Credit: Oskar Pascal

Credit: JPL

Credit: NASA

Credit: Sennheiser

3D Printing of Bulk Metallic Glasses and High Entropy Alloys

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Motivation

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Introduction of BMG

Bulk Metallic Glasses

BMGs

- Scratch resistant

- Super strong

- Shiny surface

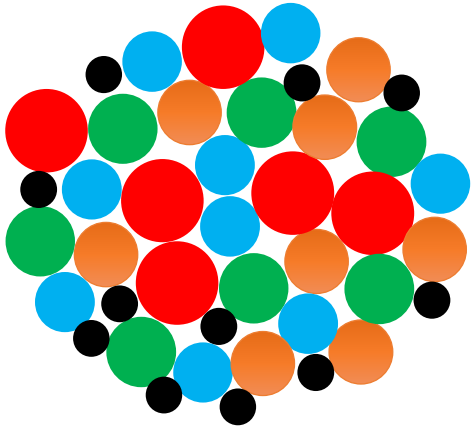
How to fabricate BMGs?

Bulk Metallic Glasses (BMGs) are metallic alloys that can solidify in an amorphous state (i.e. not crystalline) during **rapid solidification**.

Molten

Quenched and freezed

Randomly distributed
(**amorphous**)



Application of conventionally fabricated BMGs

high strength

ultra-precision

metallic glass
excellent feature

High corrosion resistance

low Young's modulus

watch

bezel
buckle
Movement Part

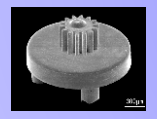
mobile terminal

Case
SIM Tray
Hinge

automotive component

pressure sensor
jet nozzle

micro-mechanical



microgear
bearing
Spring

semiconductor

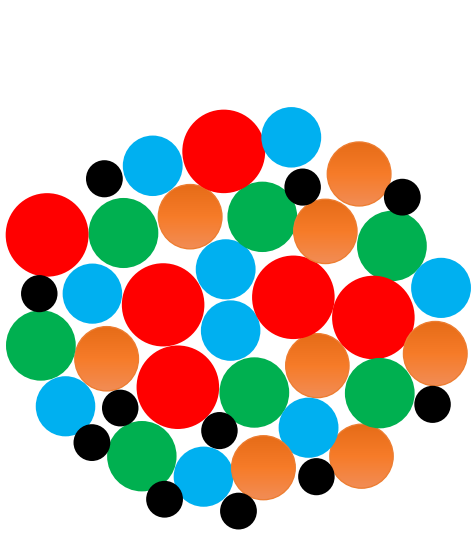
Adsorption Collet

Medical and biological materials

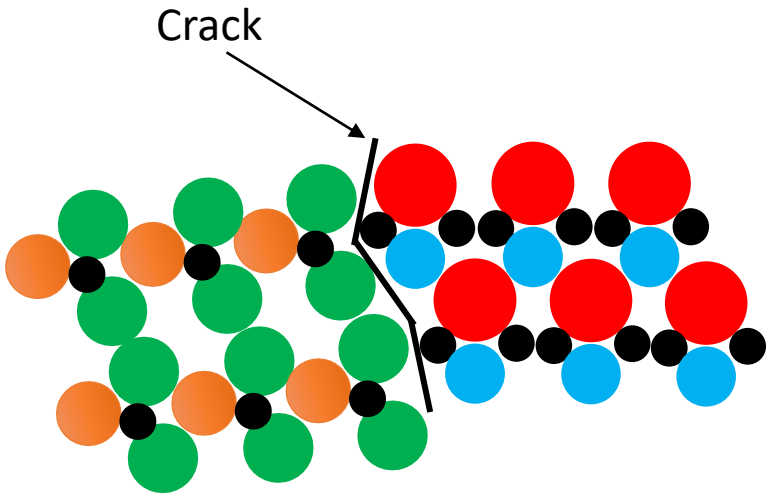
orthodontic bracket
anchor screw
artificial joint

Introduction of BMG

If the cooling rate is not high enough!



Low cooling rate



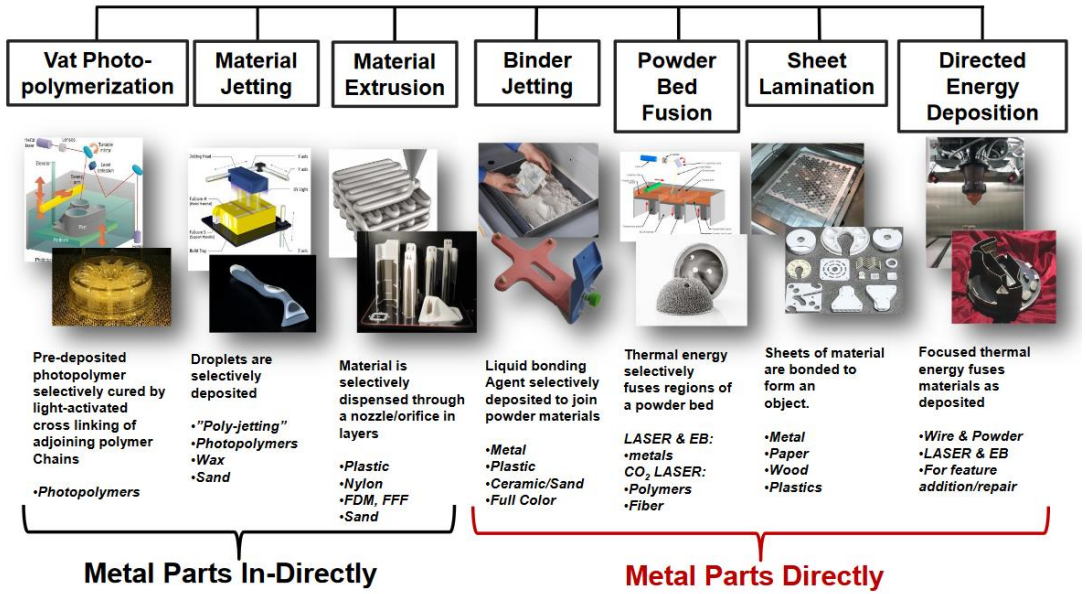
Cause brittleness

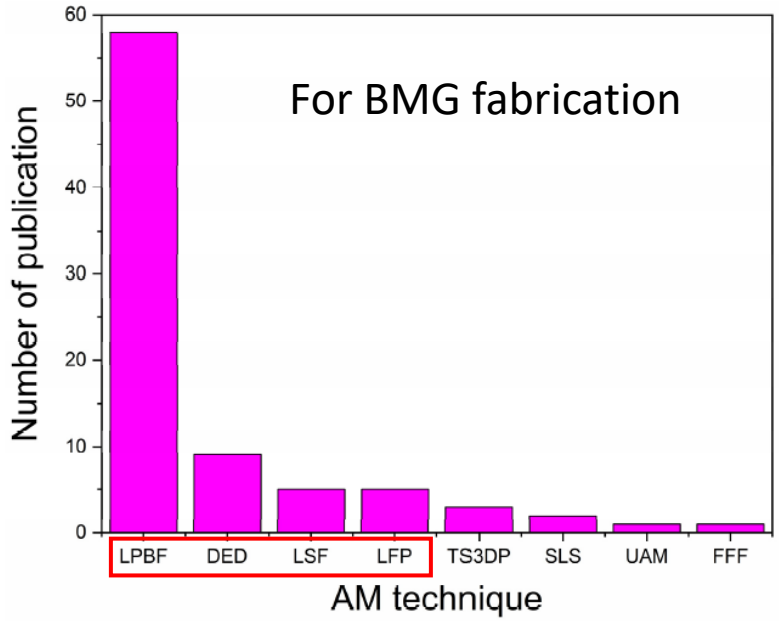
Amorphous

Crystallized

Limitation in the production method → Not all methods can provide a high cooling rate

State-of-the-art in 3D printing of BMGs





Credit: TURMPF

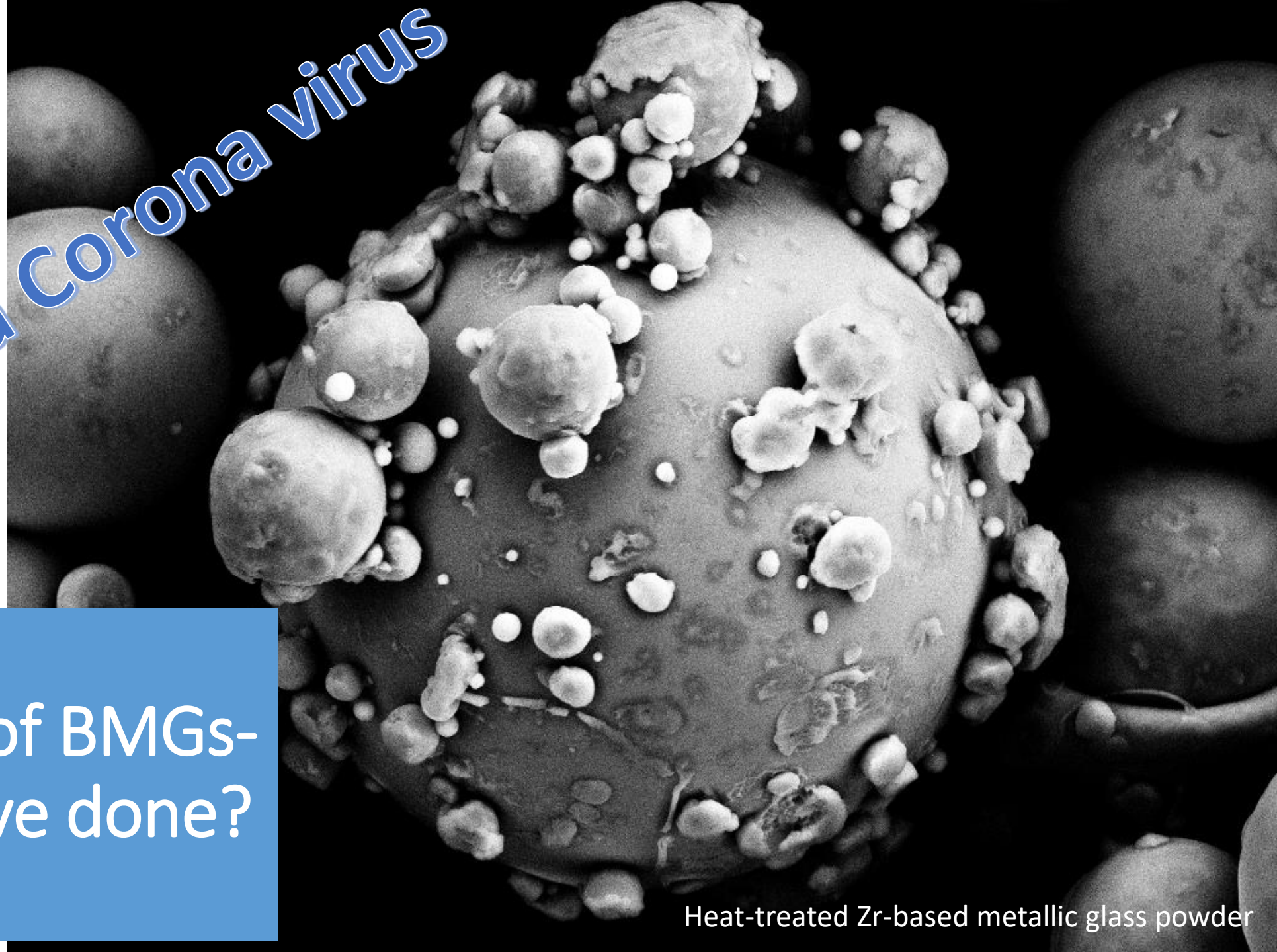
Advantage

Ability to process demanding materials because of high heating and cooling rates

Able to produce BMGs

~ 10^4 - 10^6 °C/s

It is NOT a Corona virus

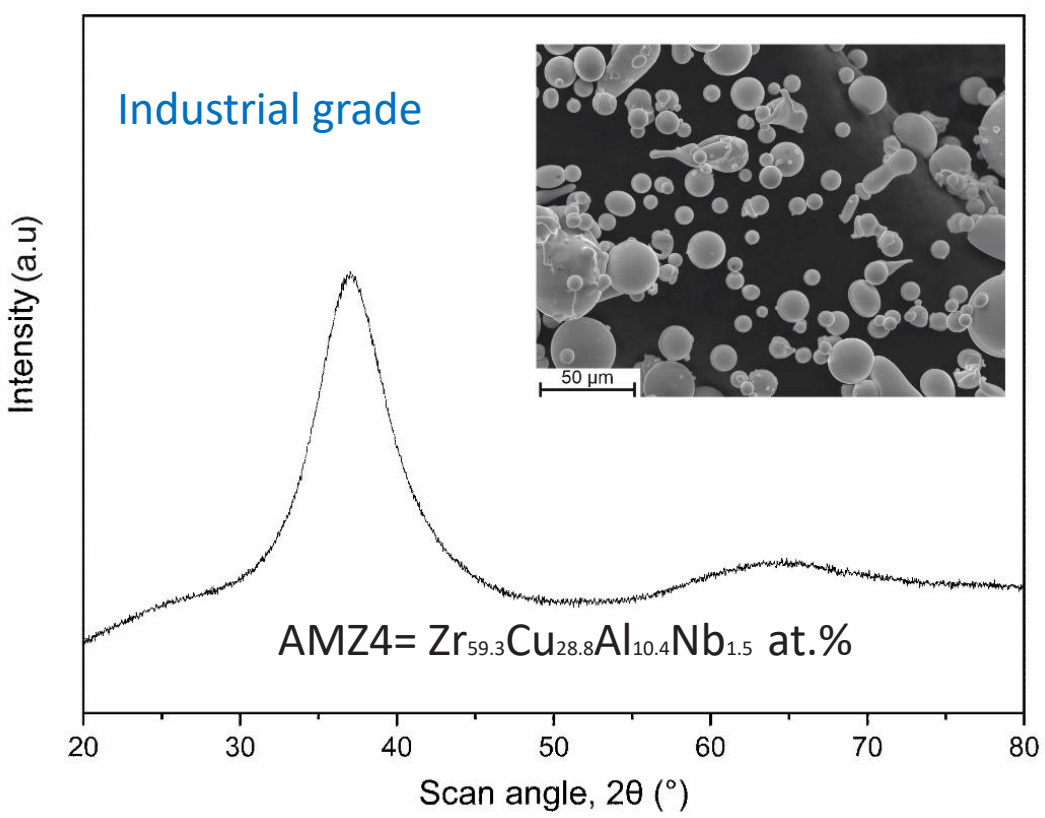


Heat-treated Zr-based metallic glass powder

3D printing of BMGs- what we have done?

Can we use LPBF process to fabricate large amorphous BMG parts?

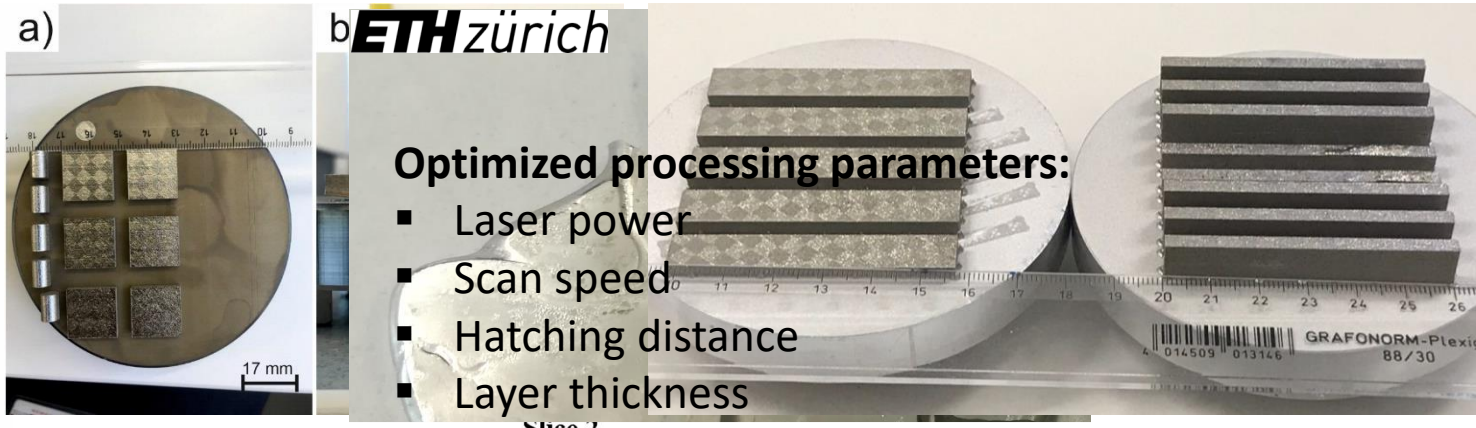
Gas-atomized powder
XRD amorphous



Oxygen content:
Powder= 1300 ± 16 ppm

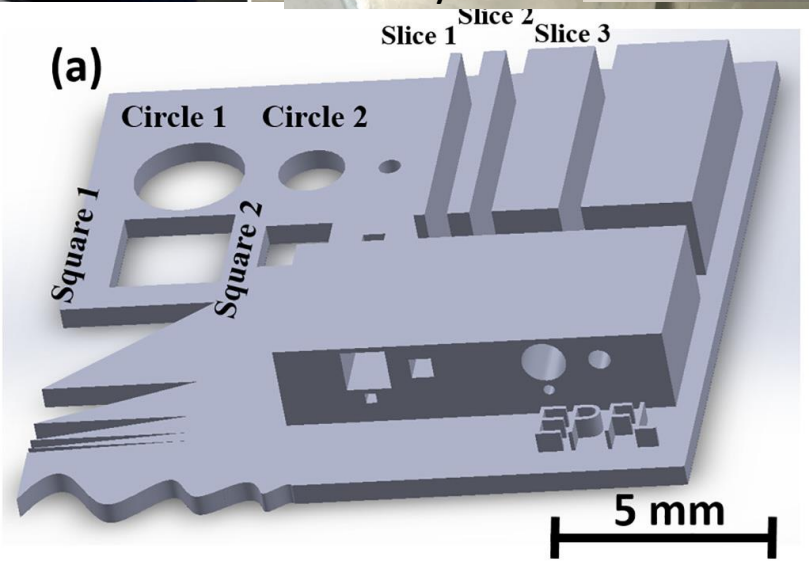
Samples with different size and shapes

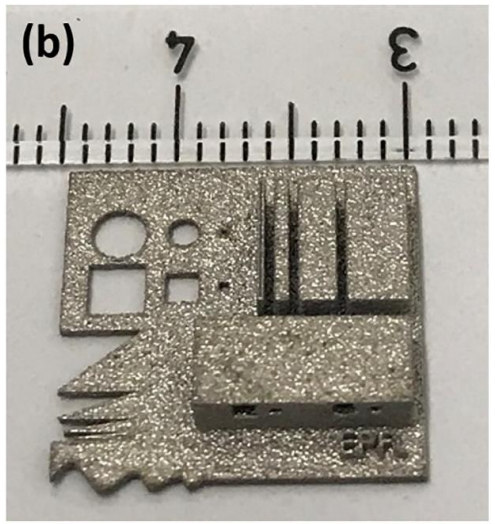
Cast from the melted powder



Optimized processing parameters:

- Laser power
- Scan speed
- Hatching distance
- Layer thickness





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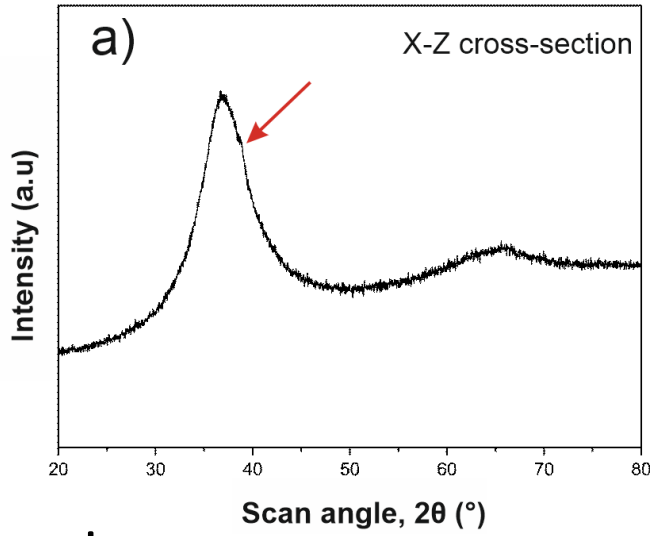
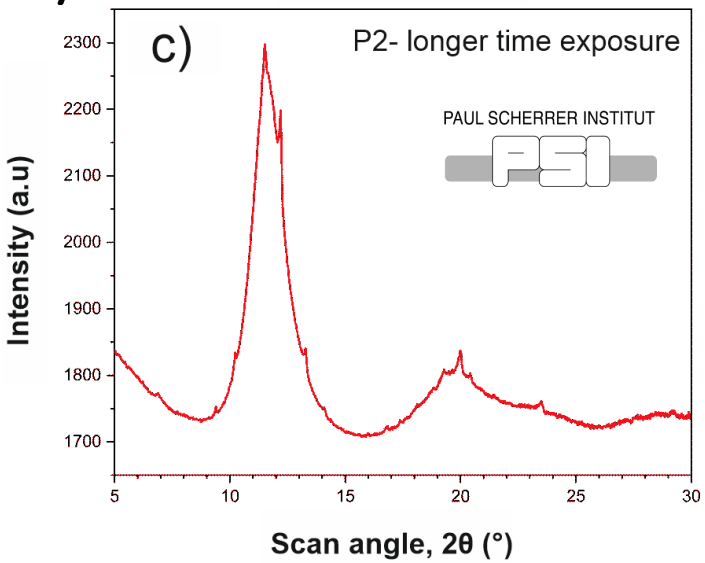
What is the reason for the crystallization?

XRD



Synchrotron



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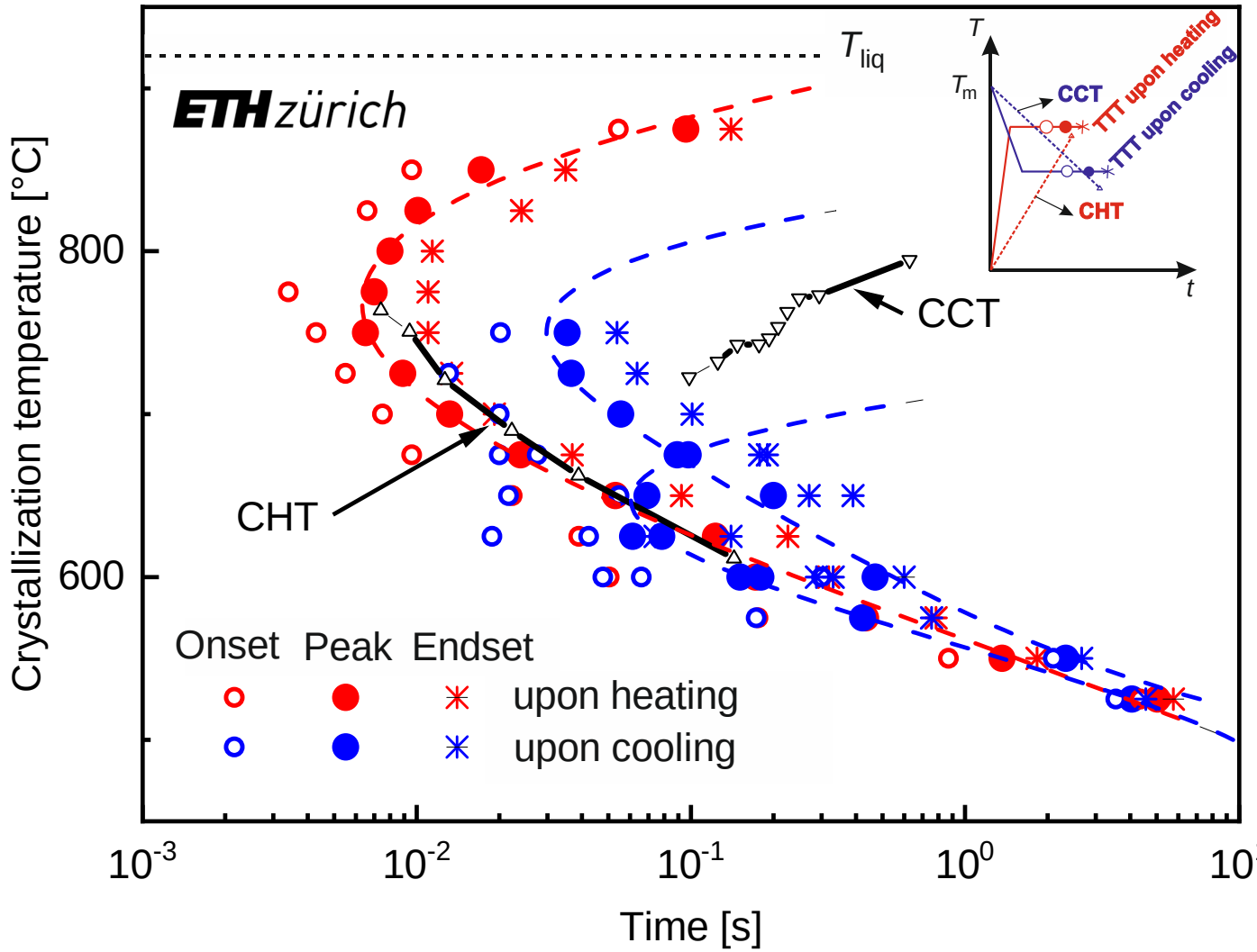
Critical cooling rate= 2500 K/s

Critical heating rate= 45,000 K/s



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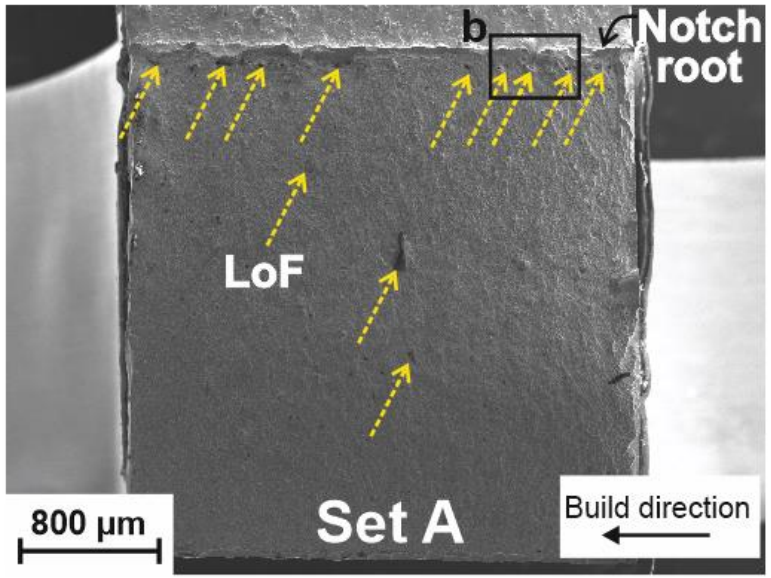
Select another BMG with a better **glass forming ability** and **lower oxygen content**

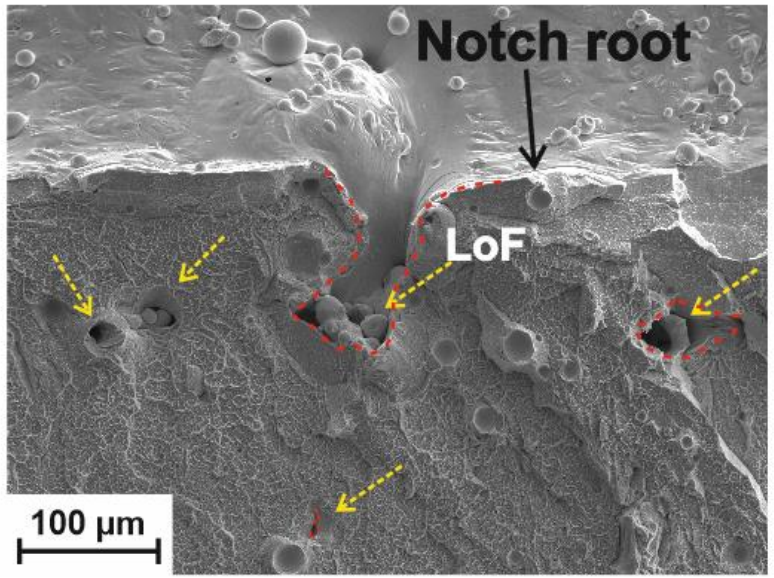
Crystallization is more detrimental or defects?

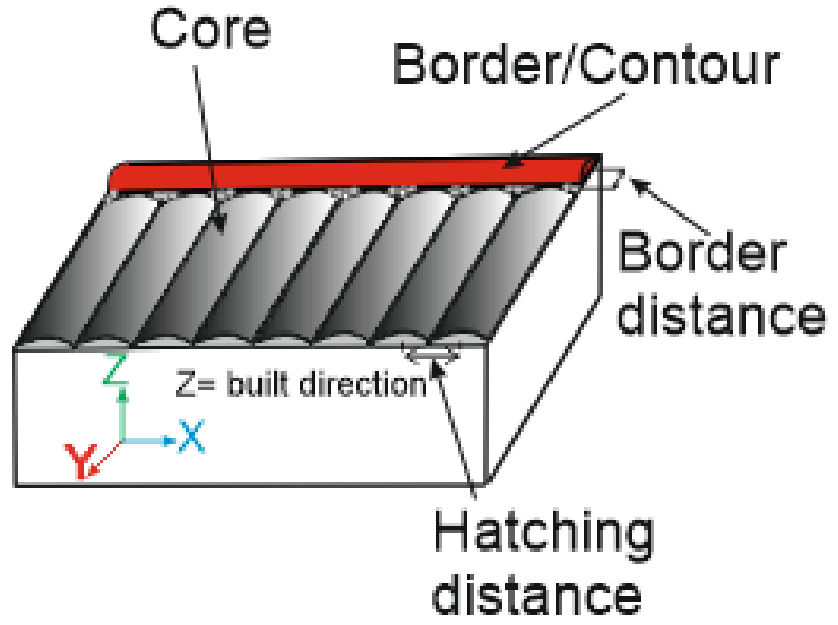
Tensile strength= 880 ±88 MPa
Impact toughness= 123 ± 28 mJ

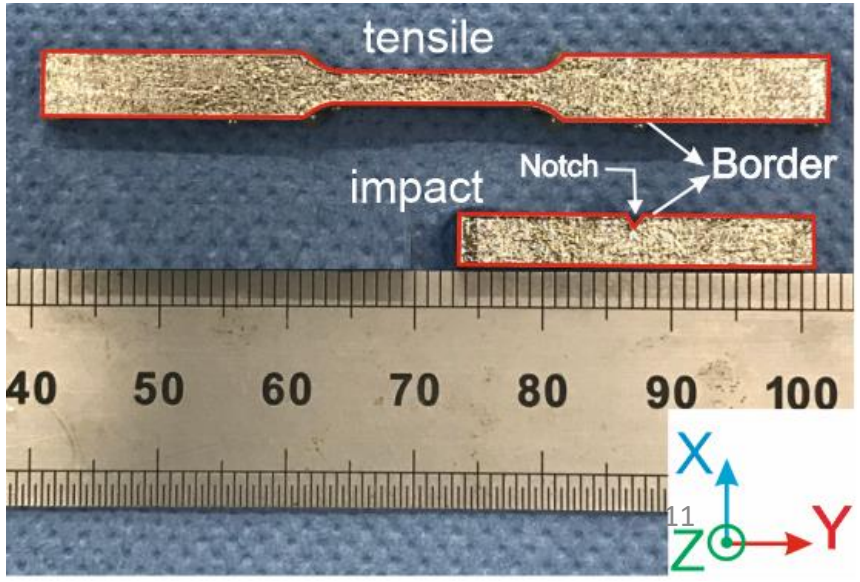
Same parameters as the fatigue samples

Set A









Strategies to improve:

1. Increase power of contour/border_ **Set B**

2. Increase power of core + Increase power of contour/border_ **Set C**

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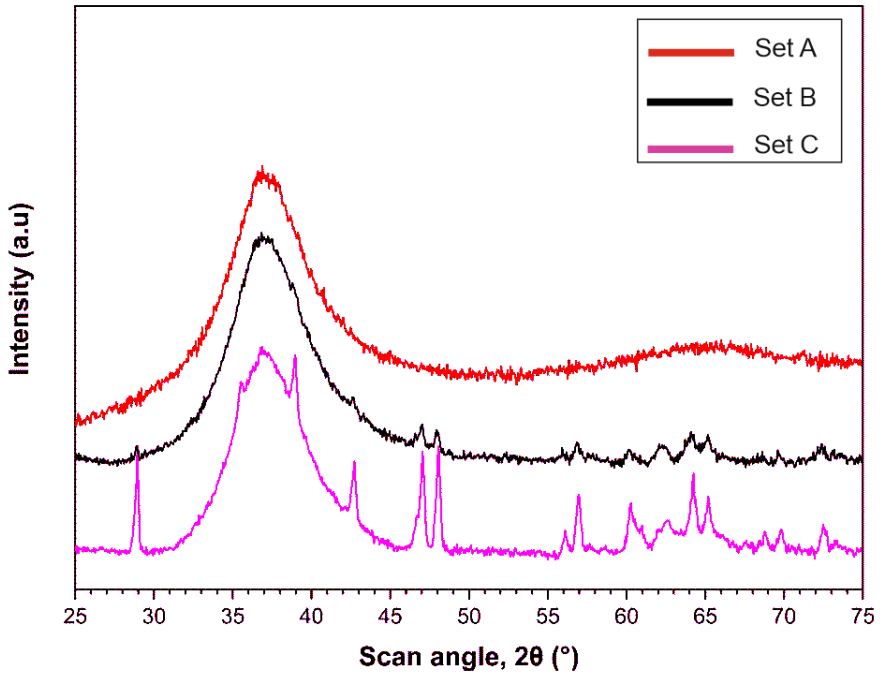
Crystallization is more detrimental or defects?



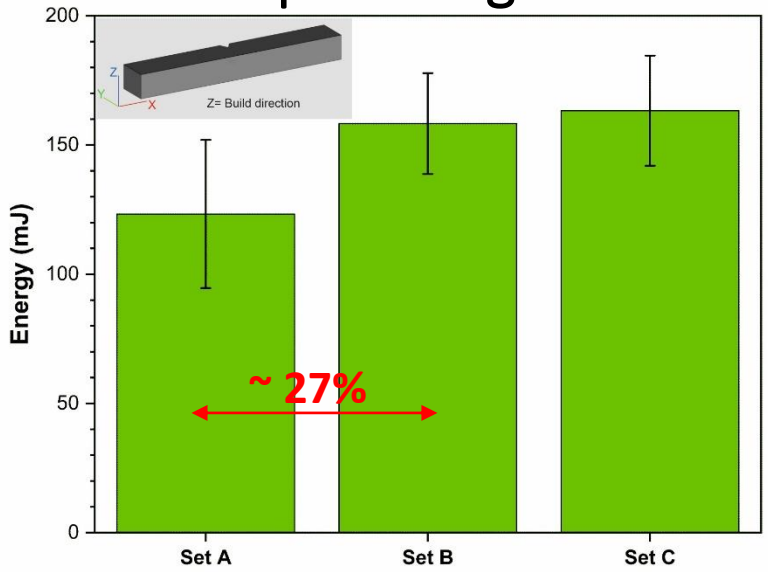
Crystalline fraction (DSC)

Set A= 6%

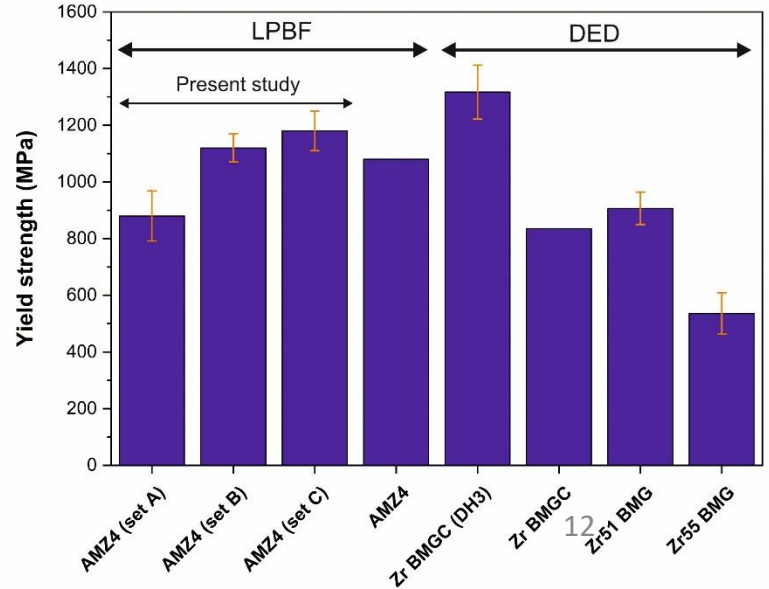
Set B= 9% Increase power of contour/border

Set C= 17% Increase power of core + Increase power of contour/border

Impact toughness



Tensile



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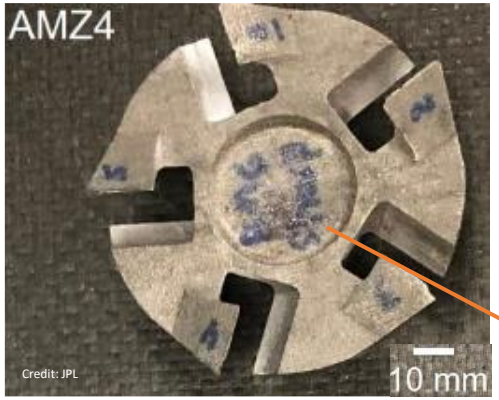
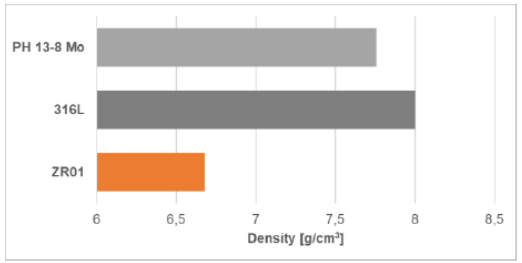
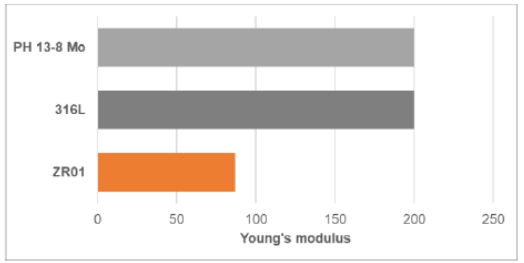
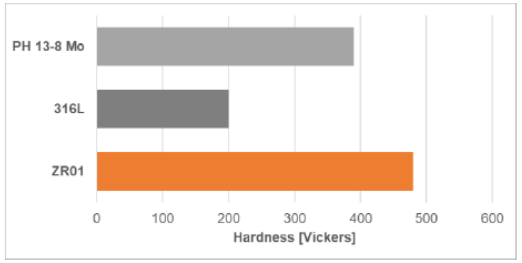
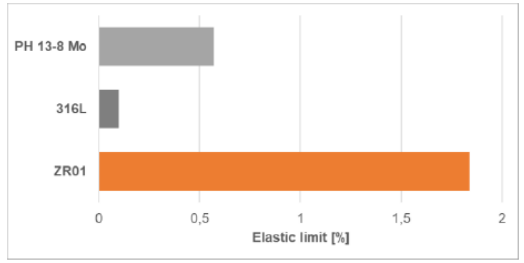
Application of 3D printed BMGs

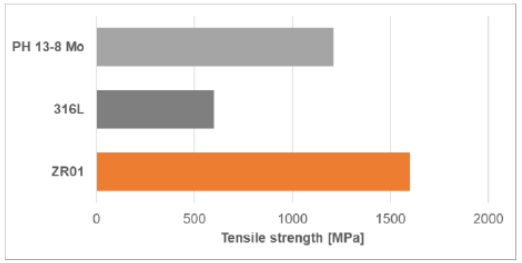


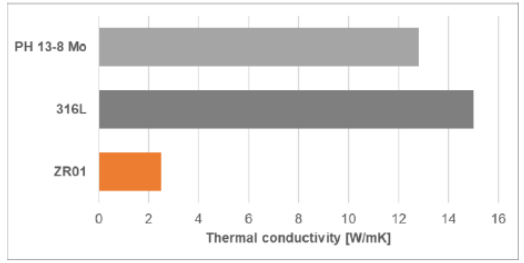


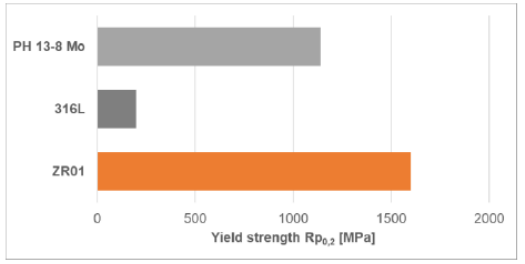












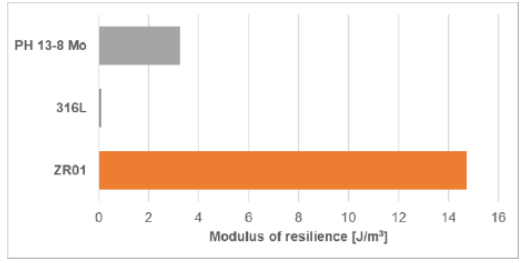


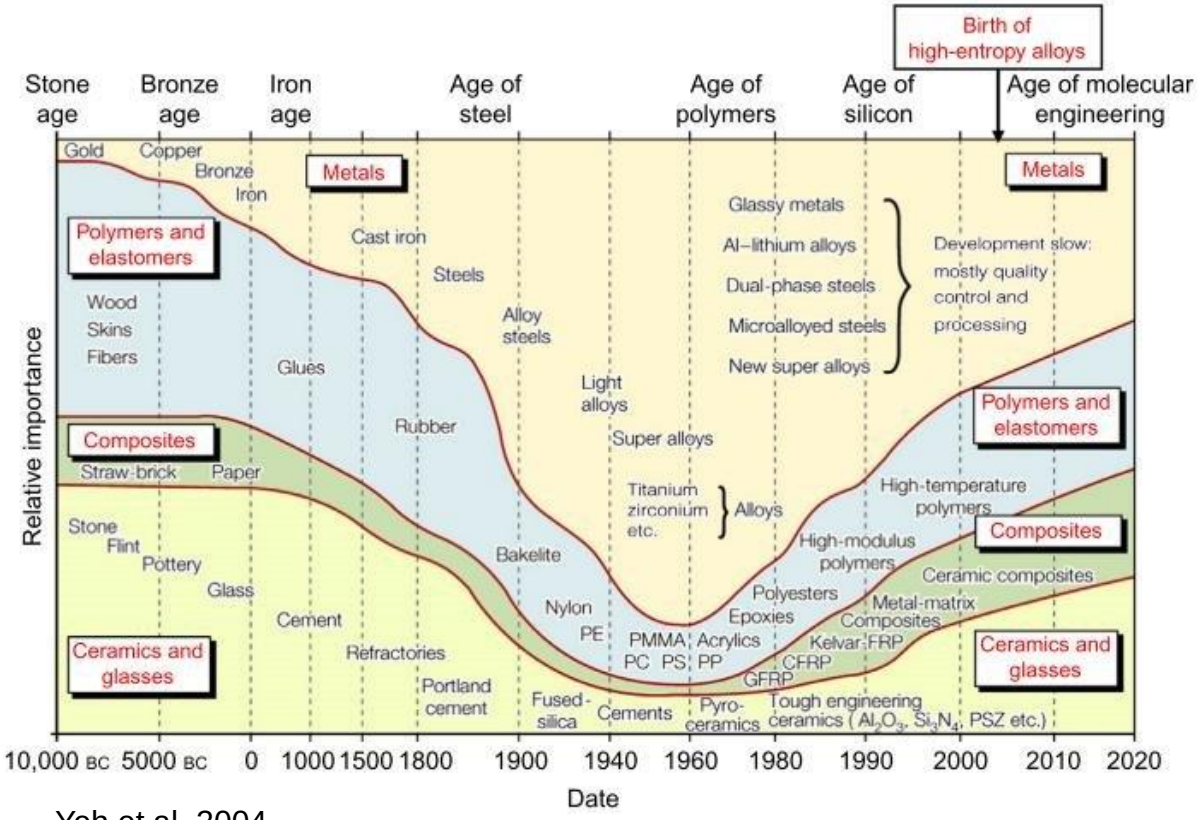
Figure 7: Mechanical properties of AMLOY-ZR01 in comparison to PH 13-8Mo and 316L

Credit: Heraeus

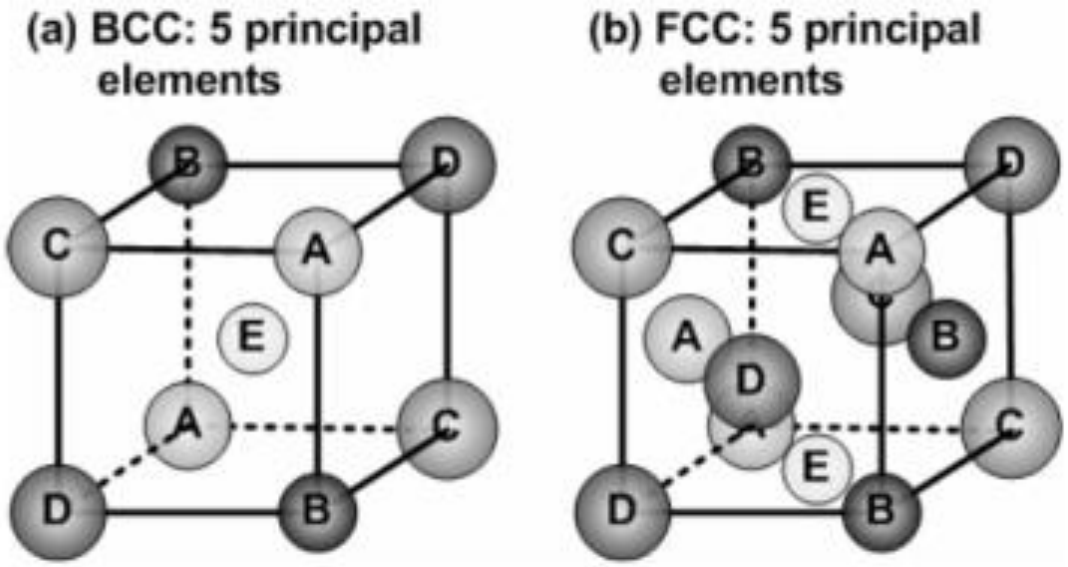
Introduction of HEA

Solid solution alloys with five principal or more elements (5-35 at%)

Better **strength-to-weight ratios**, with a higher degree of **fracture resistance, tensile strength, good ductility**, **high hardness**, as well as **corrosion** and **oxidation resistance**



Yeh et al. 2004



Yeh et al. 2006

Thank you

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