# Theories and Applications of Amorphous Materials


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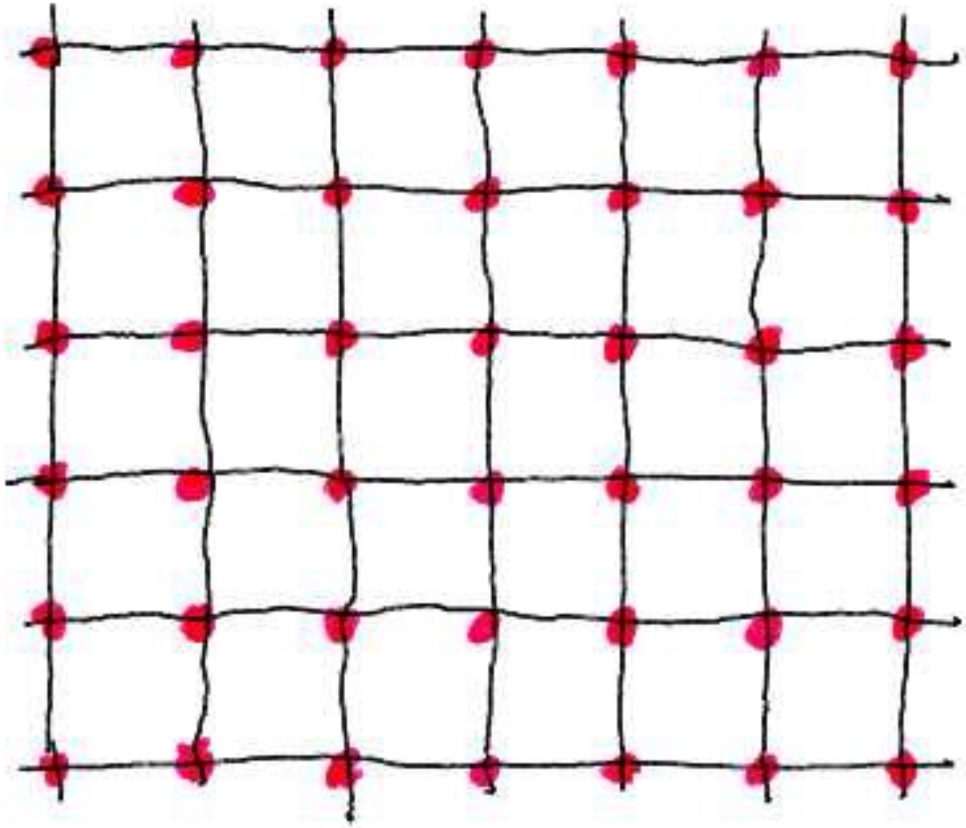
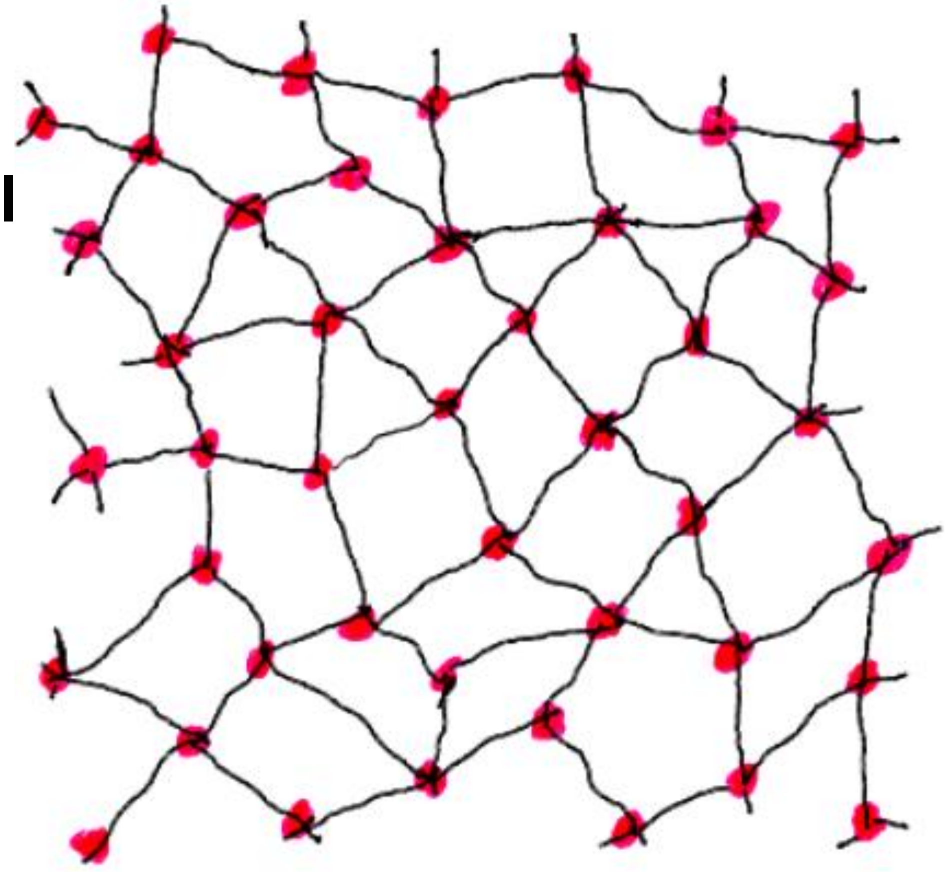
# Crystalline

- regular atomic arrangement
- slip planes for plastic deformation
- grain boundaries

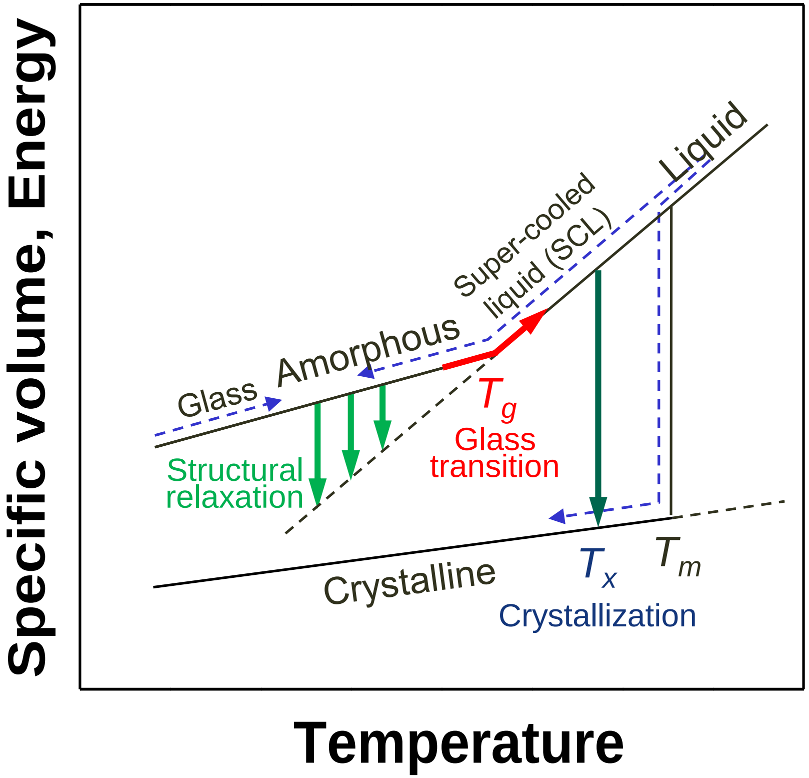


# Glass

- no periodicity, but
- density ~ same as crystal
- local configurations ~ same as crystal
- plastic flow is difficult
- no grain boundaries



# Phase Transformation of glass




R. E. Reed-hill, *Physical Metallurgy Principles 3ed.* (1991)

## Crystallization ($T_x$)

Transition from super-cooled liquid to crystalline

## Glass transition ($T_g$)

Transition from glass to super-cooled liquid

## Structural relaxation

Temporal changes of structure below $T_g$

- a glass forms if crystallization is avoided on cooling
- the density of the glass depends on cooling rate

# Preparation methods of glass

- Melt quenching
- Splat cooling
- Melt spinning
- Thermal evaporation
- Sputtering
- Glow-discharge decomposition
- Chemical vapor deposition
- Sol-gel processes
- Electrolytic deposition
- Reaction amorphization
- Irradiation
- Pressure-induced amorphization
- Solid-state diffusional amorphization

# Characteristics of amorphous materials

❖ **Very high mechanical strength**

❖ **Large elastic strain limit**

❖ **Low electrical conductivity**

- The structural disorder impedes the motion of the mobile electrons that make up the electrical current

❖ **Uniform properties**

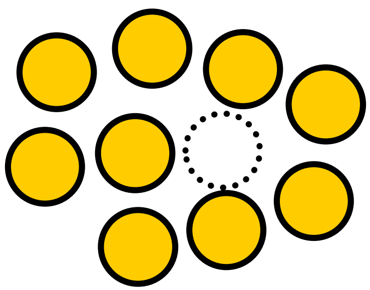
- No grain boundary

❖ **Corrosion resistance**

# The glass states

- **Glass is found for all classes of material:**
  - oxide (e.g. $SiO_2$)
  - ionic (e.g. $ZnF_2$)
  - polymeric
  - metallic
  - carbohydrates

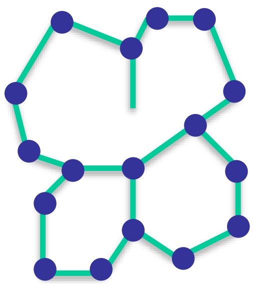
**Metallic/Ionic Glasses**



F. Spaepen, Acta Metallurgica, (1976)

Bulk metallic glass,…

**Covalent Glasses**



S. Lavizzari *et al.*, IEEE (2009)

Amorphous Si, Phase change materials,…

# Metallic glasses

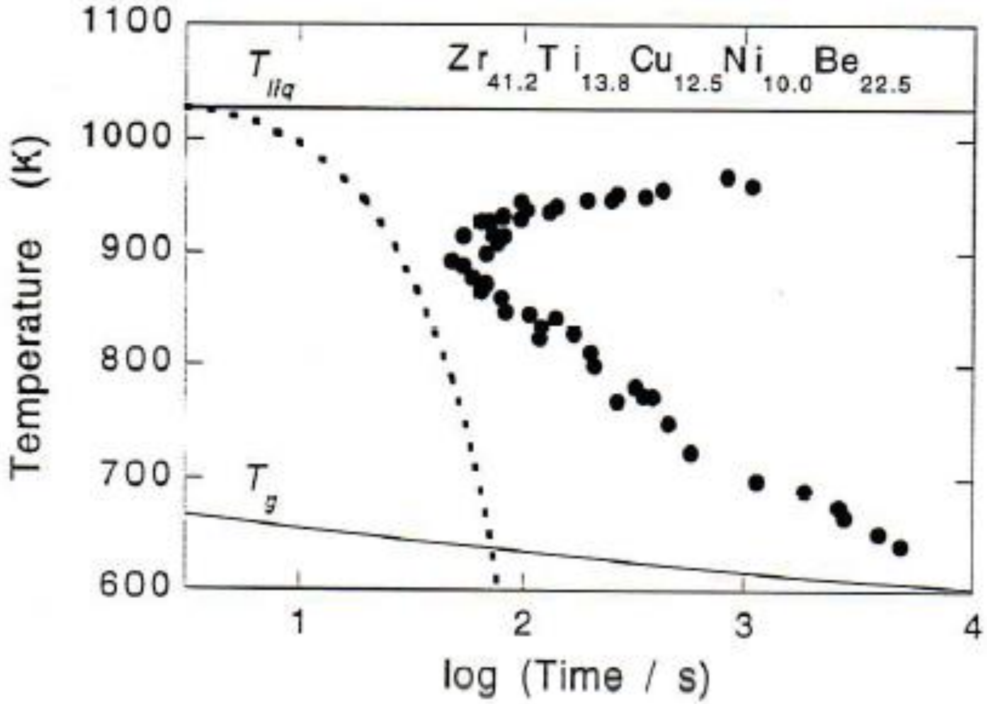
- metals and alloys are naturally crystalline

- pure metals cannot form glasses — their simple structure crystallizes too easily on cooling the liquid

- alloying can stabilize the liquid, and aids glass formation ("confusion principle")

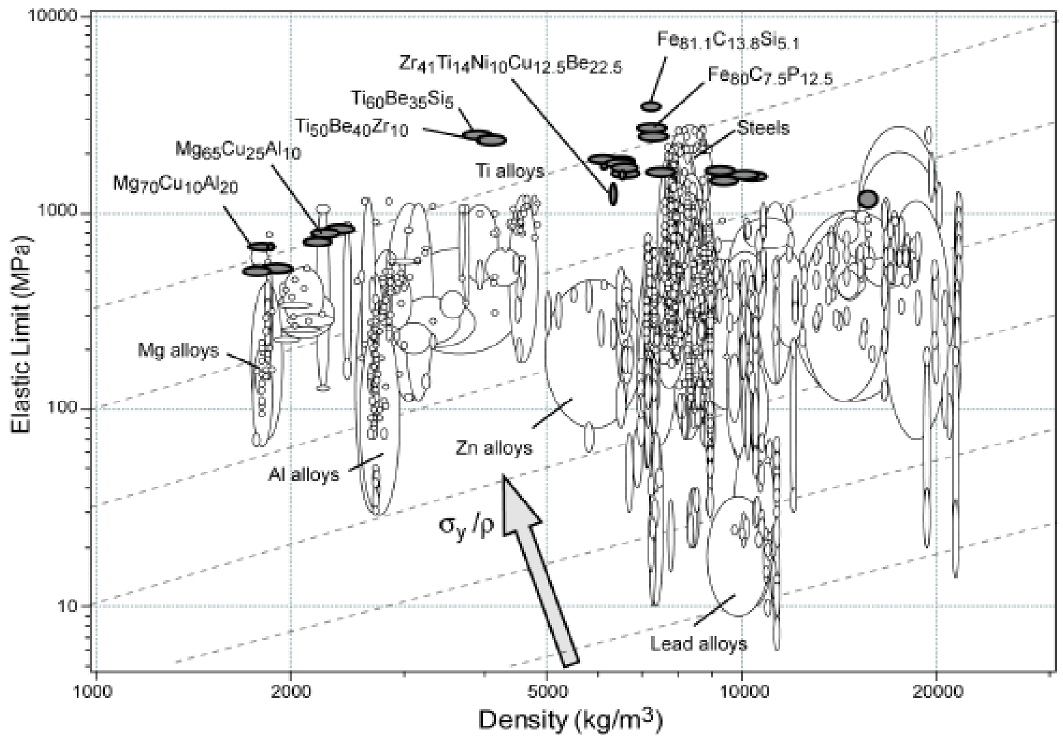
- for a binary alloy such as Fe80B20 (atomic %), the critical cooling rate for glass formation is 105 to 106 K s–1

# Bulk metallic glasses




- multicomponent compositions aid glass formation
- the critical cooling rate is much lower (~1 K s–1)
- glasses can be formed in bulk

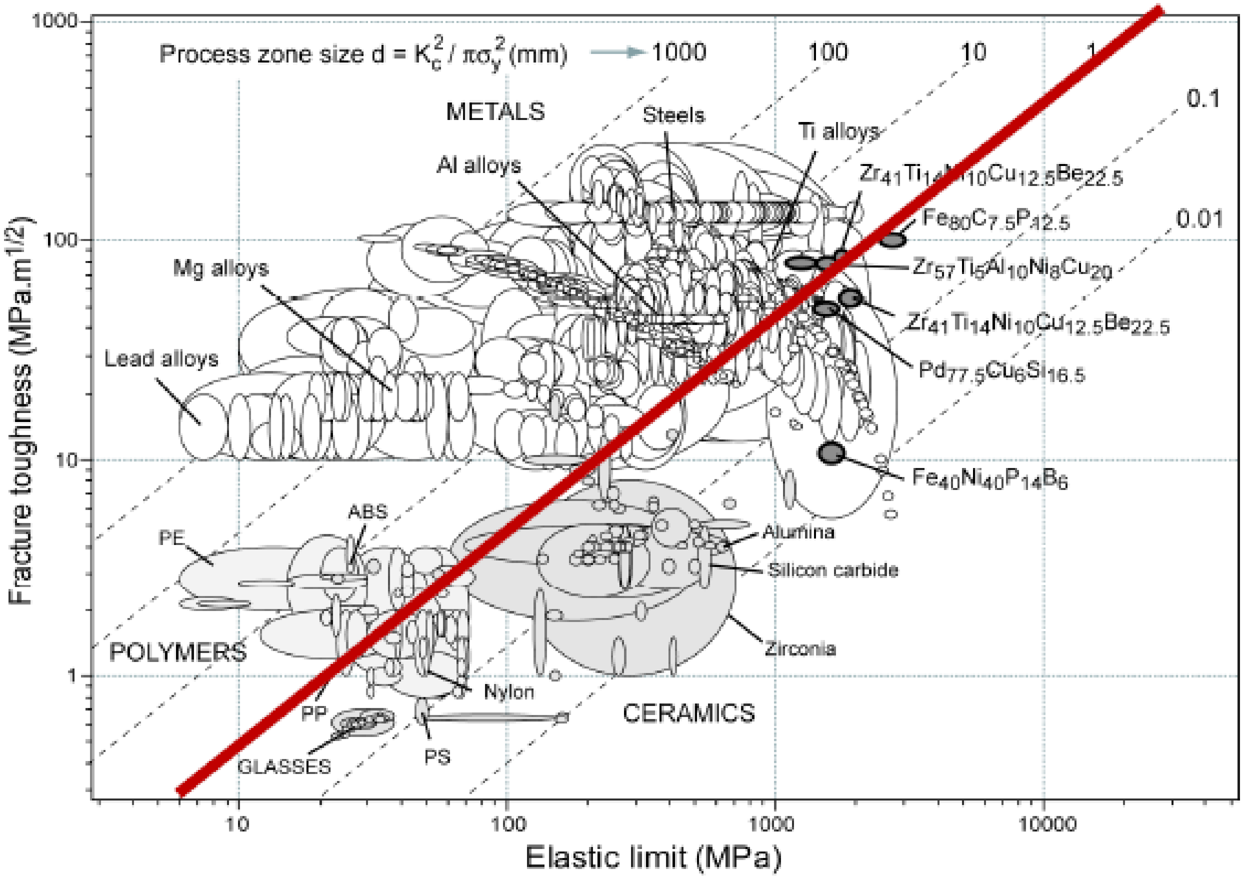
# Metallic glasses for structural applications

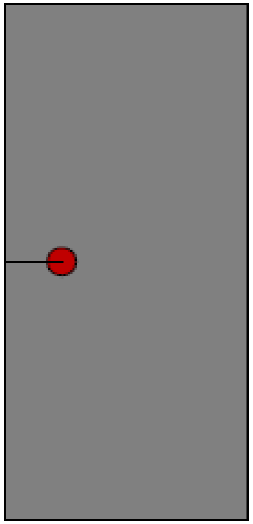



❖ **Elastic limit** sy plotted against **density** r for 1507 metals, alloys, metal-matrix composites and metallic glasses.

❖ The contours show the **specific strength** sy/r.

M.F. Ashby & A.L. Greer: *Scripta Materialia* **54** (2006) 321.
(in Viewpoint Set on *Mechanical Behavior of Metallic Glasses*, edited by T.C. Hufnagel)



❖ **Fracture toughness** and **elastic limit** for metals, alloys, ceramic, glasses, polymers and metallic glasses. The contours show the **process-zone size** *d* in mm.

M.F. Ashby & A.L. Greer: *Scripta Materialia* **54** (2006) 321.
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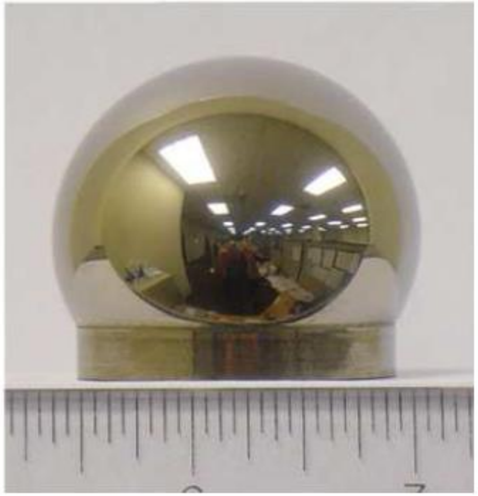
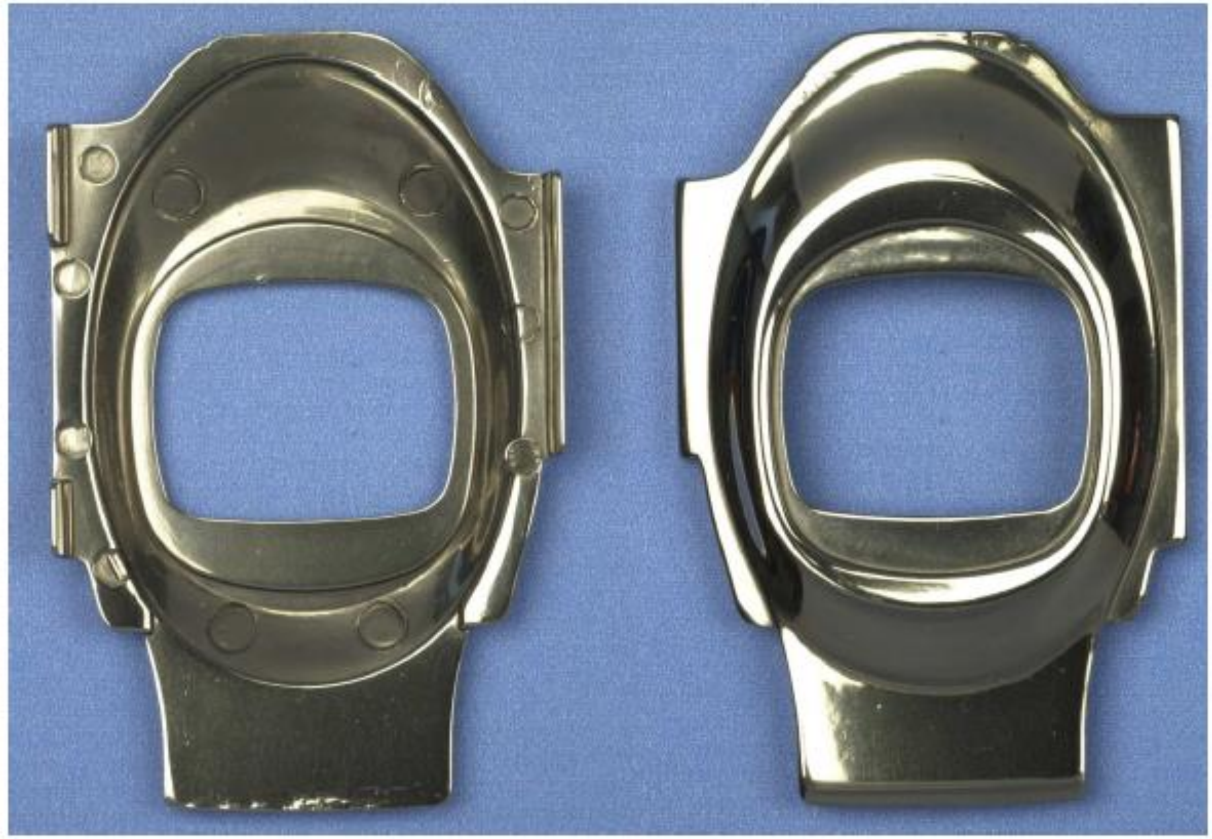
# Properties and applications of BMG

| No. | Properties | Application |
|---|---|---|
| 1. | High strength | Machinery materials |
| 2. | High hardness | Optical precision materials |
| 3. | High fracture toughness | Die materials |
| 4. | High impact fracture energy | Tool materials |
| 5. | High fatigue strength | Cutting materials |
| 6. | High corrosion resistance | Corrosion resistant materials |
| 7. | High wear resistance | Hydrogen storage materials |
| 8. | High reflection ratio | Composite materials |
| 9. | Good soft magnetism | Writing appliance materials |
| 10. | High magnetostriction | Bonding materials |





Golf clubs …. and tennis-racket frames, baseball bats, skis …