Solids and Its Classification

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Matter

Subdivisions-

in terms of Fluidity- • Fluids • Solids

in terms of Condensation- • Gaseous • Condensed – Solids and Fluids

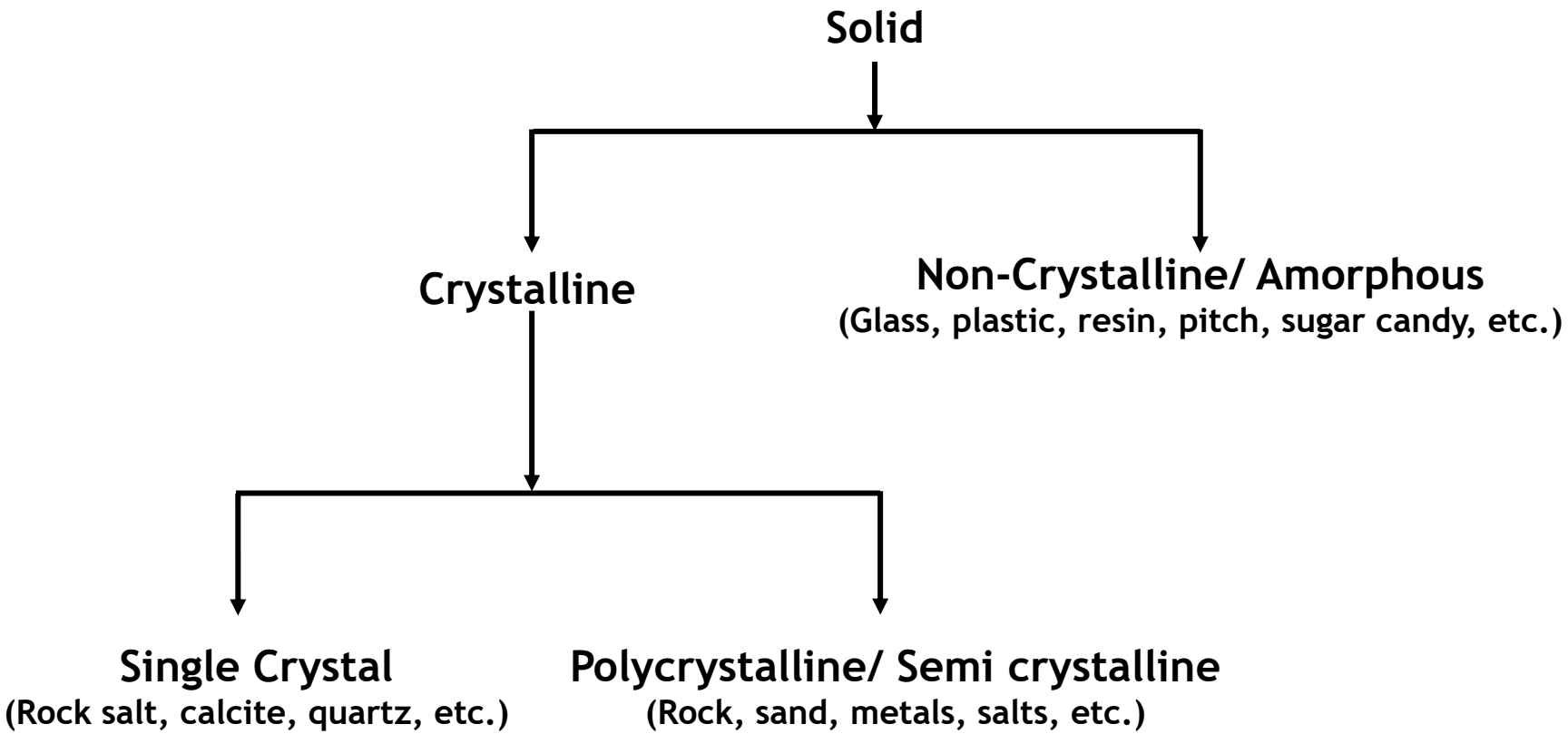
3 Stable States of Matter-

• Solid • Liquid • Gas

❖ Solid only has definite structure.

❖ Solid is known as the super cooled state of matter.

Classification of Solid



Crystalline Solid

A solid in general is said to be a crystal if the constituent particles (atoms, ions or molecules) are arranged in a three dimensional periodic manner or simply it has a reticular or granular structure.

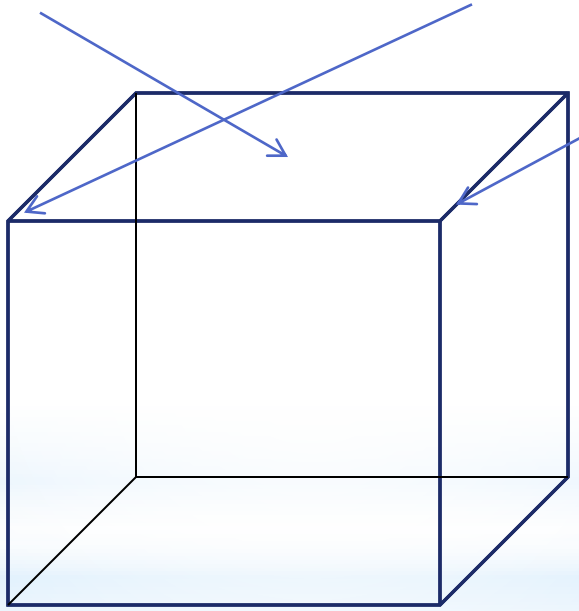
Properties

- **In crystalline solids the atoms are stacked in a regular manner, forming a repetitive 3D pattern.**
- **It has long-range order and sharp melting point.**
- **When the crystal grows under constant environment, the external geometrical shape of the crystal often remains unchanged as a consequence of the internal arrangement of constituent particles.**
- **Crystals are bounded by optically plane faces , sharp- straight edges and interfacial angles.**

For a crystal we can write the relation,

$$f + c = e + 2$$

f = No. of faces, c = No. of corners, e = No. of edges



For a cube

f = 6

c = 8

e =12

Steno's law

"The angles between two corresponding faces on the crystals of any solid chemical or mineral species are constant and are characteristic of the species; this angle is measured between lines drawn perpendicular to each face."

The law, also called the law of constancy of interfacial angles, holds for any two crystals, regardless of size, locality of occurrence, or whether they are natural or man-made.

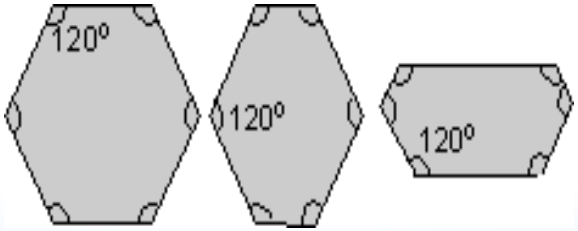


Fig: Constancy of interfacial angles

Single crystal

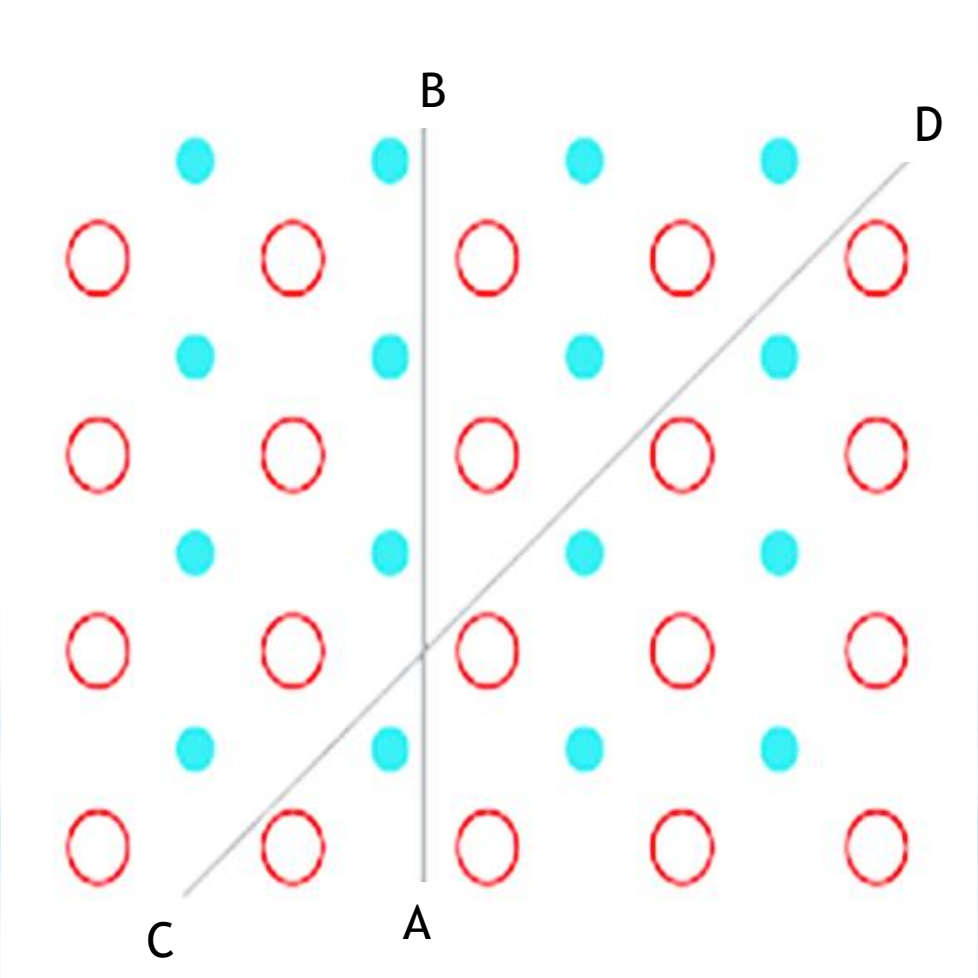
When the periodicity in crystal pattern extends throughout a certain piece of materials, it is said to be a single crystal or unit crystal or mono-crystal.

Figure 1: Single crystals of various shapes and materials.

Properties

- Arranged in reticular pattern (no grain boundaries).
- Exhibit anisotropy of physical properties.
- Have very fewer defects.
- Have the consistency of chemical composition.
- No optical absorption/ scattering effects / no trapping of conduction electrons.
- They have sharp melting points.

Anisotropy in crystal is due to different arrangement of particles along different directions



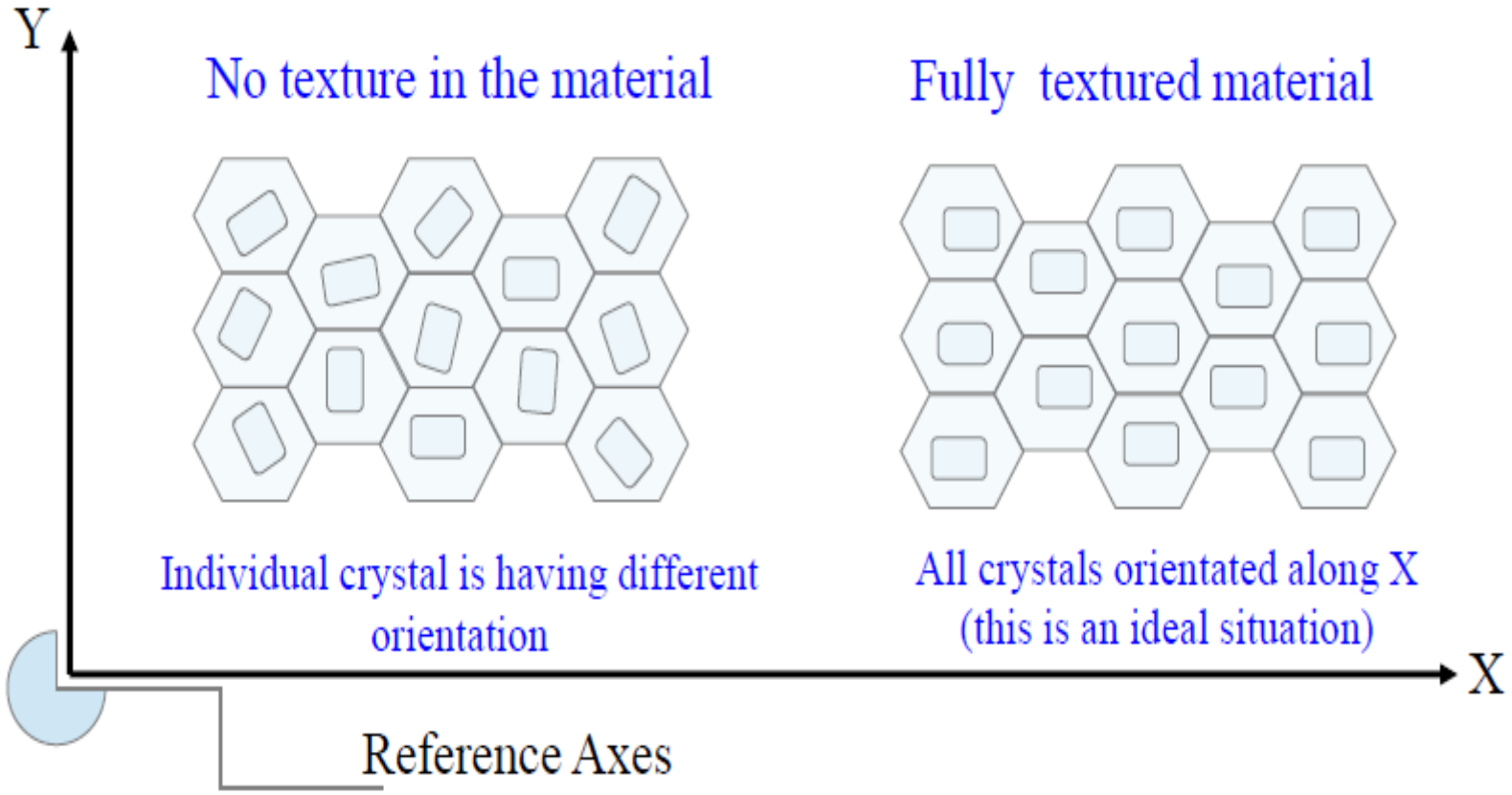
Polycrystalline solids

When the periodicity in the crystal structure is interrupted at so called grain boundaries, the crystal is said to be polycrystalline.

Properties

- Granular in arrangements.
- Grains are grown in the form of interlocking masses separated by grain boundaries.
- Show isotropy of physical properties.
- They are irregular in shape.
- Textured- if majority grains have same orientation and non-textured if fully random grains.

❖ **Texture** is the distribution of crystallographic orientations of a polycrystalline sample.



Anisotropy and Isotropy

- In a single crystal, the physical and mechanical properties often differ with orientation. When the properties of a material vary with different crystallographic orientations, the material is said to be **anisotropic**.

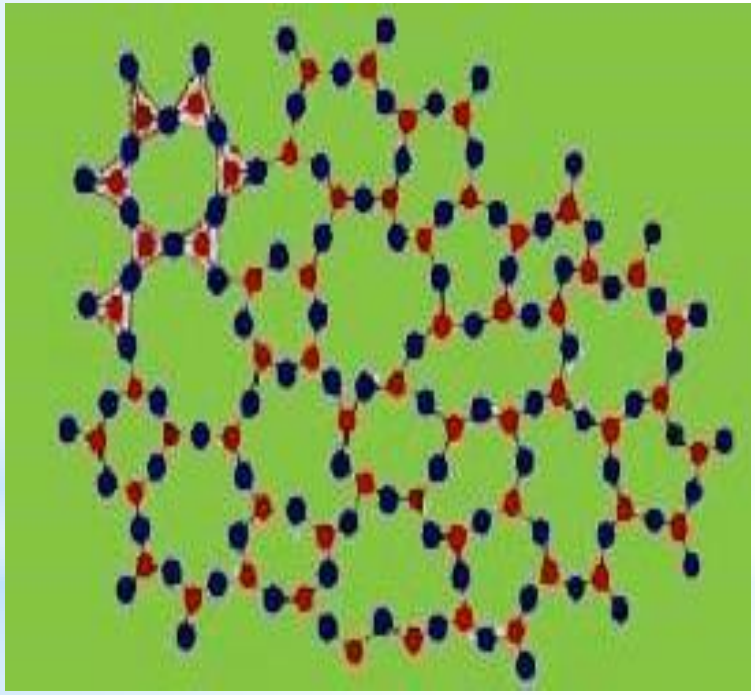
- Alternately, when the properties of a material are the same in all directions, the material is said to be **isotropic**.

- For many polycrystalline materials, the grain orientations are random (non-textured) before deformation of the material is done. Therefore, even if the individual grains are anisotropic, the property differences tend to average out and, overall, the material is isotropic.

- When a material is formed, the grains are usually distorted and elongated in one or more directions which makes the material anisotropic.

Non-crystalline solids

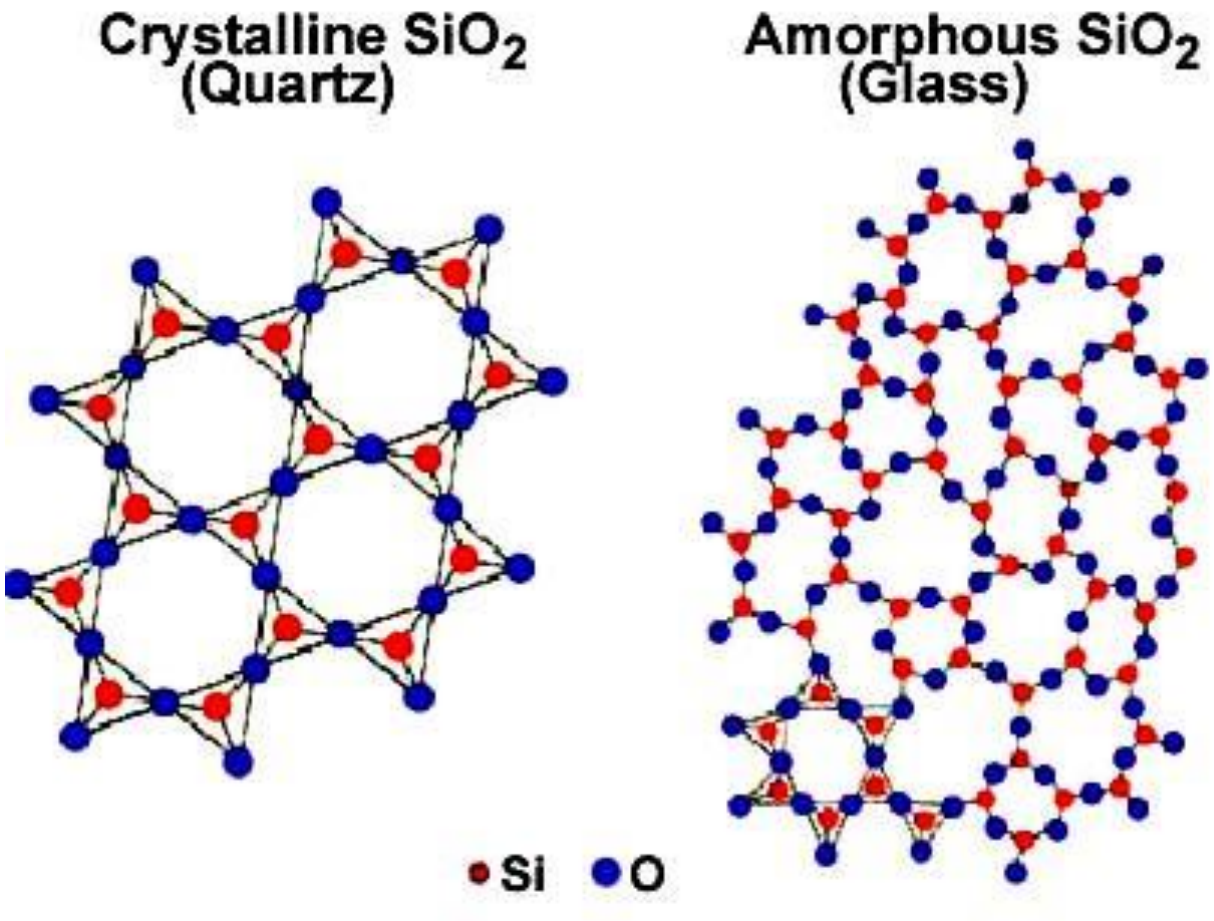
A solid which is an opposite extreme of single crystal, follows neither reticular nor granular structure, where there is a lack of symmetric arrangement of atoms and size of grains are comparable to the pattern unit is known as a non-crystalline solid.



Properties

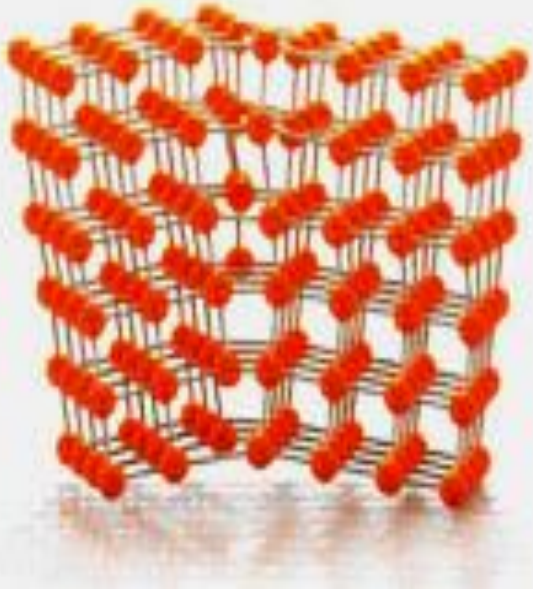
- No definite melting points.
- Becomes gradually soft when temperature is raised.
- No long-range order but may have some short-range order.
- Non-crystalline solids can be crystalline after heat treatment.

Property	Crystalline solids	Amorphous solids
Shape	Definite characteristic geometrical shape	Irregular shape
Melting point	Melt at a sharp and characteristic temperature	Gradually soften over a range of temperature
Cleavage property	When cut with a sharp edged tool, they split into two pieces and the newly generated surfaces are plain and smooth	When cut with a sharp edged tool, they cut into two pieces with irregular surfaces
Heat of fusion	They have a definite and characteristic heat of fusion	They do not have definite heat of fusion
Anisotropy	Anisotropic in nature	Isotropic in nature
Nature	True solids	Pseudo solids or super cooled liquids
Order in arrangement of constituent particles	Long range order	Only short range order.


Crystalline SiO_2
(Quartz)
Amorphous SiO_2
(Glass)
Si
O

Crystalline

Polycrystalline

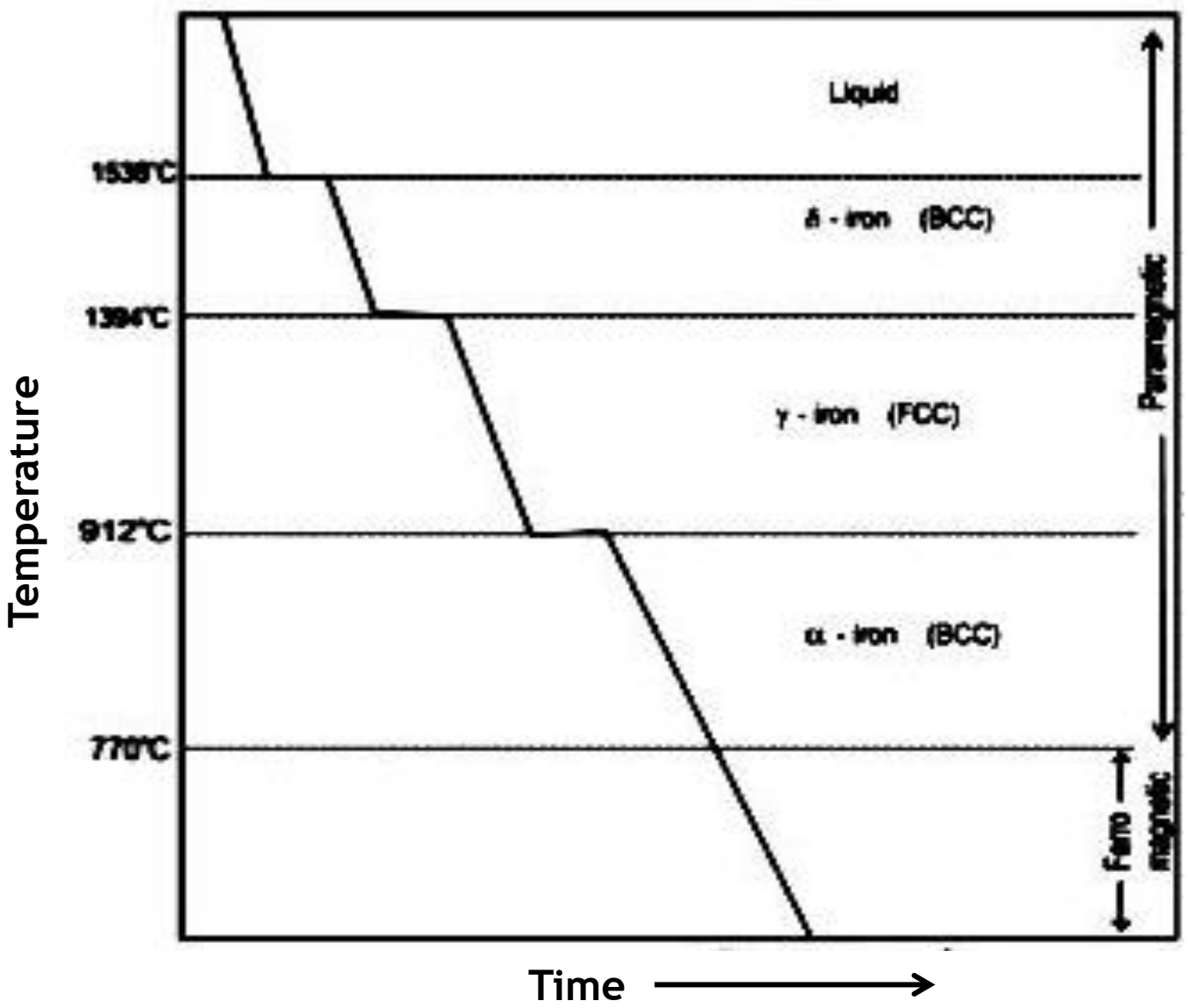


Non-Crystalline

Polymorphism

- Polymorphism refers to the ability of a solid to exist in more than one crystalline form or structure.
- Allotropy- elemental solids.
- Polymorphism can potentially be found in many crystalline materials including polymers, minerals, and metals.
- Ploymorphs of SiO_2: α-quartz, β-quartz, tridymite, cristobalite, coesite, and stishovite

Allotropes of Iron



Allotropes of Tin (Sn)

α-tin or gray tin

Diamond cubic
less than 13.2 °C
Brittle powder

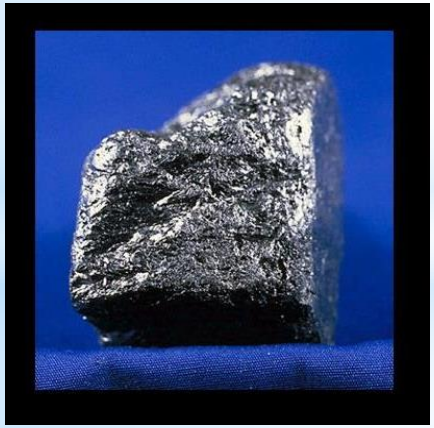
β- tin or white tin

"Tin disease"
1850, Russia

BCC
Compact
white solid

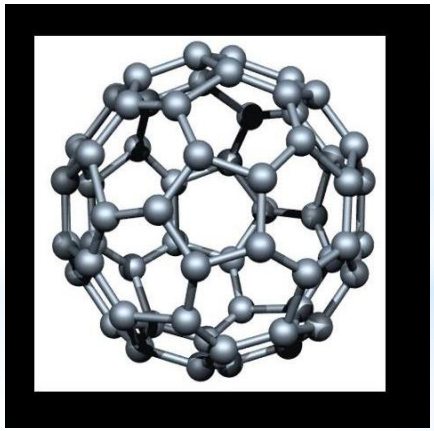
Allotropes of Carbon

Graphite

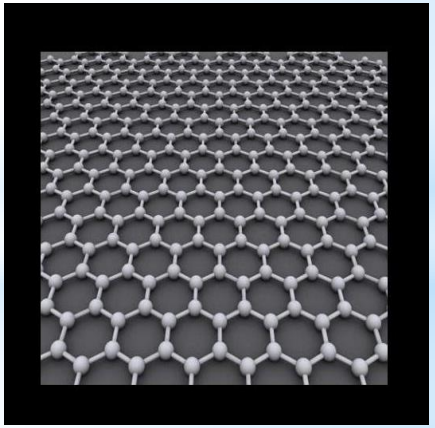


Diamond

Fullerene

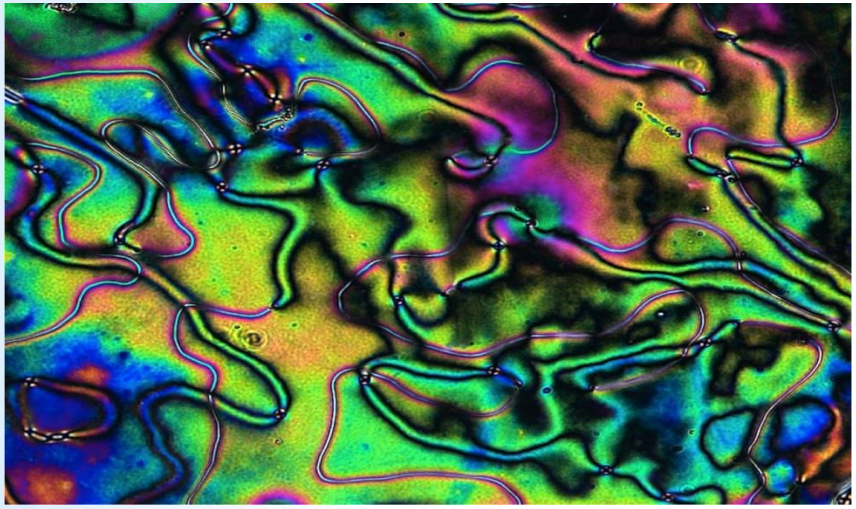


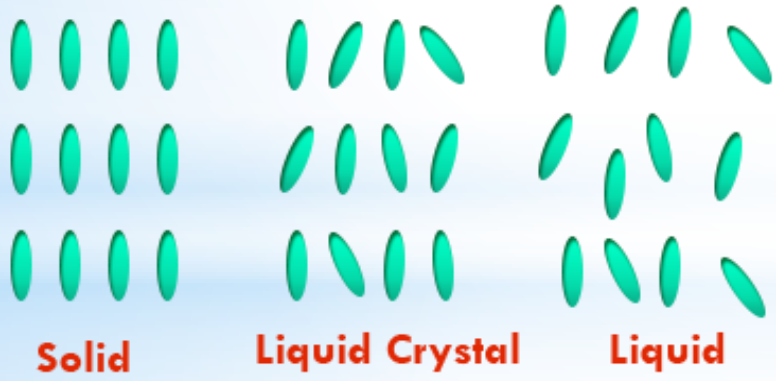
Graphene



2010 Nobel Prize in Physics→ A. Geim and K. Novoselov 2D graphene"

Liquid crystals





- A state of matter that have properties between those of a conventional liquid and those of a solid crystal.
- For instance, an LC may flow like a liquid, but its molecules may be oriented in a crystal-like way.
- There are many different types of LC phase which can be identified by a microscope using a polarized light source.
- Example: Ammonium oleate, proteins, cell membranes, soap and detergents, tobacco mosaic virus, etc.