## Class 1: Introduction to Vascular Stents (Biomaterials Module)

Vascular stent made of memory metal
www.endovasc.com

PRIME Modules
Project-based Resources for Introduction to Materials Engineering

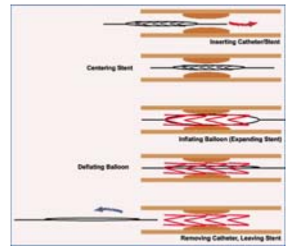
## Memory metals change shape upon heating due to a solid to solid phase change.

Memory metals are a class of alloys that change shape when they go through a solid to solid phase change.

Solid to solid phase change is going from one solid crystal structure to a different solid crystal structure at a specific temperature.

Applications of memory metal utilize the fact that the macroscopic sample returns to a shape it was processed in when heated.

The mechanical properties also change upon heating, with one crystal structure having different mechanical properties than the other.



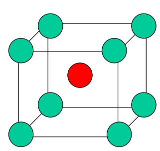

Balloon inflated stent
http://www.amtbe.com/medical.html

## Nitinol is a NiTi alloy that is a shape memory alloy

A common memory metal (also known as SMA: shape memory alloy) is Nitinol.

Nitinol is a NiTi alloy. *SMA materials have a range of elements, Ni and Ti are just the most common.*

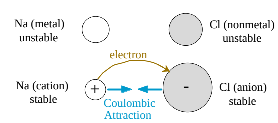
NiTi is an intermetallic compound. This means two or more elements are mixed together on the same solid lattice. This is only one phase, they share the same crystal structure.



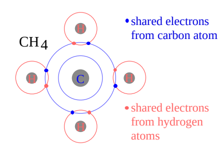
Crystal Structure of NiTi
(Austenite Phase)
a = 3.105 Angstroms

## How did you think of bonding in chemistry?

Ionic Bonding
- •one atoms donates electrons to another
- •A strong bonds (high melting temperatures)
- •Hard and brittle *(We will talk about this later in the semester but due to the ionic bond these materials don't have plastic deformation)*



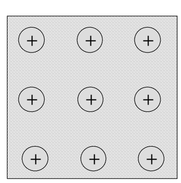

Covalent Bonding
- Neighboring atoms share electrons
- Varying properties (bond strength, TM etc)
- Si is a very common example of this we will talk about



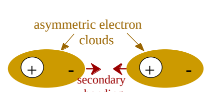

Figures from Callister

## How did you think of bonding in chemistry?

Metallic Bonding
- •Valence electrons (electrons in the outermost shell) dissociate from individual atoms and contribute to an "electron sea"
- •Creates materials that are good conductors and ductile (deform plastically)



Secondary Bonding
- Weak bonding that results from Coulombic attraction set up by fluctuating charge

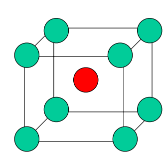



Figures from Callister

## In materials, we talk about structural bonding

In materials, we are concerned with the 3-D representation of the atoms.

We will be discussing a uniform system of naming the 3-D arrangement of atoms that can be applied to all crystal structures with a long range pattern.



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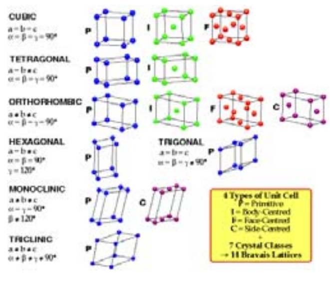
## There are 7 crystal systems and 14 Bravais lattices

There are 7 crystal systems that describe all the possible variations of side lengths and angles

14 Bravais lattices have been defined. *There are many more possibilities, 14 is all that is needed to describe all the world's crystal structures .*

We will study the cubic lattice: simple cubic (SC), face centered cubic (FCC), and body centered cubic (BCC).




http://www.iit.edu/~felfkri/report_files/image002.gif

## A lattice plus the basis on each lattice site creates the unit cell.

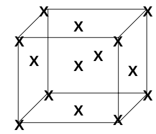
A lattice is the framework that is used to replicate the atomic arrangement of the sample.

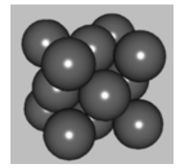
Lattice sites (also known as a lattice points) are identical points on a lattice. This means that they have the same atoms on and surrounding the point.

- *A lattice site is not necessarily an atom. A lattice site can have more than 1 atom associated with it.*

A basis is the one or more atoms that are clustered on a lattice site to recreate the crystal structure.

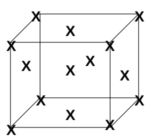
A unit cell is the 3-D cube that is repeated throughout space to create the atomic arrangement of the sample.
*The edges of the cubes are not necessarily atomic bonds. They usually aren't! They are just there to make the box easier to draw.*



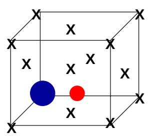


http://members.tripod.com/~EppE/jpgs/faccubic.jpg

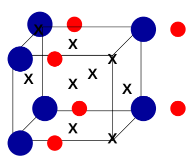
## A lattice plus the basis on each lattice site creates the unit cell.



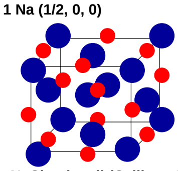
Start with an FCC lattice
X = lattice site



Add a basis of 1 Cl (000) and 1 Na (1/2, 0, 0)



Stamp the basis out on each lattice site. Some atoms end up in other unit cells



Get NaCl unit cell (Callister Fig 12.2)

## Simple cubic with a basis of 1 has 1 atom per lattice site.

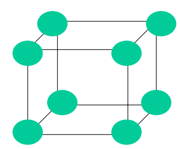
The easiest of the structures we will look at is simple cubic.

When counting the lattice sites or atoms in a unit cell, you must only count the fraction in that cell.

Each corner lattice site and atom are only 1/8th in this unit cell.

With a basis of 1 atom per lattice site, this structure has
1/8 * 8 = 1 lattice sites/ unit cell
1/8 * 8 = 1 atoms/ unit cell

Ball & Stick Model



Start with the SC lattice

Add a basis of 1 atom per lattice site to get the unit cell

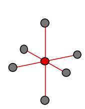
How the atoms really fill the space

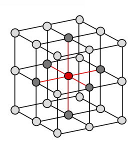
Figure from Callister

## SC with a basis of 1 has a coordination number of 6

For SC structures with a basis of 1 atom per lattice site, the atoms touch (are bonded) along the cube edges.

The atoms have a coordination number (number of atoms they are bonded to) of 6.





Figures from Callister

## The APF is the ratio of the space the atoms take up to the volume of the unit cell

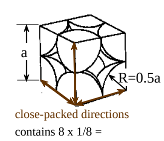
To calculate the APF (atomic packing fraction), you must calculate the ratio of the volume the atoms take up to the volume of the unit cell

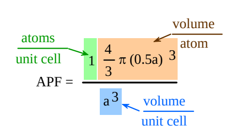
To do this you must calculate the a (lattice parameter, side edge) to R (atomic radius) ratio

$a = 2R$

$R = 0.5a$

In SC, the APF is 0.52 (if there is 1 atom per lattice site)



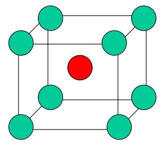

Figures from Callister

## NiTi has a cubic crystal structure with 2 atoms per lattice site.

The lattice is SC: It is not BCC because the atom in the body center is not identical to those on the corners.

There is 1 Ni atom and 1 Ti atom per unit cell. Note, that you can redraw this structure with the red atoms on the corner and the green in the center. The basis is 1 Ni atom at (0,0,0) and 1 Ti atom at (½, ½, ½).

Each Ni atom bonds with 8 Ti (a coordination number of 8) and vice versa.



Crystal Structure of NiTi
(Austenite Phase)
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## In summary, nitinol has a shape change due to a crystal structure change

Nitinol is a common alloy used to make biomedical stents.

The alloy changes crystal structure at the body temperature.

Crystal structures are classified by 7 crystal systems, 14 Bravais lattices, and their basis.

We will be studying crystal systems with SC, FCC, and BCC lattices

It is important to know the # of atoms per unit cell, a/r ratio, APF, and coordination number.

Vascular stent made of memory met
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