NON-CRYSTALLLINE 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

As Deposited (amorphous)  After Initialisation/erase (crystalline)  Written mark (amorphous)

Readout of data:
Difference in %R between amorphous & crystalline states
E.g. \( R_{\text{amorphous}} = 5\% \); \( R_{\text{cryst}} = 25\% \)
Delta \( R = 20\% \)

Figure by MIT OCW.

3.012 Fundamentals of Materials Science: Bonding - Nicola Marzari (MIT, Fall 2005)
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.
Erasure: nucleation and growth of crystalline material

NUCLEATION driven erasure

Growth driven erasure

Crystalline Background

Nucleation (and growth)

Written amorphous marks

Crystalline Background

Growth

Written amorphous marks

Figure by MIT OCW.

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Te-Sb-Ge Alloy

Nucleation dominated:
4.7 GB DVD-RAM
(Sb$_2$Te$_3$ 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?

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Photo courtesy of Ansgar Walk.
What do ice and silicon have in common?
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**Compression**

- Si(I) diamond $z=4$
- Si(II) β-tin $z=6$
- Si(XI) Imma $z=6$
- Si(V) hexagonal $z=8$
- Si(VI) orthorhombic $z=10$
- Si(VII) hcp $z=12$
- Si(X) fcc $z=12$

- 11 GPa
- 13 GPa
- 16 GPa
- 36 GPa
- 42 GPa
- 79 GPa

**Slow Pressure Release**

- Si(II) β-tin $z=6$
- Si(XII) R8 $z=4$
- Si(III) BC-8 $z=4$
- Si(IV) hex. diamond $z=4$

- 9 GPa
- 2 GPa
- >480 K

**Fast Pressure Release**

- Si(VIII) and Si(IX) tetragonal
What do ice and silicon have in common?

Figure by MIT OCW.
Phase transitions in silicon
Order Parameters for Silicon

\[ \mu = \frac{1}{N} \sum_{i} \theta_{i} \quad \sigma \left( \frac{1}{N} \sum_{i} \theta_{i}^{2} - \mu^{2} \right)^{\frac{1}{2}} \]

Before compression

During compression

P = 40 GPa

Pair correlation functions

Graphs of the pair-distribution functions for gas, liquid/gas, and monatomic crystal removed for copyright reasons.
Pair correlation function: water

Courtesy of Dr. J. Kolafa. Used with Permission.
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Pair correlation function: water
Count thy neighbours

Figure by MIT OCW.
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)

Quantitative Definitions of Voronoi Polyhedra

Figure by MIT OCW.
Mean Square Displacements
Mean Square Displacements
Mean Square Displacements