2014 Spring

"Advanced Physical Metallurgy"

- Bulk Metallic Glasses -

03.06.2014

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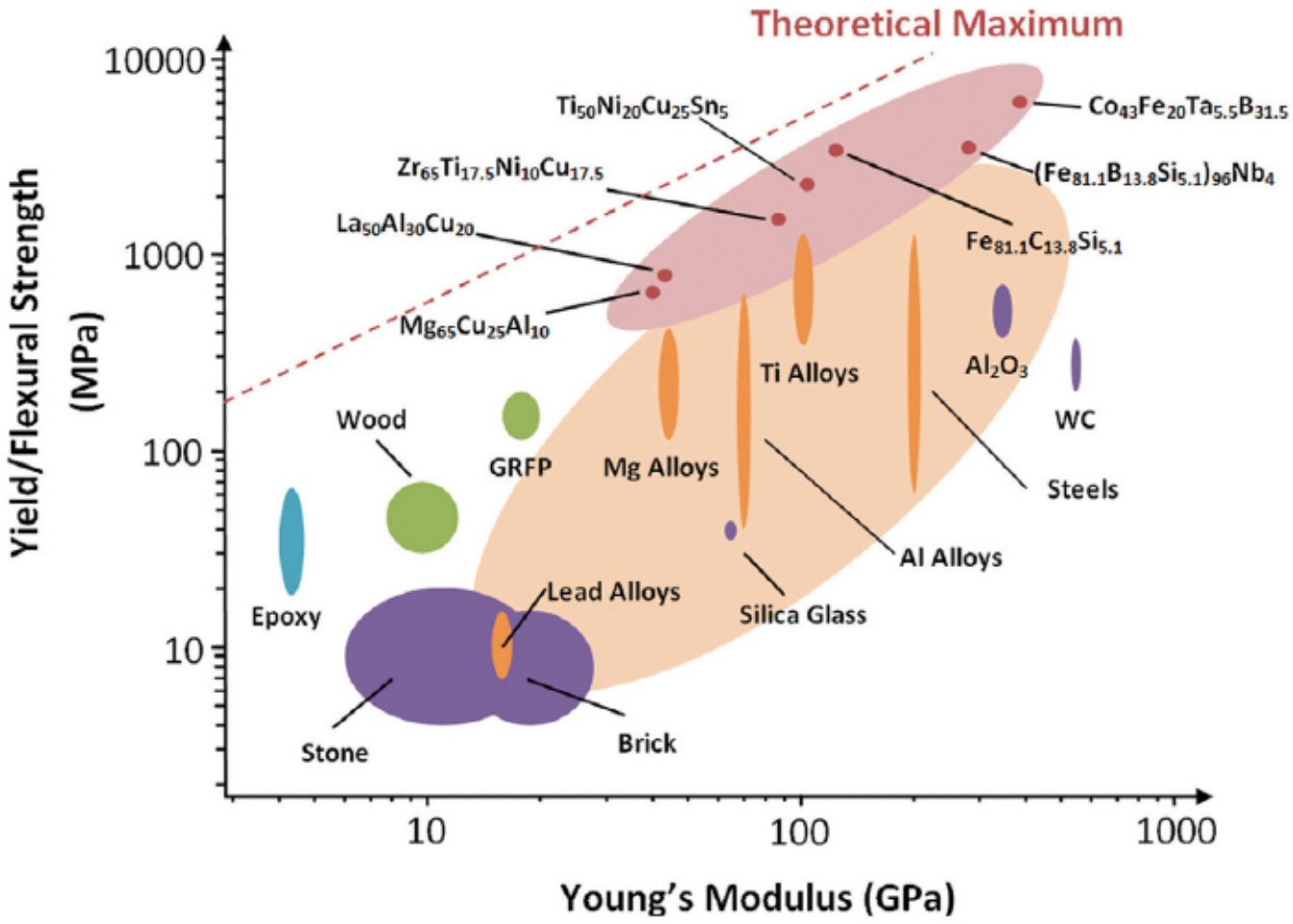
Are amorphous metals useful?

1. High strength of BMGs



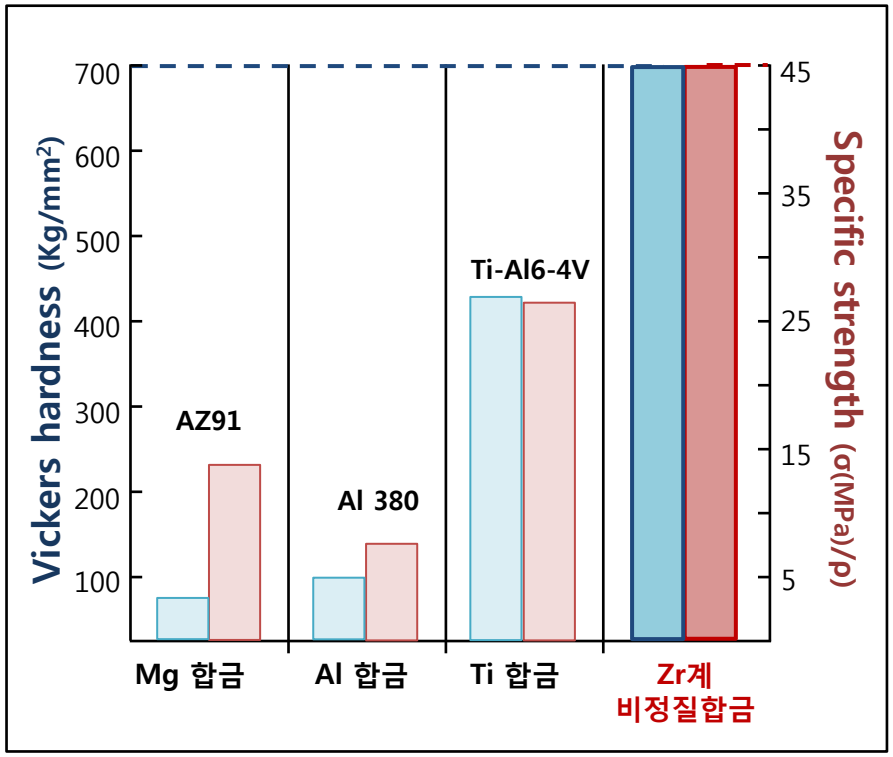
High fracture strength over 5 GPa in Fe-based BMGs

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

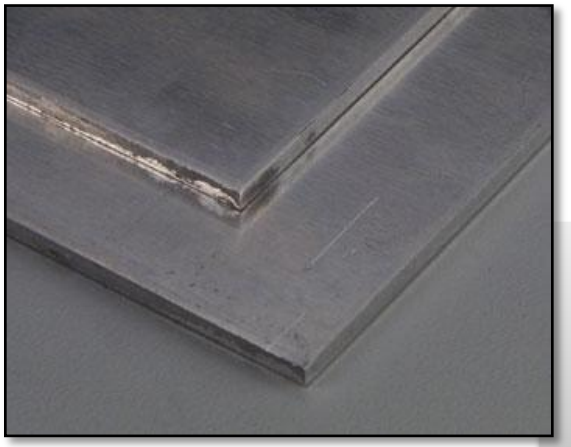
1. High strength of BMGs

Bulk metallic glasses with high strength

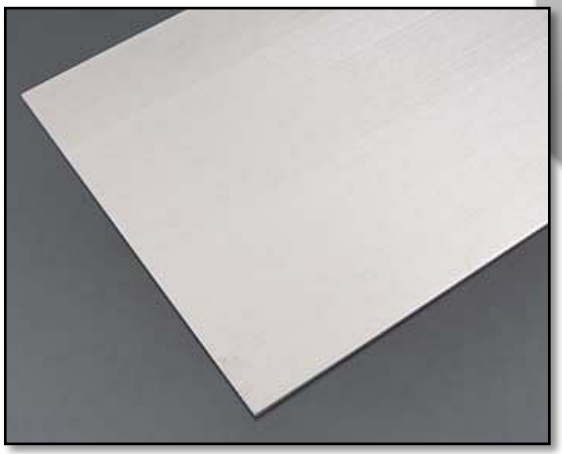
- 고비강도 및 고경도 (강도)
  - 초경량화 및 초경박화에 적합
    기존 상용 경량합금에 비하여 월등한 비강도로 재료의 획기적인 두께 감소가 가능



Zr계벌크 비정질 합금과 타 경량 합금의 경도와 비강도



Mg – AZ91

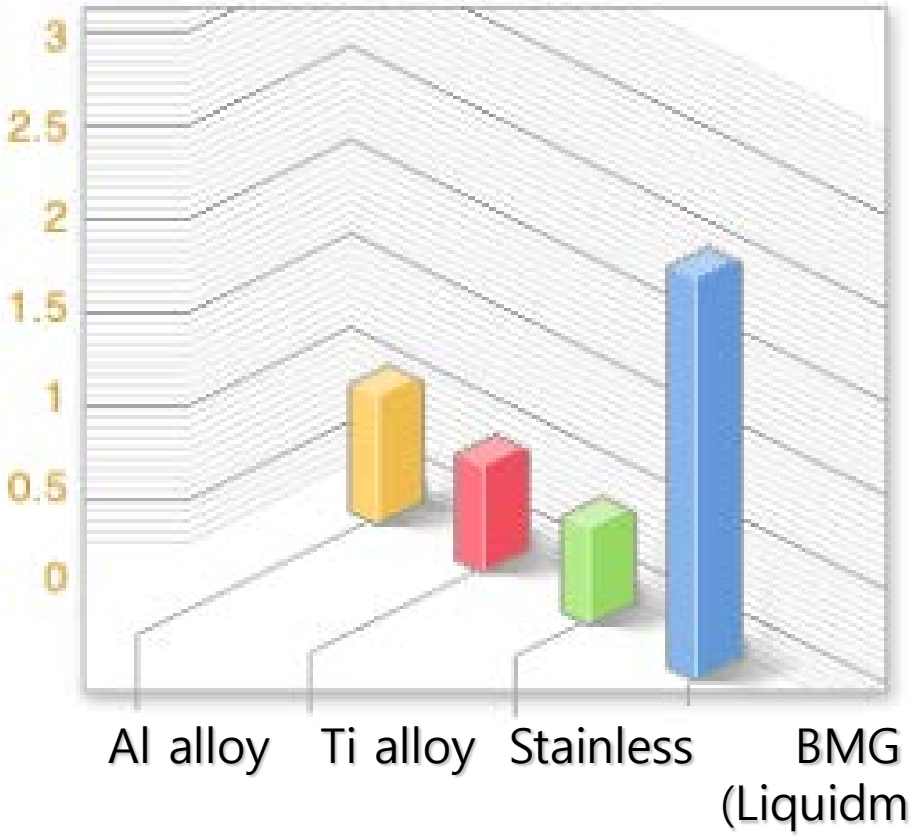


More thin plate: 비정질 합금

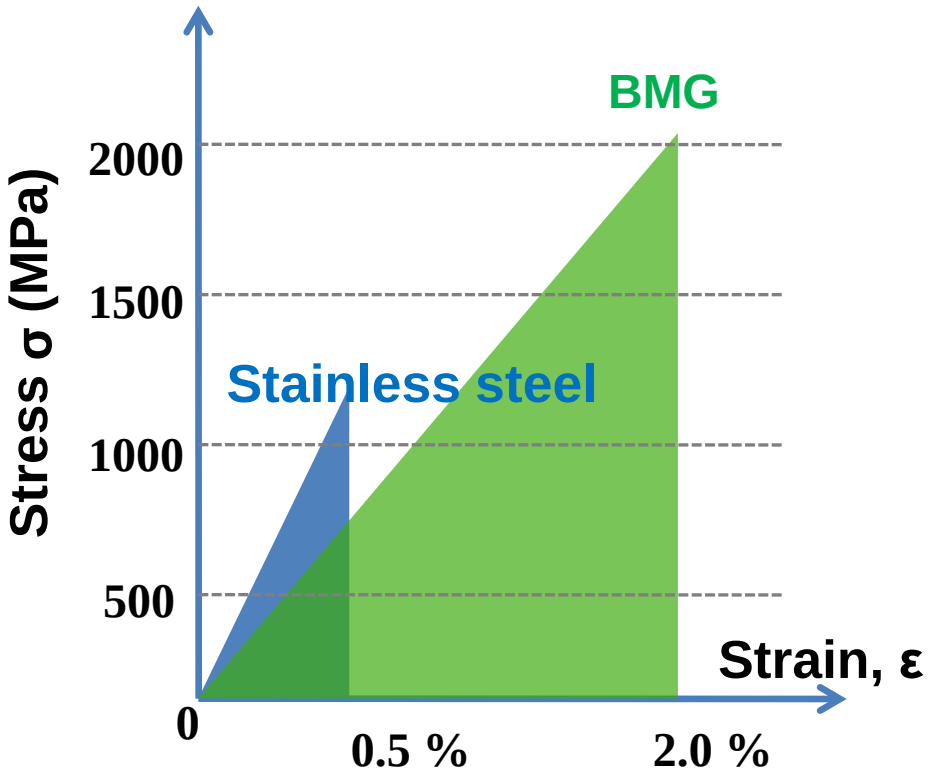
2. Large elastic strain limit of BMGs

Elastic Strain Limit

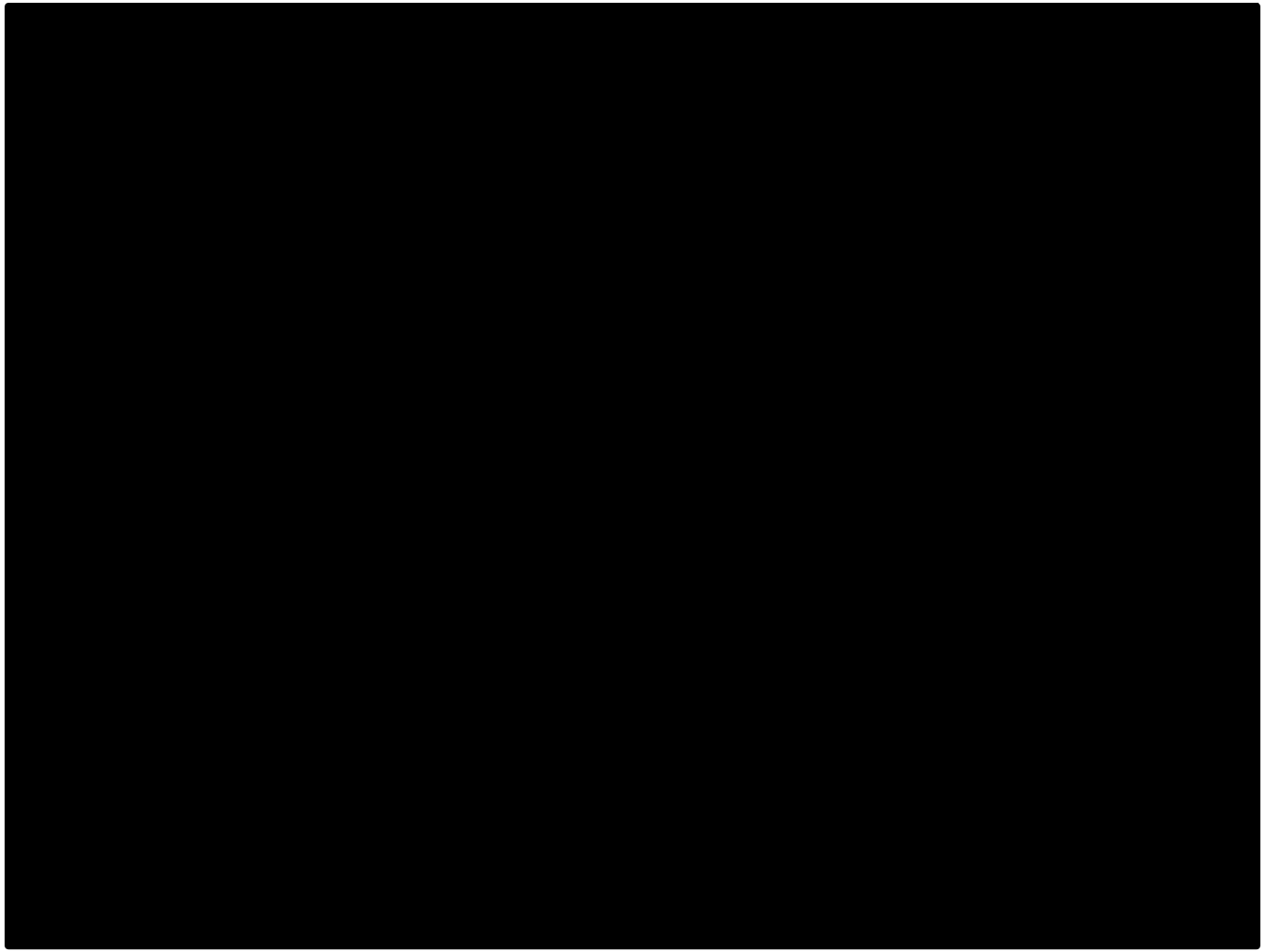
[as % of Original Shape]



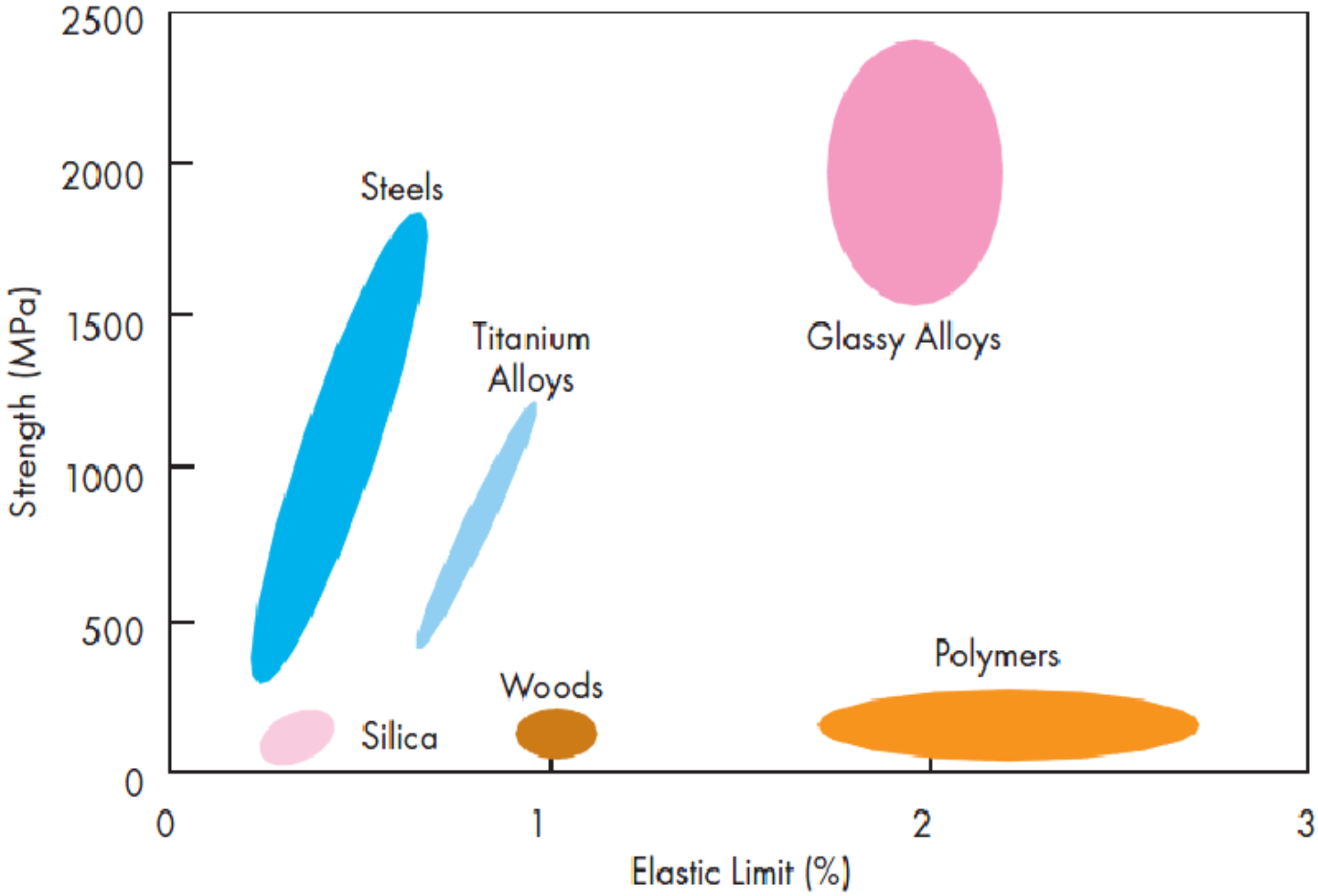
Stress-Strain Curve



2. Large elastic strain limit of BMGs

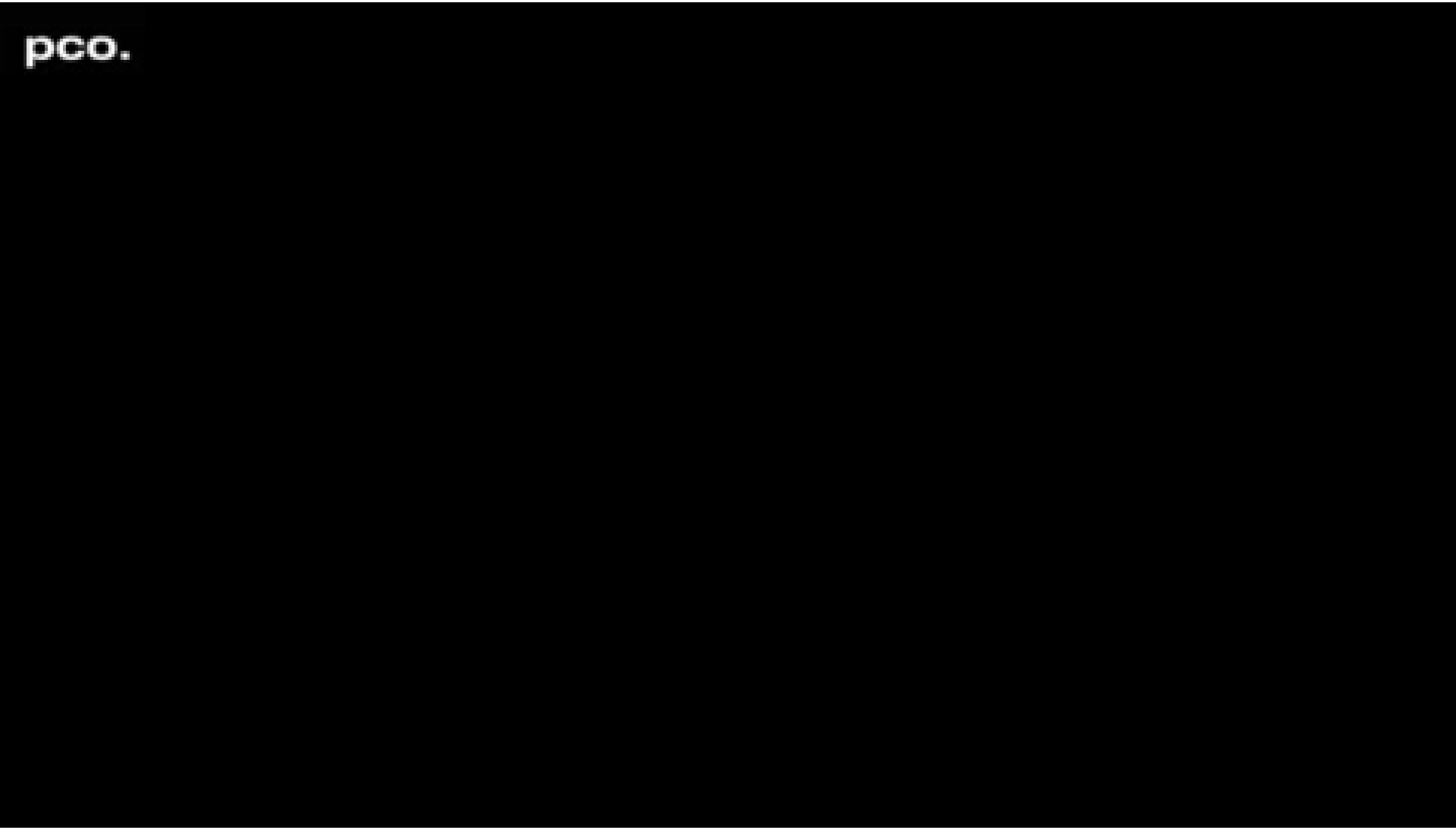


Bulk metallic glasses with high strength & high elastic limit



: Metallic Glasses Offer a Unique Combination of High Strength and High Elastic Limit

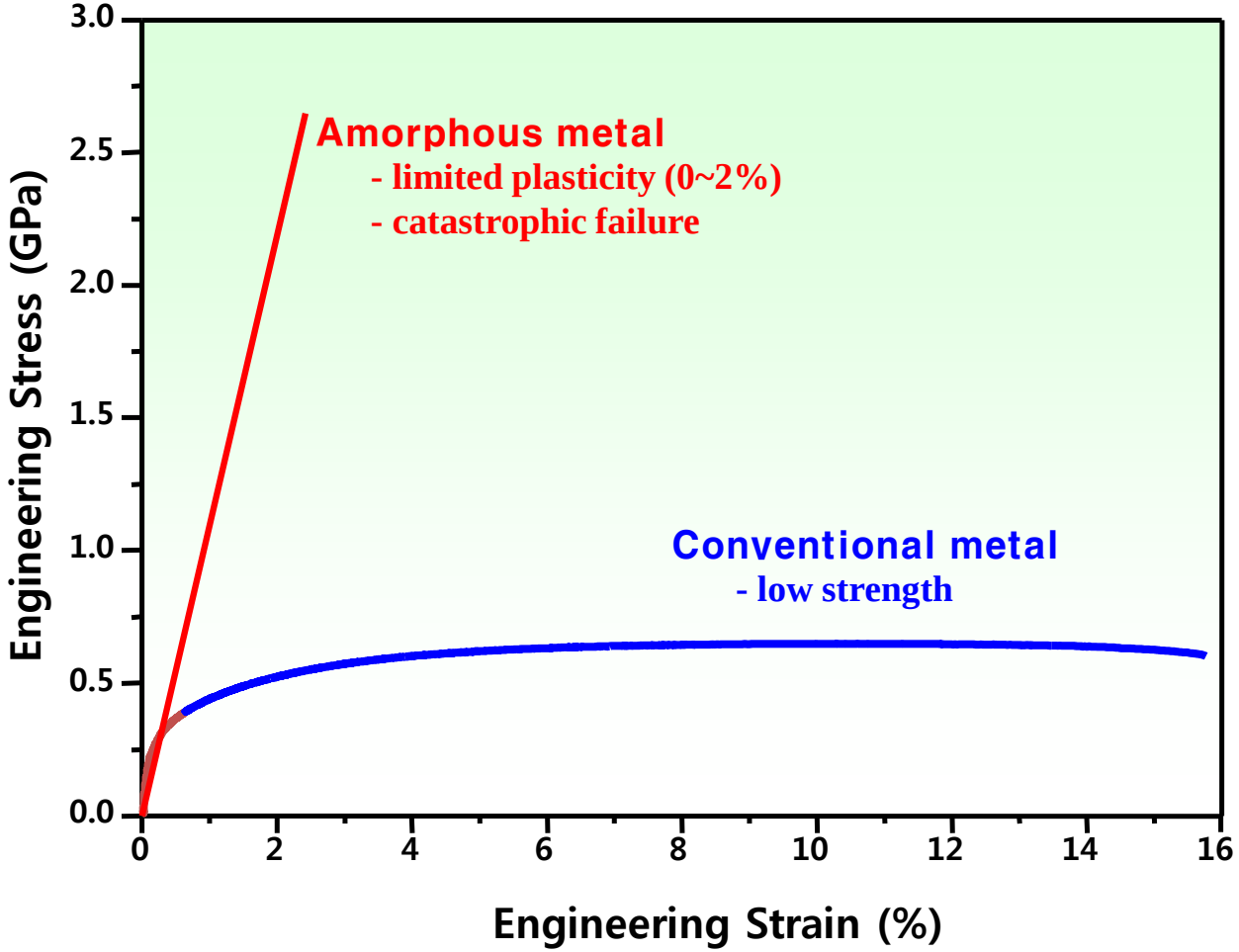
구조재료로서 비정질 합금의 Drawback

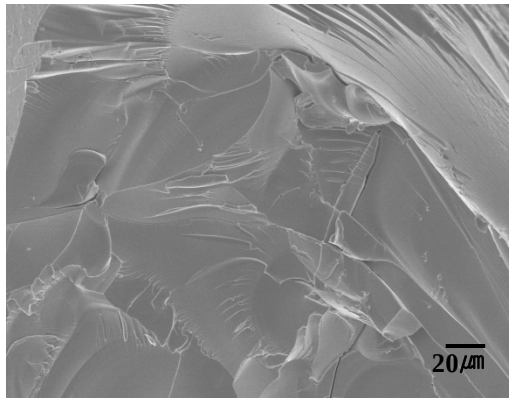


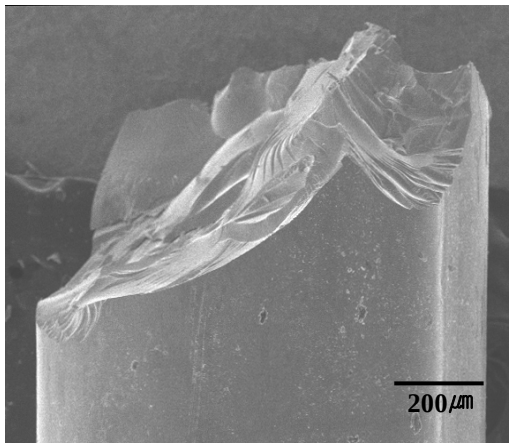
Limited Plasticity by shear softening and shear band

- Microscopically brittle fracture

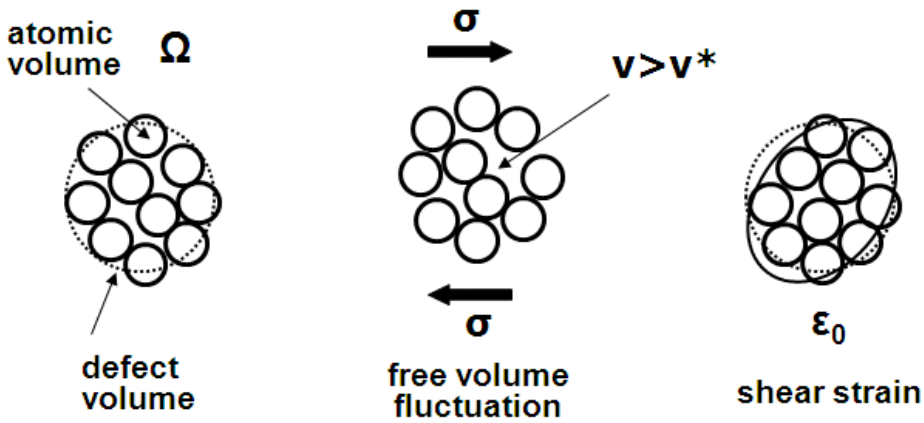
➡ Death of a material for structural applications

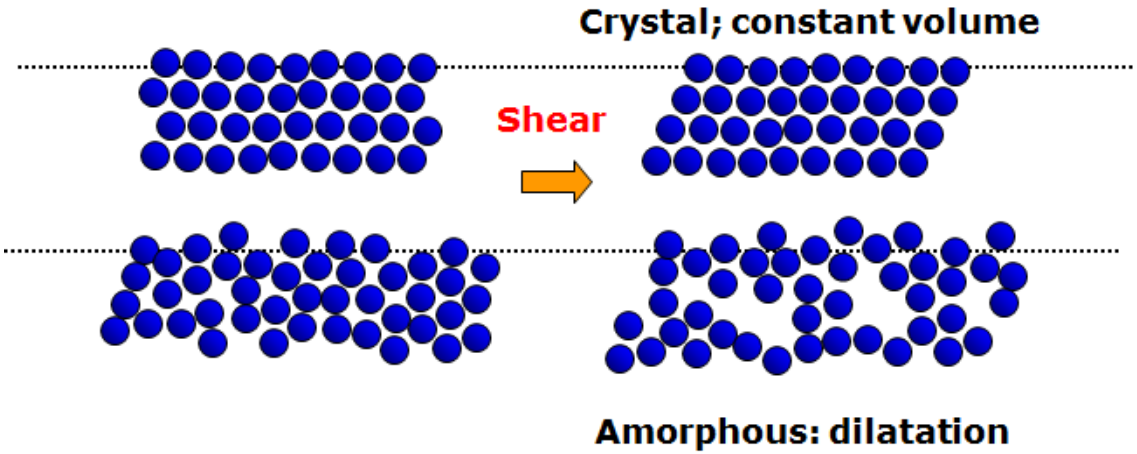






Elementary flow events in metallic glasses





Footprints in sand.
Water quickly disappears underneath

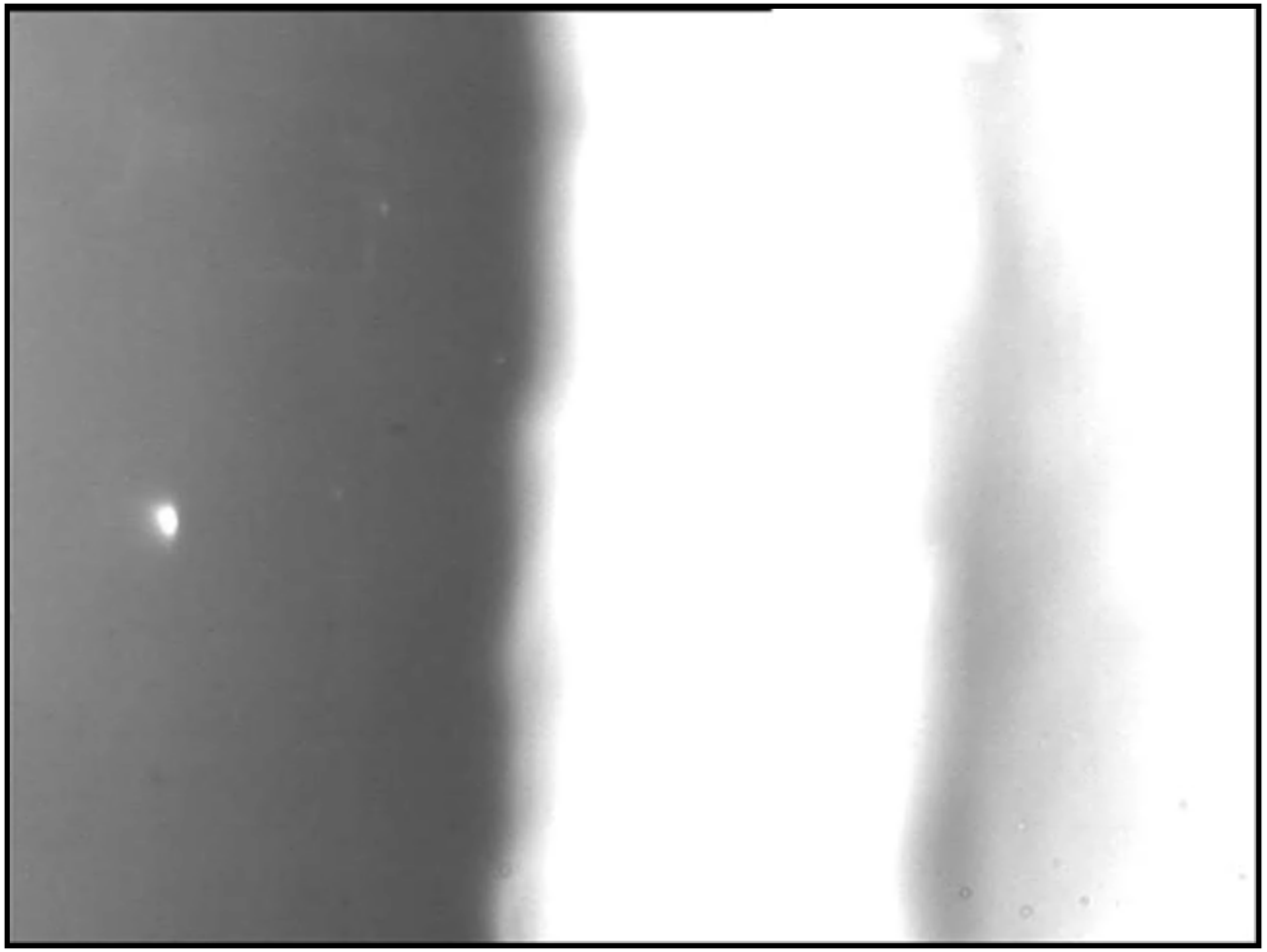
➡ Shear bands form by accumulation of defects during deformation.

nature materials | VOL 5 | JANUARY 2006 | www.nature.com/naturematerials

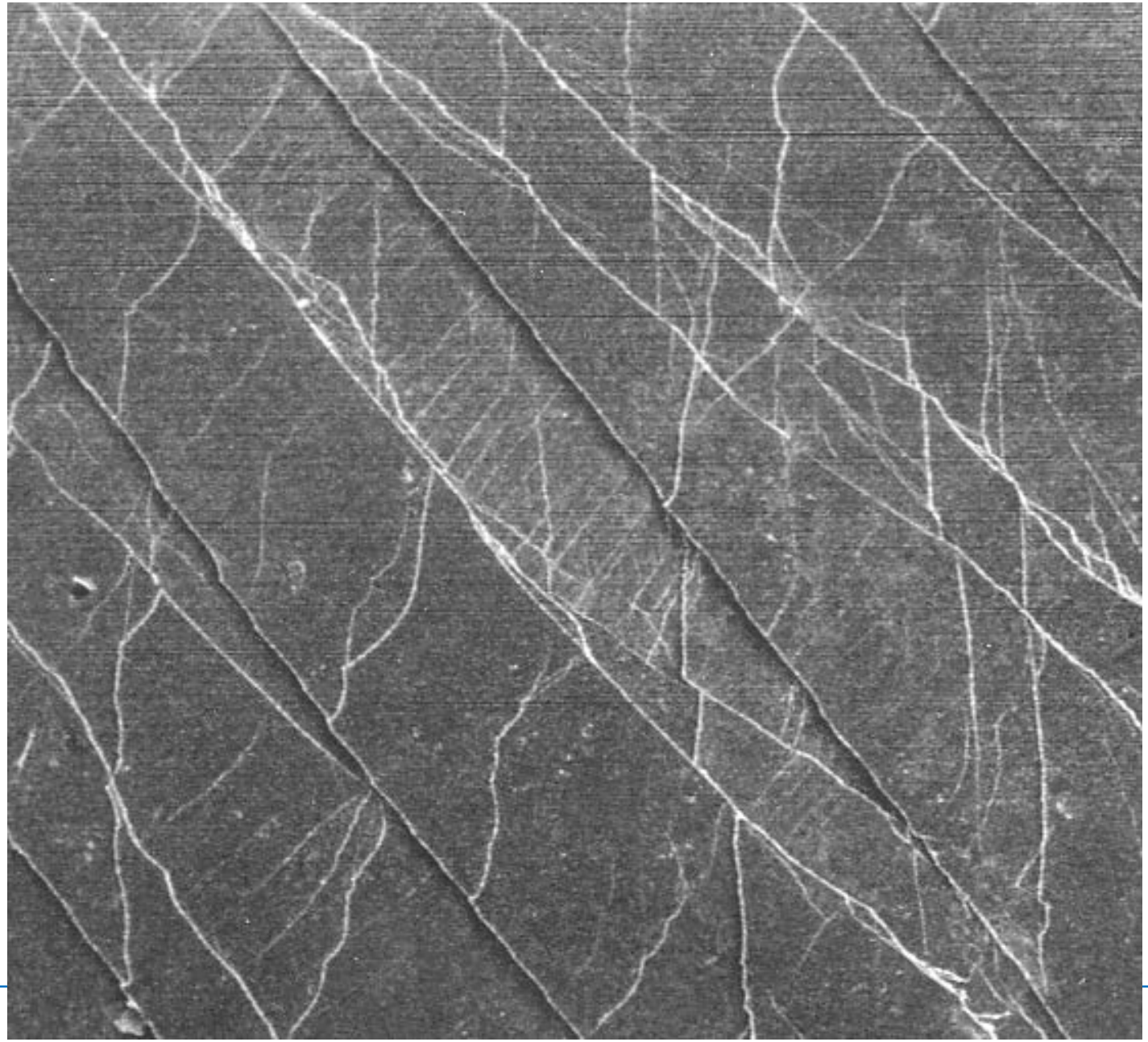
Effect of local favored structure on SB nucleation

- $Ni_{60}Nb_{40}$: fully amorphous phase

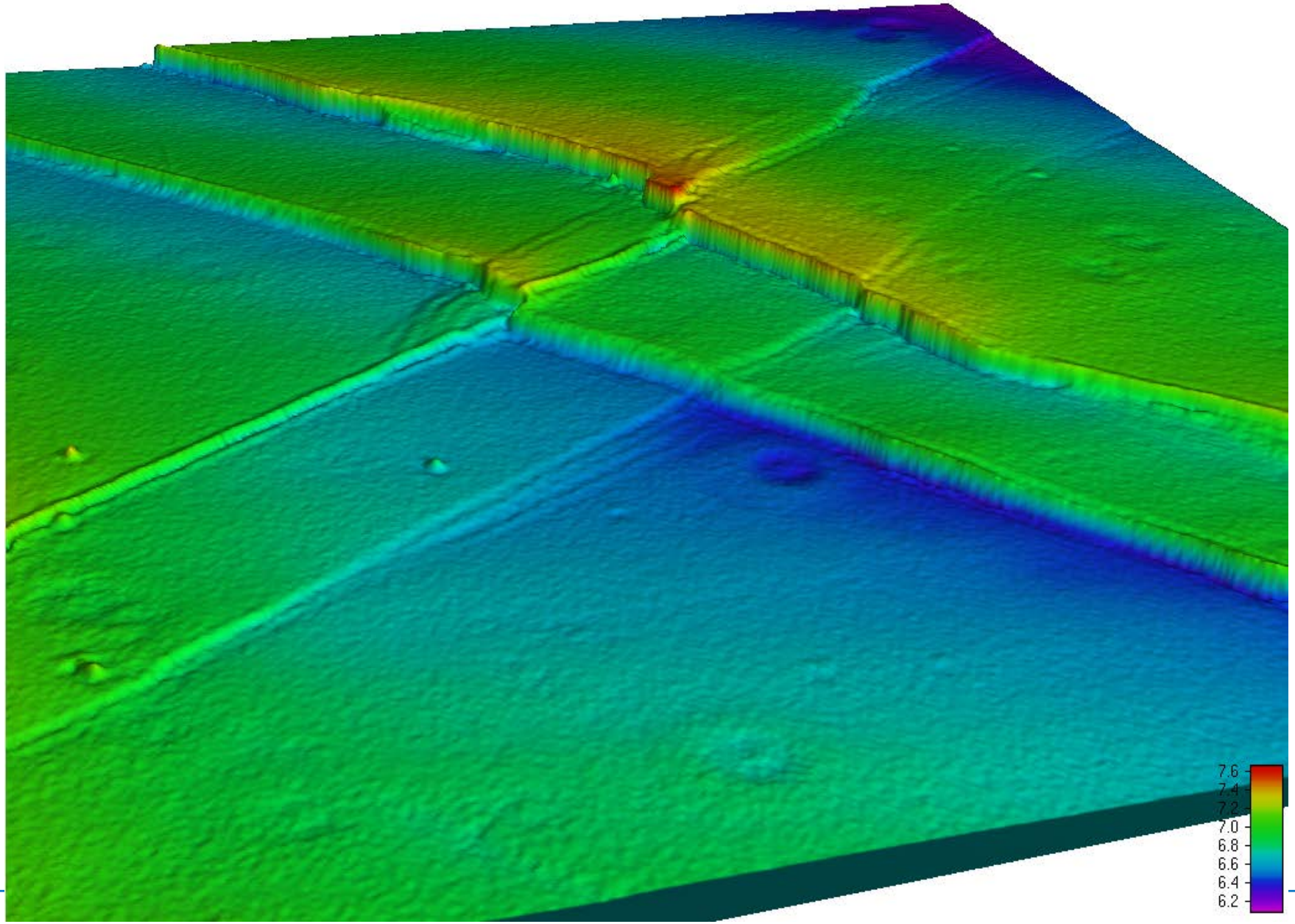
S=0.016 mm/sec



Formation of multiple shear bands during deformation

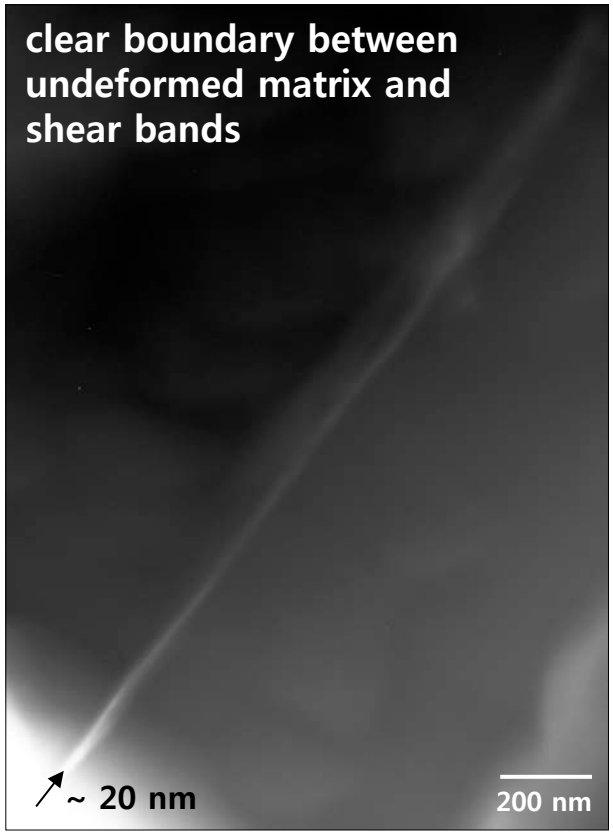


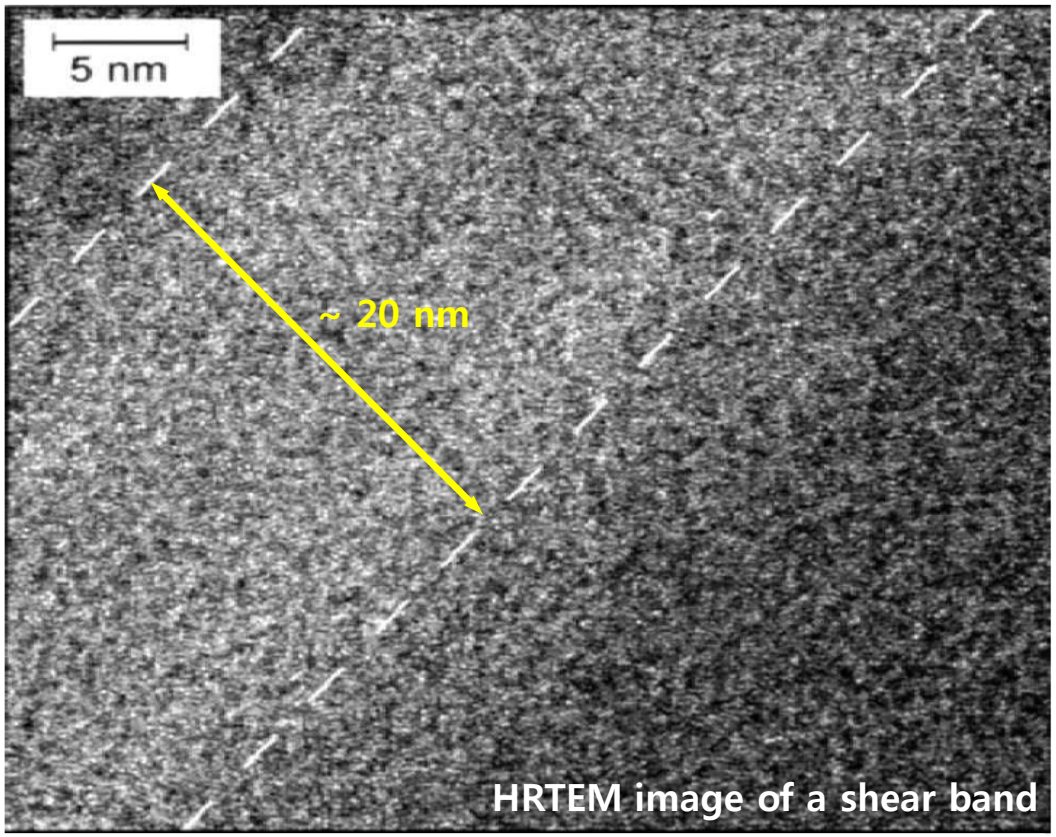
Multiple shear bands = Multiple shear planes



Formation of shear bands : variation of free volume

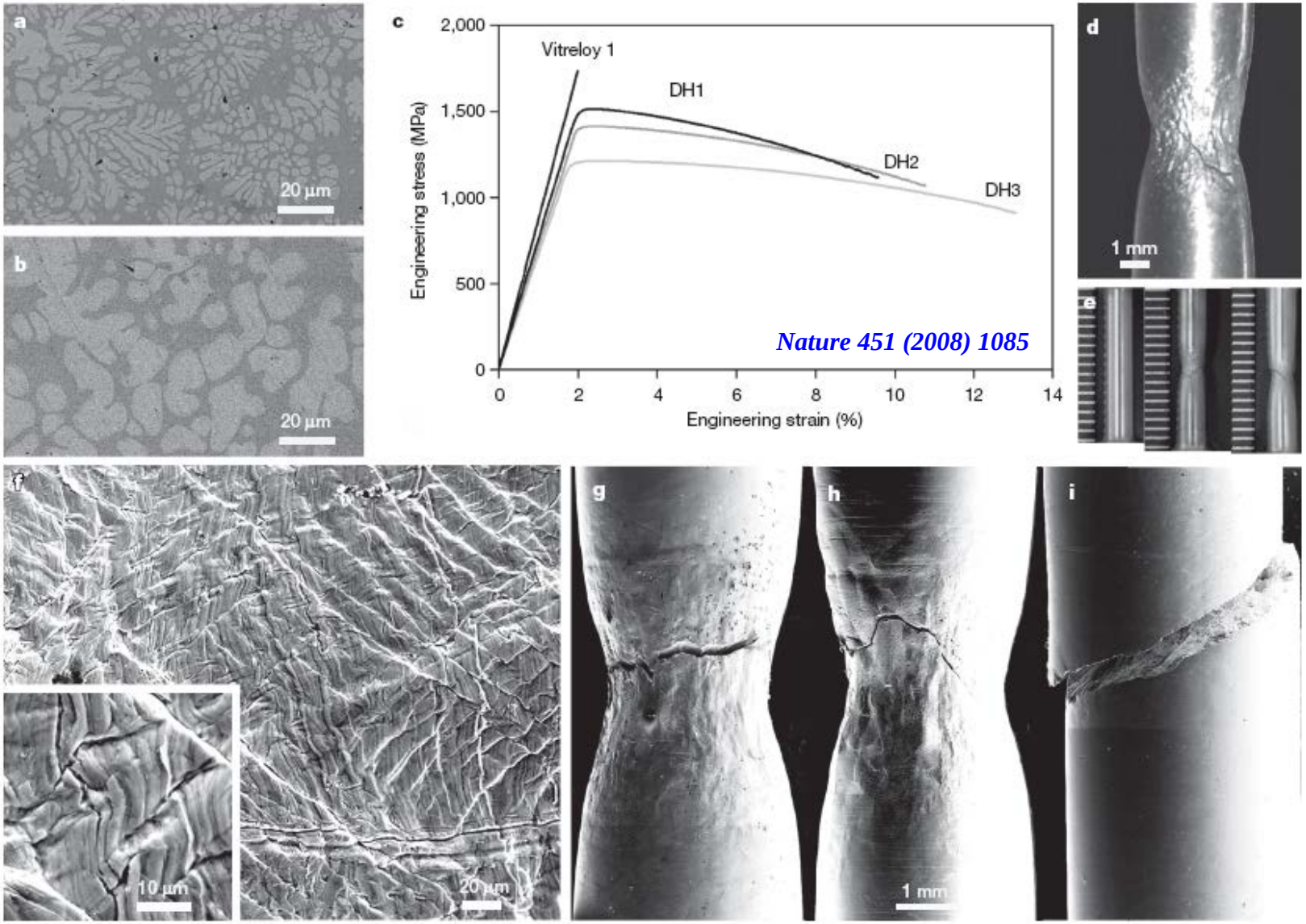
Shear bands form by **accumulation of defects** during deformation.





Shear deformed areas with the **same composition** & **different density of free volume**

In-situ BMG matrix composites with tensile ductility

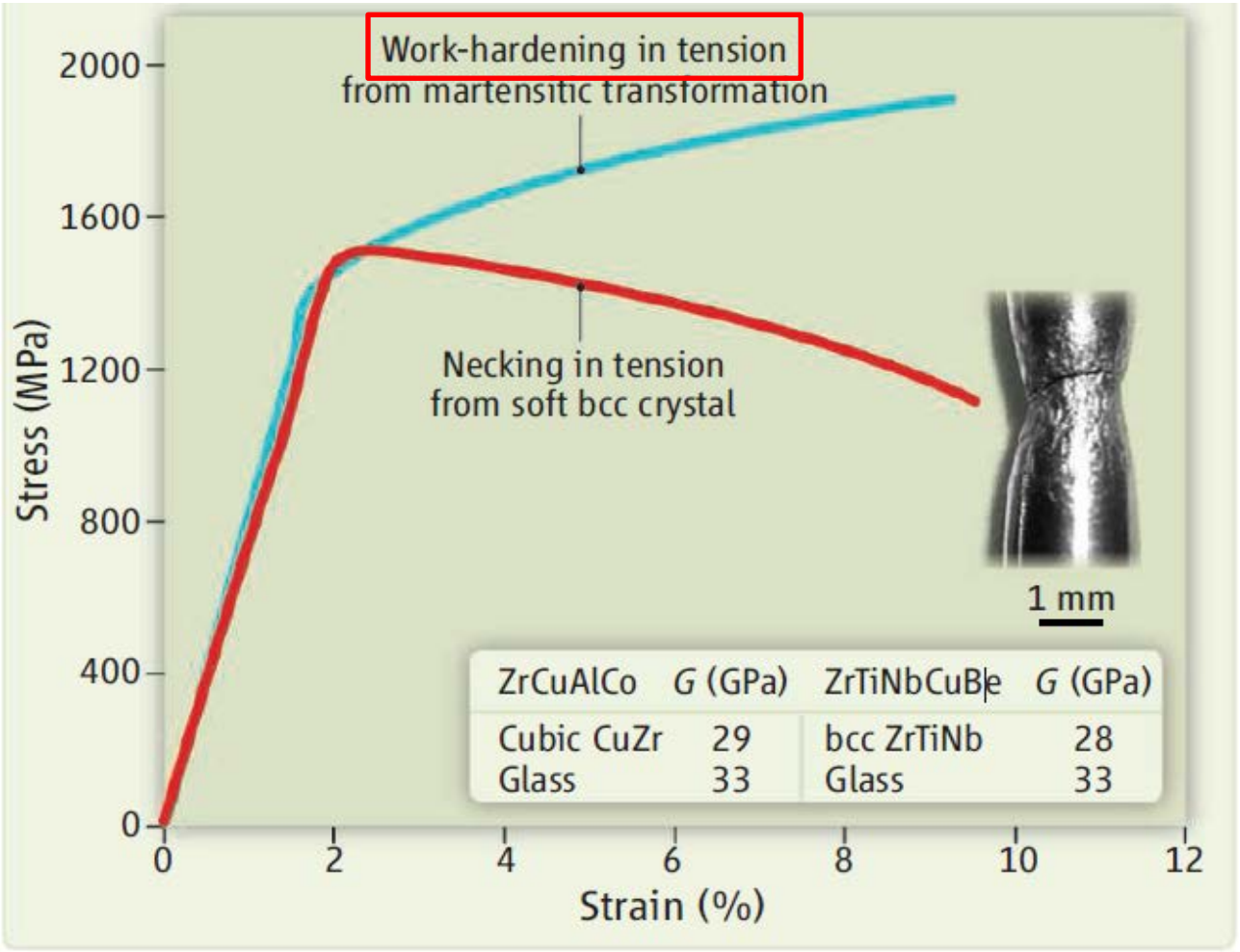


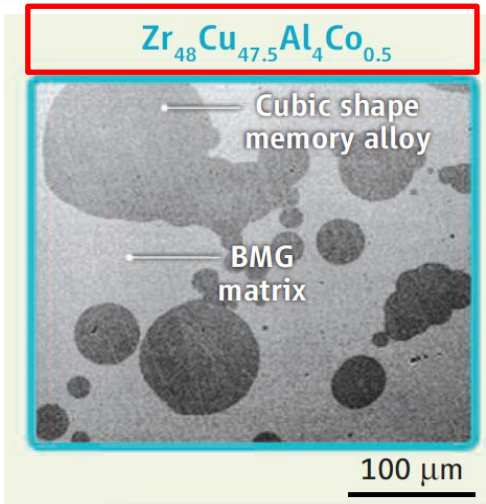
High fracture toughness: > 10 % plastic strain in tensile test

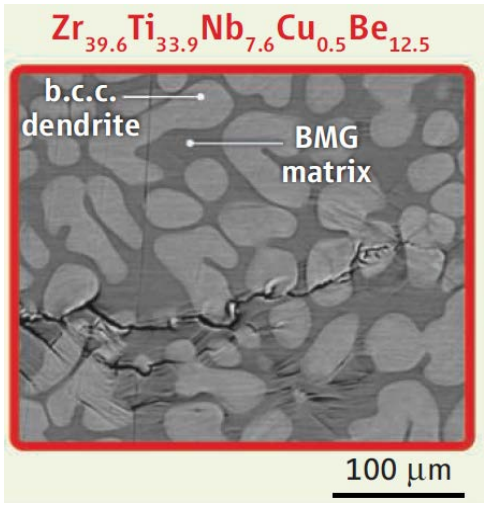
Shape Memory Bulk Metallic Glass Composites

Glass-forming and shape memory metals may provide a route to fabricating materials with enhanced mechanical properties.

Douglas C. Hofmann







nature materials

NATURE MATERIALS | LETTER

Transformation-mediated ductility in CuZr-based bulk metallic glasses

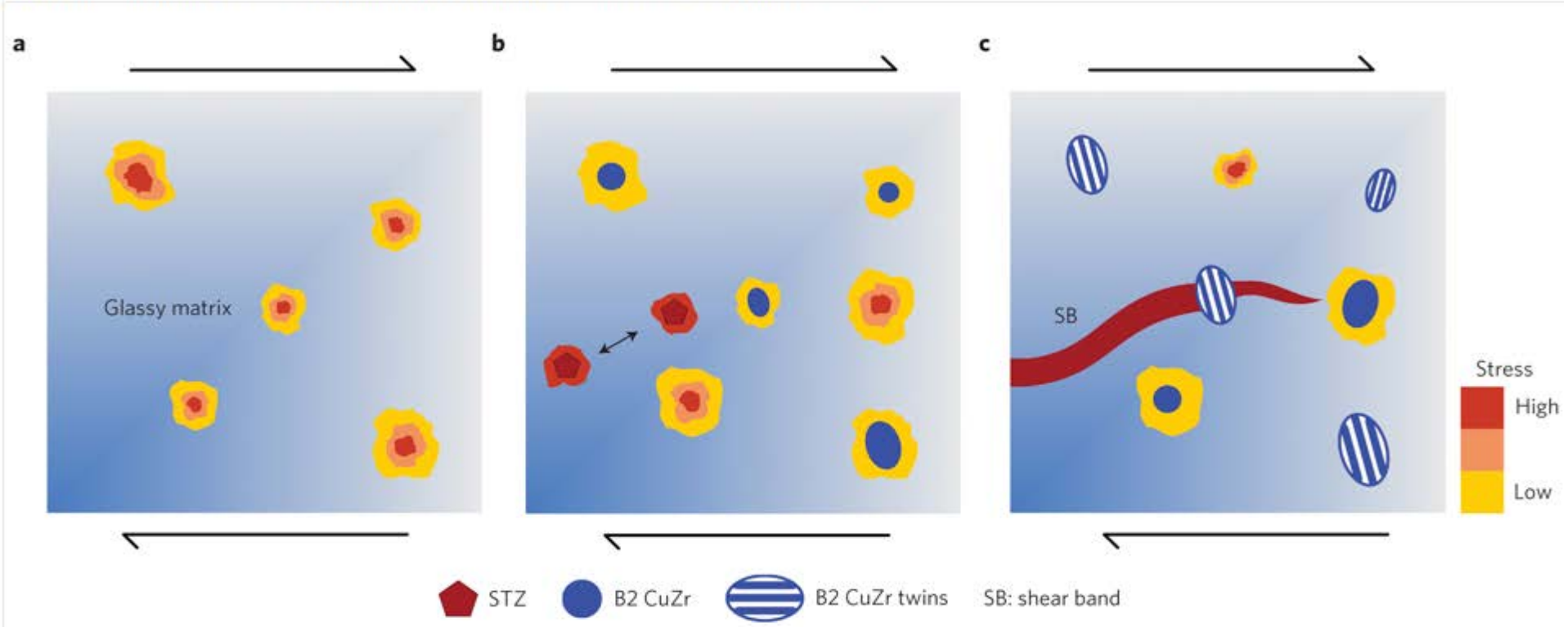
S. Pauly, S. Gorantla, G. Wang, U. Kühn & J. Eckert

Affiliations | Contributions | Corresponding author

Nature Materials 9, 473–477 (2010) | doi:10.1038/nmat2767

Received 17 November 2009 | Accepted 09 April 2010 | Published online 16 May 2010

Figure 4: Schematic of the deformation process in the CuZr-based alloys investigated.



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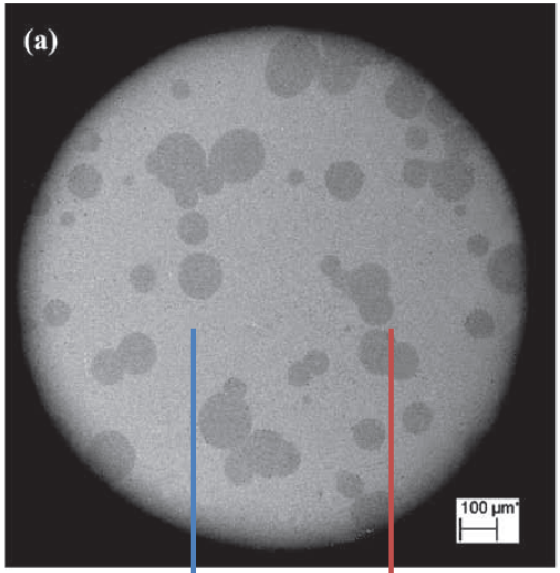


BMG matrix

CuZr B2 Transformation Media

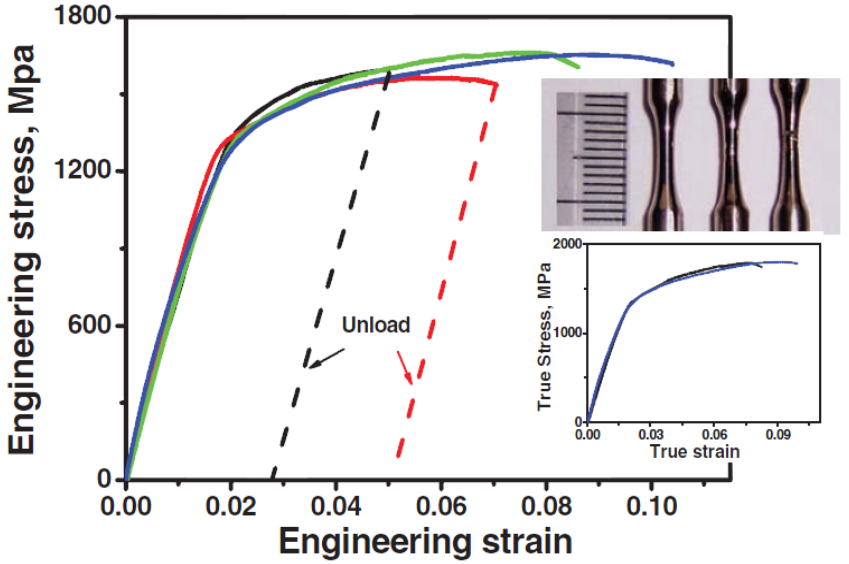


Figure 2. Engineering tensile stress–strain curves of the BMG composites. Dashed lines indicate the unloading process. Top inset shows the outer appearance of the tensile samples pre-strained at the different stages and the lower inset shows the true tensile stress–strain curves, indicating a significant strain-hardening behavior.

Z.P. Lu, et al. Adv. Mater. 2010, 22, 2770–2773

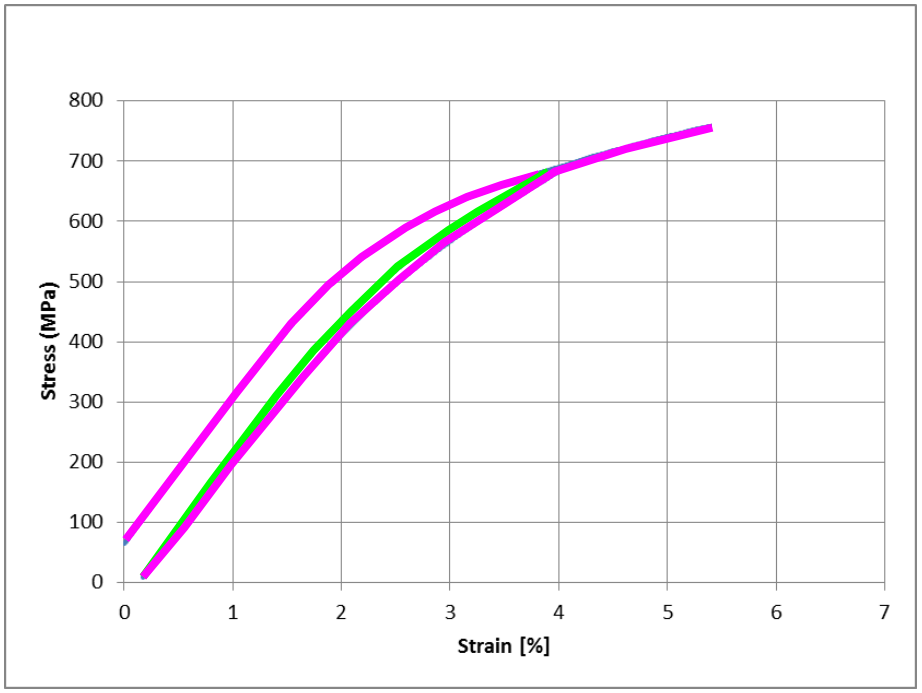
➡ Cu-Zr-Al system

Development of superelastic bulk metallic glass composites

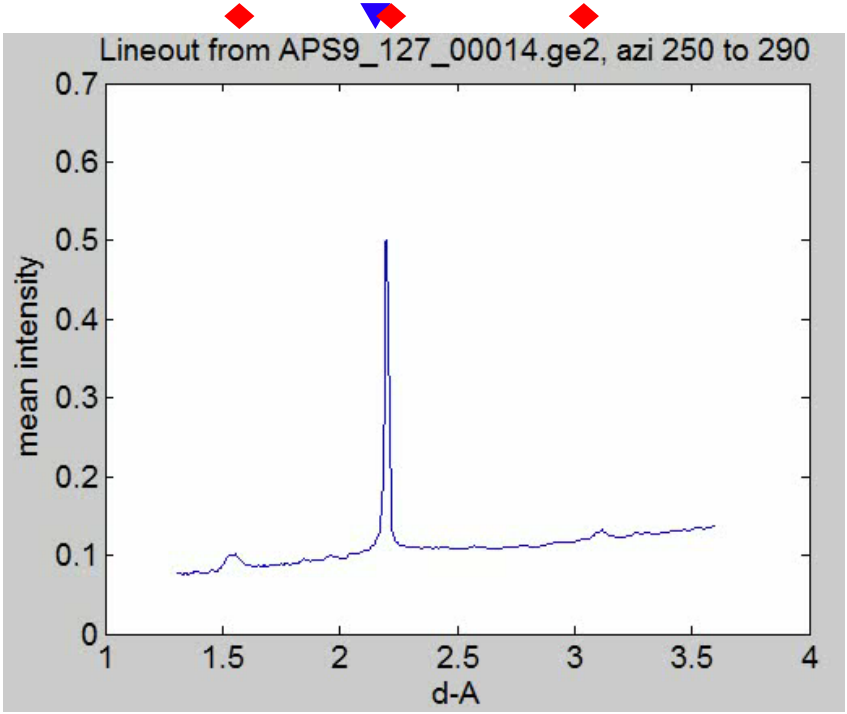
Reversible phase transformation behavior during cyclic tensile test _ ESPark group, SNU

Ti-Cu-Ni-X Φ3mm
Water cooled Cu mold suction casting,

Loading → Unloading → Reloading

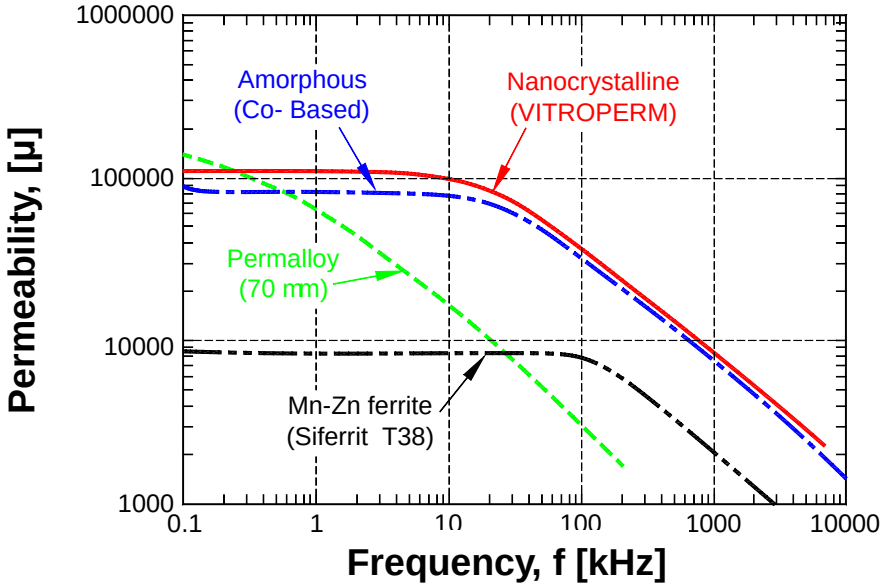


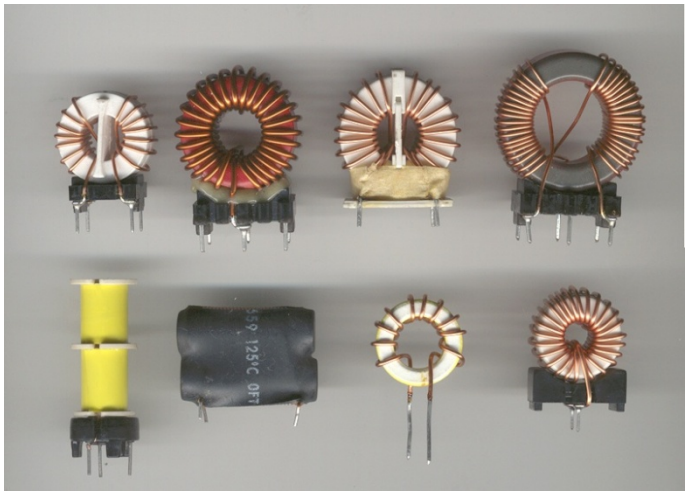
▼ Initial BCC phase in as-cast sample
◆ Deformed martensite phase



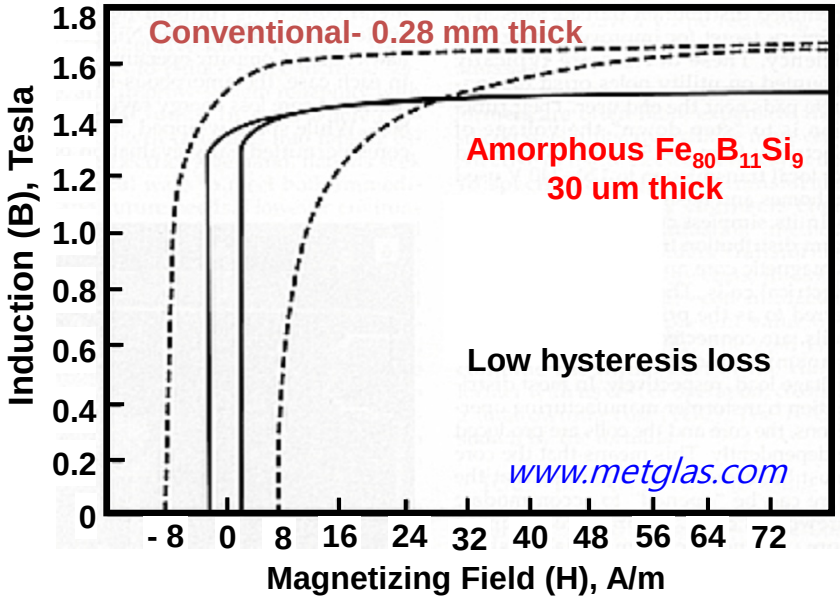
By Dr. Ryan Ott (AMES) at APS beam line

3. Old uses: soft magnet





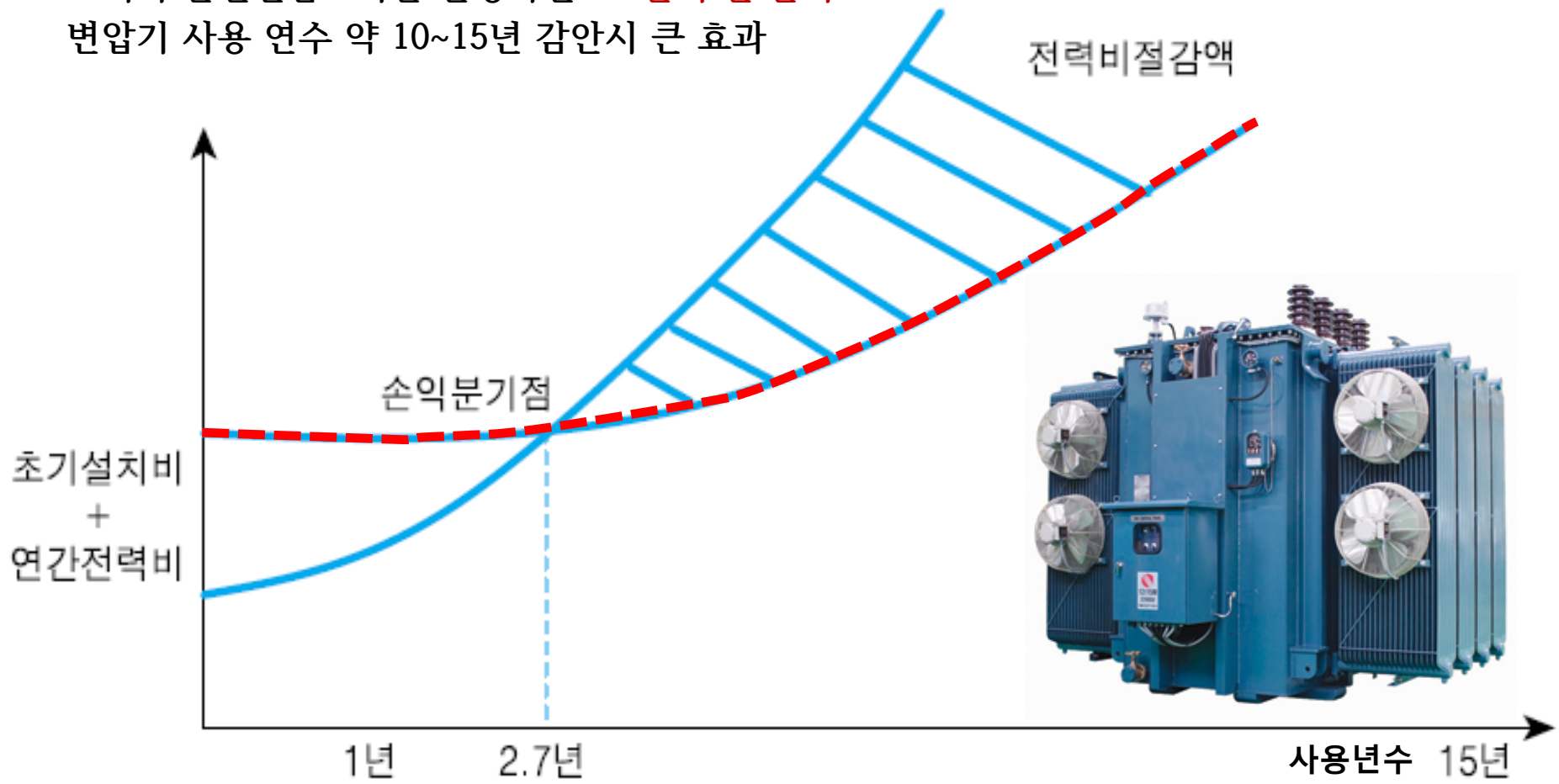
Magnetic cores



Transformers

< 아몰퍼스변압기 사용연수 대비 에너지절감효과 >

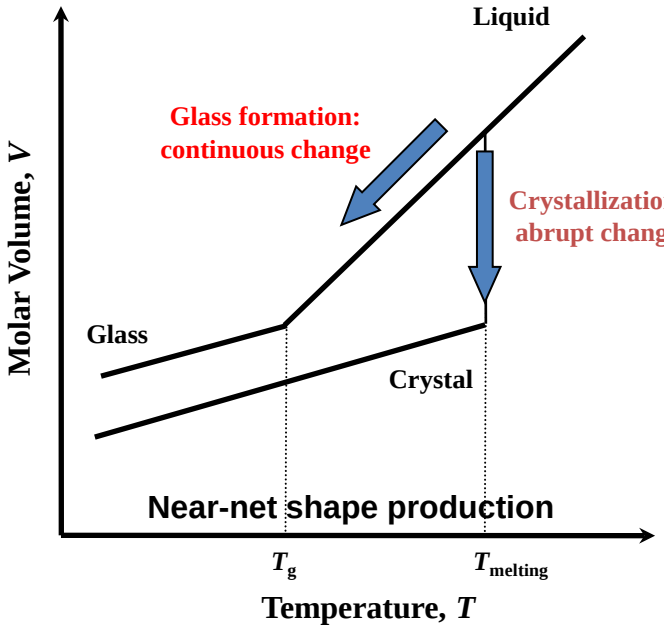
- 초기설치비는 기존 변압기에 비해 1.5배 정도 비쌈
  일반 규소강판 변압기 대비 대기 전력 75% 이상 절감
  그러나 손실절감효과를 반영하면 2.7년 후면 만회
  변압기 사용 연수 약 10~15년 감안시 큰 효과

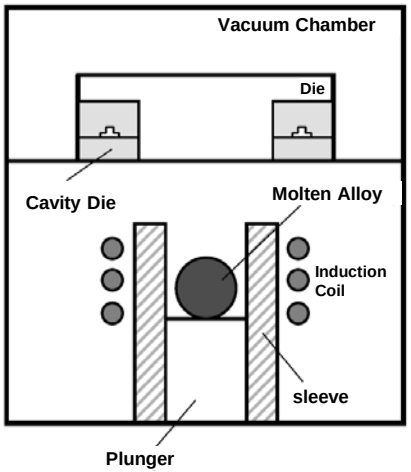


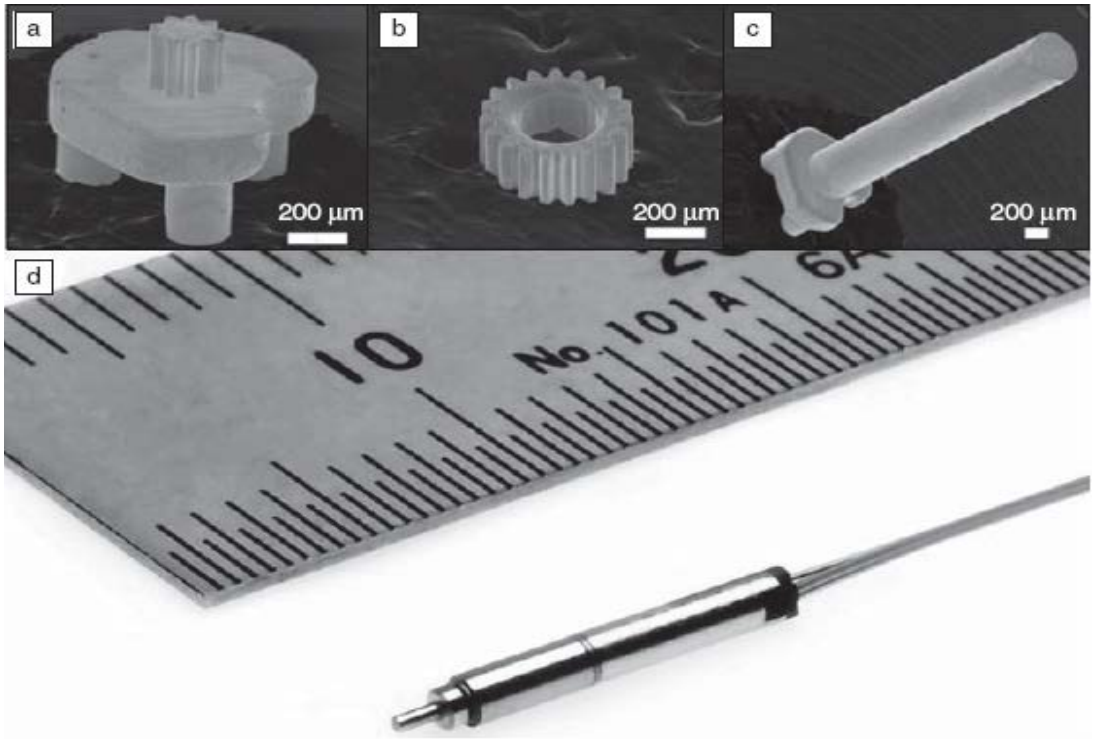
(전기안전, 대우증권 리서치본부)

4. Processing metals as efficiently as plastics

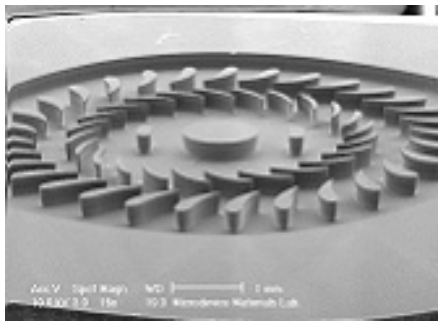
1) Micro-casting

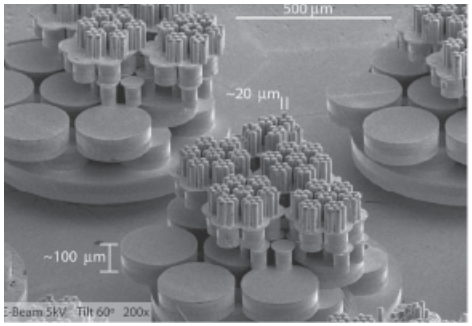






Precision Gears for Micro-motors



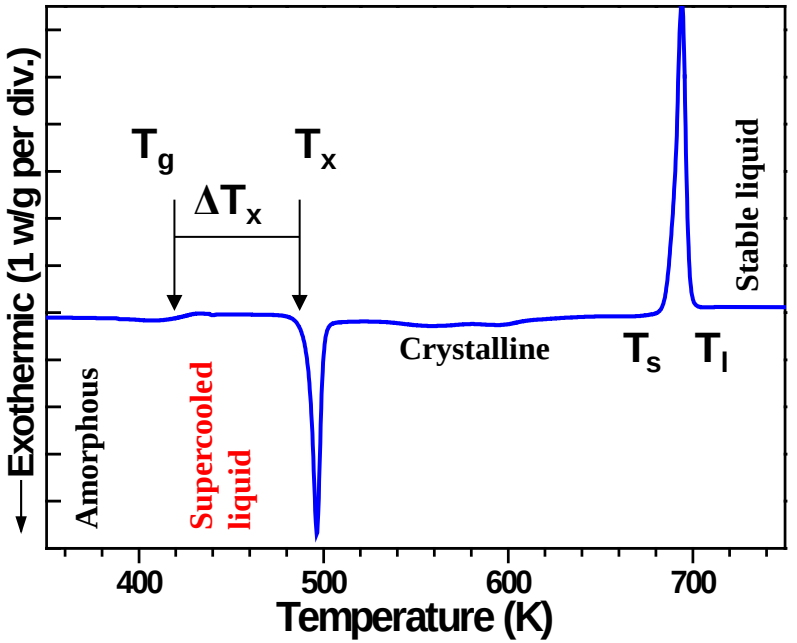


Precision die casting

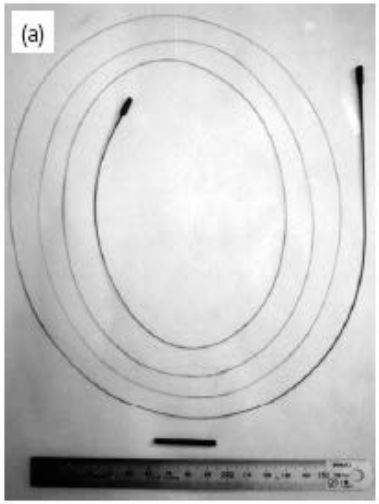
MRS BULLETIN ***32*** *(2007)654.*

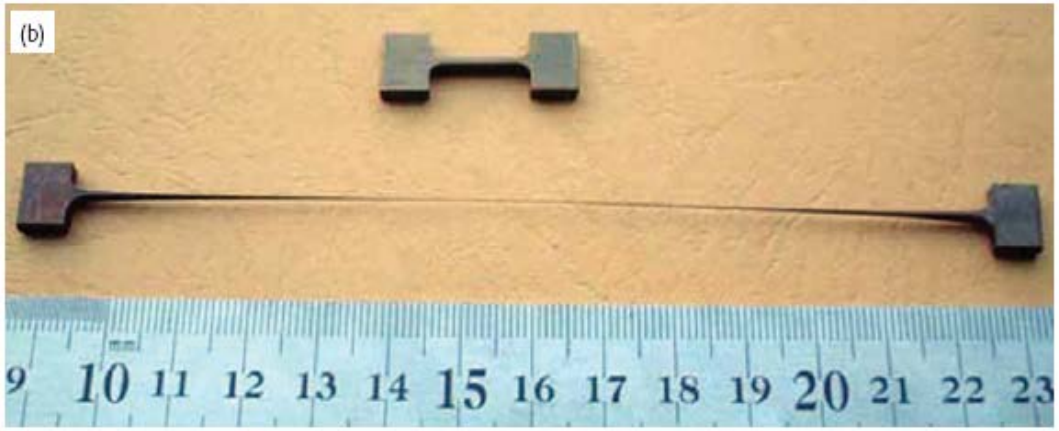
4. Processing metals as efficiently as plastics

2) Thermoplastic forming



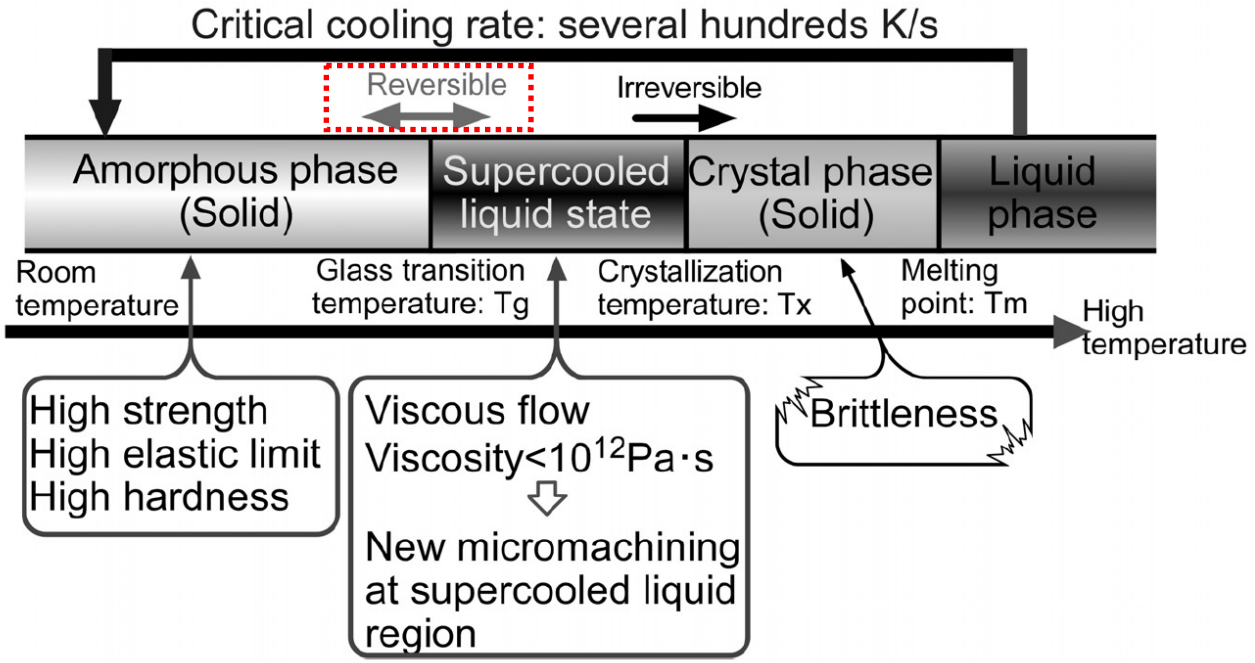
Tensile specimens following superplastic forming in supercooled liquid region





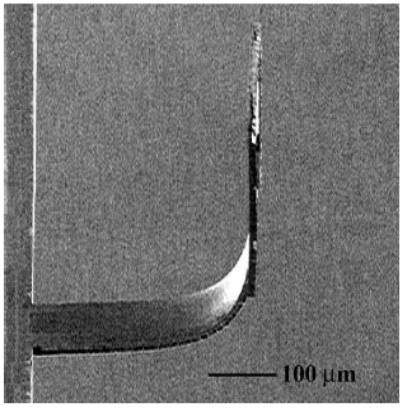
4. Processing metals as efficiently as plastics

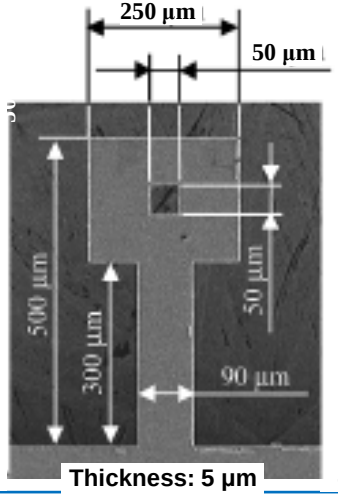
3) Micro-forming



Micro-forming of three-dimensional microstructures from thin-film metallic glass

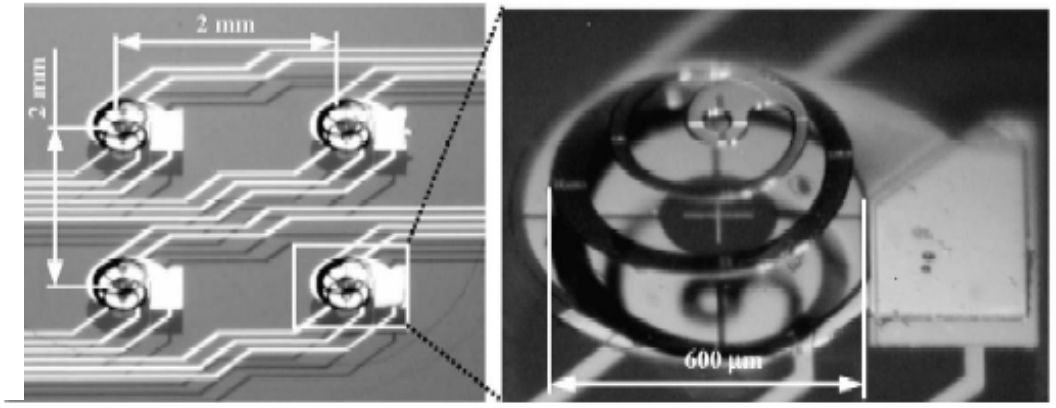
Micro-cantilever



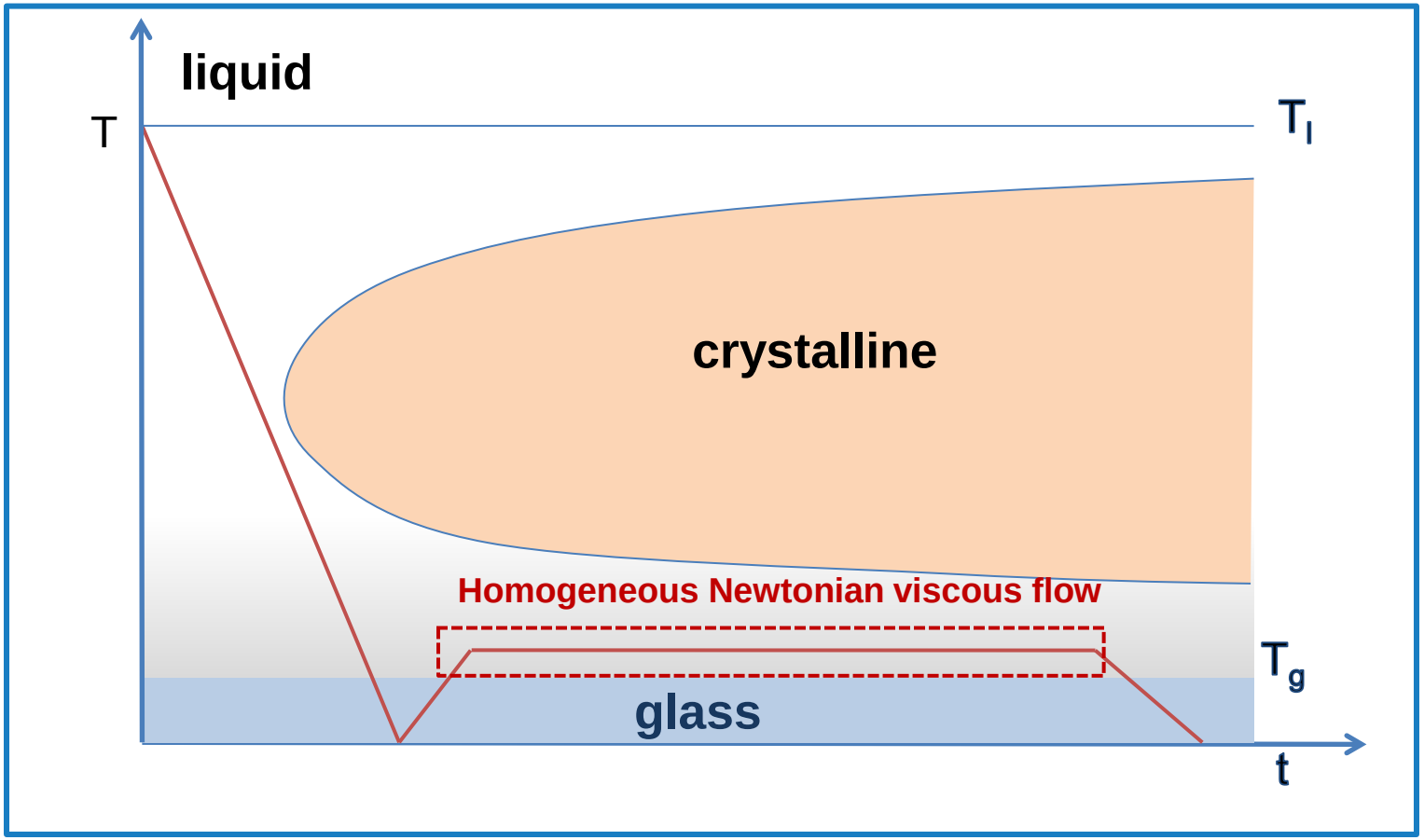


Thickness: 5 μm

Integrated conical spring linear actuator



Thermoplastic forming in SCLR

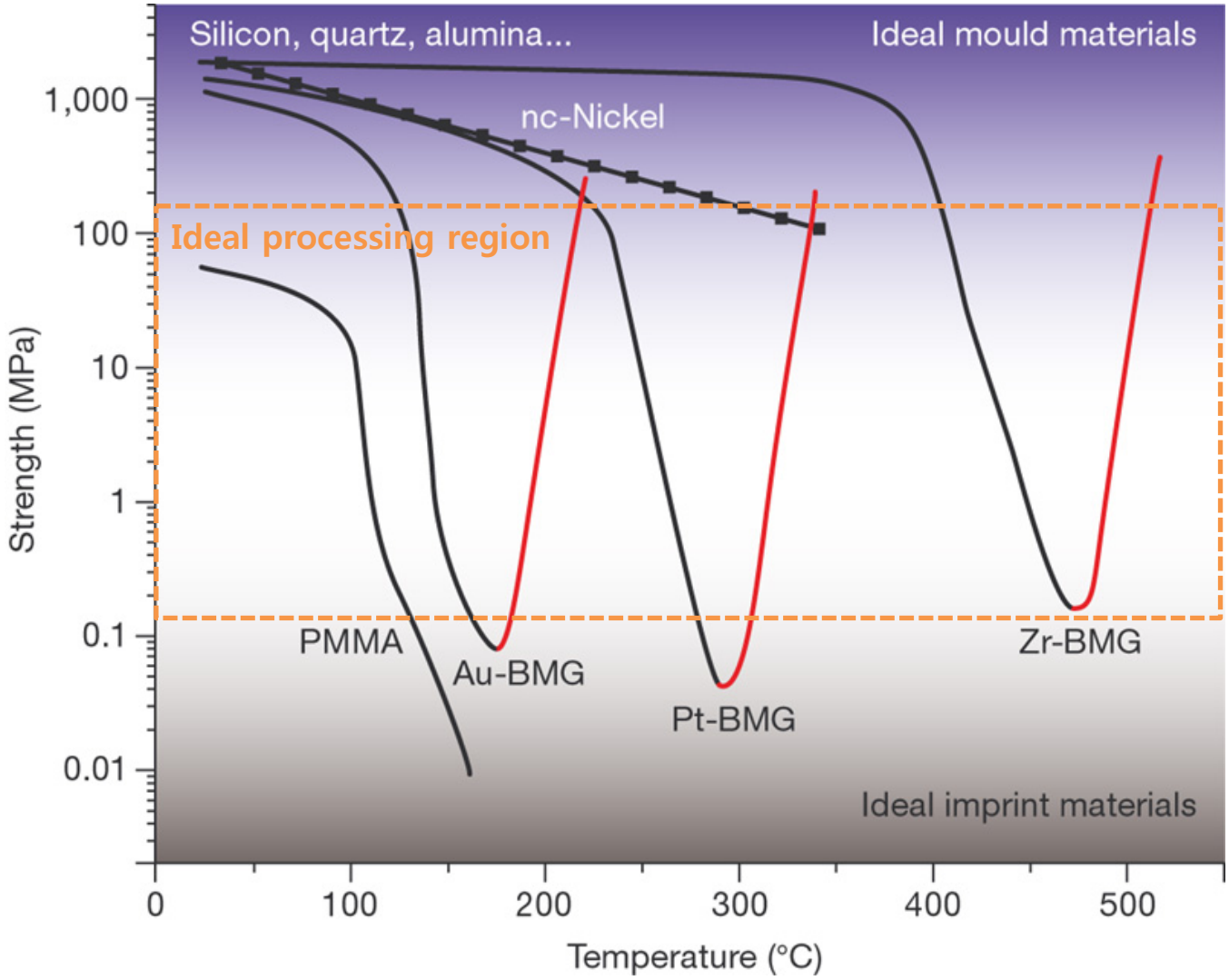


Metallic glass can be processed like plastics by homogeneous Newtonian viscous flow in supercooled liquid region (SCLR).

➡ **Possible to deform thin and uniform MG**

High processibility of metallic glass according to temperature

Nature ***457****, 868-872* (12 February 2009)

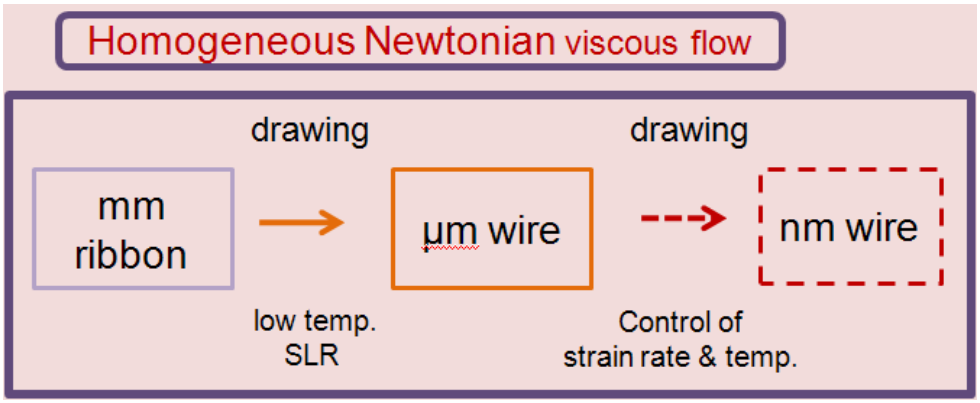


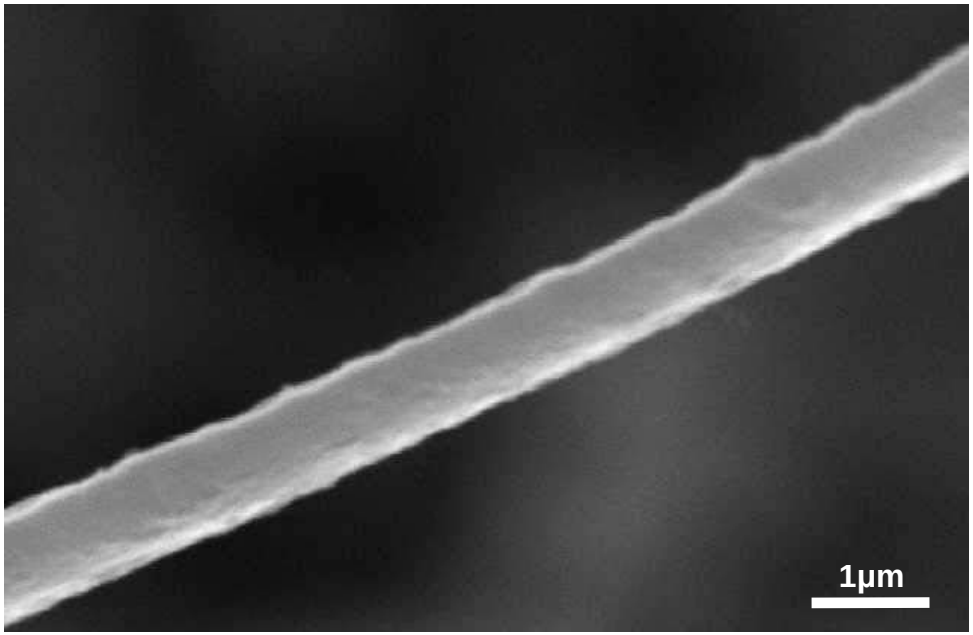
Thermoplastic forming in supercooled liquid region

$Mg_{65}Cu_{25}Gd_{10}$ metallic glass ribbon

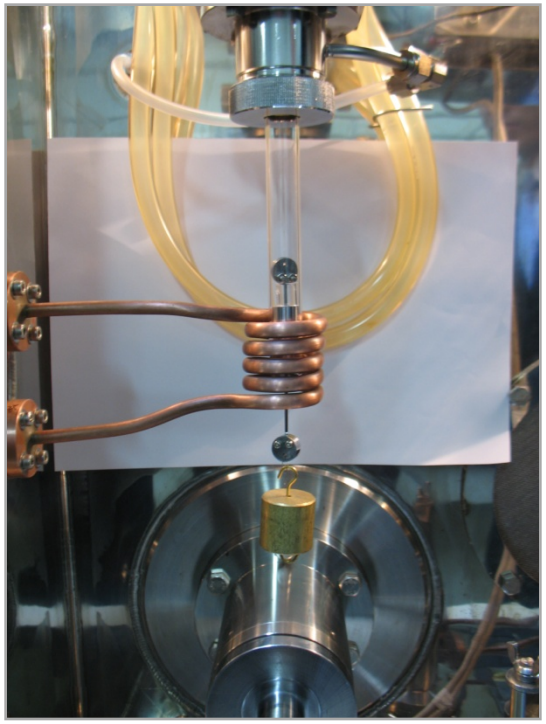
- Drawing sample at 220°C ➡ Elongation over 1100%

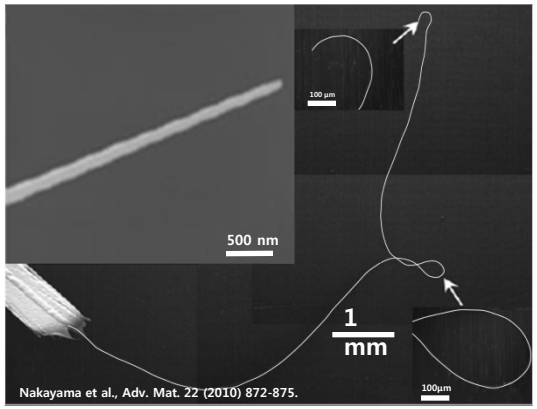
Thermoplastic forming - Fabrication of nanowire





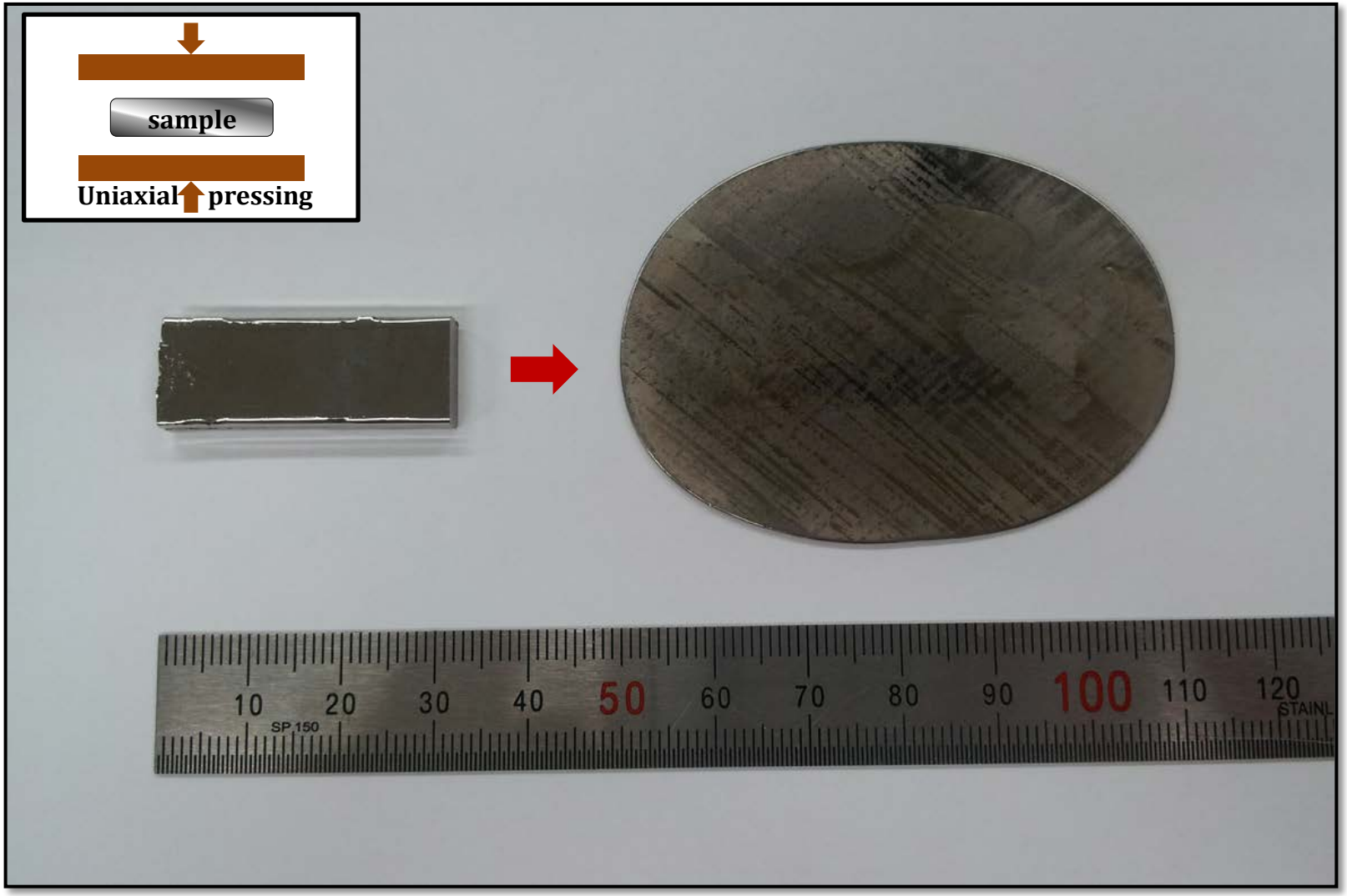
SEM image of nanometer scale metallic glass wire formed by drawing micrometer scale wire on hotplate





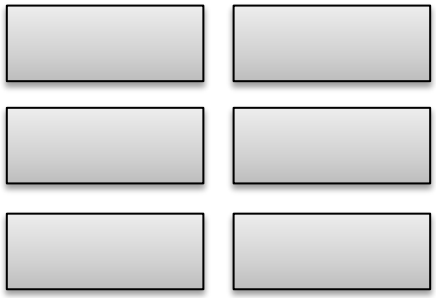
Thermoplastic forming - Fabrication of BMG plate

- 상용 비정질 합금 LM1b ($Zr_{44}Ti_{11}Cu_{10}Ni_{10}Be_{25}$) 의 TPF을 이용한 가압 성형

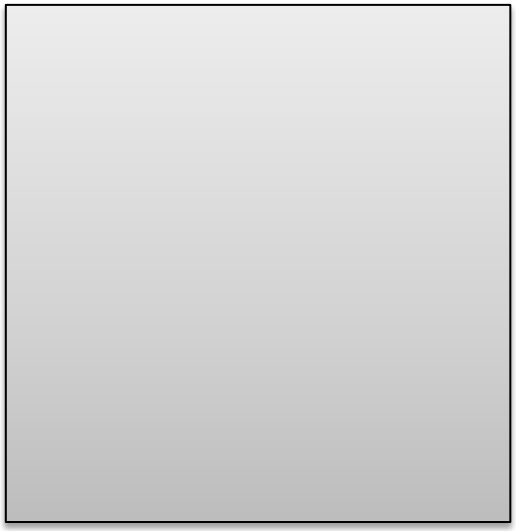


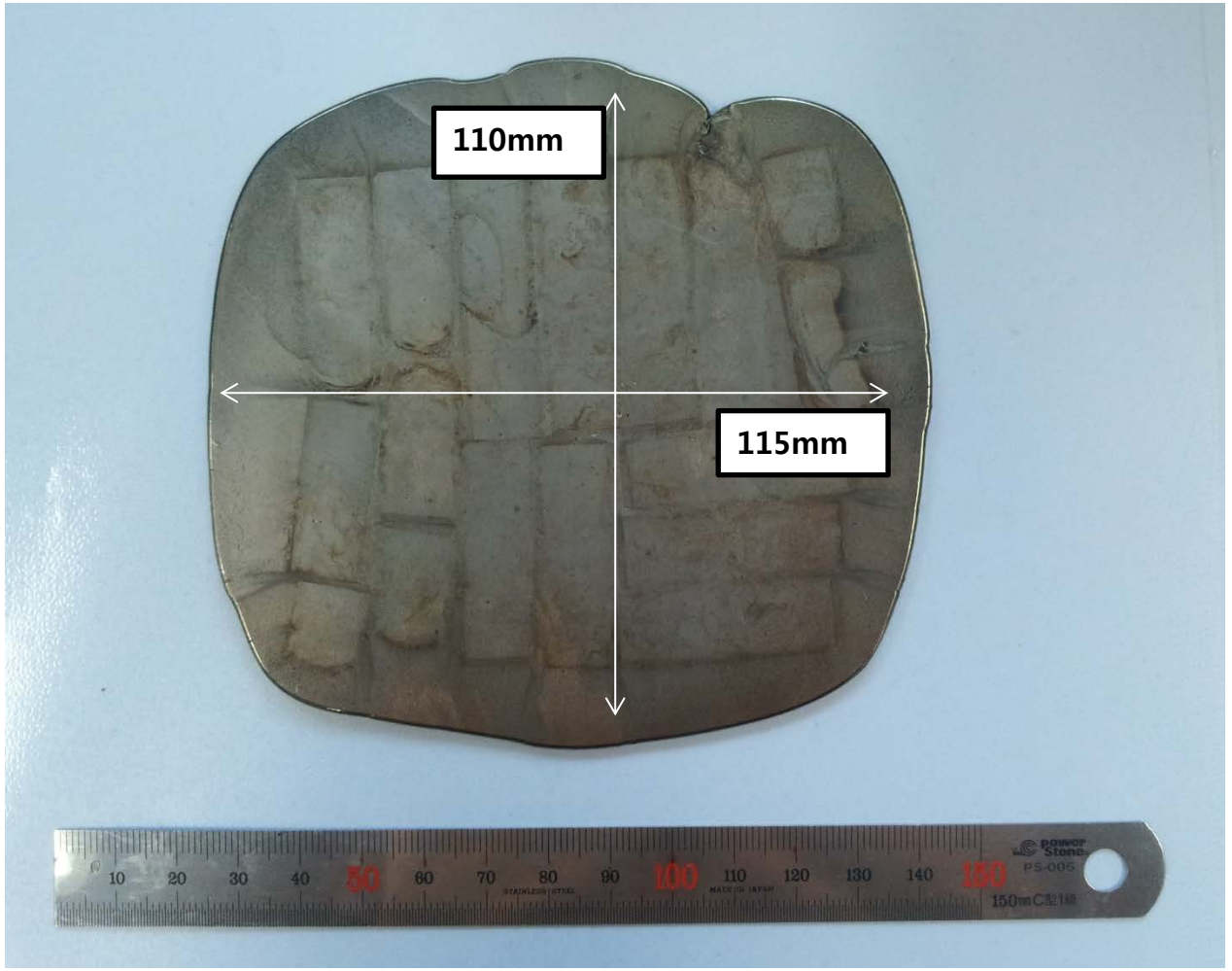
Thermoplastic forming & joining - Fabrication of BMG plate

- 기존의 bulk sample 제작 기술로 구현이 불가능했던 대면적/부피의 비정질 합금 제조 가능. 비정질 형성능의 제약 극복, 다양한 조성에서 제품 제작 가능.



Joining을 통한 대면적화





“비정질 형성능 제약 극복”

Thermoplastic forming & Joining technique

최소 크기의 bulk 비정질 합금을 제조 할 수 있다면 조건에 따라 어떠한 크기로도 성형 가능, 복잡한 형상을 HT pressing 만으로 단일 구조로 제작 가능.

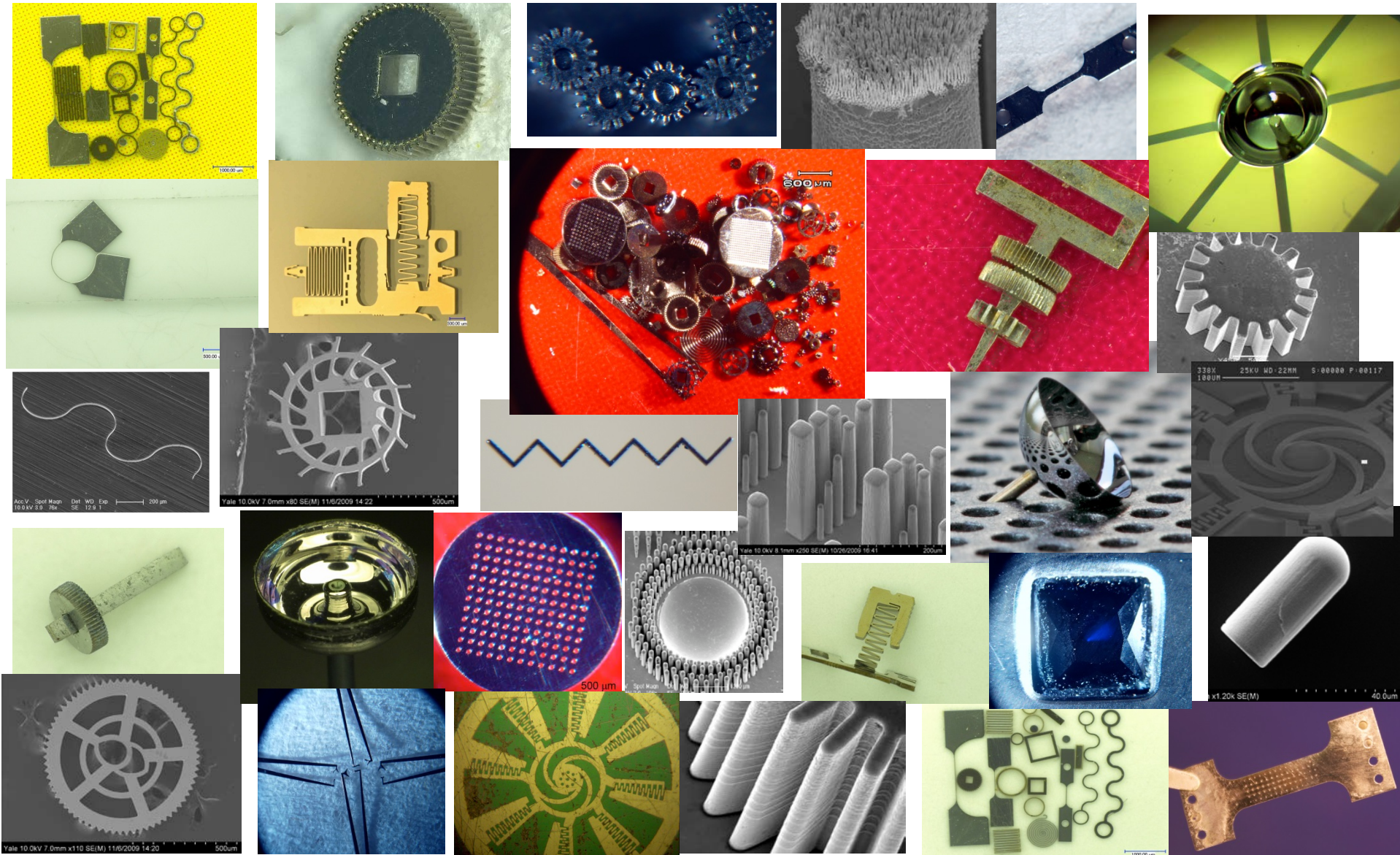
J. Schroers, JOM, 57, 34 (2005)
PtNiCuP
T = 270°C
P = 10 Mpa
100 sec

Materials Views
www.MaterialsViews.com

ADVANCED MATERIALS
www.advmat.de

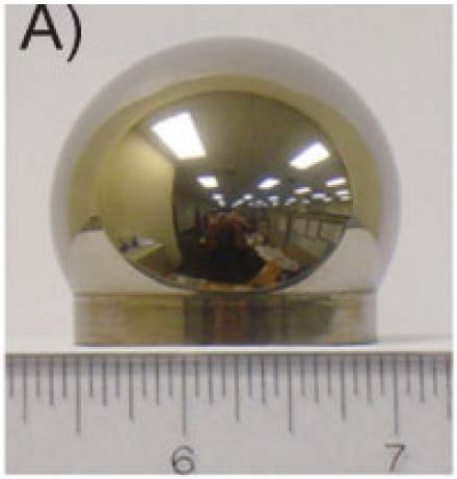
Processing of Bulk Metallic Glass

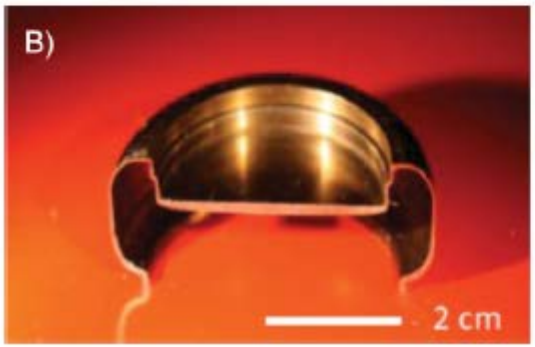
Adv. Mater. **2009**, *21*, 1–32

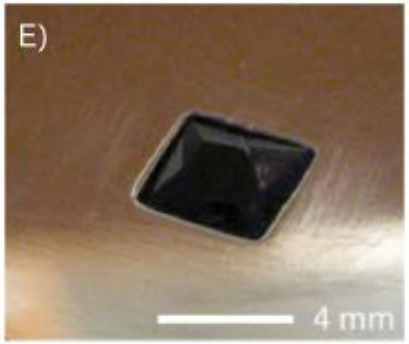


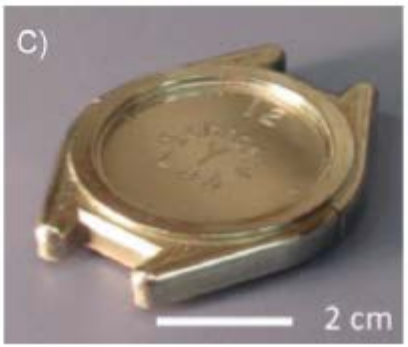
Processing of Bulk Metallic Glass

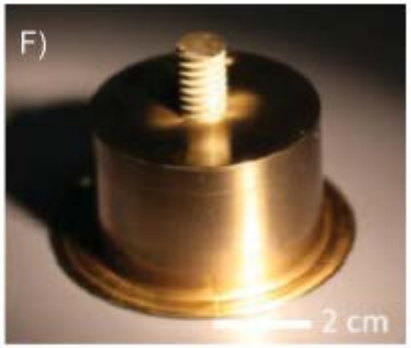
Adv. Mater. **2009**, *21*, 1–32









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N°5
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PARIS
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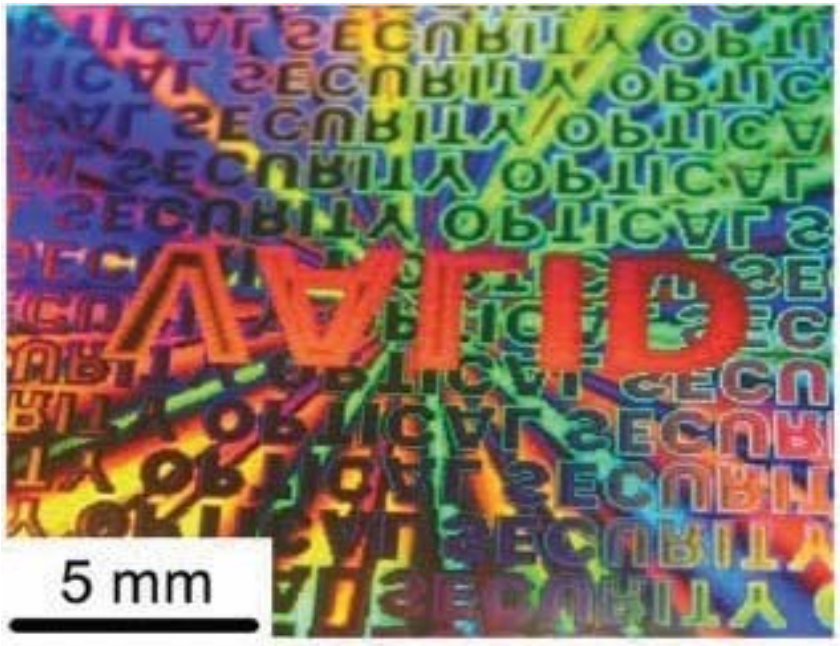
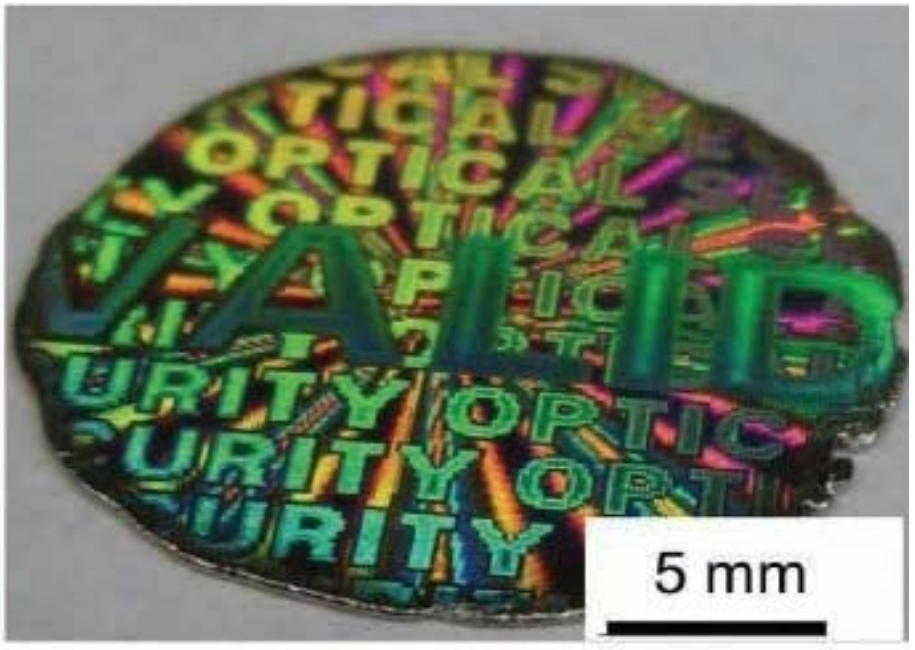
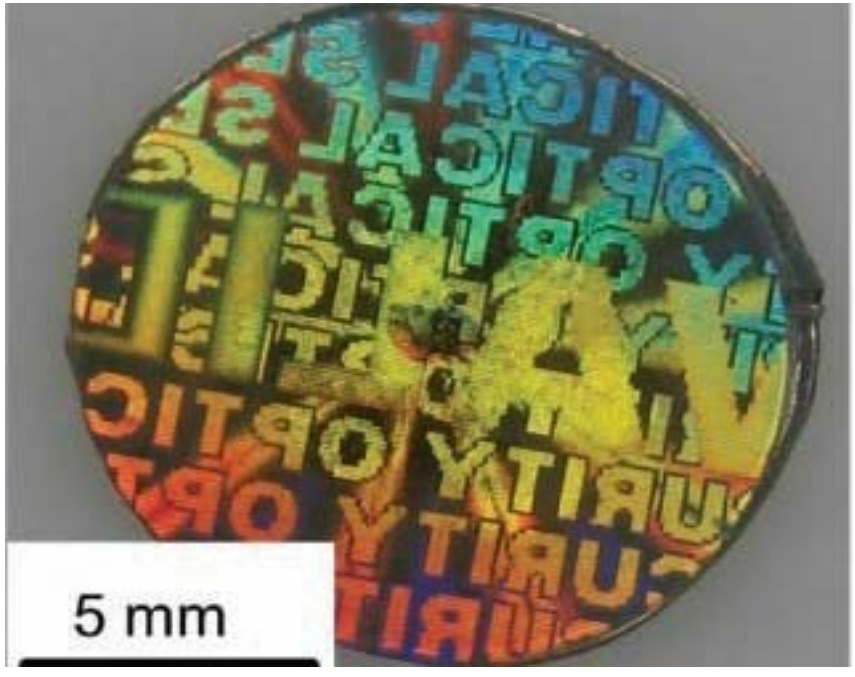
ENGINEERING
APPLIED SCIENCE

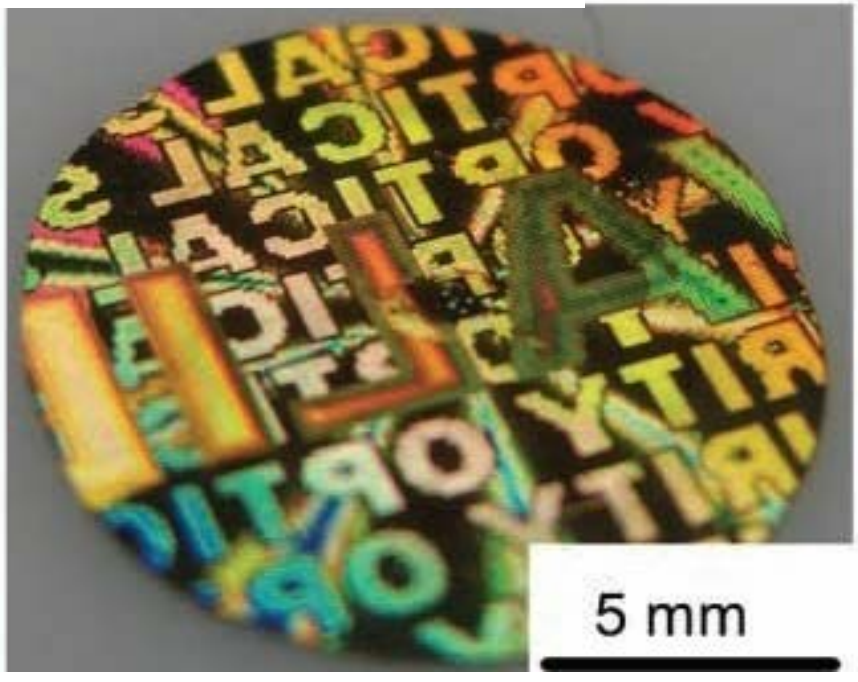

SuperCool
shaping technologies





Jan Schroers, Adv. Mater., 2010, hologram pattern






OPTICAL
OPTICAL
OPTICAL
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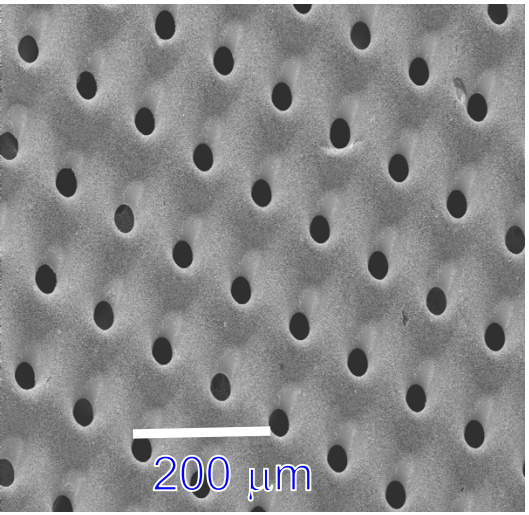
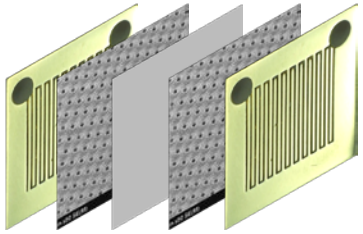
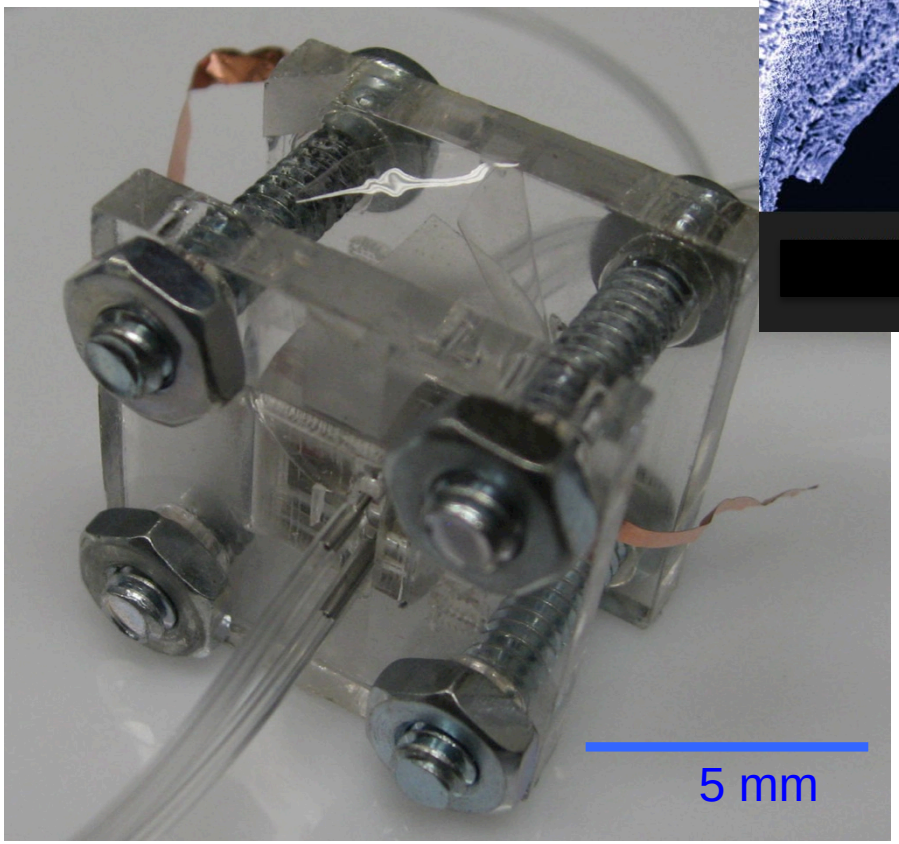
OPTICAL
OPTICAL

Metallic Glass Fuel Cell

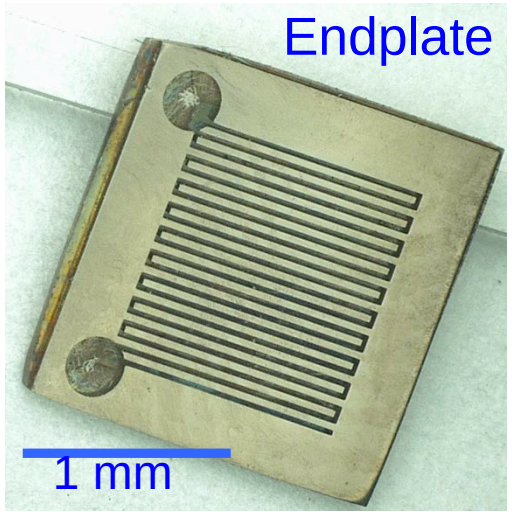
Electrode, Catalyst



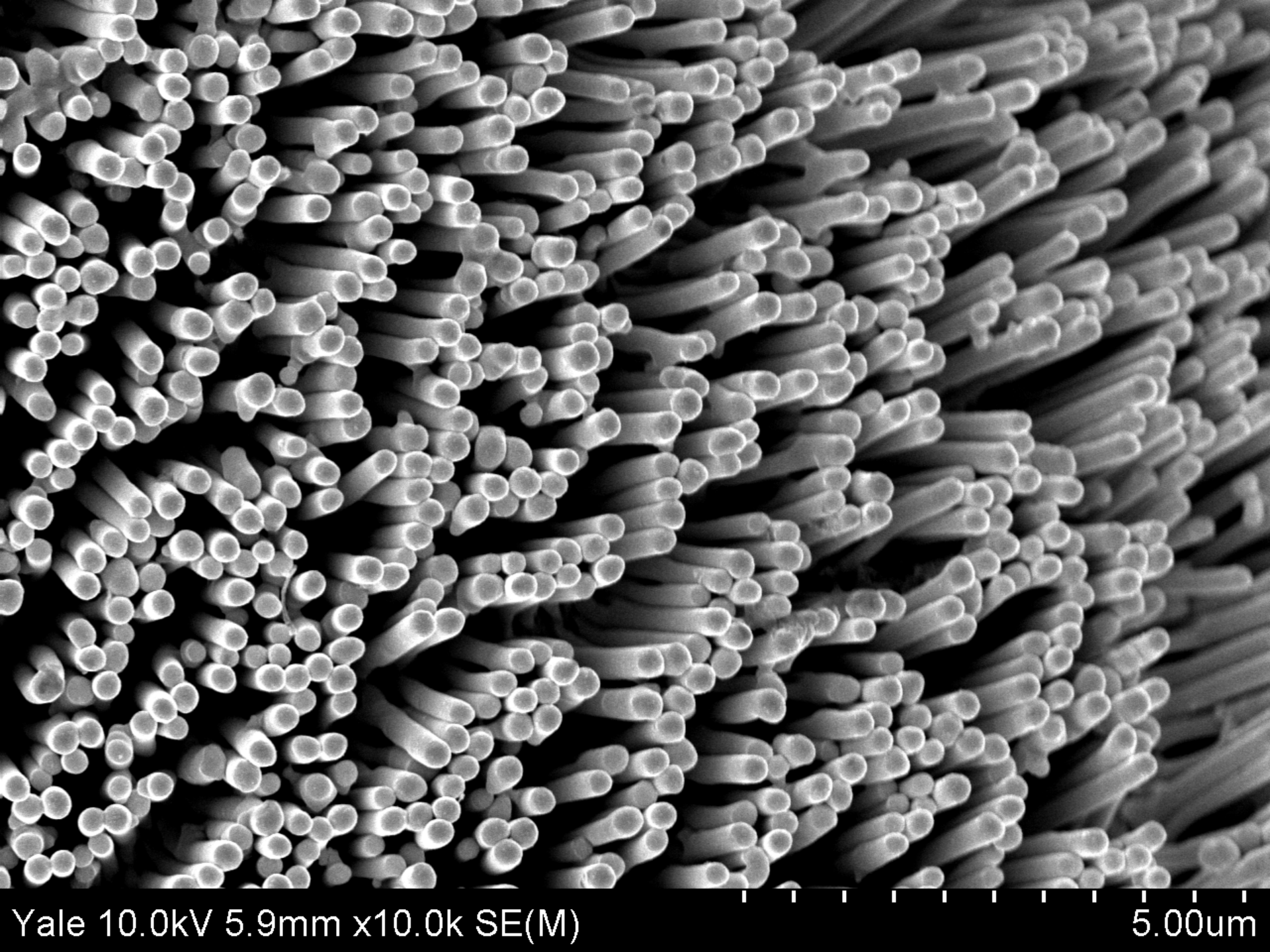




Endplate



R. C. Sekol, M. Carmo, G. Kumar, J. Schroers, and A. D. Taylor, Small 9, 2081 (2013)


Yale 10.0kV 5.9mm x10.0k SE(M)
5.00um

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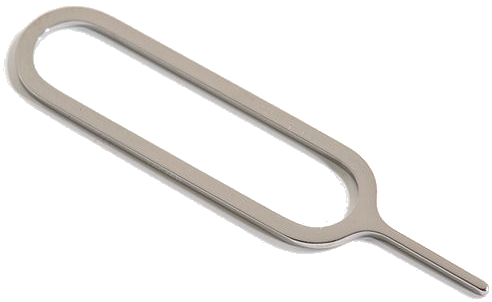


USIM ejector (iphone 4)

Enclosure / Antenna

Commercialization of BMG products

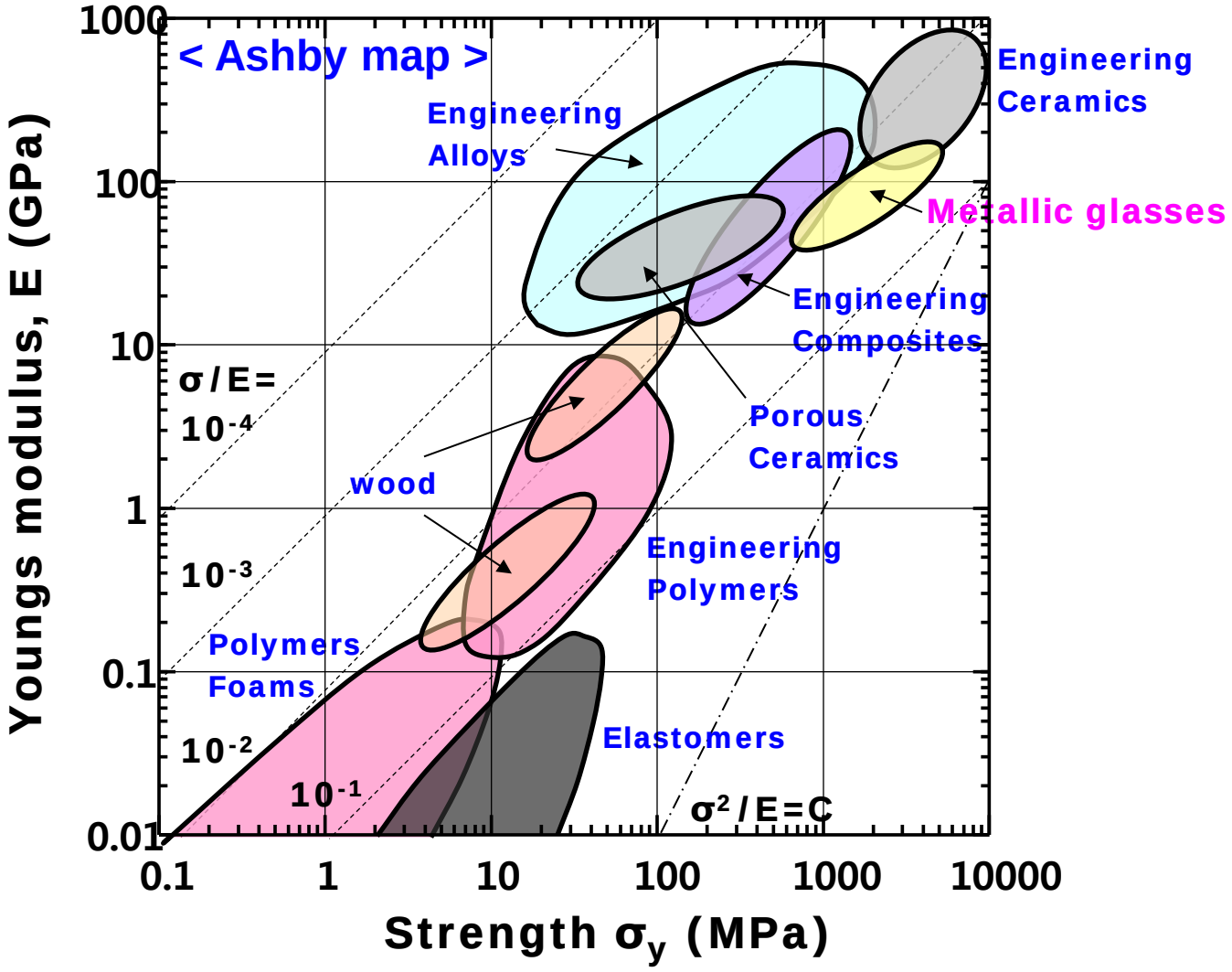
Medical Devices

Fine jewelry

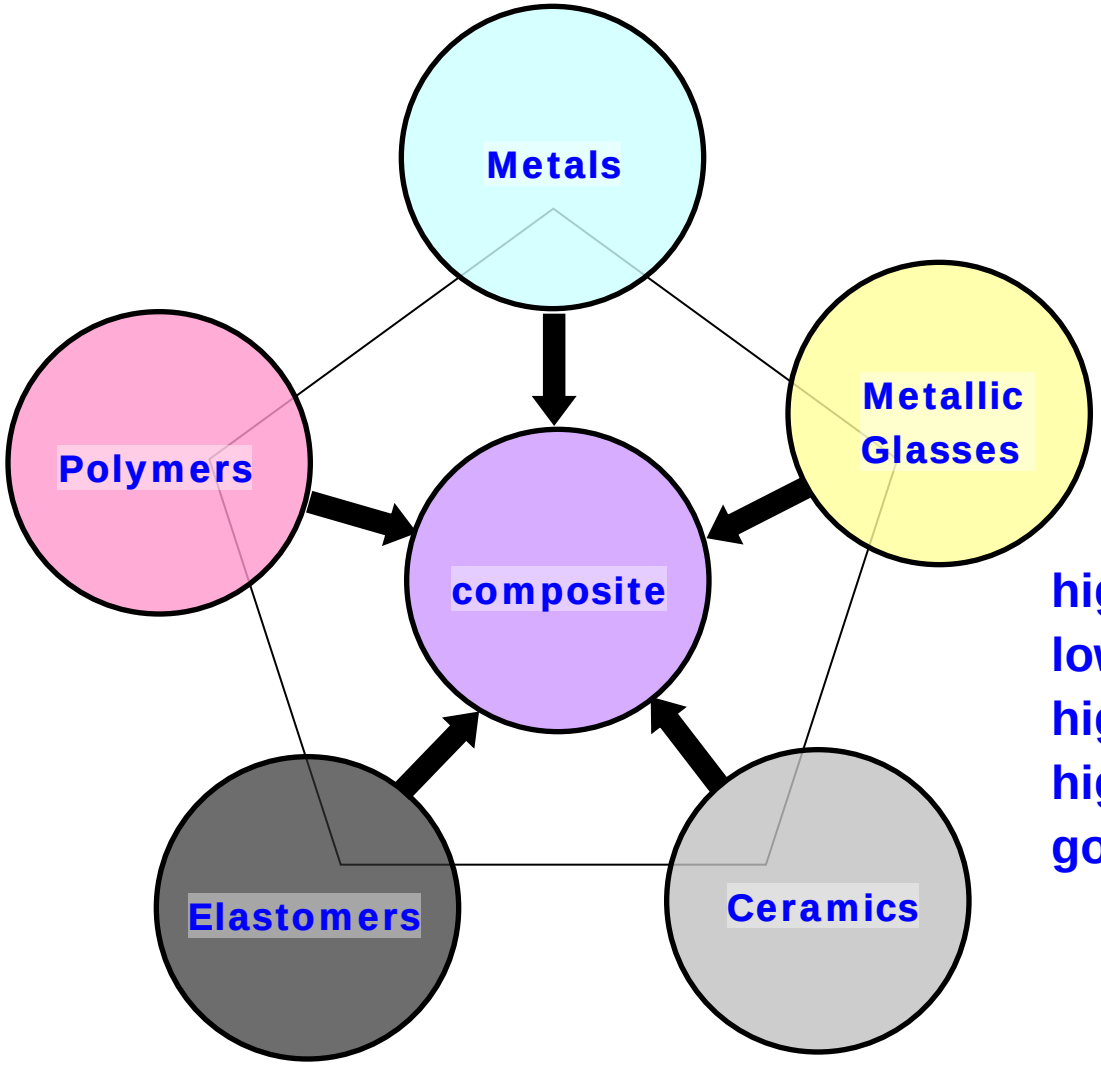
Sporting Goods

Drill pipe, container etc.

Ashby map


< Ashby map >
Engineering Alloys
Engineering Ceramics
Metallic glasses
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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the effectiveness of
heterogeneous nucleatio
it should be possible to f
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