2010 Spring

# "Amorphous Materials"

03.02.2010

Eun Soo Park

Office: 33-316
Telephone: 880-7221
Email: espark@snu.ac.kr
Office hours: by an appointment

# 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: "Physics of amorphous materials",** S.R. Elliott,
Longman Scientific&Technical (2nd ed. 1990) &

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

**References: 1) "Metallic Glasses",** P. Duwez et al.
American Society for Metals, Metals Park, Ohio (1976)
**2) "Bulk Metallic Glasses",** M.K. Miller, P.K. Liaw,
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.**

# Schedule

**week 1** Introduction to Amorphous materials
**week 2** Classification of Solids
**week 3** Definition of Amorphous Materials
**week 4** Preparation of Amorphous Materials
**week 5** Phase Transition: glass transition
**week 6** Measurement of Glass Transition Temperature
**week 7** Theories for the Glass Transition I: thermodynamic / entropy
**week 8** Theories for the Glass Transition II: relaxation behavior / viscosity
**week 9** Structural Approach to Glass Formation
**week 10** Kinetic Approach to Glass Formation
**week 11** Ease of Glass Transition: glass forming ability
**week 12** Glass Forming Ability Parameters
**week 13** Formation of Bulk Metallic Glasses
**week 14** Mechanical Properties of Bulk Metallic Glasses and Their Composites
**week 15** Unique Properties of of Bulk Metallic Glasses
**week 16** Potential Applications of Bulk Metallic Glasses

# *Components of Your Grade:*

1) **Exams (mid: 30% + final: 35%)**

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%) (+Incentive Homework 5%)**

Assignments handed in after the start of class lose credit depending on the timing. If you wish, you may work together on homework assignments. But, you must hand in your own work, in your own words.

3) **Quiz (15%) and attendance (5%)**

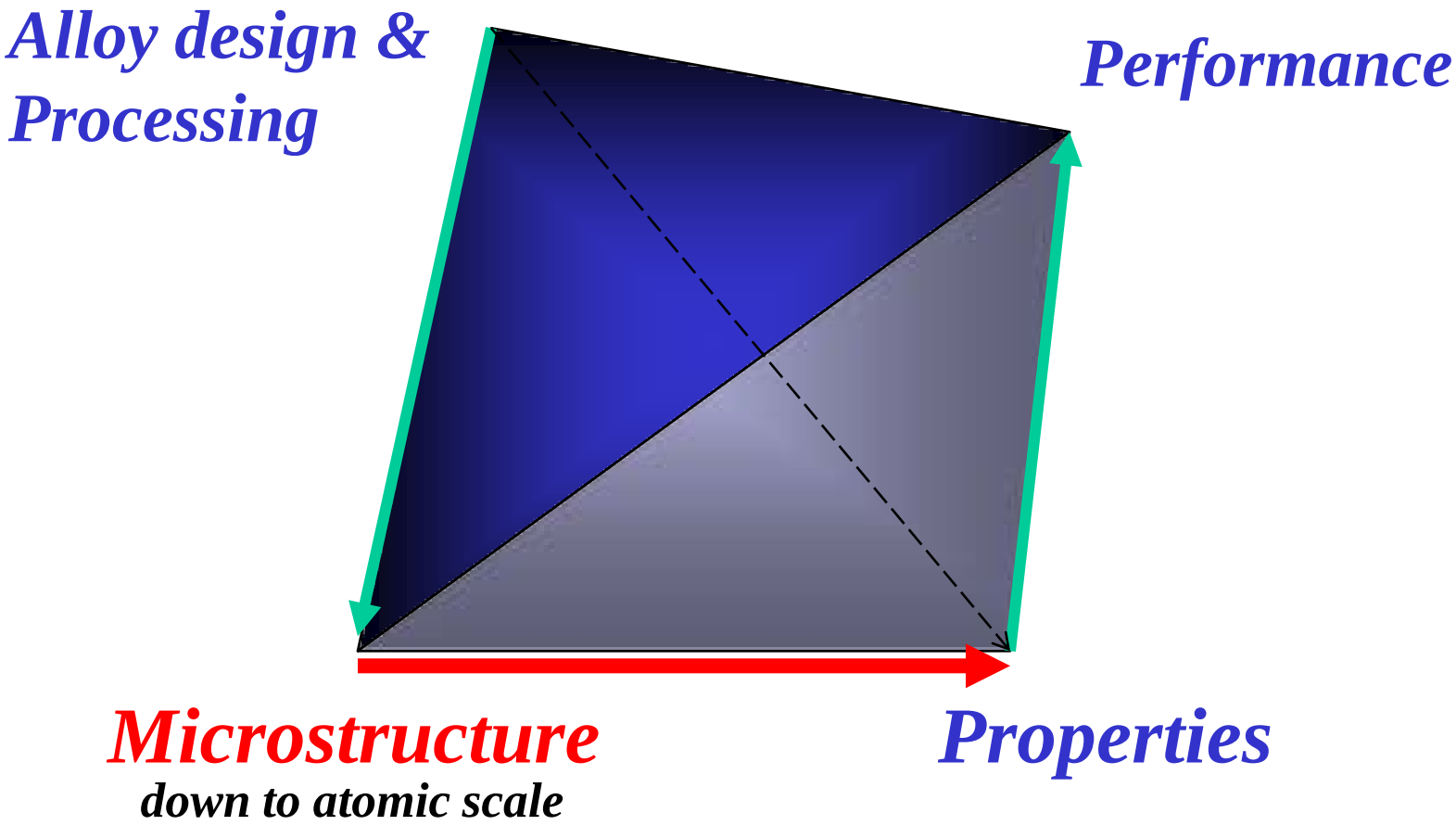
There will be a few short quizzes among the major exams. These will take place in class and early for 20 minutes.

**REMARK: The ratio for grade is possible to change up to 5% depending on the student's achievement.**

# 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 **Thursday,** you can get 80% credit if you turn it in on **Friday,** 50% on next **Tuesday,**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



# *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

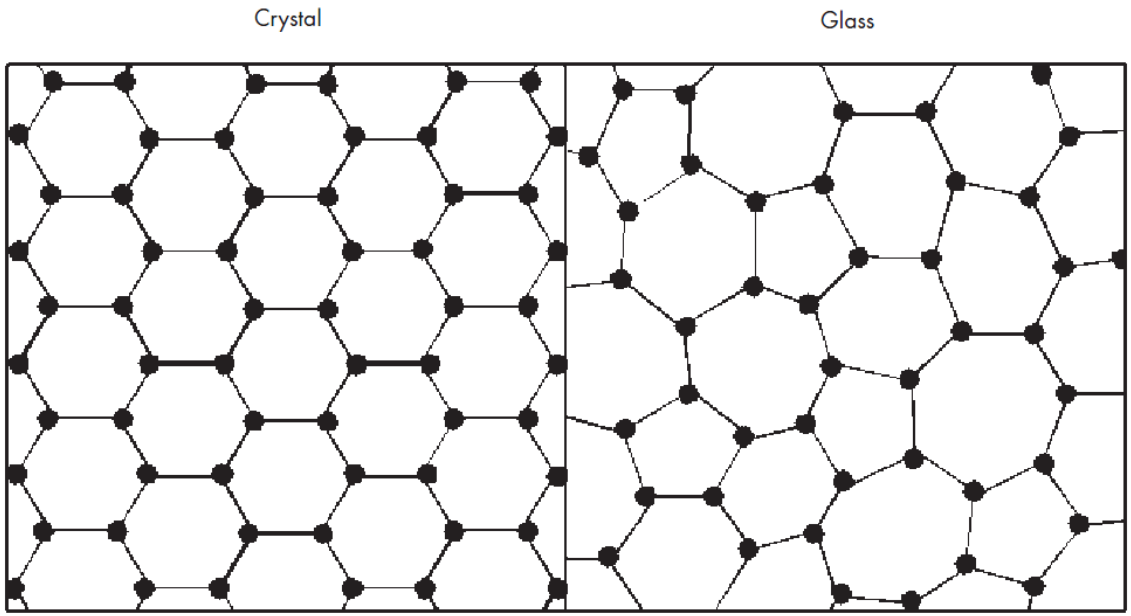
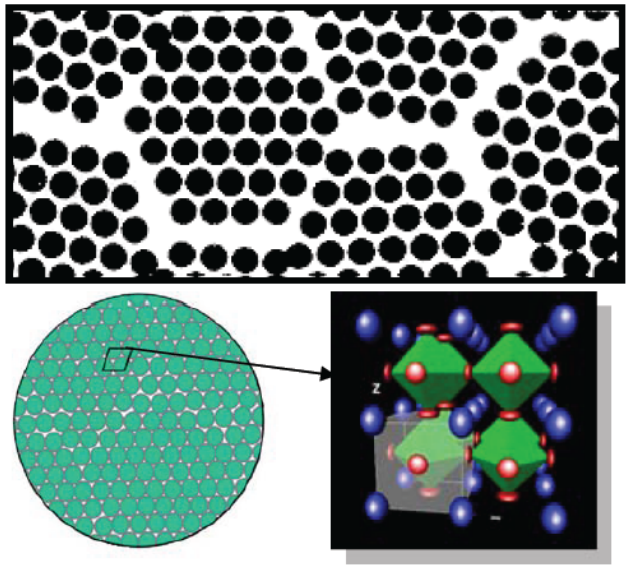



**Figure 1.** Schematic Illustration of the Structures of Crystals and Glasses.

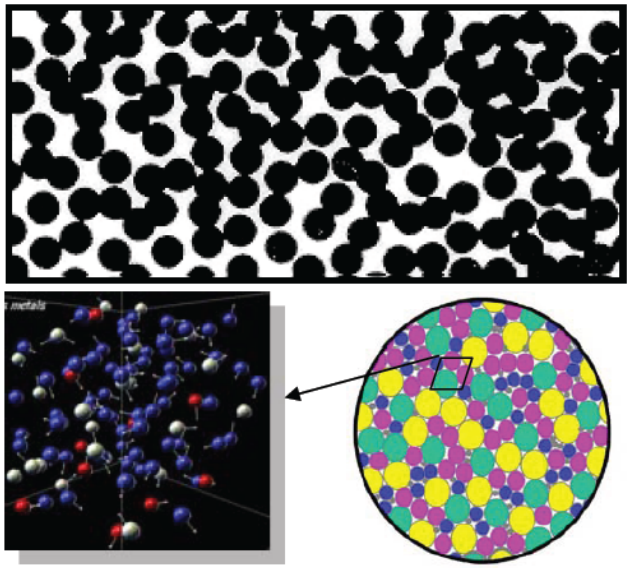
closely packed and chemically bonded solid
~ elastic response to shear stress

# Structure of Crystals, Liquids and Glasses

**Crystals**



**Liquids, glasses**



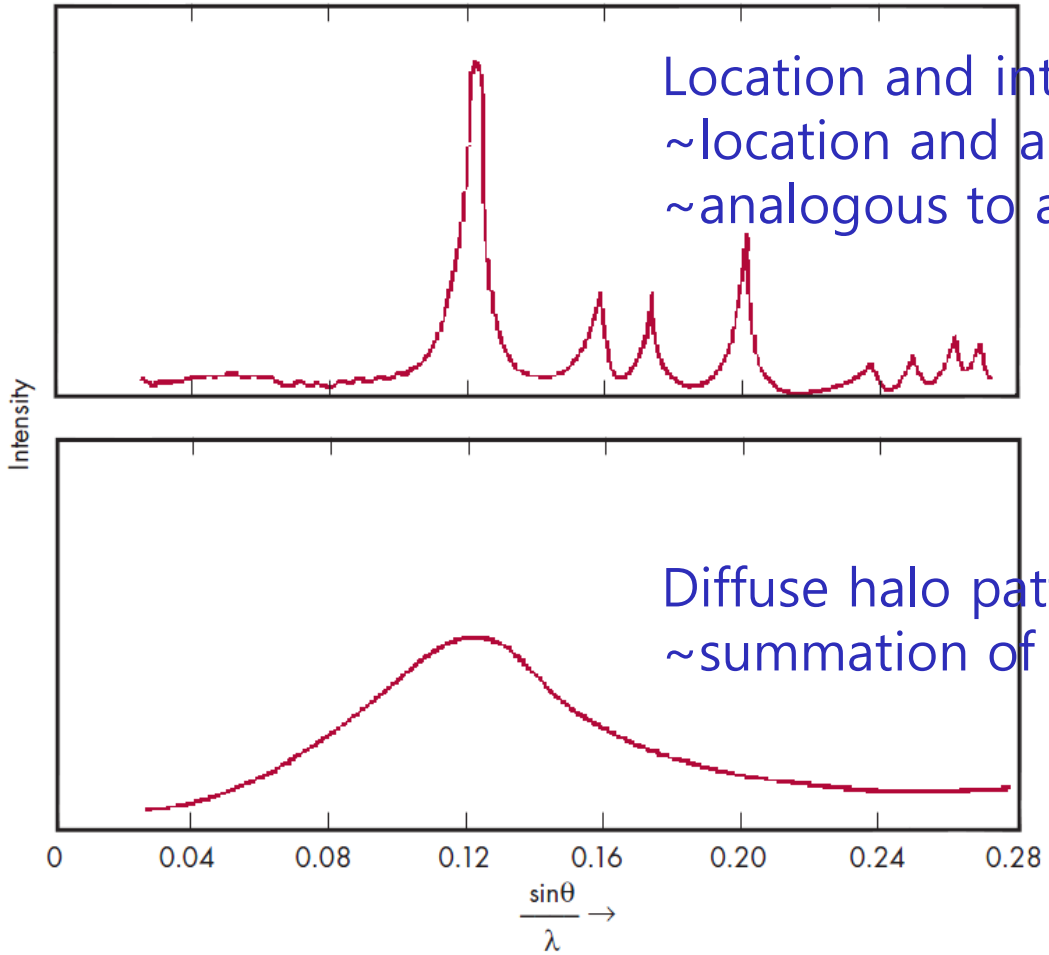
Building block: arranged in orderly, 3-dimensional, periodic array

- **grain boundaries**

nearly random = non-periodic

- **no grain boundaries**

# X-ray or Neutron results




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

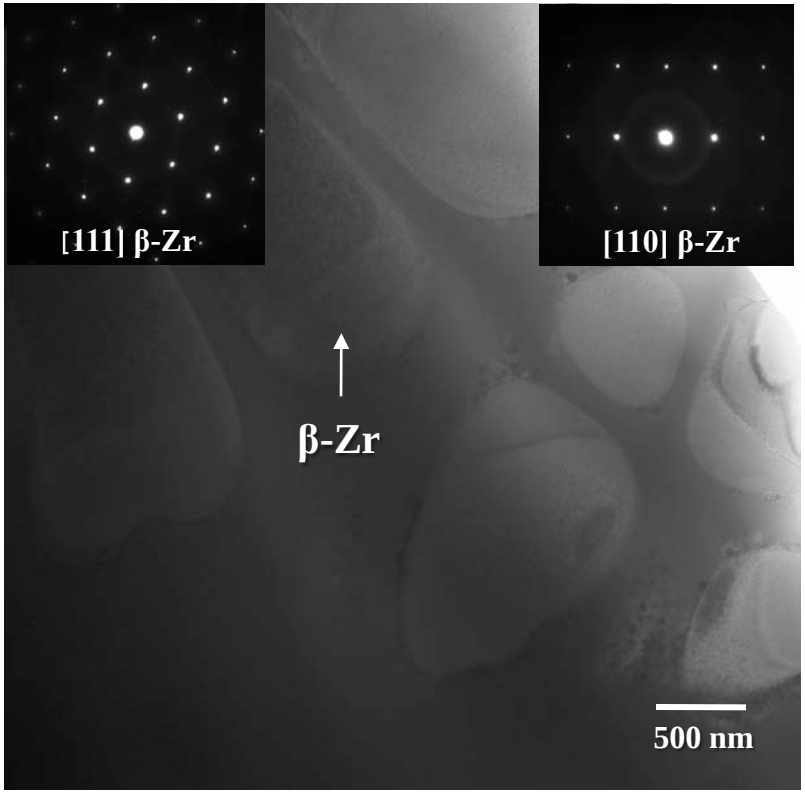
Diffuse halo pattern
~summation of interference

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

# TEM results_Zr-based BMGs

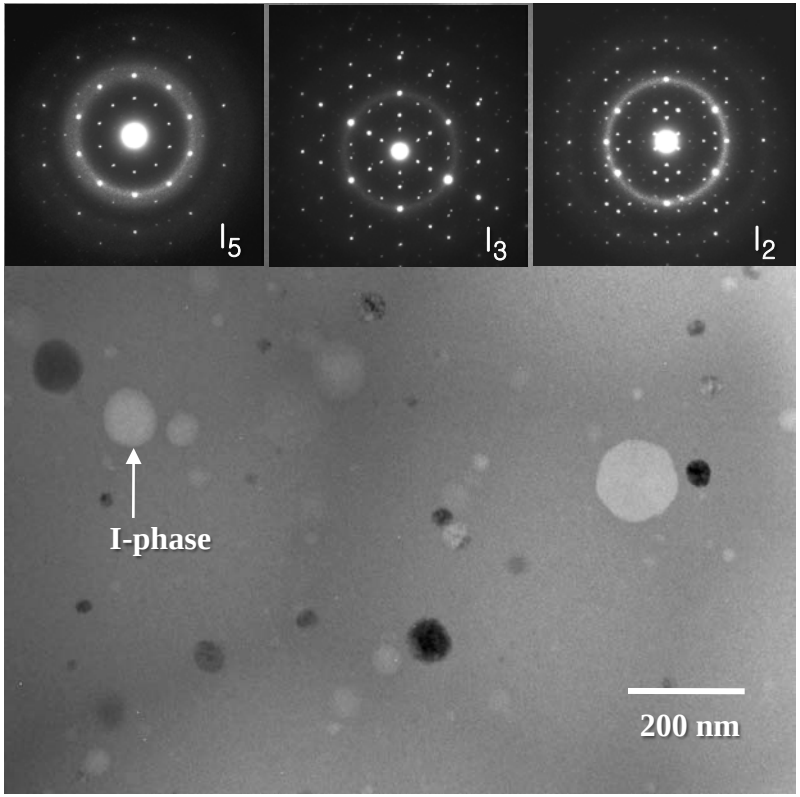
**3 mm rod**

**(a) $Zr_{63}Ti_5Nb_2Cu_{15.8}Ni_{6.3}Al_{7.9}$**



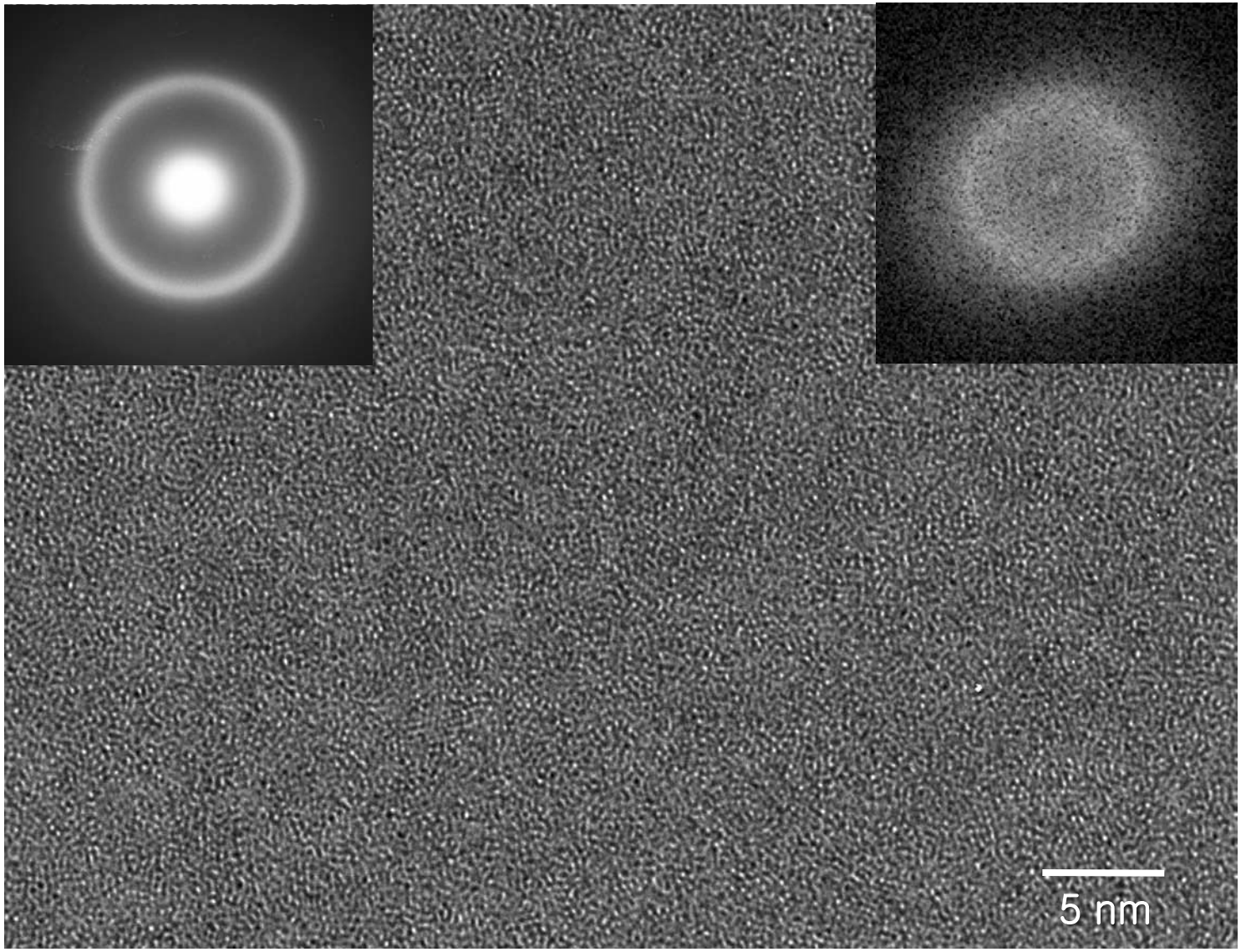

**β-Zr dendrite in amorphous matrix**

**(b) $Zr_{57}Ti_8Nb_{2.5}Cu_{13.9}Ni_{11.1}Al_{7.5}$**

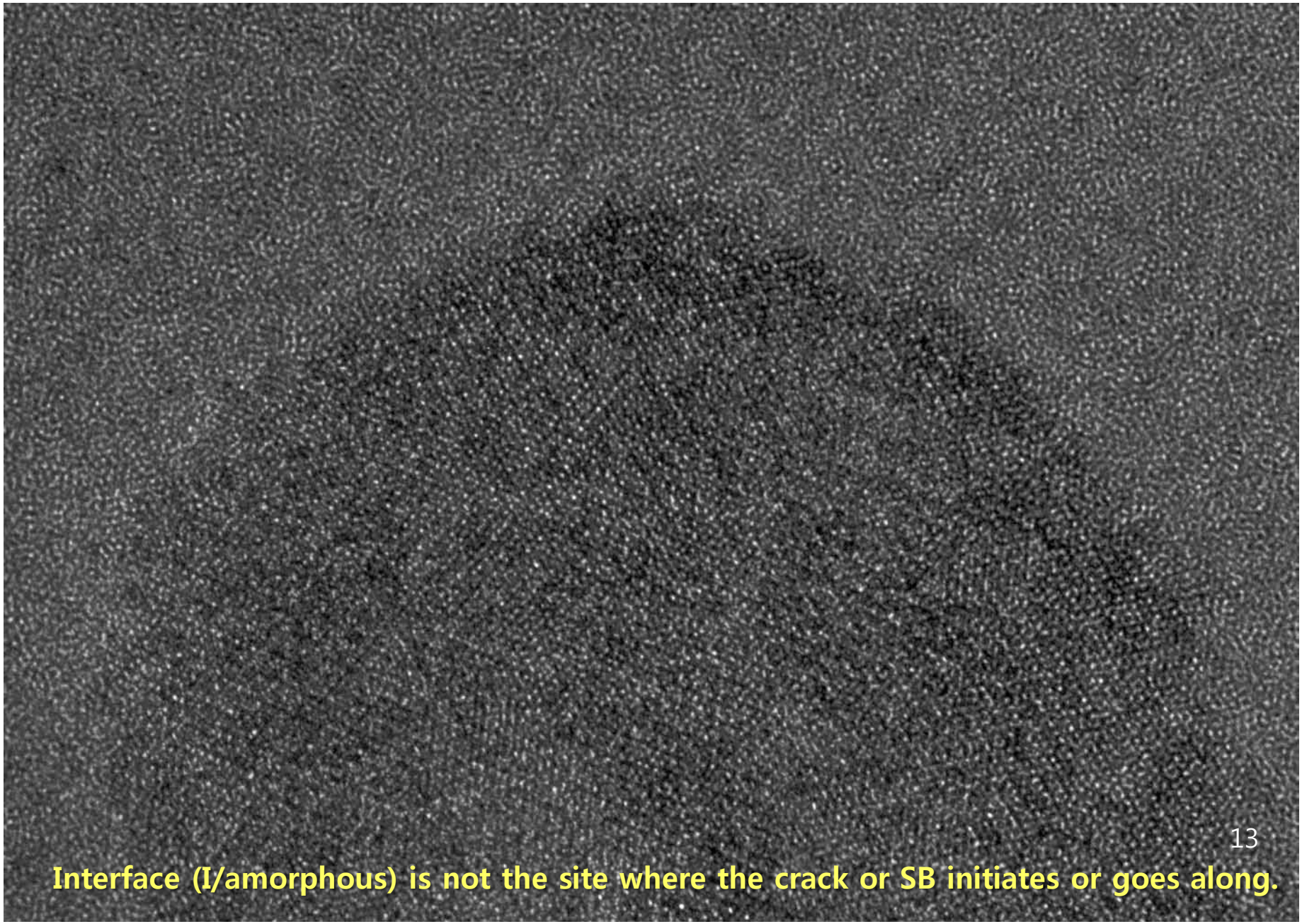



**I-phase particle in amorphous matrix**

# TEM results_Zr-based BMGs



# Continuous interface between amorphous and I-phase

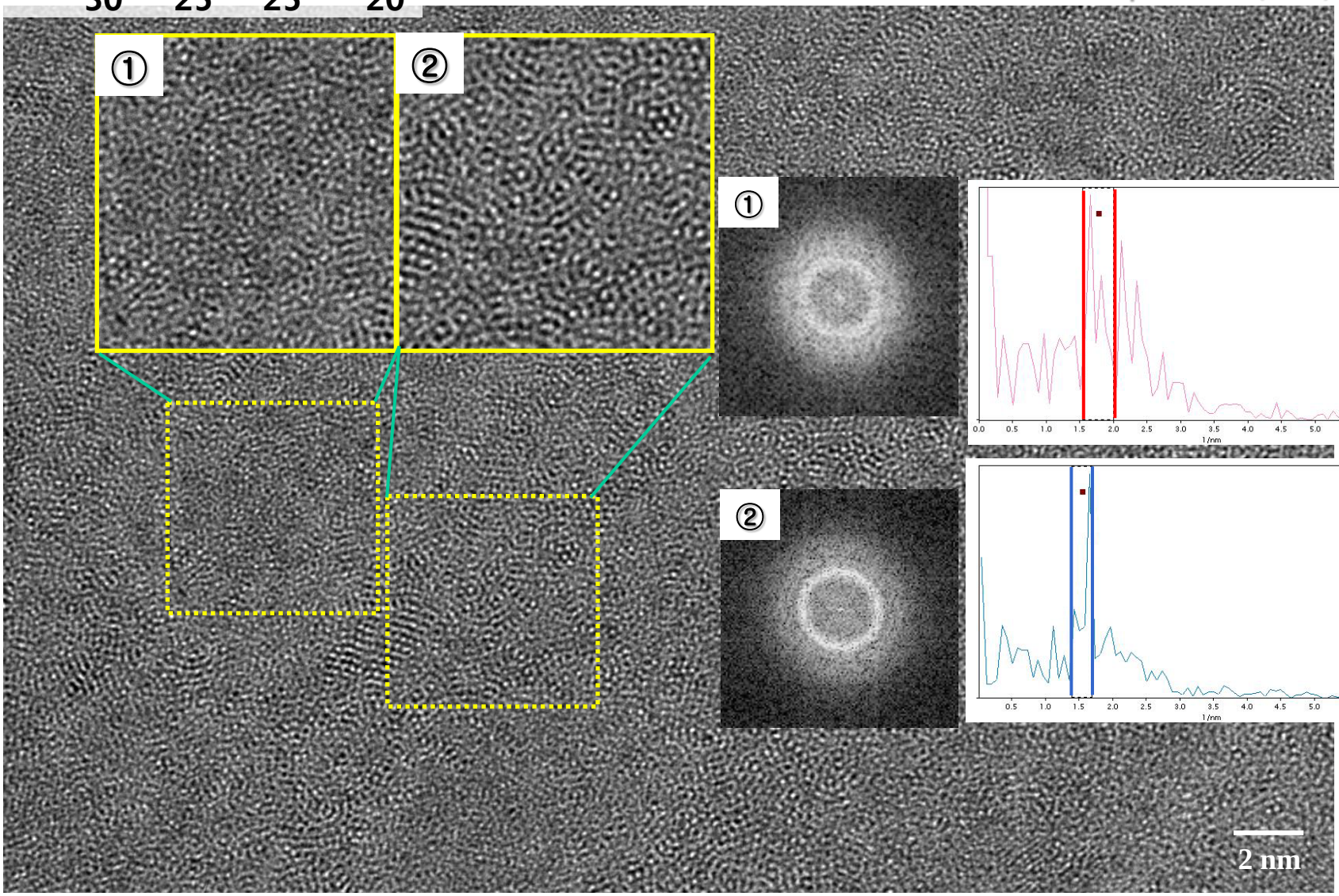


Interface (I/amorphous) is not the site where the crack or SB initiates or goes along.

# Nano scale (<3 mm) interconnected Phase separation

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

* unpublished (2010)



# Strength vs Elastic Limit

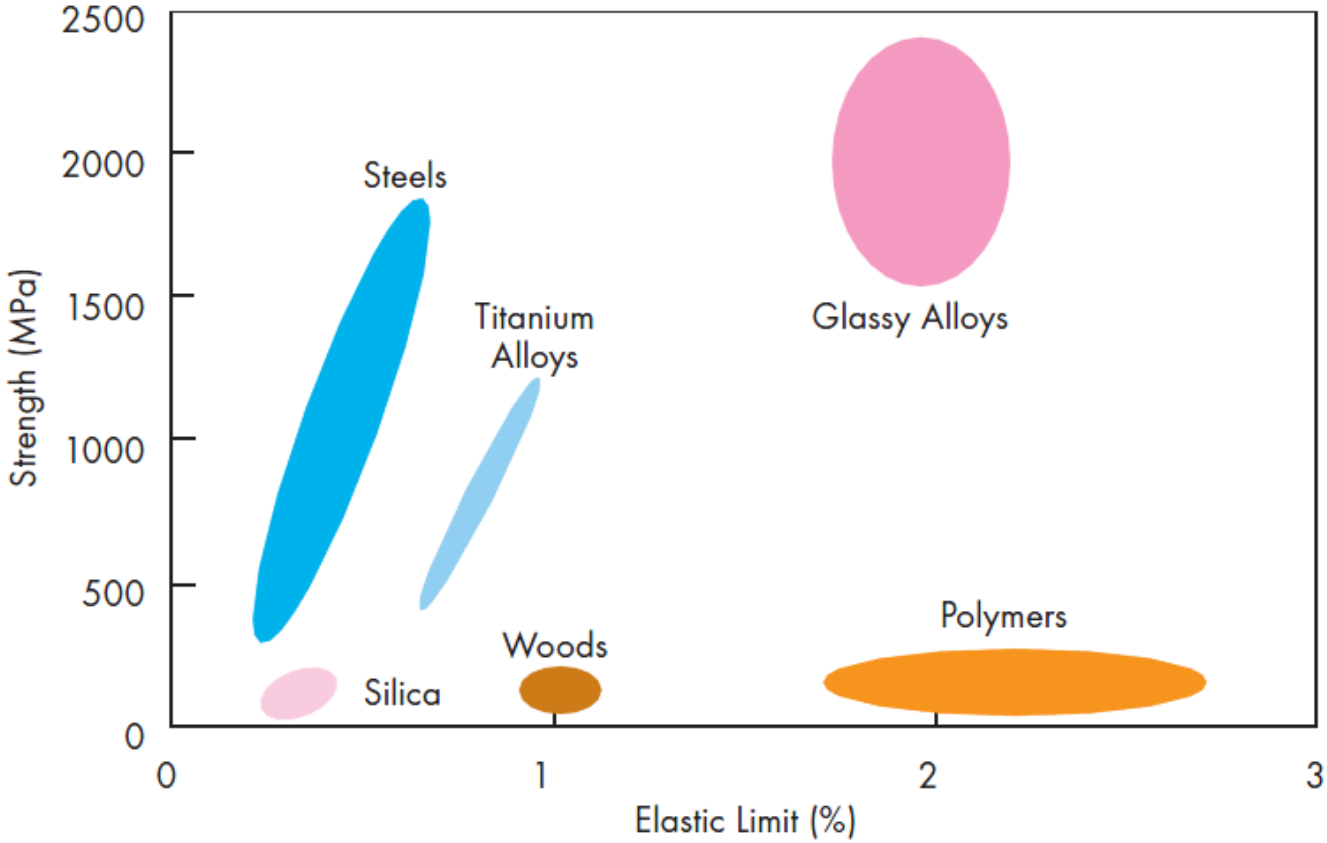
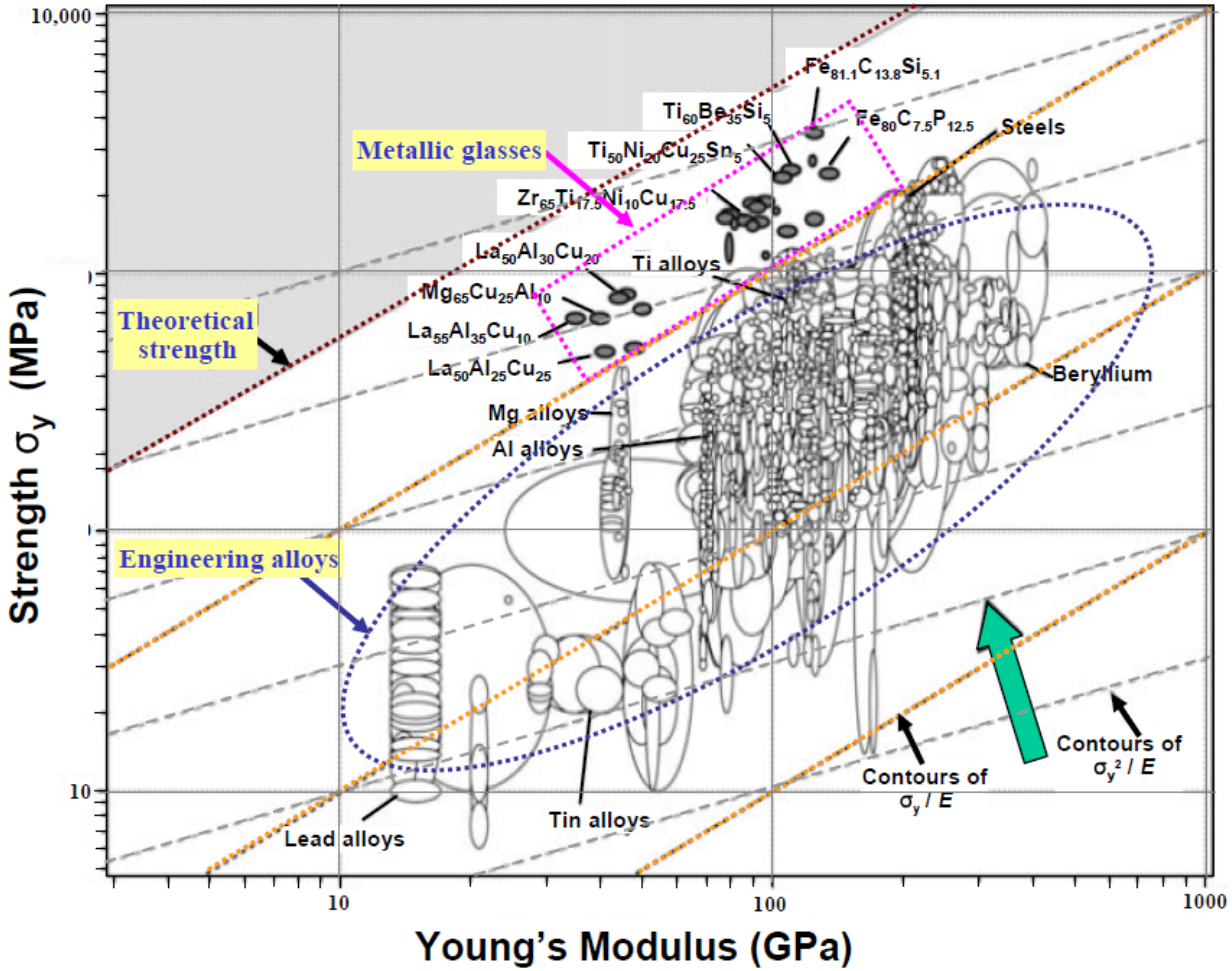



**Figure 2.** Strength vs. Elastic Limit for Several Classes of Materials – Metallic Glasses Offer a Unique Combination of High Strength and High Elastic Limit .

# High strength, but limited by shear softening and shear band



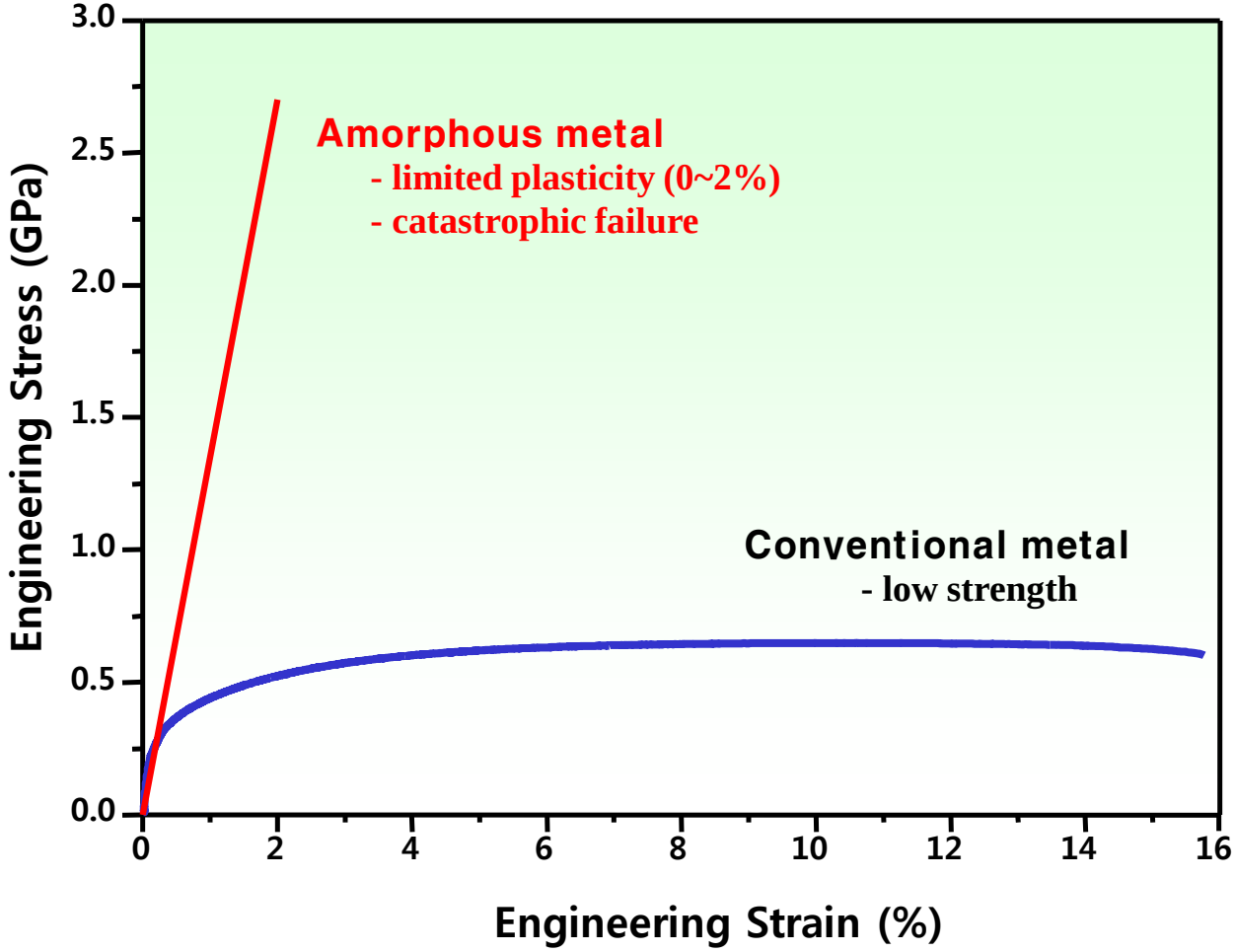

**High fracture strength over 5 GPa in Fe-based BMGs**

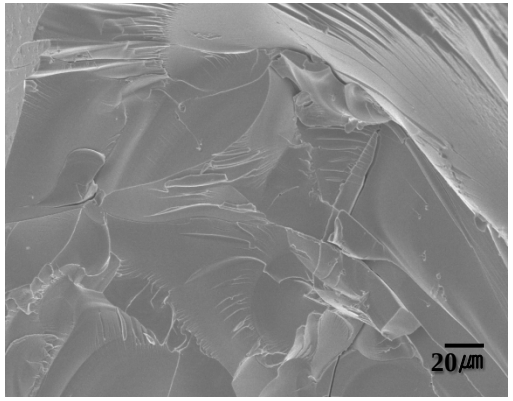
*A.L. Greer, E. Ma, MRS Bulletin, 2007; 32: 612.*

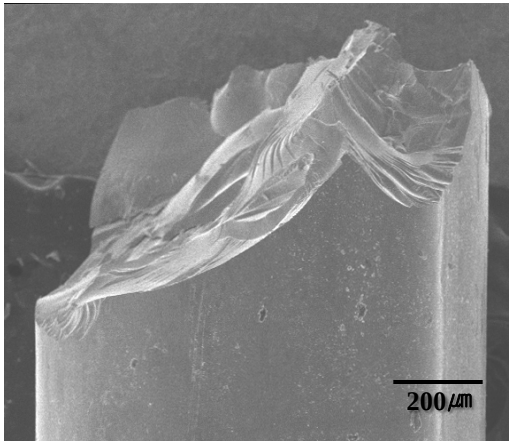
# High strength, but limited by shear softening and shear band

- Microscopically brittle fracture

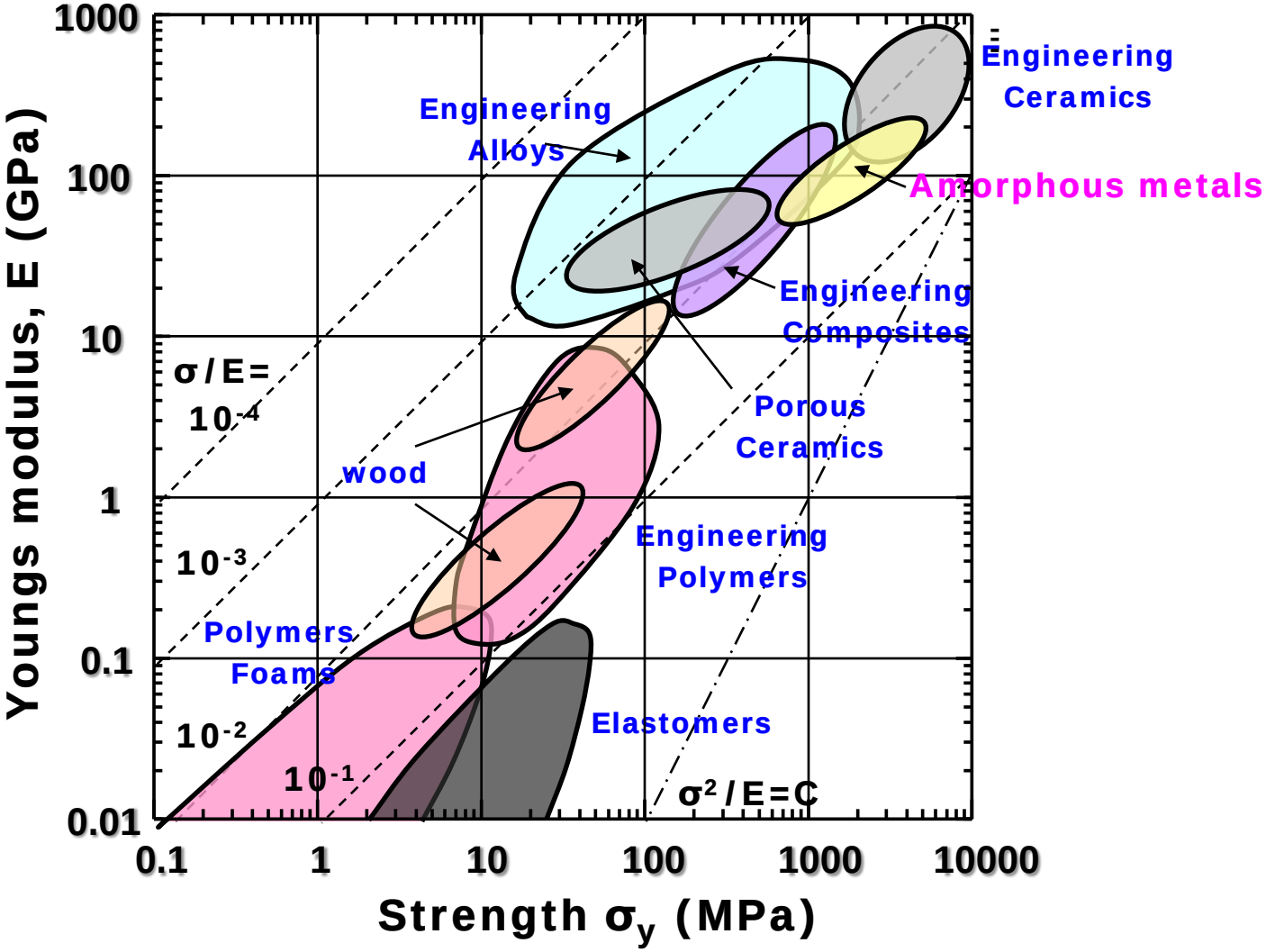
  ➡ Death of a material for structural applications



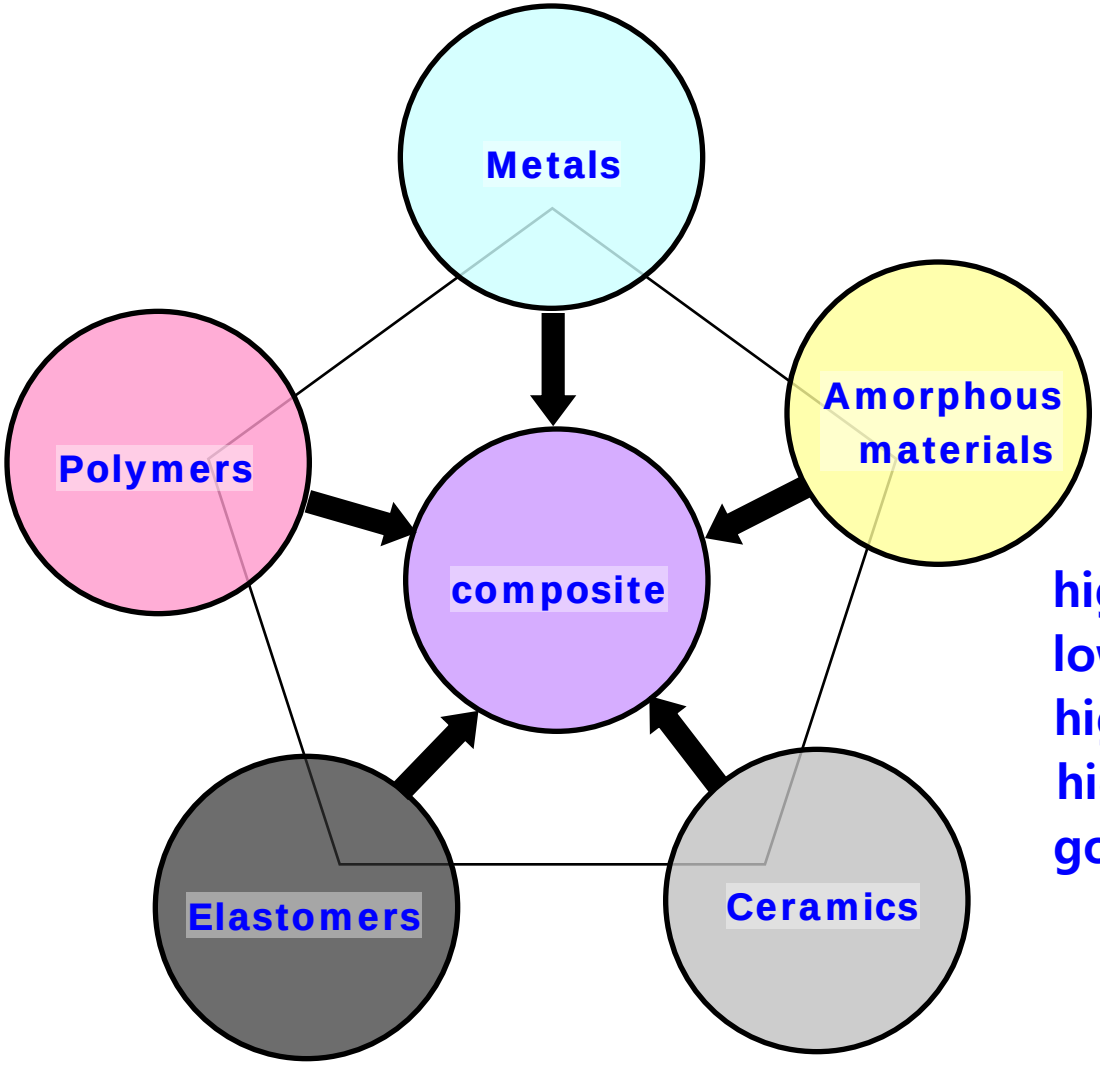



## < Ashby map >


Engineering Ceramics
Engineering Alloys
Amorphous metals
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

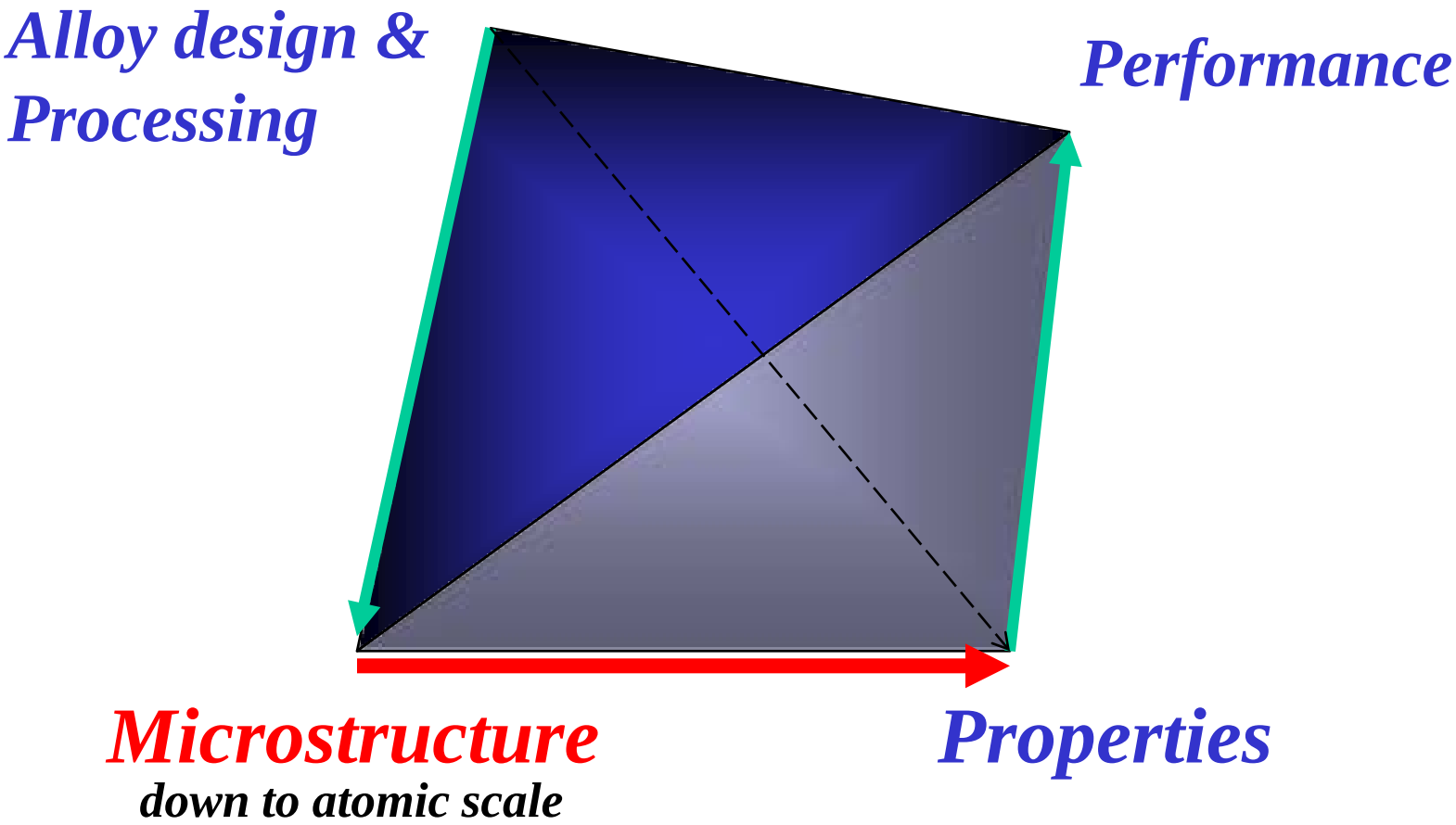



High GFA

High plasticity

higher strength
lower Young's modulus
high hardness
high corrosion resistance
good deformability
⋮

# Materials Tetrahedron




***"Tailor-made Materials Design"***