Introduction to texture and related phenomenon

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Suggested Textbooks:

1. M. Hatherly and W.B. Hutchinson, An Introduction to Textures in Metals

2. V. Randle and O. Engler, Introduction to Texture Analysis

3. F.J. Humphreys and M. Hatherly, Recrystallisation and Related Phenomenon

Course objectives

- **To learn about the arrangement of crystals in a polycrystalline material**

- **To learn how to represent polycrystal diffraction data in stereographic projection**

- **To learn the principles of texture measurements by X-ray, neutron and electron diffraction**

- **To learn three dimensional texture representation**

- **To know about different textures form as a result of deformation**

- **To know about different textures that form after annealing**

- **To know about texture formation during liquid-solid and solid-solid transfomation**

- **To know about the texture in thin films**

- **To know about texture in ceramics**

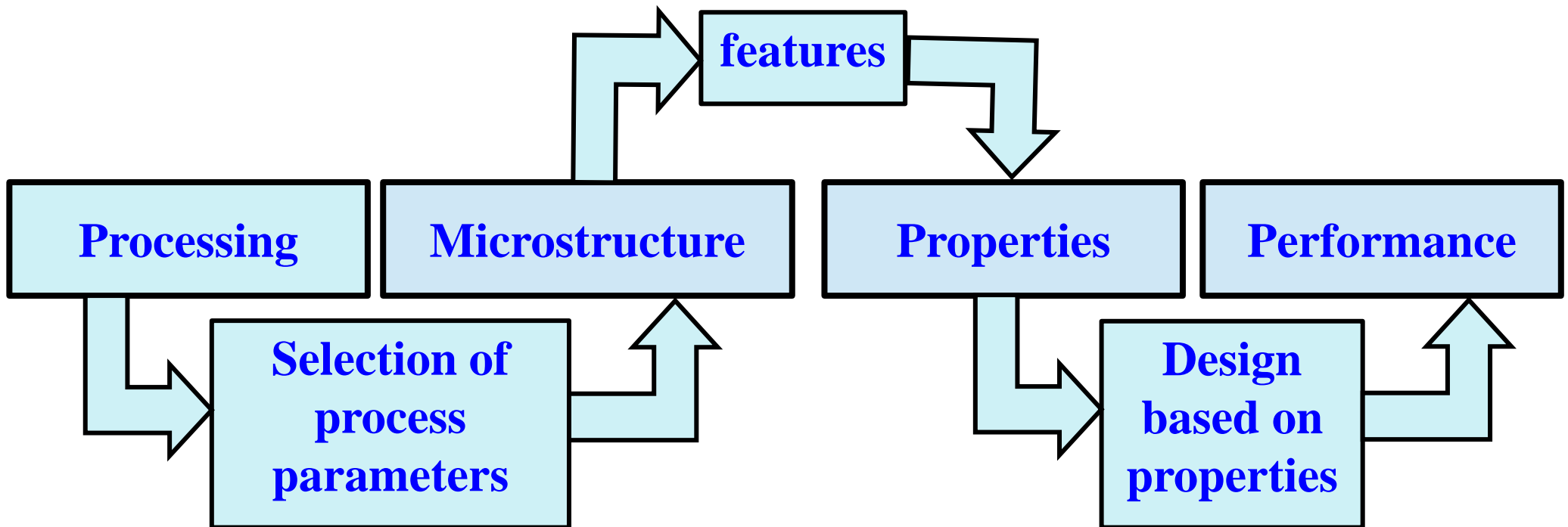- **To know about the dependence of properties on texture**

Introduction

Microstructure-Properties Relationship

Material tetrahedron: a representation of different stages of materials engineering leading to product design
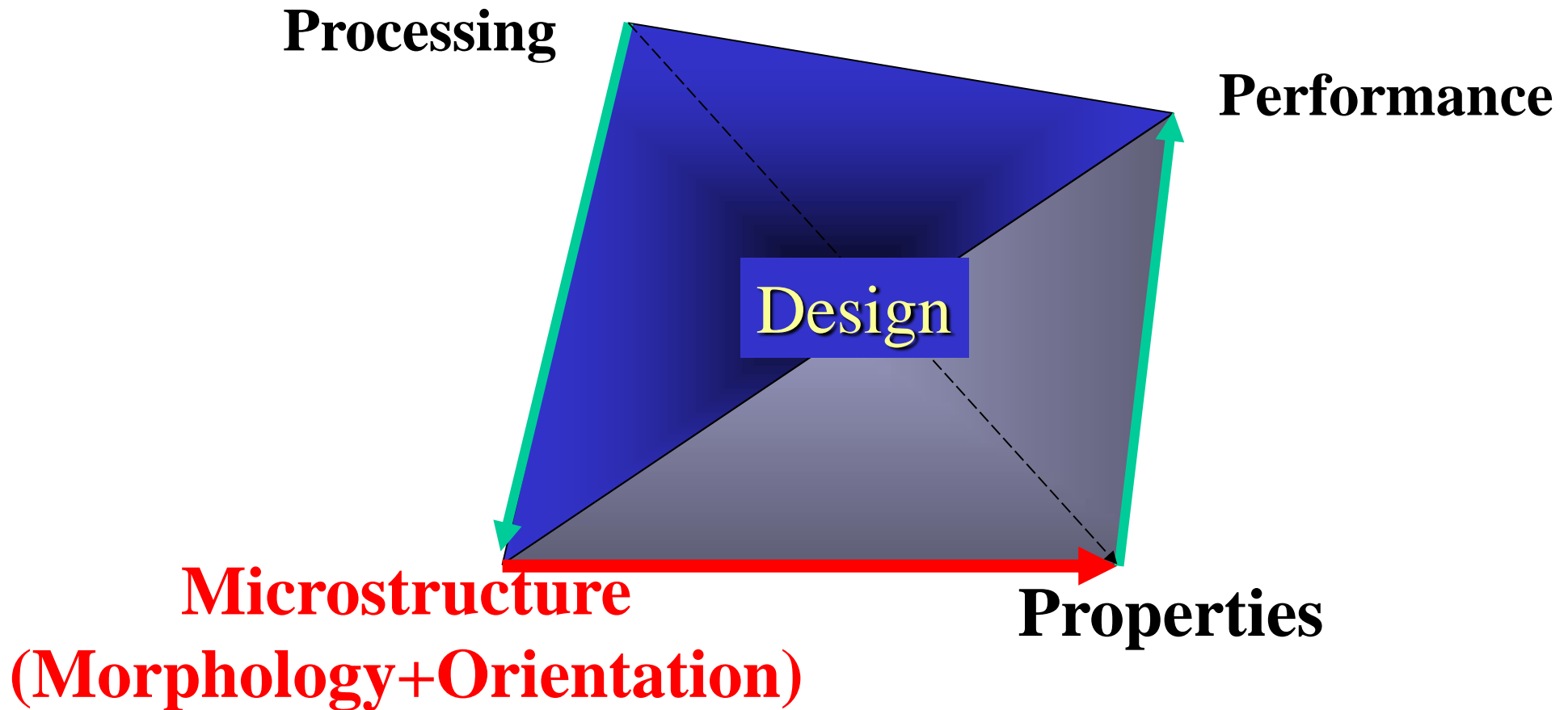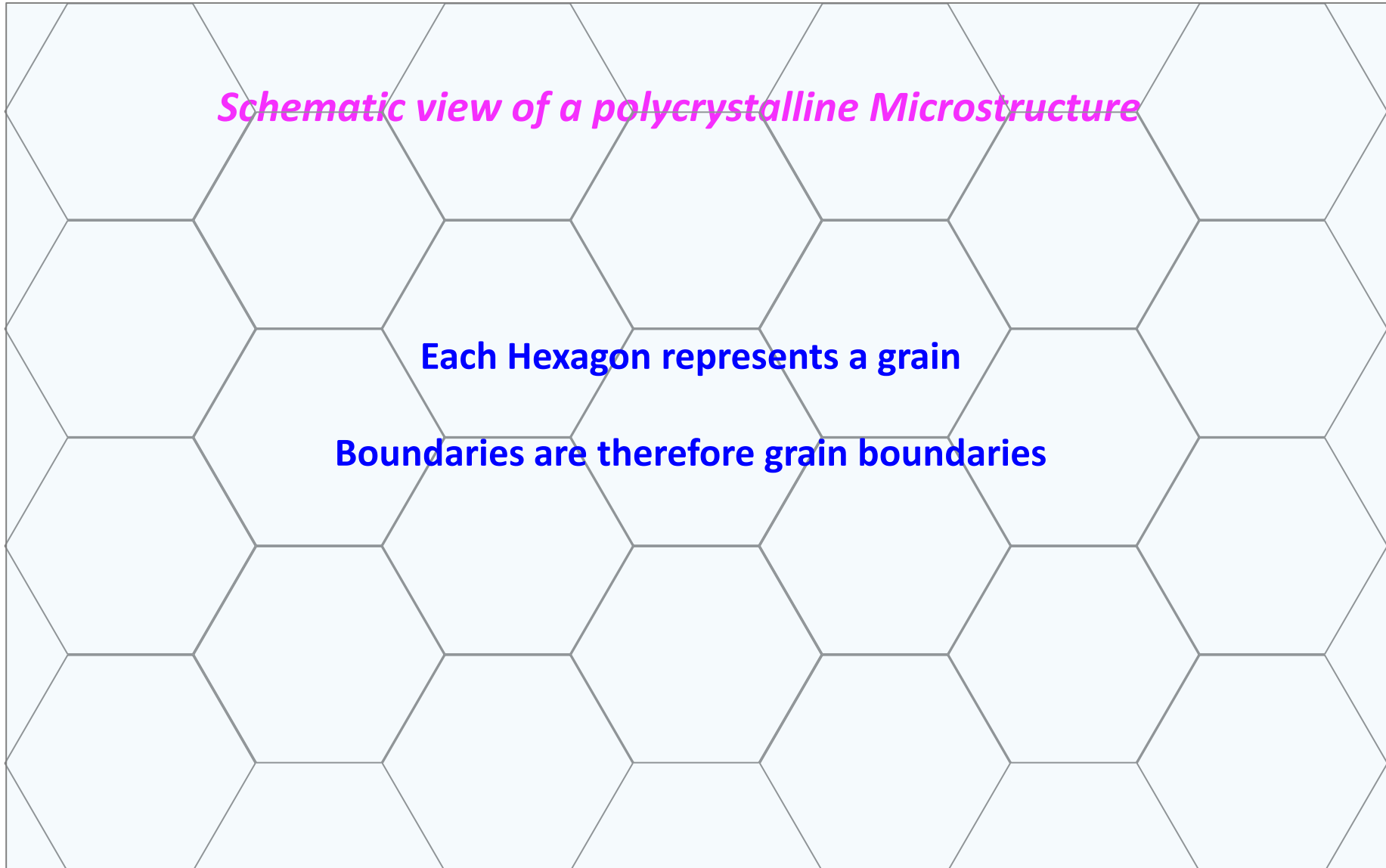
Understanding materials' tetrahedron

•**Processing of Materials determines the microstructure**

•**Microstructure controls the properties of the material**

•**Properties decide the performance of a material for an application**

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                          ┌──────────┐
                          │ features │
                          └──────────┘

┌────────────┐   ┌──────────────┐   ┌──────────────┐   ┌──────────────┐
│ Processing │   │ Microstructure │   │ Properties │   │ Performance │
└────────────┘   └──────────────┘   └──────────────┘   └──────────────┘

      ┌──────────────┐                        ┌──────────────┐
      │ Selection of │                        │   Design     │
      │   process    │                        │  based on    │
      │  parameters  │                        │ properties   │
      └──────────────┘                        └──────────────┘
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Microstructure: The most important parameter

What is a microstructure ?

Schematic view of a polycrystalline Microstructure

Each Hexagon represents a grain

Boundaries are therefore grain boundaries

What are the other information that can be derived from the microstructure given in the previous slide?

Grain Size: *What is the size of each hexagon?*

Grain Boundary fraction: *What is total boundary length associated with the hexagons?*

Grain size distribution: *How the hexagons are distributed in the given area, whether then size of the hexagons are following any size distribution etc?*

Grain orientation: *How are the hexagons orientated with the assumed reference frame?*

What is texture?

- **In latin,** *textor* **means** *weaver.*

- **In materials science, texture is the** *way in which a polycrystalline material is woven*

Texture of textile

ND

RD

TD
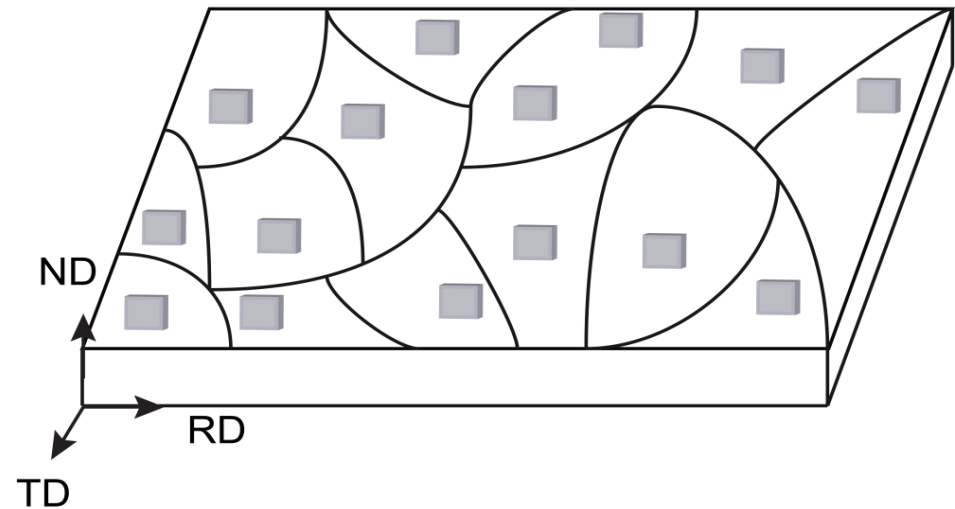
Texture of a polycrystal

# Some possible arrangements of crystallites in polycrystalline materials : a two dimensional view

Y

No texture in the material

Fully textured material

Individual crystal is having different orientation

All crystals orientated along X (this is an ideal situation)

X

Reference Axes
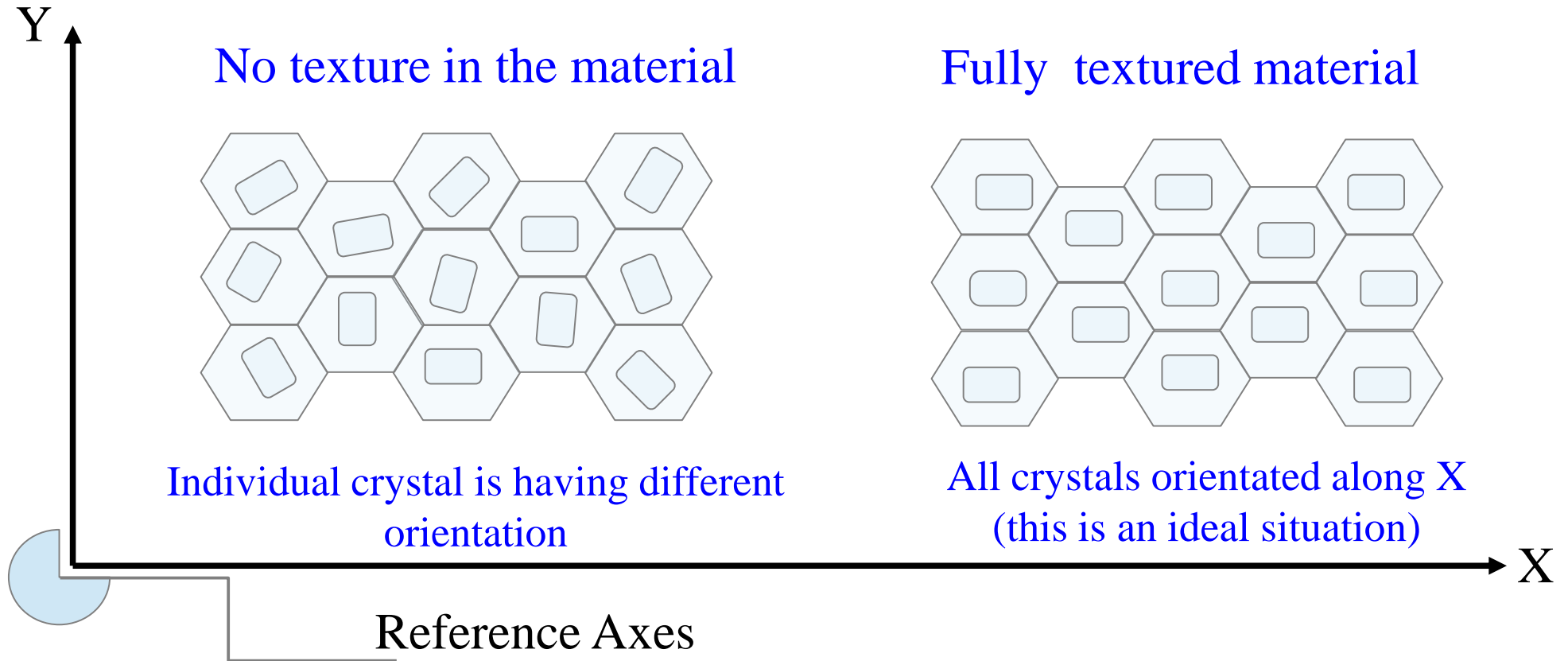
What is a crystallite?
- Limited volume of material in which periodicity of crystal lattice is present.
- Each of these crystallites has *a specific orientation* of the crystal lattice

• *Texture deals with grain orientations (Crystallite orientations) in a polycrystalline materials.*

Polycrystalline material is constituted from a large number of small crystallites (limited volume of material in which periodicity of crystal lattice is present). Each of these crystallites has *a specific orientation* of the crystal lattice.

A texture-less sheet
(Configuration like a powder aggregate)
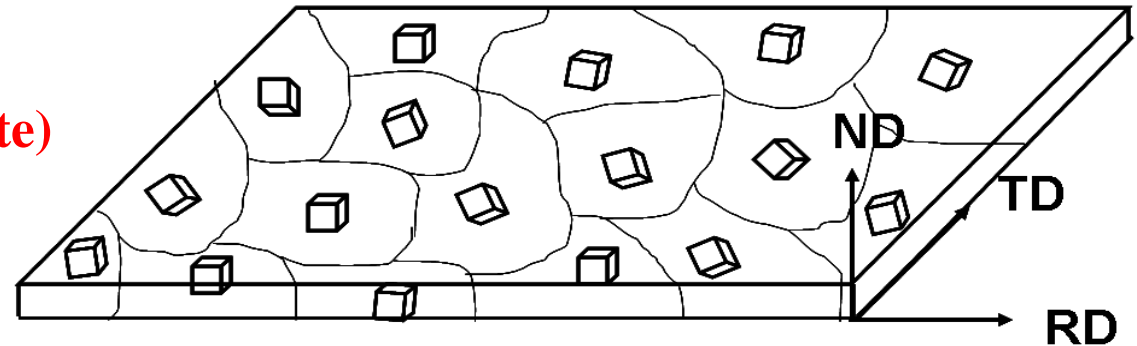
A fully textured sheet

The cube texture
(001) ‖ ND (Sheet Normal Direction)
[100] ‖ RD (Sheet Rolling Direction)
(Configuration like a single crystal)
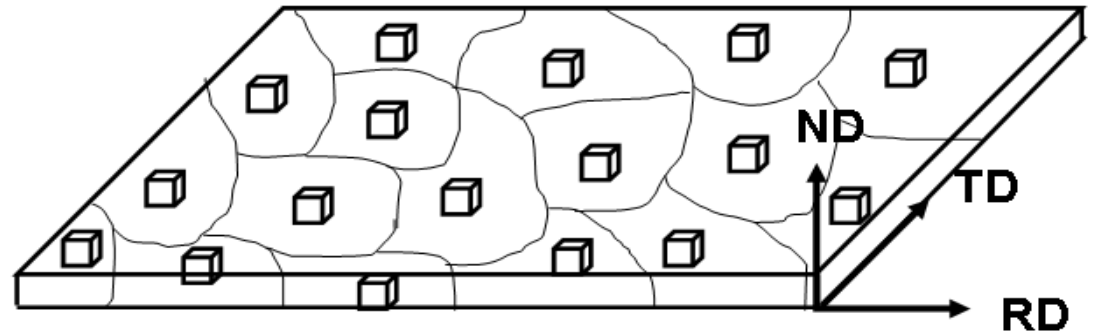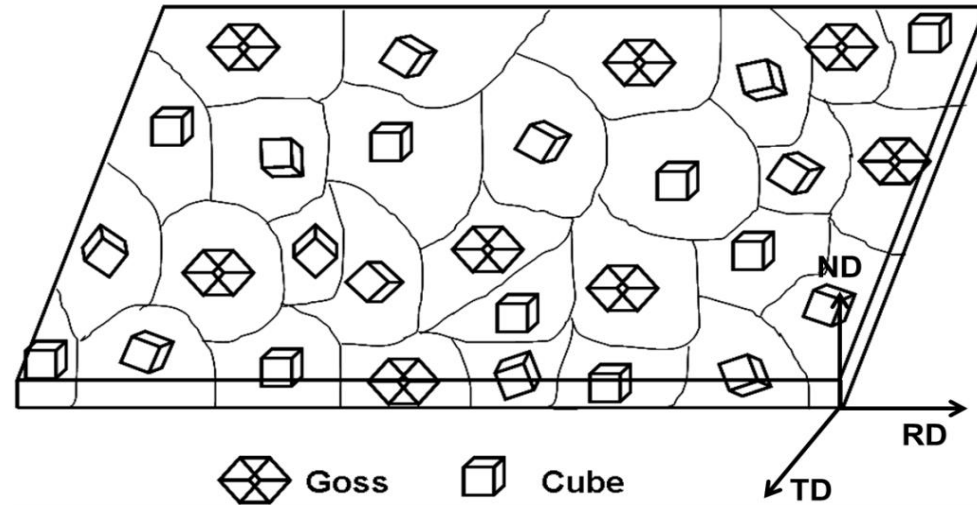
The real situation:
Many grains have common orientation, but they are spatially apart.

How to *Describe Textures?*

For uniaxial deformation or other processes, texture is expressed in terms of miller indices of directions [uvw] aligned along the specimen axis, also called *Fibre texture*.

Look at the crystal configurations in the wires:
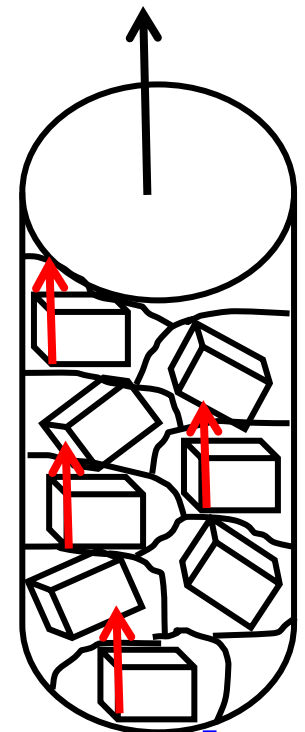
All crystals are randomly oriented
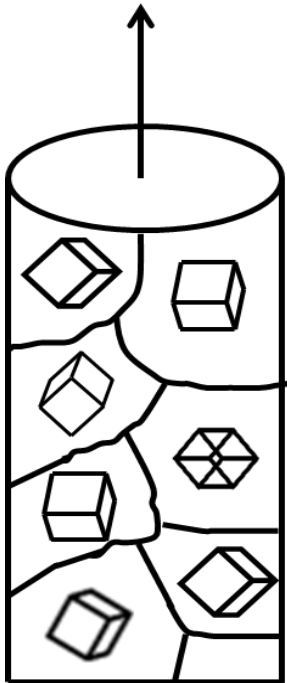
All crystals are oriented with their [001] ‖ WD -like a single crystal
–an ideal situation
–not practicable
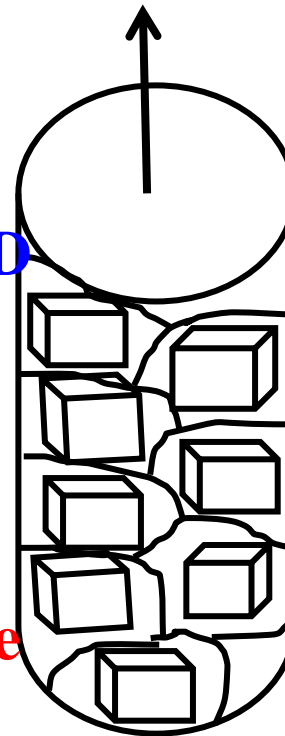
Texture is expressed as <001>, the direction parallel to wire axis

**Most crystals are oriented with their [001] ‖ WD -a real situation**

**Texture is expressed as <001>, the direction parallel to wire axis**

For biaxial deformation, like rolling, a combination of miller indices of sheet plane and the miller indices of the directions parallel to the longitudinal axes, say, (hkl) [uvw]

- **For the subsequent processes also , for example annealing, texture is described in terms of frame of reference of the prior deformation history. That means the texture of annealed sheet will be represented as (hkl)[uvw]**
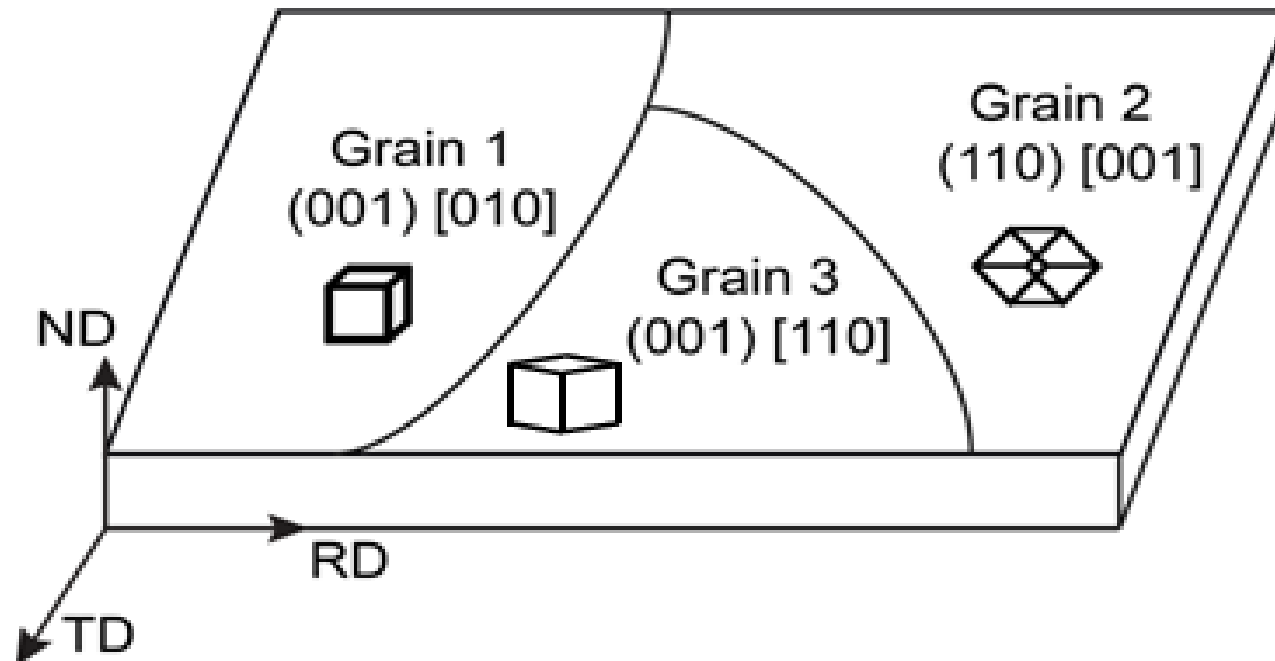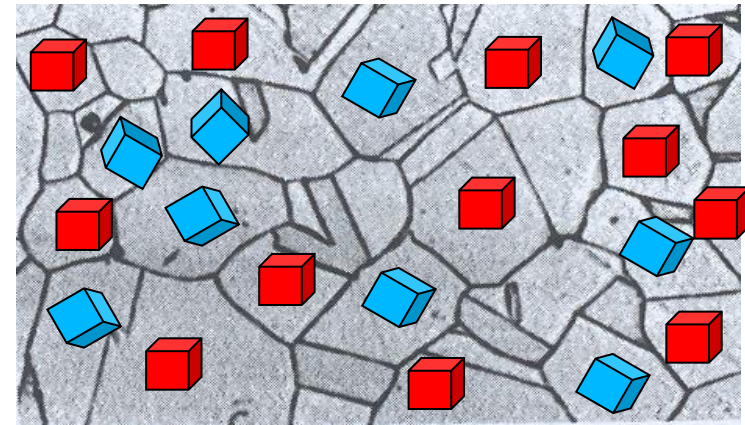
How texture is related to microstructure?

- *Crystallographic texture is different from the patterns observed in optical or scanning electron micrographs*
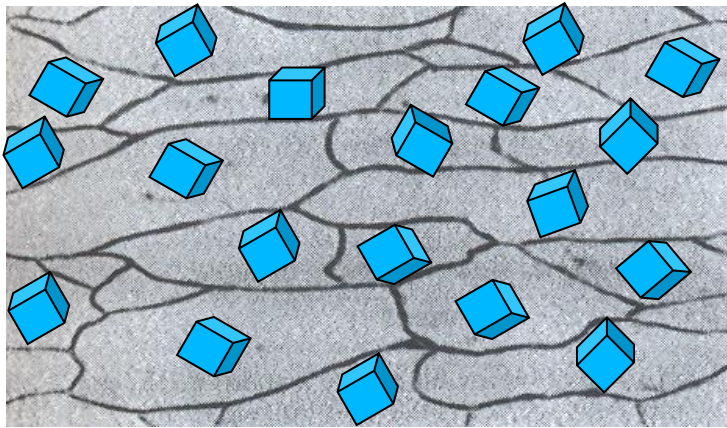

In this micrograph, most of the grains are depicted to have randomly oriented grains, as obtained by cross rolling with intermediate annealing. The morphology of grains appears to be, however, aligned.

In this micrograph, large number of the red grains are depicted to have cube orientation, as obtained after annealing. The morphology of grains appears to be equiaxed.

- Elongated or flattened grains do not imply a certain texture, or even the presence of texture at all
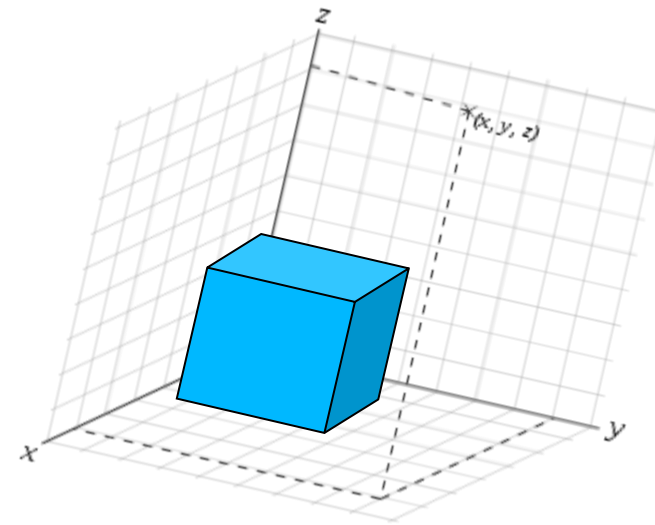- Presence of equiaxed grains does not imply a random orientation.

Reference system is the most important parameter to define crystallographic texture
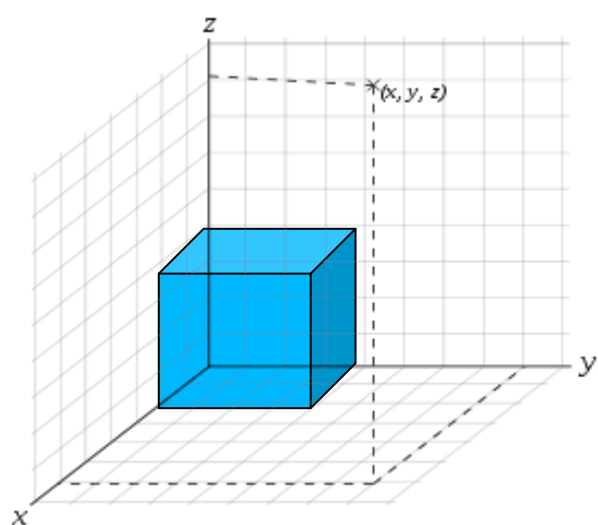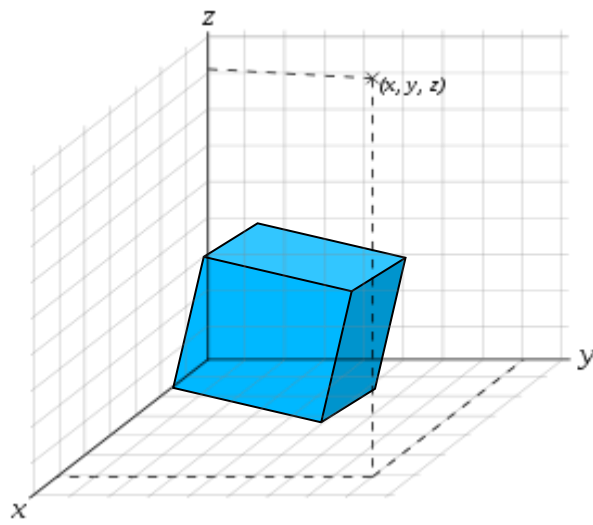
**Configuration A**   **Configuration B**   **Configuration C**

- **Configurations B and C represent different orientations**
- **Configurations A and C represent the same orientation**

Diffraction patterns from textured polycrystalline material

- Diffraction patterns from a single crystal is in the form of isolated spots, while for a randomly oriented polycrystalline material, the diffraction pattern is in the form of concentric rings (Debye-Scherrer rings).

- Textured polycrystalline materials are somewhat in-between. Here the diffraction pattern consists of Debye-Scherrer rings, but the intensity distribution is non-unform along the circumference of the rings.

Diffraction pattern from the crystals of materials

Single Crystal

Texture

Random Sample
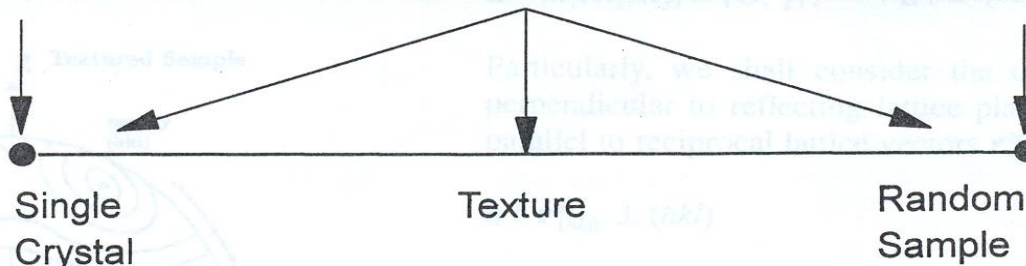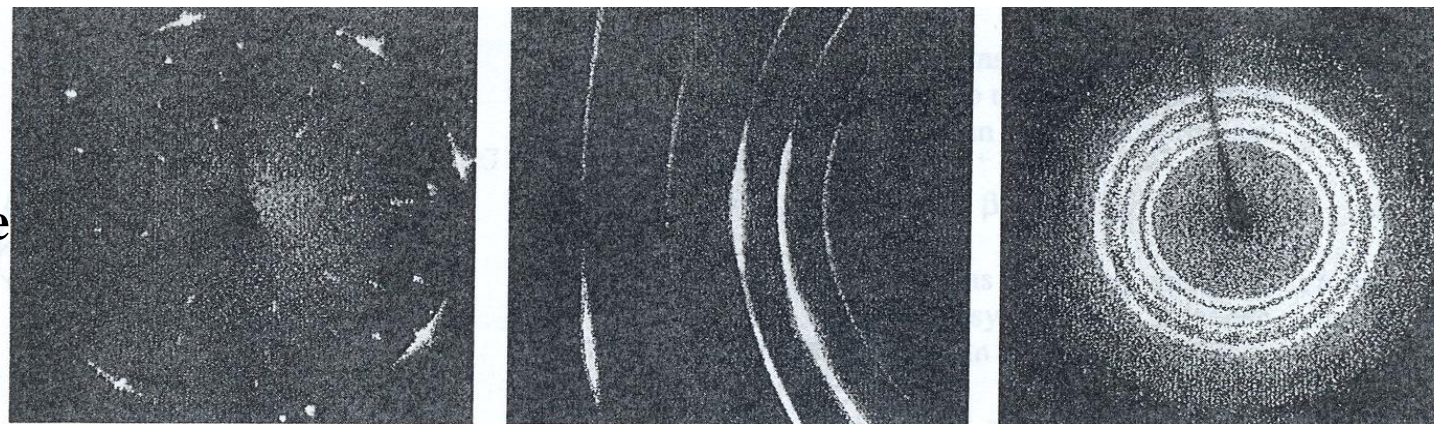
Courtesy: H.-J. Bunge

Texture Formation processes

Texture develops or changes due to:

(i) Crystallisation/ solidification

(from a non-crystalline / liquid state)

(ii) Plastic deformation

(by slip and twinning)

(iii) Annealing

(from the same phase)

(iv) Phase transformation

(from a different phase)

Questions

1.Choose the correct answer:

(i) Crystallographic texture refers to

    a.Morphology of grains in a polycrystalline material

    b.Orientation of grains in a polycrystalline materials

    c.Orientation of dislocation

    d.Surface topography of polycrystalline material

(ii)Single crystal has

    a.   No texture;   b.   Weak texture; c.   Strongest texture; d.   Random texture

(iii)A powder aggregate has

    a.   No texture;   b.   Weak texture; c.   Strongest texture; d.   Random texture

2. Which of the following statements are NOT correct?

    a. elongated or flattened grains always imply a very strong texture

    b. equiaxed grains imply no texture or random texture

    c. texture is an absolute quantity and does not require any frame of reference for description

    d. the intensity of the Debye-Scherer rings from a texture polycrystal is non-uniform.

3. How to represent the orientation of a crystal

    a.   Orientation matrix, g;   b.   Miller indices, {hkl} <uvw>;

    c.   Euler angles, φ_1, φ, φ_2; d.   All the above.

4.How does the XRD pattern of a single crystal is different from a polycrystalline materials?

5.At what stages of processing, texture changes occur in materials?