3.012 Fund of Mat Sci: Structure – Lecture 21

NON-CRYSTALLINE MATERIALS

Images of a silicon nanocrystal removed for copyright reasons.

Light amplification for crystalline silicon in a glassy SiO_2 matrix

Homework for Fri Dec 2

- Study: Chapter 2 of Allen-Thomas until 2.3.1

Last time:

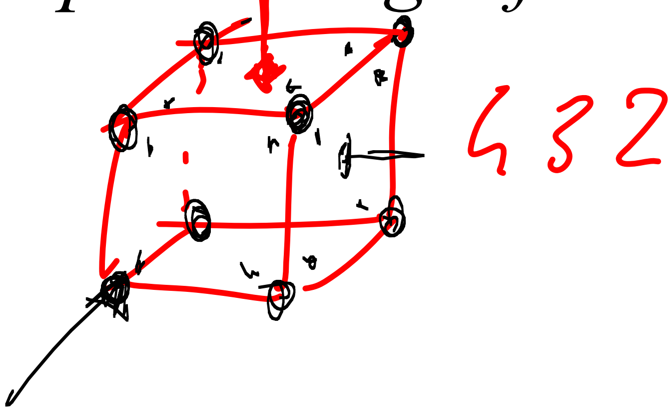
1. Tensors, and their transformations
2. Orthogonal matrices
3. Neumann's principle
4. Symmetry constraints on physical properties
5. Curie's principle

Physical properties and their relation to symmetry

- Density (mass, from a certain volume)
- Pyroelectricity (polarization from temperature)
- Conductivity (current, from electric field)
- Piezoelectricity (polarization, from stress)
- Stiffness (strain, from stress)

Curie's Principle

- *a crystal under an external influence will exhibit only those symmetry elements that are common to both the crystal and the perturbing influence*

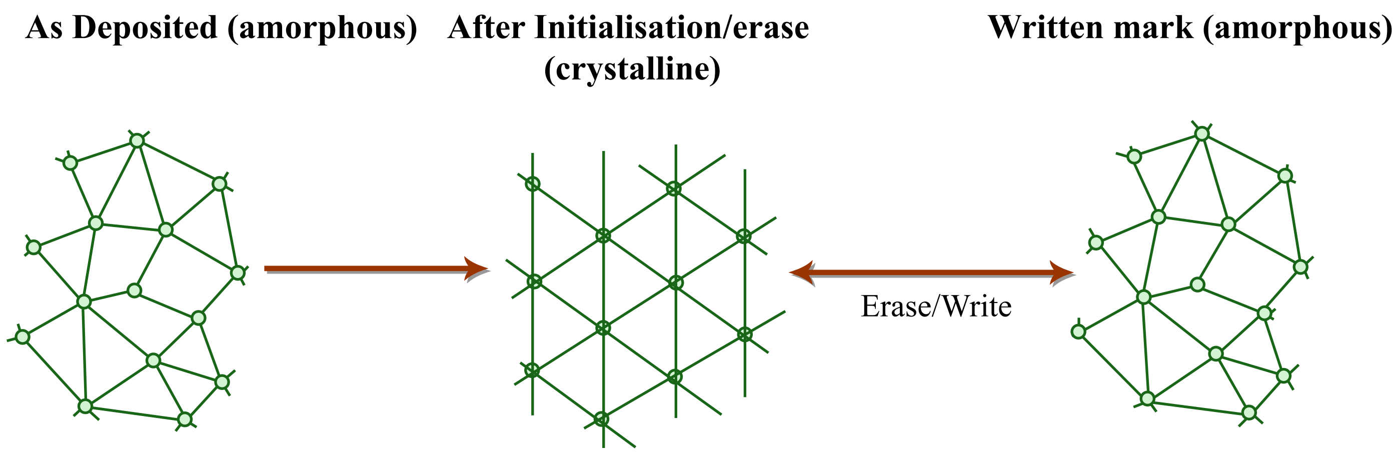


Loss of periodic order

- Liquids (“fluid”)
- Glasses (“solid”)
  – Oxide glasses (continuous random networks)
  – Polymeric glasses (self-avoiding random walks
- Oddballs
  – Quasicrystals
  – Superionics

Table of the applications of noncrystalline materials removed for copyright reasons.

Principle of operation of a CD-RW



Readout of data:

Difference in %R between amorphous & crystalline states

E.g. $\%R_{amorphous} = 5\%$; $\%R_{cryst} = 25\%$

Delta R = 20%

Figure by MIT OCW.

Principle of operation of a CD-RW

Writing - Amorphous

The active layer is heated above its melting point and quenched into the amorphous phase with a short laser pulse to produce marks.

Erasure – Crystalline

Intermediate laser power is used, so that the active layer does not melt, but rather remains within the crystallization temperature region long enough that the amorphous marks re-crystallize.

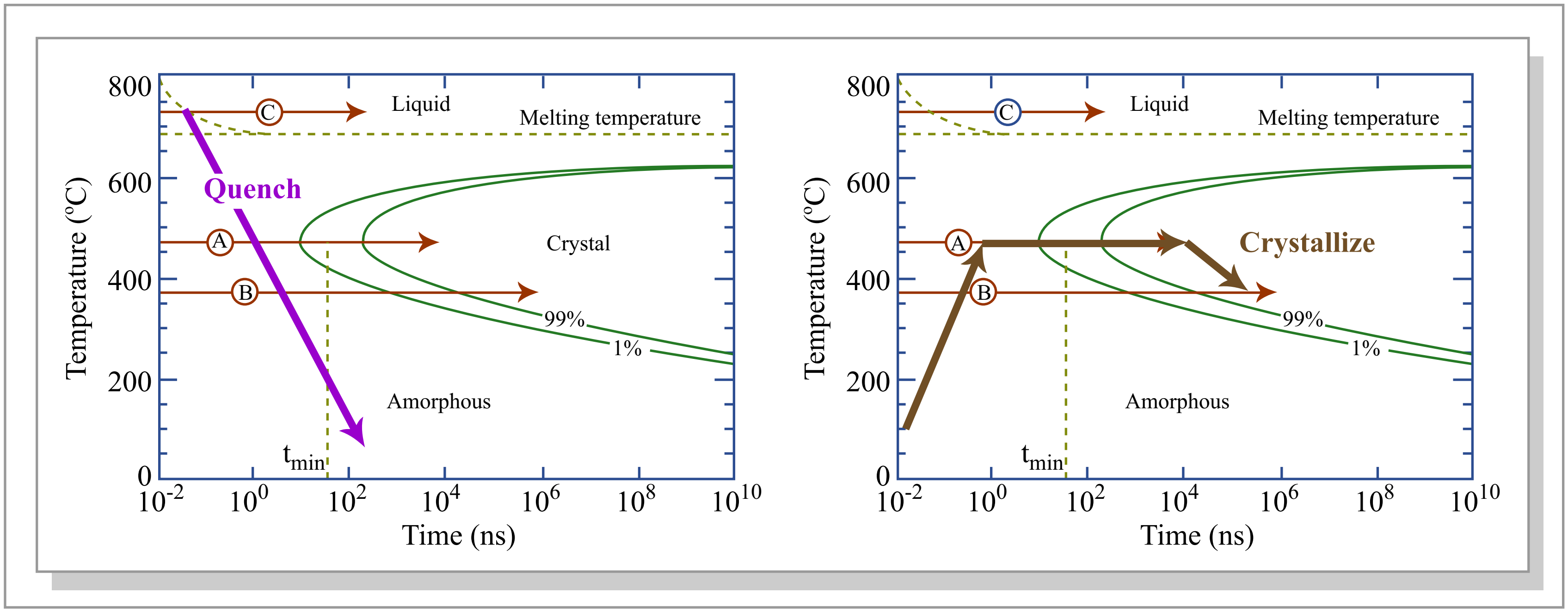


Figure by MIT OCW.

Erasure: nucleation and growth of crystalline material

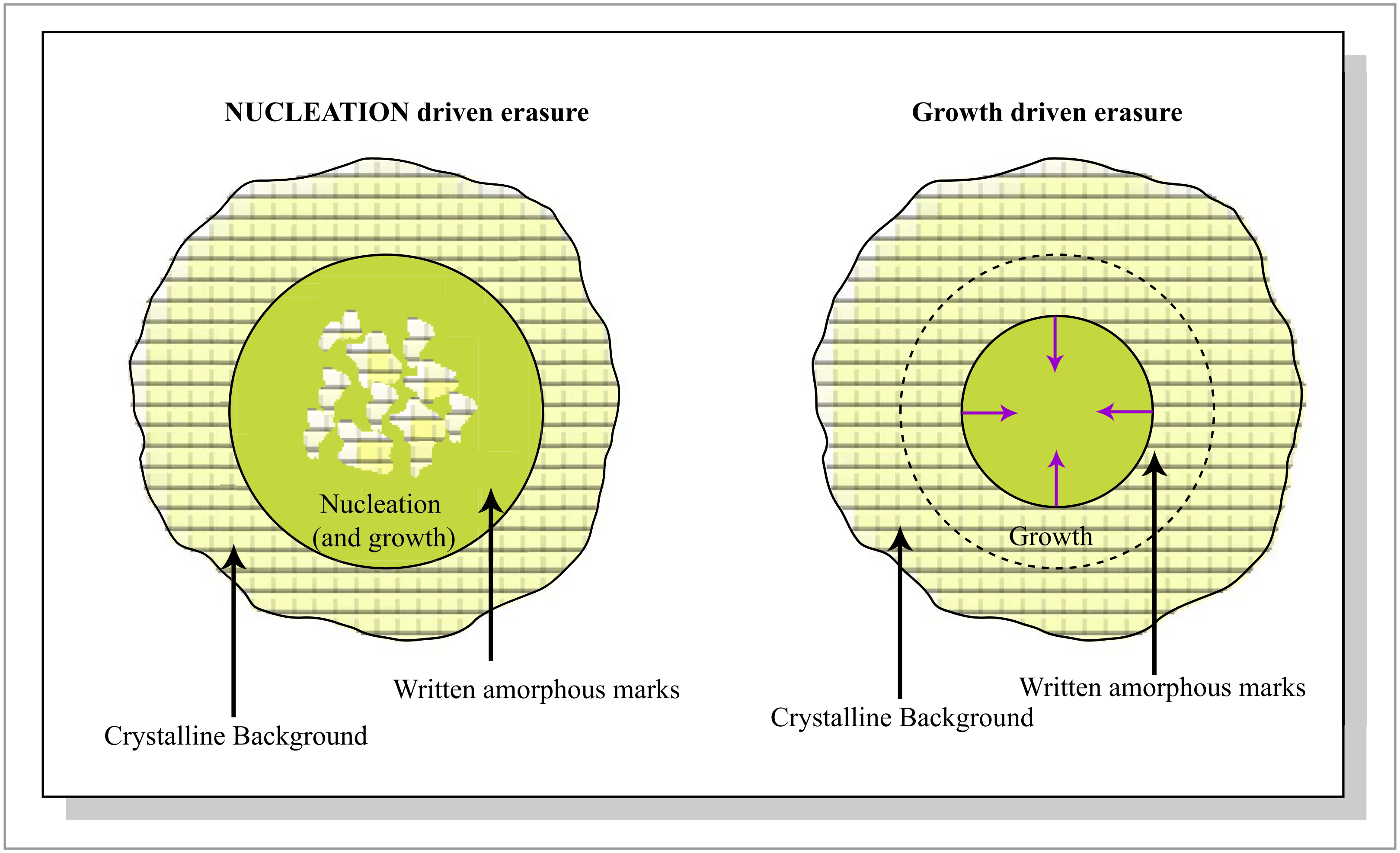


Figure by MIT OCW.

Te-Sb-Ge Alloy

Nucleation dominated: 4.7 GB DVD-RAM (Sb_2Te_3 to GeTe)

Growth dominated: CD-RW, DVD-RW, Blu-ray ($Sb_{69}Te_{31}$ eutectic)

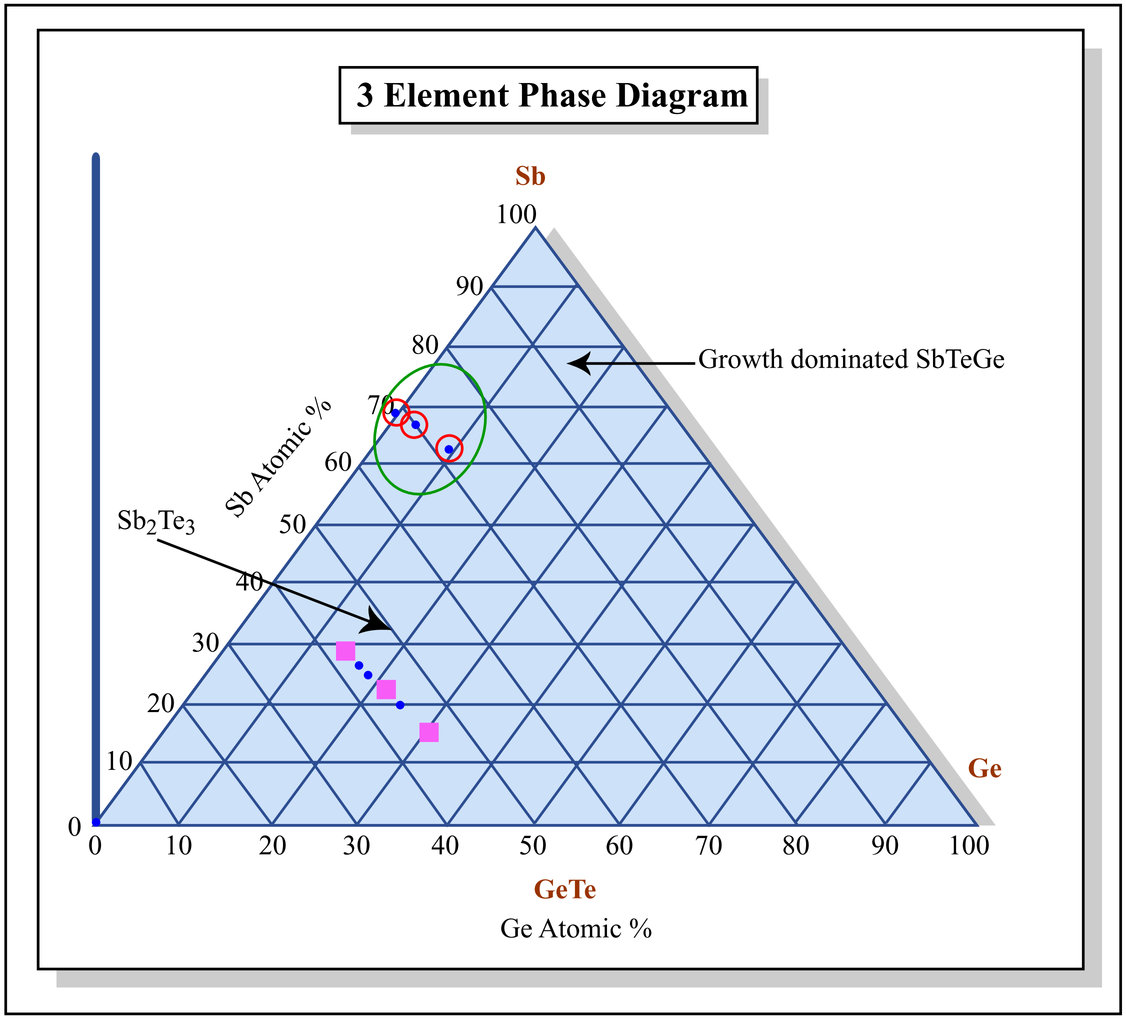
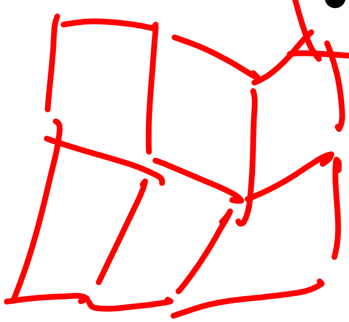
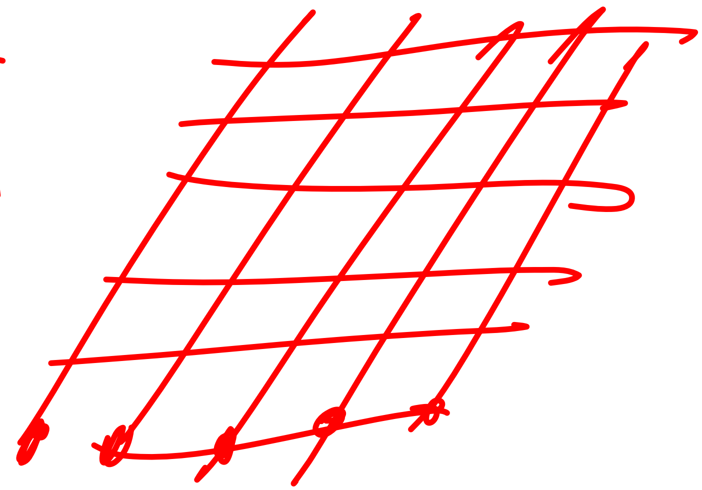


Figure by MIT OCW.

Structural Descriptors

- Long-range order
- Short-range order





What do ice and silicon have in common ?

Source: Wikipedia

What do ice and silicon have in common ?

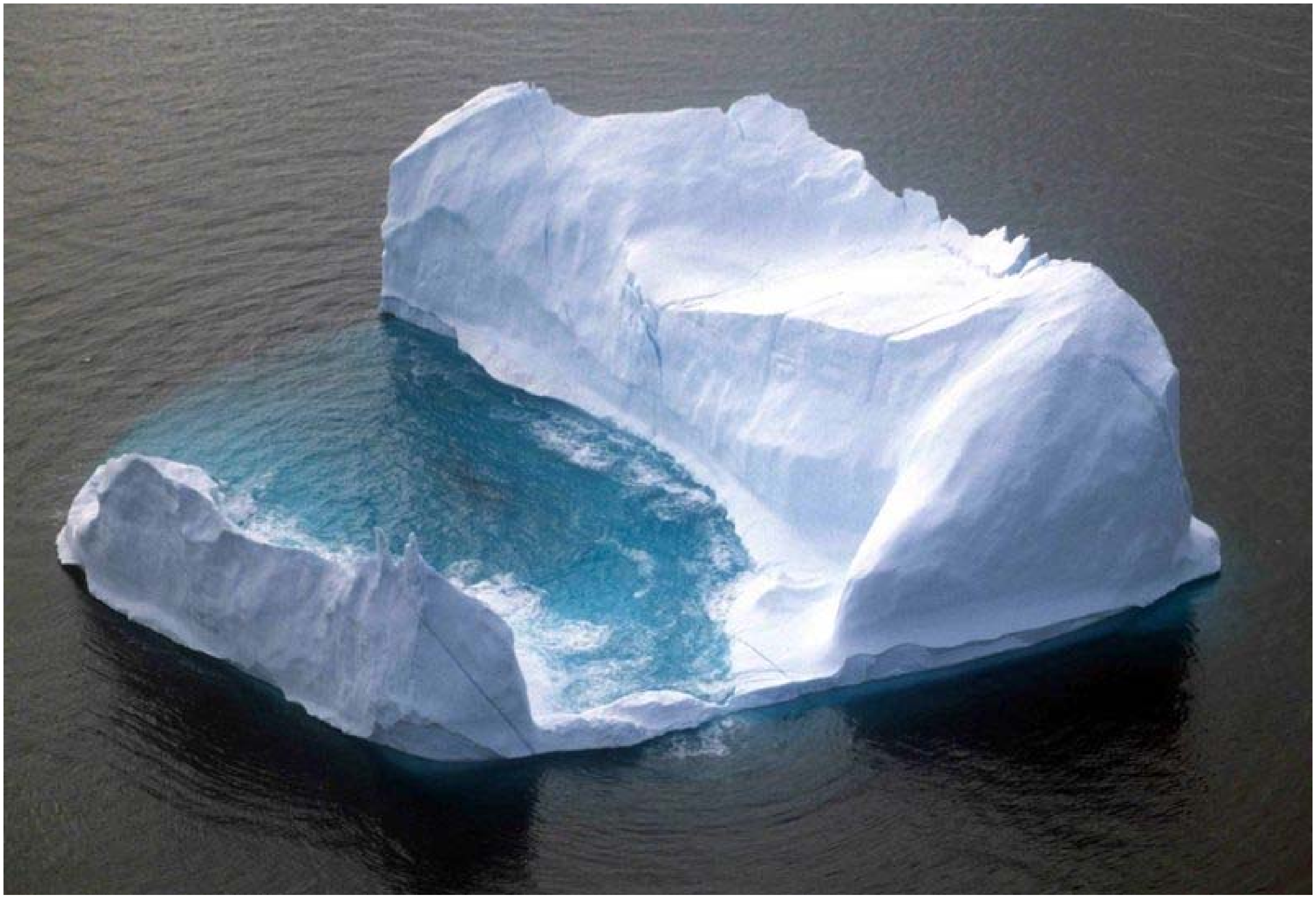


Photo courtesy of Ansgar Walk.

ABAB → WURTZITE
→ ICE HEXAGONAL

FCC [111] ABCABC

What do ice and silicon have in common ?

Si = FCC 2 ATOM BASIS

CUBIC ICE

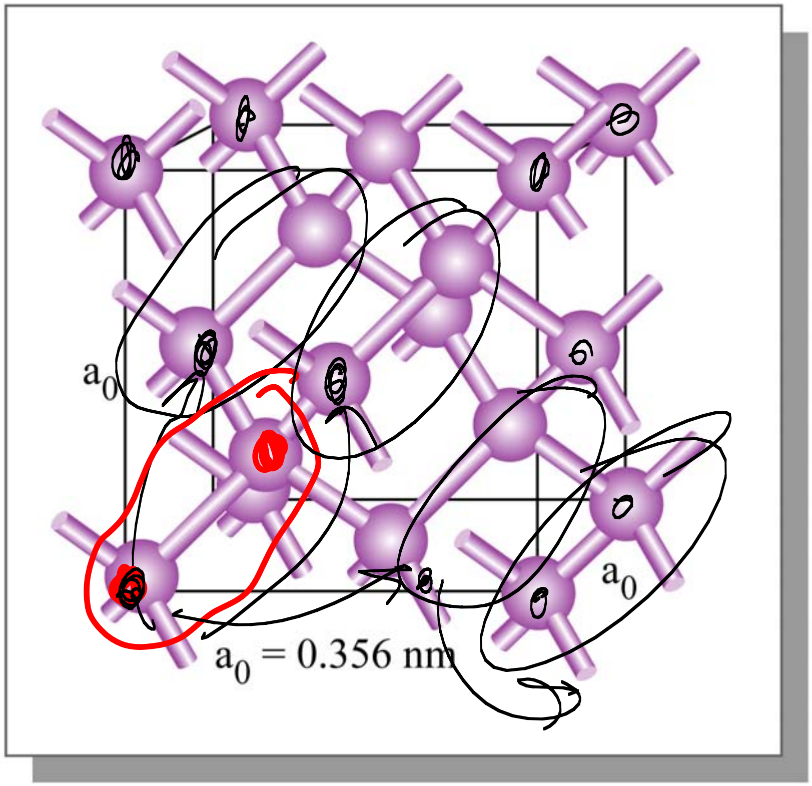


Figure by MIT OCW.

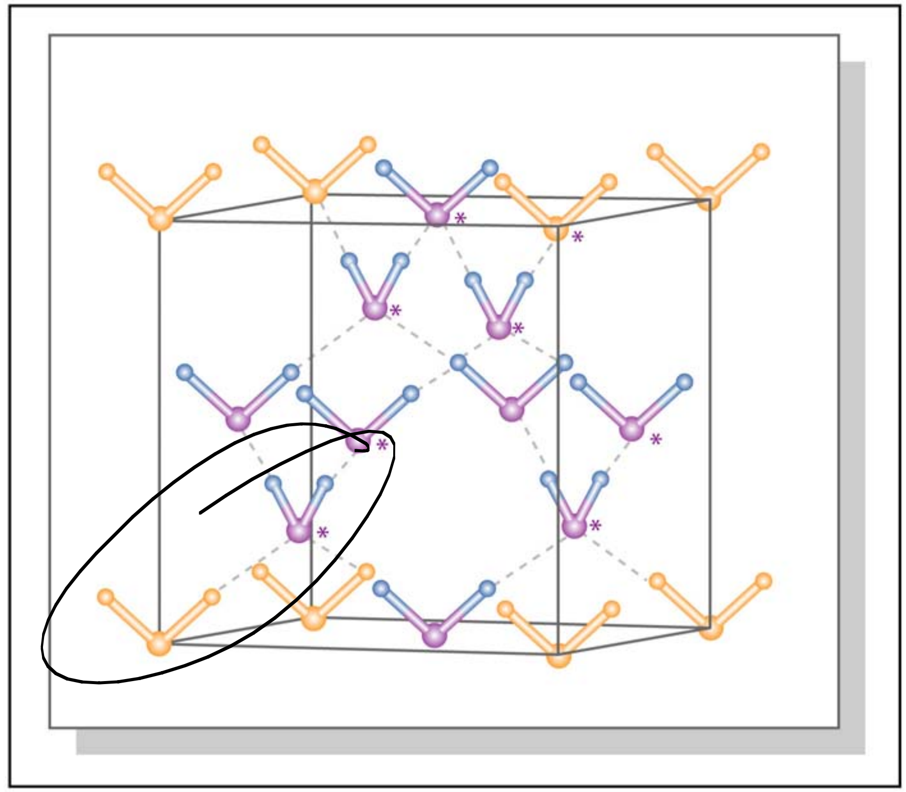


Figure by MIT OCW.

What do ice and silicon have in common ?

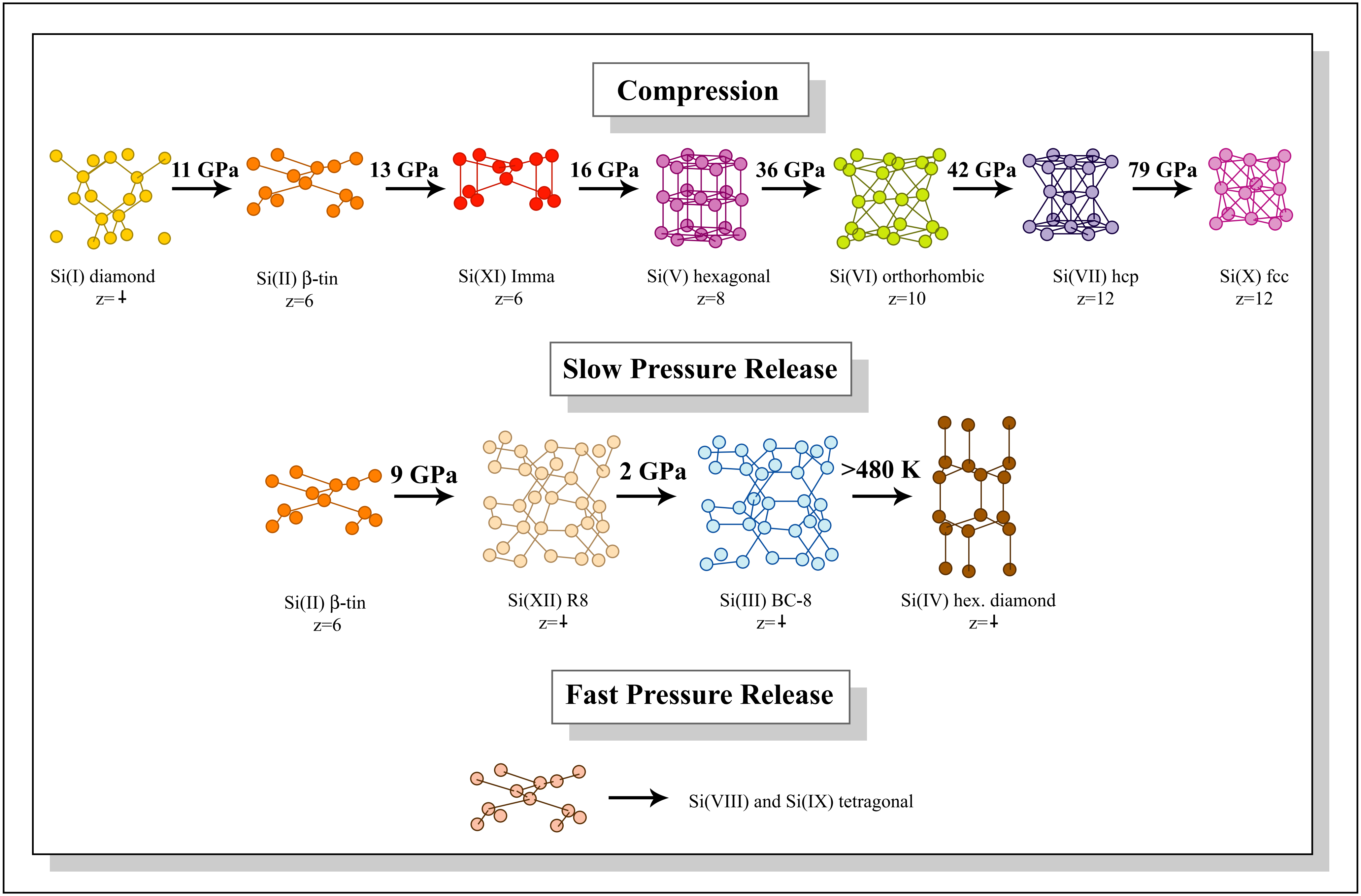


Figure by MIT OCW.

What do ice and silicon have in common ?

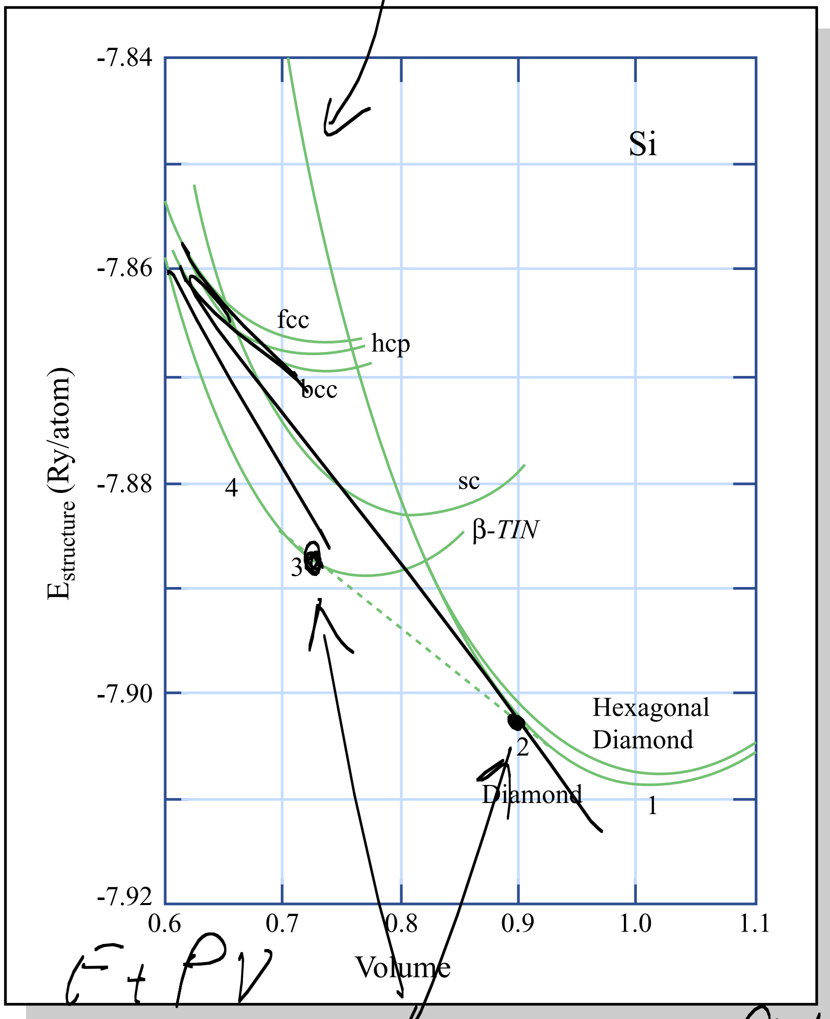


Figure by MIT OCW.

$$E_1 + PV_1 = E_2 + PV_2$$

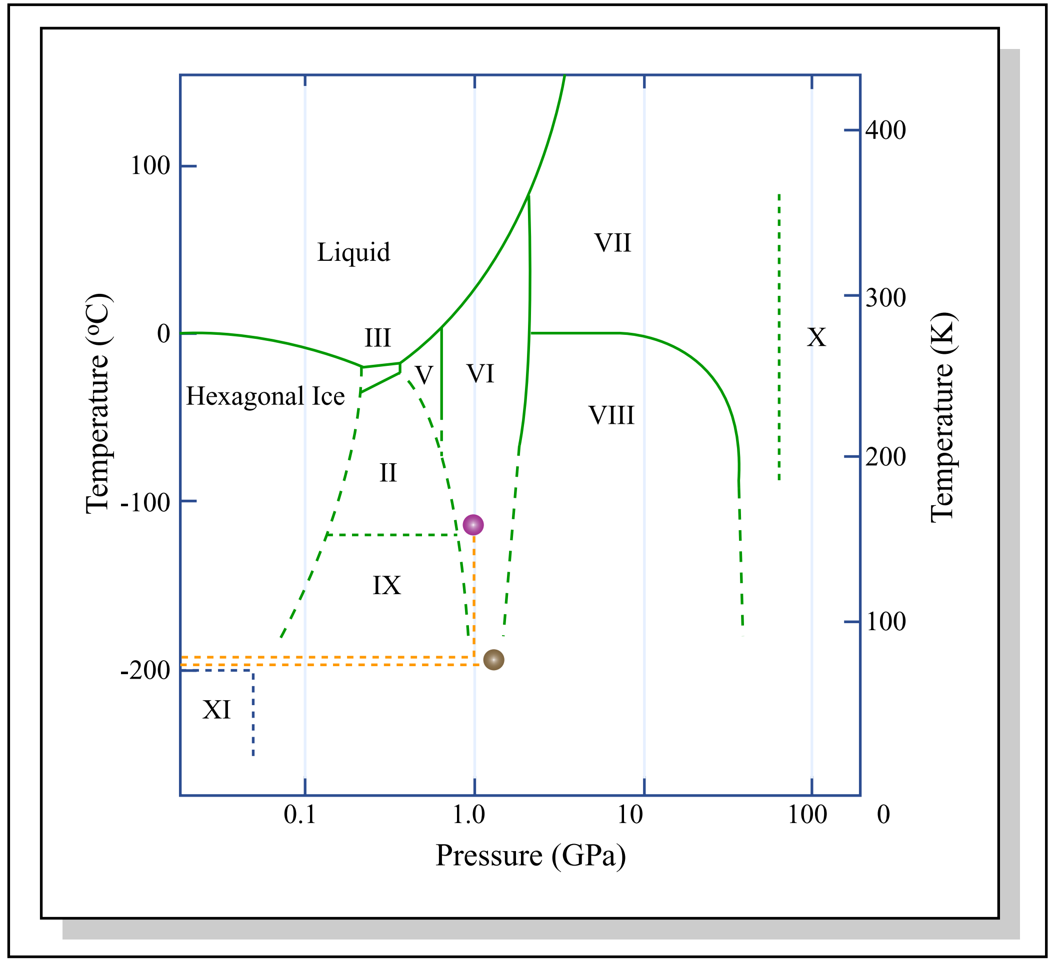
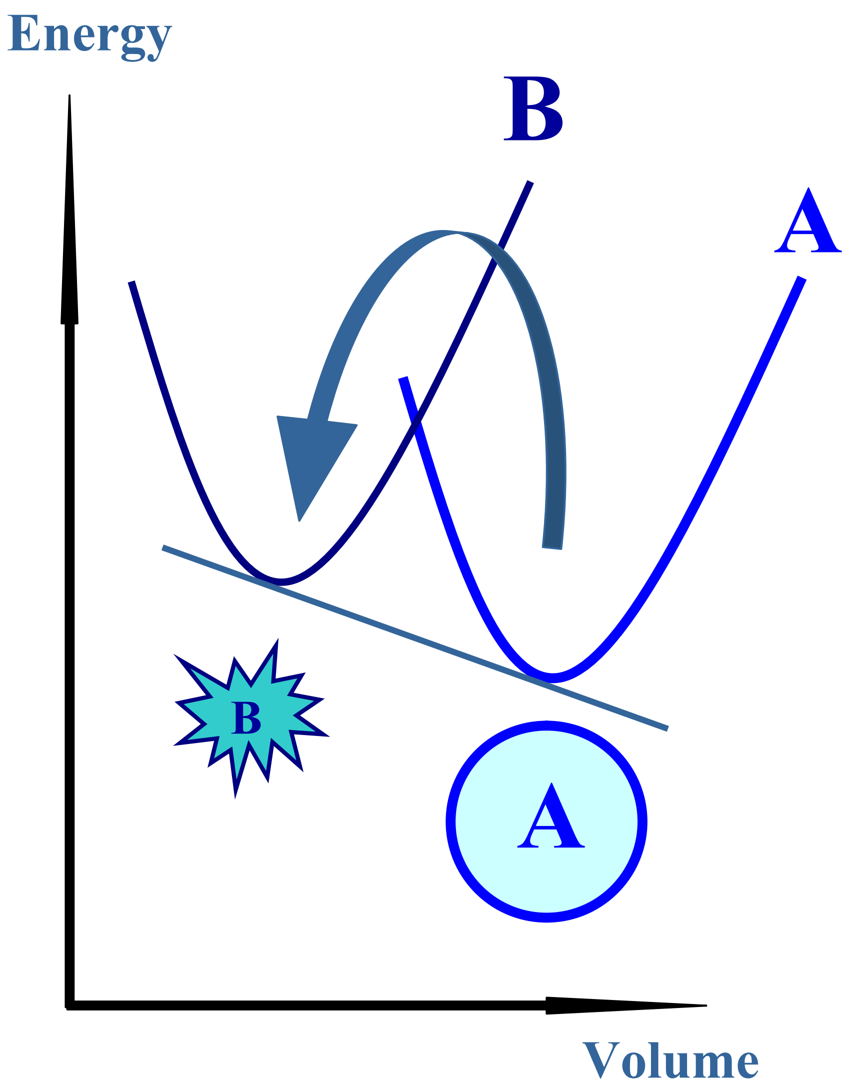
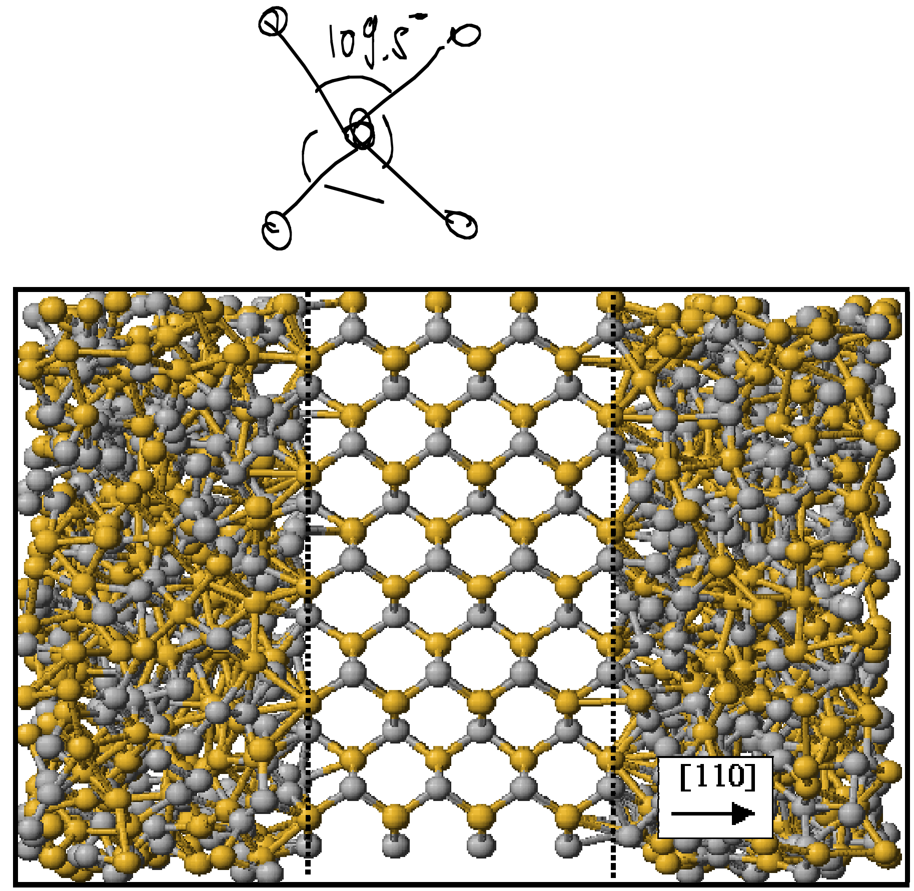


Figure by MIT OCW.

Phase transitions in silicon

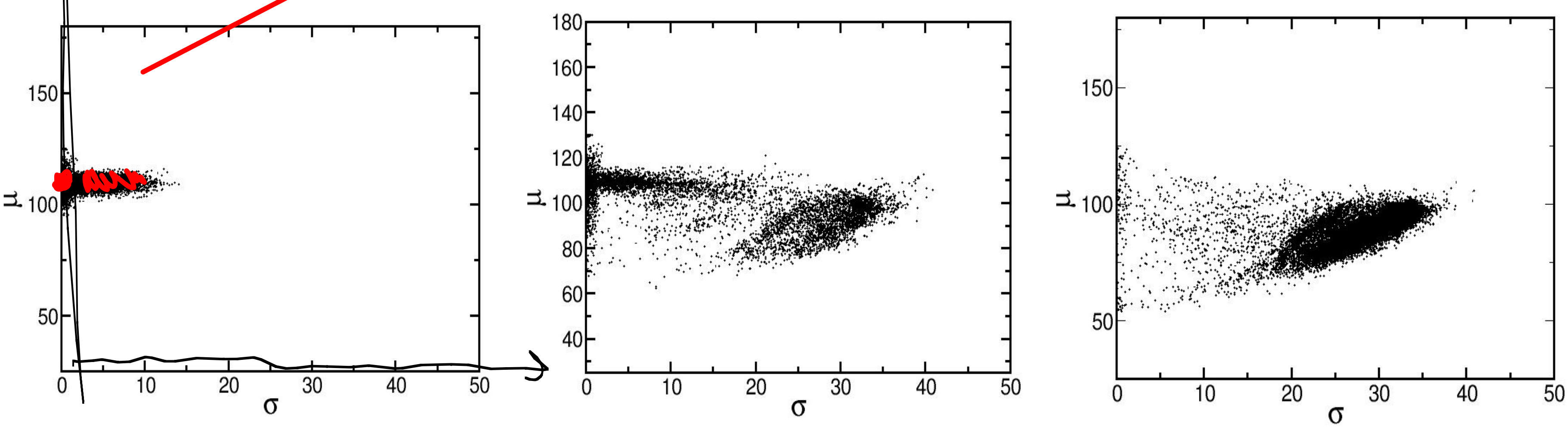




Order Parameters for Silicon

$$\mu = \frac{1}{N}\sum_i \theta_i \qquad \sigma = \left(\frac{1}{N}\sum_i \theta^2 - \mu^2\right)^{\frac{1}{2}}$$

Before compression During compression P = 40 GPa

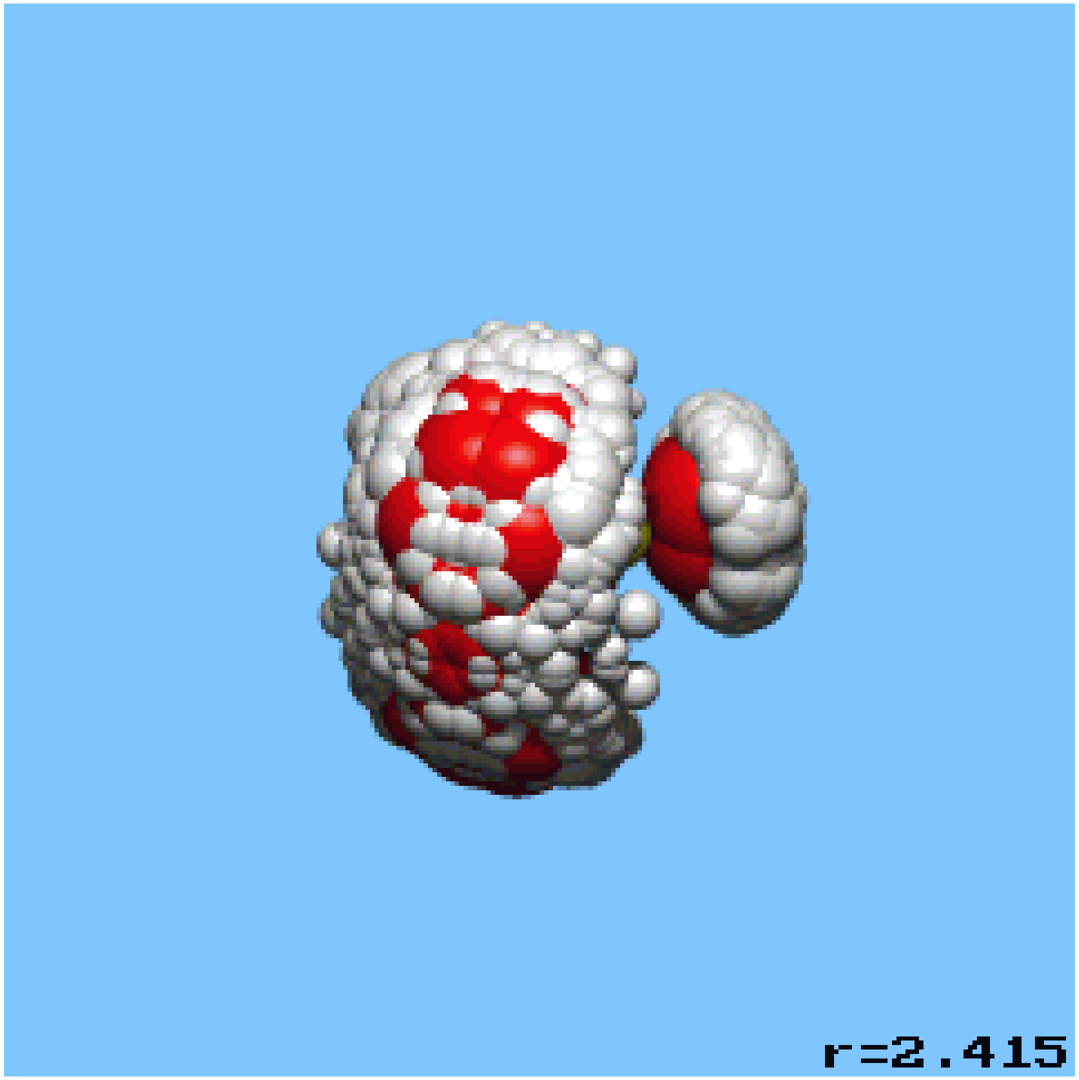


M. J. Demkowicz and A. S. Argon, Phys. Rev. Lett. 93, 25505 (2004)

Pair correlation functions

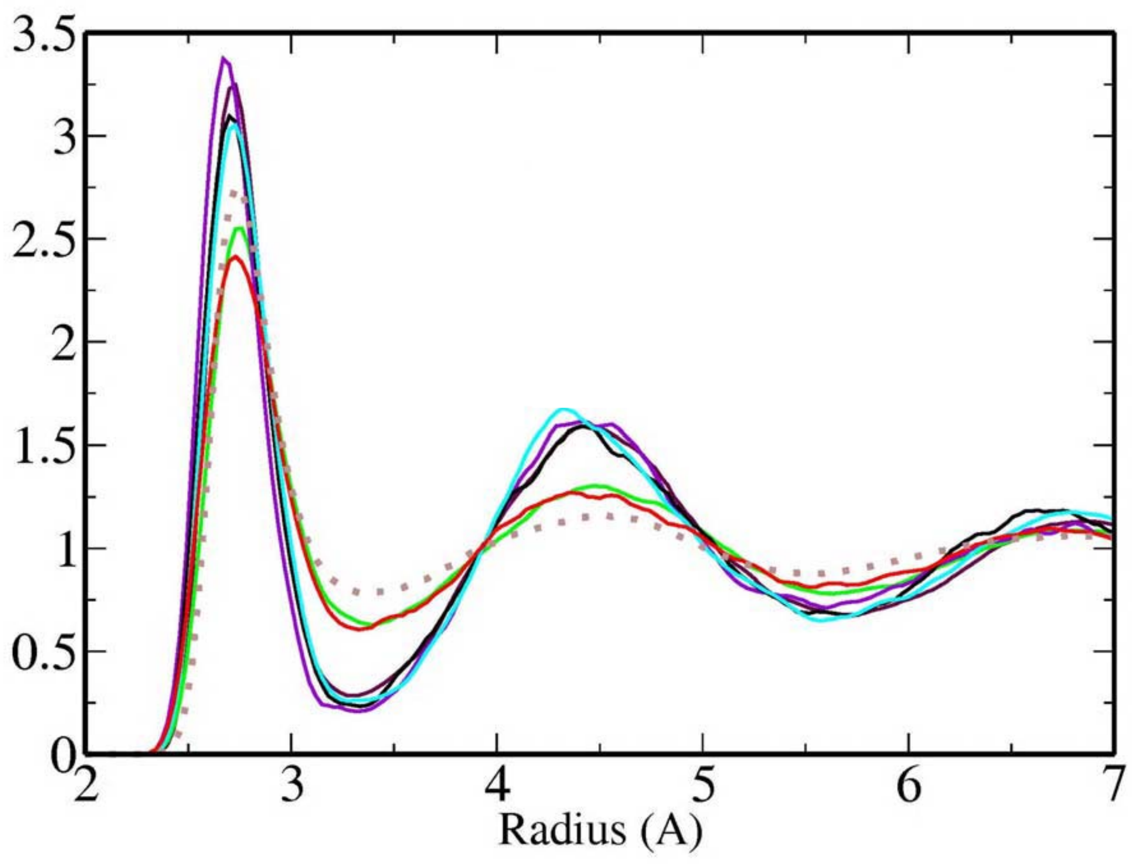
Graphs of the pair-distribution functions for gas, liquid/gas, and monatomic crystal removed for copyright reasons.
See page 41, Figure 2.5 in in Allen, S. M., and E. L. Thomas. *The Structure of Materials*. New York, NY: J. Wiley & Sons, 1999.

Pair correlation function: water

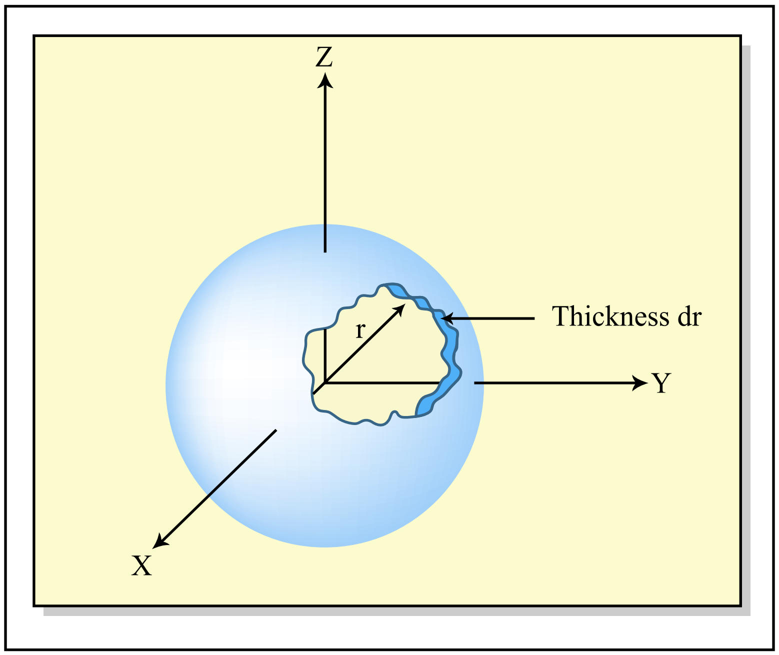


See animation at http://www.icpf.cas.cz/jiri/movies/water.htm.

Pair correlation function: water



Count thy neighbours



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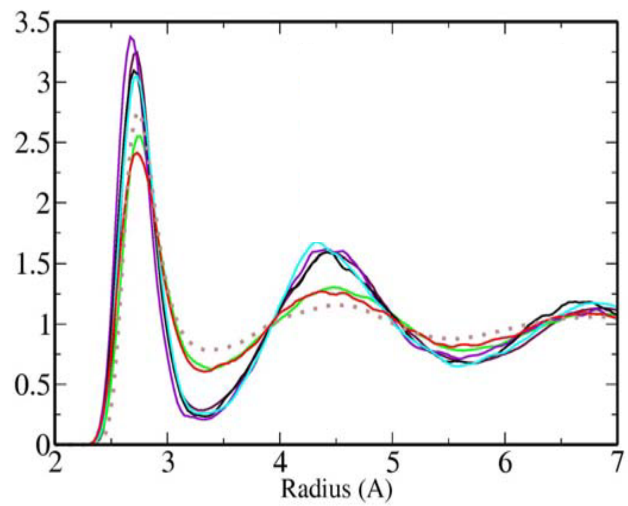

Models of disorder: hard spheres

- Bernal random close packed sphere model

Photos of the Bernal random close-packing model removed for copyright reasons.
See them at the Science & Society Picture Library: Image 1, Image 2.

Models of disorder: hard spheres

- Voronoi polyhedra (in a crystal: Wigner-Seitz cell)

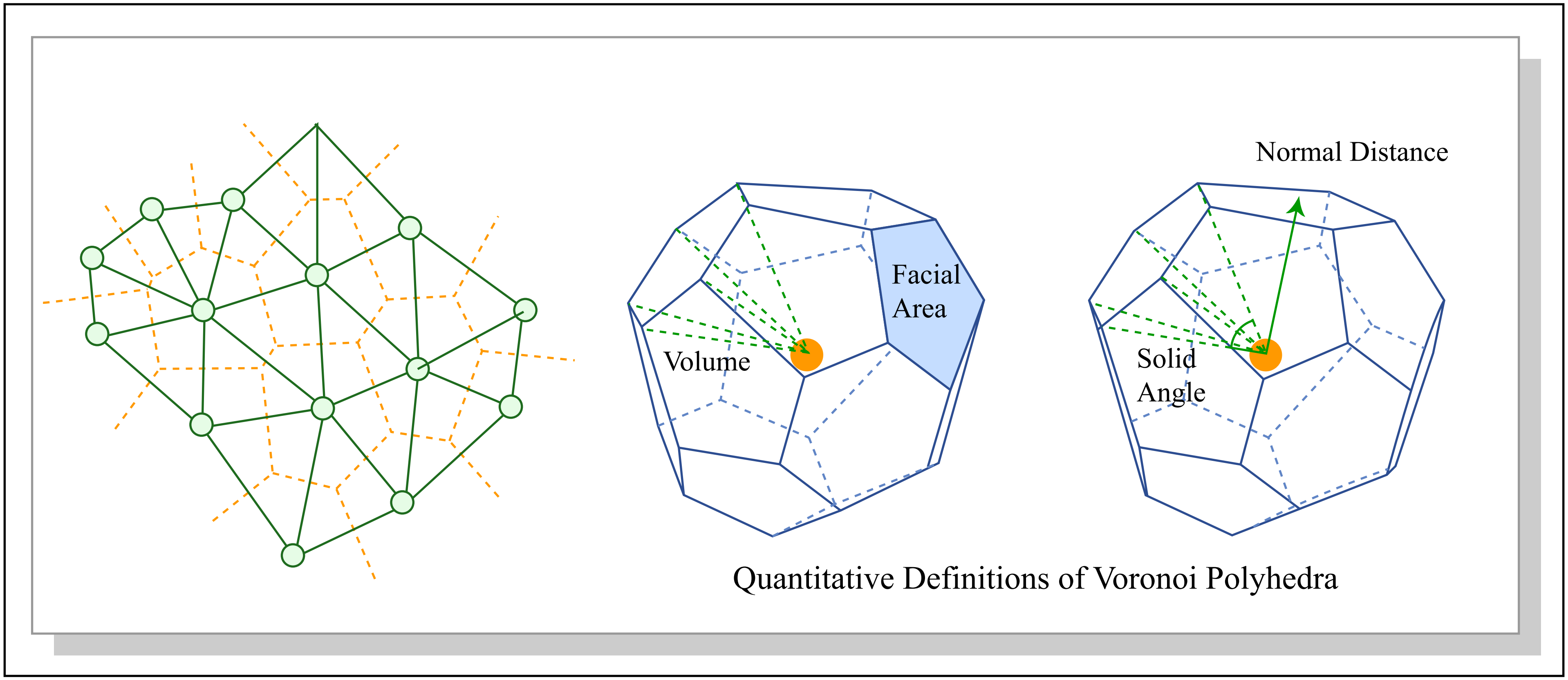

Figure by MIT OCW.

Mean Square Displacements

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