TeachEngineering

Investigations With Nitinol: The Metal With Shape Memory!

Introduction and Motivation

Nitinol: A Shape Memory Alloy

- The material you are seeing in the demonstration is called Nitinol (NiTi), and it is a shape memory alloy.
- Nitinol was first developed in the 1960s by a team of researchers at the United States Naval Ordnance Laboratory.
  - The name Nitinol is an acronym for: <u>Ni</u>ckel <u>Ti</u>tanium <u>N</u>aval <u>O</u>rdnance <u>L</u>aboratories.
  - Supposedly, its shape-changing properties were found accidentally.
- Shape memory alloys are metals that exhibit shape-changing properties when heated.
- When used in advanced applications, these alloys are often called smart metals.

Smart Metals and Their Applications

- Because of the shape-changing ability of smart metals, there are many uses for them.

Braces
Photo by Atikah Akhtar on Unsplash

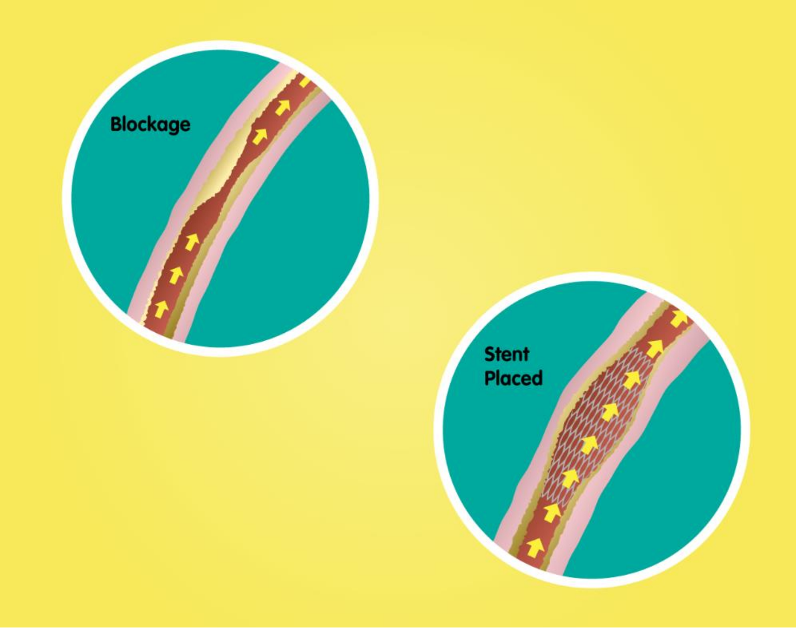
Art and Jewelry
Photo from
https://shopinde.com/product/7746?v=15646

Aviation
Video from
https://www.nasa.gov/feature/glenn/2019/memory-metals-are-shaping-the-evolution-of-aviation

Smart Metals and Their Applications

Eyeglasses
Photo from
http://resource.download.wjec.co.uk.s3.amazonaws.com/vtc/2016-17/16-17_1-4/website/category/2/shape-memory-alloys-sma/index.html

Rover Wheel
Video from NASA Glenn Research Center



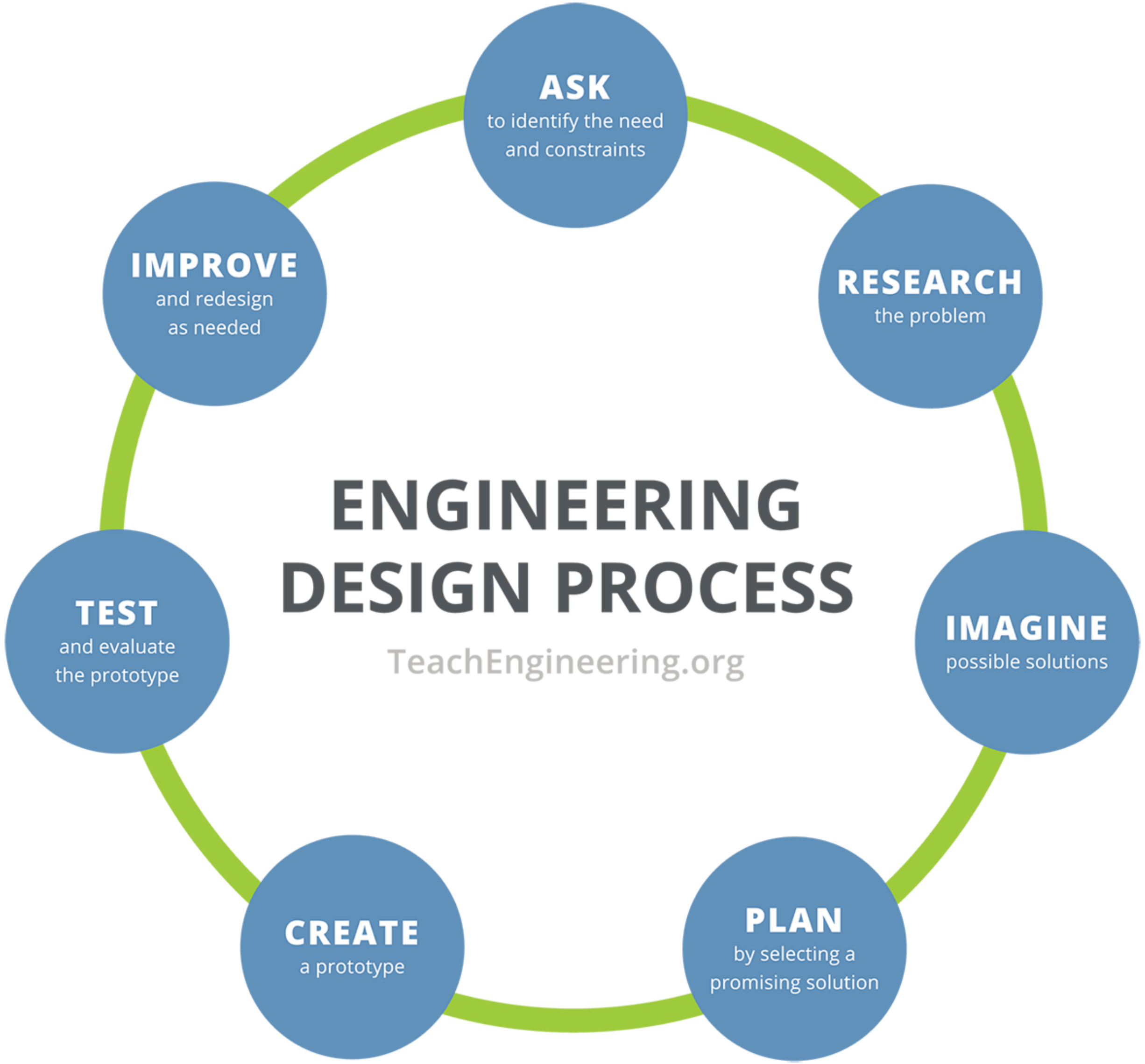
Artery Stint
Photo from
http://resource.download.wjec.co.uk.s3.amazonaws.com/vtc/2016-17/16-17_1-4/website/category/2/shape-memory-alloys-sma/index.html

Engineering Design Challenge

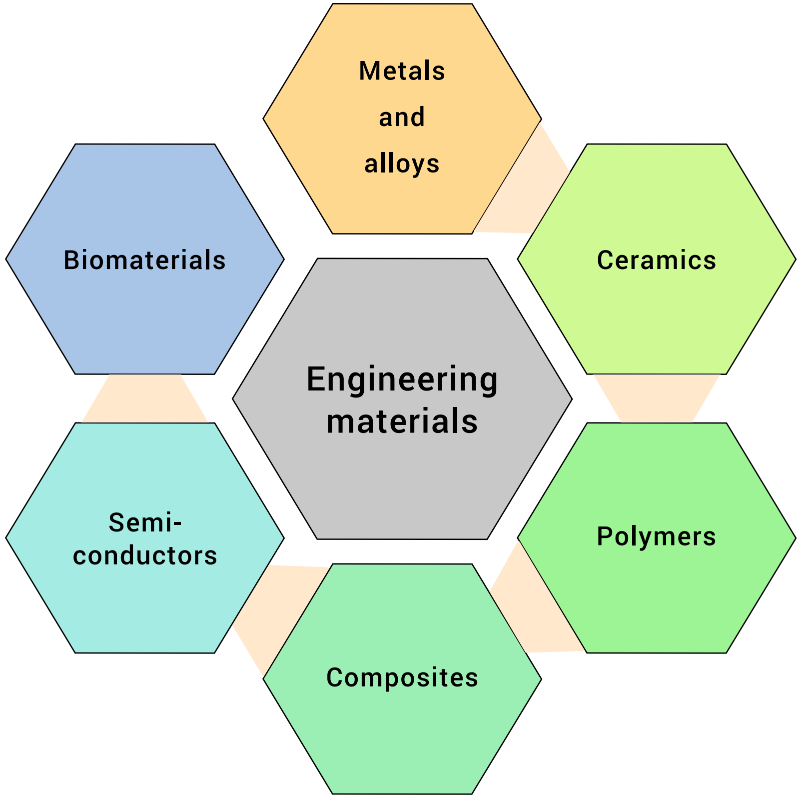
Use the engineering design process to invent your own use for Nitinol.

Think of eyeglasses that repair themselves, or robots that move without motors. Let’s see if you can turn this strange wire into the next big thing in technology.

Engineering Design Process



Materials Science and Engineering

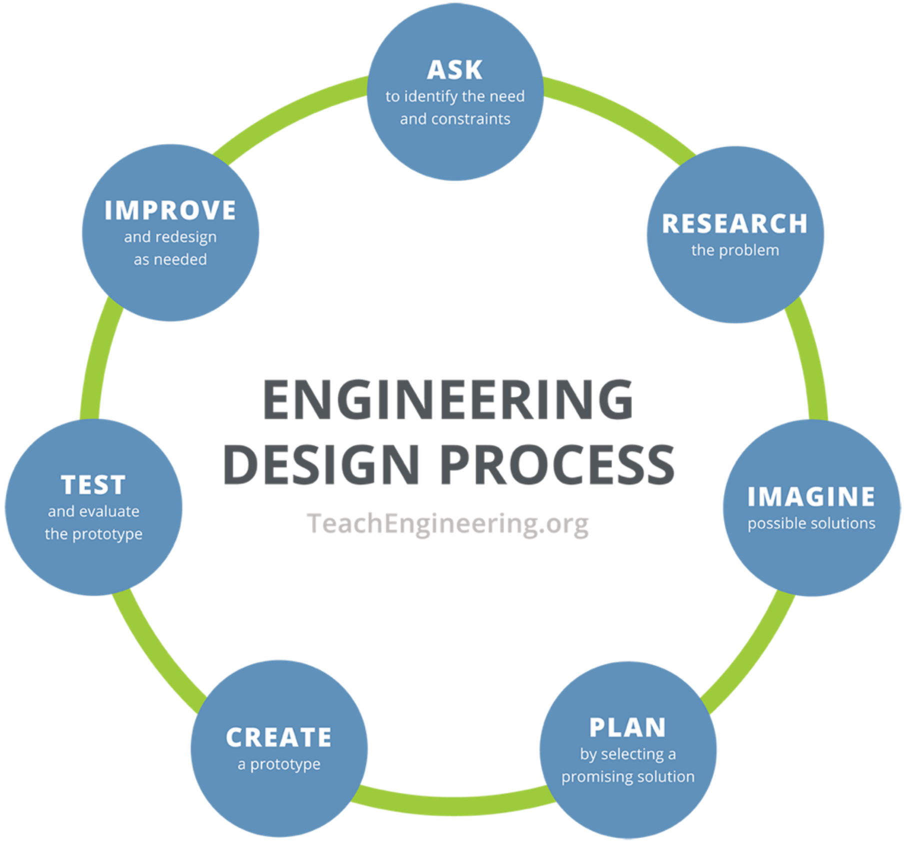


- In this activity, we will be learning about materials science:
  - **Materials scientists** work in an interdisciplinary field, discovering new materials and understanding their properties.
- In this activity, we will be thinking like materials engineers:
  - **Materials engineers** focus on understanding the properties of materials and applying that knowledge to design, develop, and improve materials for use in various industries and fields.

Thinking Like an Engineer

- Engineers use a specific process to produce designs and solve problems.
- You will be using this process in your activity today. This process is called the engineering design process, and it contains the following steps:

1. Define the problem
2. Research the problem
3. Imagine solutions
4. Plan a solution
5. Create a prototype design
6. Test and evaluate the prototype
7. Improve design as needed



This process can repeat over and over again because the goal is the best possible solution!

Background Information

- Which of the following are nonmetals? How do you know?
- Which of the following are metals? How do you know?

Ni Ca Ti O N F C

- Remember:
    - Nonmetals are dull, brittle, poor conductors of heat and electricity—located on the right side of the periodic table.
    - Metals are shiny, malleable, and good conductors of heat and electricity—located on the left side of the periodic table.

Structure of Metals and Alloys

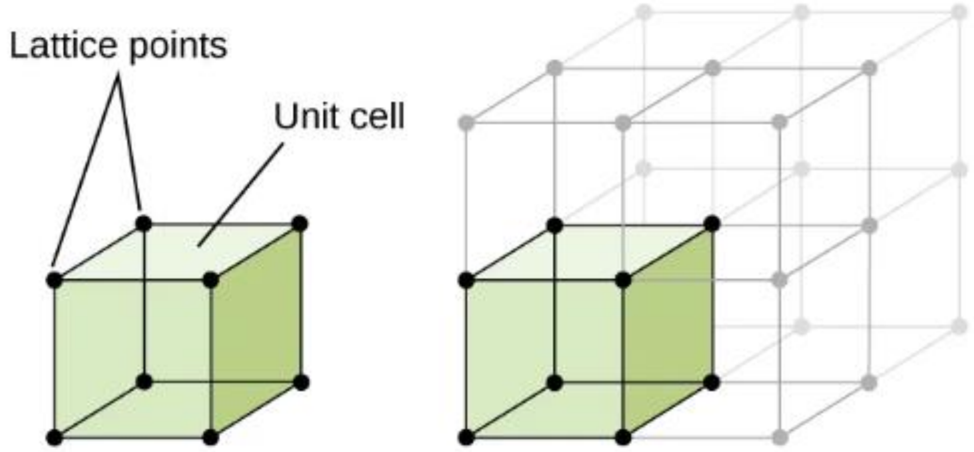


Figure 10.46 A unit cell shows the locations of lattice points repeating in all directions.

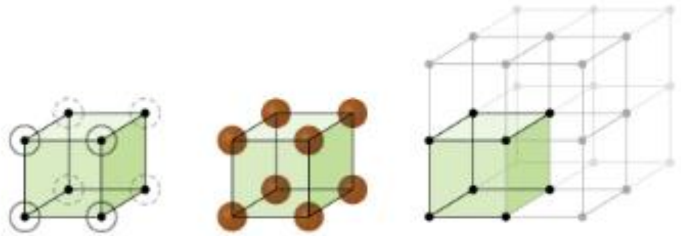


Figure 10.47 When metal atoms are arranged with spheres in one layer directly above or below spheres in another layer, the lattice structure is called simple cubic. Note that the spheres are in contact.

- Metals have a specific repeating micro-structure called a unit cell.
- Unit cells have lattice points that show the position of each of the atoms.
- One type of unit cell pattern is called a simple cubic structure.

Microscopic and Macroscopic

- The regular arrangement of the simple cubic structure is reflected on the macroscopic level.
- Macroscopic properties such as strength of metals are due to features of the microscopic arrangement.
- The size of atoms, arrangement of atoms, and distance to other atoms all affect macroscopic properties such as strength.

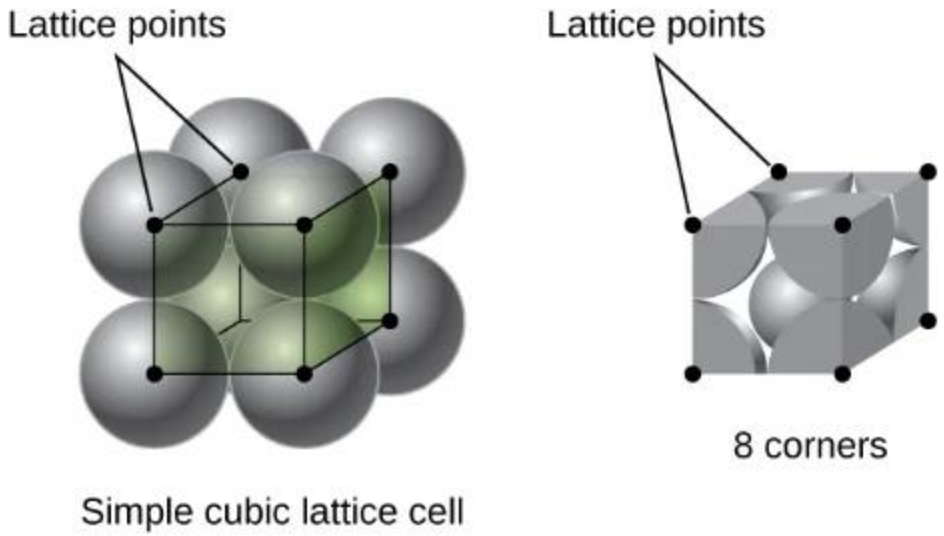
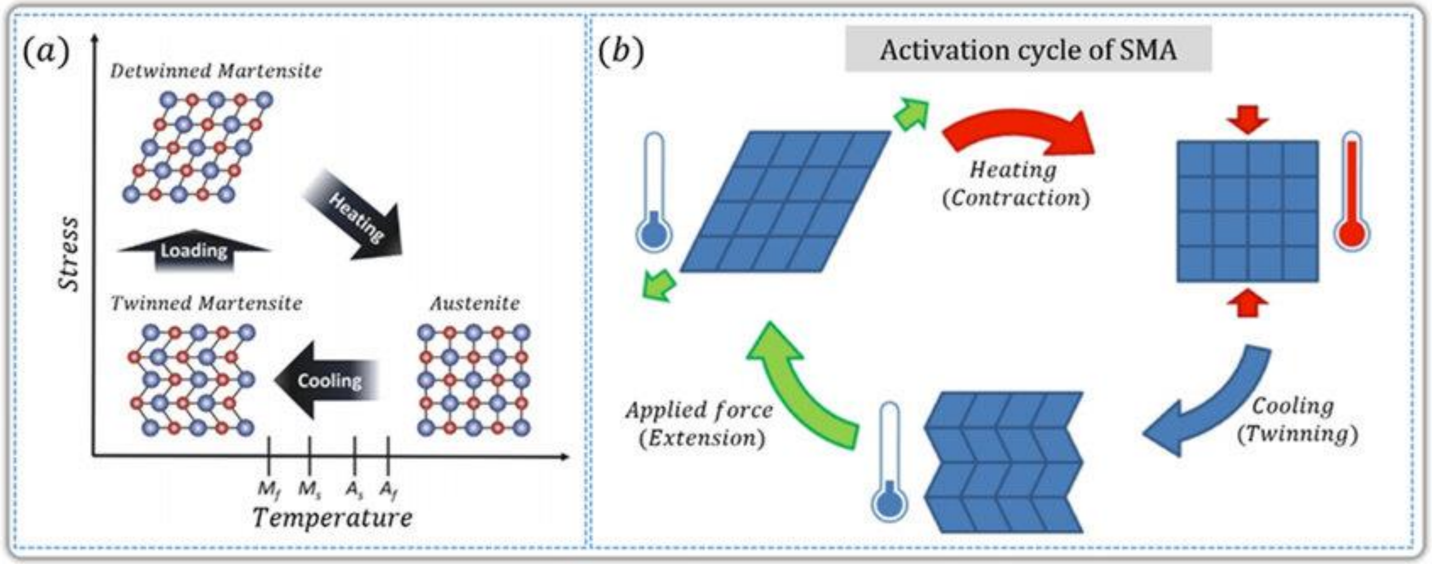


Figure 10.49 A simple cubic lattice unit cell contains one-eighth of an atom at each of its eight corners, so it contains one atom total.

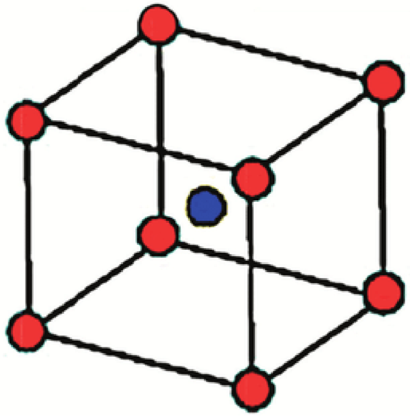
Structure of Nitinol (NiTi)

- The macroscopic changes in the shape of NiTi are due to microscopic changes in its structure.
- The NiTi structure in a straight wire starts as a cubic structure called austenite and changes to a squished cube structure called martensite.

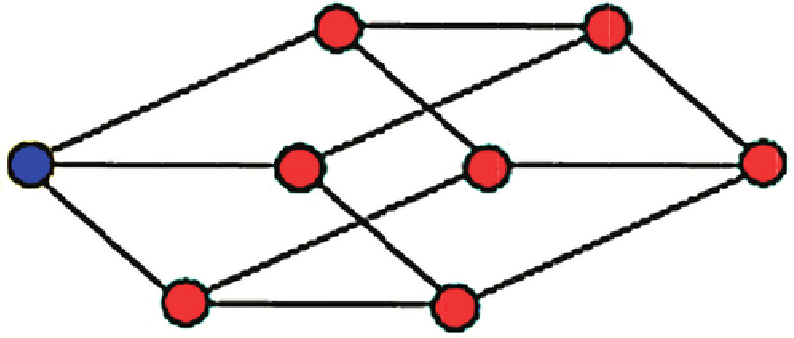


Changes in NiTi Microstructure

Austenite



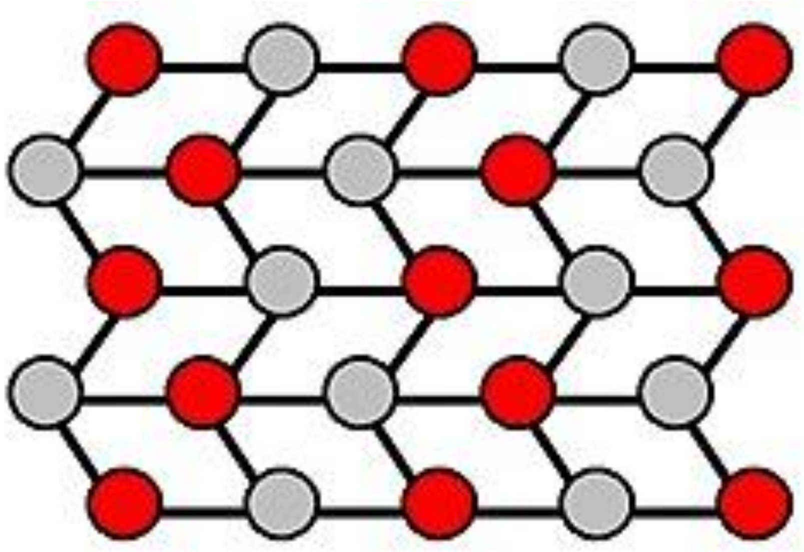
Martensite



- Let’s walk through the demonstration from the beginning of class and discuss the changes that occurred in the macroscopic, along with the changes in the microscopic.

Changes in NiTi Microstructure

Microscopic



Martensite

Macroscopic

When we started the demonstration, what did the metal look like?

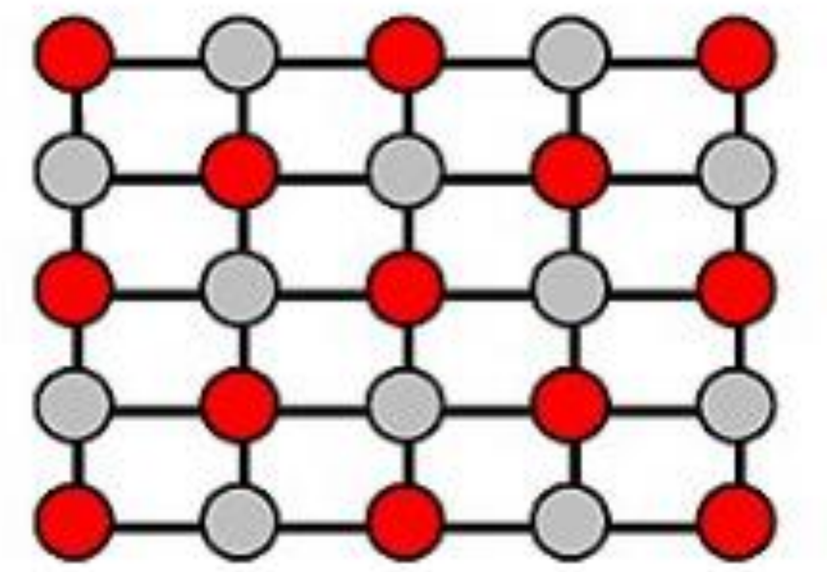
What is the temperature of the metal?

Are there any stresses on the metal?

Changes in NiTi Microstructure

Microscopic

Austenite



Macroscopic

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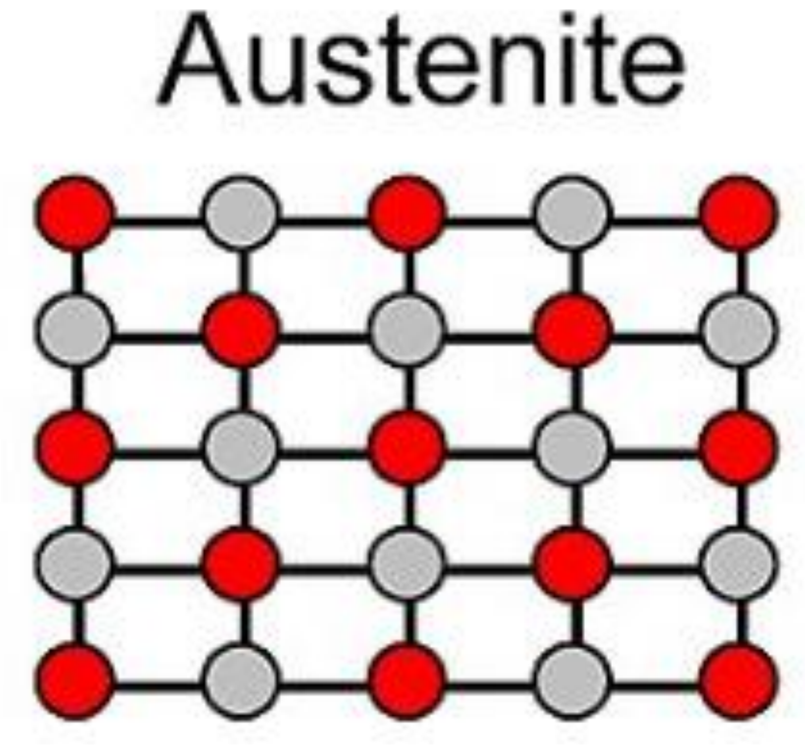
Changes in NiTi Microstructure

Microscopic



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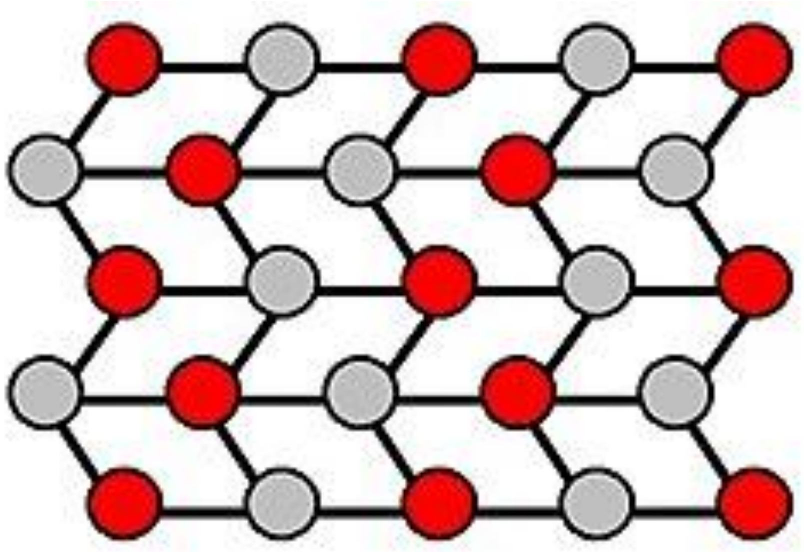
Changes in NiTi Microstructure

Microscopic



Martensite

Macroscopic

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Design Challenge

- Design a device that performs a mechanical task using the shape memory properties of NiTi.
    - You can use any of the following materials: paper, scissors tape, glue, stapler, other small objects, and power supply with alligator clips.

- **<u>The goal of this task is to create a working design that performs a mechanical task with NiTi.</u>**

- You will use the engineering design process to create your prototype.

Example Procedure: Mechanical Design

1. Make a small pocket out of paper and tape to hold pennies.
2. Loop into or run the wire through the paper pocket.
3. Tape the wire to a lab table surface, allowing it to hang off the edge.
4. Add a few pennies to the pocket, causing it to droop down below the table surface.
5. Connect the alligator clips to each end of your wire.
6. Turn on the power supply to cause your design to move and lift.

Nitinol: Board Requirements

- Use a good layout for your board: Think “webpage,” not paragraphs or lists.
- Make sure you EXPLAIN the microscopic and macroscopic changes in your prototype.
- Your board must include:
    - Name of your prototype.
    - Sketch of your team’s prototype.
    - Explanation of macro/microscopic changes that occur in your prototype.
    - Use of new vocabulary.
    - Difficulties your group faced, and how you persevered.
    - Ways to improve your prototype.