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

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

Audio test:

C8965 Equilibrium States and Phase Transformations of Materials

Lecturer: Prof. RNDr. Jiří Sopoušek, CSc.
E-mail: sopousek@mail.muni.cz, tel.: 549497138
Office: UKB A12/M231

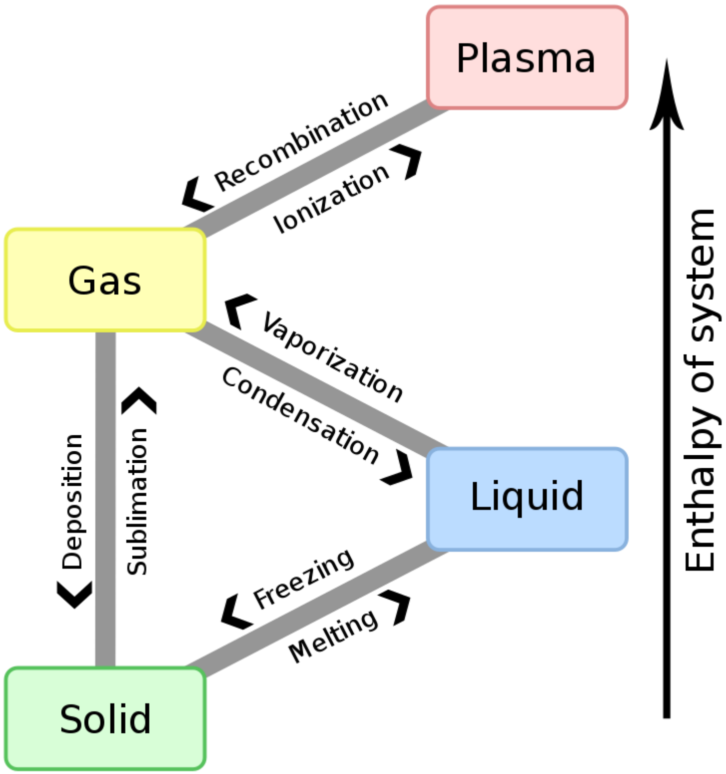
Department of Chemistry: http://ustavchemie.sci.muni.cz/

Brno, PS

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

Anotation

- Advanced equilibrium Thermodynamics of materials. The conditions of phase equilibria. The Gibbs energy and chemical potential of the system.
- The application of computational thermodynamics on the description of the equilibrium in the materials. Stable and metastable phase diagrams of multicomponent systems.
- Phase transformations, diffusion less phase transformations. Diffusion and nucleation mechanisms of phase transformations.
- Simulation of diffusion controlled phase transformations.
- Transformation diagrams of the materials.
- Advanced methods of study of phase transformations. Methods of thermal analysis of materials.



Phase transformations (simplified)

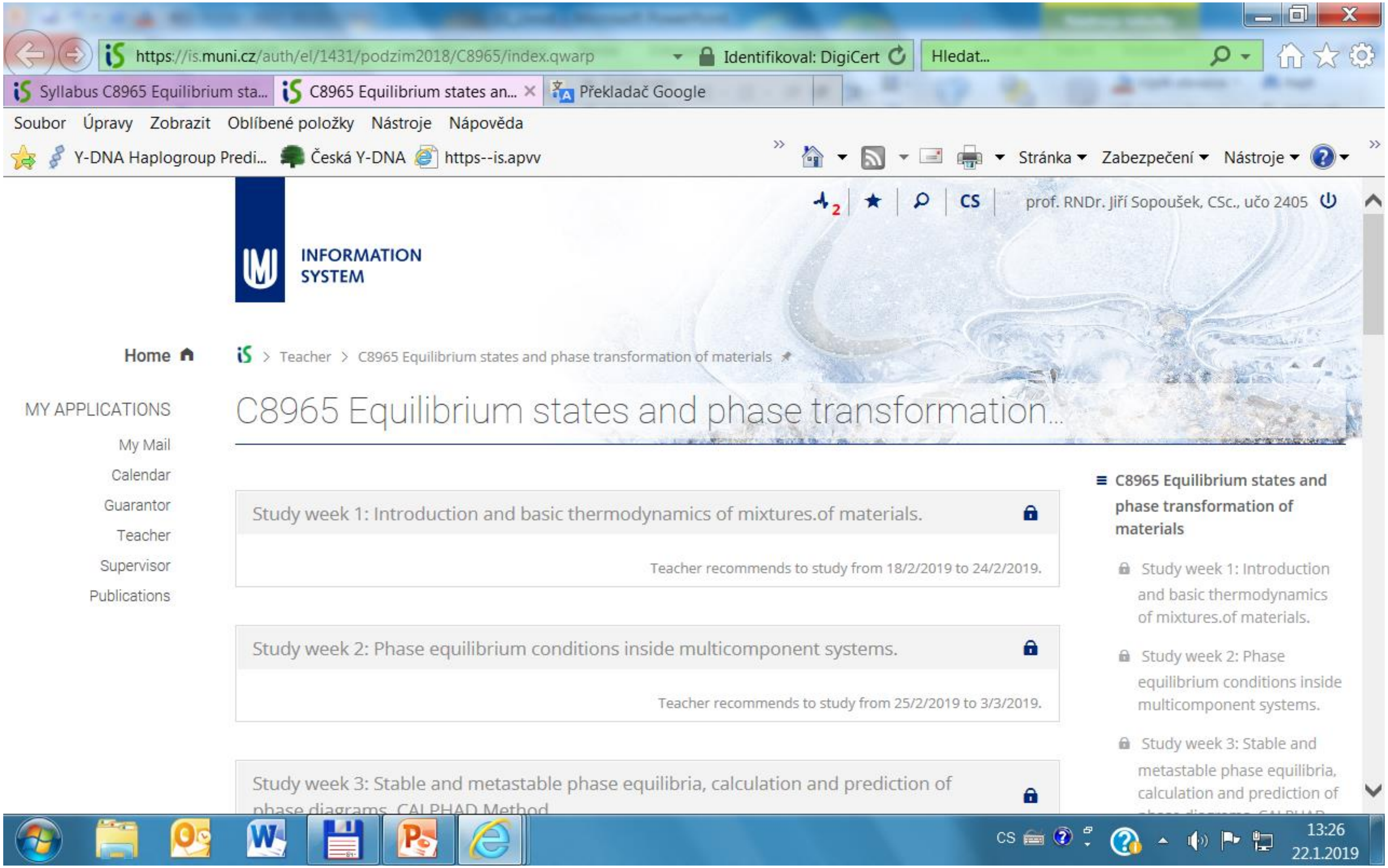
Subject administration

- 2hrs/week
- Use of**: Interactive syllabi of the subject**
- (2+2) credits requirements: short presentation, passing the exam.

Teaching time:
Class UKB A12/M311

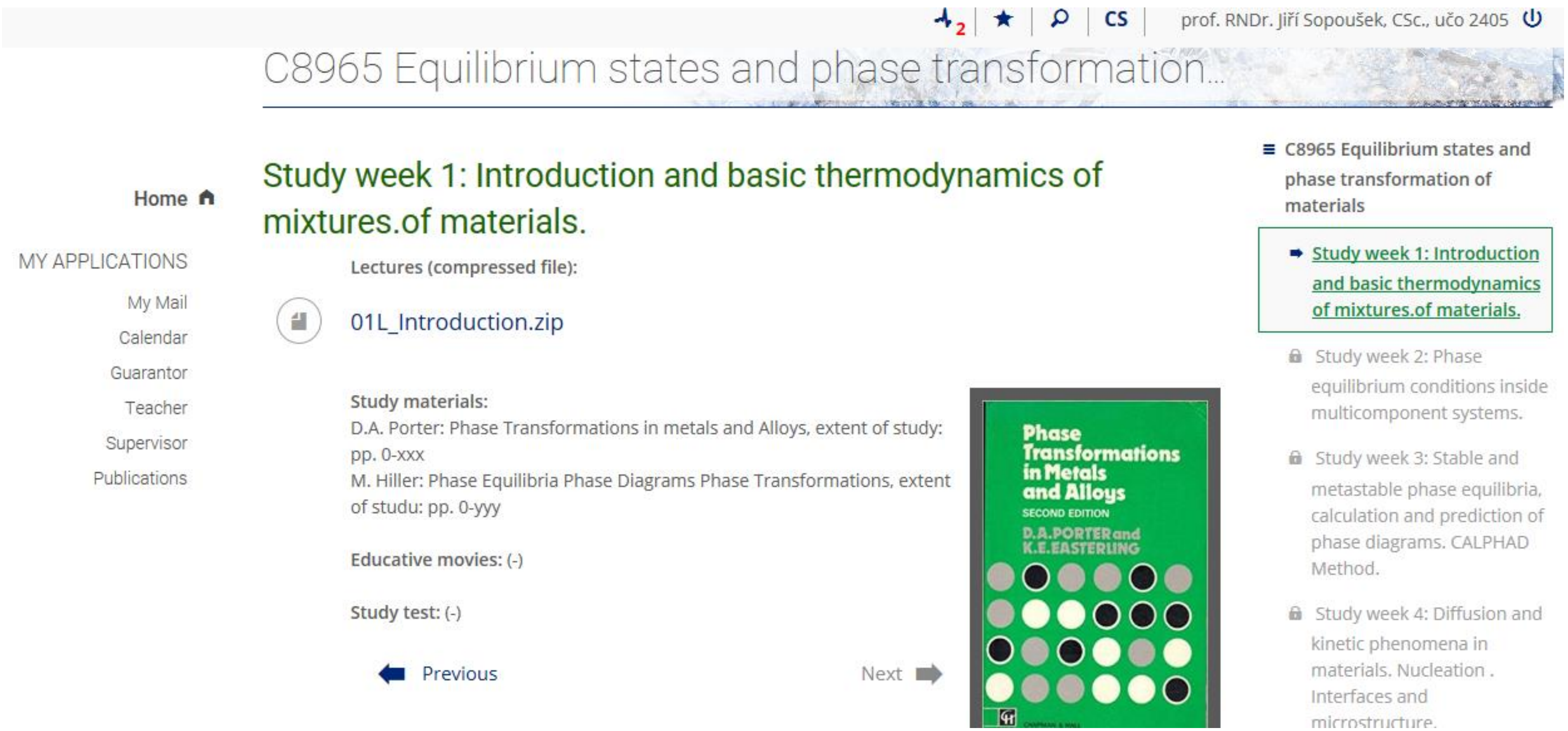
Study materials:
Information system of Masaryk University

Interactive syllabi (IS MU)



Interactive syllabi (content):

- Lectures (compressed file)
- Study materials (recommended pages)
- Movies
- Solution examples
- Testing

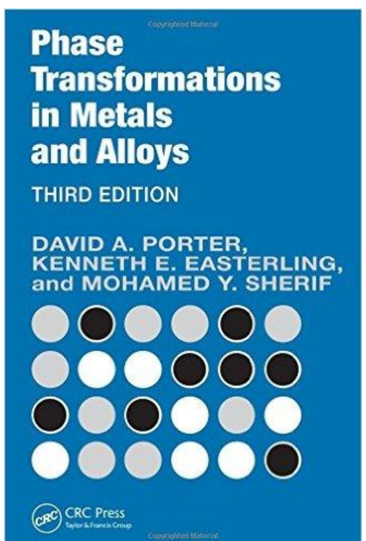


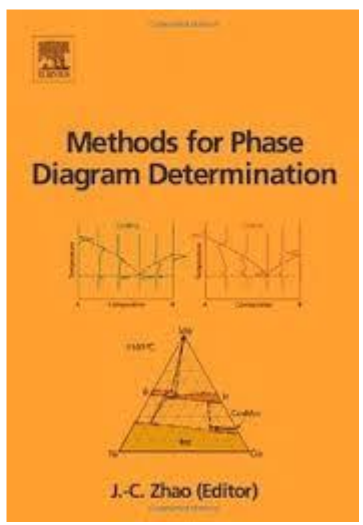
Time shedule

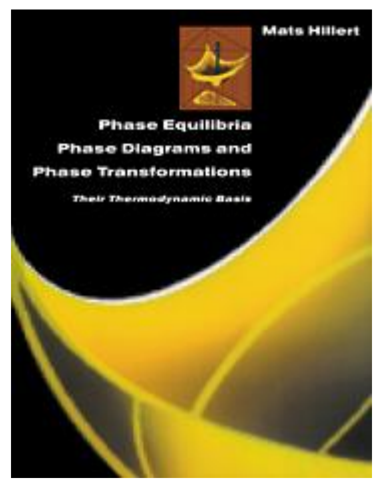
Study week	Lecture	Study week	Program
1.	Introduction and basic thermodynamics of mixtures.of materials.	8.	Crystallization and melting.
2.	Phase equilibrium conditions inside multicomponent systems.	9.	Diffusion controlled phase transformation(DICTRA), massive transformation.
3.	Stable and metastable phase equilibria, calculation and prediction of phase diagrams. CALPHAD Method.	10.	Non-diffusion phase transformations. Simulations of phase transformations controlled by diffusion.
4.	Diffusion and kinetic phenomena in materials. Nucleation . Interfaces and microstructure.	11.	Non-diffusion phase transformations. Simulations of phase transformations controlled by diffusion.
5.	Transformation diagrams of materials (TTT and CCT diagrams).	12.	Non-ferrous alloys and special materials.
6.	Heat treatment of materials.	13.	Short student`s presentation
7	Experimental methods . Thermal analysis (TGA, DTA, DSC, ...). Electron microscopy, diffraction methods, etc.	14.	SW Presentations (ThermoCalc, DICTRA)

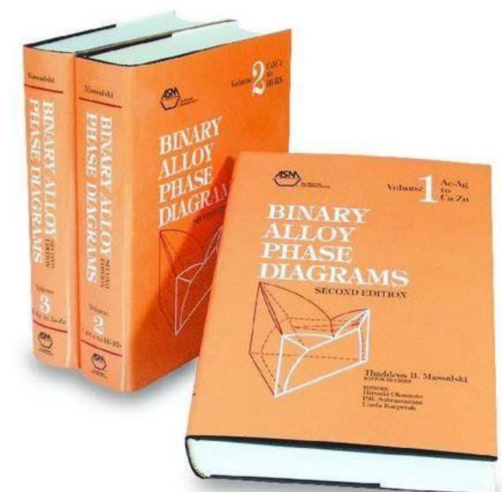
Recommended literature

- PORTER, David A. Phase Transfformations in Metal and Alloys. New York: Van Nostrand Reinhol, 1981. 445 s. ISBN 0-442-30439-0. info (http://ebooks.bfwpub.com/pchemoup.php, user: knihovna, password: uzivatel1)
- SAUNDERS, Nigel a Peter A. MIODOWNIK. *Calphad :calculation of phase diagrams : a comprehensive guide*. Oxford: Pergamon, 1998. xvi, 479 s. ISBN 0-08-042129-6. info
- Mats Hillert: Phase Equilibria, Phase Diagrams and Phase Transformations (Their Thermodynamic Basis), 2nd Edition, ISBN: 9780521853514



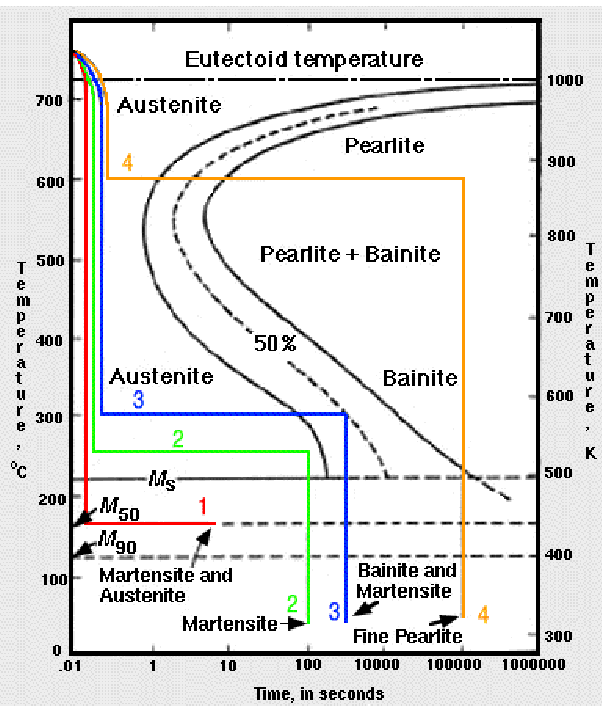


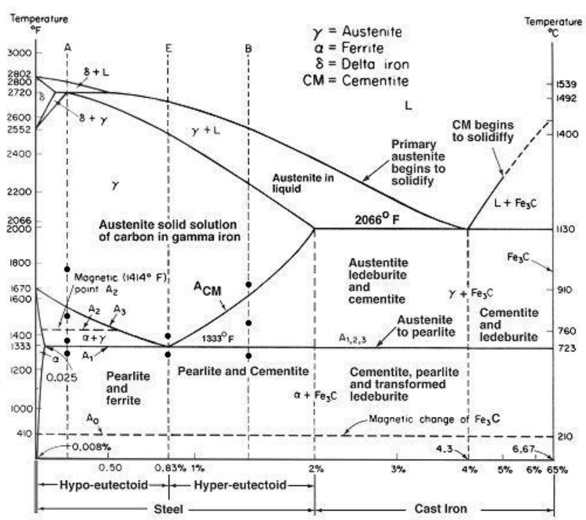


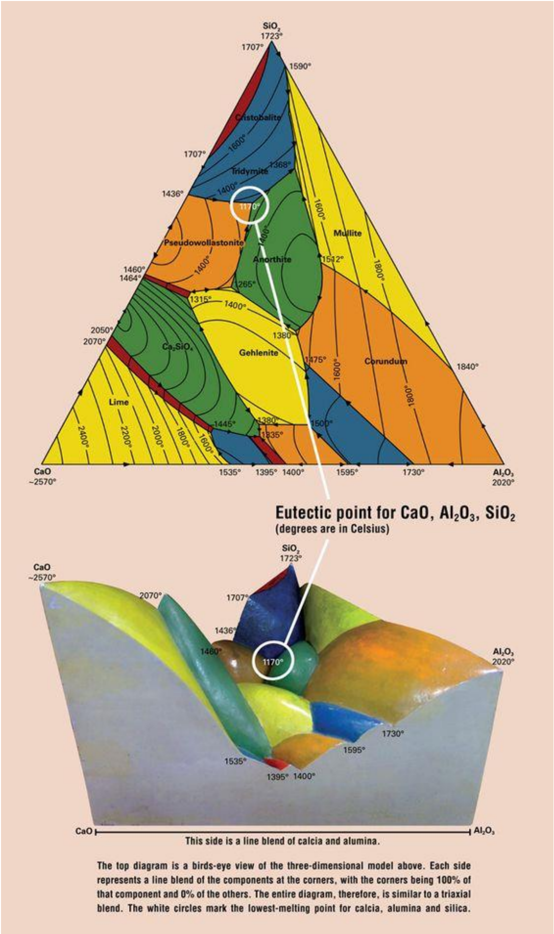


Learning Outcomes

- Phase diagram reading
- TTT and CCT reading
- Knowledge of transformations of common material
- SW: ThermoCalc, DICTRA







Selected application of phase transformations

Videos:

In Situ Electron Microscopy | Thermo Fisher Scientific - CZ

In-Situ Austenite-Ferrite Phase Transformation - YouTube

in situ phase transformation - Hledat Googlem

Videos (insitu microscopy):

In situ | Gatan, Inc.

Phase transformations for energy saving

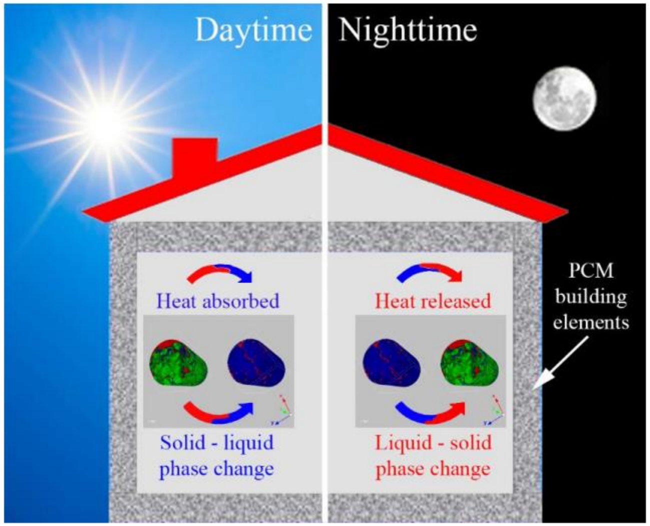


Figure 4. Charging process (working of PCM during daytime) and discharging process (working of PCM during nighttime).

	Material	Melting Temperature (°C)	Melting Enthalpy (J/g)
Fatty acids	Capric Acid	30.2	142.7
	Capric Acid	32	152.7
	Lauric acid	43.05	172.3
	Myristic acid	51.80	178.14
	Palmitic acid	60.42	233.24
	Stearic acid	54.29	188.28
Fatty acids esters	Butyl stearate	19	140
	Propyl palmitate	19	186
	Methyl palmitate	29	205
	Methyl eicosanate	45	230
	Methyl behenate	52	234
Alcohols	1-dodecanol	26	200
	Phenol	41	120
	Cetyl alcohol	49.3	141
Polyethylene glycol (PEG)	PEG 400	3.2	91.4
	PEG 600	22.2	108.4
	PEG800	25.39	133.6
	PEG 1000	34.89	143.62
	PEG 2000	52.63	180.70
	PEG 4000	48.95	183.10

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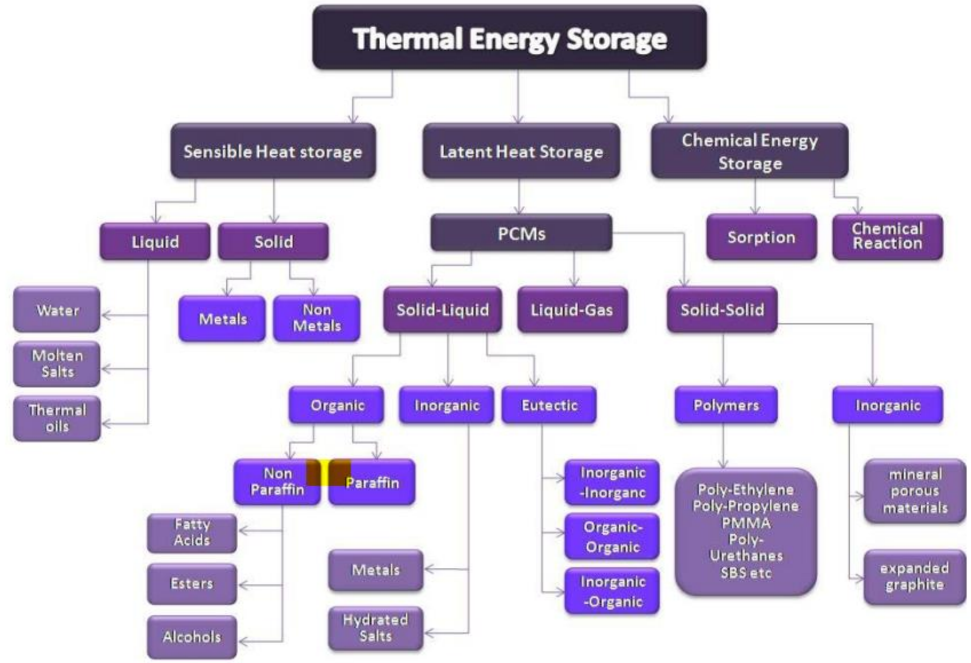


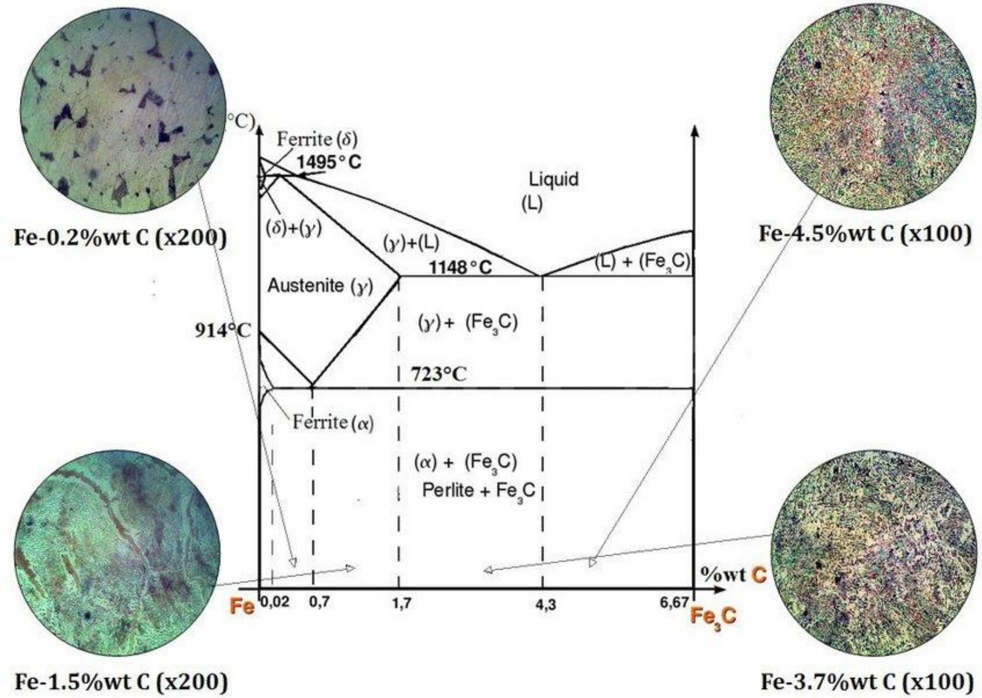
Figure 1. Classification of thermal energy storage types and materials.

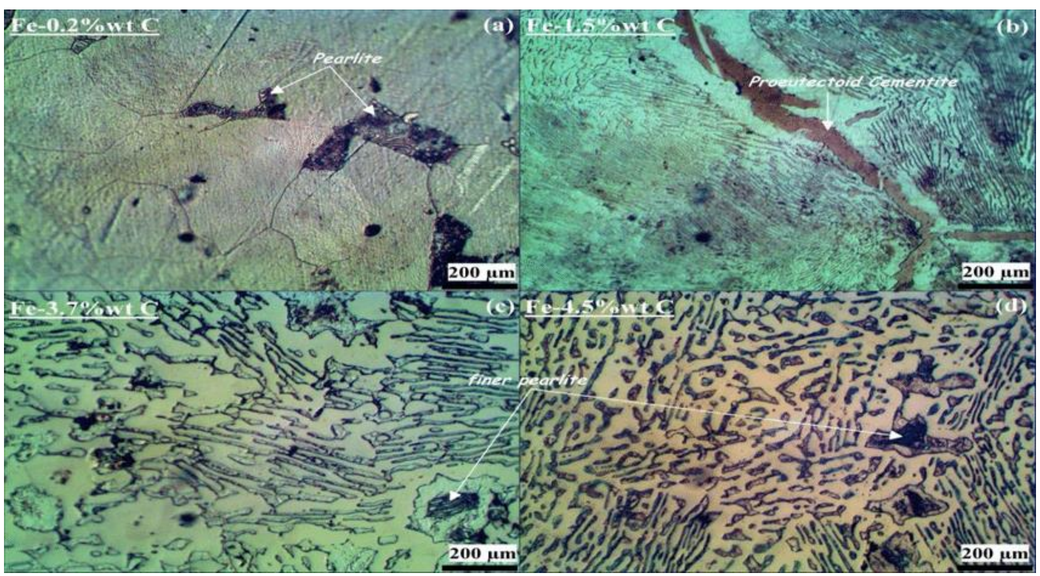
Encapsulation needed

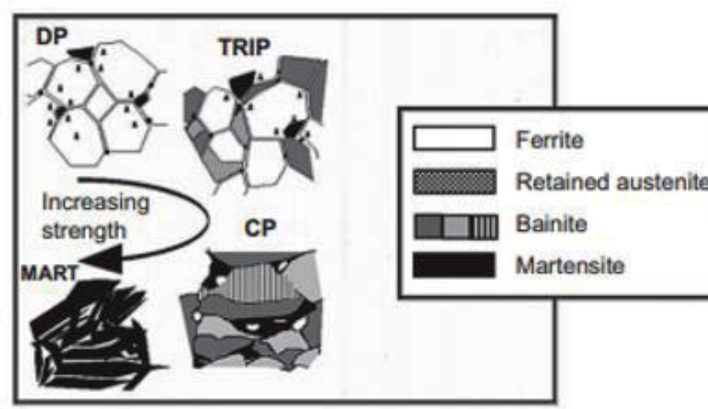
Latent heat of H_2O: 333J/g

Phase transformations and microstructure

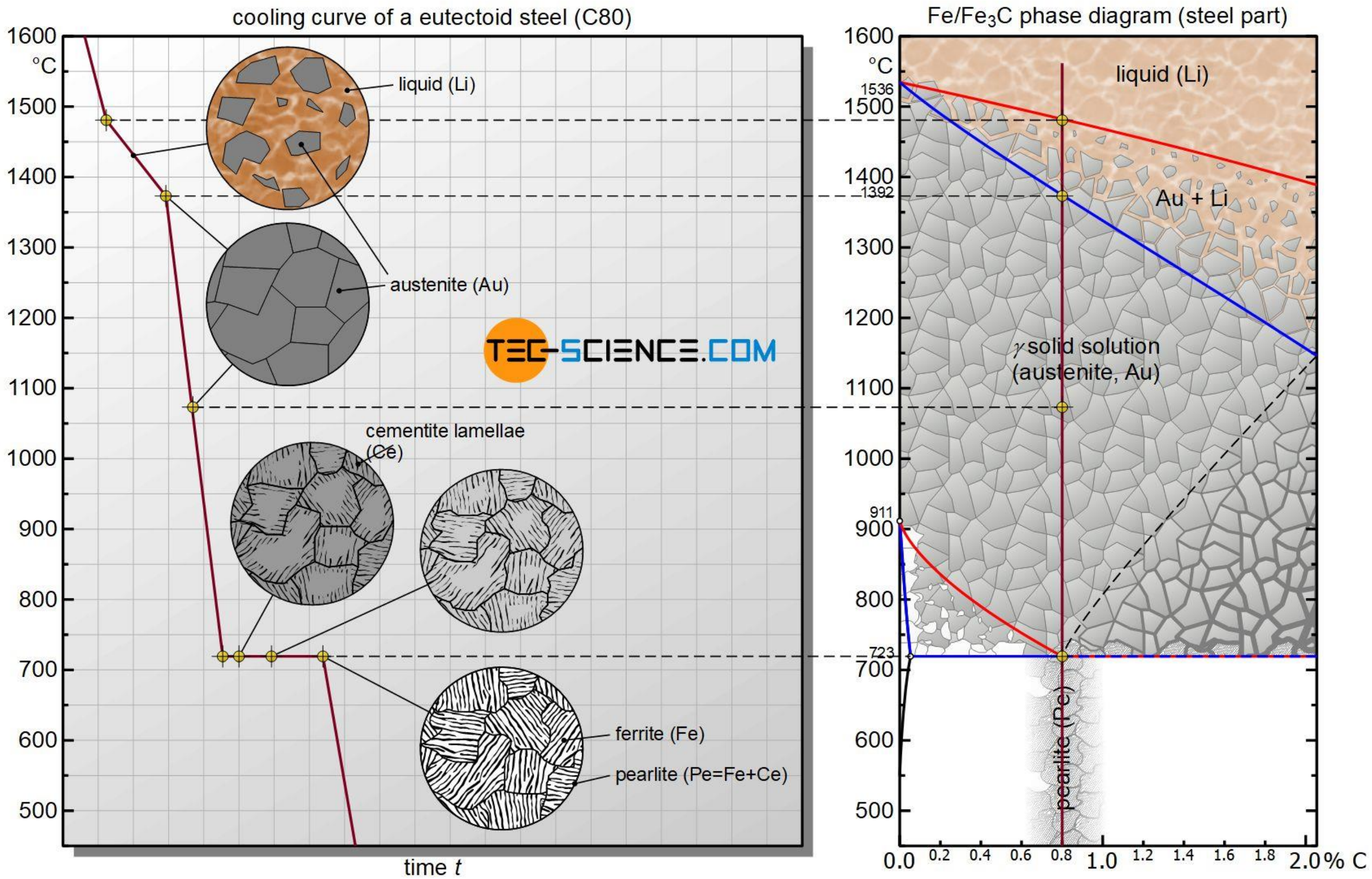
[Optical micrograph of Fe-xC alloys, etched with 4% Nital | Download Scientific Diagram (researchgate.net)]







Heat induced microstructure (eu.Fe-C)



[Phase transformations of steels in solidified state (metastable system) - tec-science]

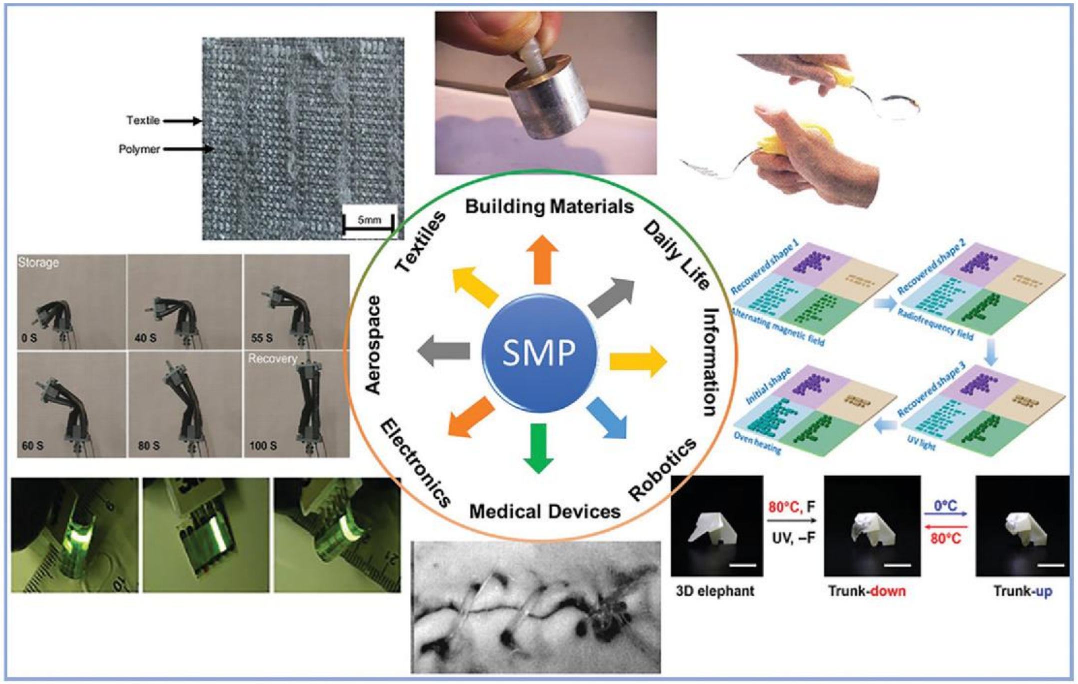
Shape memory alloys

Videos:

[A shape memory alloy: why nitinol items return to their initial state - YouTube]

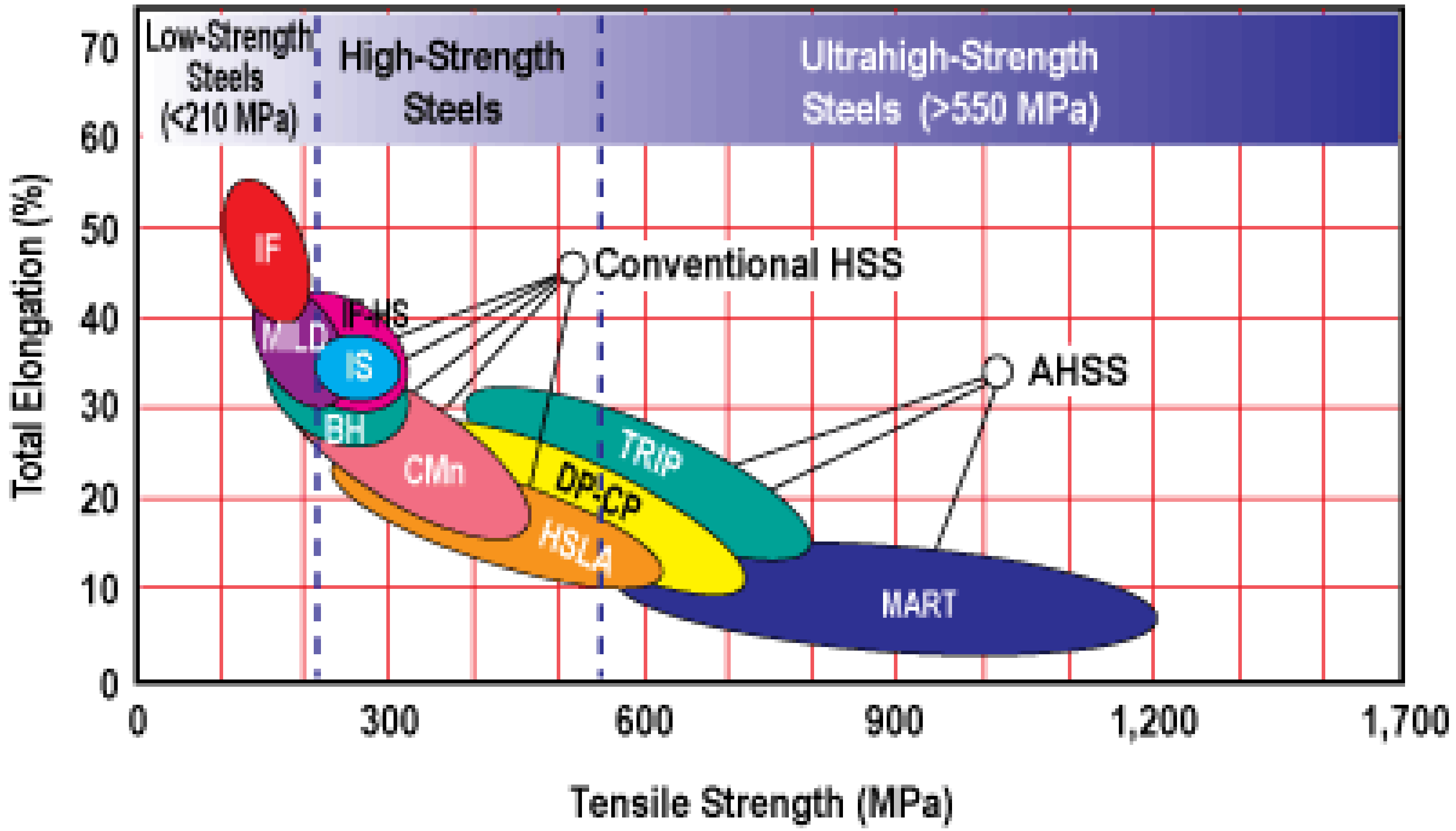
[Mini Lesson 5: What is a Shape Memory Alloy? - YouTube]

[Figure 1 from The research status and challenges of shape memory polymer-based flexible electronics | Semantic Scholar]

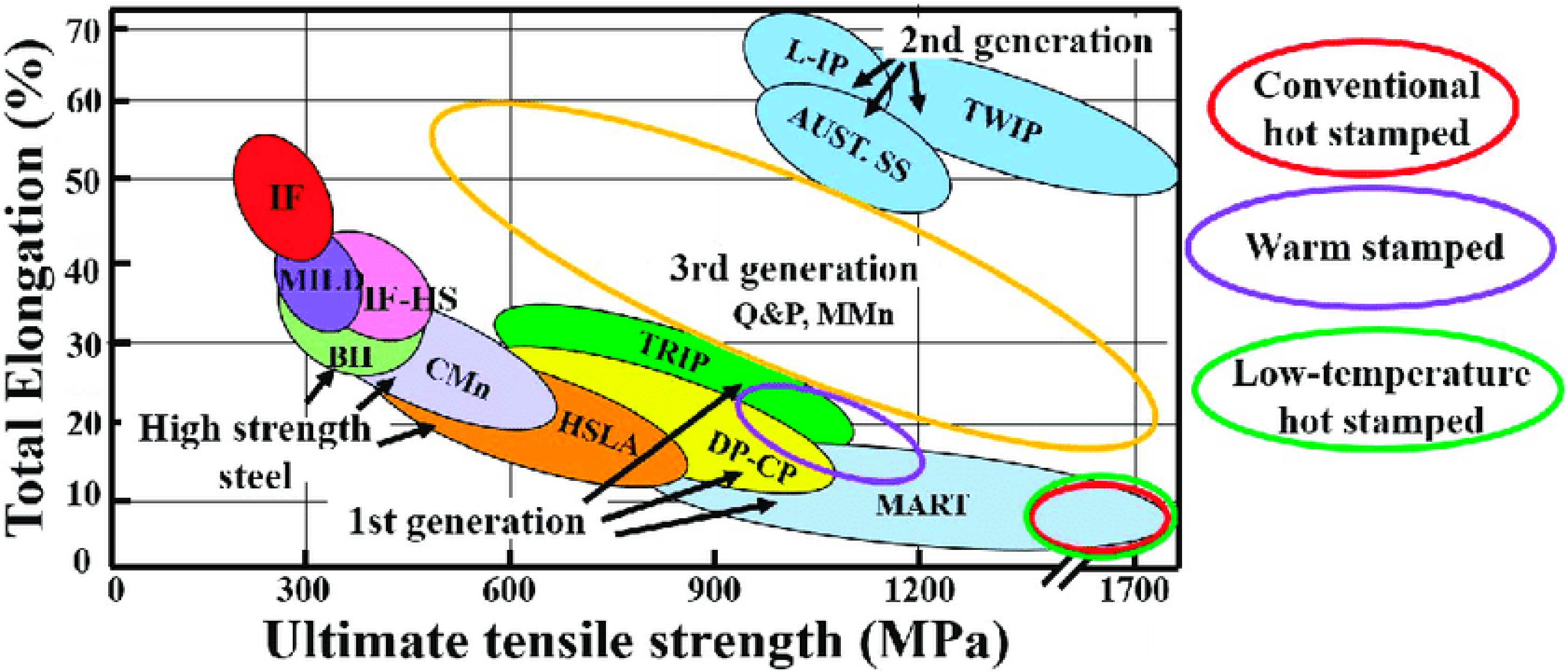


ıpplications of SMPs in the areas of medical devices,[43] textiles,[70] aerospace,[71] building materials,[72] robotics,[73] daily life,[74] elec

High strength materials - steels

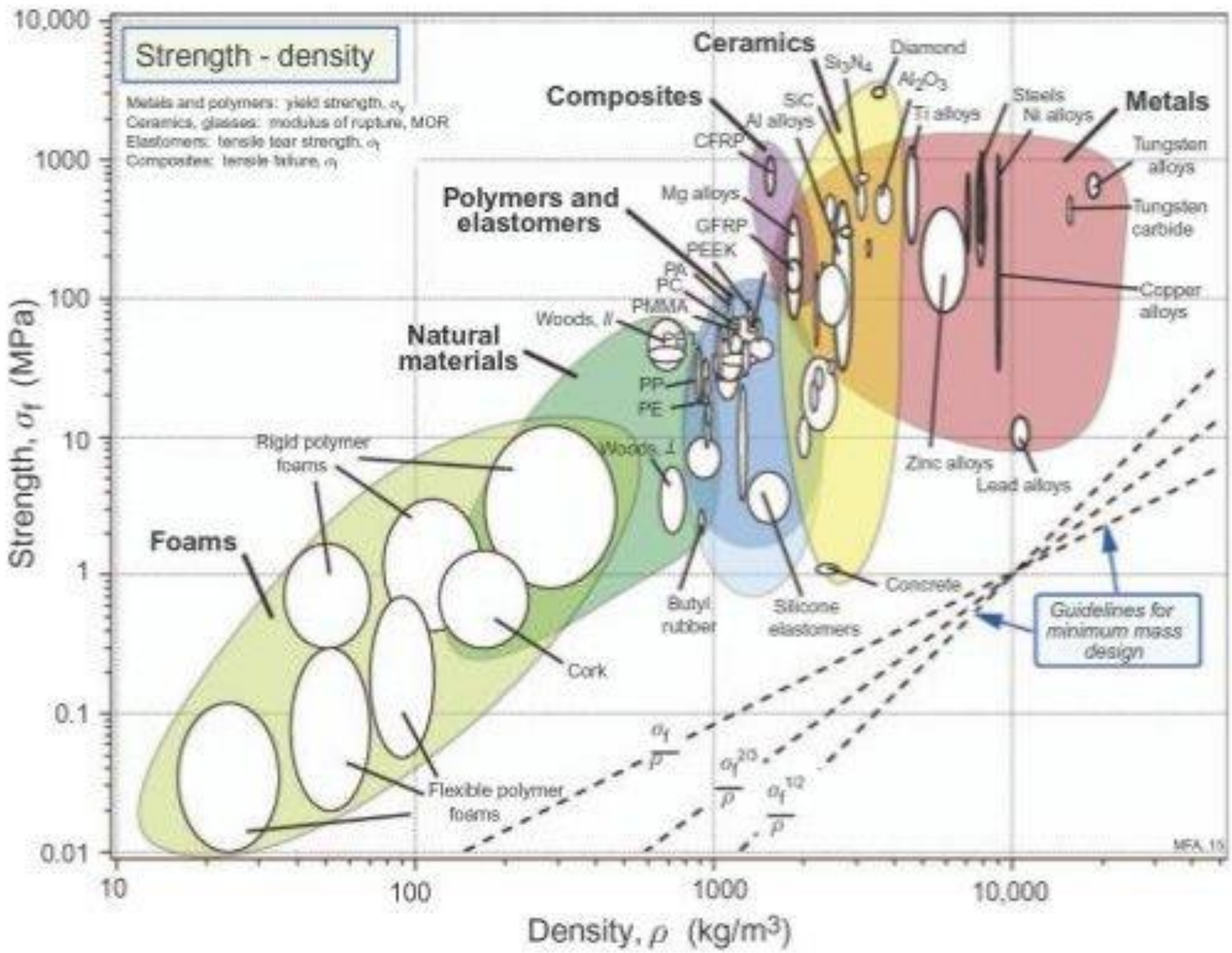


High strength materials - steels



Comparison between mechanical properties of various types of industrially manufactured steel grades and of parts produced by various hot stamping processes. Q&P: quenching and partitioning; TRIP: transformation induced plasticity. IF: interstitial-free steels; MILD: mild steels; IF-HS: interstitial-free high-strength steels; BH: bake hardening steels; CMn: carbon-manganese steels; HSLA: high-strength low-alloy steels; TRIP: transformation induced plasticity steels; DP-CP: dual phase and complex phase steels; MART: martensitic steels; Q&P: quenching and partitioning steels; MMn: medium-Mn steels; AUST. SS: austenitic stainless steel; L-IP: lightweight steels with induced plasticity; TWIP: twinning-induced plasticity steels.

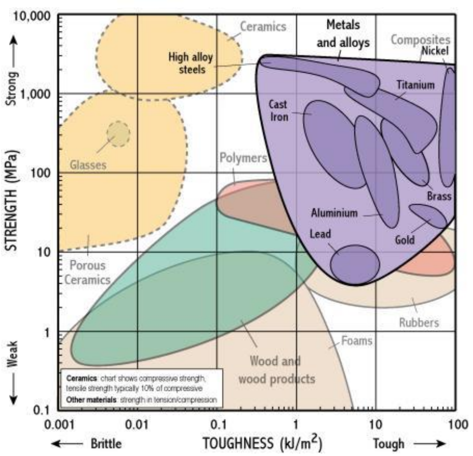
Strength

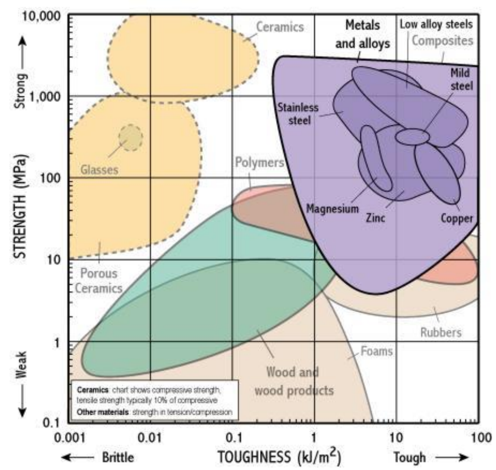


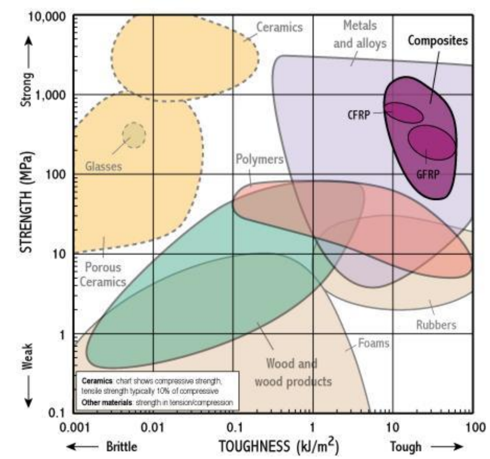
Strength - density
Metals and polymers: yield strength, σ_y
Ceramics, glasses: modulus of rupture, MOR
Elastomers: tensile tear strength, σ_t
Composites: tensile failure, σ_t
Ceramics
Composites
Metals
Polymers and elastomers
Natural materials
Foams
Diamond
Si3N4
Al2O3
SiC
Al alloys
Ti alloys
Steels
Ni alloys
CFRP
Tungsten alloys
Tungsten carbide
Mg alloys
GFRP
PEEK
PC
PMMA
Woods, ∥
Copper alloys
PP
PE
Woods, ⊥
Rigid polymer foams
Zinc alloys
Lead alloys
Butyl rubber
Silicone elastomers
Concrete
Cork
Flexible polymer foams
Guidelines for minimum mass design
Strength, σ_f (MPa)
Density, ρ (kg/m³)

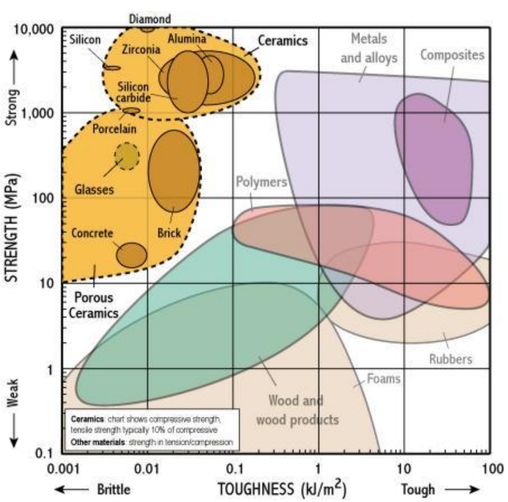
Strength vs. toughness

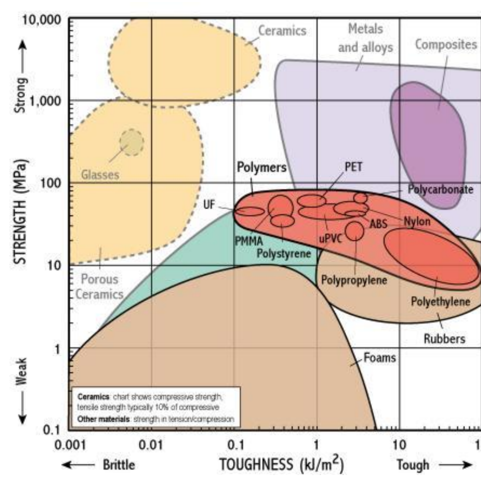
- Strength measures the resistance of a material to failure, given by the applied stress (or load per unit area)
- The chart shows yield strength in tension for all materials, except for ceramics for which compressive strength is shown (their tensile strength being much lower)
- Toughness measures the energy required to crack a material; it is important for things which suffer impact
- There are many cases where strength is no good without toughness, e.g. a car engine, a hammer
- Increasing strength usually leads to decreased toughness
- Tempered steel is tougher but less strong than after quenching.

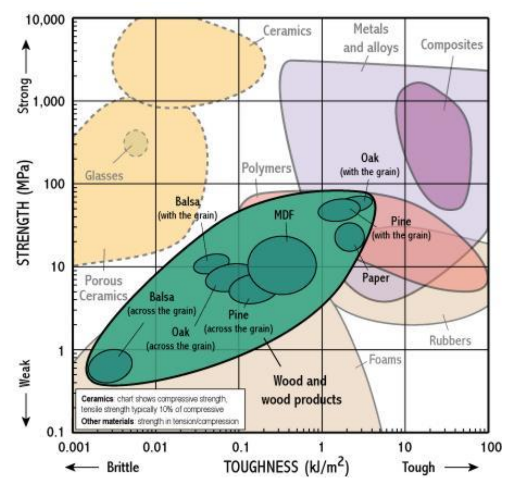




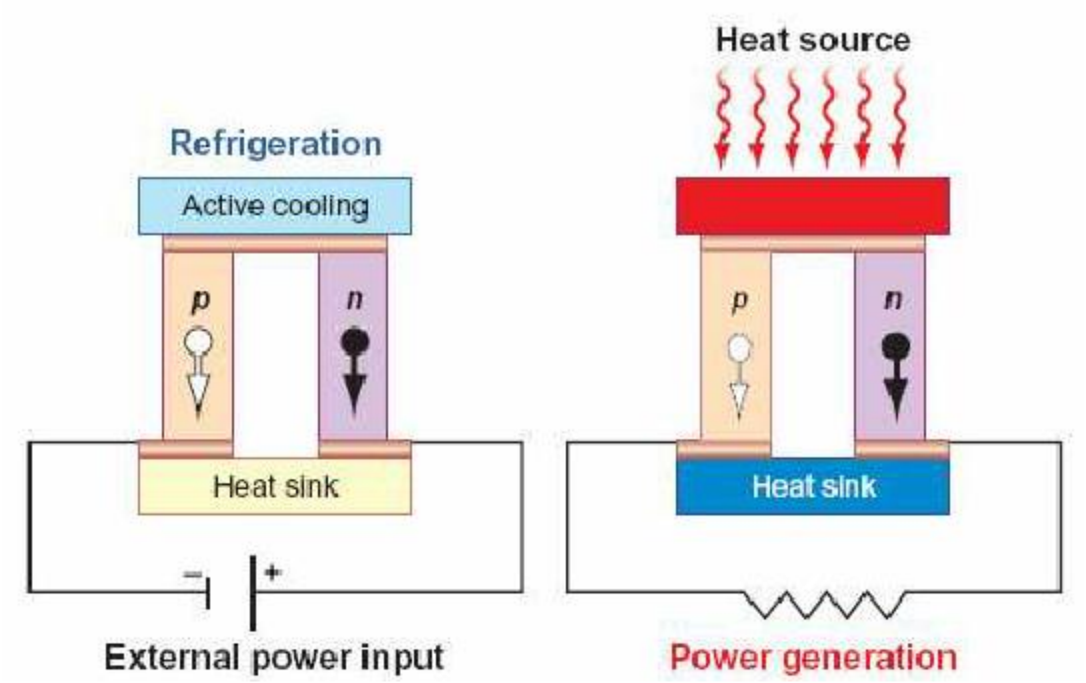




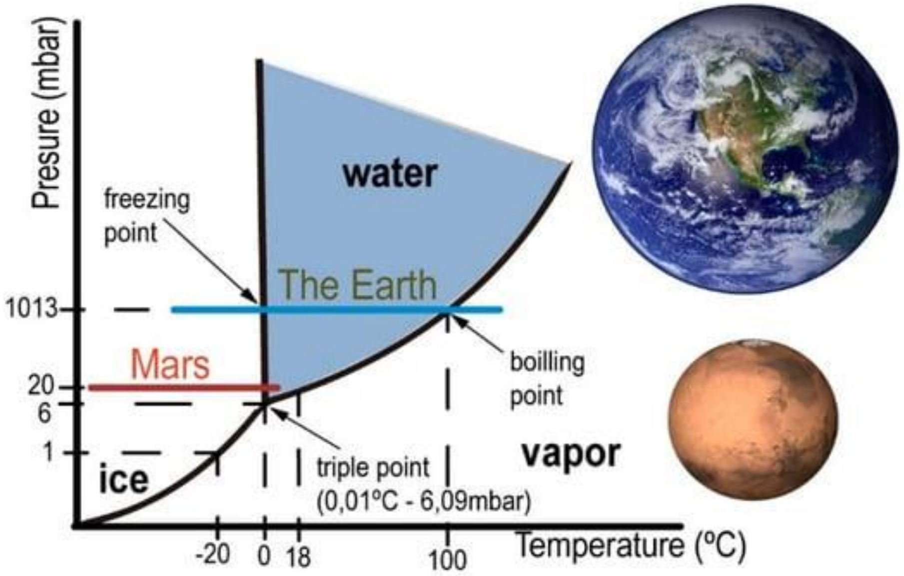


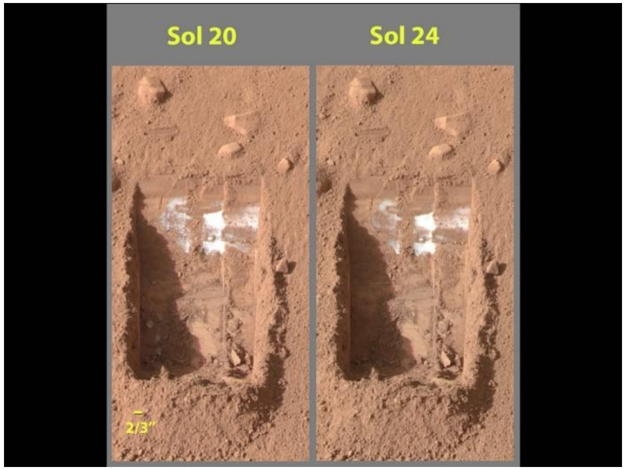


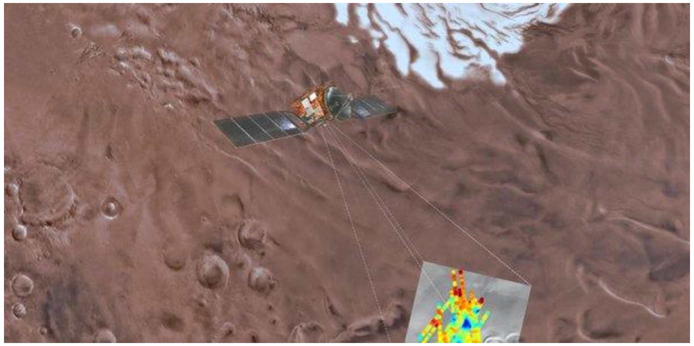
2017-2019, GA17-12844S: **Thermal and phase stability of advanced thermoelectric materials** (Investigator: P. Brož). Focused also on nanostructured thermoelectric materials.

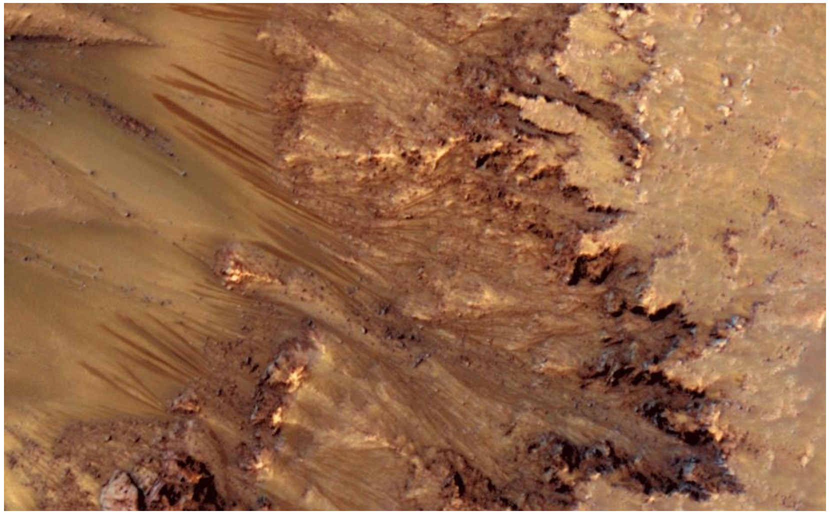


Phase transformations outside the Earth









[Water, Water Everywhere, but Not All Drops Have Life (phys.org)]

Discussion

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