MSE-483 : Advanced Phase Transformations

Lecture 1 : Introduction

COURSE DETAILS | BASIC DEFINITIONS | STATE & PATH VARIABLES | MATHEMATICAL STRUCTURE OF THERMODYNAMICS

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MADES

LABORATORY OF MATERIALS DESIGN AND SIMULATION

Introduction & Course organization

Location : MXF 1
Lectures : 09:15 – 11:00
Excercises : 13:15 – 14:00
Office Hours : *By appointment* (Friday 14:00-16:00)

Assistants : Lorenzo Piersante (lorenzo.piersante@epfl.ch)

Course Language : English

References:

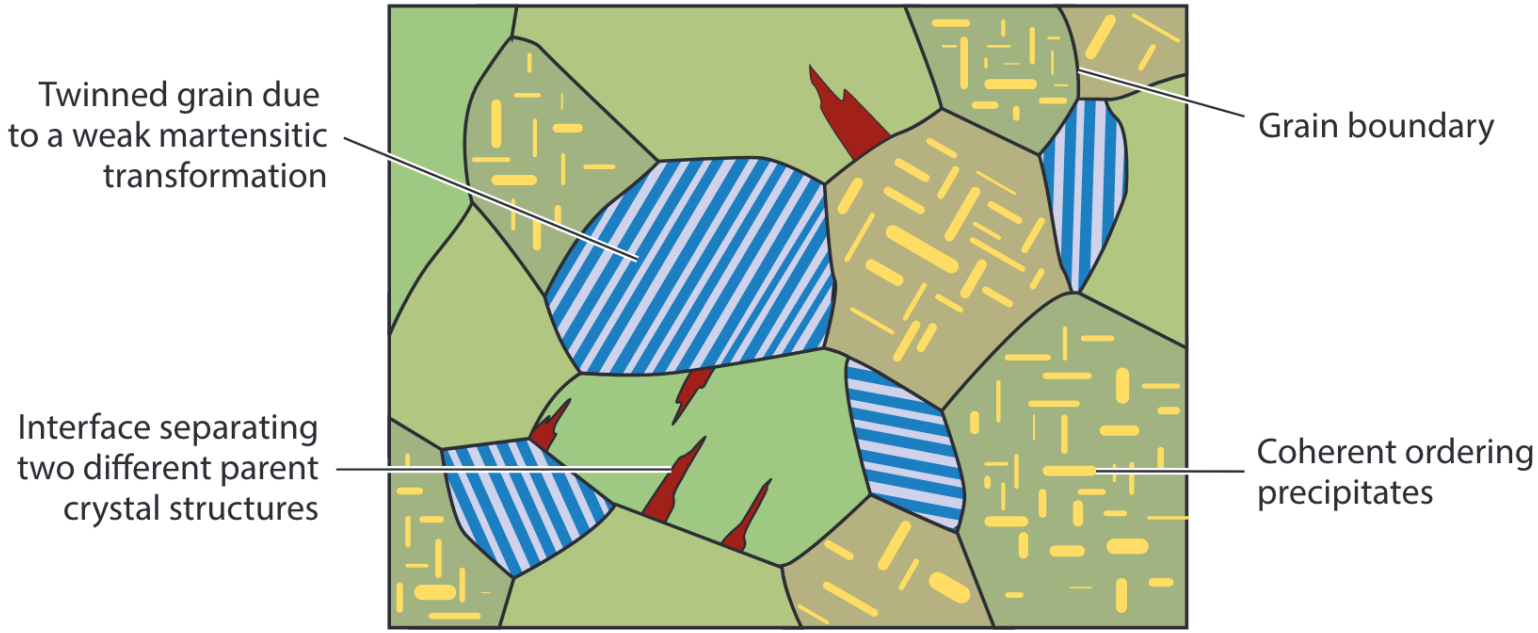
- Principles of Classical Thermodynamics: Applied to Materials Science Didier de Fontaine (Available online through the library)
- Theory of Structural Transformations in Solids, Khachaturyan, Dover
- Kinetics of Materials, Balluffi, Allen, Carter, Wiley 2005
- Phase Transformations in Metals and Alloys, Porter and Easterling

3 credits ~ 3 x 30 hours = 90 hours
14 x 3 hours of lectures/exercise → 48 hours at home/library ~ 3.5 hours a week

Final Exam : Final exam during the exam month. Date and location will be announced as soon as they are available. Students will be provided with a single formula sheet along the with the exam. No other papers/exam aids are allowed or required.

Advanced phase transformations

This course provides an overview of the phenomenological concepts and mathematical tools that have been developed to study the thermodynamics, kinetics and mechanics of solid-state phase transformations. We will focus on phase transformations in metallic alloys, energy storage materials, ceramics, electronic materials etc.

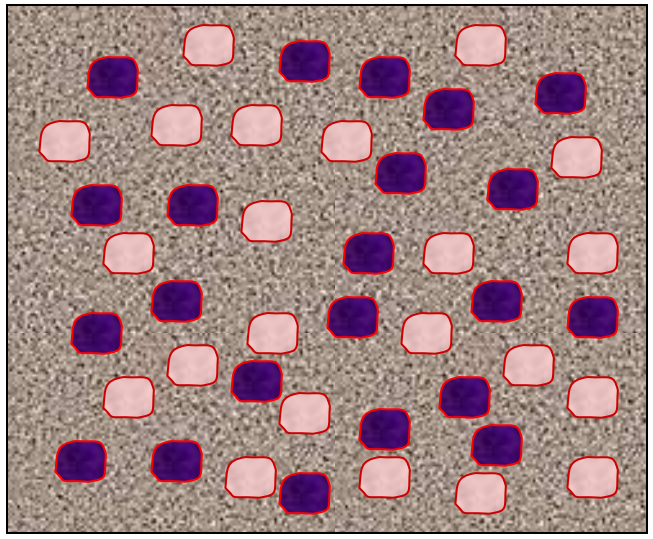


Course organization

Date	Topic
September 12	Introduction, Course overview, thermodynamics of phase transitions *(No exercise session)*
September 19	Mathematical structure of thermodynamics *(No exercise session)*
September 26	Equilibrium conditions and phase transitions in unary systems
October 3	Clausius-Clapeyron relation
October 10	Kinetics of phase transitions
October 17	Kinetics of phase transitions
October 24	*Mid-semester Break*
October 31	Phenomenological theories of spinodal decomposition
November 7	Phenomenological theories of spinodal decomposition
November 14	Descriptors of phase transitions and phase-field models
November 21	Classical nucleation theory
November 28	Phase transformations with interfaces
December 5	*No lecture, only exercise session*
December 12	Diffusionless phase transitions
December 19	Diffusionless phase transitions

A few examples of phase transitions

Crystallization of chocolate



< 20 μm

Sugar grains

Cocoa powder grains

Matrix of cocoa butter

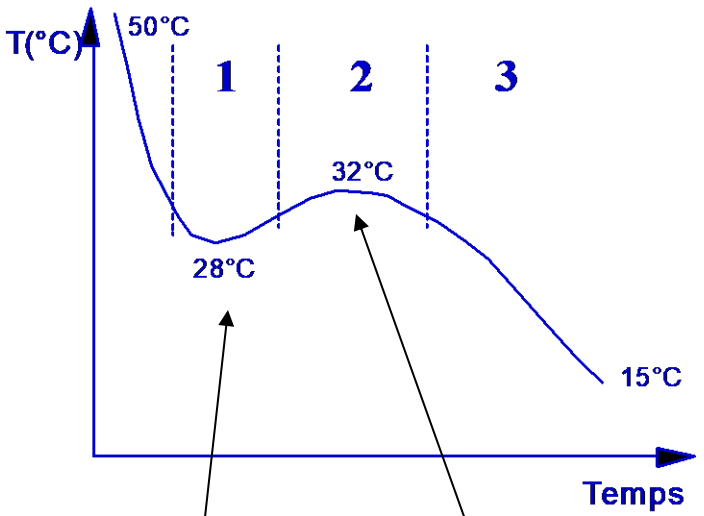
Chocolate is a “composite” material with a matrix of cocoa butter.

Energy : 550 kcal/100 g !

Additional listening

Courtesy Michel Rappaz

Crystallization of chocolate



Nucleation of β' and β

Remelting of β' and transformation $\beta' \rightarrow \beta$

The goal of the tempering operation is to obtain the right density of nuclei in the cocoa butter matrix with the right crystalline structure .

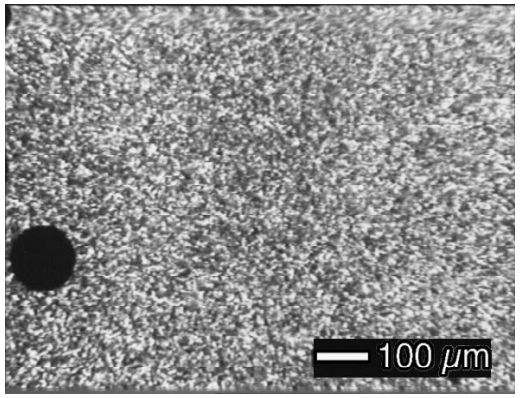
Why ? Because cocoa butter, like many lipids, is polymorphic.

Phases		T_m [°C]
I	γ	17
II	α	24
III	β_1'	28
IV	β_2'	33
V	β	35
VI	?	

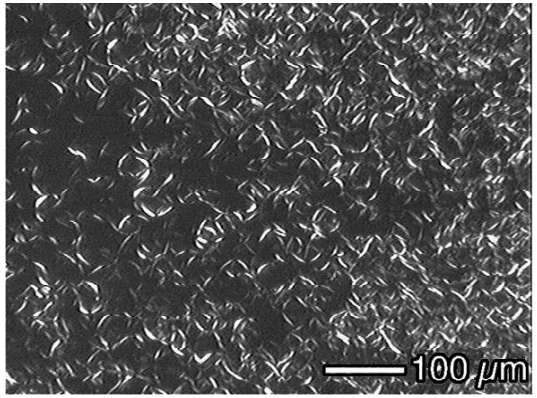
Stability

Courtesy Michel Rappaz

Crystallization of chocolate



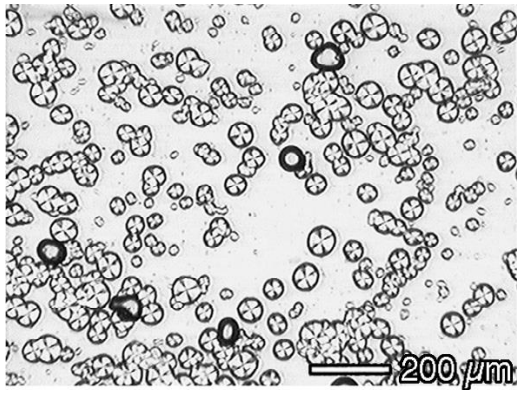
POS fine mass (16 °C)



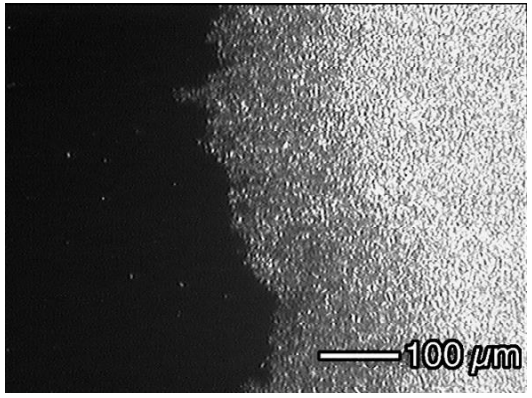
SOS needles (21 °C)

A few morphologies observed under an optical microscope when isolated components of cocoa butter are solidified isothermally.

POP, SOS and POS are three triglycerides that occur in cocoa butter



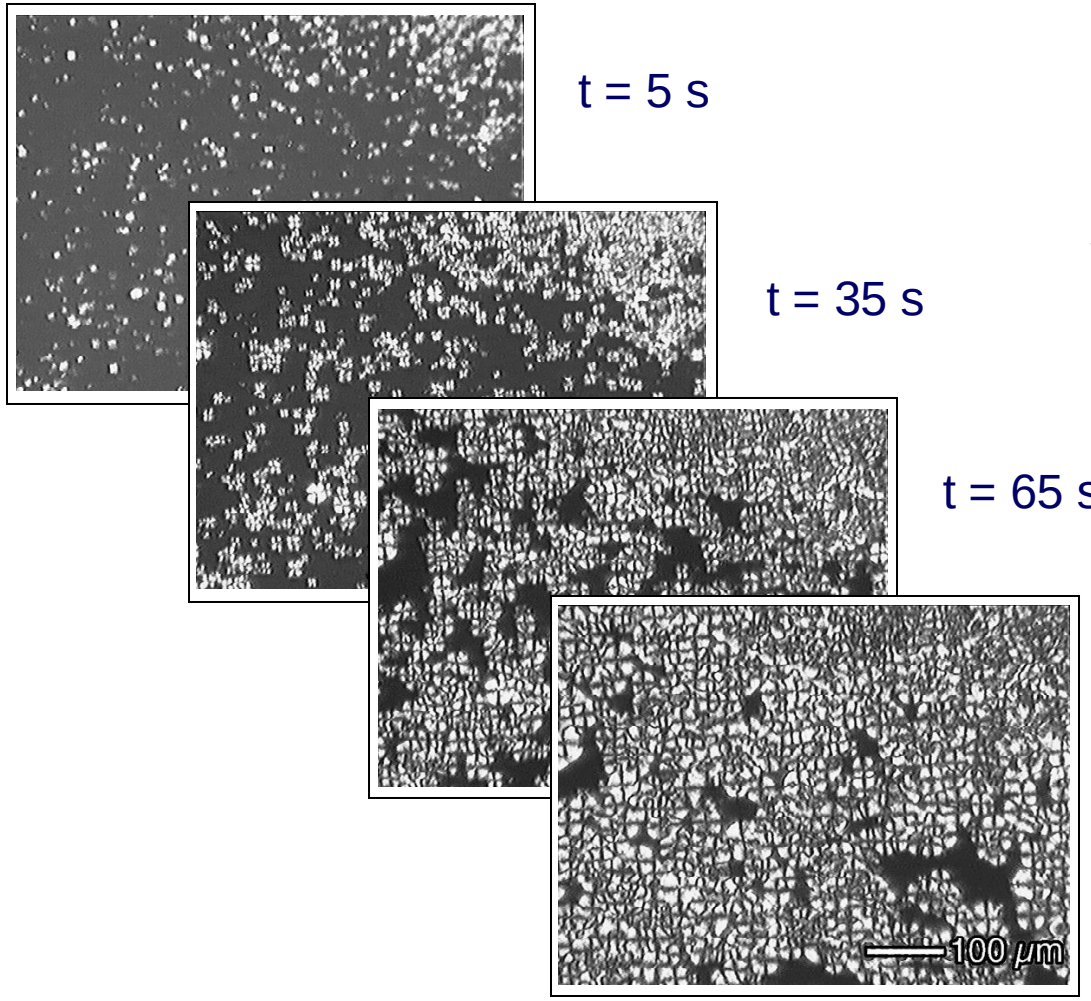
POP spherulites (16 °C)



POP directional mass (20 °C)

Courtesy Michel Rappaz

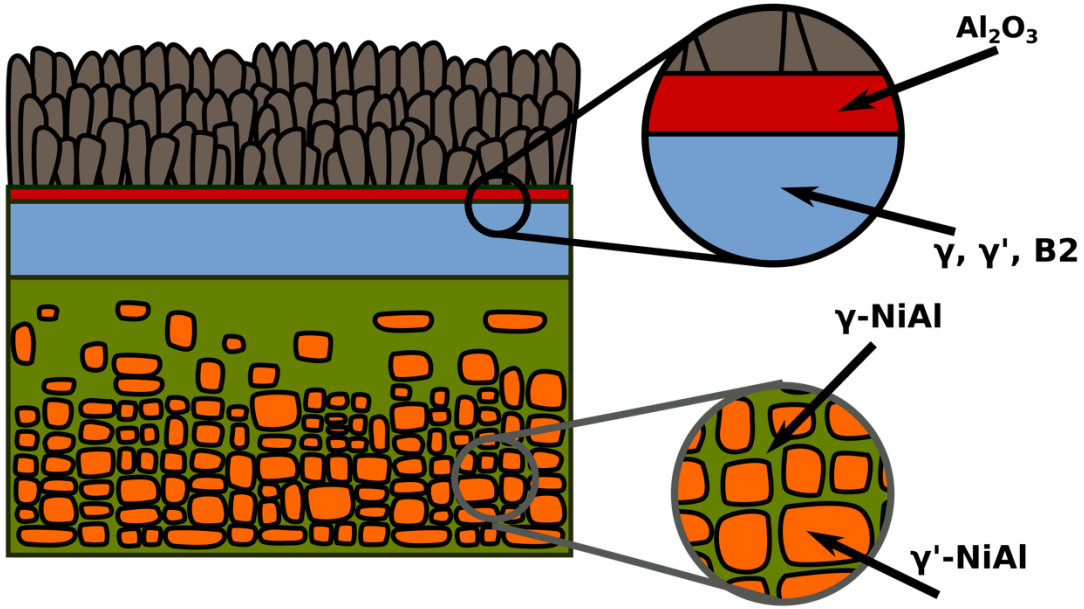
Crystallization of chocolate

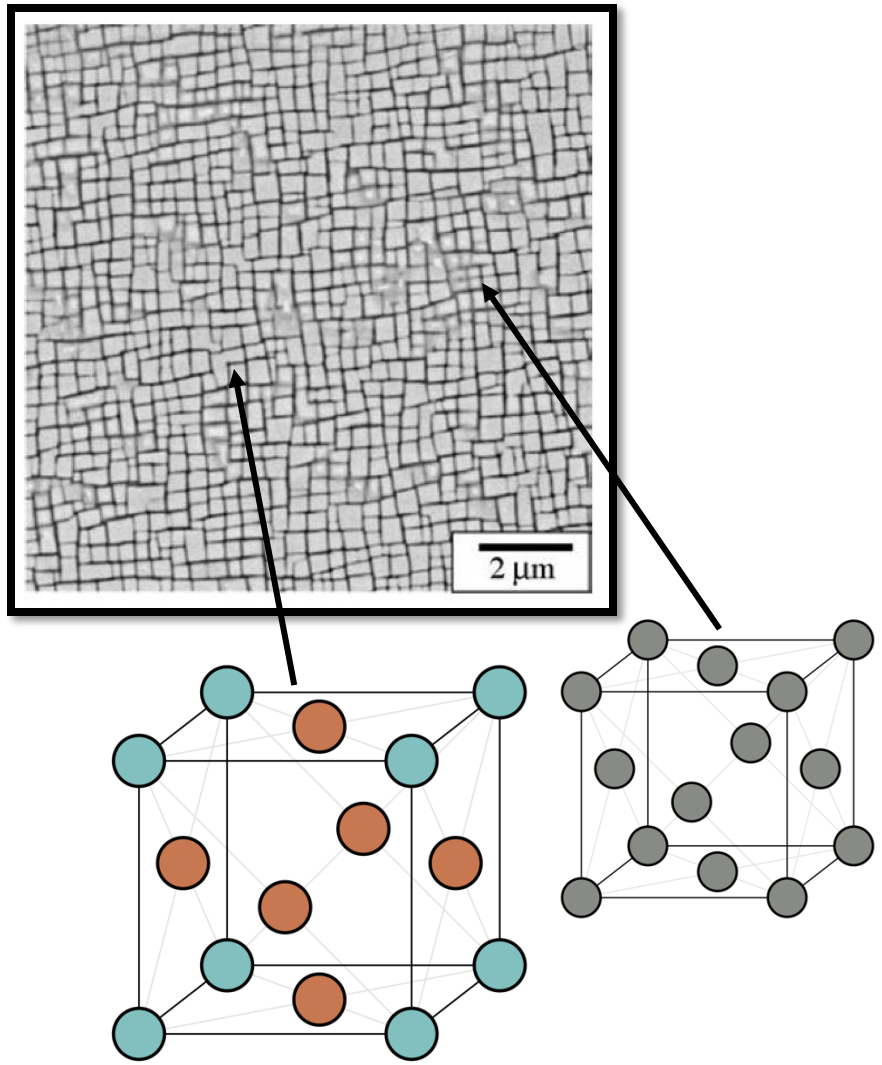


Sequence of crystallization of POP @ 15 °C (spherulites)

Courtesy Michel Rappaz

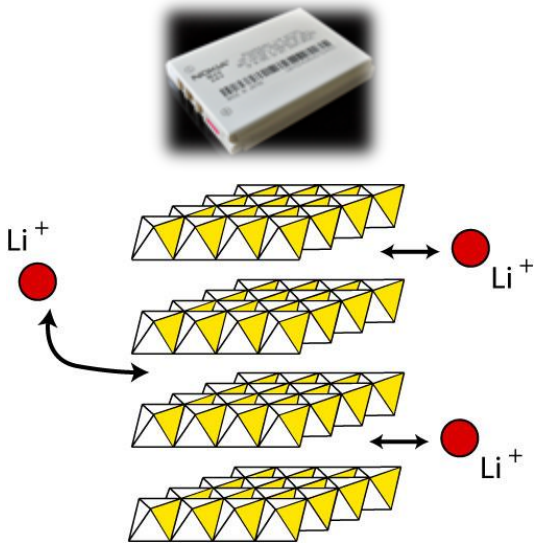
A few examples of phase transitions

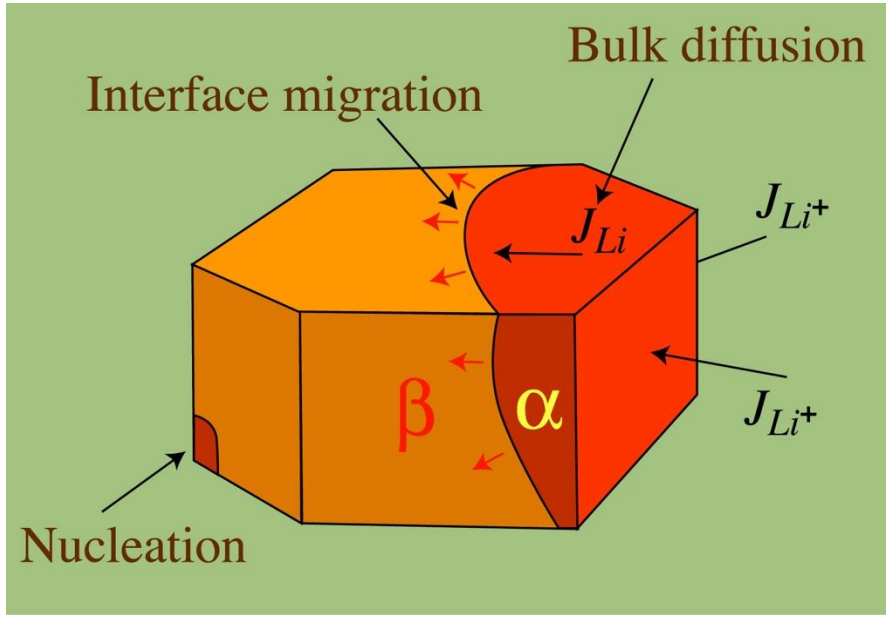


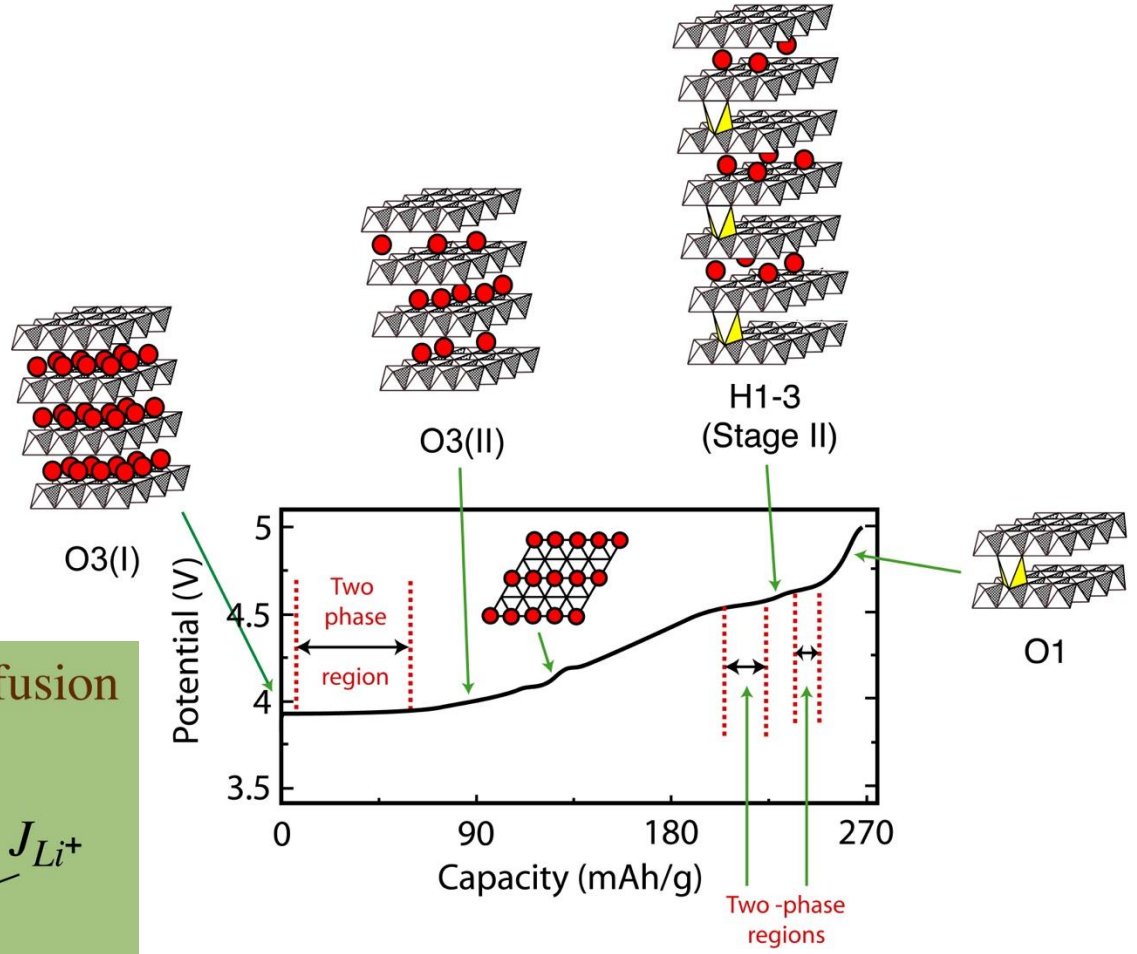


R. Reed, The Superalloys, (2006)

A few examples of phase transitions







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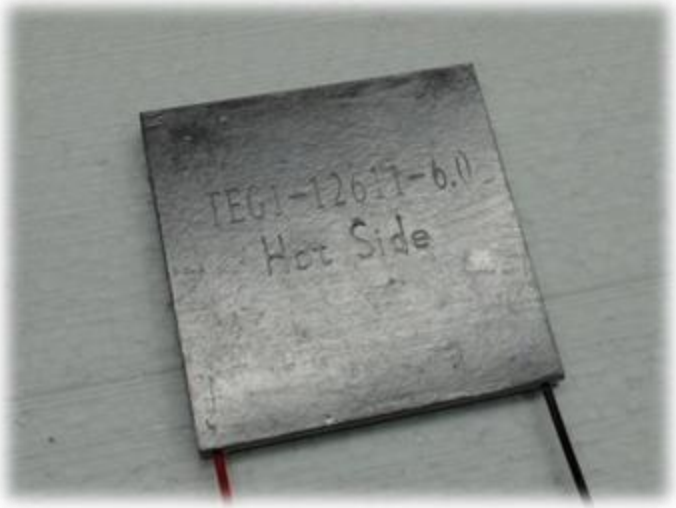
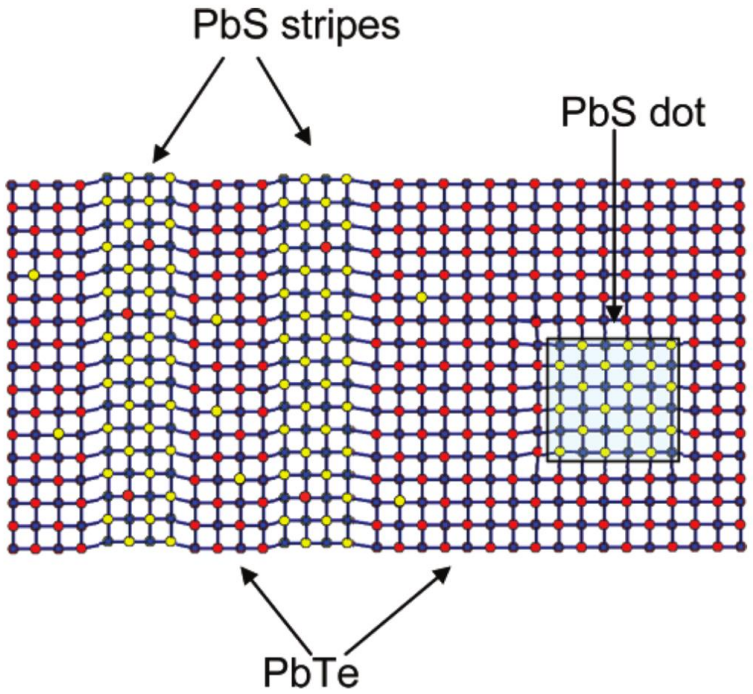
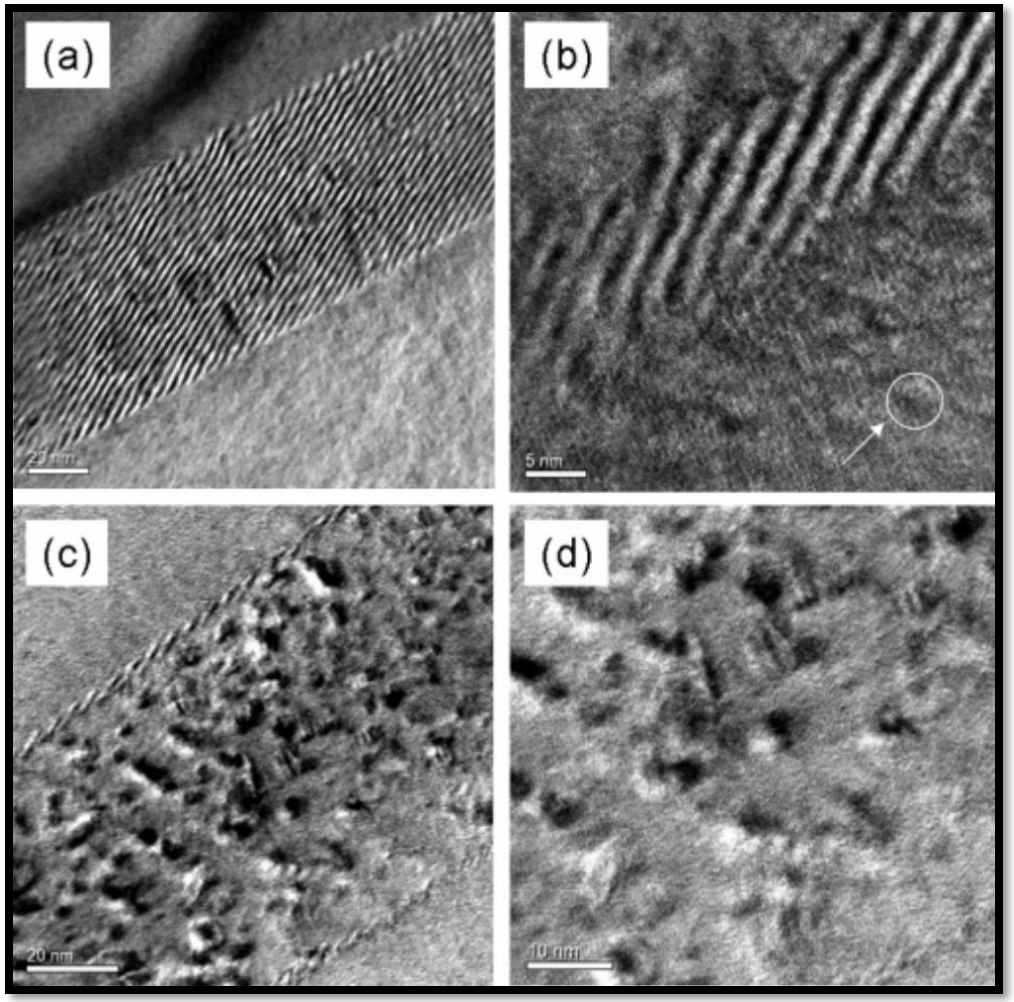
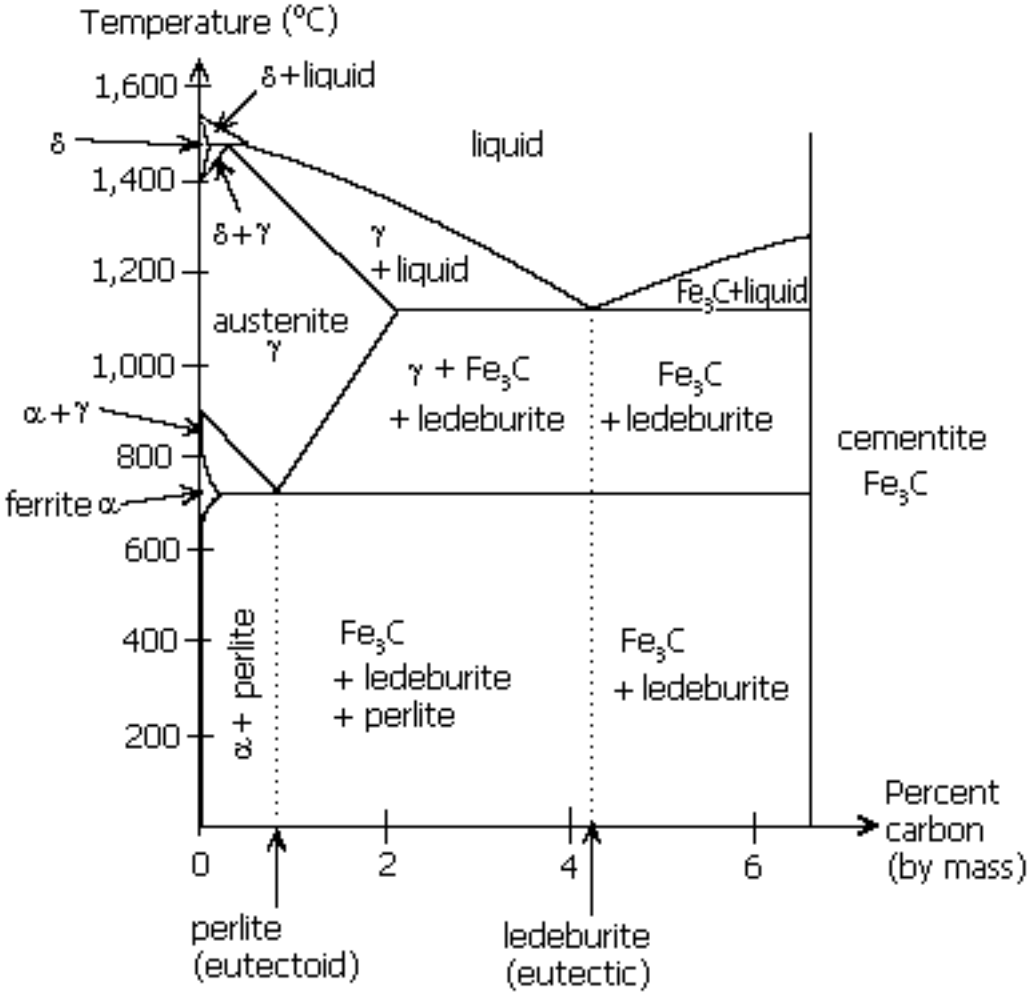


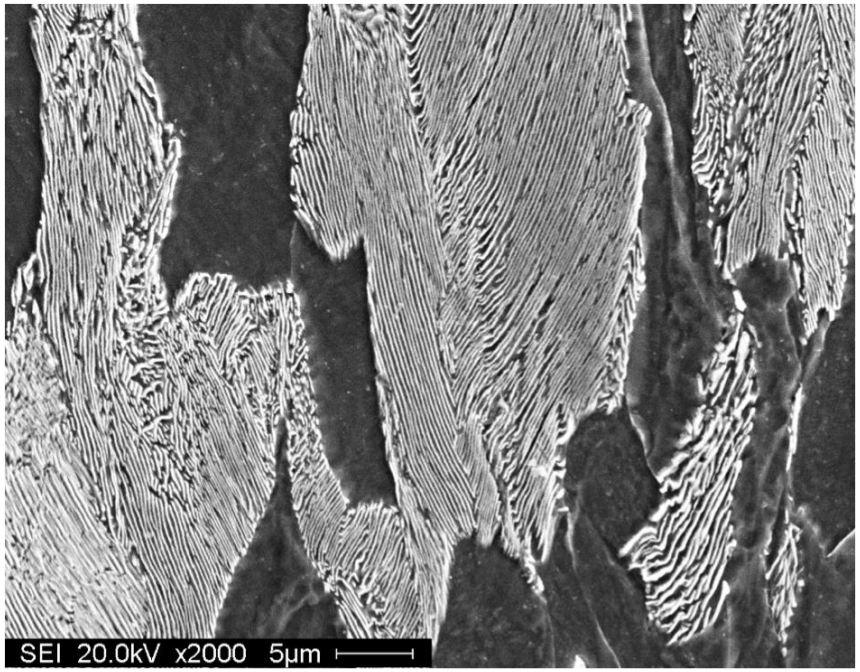




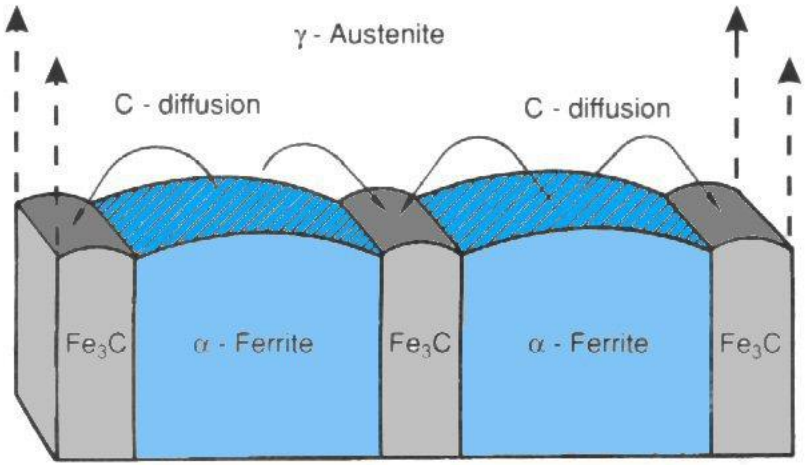
Androulakis, J., et al. (2007). *Journal of the American Chemical Society*, *129*(31), 9780–9788.

A few examples of phase transitions





Microstructure of ferrite + pearlite

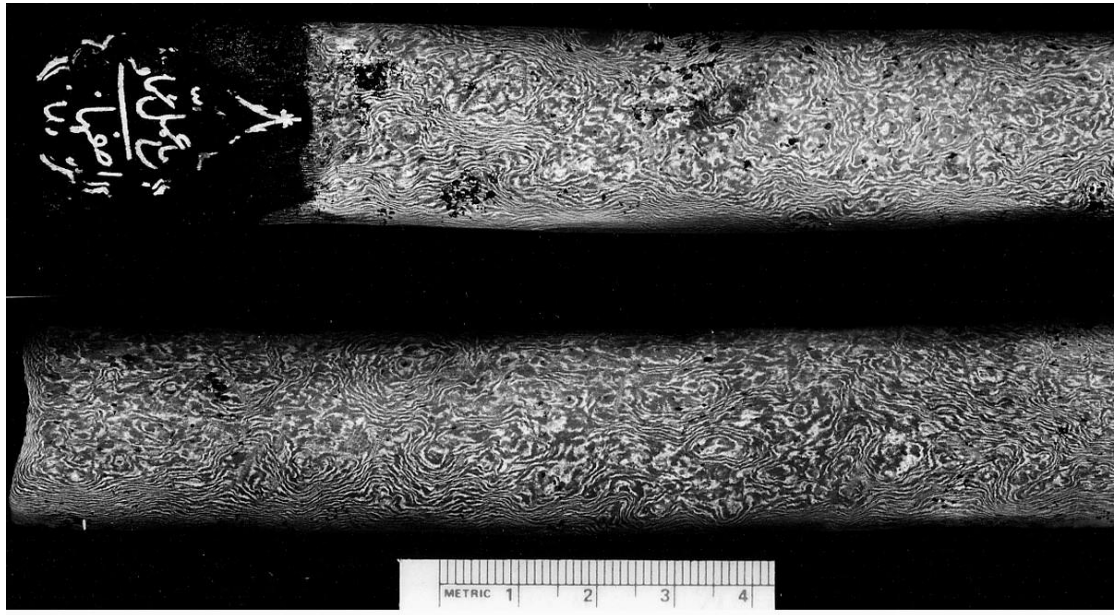


wikipedia.org
www.dierk-raabe.com

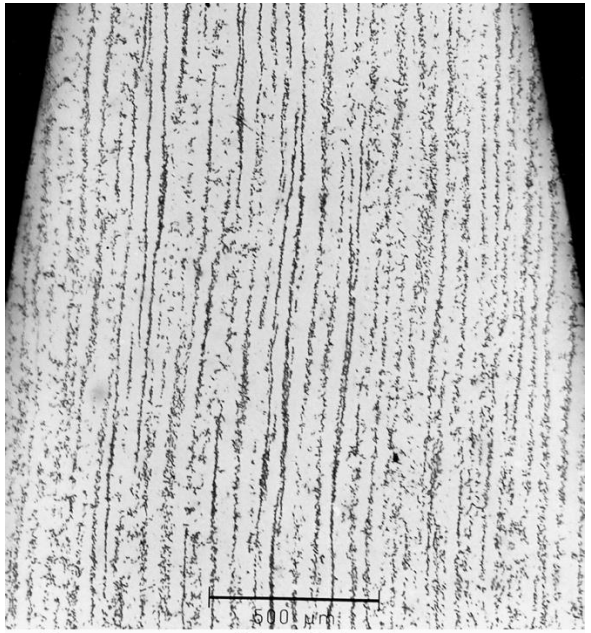
A few examples of phase transitions

Damascus Steel Swords

Additional listening



The Figiel blade purchased in Rajasthan India.



Transverse section of Figiel blade with inverse contrast

https://www.mse.iastate.edu/news/john-verhoeven/