Homework 1 Solution
INEL 5209 - Solid State Devices - Spring 2012

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Problem 1.2

a) How many atoms are contain in the Si unit cell?
   ANSWER: Si crystallizes in the fcc structure, with 4 lattice points per cell, and have a two-atom basis, so there are 8 atoms in the unit cell.

b) How many Si atom are there per cm$^3$ at room temperature?
   ANSWER: The lattice constant is $5.43095 \times 10^{-10} m = 5.43095 \times 10^{-8} cm$, so the number of atoms per is cm$^3$ is
   \[ \frac{8}{(5.43095 \times 10^{-8})^3} = 4.994 \times 10^{22} \]

c) Determine the center-to-center distance between nearest neighbors in the Si lattice.
   ANSWER: $\sqrt{3 \times 5.43095 \times 10^{-8}} / 4 = 2.35167 \times 10^{-8} cm = 0.235 nm$. 

Determine the number of Nitrogen atoms per \( cm^3 \) for AlN at room temperature.

**ANSWER:** Number of N atoms per unit cell is 6. The volume of a unit cell can be found by multiplying its height and the area of the 6 triangles that form the base:

\[
4.9798\text{Å} \times 6 \times \frac{3.1115\text{Å}}{2} \times \sqrt{(3.1115\text{Å})^2 - \left(\frac{3.1115\text{Å}}{2}\right)^2}\text{Å} = 125.257\text{Å}^3
\]

So the answer is

\[
\frac{6}{125.257 \times 10^{-24} \text{cm}^3} = \frac{4.79 \times 10^{22} \text{atoms/cm}^3}{10^{24}} = 4.79 \times 10^{22} \text{atoms/cm}^3
\]
Problem 1.4a

a) Find the Miller index notation for the plane

\[
\left( \frac{1}{6}, \frac{1}{3}, \frac{1}{2} \right) \times 6 \rightarrow (1, 2, 3) \rightarrow \boxed{(123)}
\]
Problem 1.4b

b) Find the Miller indices for the plane shown.

\[
\left( \frac{1}{2}, \frac{1}{\infty}, \frac{1}{3} \right) \times 6 \rightarrow (3, 0, 2) \rightarrow (302)
\]
b) Given a hexagonal crystal structure, find the Miller-Bravais indices for the plane show.

\( a_3 \) bisects \( a_1 \) and \( a_2 \). An axis going in the \(-a_3\) direction will make \( \angle 60^\circ \) with \( a_1 \). Intercept in \( a_3 \) is

\[ \cos 60^\circ = \frac{1}{2}. \]

\[
\left( \frac{1}{1}, -\frac{2}{1}, \frac{1}{1}, \frac{1}{1} \right) \rightarrow (\bar{1}211)
\]
Problem 1.5

Find the Miller indexes for

a) a plane passing through ABC?

\[ \left( \frac{1}{1}, \frac{1}{1}, \frac{1}{1}, \frac{1}{1} \right) \rightarrow (110) \]

b) a plane passing through BCD?

\[ \left( \frac{1}{\infty}, \frac{1}{1}, \frac{1}{1}, \frac{1}{1} \right) \rightarrow (011) \]

c) a vector passing through D?

\[ \left( \frac{1}{\infty}, \frac{1}{1}, \frac{1}{1}, \frac{1}{1} \right) \rightarrow [011] \]

d) a vector passing through E?

\[ \left( \frac{1}{1}, \frac{1}{1}, \frac{1}{1}, \frac{1}{1} \right) \rightarrow [111] \]
A Si wafer will brake apart along [111] planes if sufficient stress is applied to the surface.
a) Find the angles between the normal to the top and and the [111] planes.

\[
\cos \theta = \pm \frac{1 \times 1 + 0 \times 1 + 0 \times 1}{\sqrt{3}} = \pm \frac{1}{\sqrt{3}} \rightarrow \theta = 54.7^\circ, 125.3^\circ
\]
b) If enough pressure is applied at a point, in how many pieces will the wafer break?

Since there are four planes that are equivalent to (111), in four pieces.
c) If the wafer breaks along the (111) plane, how will the broken plane be oriented with respect to the primary wafer flat?

Primary wafer flat plane is (011), and intercepts the (111) plane at an angle

\[
\cos \theta = \frac{0 \times 1 + 1 \times 1 + 1 \times 1}{\sqrt{2} \sqrt{3}} = 35.3^\circ
\]