of vacancies you see. Assume this is equivalent to heating at 400°C. Then gently tap on the side of the model ~10 times, and count the number of vacancies again. Assume this corresponds to having your sample at room temperature. What is the vacancy formation energy for this material?

Question 4: Comparison of formation energy

Shake your model until you can see vacancies in the center and at least a vacancy near an edge (one bead away from the tape). Then tap gently on the side. Which vacancies disappear first, those in the center or those near an edge? What does it tell you about the relative magnitude of their formation energy?