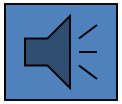
EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

Audio test:



Materials and its structure

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Tento učební materiál vznikl v rámci projektu Rozvoj doktorského studia chemie
č. CZ.02.2.69/0.0/0.0/16_018/0002593

Material

Material - Wikipedia

Material is a substance or mixture of substances that constitutes an object. Materials can be pure or impure, living or non-living matter. Materials can be classified on the basis of their physical and chemical properties, or on their geological origin or biological function. Materials science is the study of materials, their properties and their applications.

Materials can be broadly categorized in terms of their use, for example:

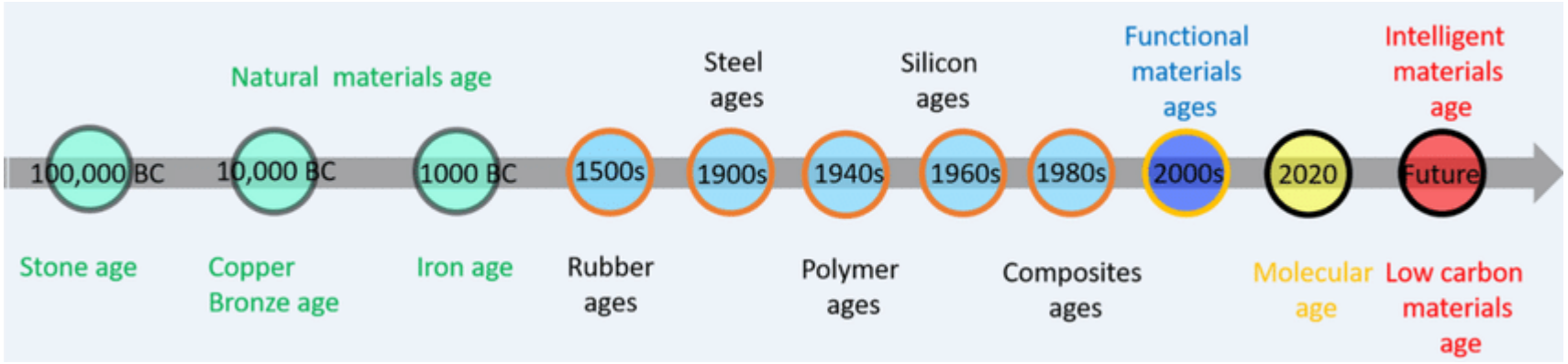
- Building materials are used for construction
- Building insulation materials are used to retain heat within buildings
- Refractory materials are used for high-temperature applications
- Nuclear materials are used for nuclear power and weapons
- Aerospace materials are used in aircraft and other aerospace applications
- Biomaterials are used for applications interacting with living systems

Material selection is a process to determine which material should be used for a given application.

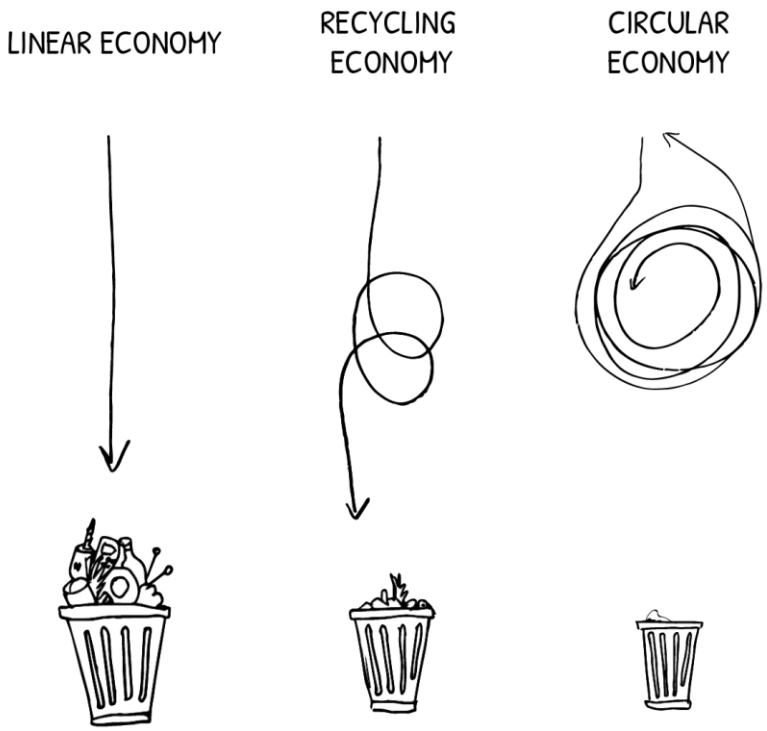
History and technologies

Materials chart the history of humanity. The system of the three prehistoric ages (Stone Age, Bronze Age, Iron Age) were succeeded by historical ages: steel age in the 19th century, polymer age in the middle of the following century (plastic age) and silicon age in the second half of the 20th century.[2]

The timeline for major materials (reproduced with permission from Liu... | Download Scientific Diagram (researchgate.net)

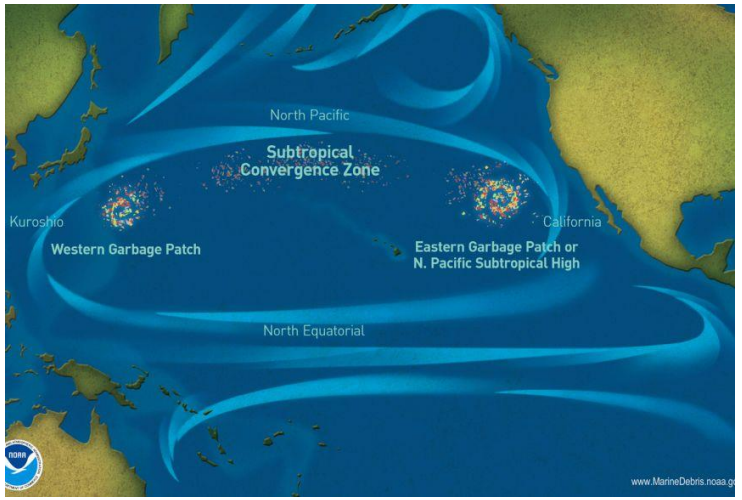


Linear economy vs. Circular economy



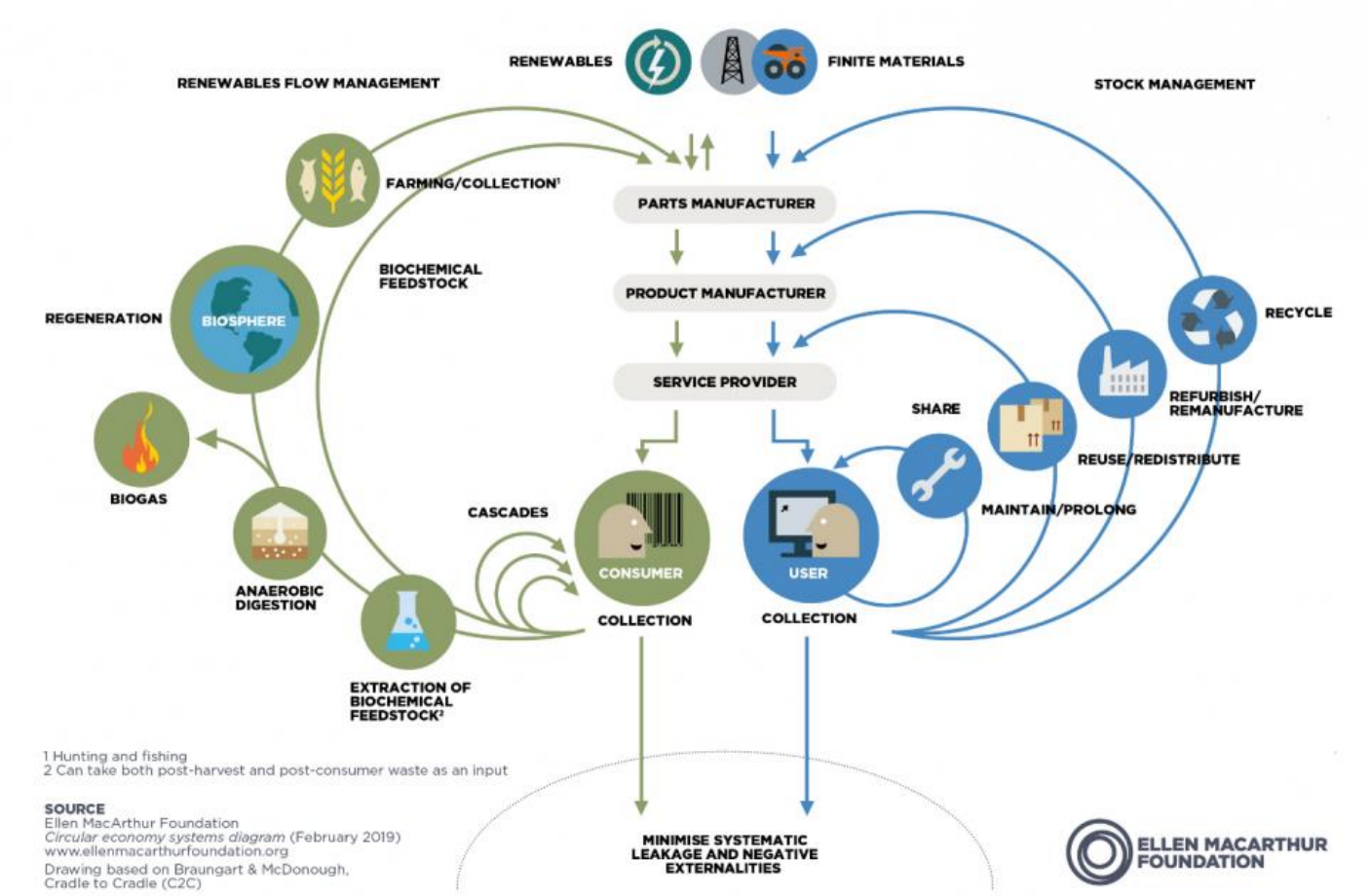
[Circular Economy Resource Box (KS3/4) - Zone (recycledevon.org)]

[Great Pacific Garbage Patch (nationalgeographic.org)]



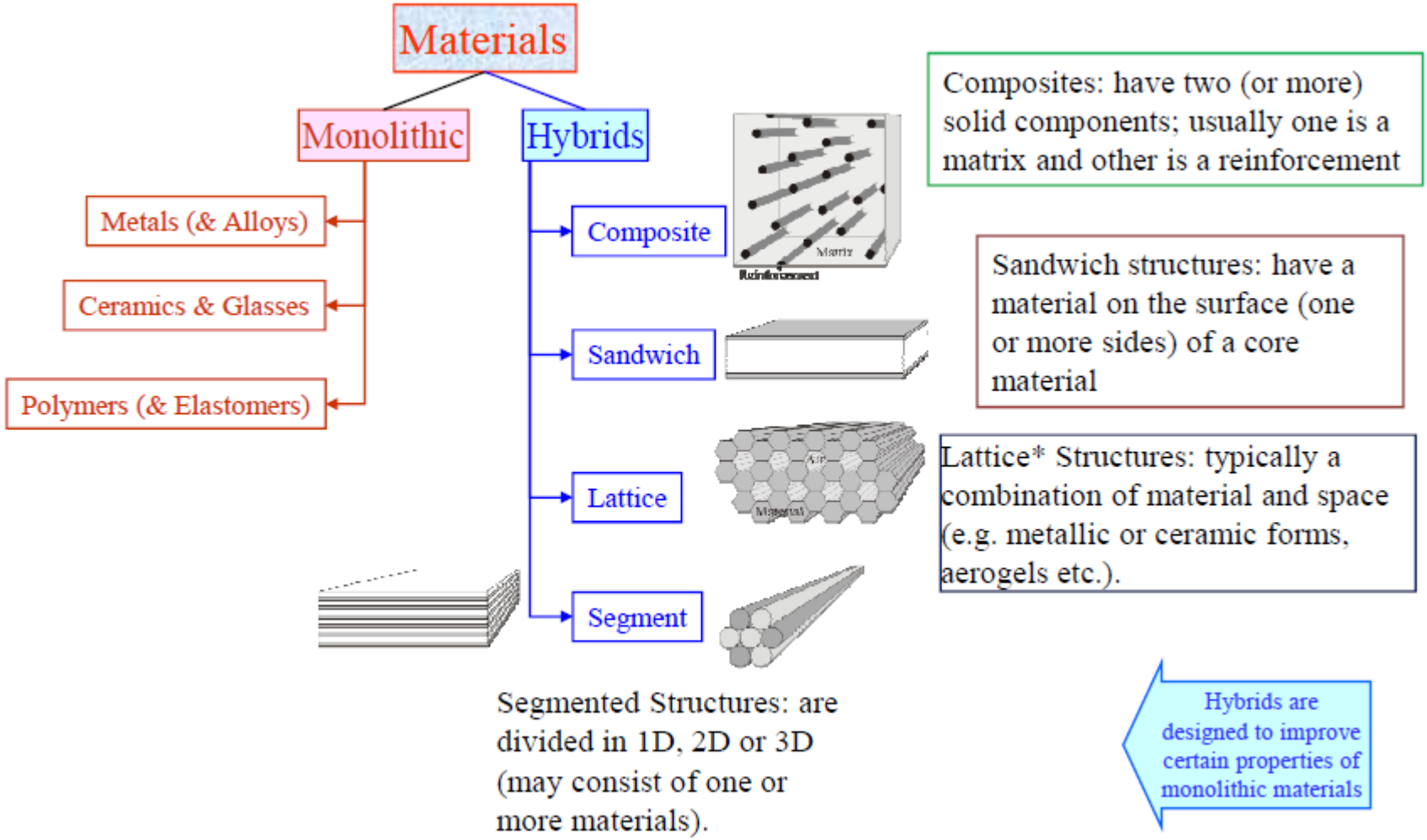
Circular Economy

A circular economy keeps materials, products, and services in circulation for as long possible.

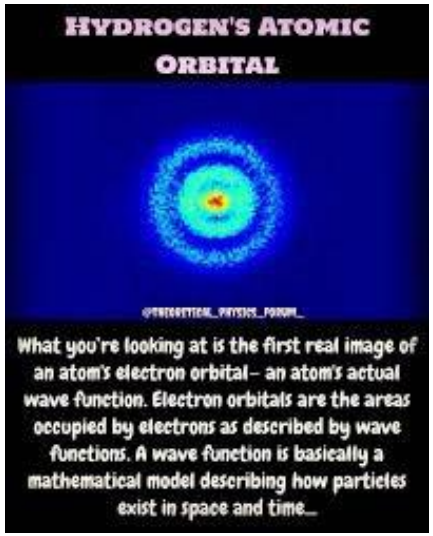


[What is a Circular Economy? | US EPA]

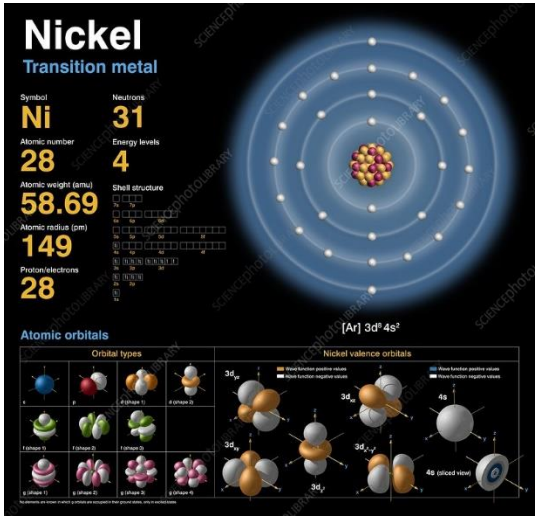
Material classification According Kumar



From atom to component



[Do we actually know what atoms look like? - Quora]



[Nickel, atomic structure - Stock Image - C018/3709 - Science Photo Library]

[Turbo TDO6-17A Turbocharger 49179-00110 ME037701 for Mitsubishi Engine 6D31T 6D14T 6D14CT 6D14-2CT (fridayparts.com)]

Experimental measurement of Submolecular charge distribution

Mallada, B., Ondráček, M., Lamanec, M. *et al.* Visualization of π-hole in molecules by means of Kelvin probe force microscopy. *Nat Commun* **14**, 4954 (2023). https://doi.org/10.1038/s41467-023-40593-3

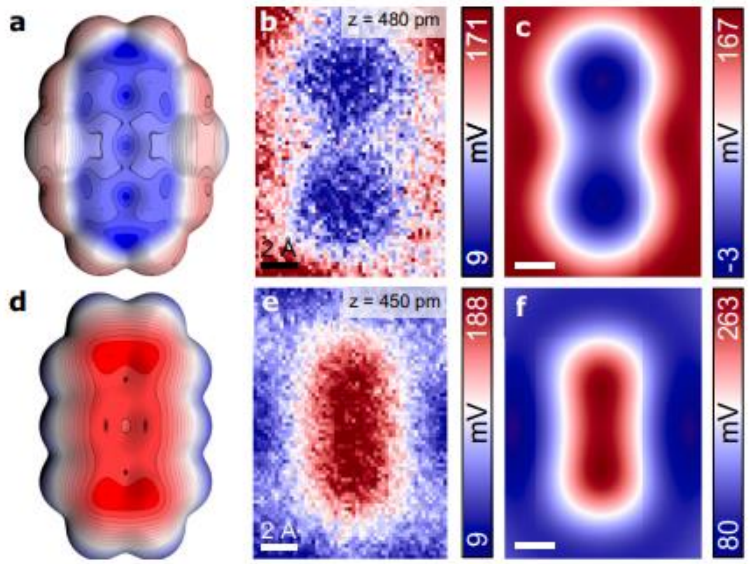
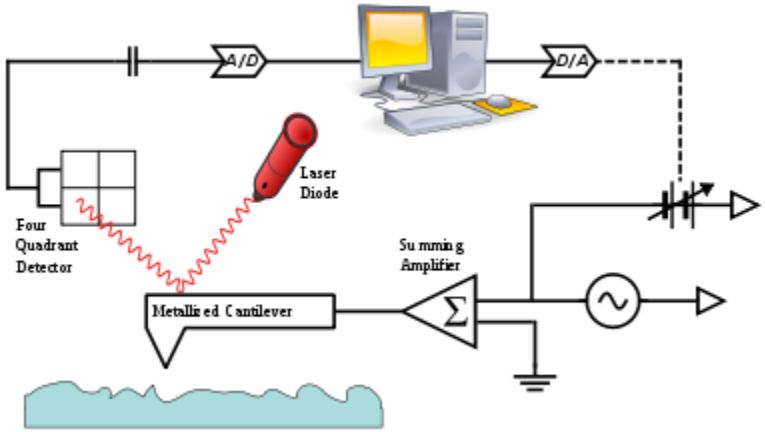


Fig. 3 | Simulated and experimental charge distributions of FCl-An and An. **a**, **d** Electrostatic potential maps of free-standing FCl-An and An molecules. **b**, **e** Experimental LCPD maps of FCl-An and An acquired with the same CO-tip in constant height mode. **c**, **f** Probe Particle simulated LCPD maps of FCl-An and An. Source data are provided as a Source Data file.

[Visualization of π-hole in molecules by means of Kelvin probe force microscopy | Nature Communications]

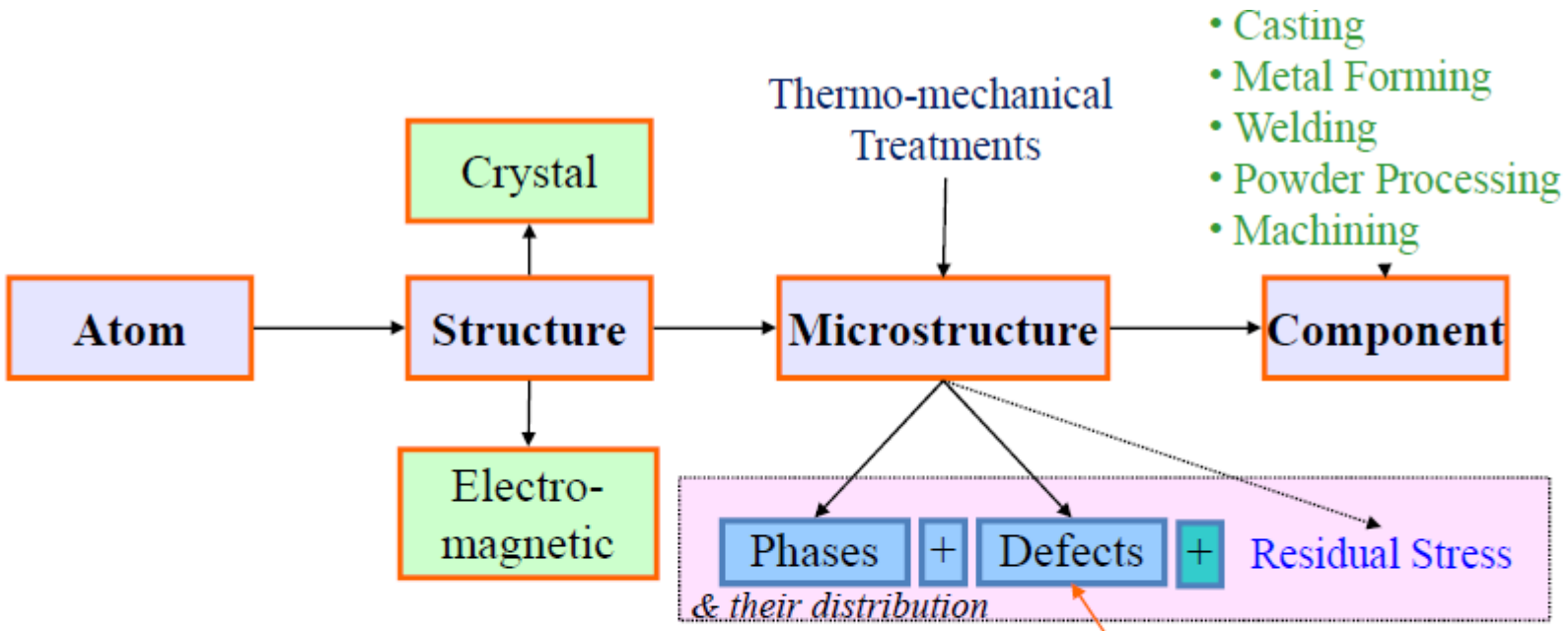
experimentally visualize the π-hole in 9,10-Dichlorooctafluoroanthracene C14F8Cl2 (FCl-An) molecule and, at the same time, its absence in anthracene C14H10 (An).

the ordered self-assembly structure of An and FCl-An molecules on Au(111).



[Kelvin probe force microscope - Wikipedia]

Length scales in metallurgy

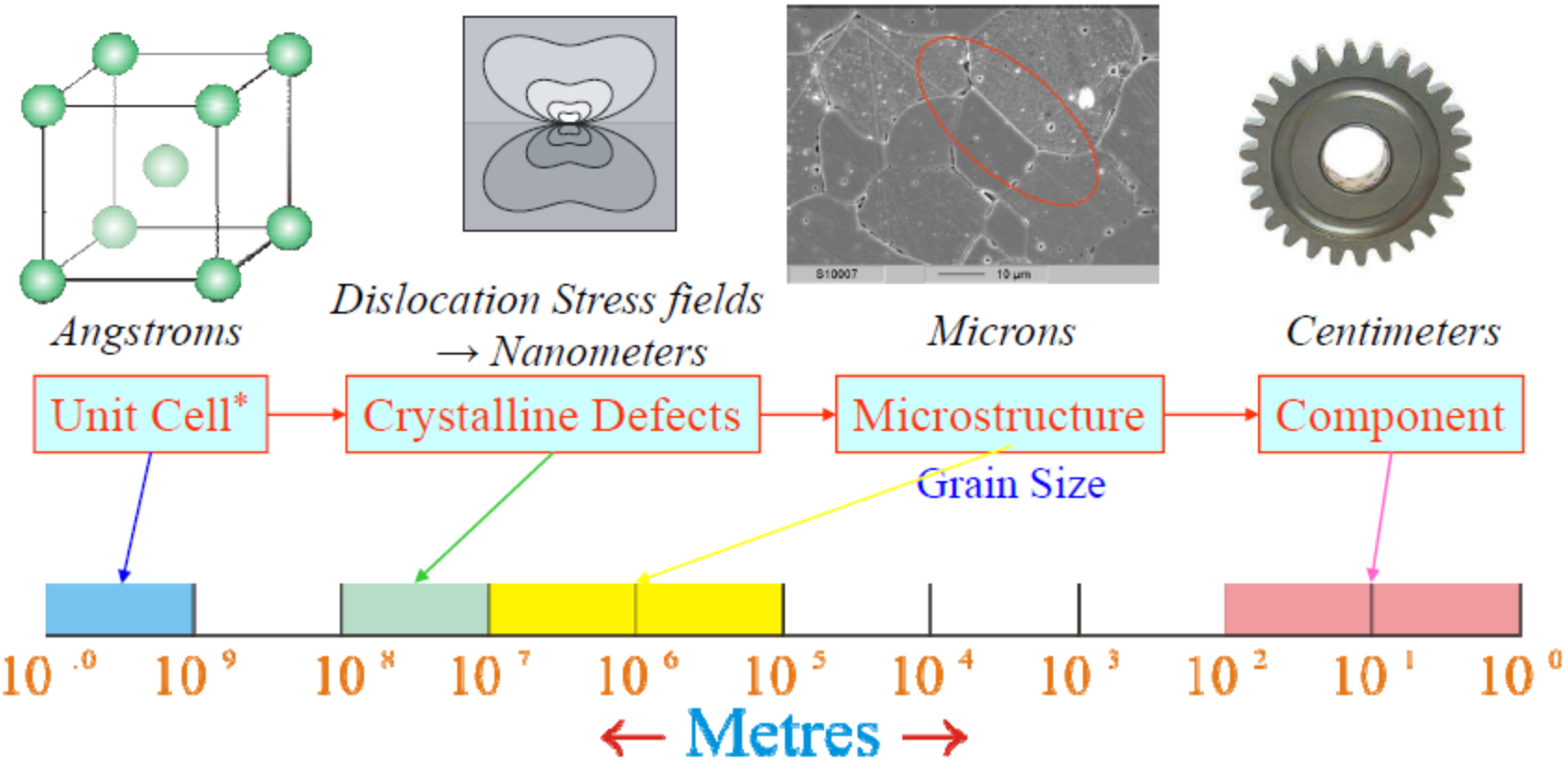


- Structure could imply two types of structure:
  - Crystal structure
  - Electromagnetic structure
  - *Fundamentally these aspects are two sides of the same coin*
- Microstructure can be defined as: (Phases + Defect Structure + Residual Stress) *and their distributions*
- Microstructure can be 'tailored' by thermo-mechanical treatments

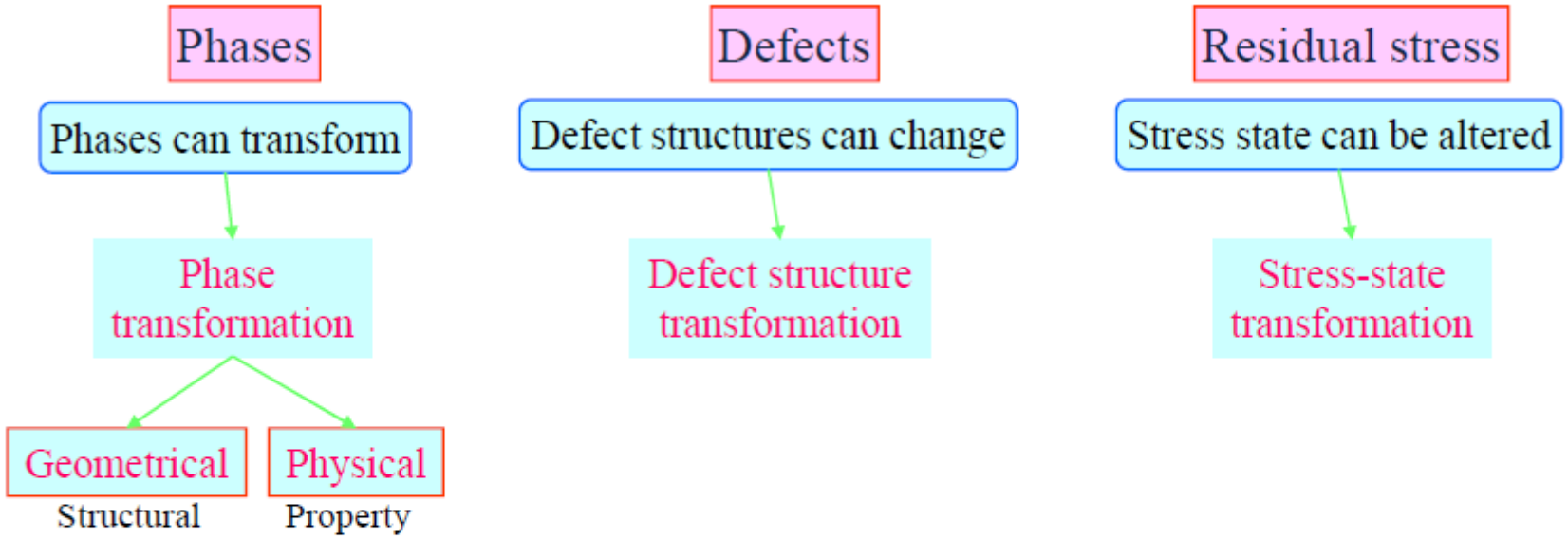
- Vacancies
- Dislocations
- Twins
- Stacking Faults
- Grain Boundaries
- Voids
- Cracks

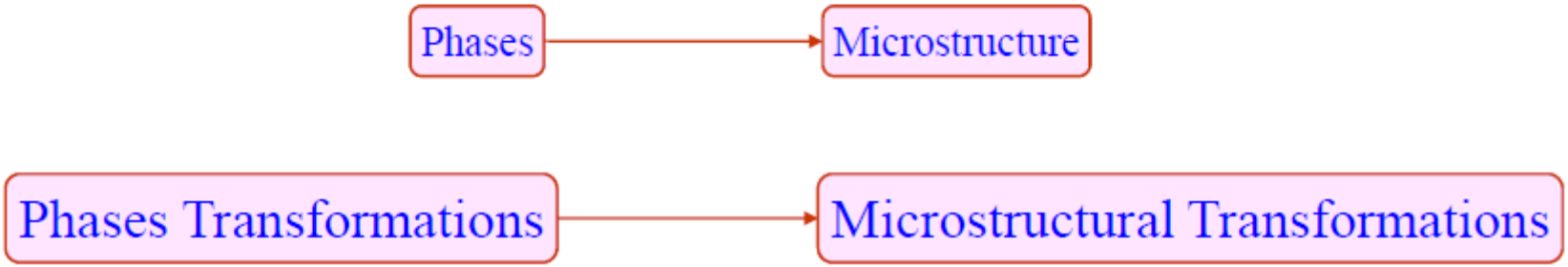
Processing determines shape and microstructure of a component

Length scales

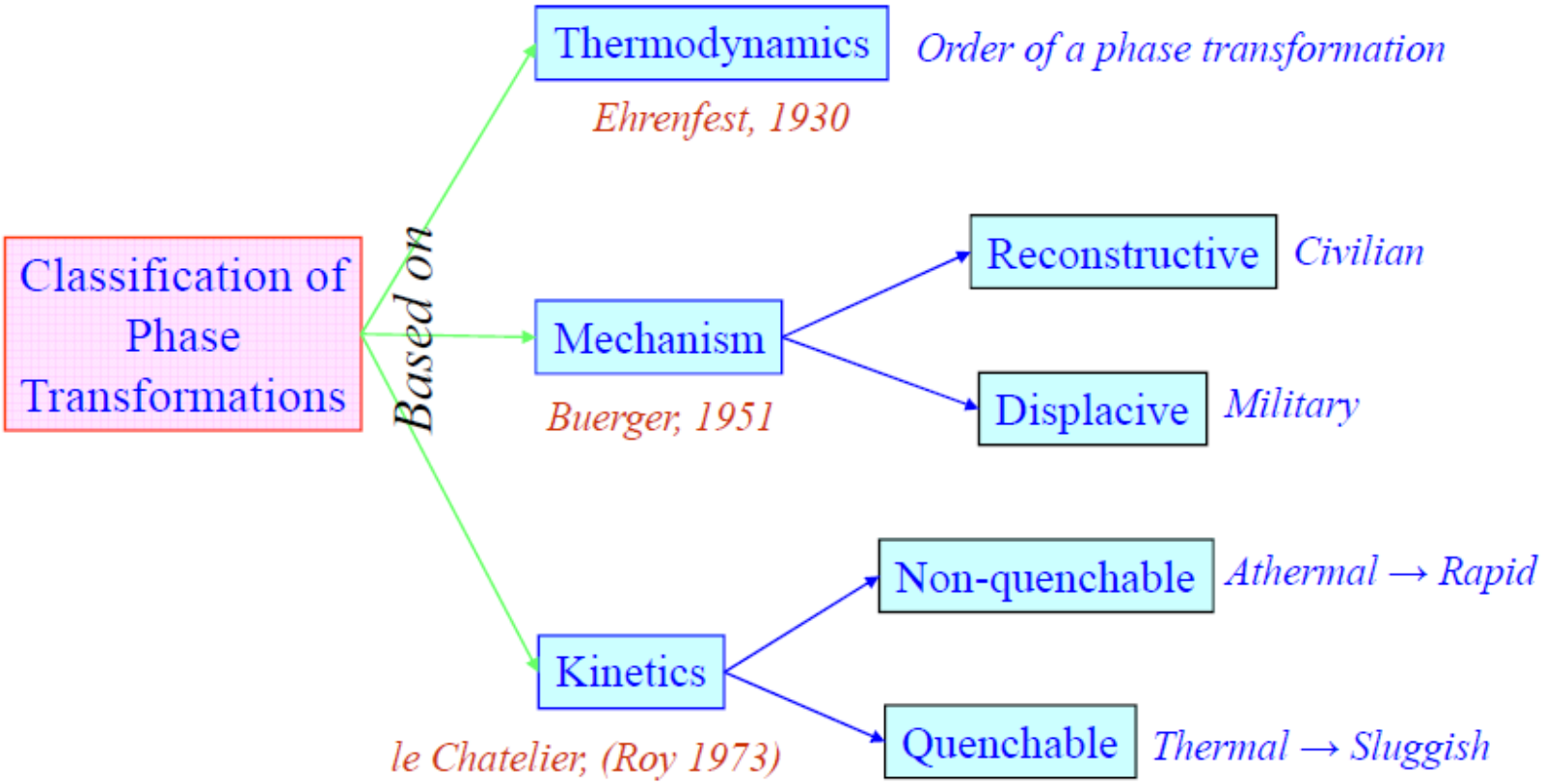


Transformations and changes in materials





Classification of Transformations



Classification of PT according to thermodynamics

- The thermodynamic characteristics associated with the phase transformations can be used to classify transformations; in this classification methodology, if the n^{th} derivative of free energy (G) with respect to temperature (T) and pressure (P) is discontinuous, it is defined as the n^{th} order transformation.
- As shown in Fig., in transformations such as melting, the first derivative has the discontinuity; hence, melting is a first order transformation; on the other hand, in some of the order/disorder transformations, it is the second derivative which is discontinuous, making it the second order transformation.

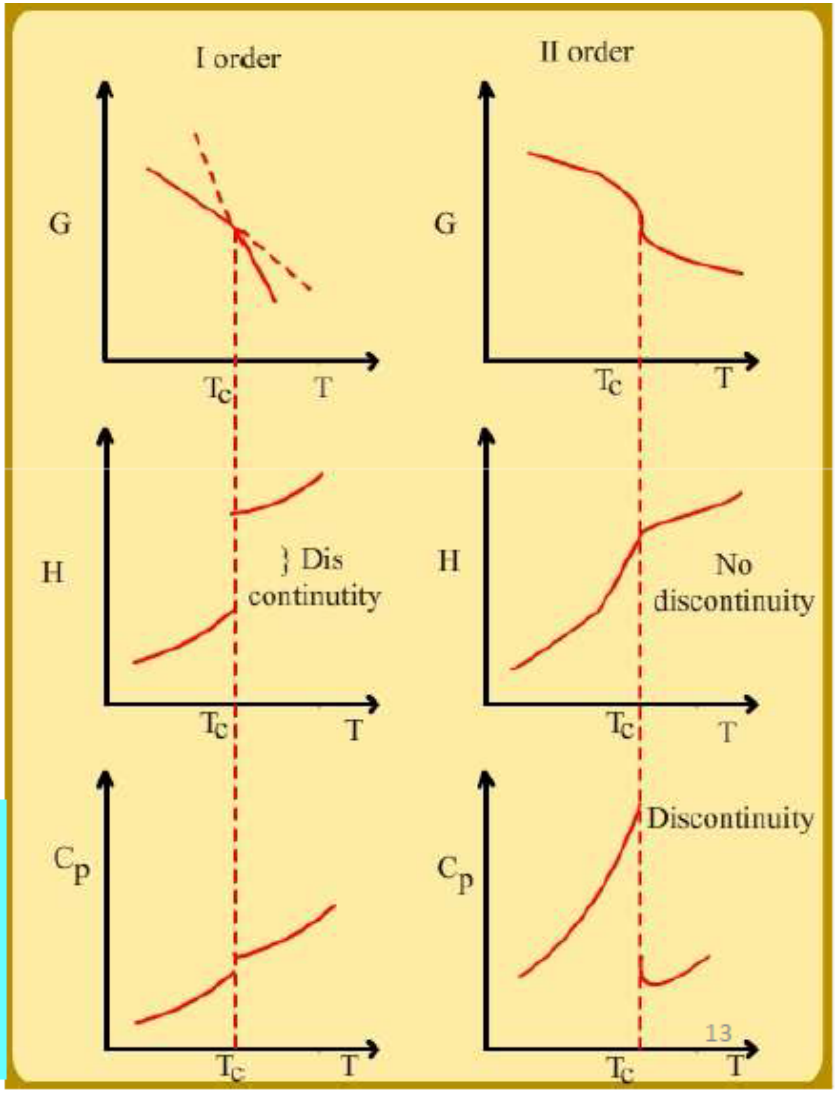


Figure: The thermodynamic classification of transformations: the first derivative of the free energy 'G' with respect to temperature 'T' , that is the enthalpy 'H' is discontinuous at the transformation temperature T_c as shown in the first column; the second derivative of the free energy with respective to temperature C_p is discontinuous while 'H' is not in the second column, making the order of transformation second.

Classification of PT according to mechanism

[Metallography of Steels (cam.ac.uk)]

RECONSTRUCTIVE

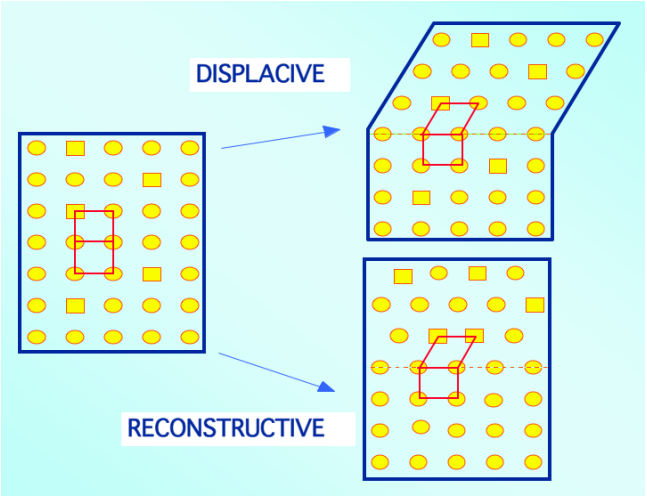
Diffusion of all atoms during nucleation and growth.
Sluggish below about 850 K.

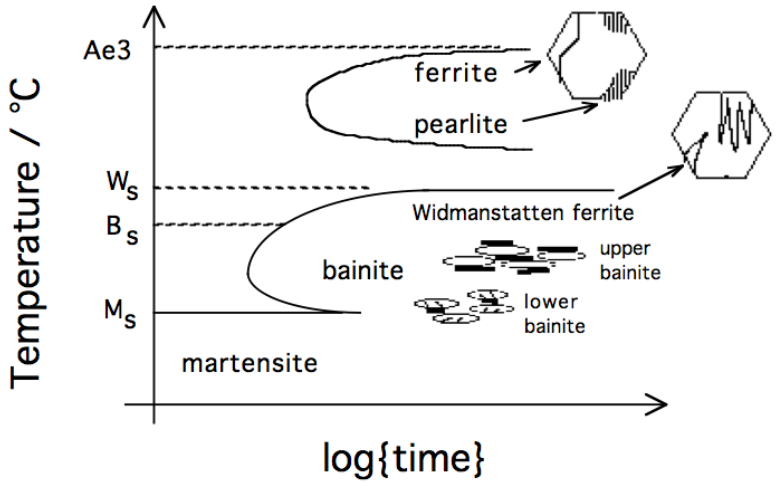
- ALLOTRIOMORPHIC FERRITE
- IDIOMORPHIC FERRITE
- MASSIVE FERRITE
  No change in bulk composition.
- PEARLITE
  Cooperative growth of ferrite & cementite.

DISPLACIVE

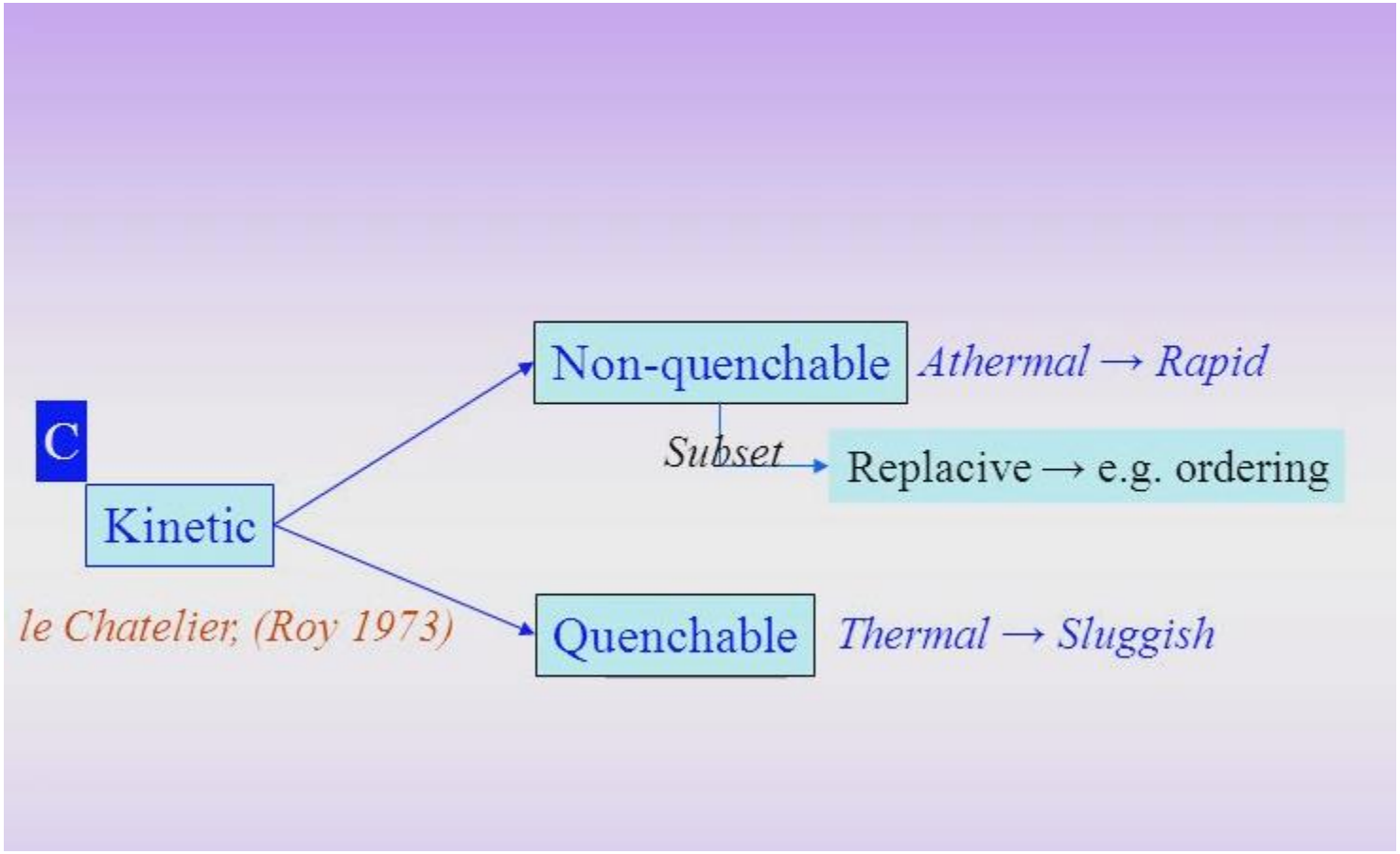
Invariant-plane strain shape deformation with large shear component.
No iron or substitutional solute diffusion.
Thin plate shape.

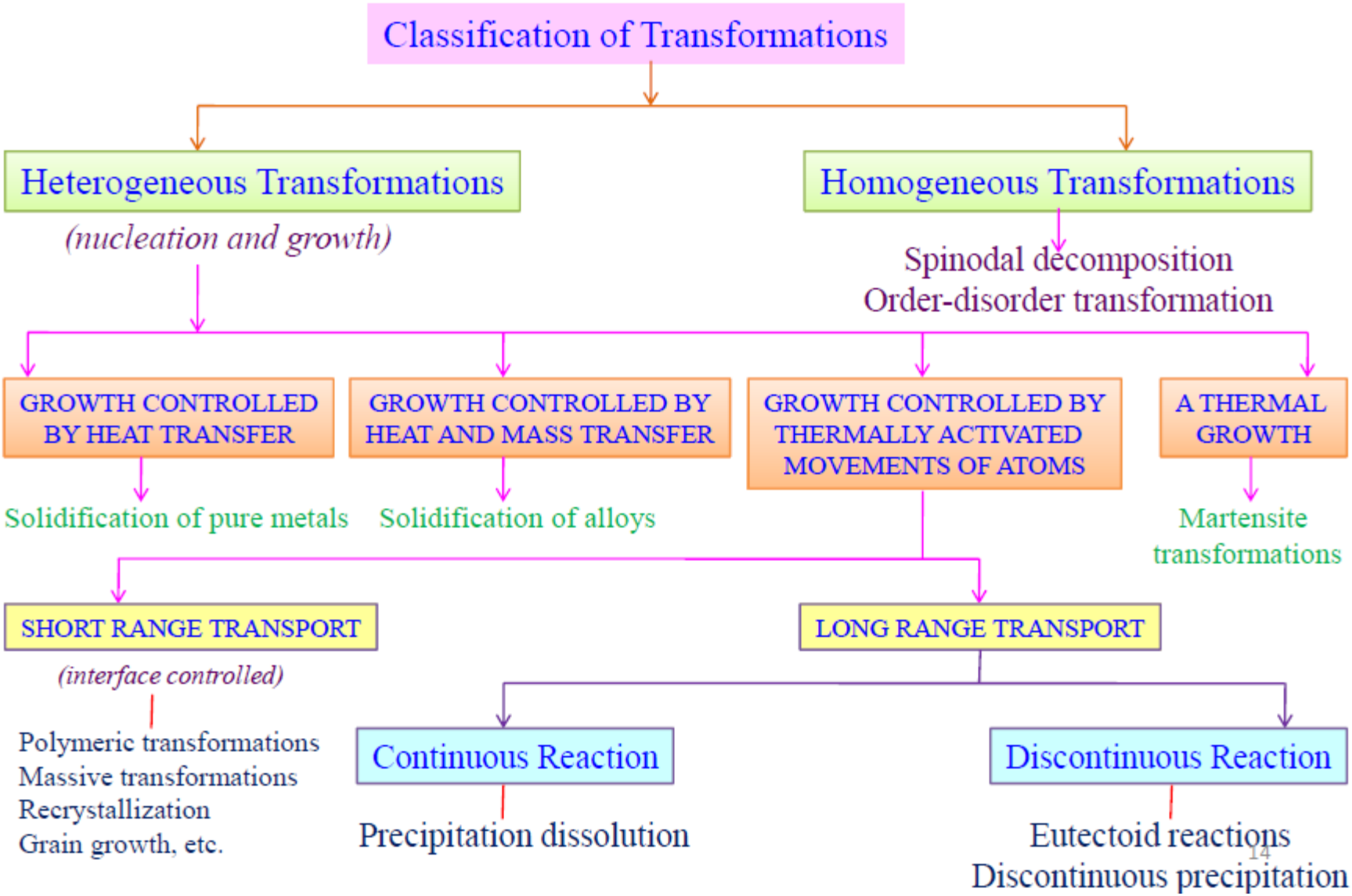
- WIDMANSTÄTTEN FERRITE
  Carbon diffusion during paraequilibrium nucleation & growth.
- BAINITE & ACICULAR FERRITE
  Carbon diffusion during paraequilibrium nucleation. No diffusion during growth.
- MARTENSITE
  Diffusionless nucleation & growth.





Classification of PT according to kinetics

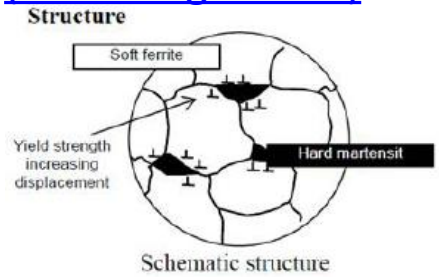




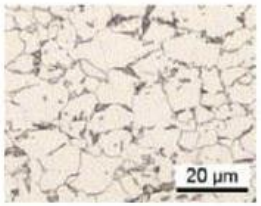
According Kumar

Structure of materials

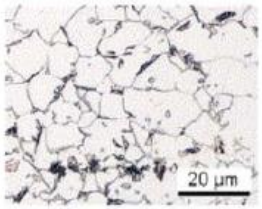
[1: The schematic structure and microstructures of DP steel (Material... | Download Scientific Diagram (researchgate.net)]



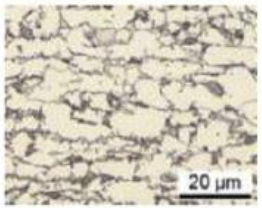
Schematic structure



DP450

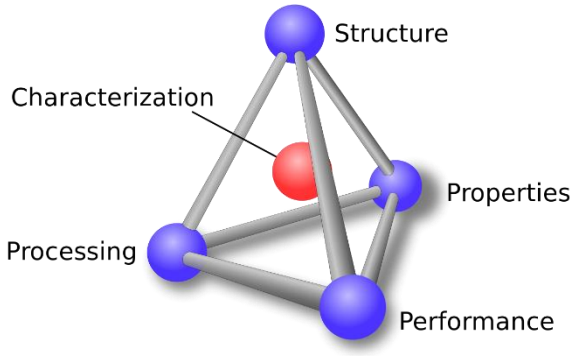


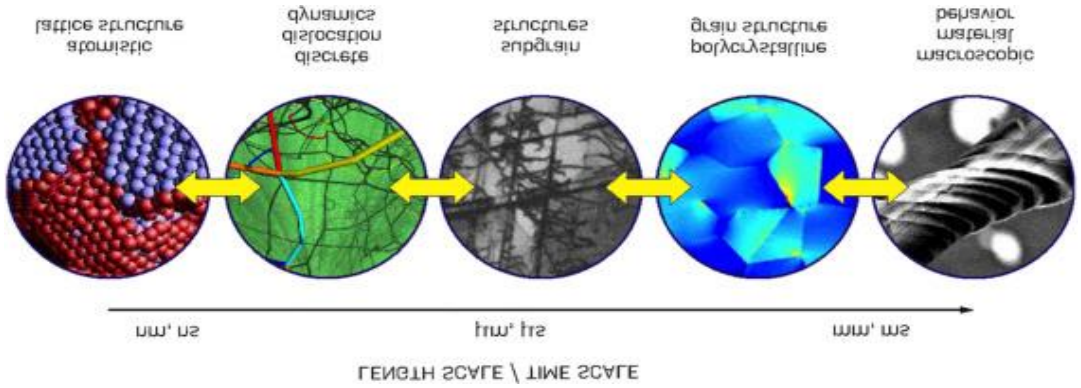
DP500



DP600

[Materials Science and Engineering | MATSE 81: Materials In Today's World (psu.edu)]

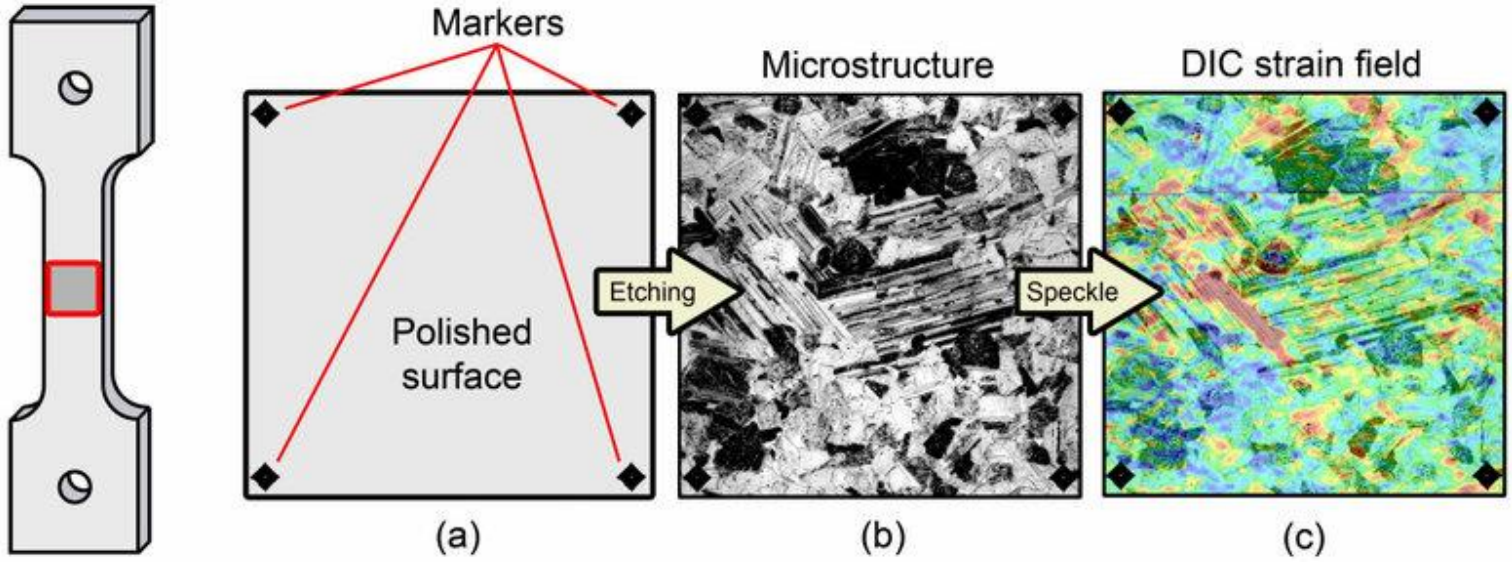




[The new frontiers in computational modeling of material structures - ScienceDirect]

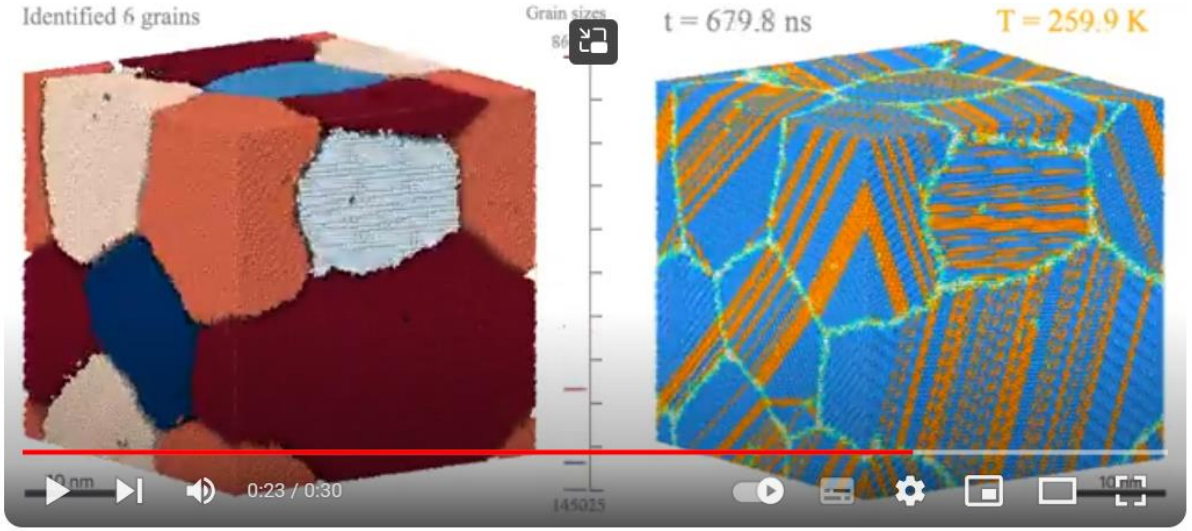
Microstructure

[Specimen preparation, positioning of fiducial markers (a),... | Download Scientific Diagram (researchgate.net)]



Capturing 3D microstructures in real time

[Capturing 3D microstructures in real time | Argonne Leadership Computing Facility (anl.gov)]



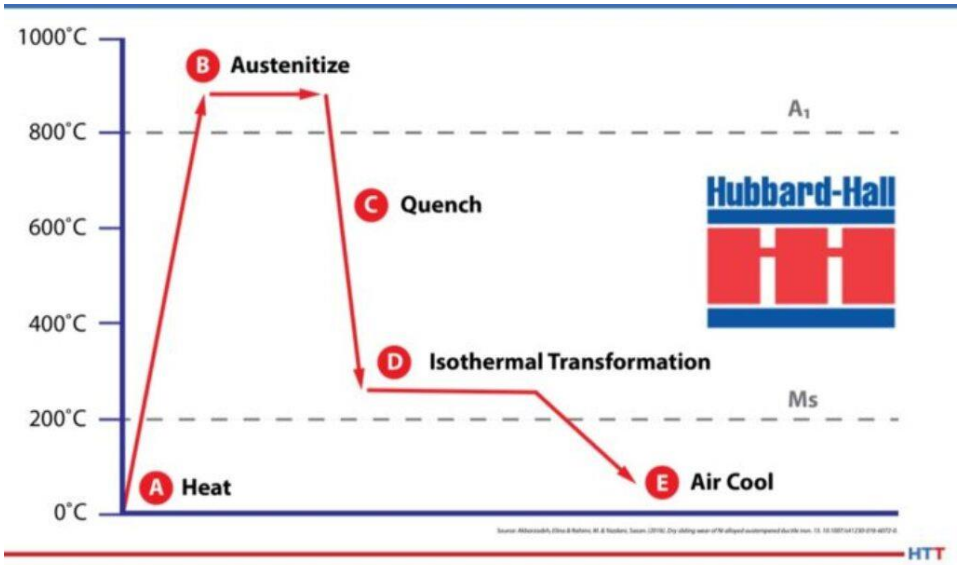
Capturing 3D microstructures in real time

Video: [Capturing 3D microstructures in real time - YouTube]

How to prepare „(Micro) structure“?

„Anthropogenic“ ways

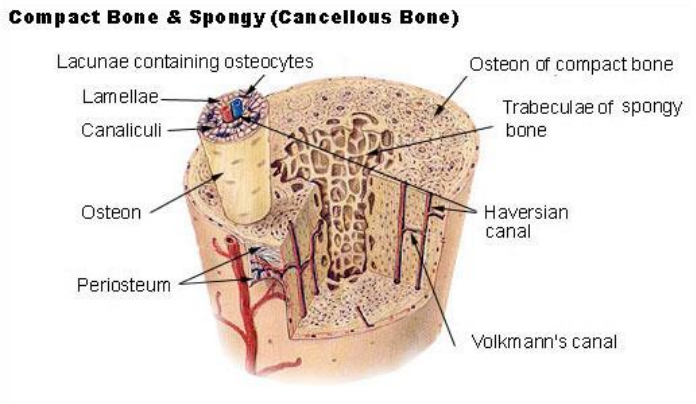
- Heat treatment
- Nano printing
- Multilayer
- templates



Heat Treating With Salts - Heat Treat Today

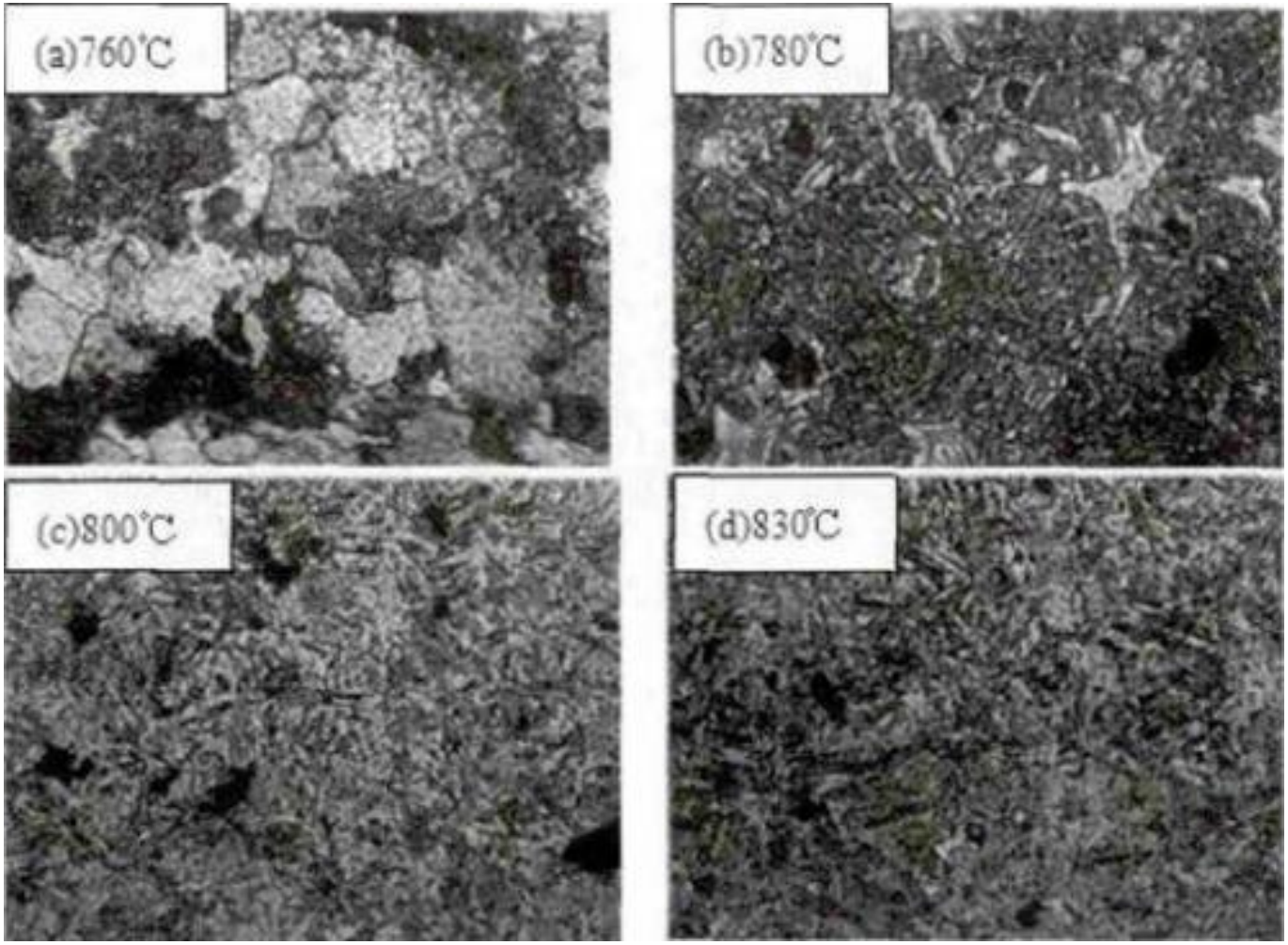
„Nature“ ways

- Cell tailoring (much more possibilities) …….



Structure of Bone Tissue | SEER Training (cancer.gov)

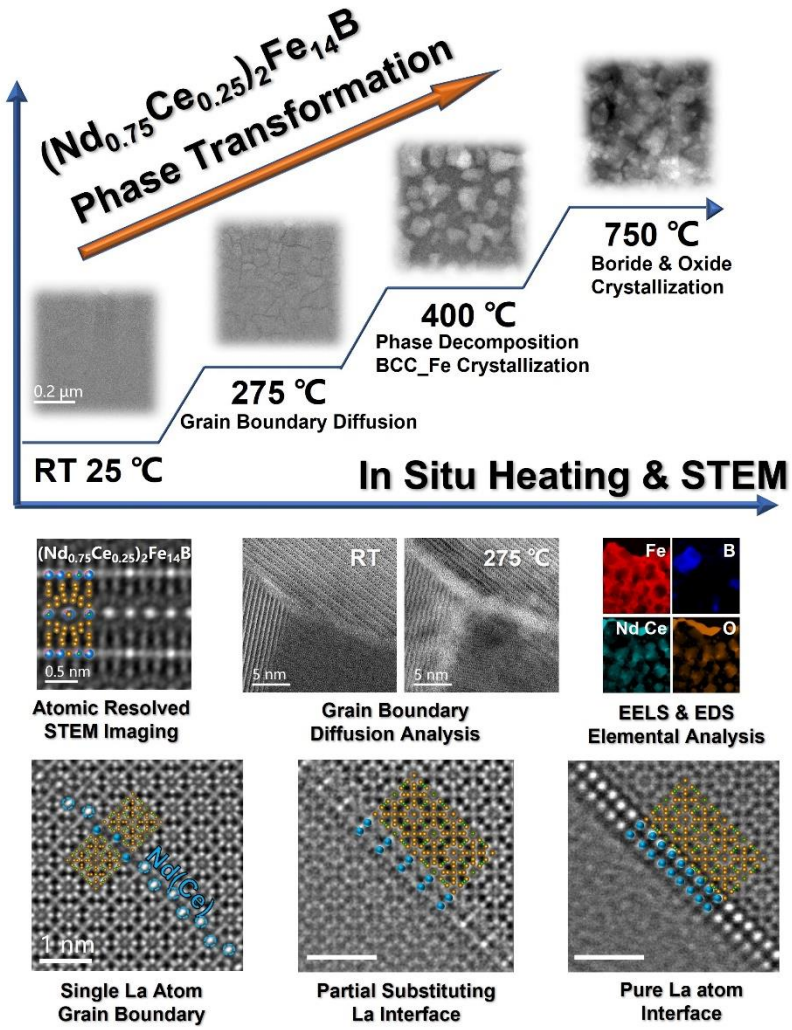
Heat treatment of steels



Study on the effect of different heat treatment processes on the microstructure and properties of 45 # steel - China piping solution supplier - China piping solution supplier (epowermetals.com)

Most used path to structural anthropogenic material - Phase transformation

[In-situ STEM study on thermally induced phase & microstructure evolution of lanthanide magnetic - American Chemical Society (digitellinc.com)]



Discussion