What is Condensed Matter Physics?

Can we manipulate materials?

Can we design new materials?

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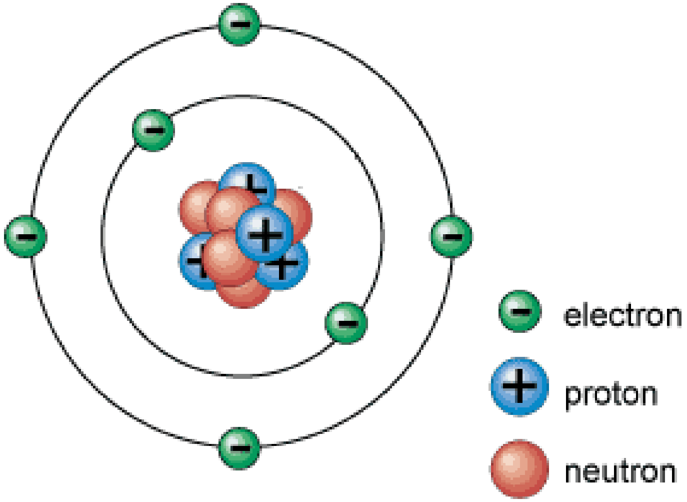
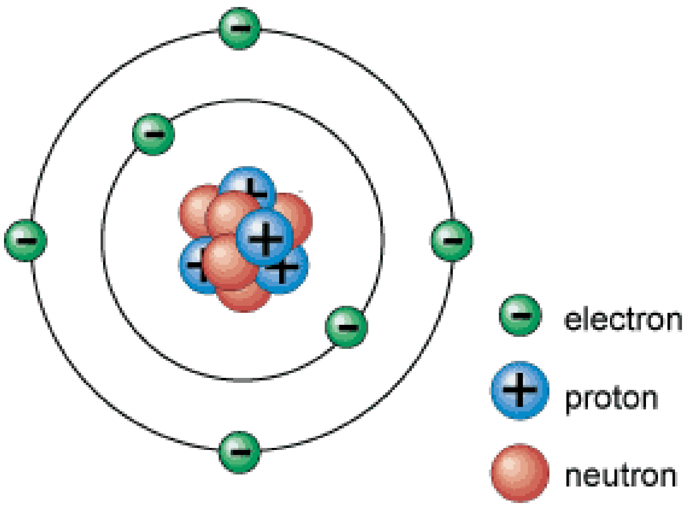
FSU Physics Department

The Building Blocks: Atoms

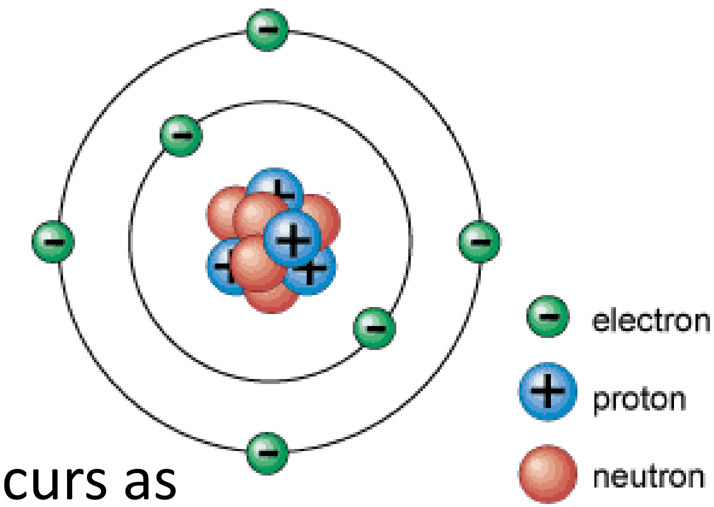


Translational and rotational invariance

The Building Blocks: Atoms



Translational and rotational invariance



Interaction is a kind of action that occurs as two or more objects have an effect upon one another.

Emergent properties

According to Wikipedia:

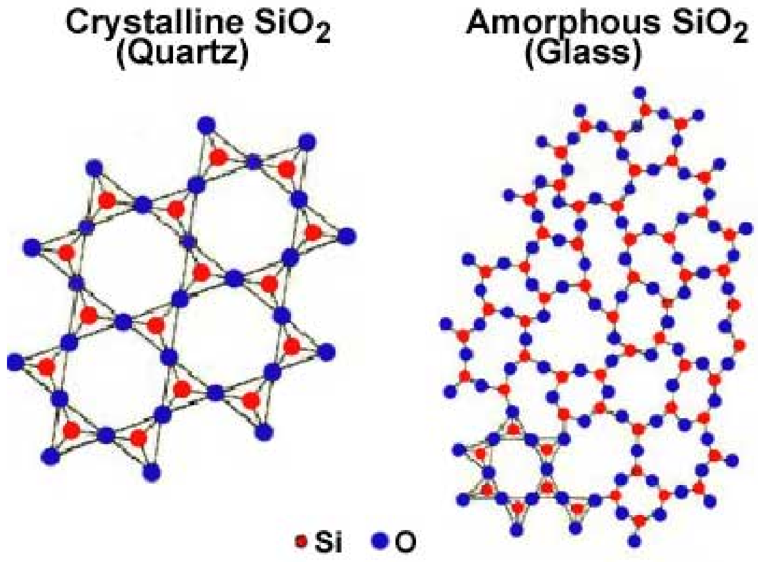
"Condensed matter physics is the field of physics that deals with the macroscopic and microscopic physical properties of matter. In particular, it is concerned with the "condensed" phases that appear whenever the number of constituents in a system is ***extremely large*** *and the* ***interactions*** *between the constituents are* ***strong****. The most familiar examples of condensed phases are solids and liquids, which arise from the electromagnetic forces between atoms*. "

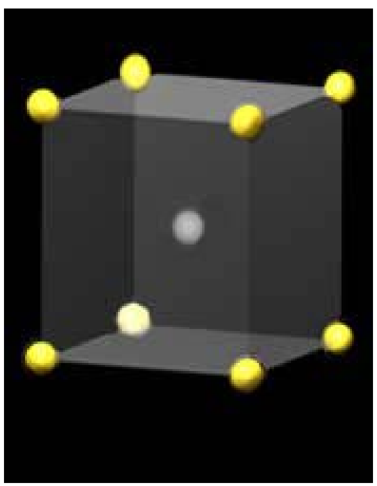
Why do we study it?

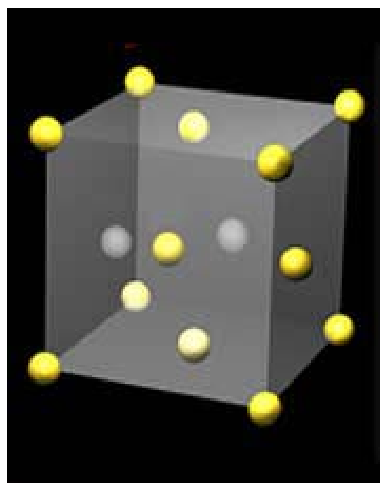
Interactions → complexity

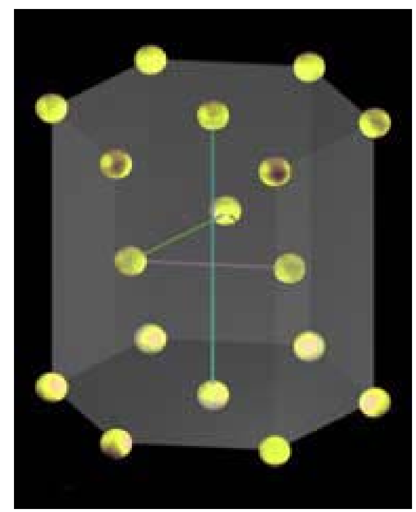
Complexity → functionality

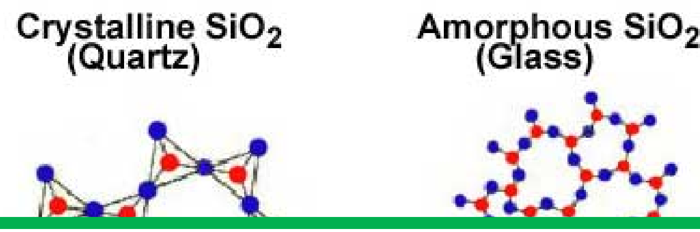
Crystalline Materials











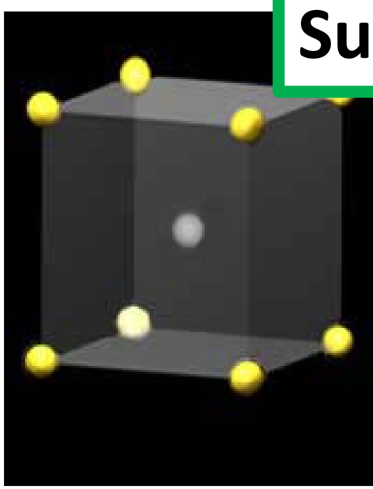
Structure:

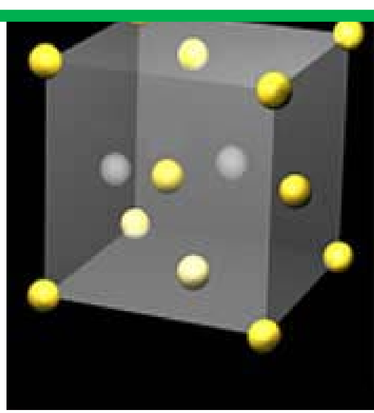
Optical properties

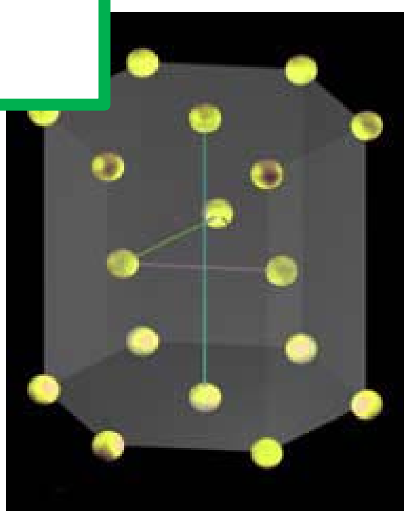
Magnetism

Conductivity

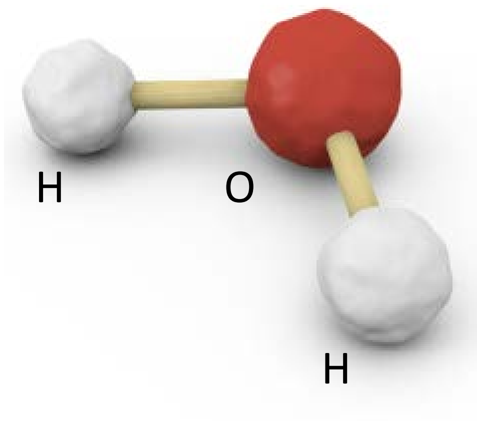
Superconductivity

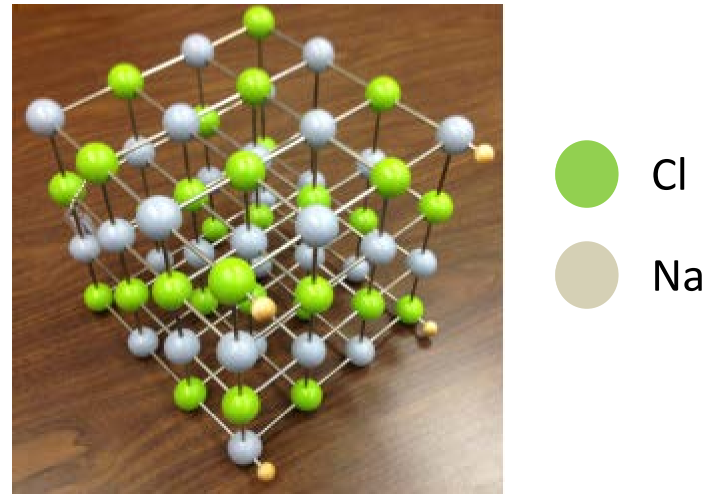






Structure and Symmetry

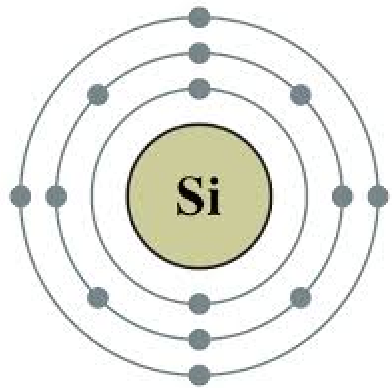


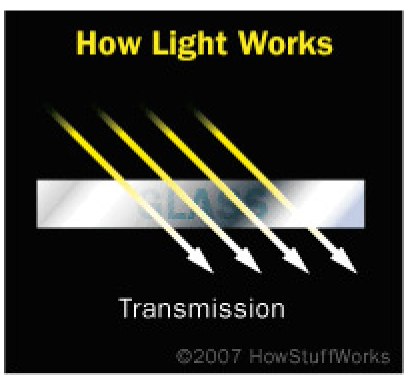


Structure and Optical Properties

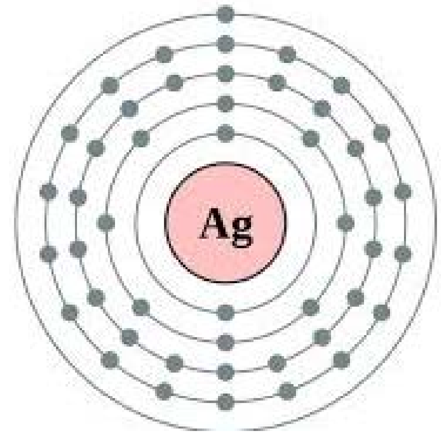
Why is glass transparent?

Glass = amorphous solid





Why are metals shiny?



It is ubiquitous

It is useful, we can use it to explain processes and objects that surround us

The knowledge from research and discovery are used to improve our everyday lives.

Can we Manipulate Materials?

NATIONAL HIGH MAGNETIC FIELD LABORATORY

The "Iceman" Lived at the Transition from Neolithic Age to Copper Age

The Iceman's Axe

At the top of the carefully smoothed **yew** haft
is a forked shaft into which the 9.5 cm blade was fixed
with **birch tar** and tightly bound with thin **leather straps**.
The blade is made of almost pure **copper**. The narrow end was produced by cold-hammering after the blade was cast.

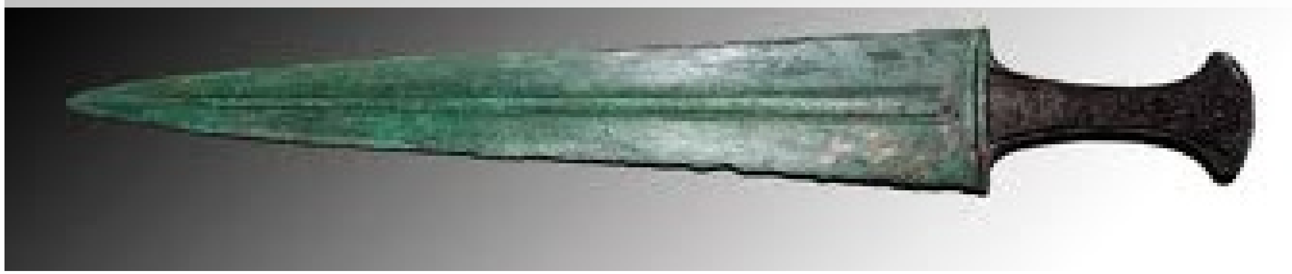
ALL OF THESE MATERIALS ARE FOUND MATERIALS

3300 B.C.E.

Human Invention of Materials begins

The Bronze Age (c. 3000 BCE – c. 1200BCE)

Bronze = Copper + 10% Tin **Required long-distance trade routes**



From Saphar-Kharaba Late Bronze Age Cemetery (c. 1300 BCE)
in Southern Georgia ***(The country, not the state)***

Iron Age (c. 1200 BCE – 400 AD)

From Tutankhamun's Tomb (c. 1323 BCE)

NATIONAL HIGH MAGNETIC FIELD LABORATORY

Human Invention of Materials for Aesthetic Reasons (700 BCE – 200 AD)

Han Purple: the first synthetic purple pigment. Likely made from a mix of barium and copper minerals, quartz, and a lead salt as an extra ingredient that acts as a catalyst and flux. The mixture needed to be heated to between 900 and 1000 C – any hotter and Han blue results, which is closely related to Egyptian blue ($CaCuSi_4O_{10}$), the oldest known synthetic pigment in the world.

Calcite - $CaCO_3$
Bone White - $Ca_5(CO_3)_2(OH)_2$
White Lead – $2Pb(CO_3)_2 \cdot Pb(OH)_2$

Soot - carbon black

Han Purple* - $BaCuSi_2O_6$**
***** human-made pigment**

Cinnabar - HgS
Hematite - Fe_2O_3
Red Lead – Pb_3O_4

Malachite – $Cu_2CO_3(OH)_2$

Han Blue* – $BaCuSi_4O_{10}$**
***** human-made pigment**

Materials Limitations in the 20th century

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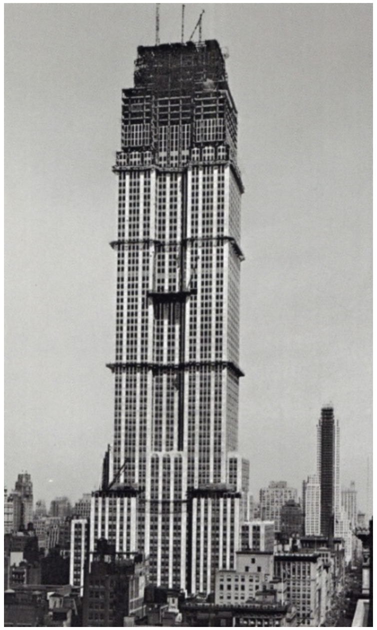
Limitation of the then State-of-the-Art Material…
CAST IRON

Cast iron building architecture reaches six stories

…Cast Iron can build Soho

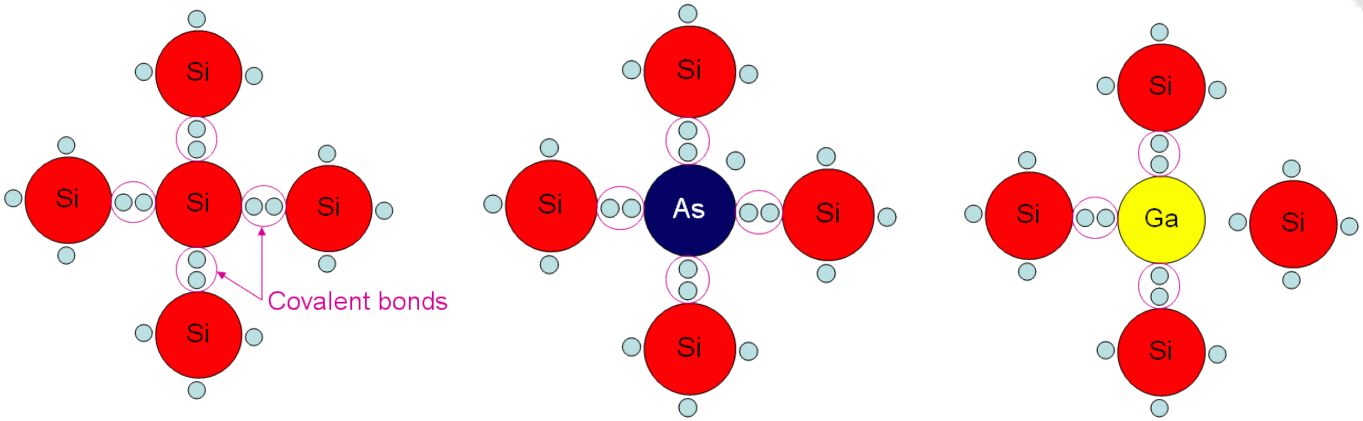
It takes STEEL to build Midtown



Research and development to improve steel continues at the MagLab

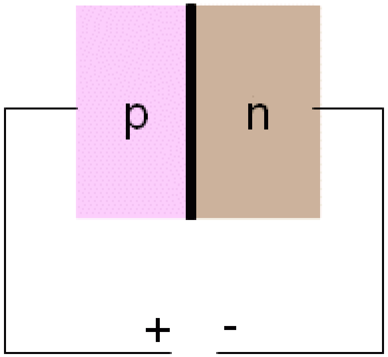
Semiconductors: (20th and 21st c.)

Doping: semiconductors to control electrical properties



n-type

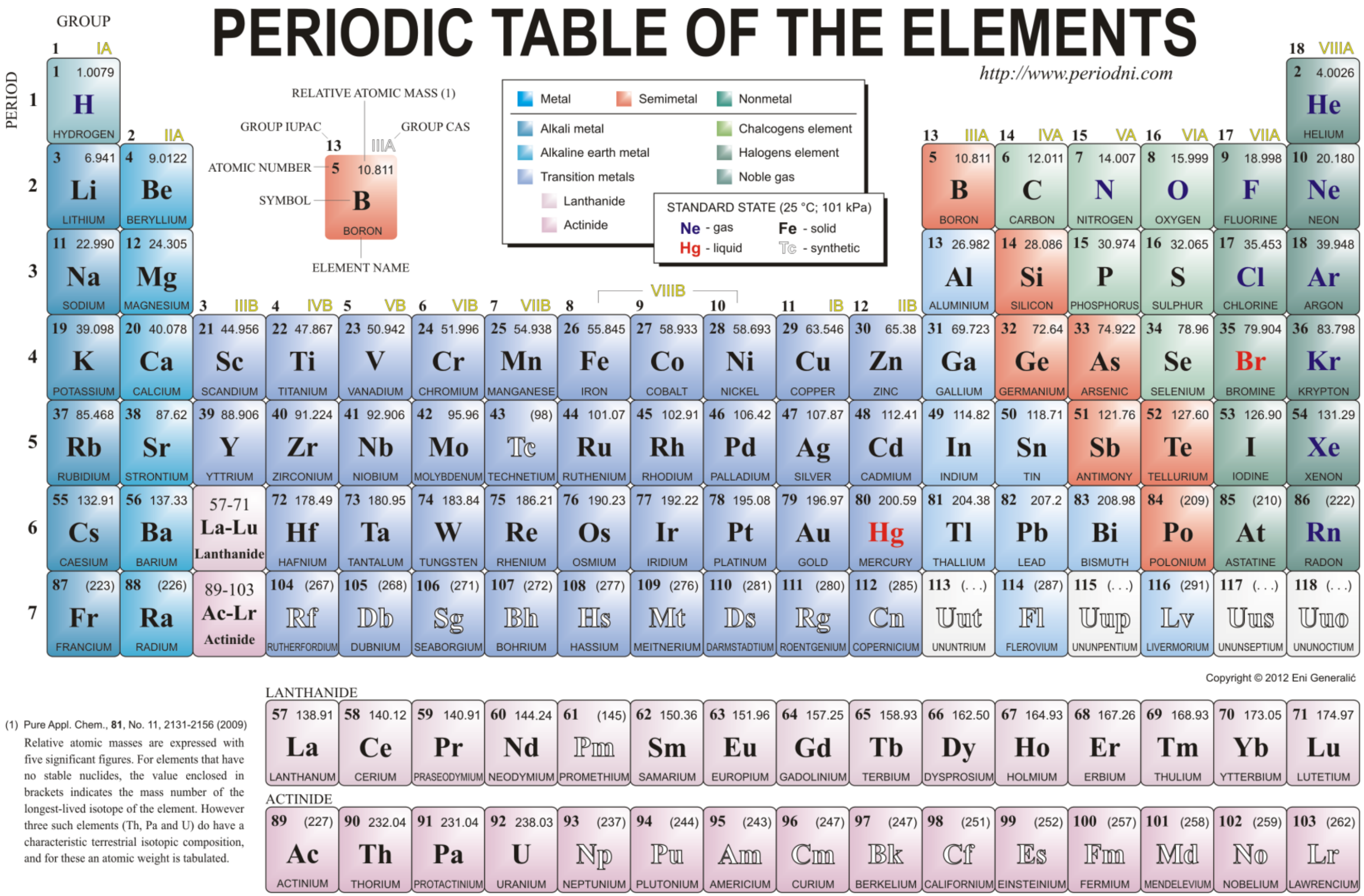
p-type



Diode, Transistors → iphones etc.

Whenever you put different atoms together interesting properties emerge

Can we Design New Materials?



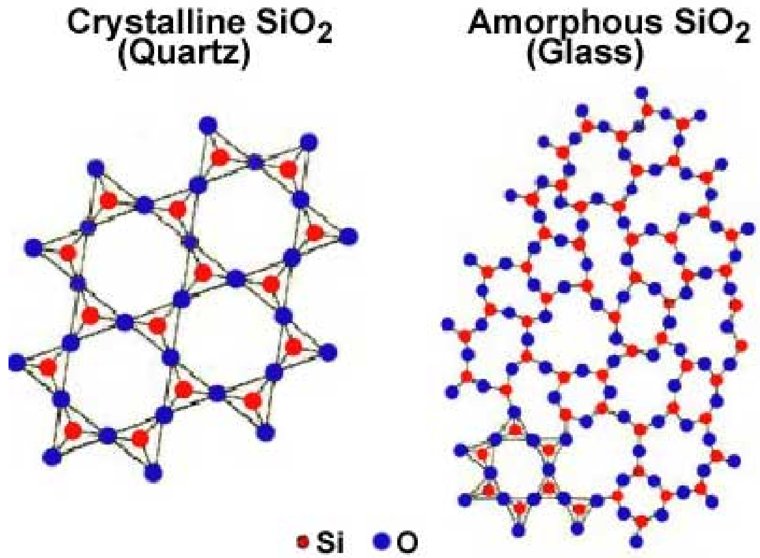
Ways to Manipulate the Lattice

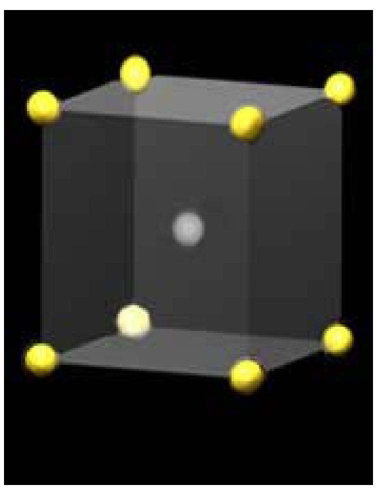
Doping and impurities

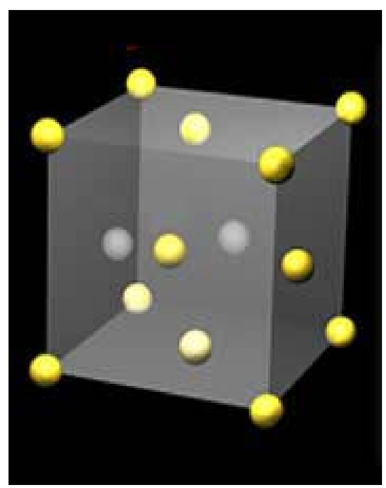
External perturbations: temperature and applied fields

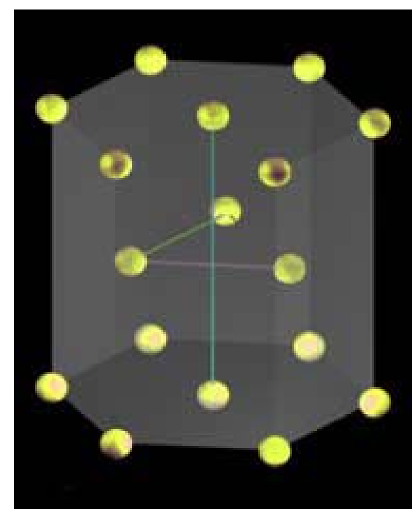
External pressure: hydrostatic and strain

Unit Cell

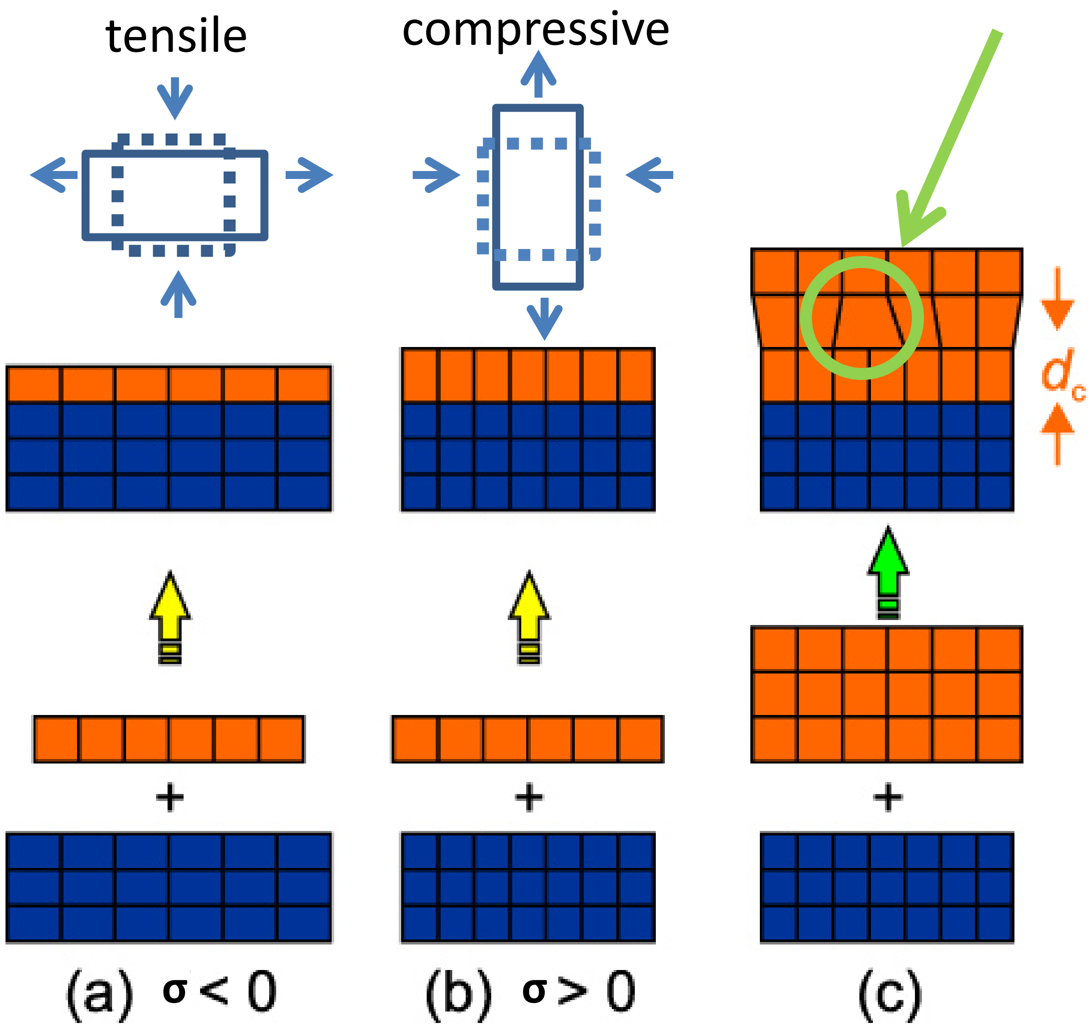




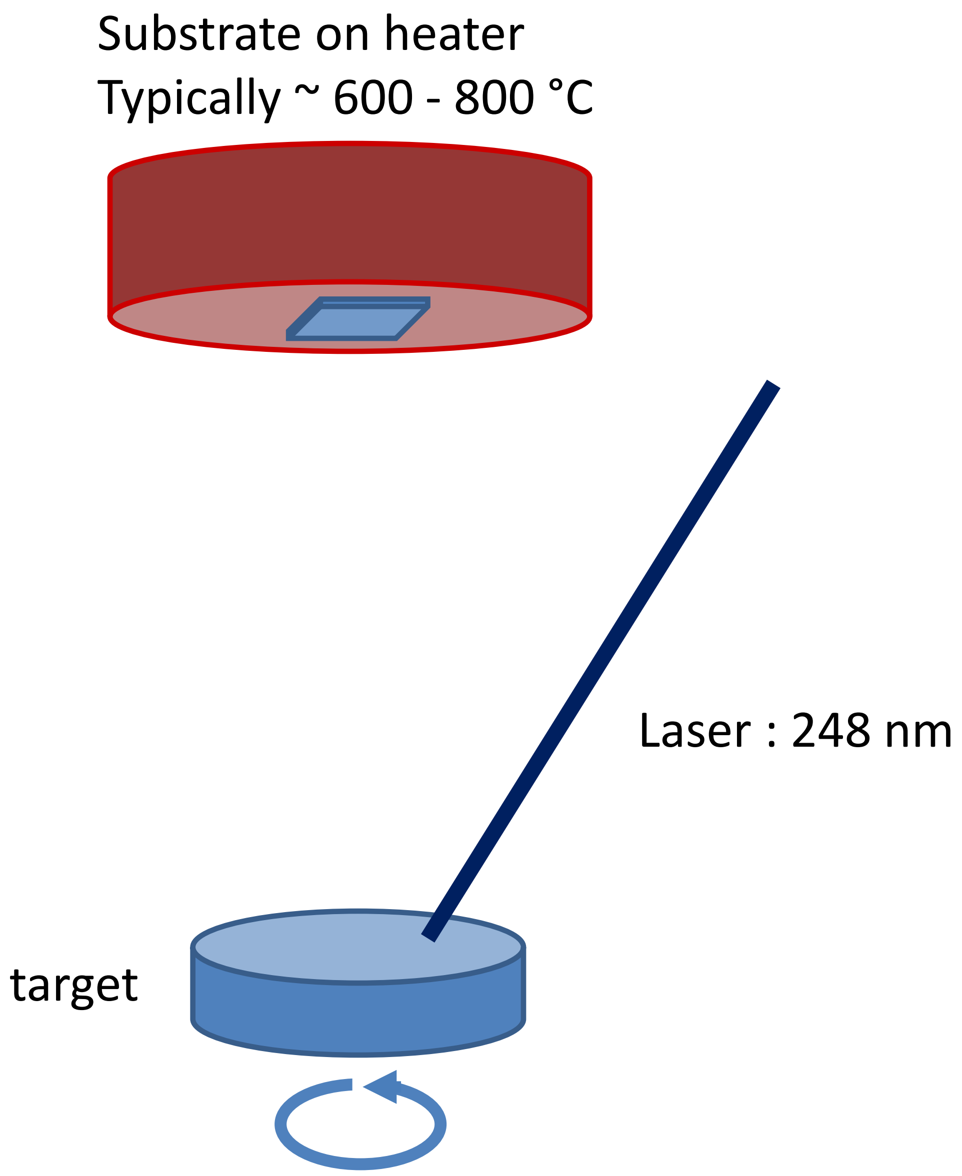




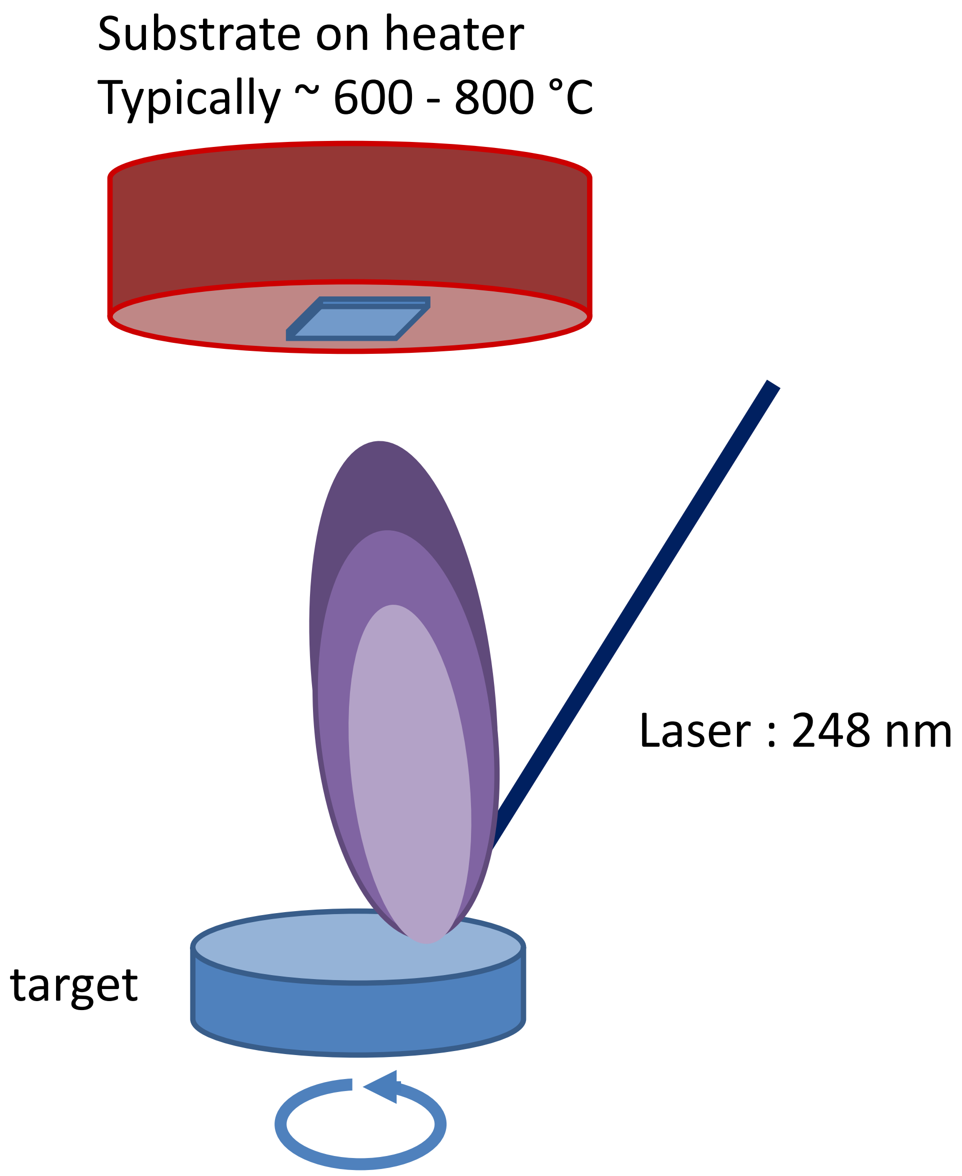
Thin Films Growth: Epitaxial Strain



How do we make thin films?



How do we make Materials?



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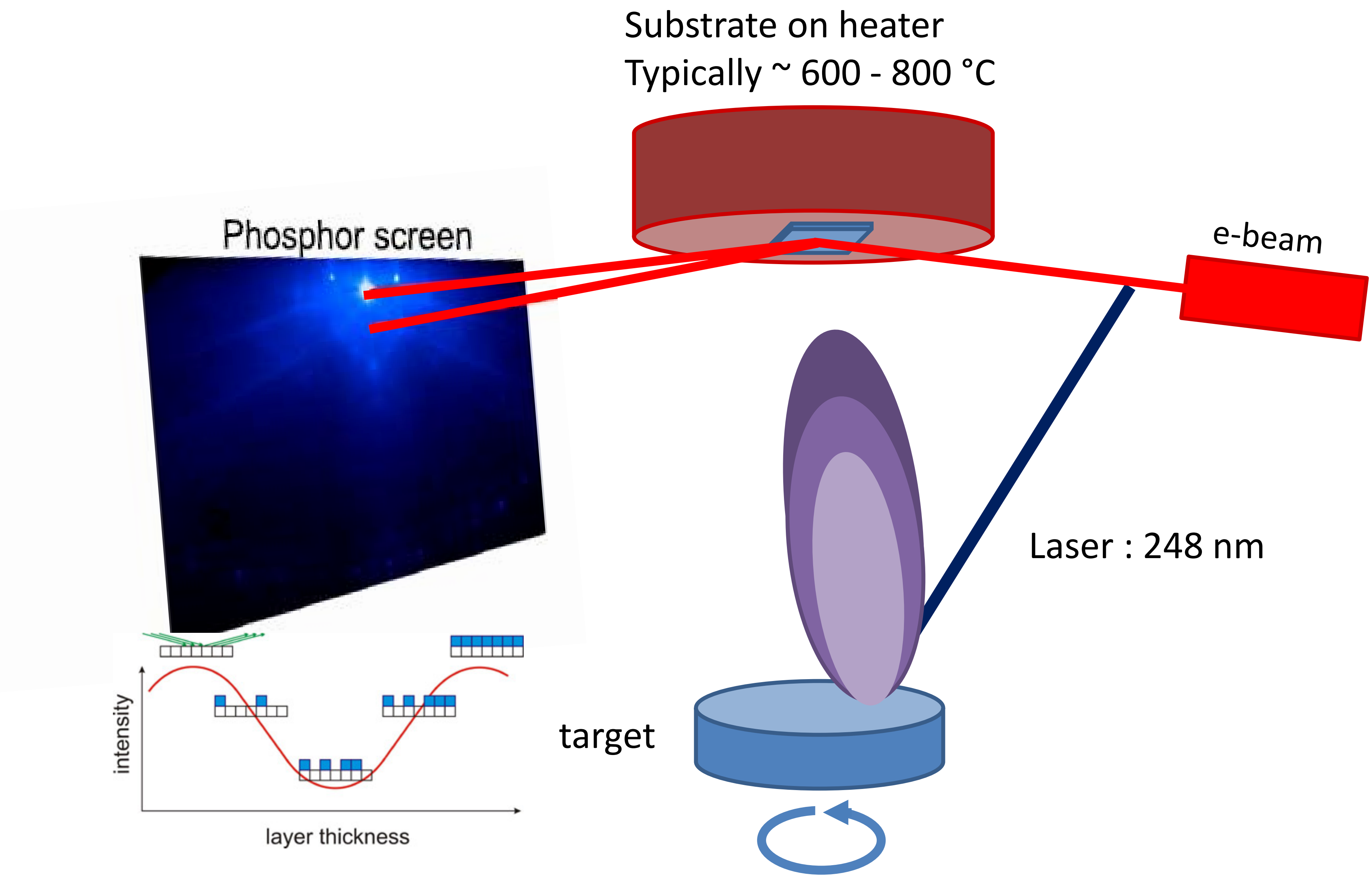
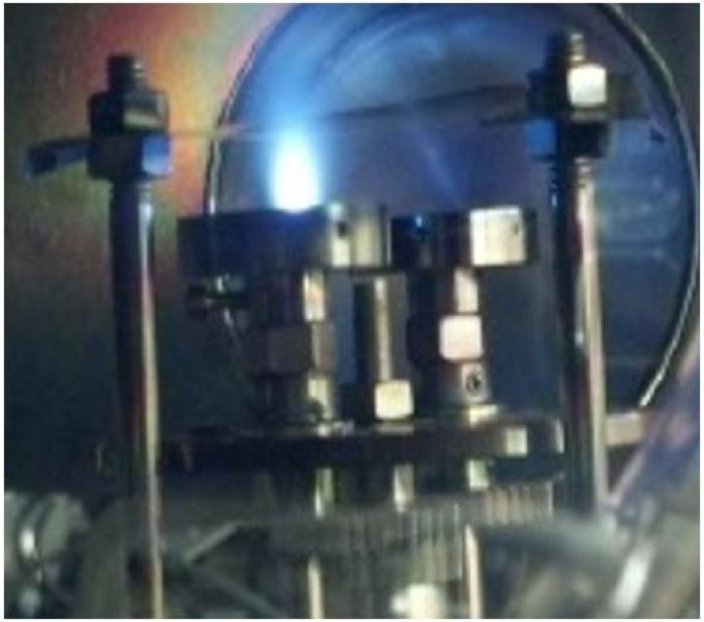
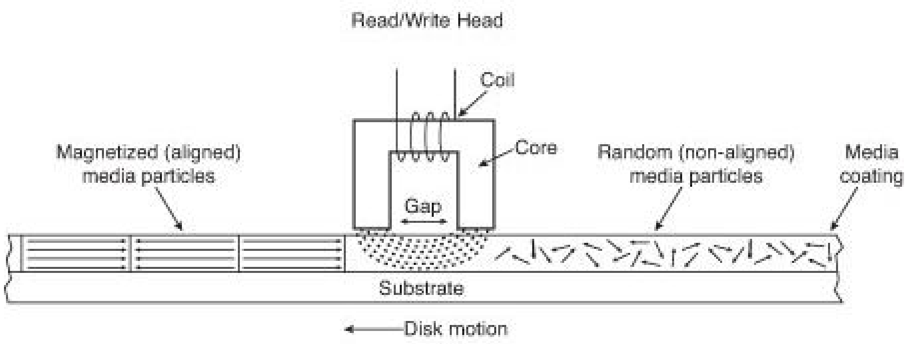


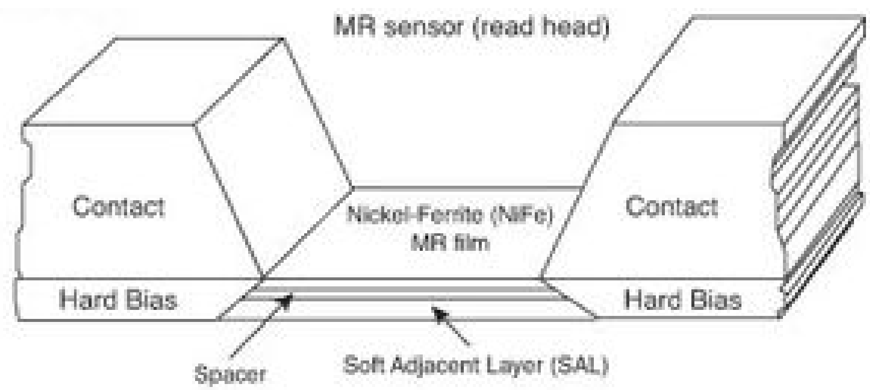
Thin Film Growth: Pulsed Laser Deposition Setup



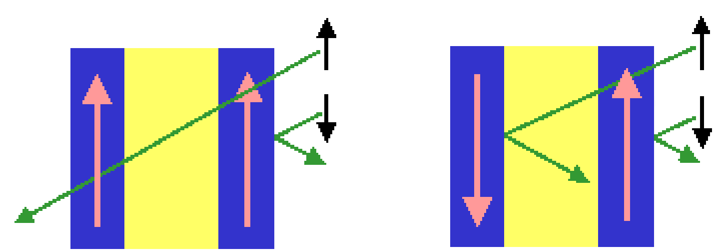
Thin Films: Applications



Older Hard drive
Locally change magnetization in a magnetic particles through applied magnetic field. Basically an electromagnet



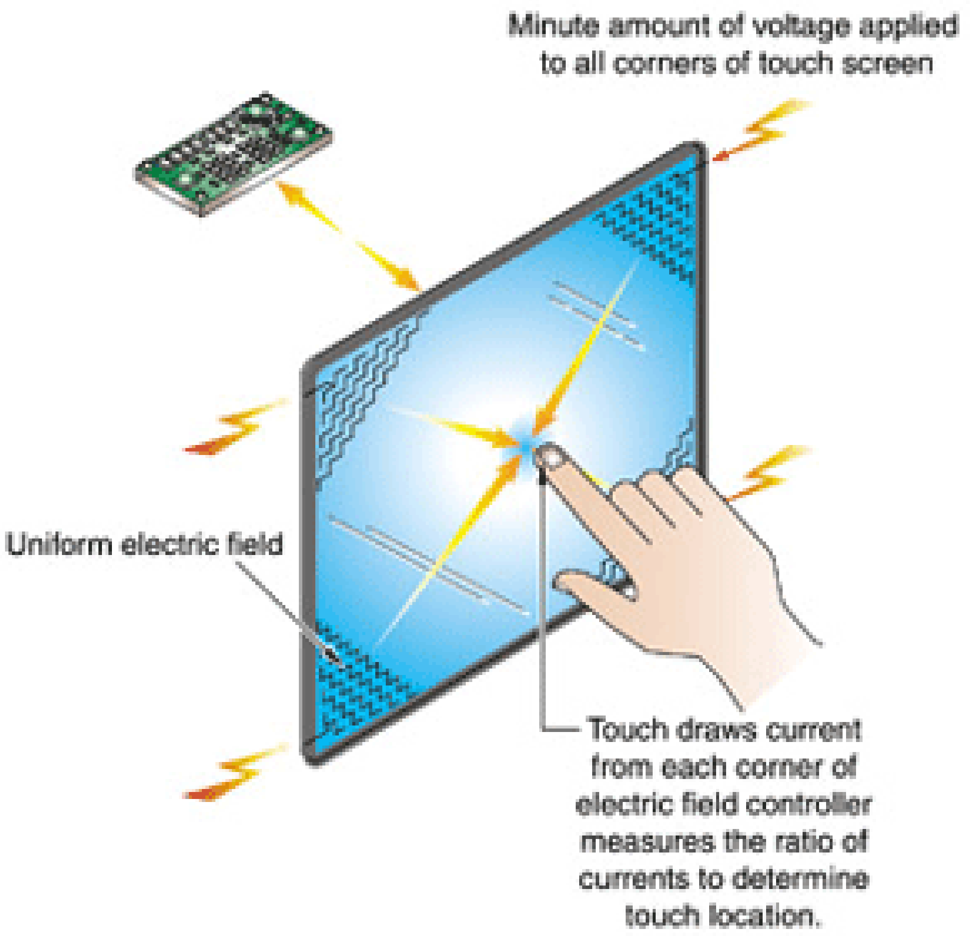
GMR Hard drive
Much more expensive to fabricate but much more sensitive and higher density



Thin Films: Applications

Touchscreen

Indium Tin Oxide is transparent like glass but is also conductive. Oxygen stoichiometry determines the conductivity. Basically n-type semiconductor.



Future

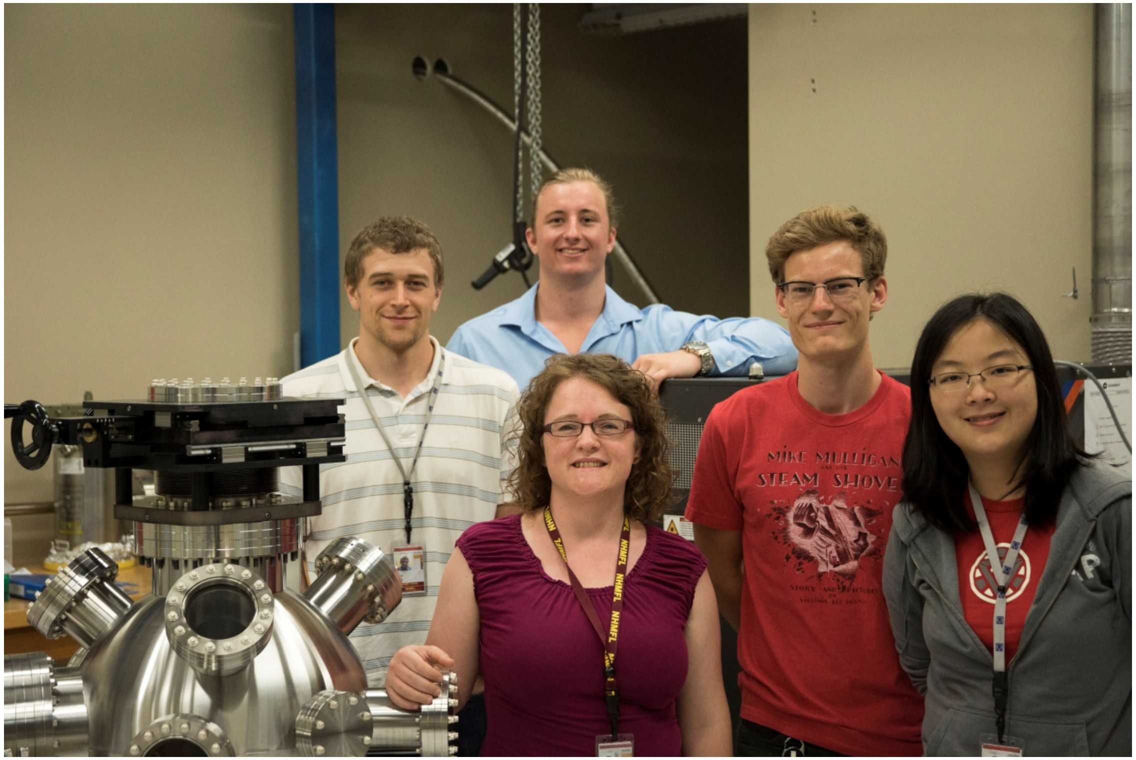
Investigate the effect of doping and impurities

Apply Strain to materials that have never been grown in thin film form

External perturbations: temperature and applied fields

Expand our knowledge about the Physics of materials

My Group



We are constantly making new materials and pushing the boundaries of condensed mater physics