2009 spring

Advanced Physical Metallurgy

"Amorphous Materials"

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Introduction

- **Web lecture assistance: http://eng.snu.ac.kr/lecture/index.php**
  - **All materials will be posted at the webpage.**

- **Hand out copied materials or scanned materials in web**

Text: F.E. LUBORSKY "**Amorphous Metallic Alloys**"
Butterworths & Co. (Publishers) Ltd., 1983

References: 1) S.R. Elliott, "**Physics of amorphous materials**",
Longman Scientific&Technical (2nd ed. 1990)
2) P. Duwez et al. "**Metallic Glasses**",
American Society for Metals, Metals Park, Ohio (1976)
3) M.K. Miller, P.K. Liaw, "**Bulk Metallic Glasses**",
Springer (2008)

Additional reading materials will be provided.

Course Goals

This course will cover the rapidly evolving field of amorphous materials, with a particular emphasis on the connection among thermodynamic, kinetic, and structural aspects of amorphous materials. This course intends to illustrate the major materials issues for amorphous metals, from processing to structure to properties and from the fundamental science of glasses to viable industrial applications. I hope that this course show why amorphous materials are attracting such an intensive interest and serve to highlight some challenging issues awaiting resolution. After completing this course, students performing experimental research using amorphous materials should be reasonably informed about materials preparation, processing, and stability. Student performing research outside this field should be able to consider amorphous materials as a new form of material suitable for selection in their innovations.

Syllabus

- **week 1** *Introduction to Amorphous Materials*
- **week 2** *Glass Formation: Alloy design and Sample preparation*
- **week 3** *Structure of Amorphous Alloys*
- **week 4** *Crystallization*
- **week 5** *Structural Relaxation in Metallic Glasses*
- **week 6** *Strength, Ductility and Toughness*
- **week 7** *Flow and Fracture*
- **week 8** *Fundamental Magnetic Properties*
- **week 9** *Electrical Transport Properties*
- **week 10** *Superconduction Properties of Amorphous Metallic Alloys*
- **week 11** *Thermal Properties of Amorphous Metallic Alloys*
- **week 12** *Chemical Properties of Amorphous Metallic Alloys*
- **week 13** *Thermodynamics and Kinetics of Bulk Metallic Glasses*
- **week 14** *Formation of Bulk Metallic Glasses and Their Composites*
- **week 15** *Mechanical Properties of Bulk Metallic Glasses*
- **week 16** *Application of Bulk Metallic Glasses*

Components of Your Grade

1) Exams (mid: 30% + final: 40%)

There will be two exams, each of which takes place in class for 2 hours. The exams will be conceptual and difficult.

2) Reports and Presentation (20%)

Problem sets are planned, to be handed out on Wednesdays and due the following Wednesday in class. Course participants will present their reports in the class.

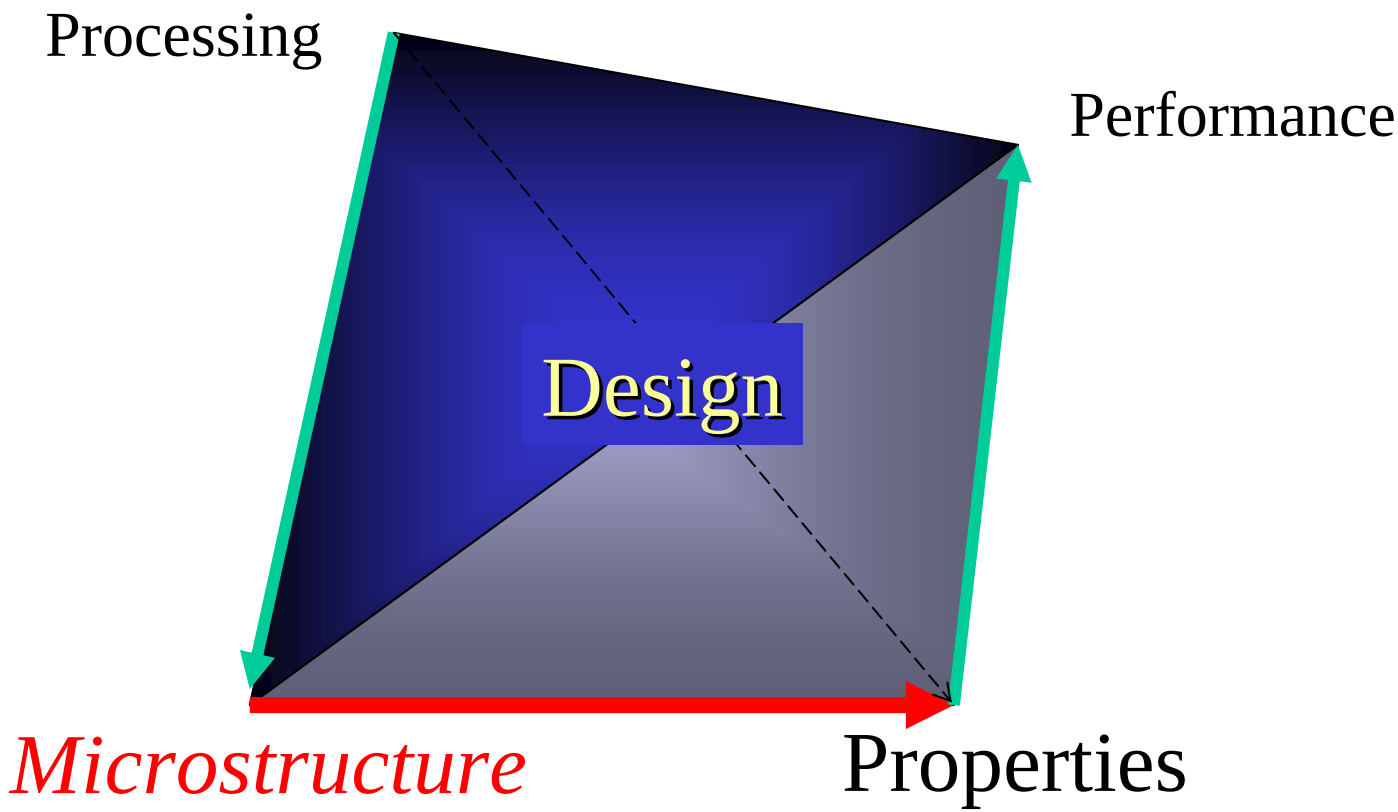
3) Quiz and attendance (10%)

There will be a few short quizzes among the major exams. These will take place in class and last for 30 minutes.

Policies and Procedures

- ***All homework are due by the start of class on the stated deadline.***
  - Late assignments go to my office. If I'm not around, slide it under my door and leave me an email so that I know when you turned it in.
  - You lose 20% of the full assignment value per day late. Since homework are due on Wednesday, you can get 80% credit if you turn it in on Thursday, 50% on next Monday, nothing thereafter.
- ***If you wish, you may work together on homework assignments. BUT, you must hand in your own work, in your own words.***
- **IMPORTANT*: you MUST reference your sources appropriately, including texts, journals web sites, etc.***
  - Article authors, title, journal, volume, year, pages
  - Book authors, title, publisher, year, pages
  - Web address
  - etc.

Materials Tetrahedron



Microstructure-Properties Relationships

What is an Amorphous Materials?

- ***Amorphous*** **– from the Greek for "without form"**
  not to materials that have no shape,
  but rather to materials with no particular structure

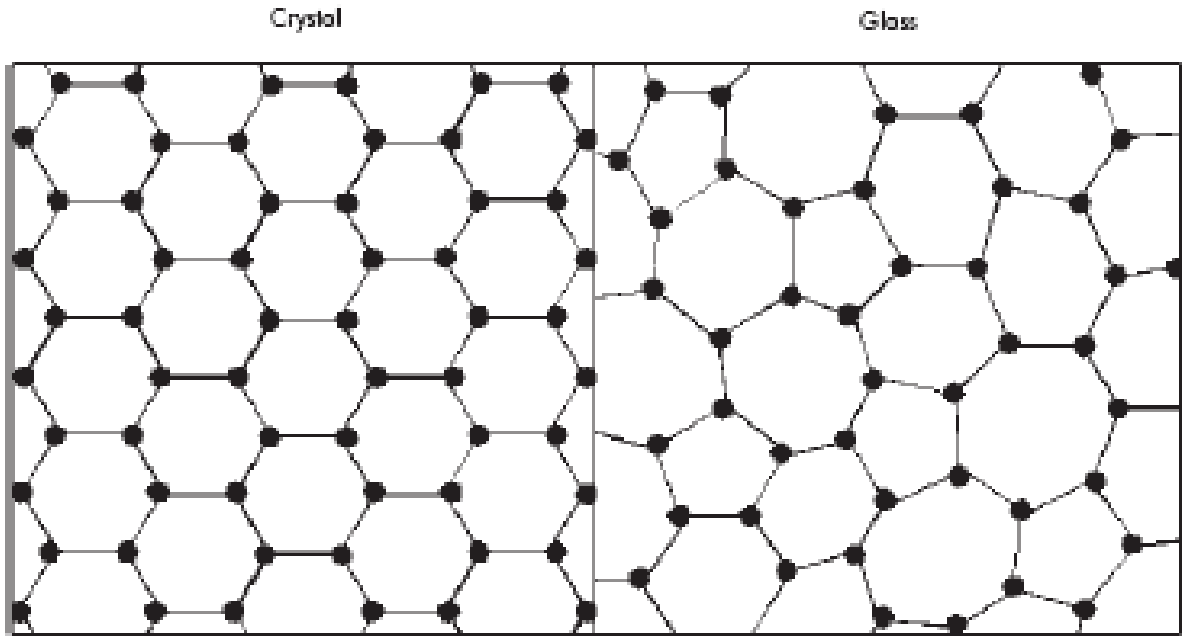
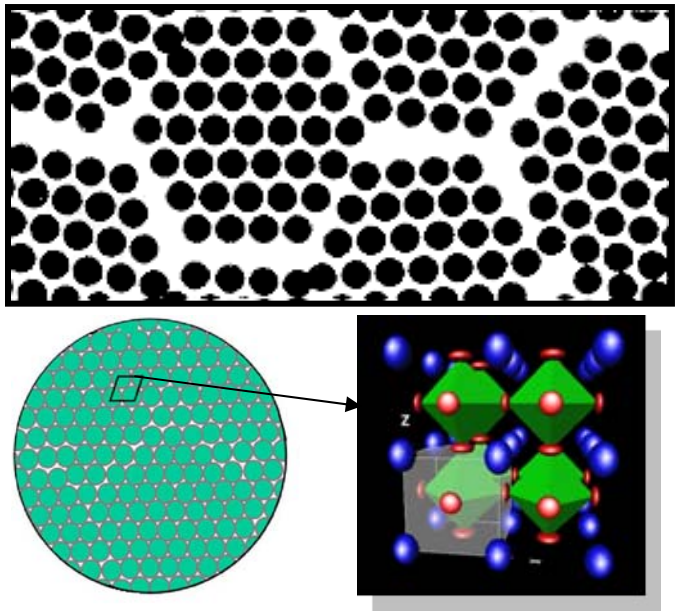


Figure 1. Schematic Illustration of the Structures of Crystals and Glasses.

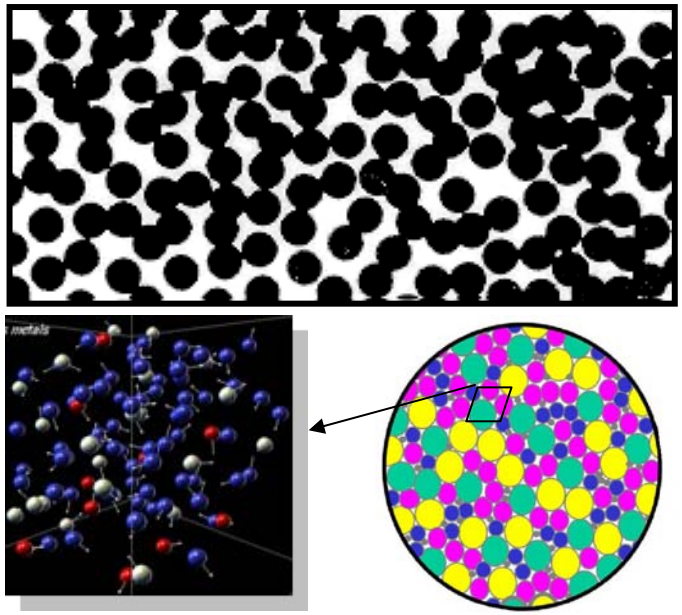
closely packed and chemically bonded solid
~ elastic response to shear stress

Structure of crystals, liquids and glasses

Crystals



Liquids, glasses



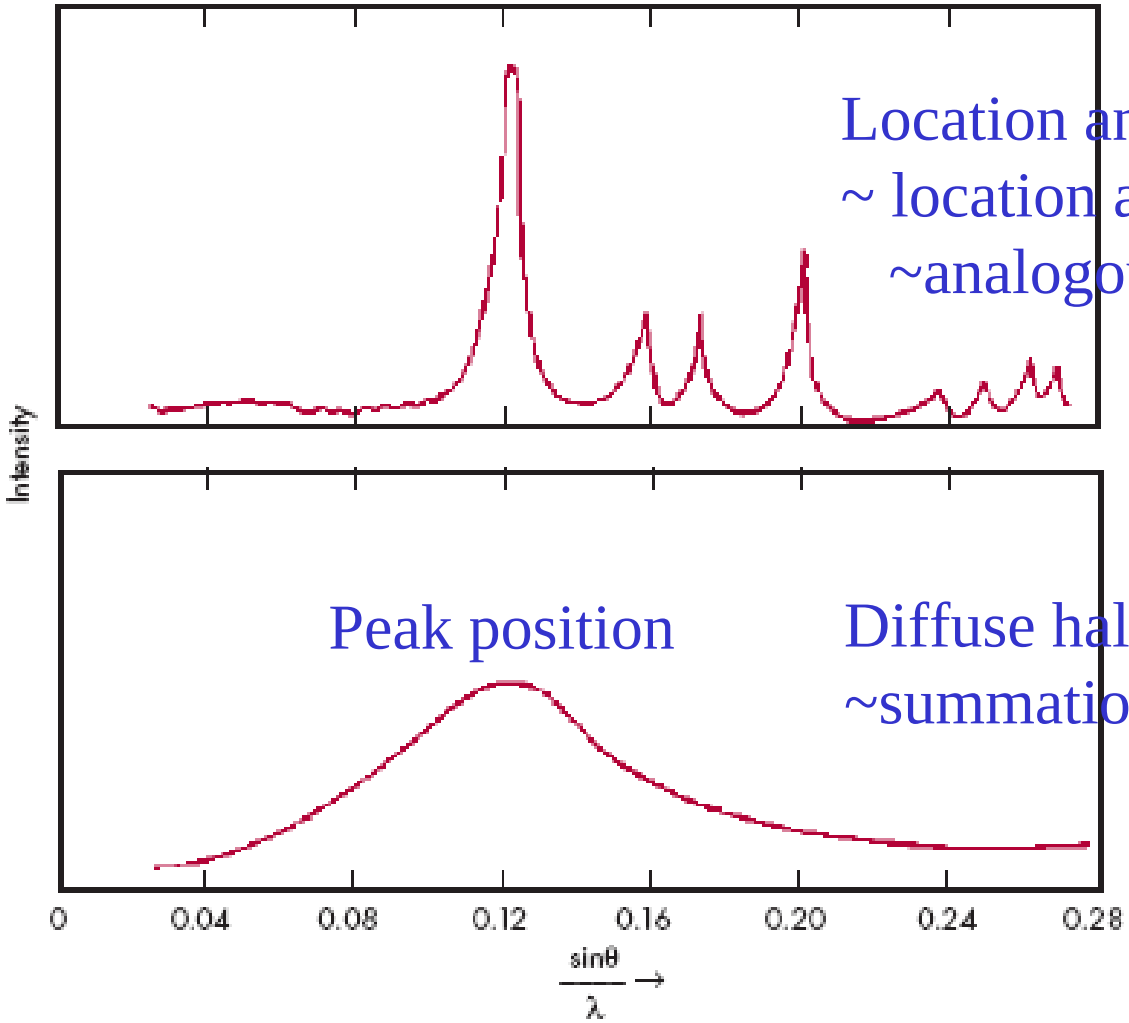
Building block: arranged in orderly, 3-dimensional, periodic array

- **grain boundaries**

nearly random = non-periodic

- **no grain boundaries**

X-ray or neutrons results



Location and intensity of peaks
~ location and arrangement of atoms
~analogous to a fingerprint

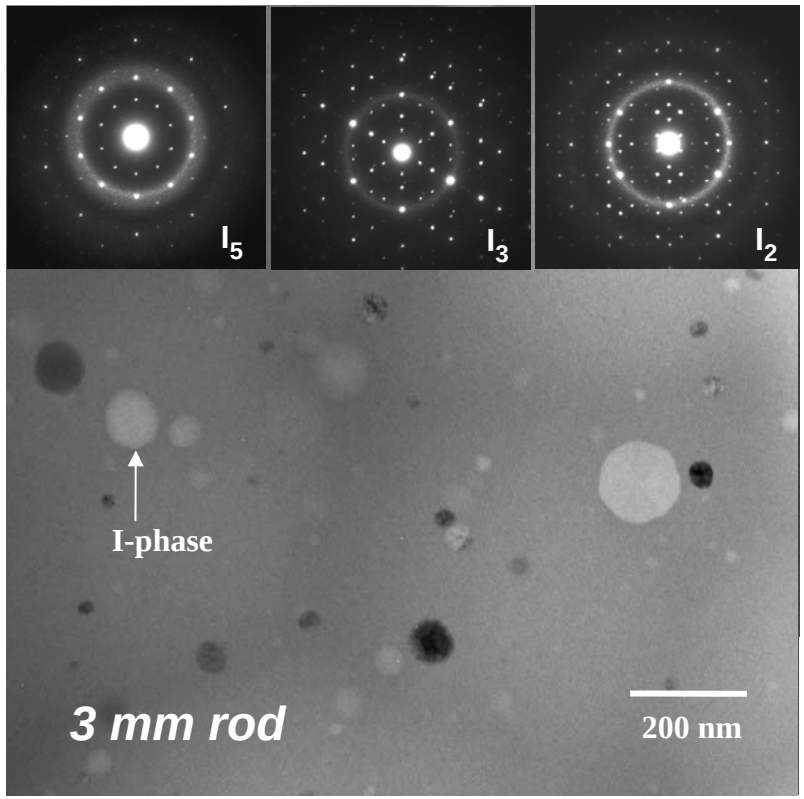
Peak position

Diffuse halo pattern
~summation of interference

Figure 3. Characteristic Diffraction Patterns from Crystalline Material (Top) and Amorphous Material (Bottom). [3]

TEM results _*Zr-based bulk metallic glasses*

$Zr_{57}Ti_8Nb_{2.5}Cu_{13.9}Ni_{11.1}Al_{7.5}$ ***2 mm rod***

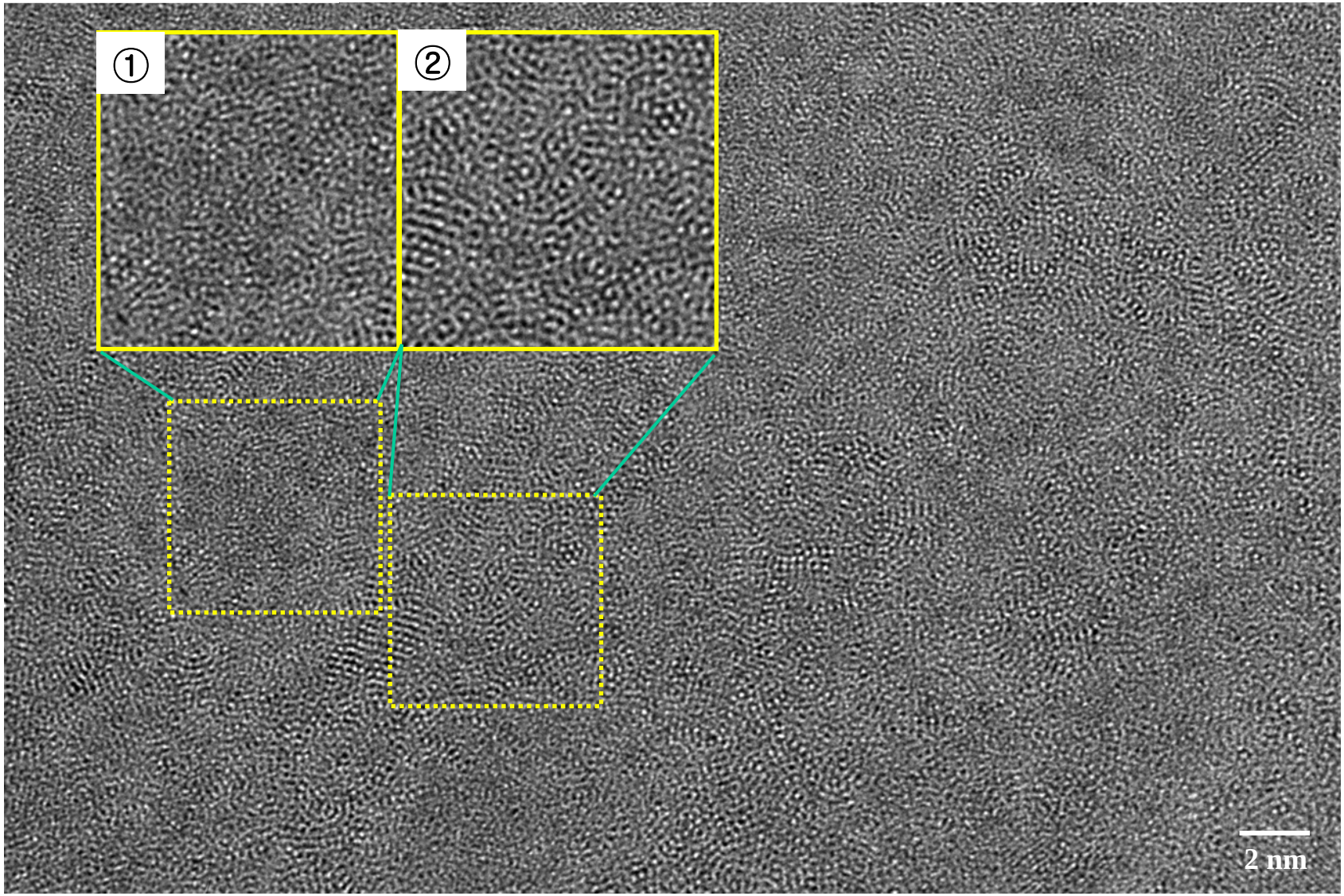


Fully amorphous structure

Nano scale (<3 mm) interconnected Phase separation

$Gd_{30}Zr_{25}Al_{25}Co_{20}$

* unpublished (2007)



Strength vs. Elastic Limit

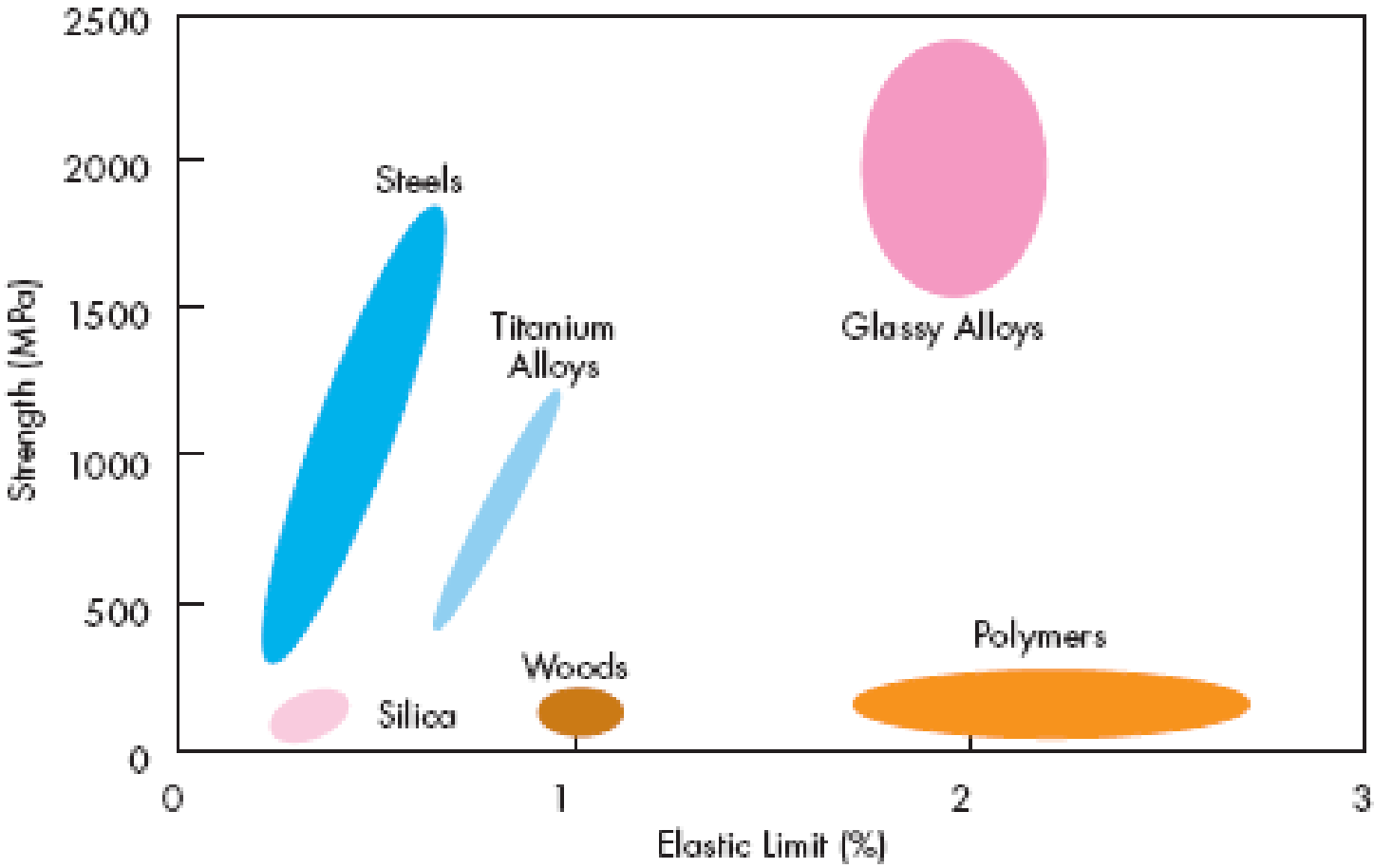
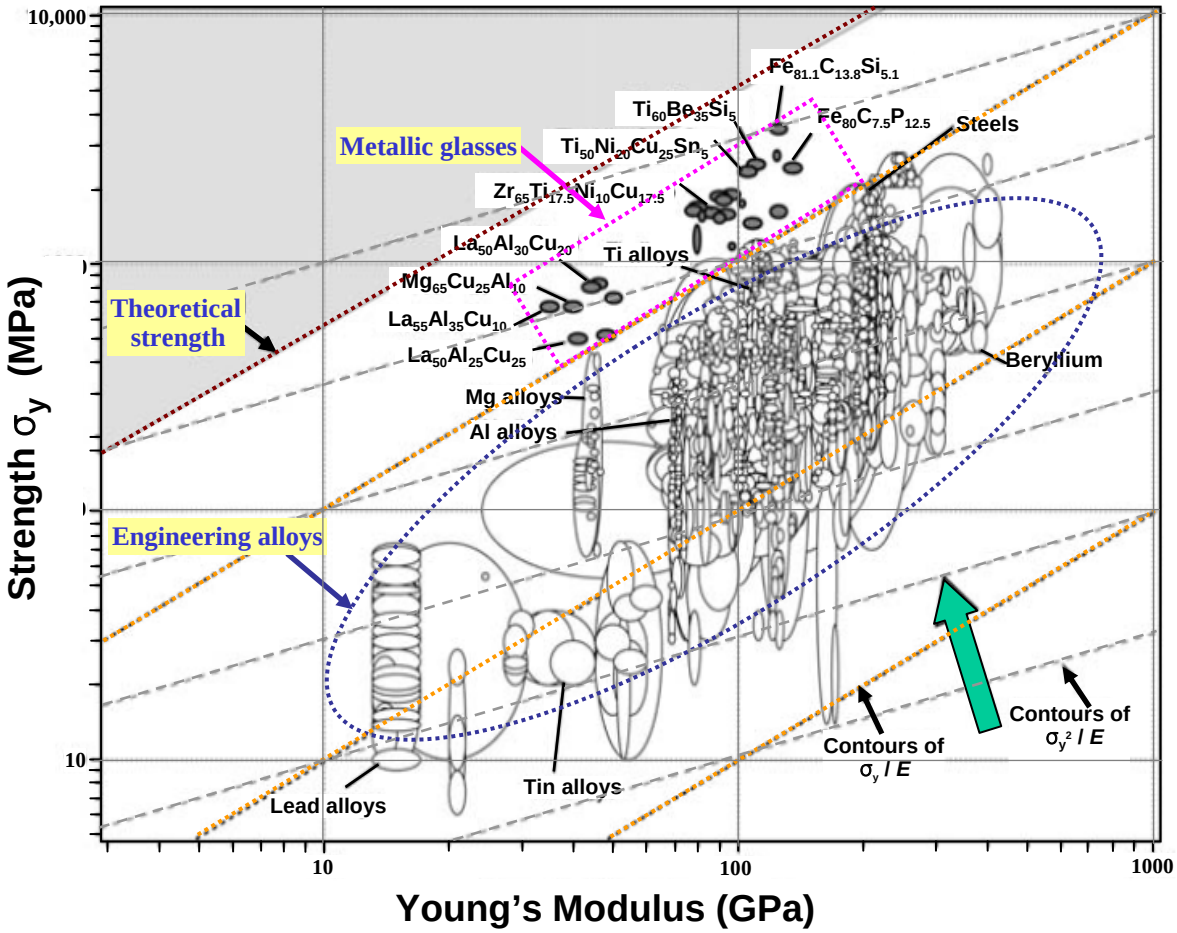


Figure 2. Strength vs. Elastic Limit for Several Classes of Materials – Metallic Glasses Offer a Unique Combination of High Strength and High Elastic Limit [2].

High strength, but limited by shear softening and shear band

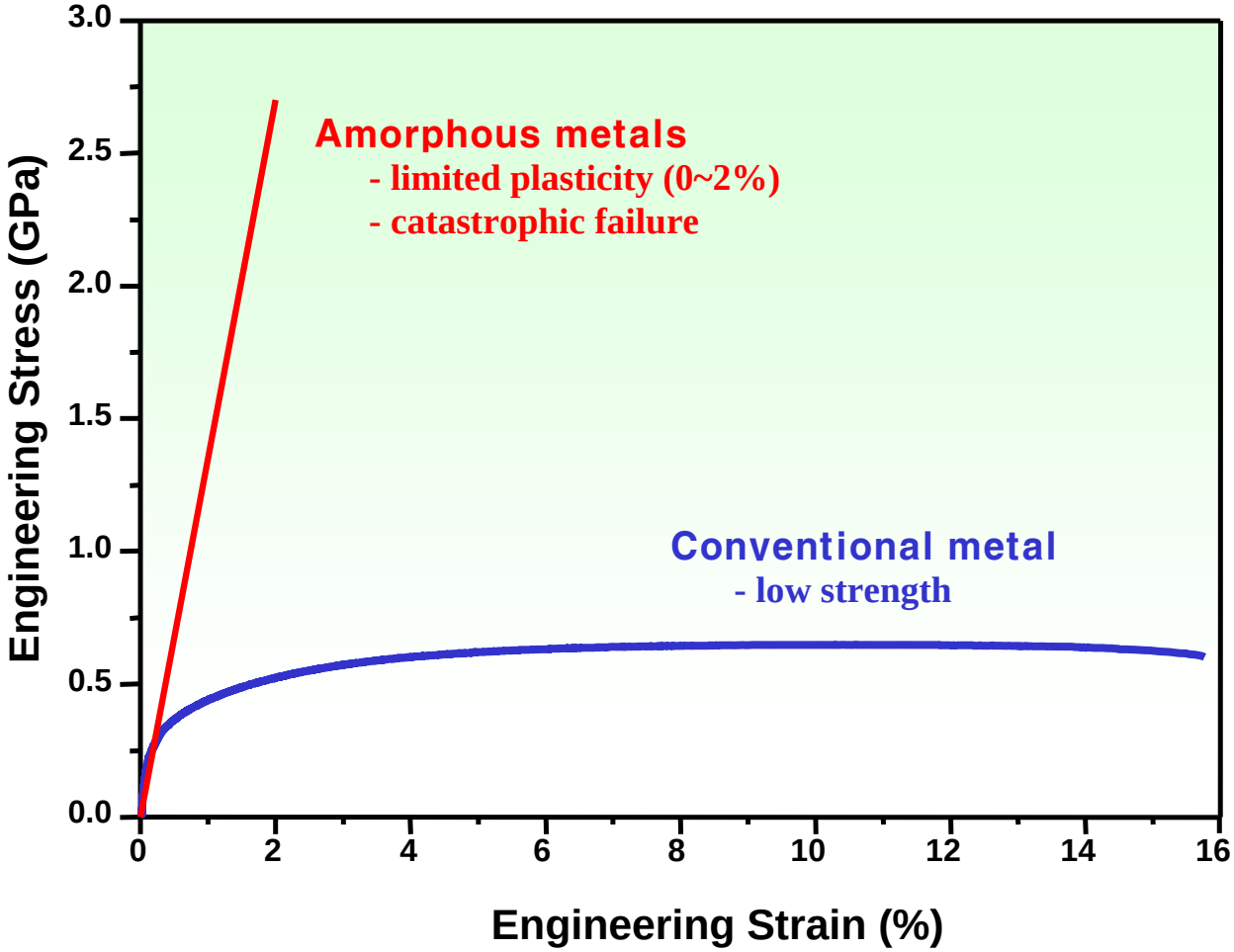


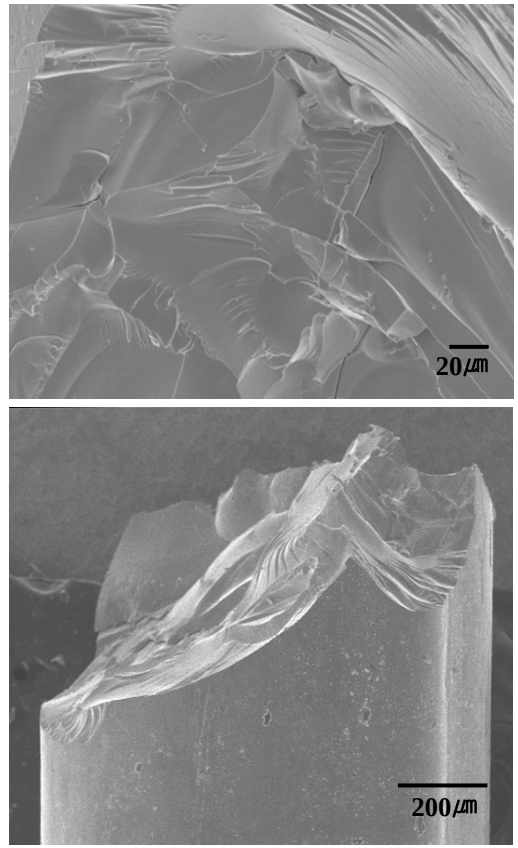
High fracture strength over 5 GPa in Fe-based BMGs

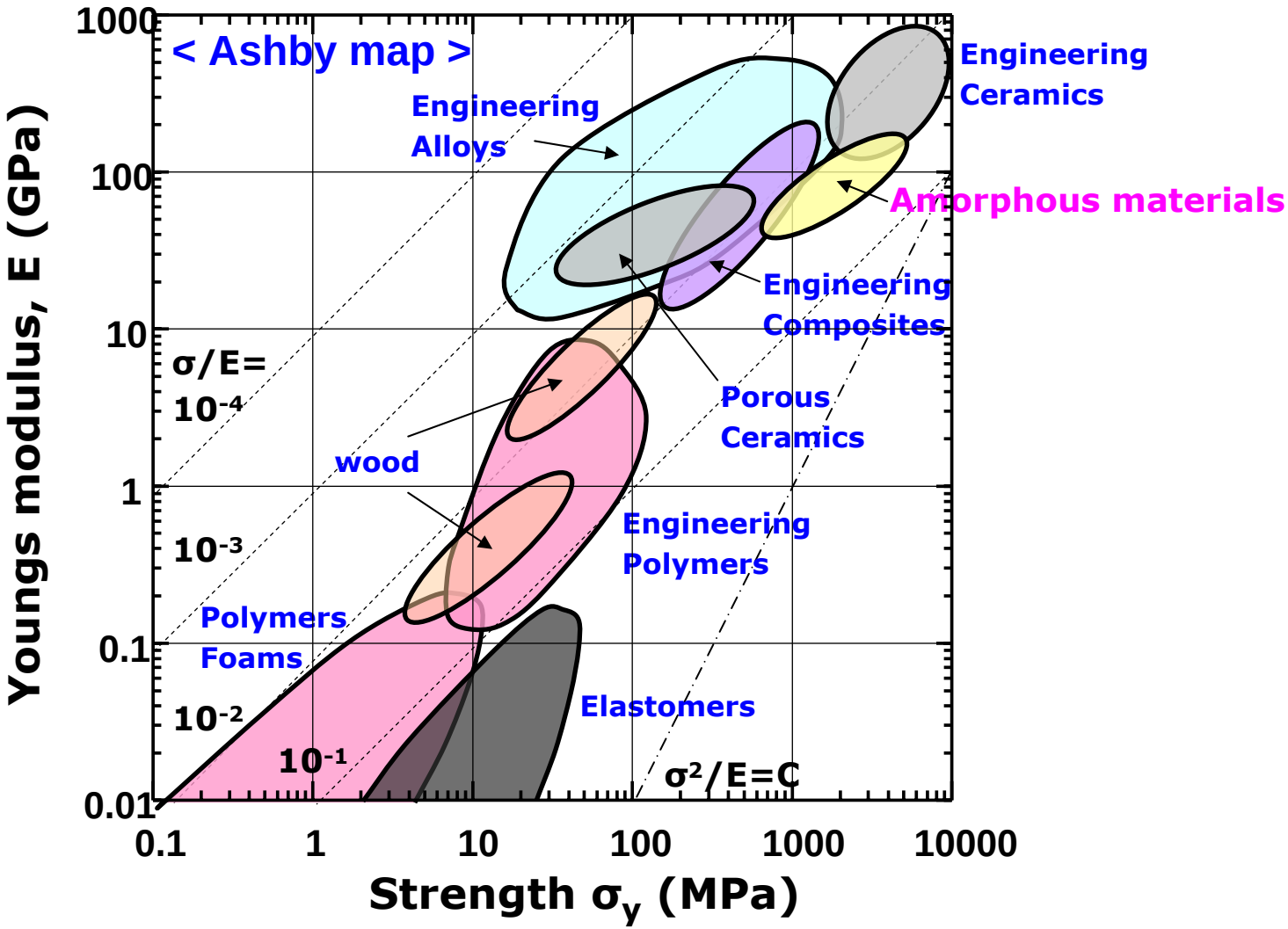
A.L. Greer, E. Ma, MRS Bulletin, 2007; 32: 612.

High strength, but limited by shear softening and shear band

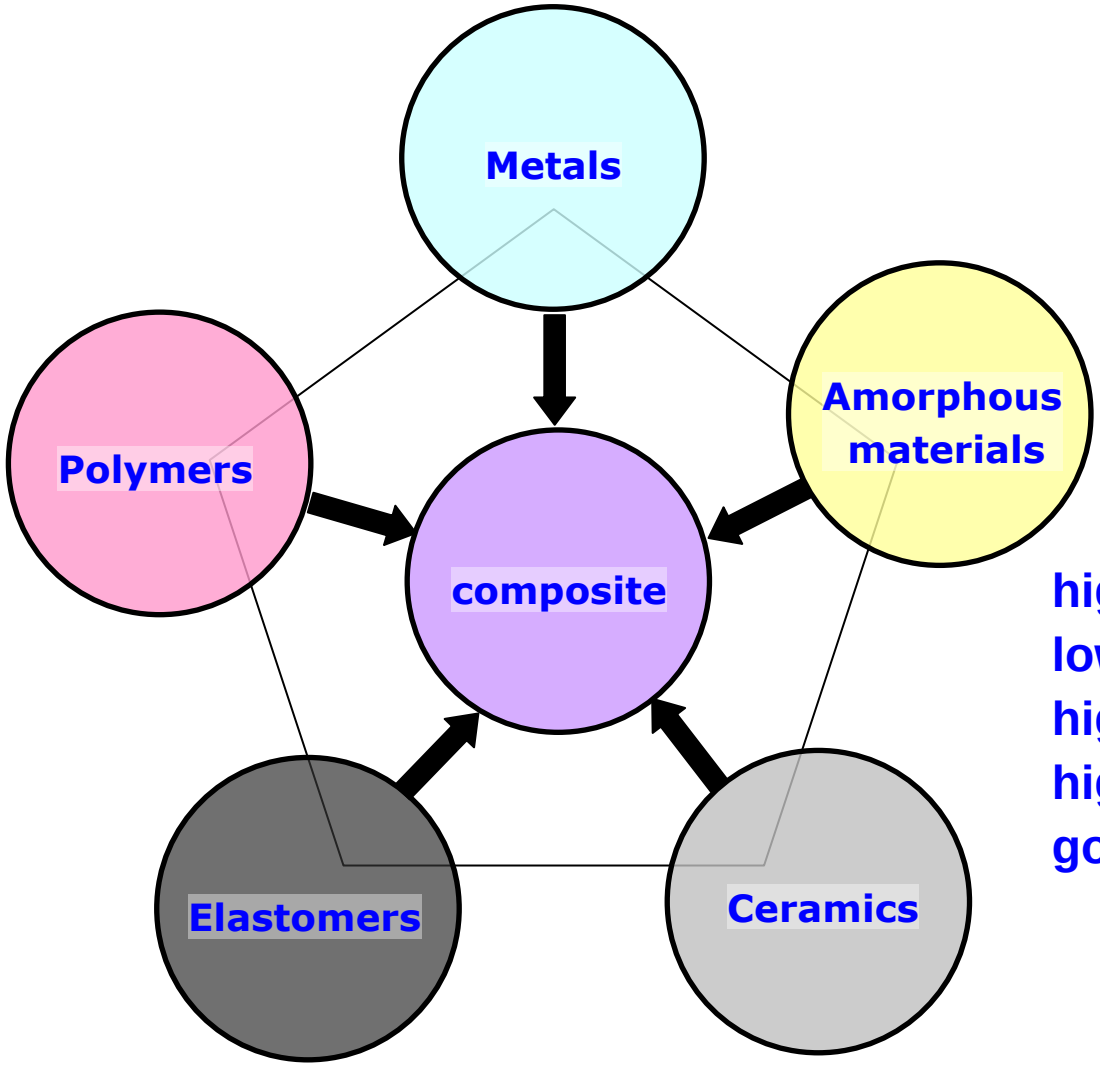
Microscopically brittle fracture ➡ Death of a material for structural applications






< Ashby map >
Engineering Alloys
Engineering Ceramics
Amorphous materials
Engineering Composites
Porous Ceramics
wood
Engineering Polymers
Polymers Foams
Elastomers
σ/E=
10-4
10-3
10-2
10-1
σ2/E=C
Youngs modulus, E (GPa)
Strength σy (MPa)
1000
100
10
1
0.1
0.01
0.1
1
10
100
1000
10000

Menu of engineering materials



High GFA

High plasticity

higher strength
lower Young's modulus
high hardness
high corrosion resistance
good deformability
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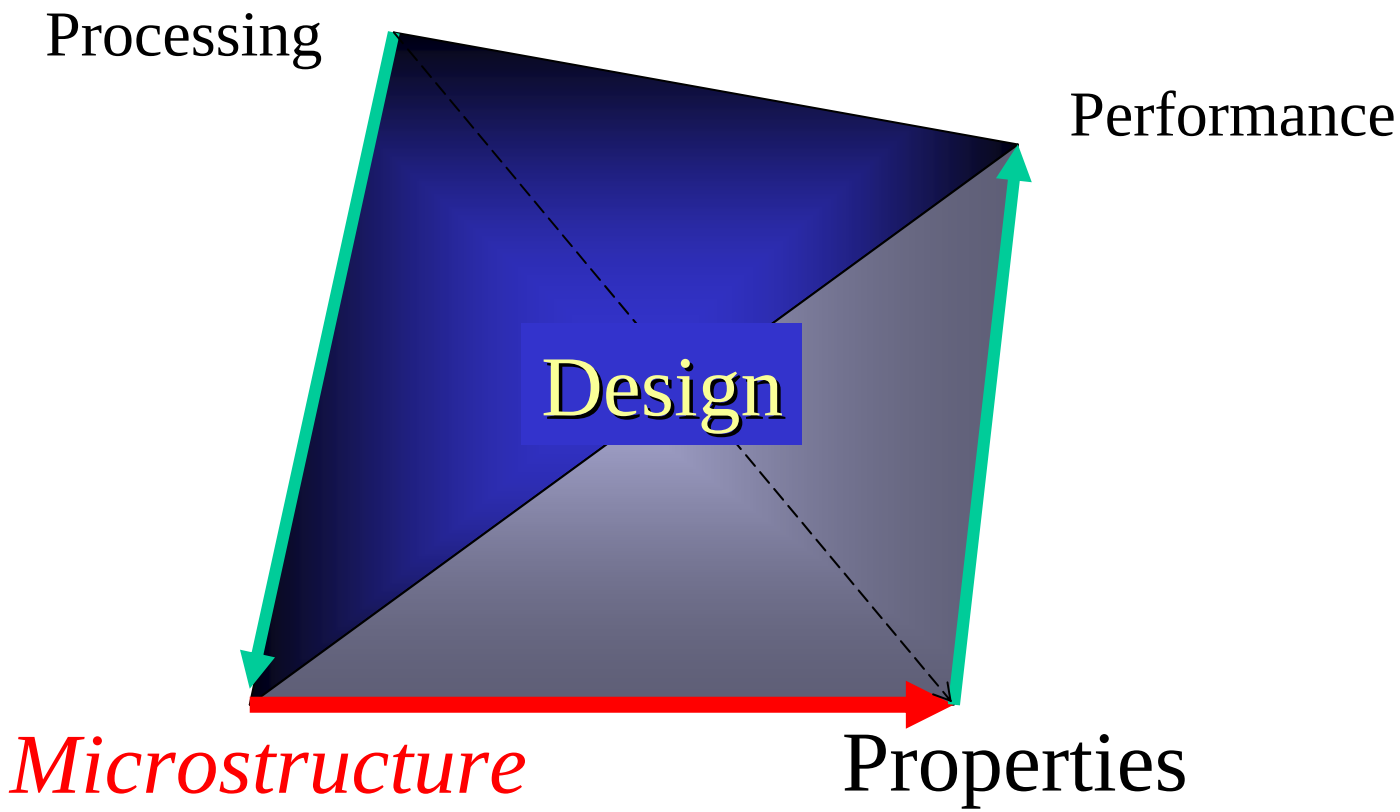
Microstructure-Properties Relationships



"Tailor-made Materials Design"