Thermophysical and Mechanical characterization of cuprous materials

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Materials characterized and test matrix

- **CuCrZr – longitudinal** [ρ=8.90 g/cm^3]
- **DiscupEXT – radial** [ρ=8.72 g/cm^3] **& axial** [ρ=8.70 g/cm^3]
- **DiscupHIP** [ρ=8.75 g/cm^3]
- **GlidcopEXT – longitudinal** [ρ=8.87 g/cm^3] **& transversal** [ρ=8.87 g/cm^3]
- **GlidcopHIP** [ρ=8.87 g/cm^3]

Thermophysical characterization	
Dilatometry	Coefficient of thermal expansion, CTE(T)
Differential Scanning Calorimetry	Specific heat, $c_p(T)$
Laser Flash Analysis	Thermal Diffusivity, α(T)

Mechanical characterization *Room temperature, 100 ℃, 200 ℃, 400 ℃, 600 ℃*	
Tensile test	Young's modulus, E(T)
	Yield strength, $R_{p0.2}(T)$
	Ultimate strength, $R_m(T)$
	Elong at Break(A)

Dilatometry – Thermal expansion and CTE measurements

- Horizontal push-rod dilatometer NETZSCH DIL 402E
- Standard test method ASTM E228
- CTE uncertainty = +/- 5.3 %

Test set-up				
Atmosphere	**Isothermal step**	**Heating phase**	**Cooling phase**	**Isothermal step**
He – 100 ml/min	20 ℃ – 10 min	5 K/min up to 850 ℃	5 K/min down to 20 ℃	20 ℃ – 10 min

Calorimetry – Specific heat

- Differential Scanning Calorimeter NETZSCH DSC Pegasus 404 C
- Standard test method DIN 51007
- c_p uncertainty = +/- 3.5 %

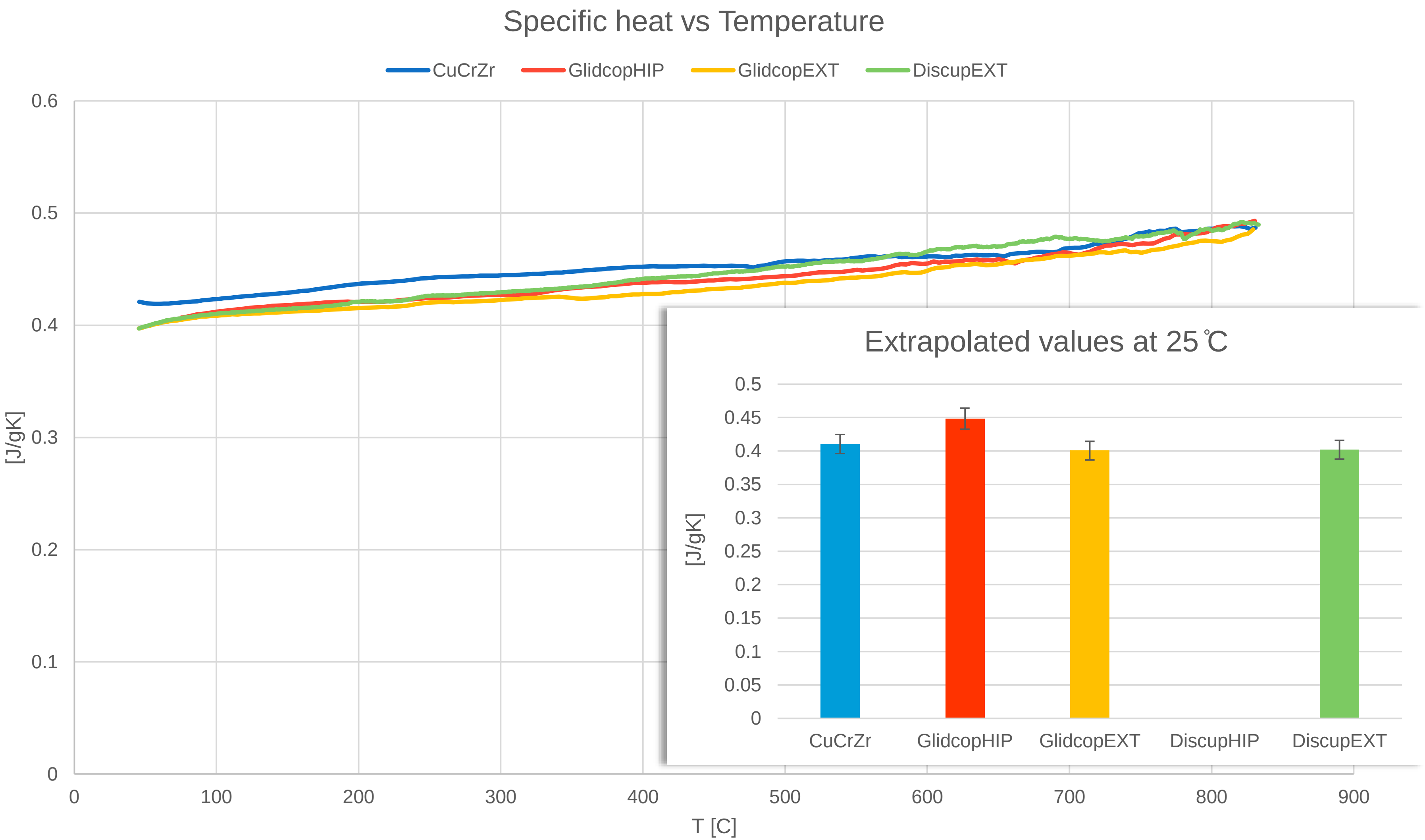
Test set-up					
Crucibles	**Reference**	**Atmosphere**	**Isothermal step**	**Heating phase**	**Isothermal step**
Pt/Rh + Al_2O_3 lids	Sapphire 83.8 mg	Ar – 50 ml/min	25 °C – 10 min	15 K/min up to 850 °C	850 °C – 10 min

Laser flash analysis – Thermal diffusivity

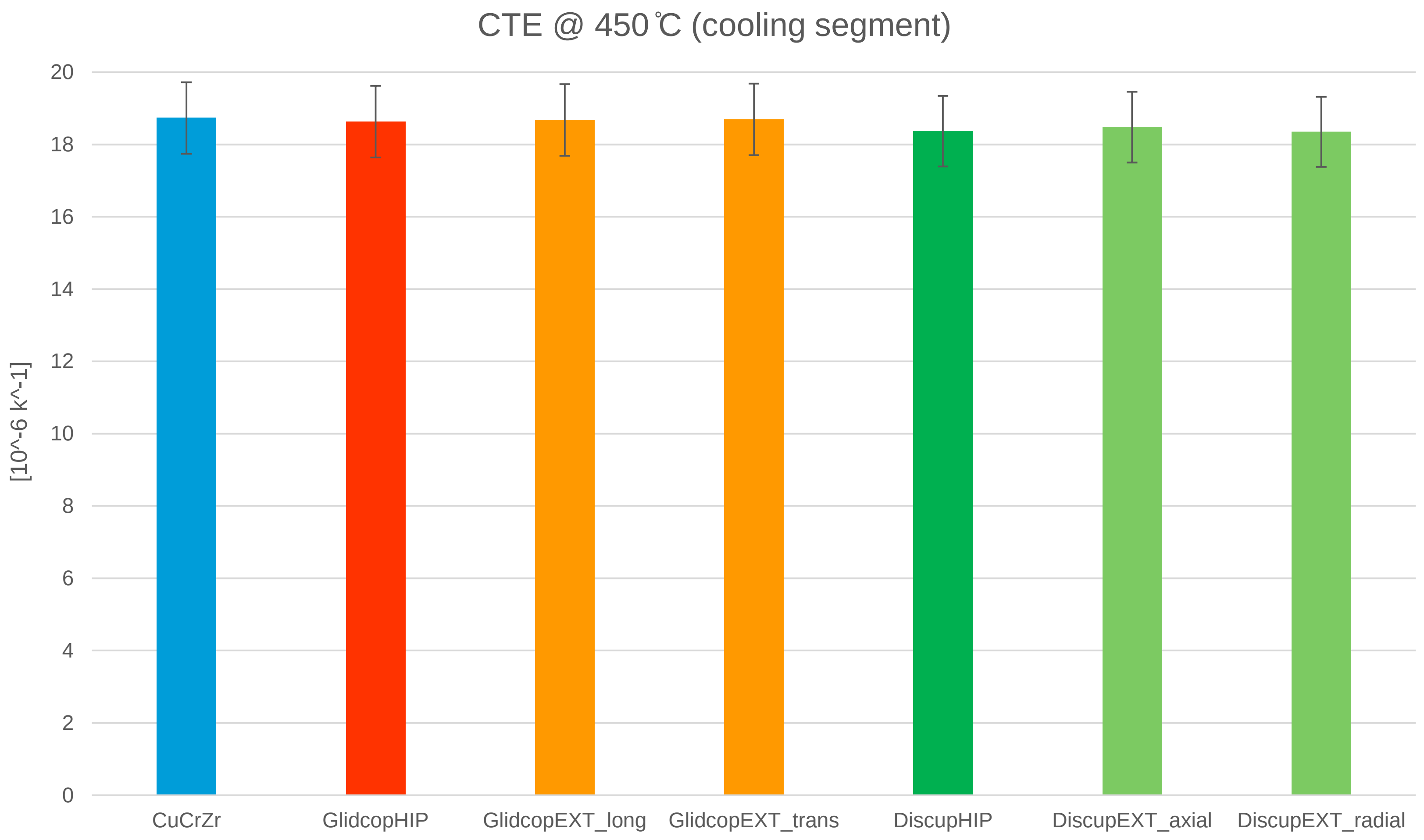
- Laser Flash Apparatus NETZSCH LFA 427
- Standard test method ASTM E2585
- α uncertainty = +/- 5.6%

Test set-up			
Atmosphere	**Laser Voltage and Pulse Duration**	**Temperature range**	**Analysis Model**
Ar – 100 ml/min	550 V – 0.6 ms	RT – 850 °C	Cape Lehman

Results Thermophysical characterization (1/3)

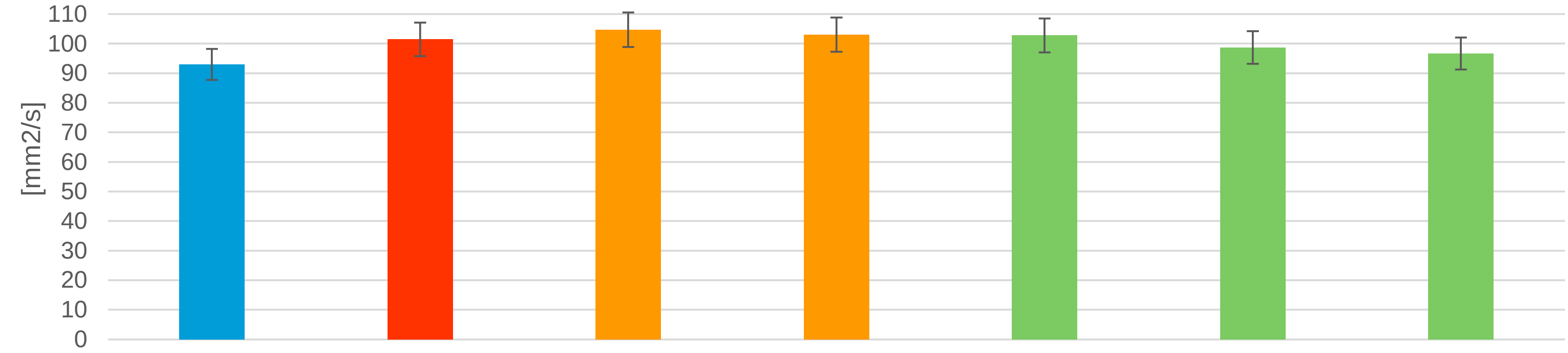


Results Thermophysical characterization (2/3)

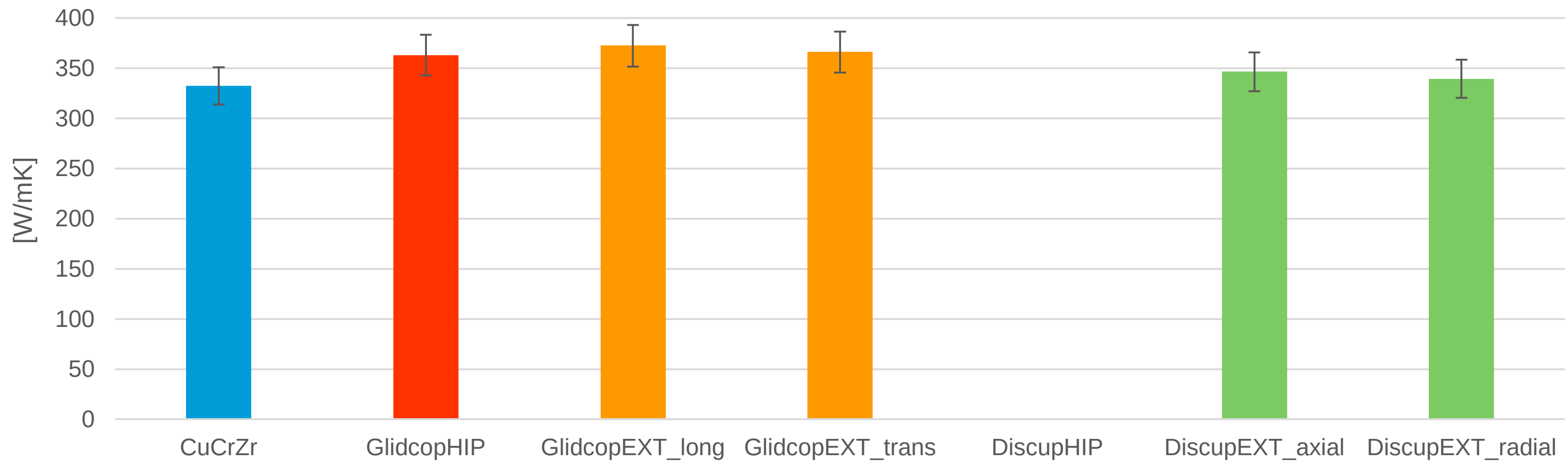


Results Thermophysical characterization (3/3)

Thermal Diffusivity @ RT



Thermal Conductivity @ RT

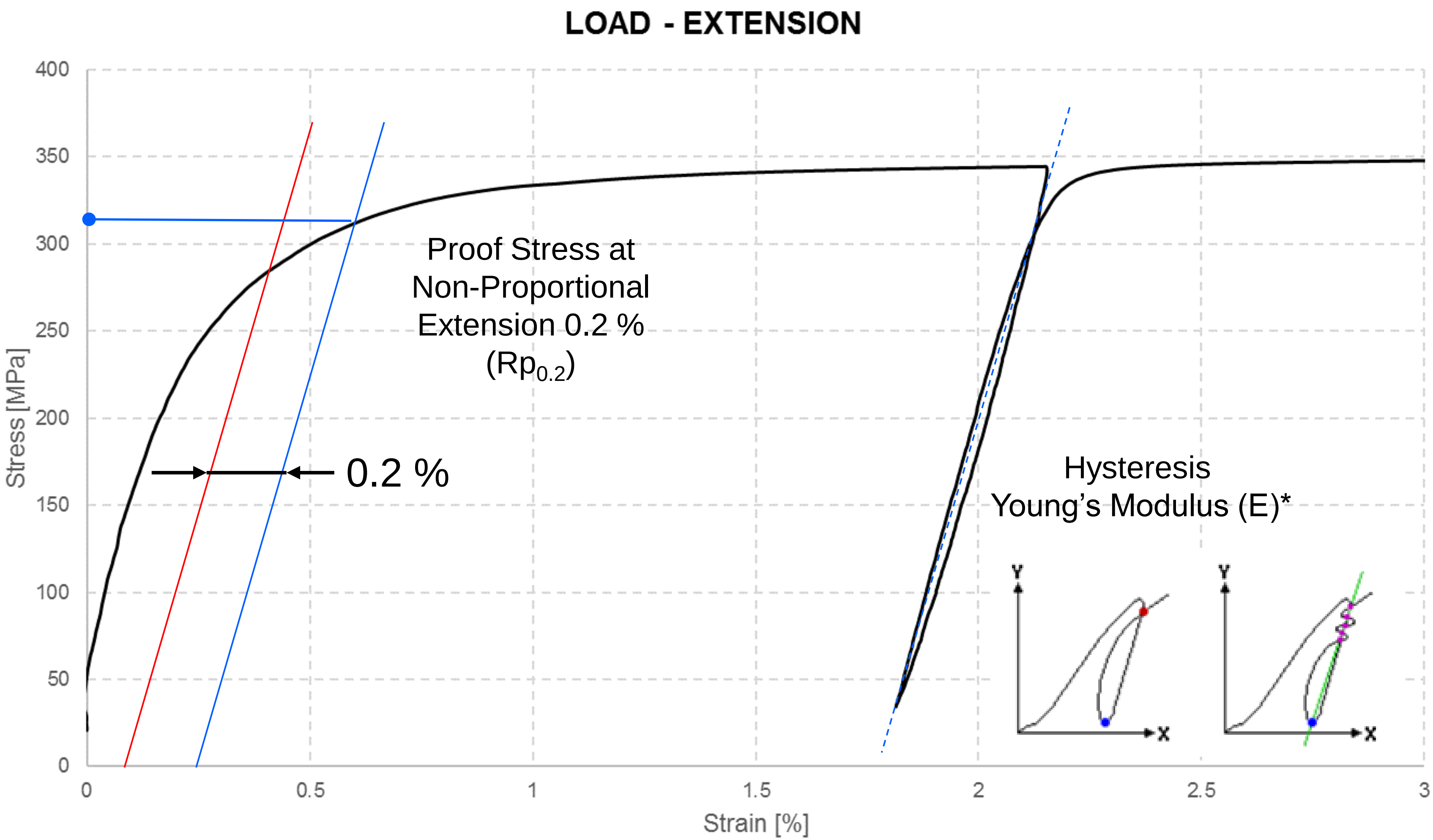


High Temperature Tensile Tests

- ZWICK/ROELL Z400 with High Temperature Furnace
- Optical laser extensometer
- Standard test method ISO 6892-2

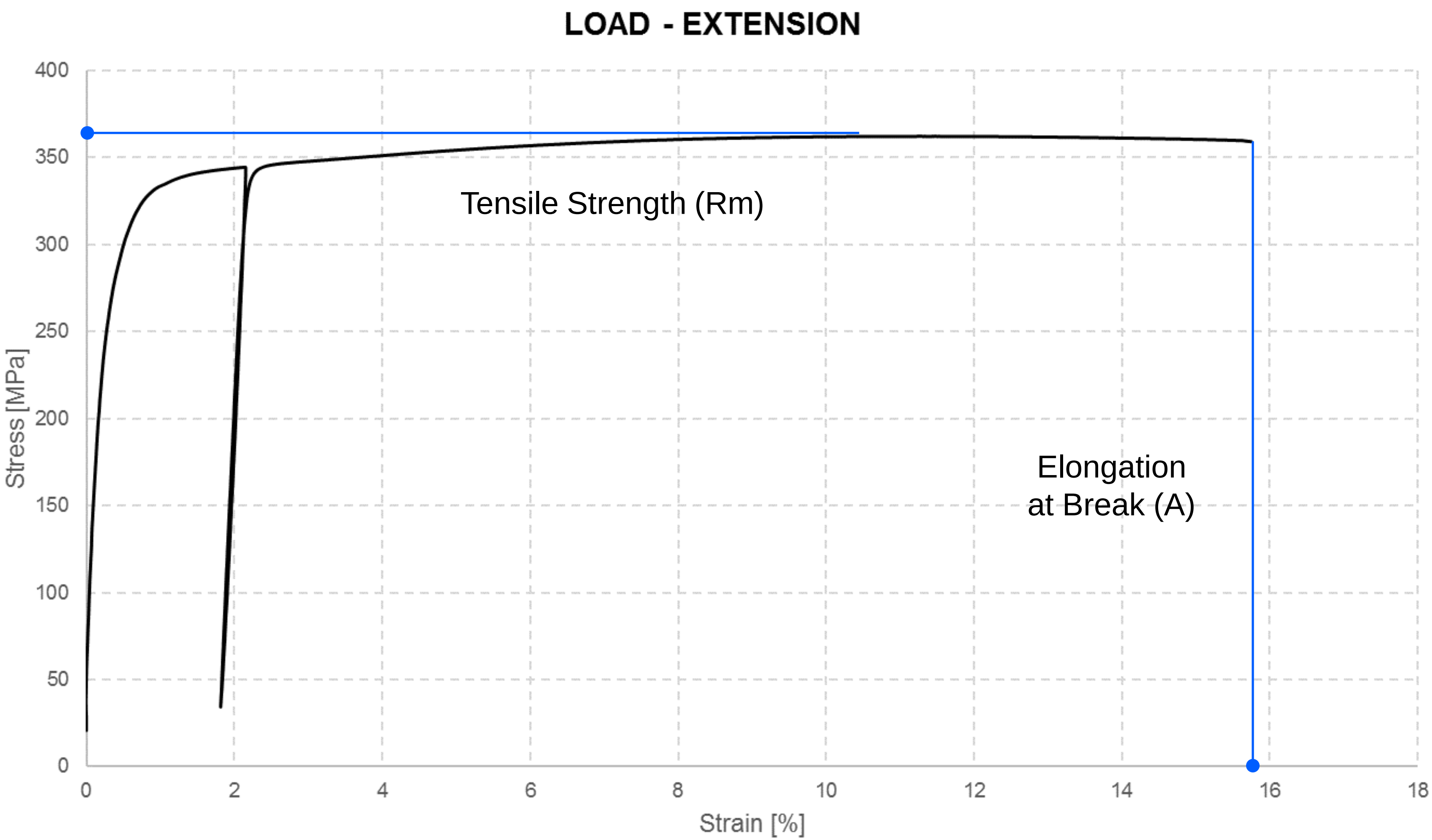
Test set-up				
Test Piece	**Load Rate**	**Soaking Time**	**Testing Temperatures**	**Gauge Length**
A.4 Round Threaded	Method A 0.00025 s^{-1}	10 min	RT,100, 200, 300, 400 and 600 ℃	20 mm – 2a

High Temperature Tensile Tests Results

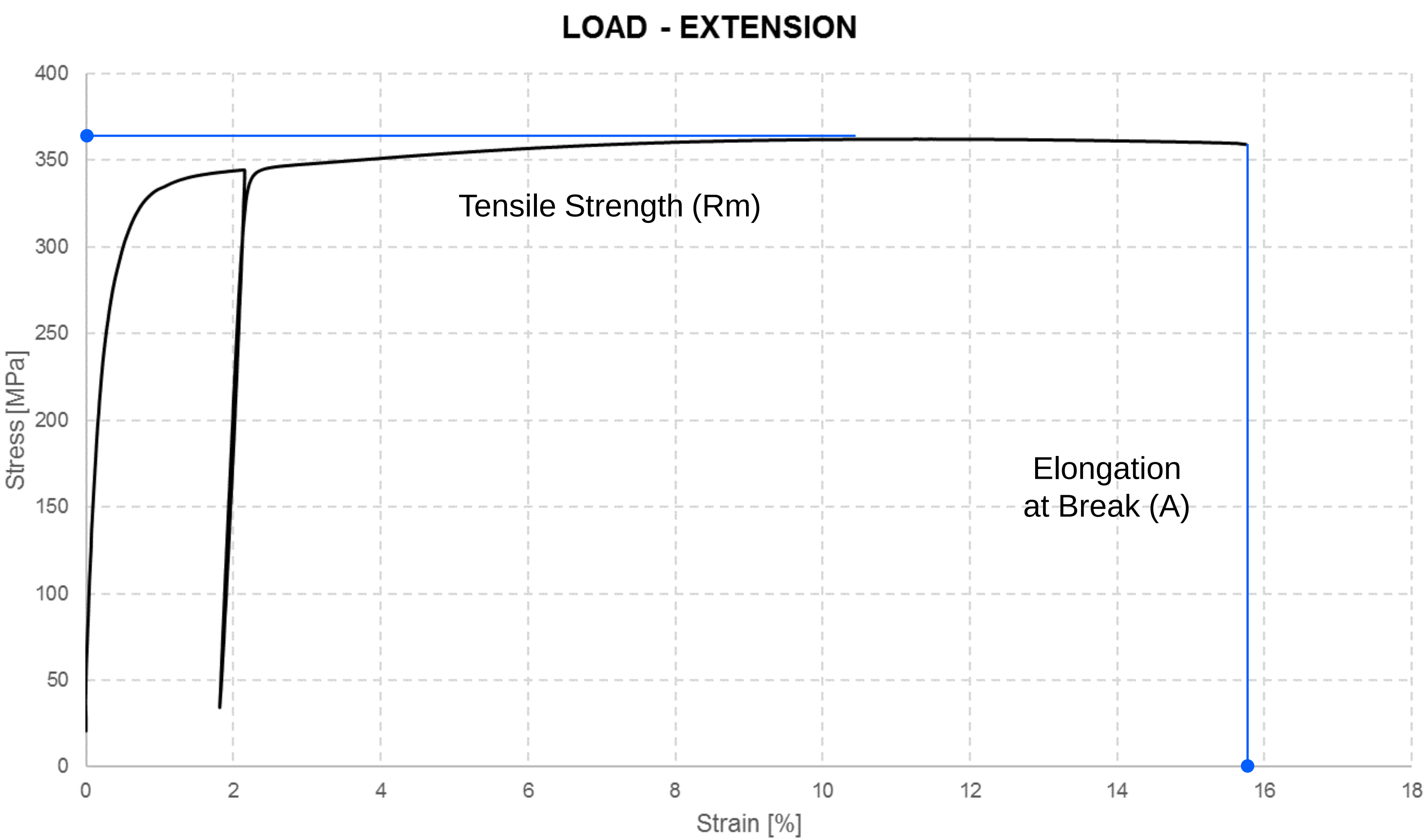


*for CuCrZr Young's Modulus determination, the initial slope was taken into account (no hysteresis loop)

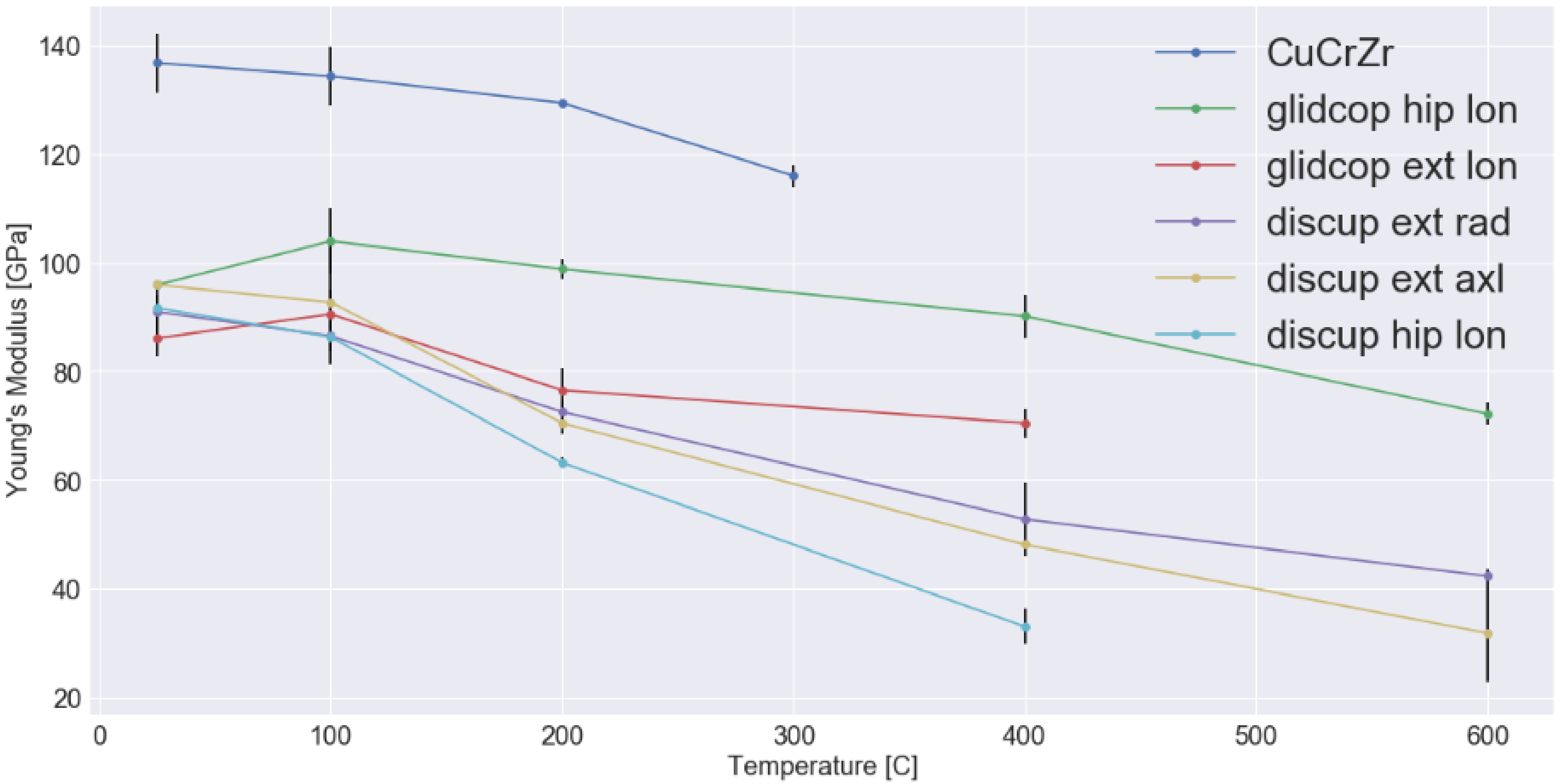
High Temperature Tensile Tests Results



High Temperature Tensile Tests Results

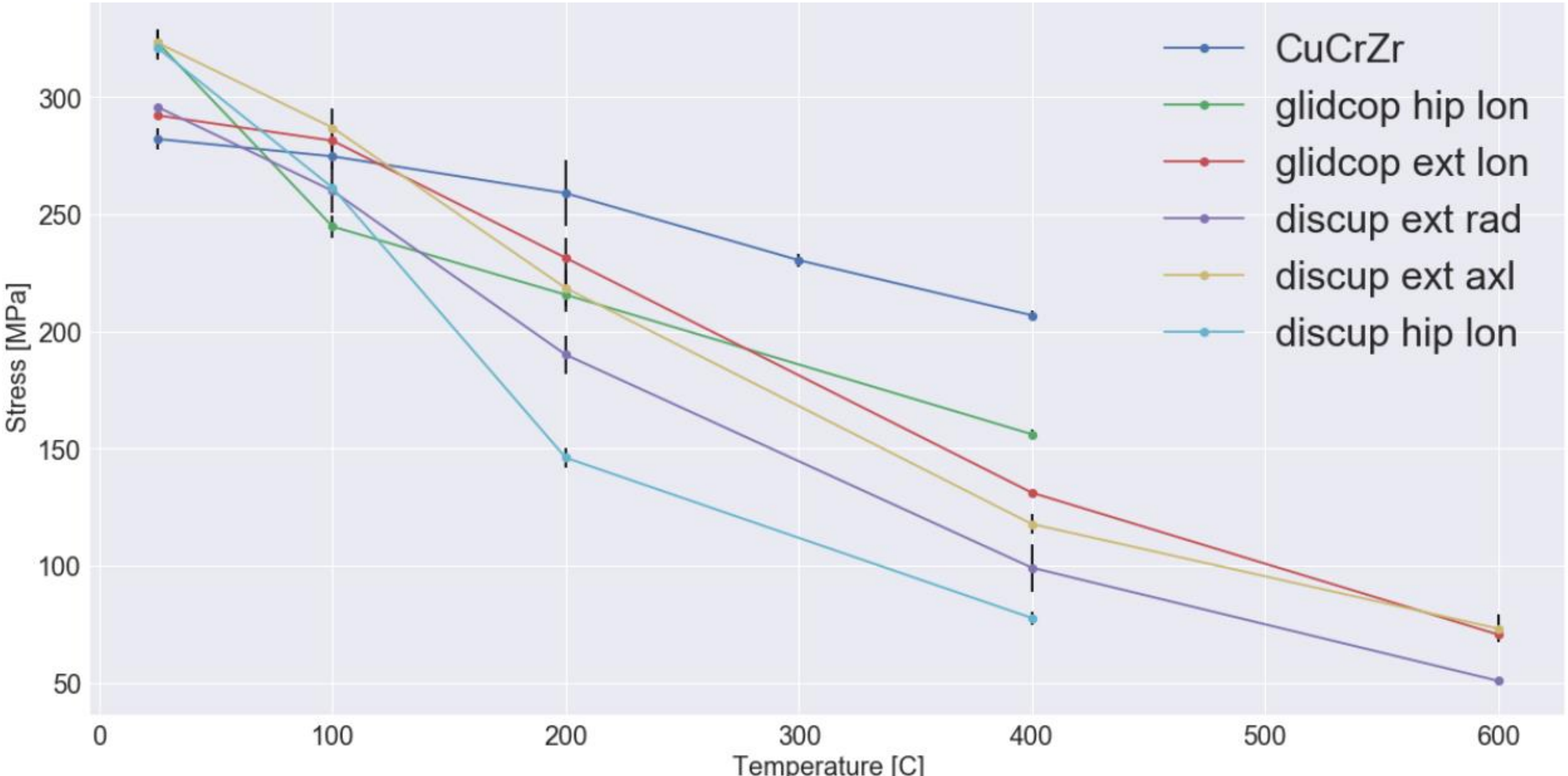


High Temperature Tensile Tests – Young's Modulus



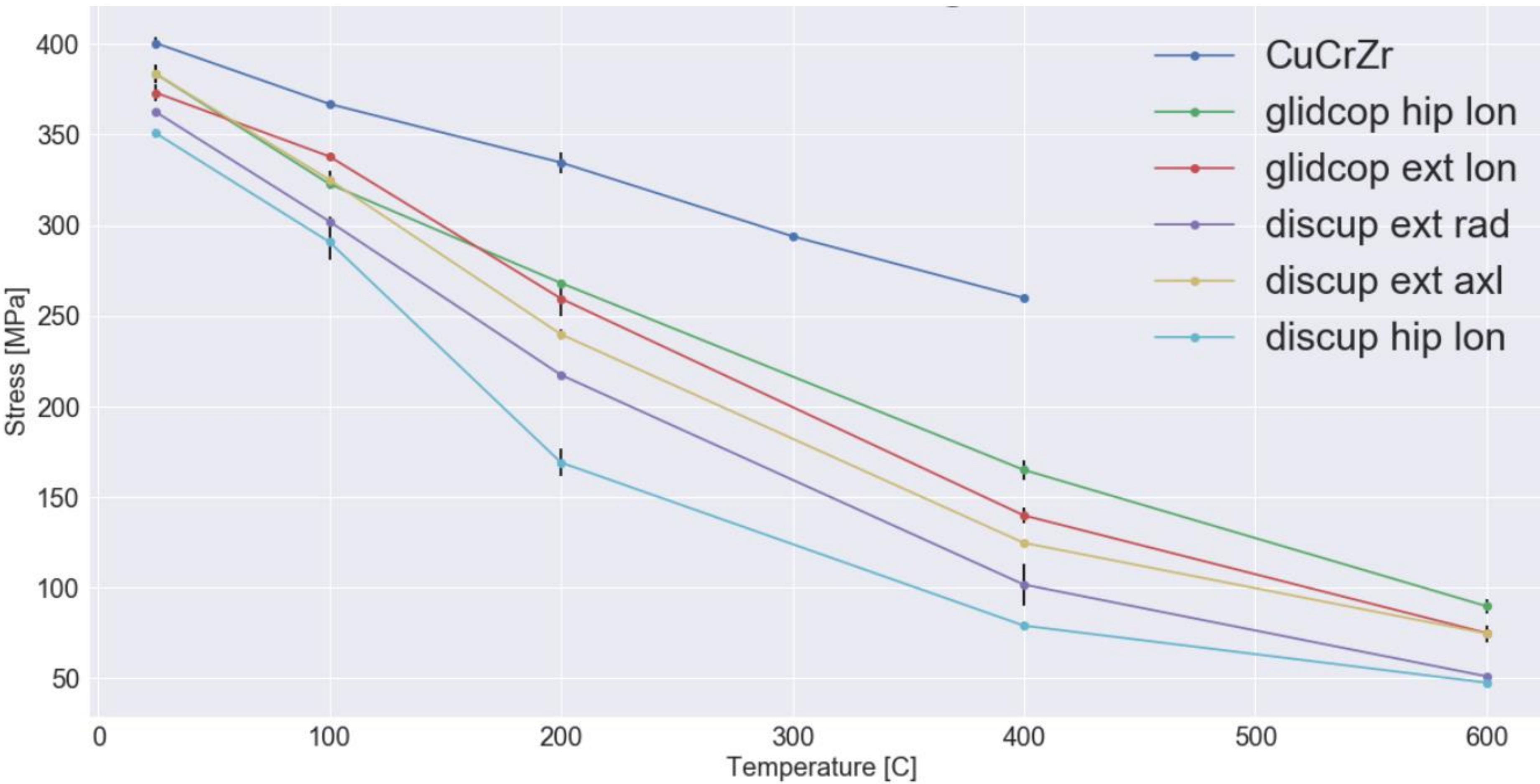
Error bars depict 95% confidence interval

High Temperature Tensile Tests – $Rp_{0.2}$



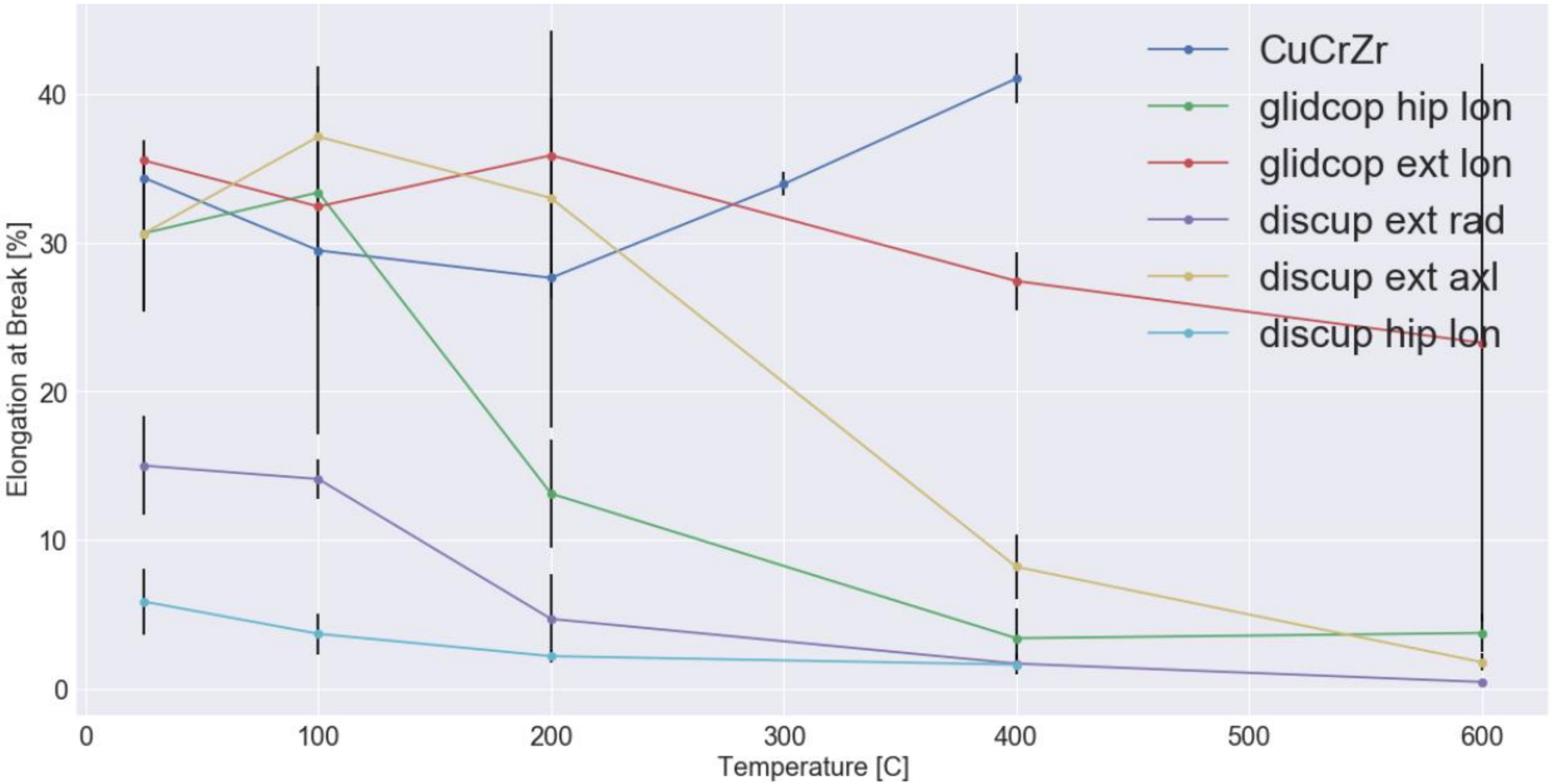
Error bars depict 95% confidence interval

High Temperature Tensile Tests – Tensile Strength



Error bars depict 95% confidence interval

High Temperature Tensile Tests – Elongation at Break



Error bars depict 95% confidence interval

Conclusions…

- No big surprises in thermal analysis:
  - Characteristic behavior of copper (Cp and CTE)
  - Consequent reduction of the heat transfer properties due to the alloying agents
- In terms of mechanical properties:
  - Logical drop of the mechanical properties with temperature, with sensible inter-material variation
  - Low ductility of several materials (discup ext rad, discup hip lon, glidcop hip lon), which worsens with temperature
  - Resource intensive tests

…and next steps?