



Material study for high pressure gas regulation (revised)

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Objectives of material tests

- Materials of cryomodules and cavities are not specified in the high pressure safety regulations
- Operation temperature at 2K is not defined in the regulations
- We shall verify that all materials including welded parts, employed for cryomodules and cavities, are strong enough at the operation temperature
- Data sets of tensile strength and Charpy impact strength should be submitted



Material tests

Materials	Tensile Test	Impact Test
Nb	completed	---
Ti	completed	in progress
NbTi	in progress	in progress
Nb-Nb Welded Part (EBW)	in progress	in progress
Nb-Ti Welded Part (EBW)	in progress	in progress
Ti-Ti Welded Part (EBW)	in progress	in progress
NbTi-Ti Welded Part (TIG)	planned	planned
Nb-(Cu)-SS HIP	completed	completed

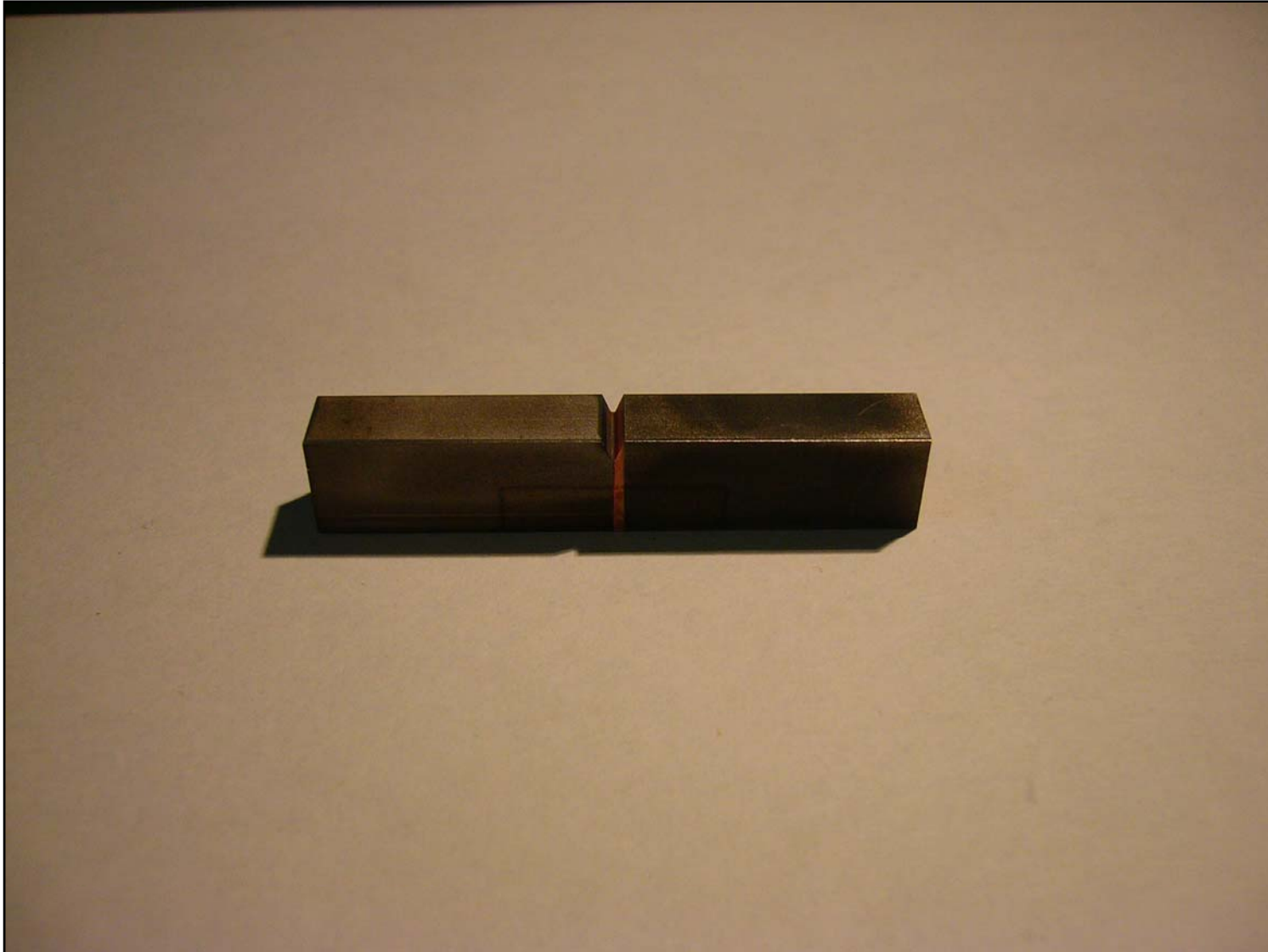


Nb-SS HIP Materials

- HIP (Hot Isostatic Pressing) to join different metals
- Joint of niobium (cavity) and stainless steel 316L (helium vessel)
- Interlayer metal - copper
- Specimens from 2 companies to compare the difference, if any
 - Kuroki Composite (Kuroki)
 - Kinzoku-giken (Kinzoku)



Specimen (7.5 mm wide)



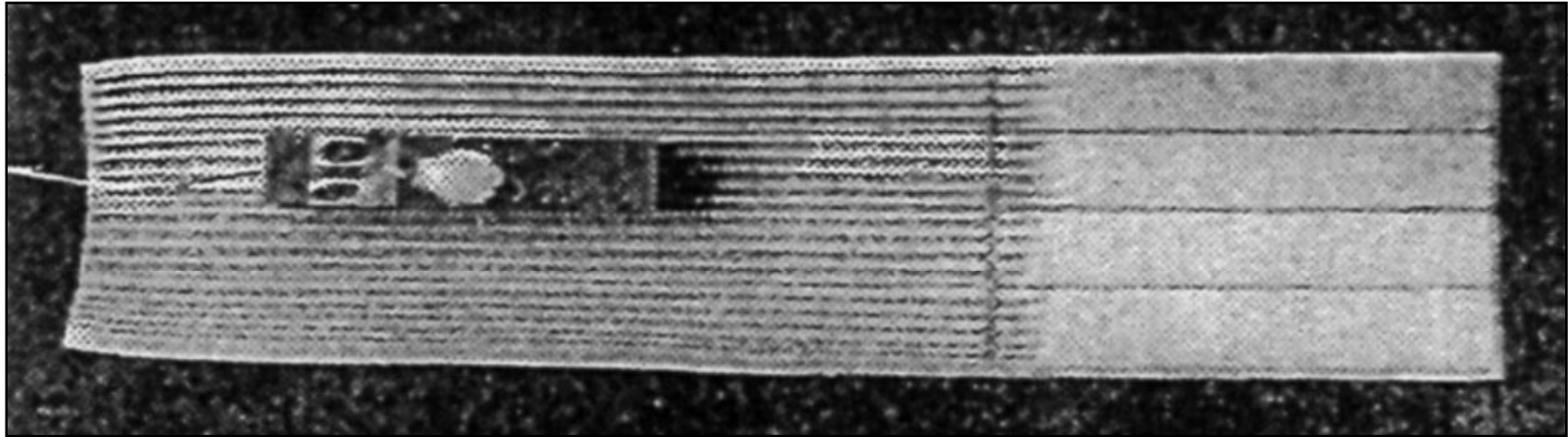


Charpy Impact Test at LHe Temp.

- Tests performed by a company
 - Kawaju Techno Service Corp., Kobe, Japan
- Specimens in insulation capsules made of “polyethylene foam”
- Energy absorbed by the capsule extracted in impact strength calculation
- Grooves on the insulation capsules for liquid helium flow cooling the specimens
- Specimen temperature monitored with AuFe-Chromel thermocouple



Specimen with insulation capsule

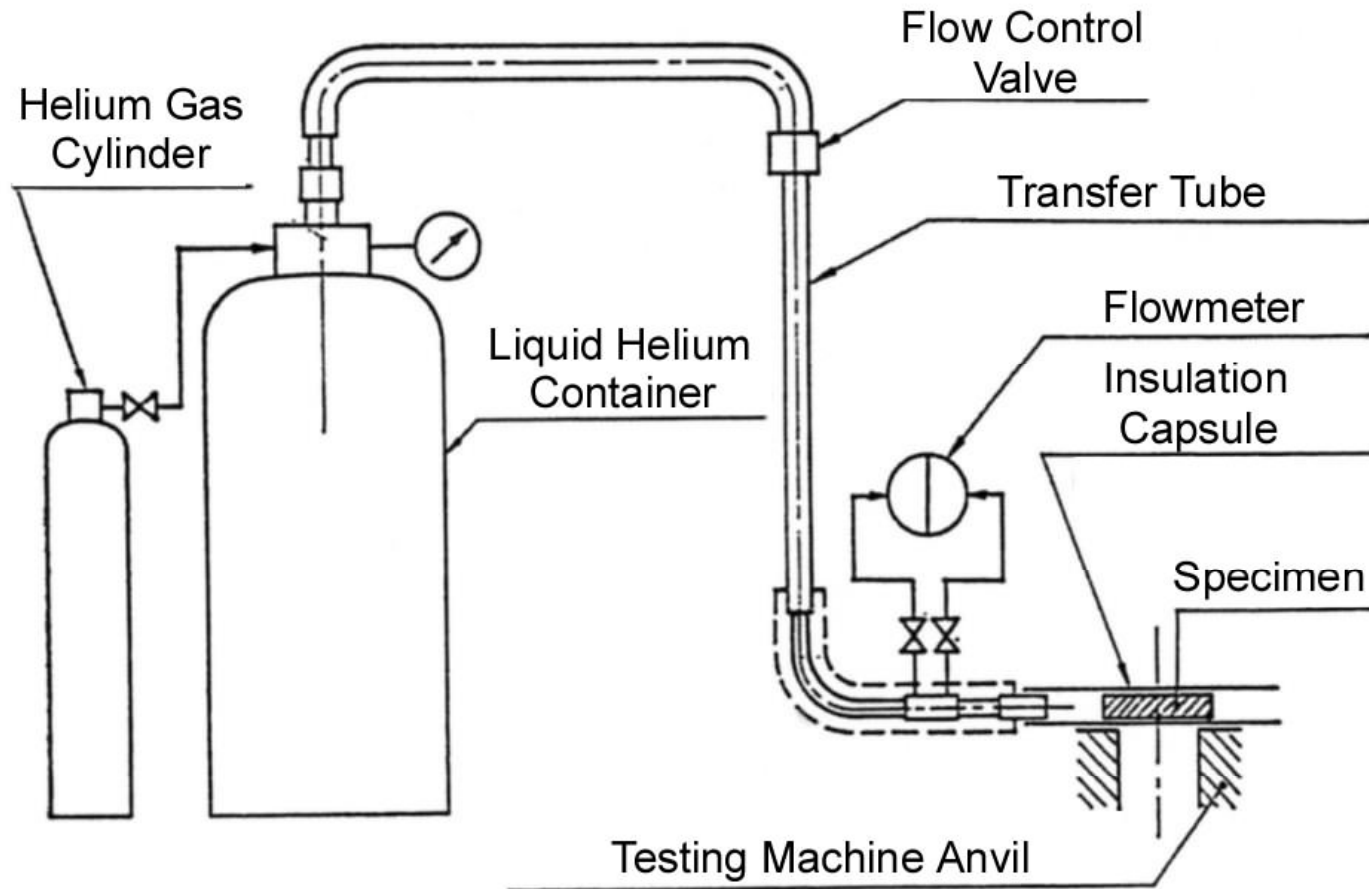




Charpy impact testing machine



Test setup schematic





Specimen under test at LHe temp.





Experimental Results (Preliminary!)

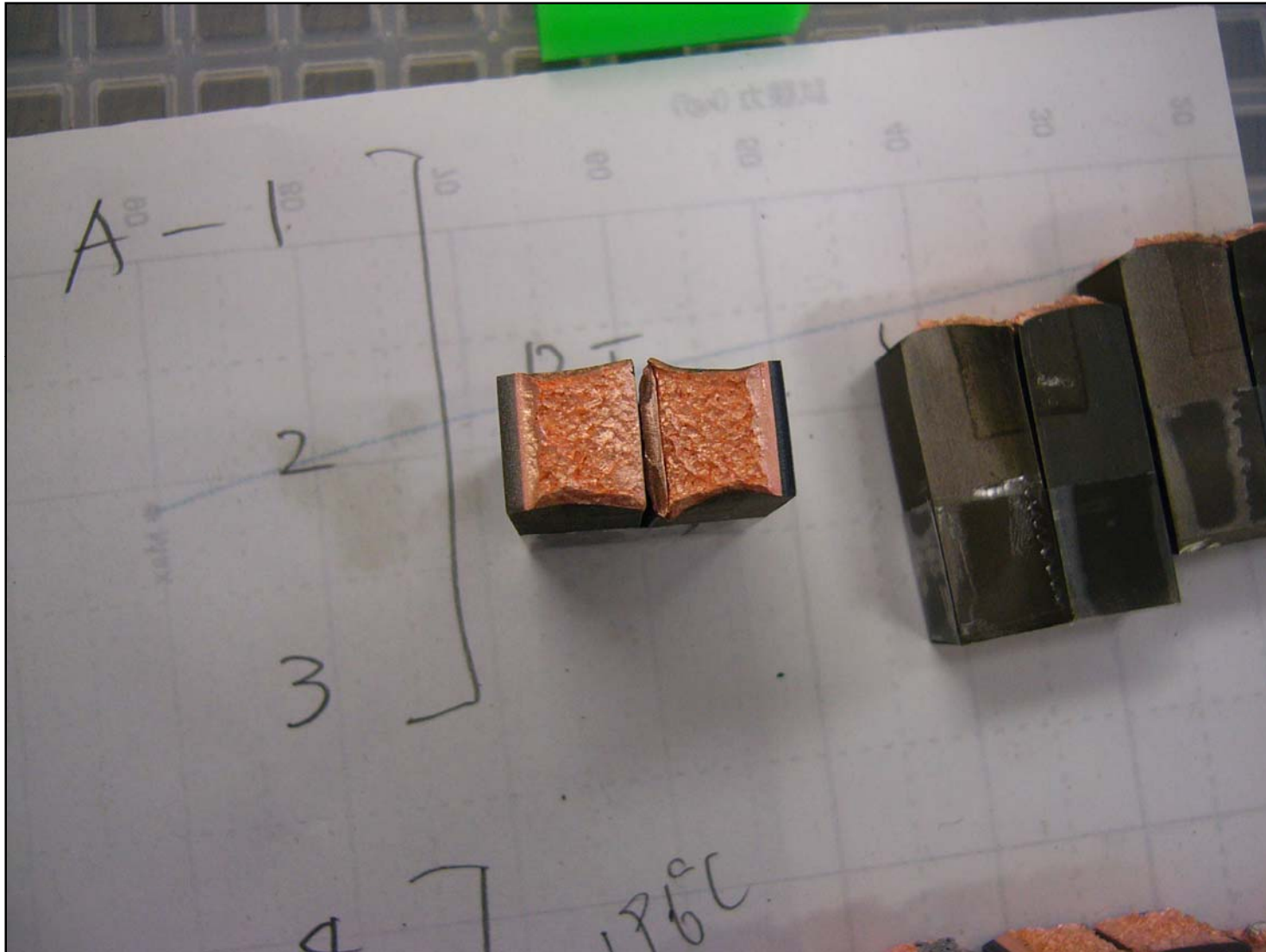


Overview of results

- Tensile Tests
 - All specimens cut in niobium part
- Impact Tests
 - Most specimens with notches in copper part (center of interlayer metal)
 - Some with notches in boundaries between niobium and copper, and between stainless steel and copper
 - All specimens cut at notch positions

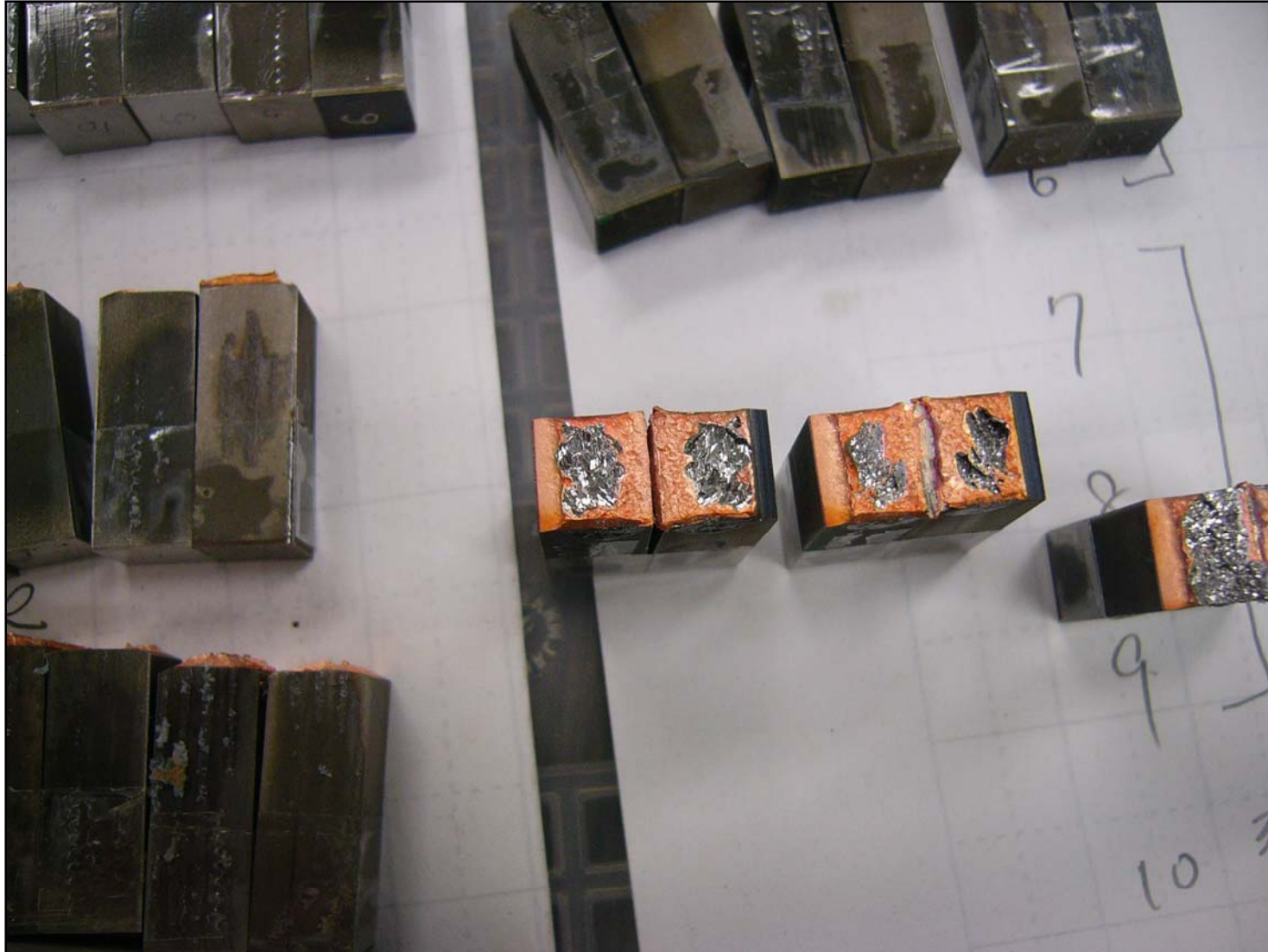


HIP specimens broken at RT



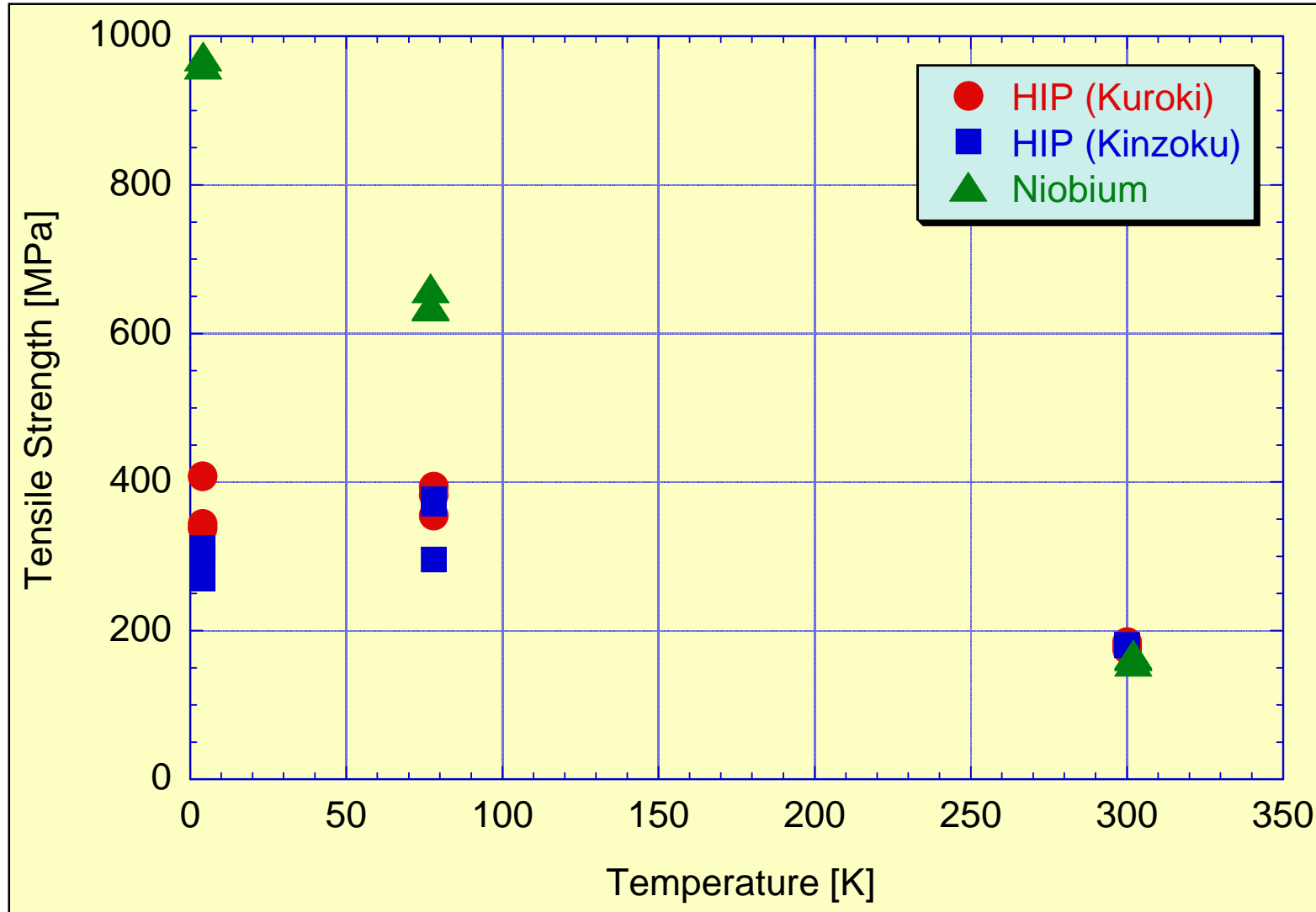


HIP specimen broken at LHe temp.



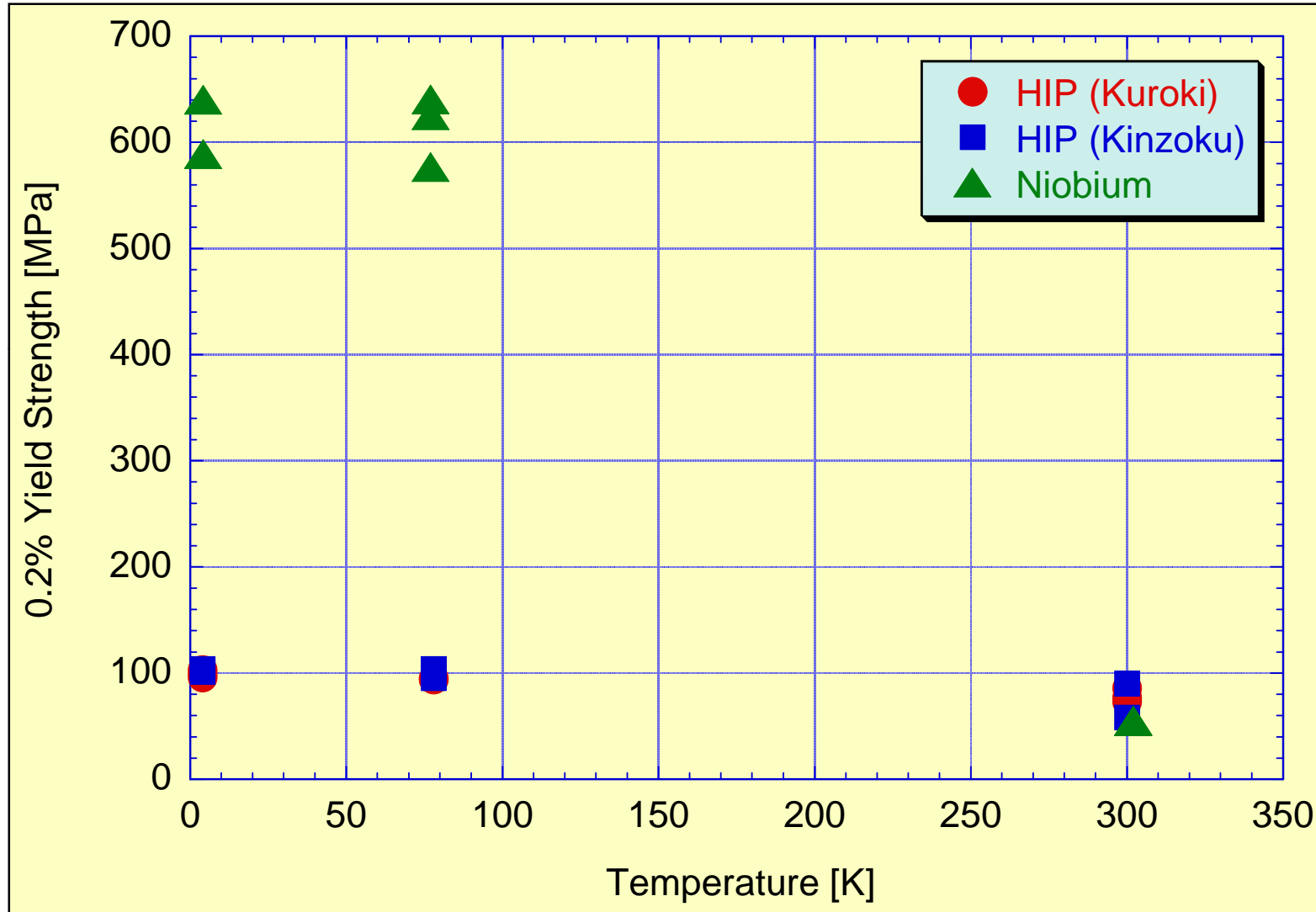


Tensile strength



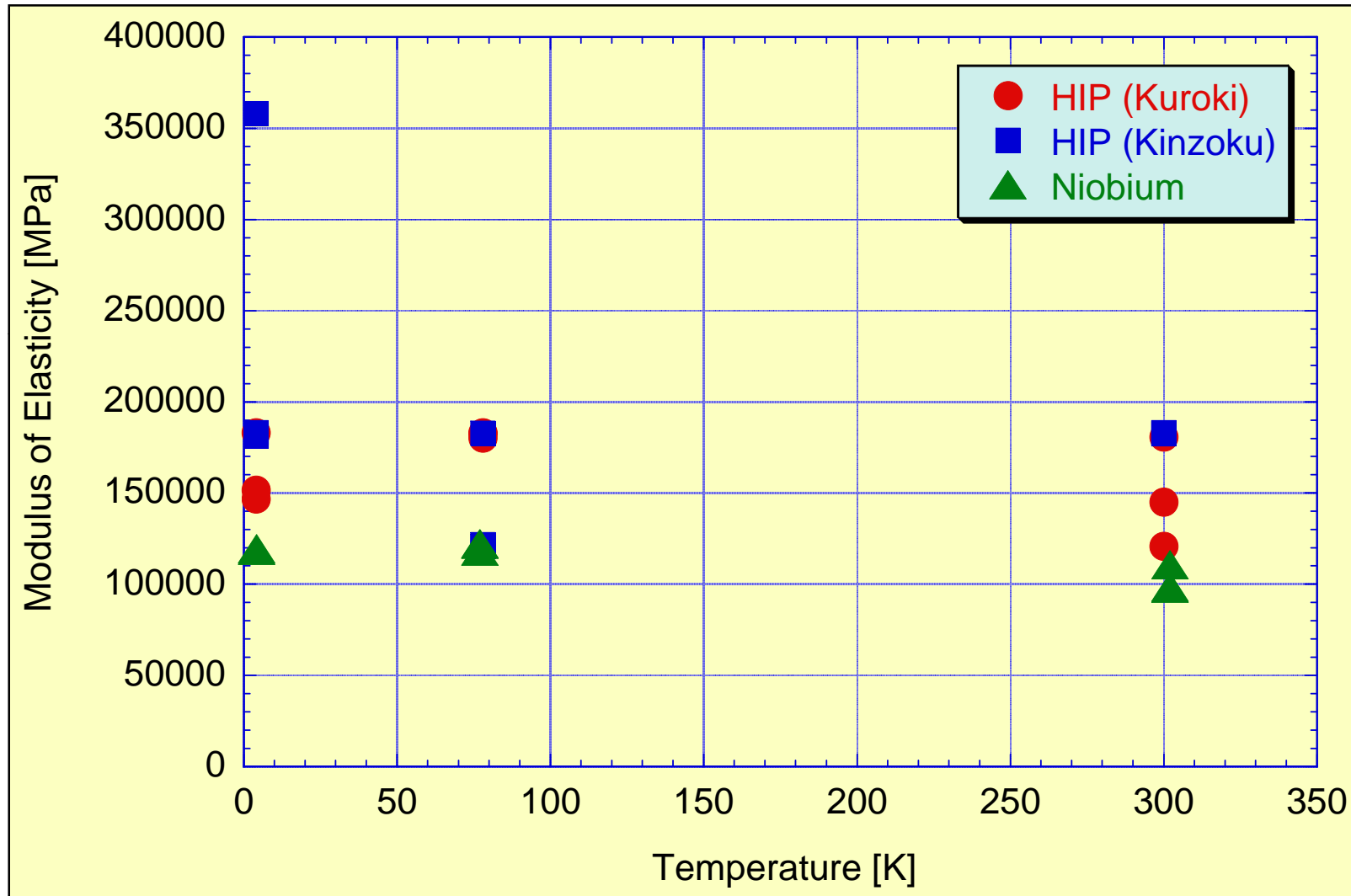


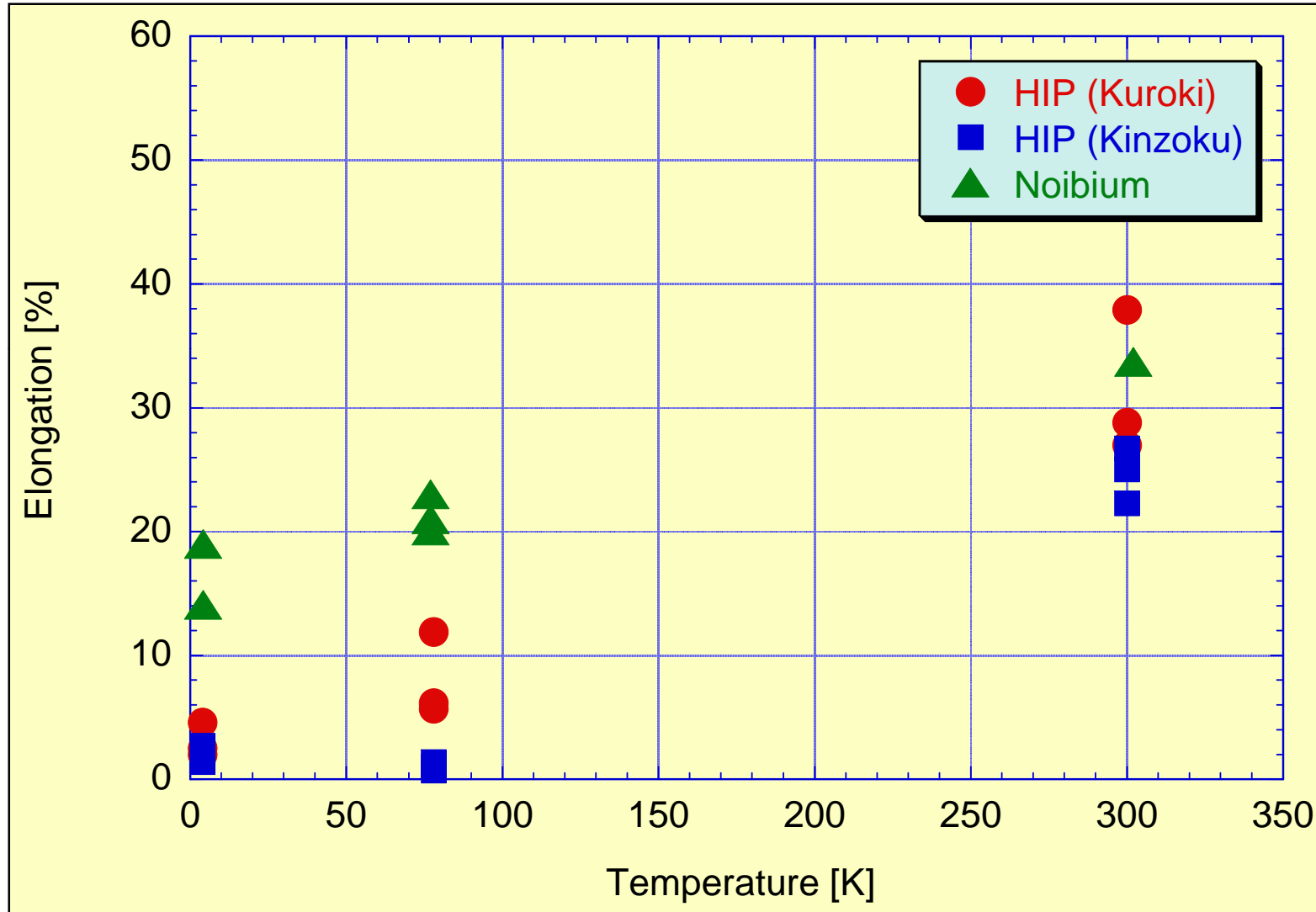
0.2% yield strength

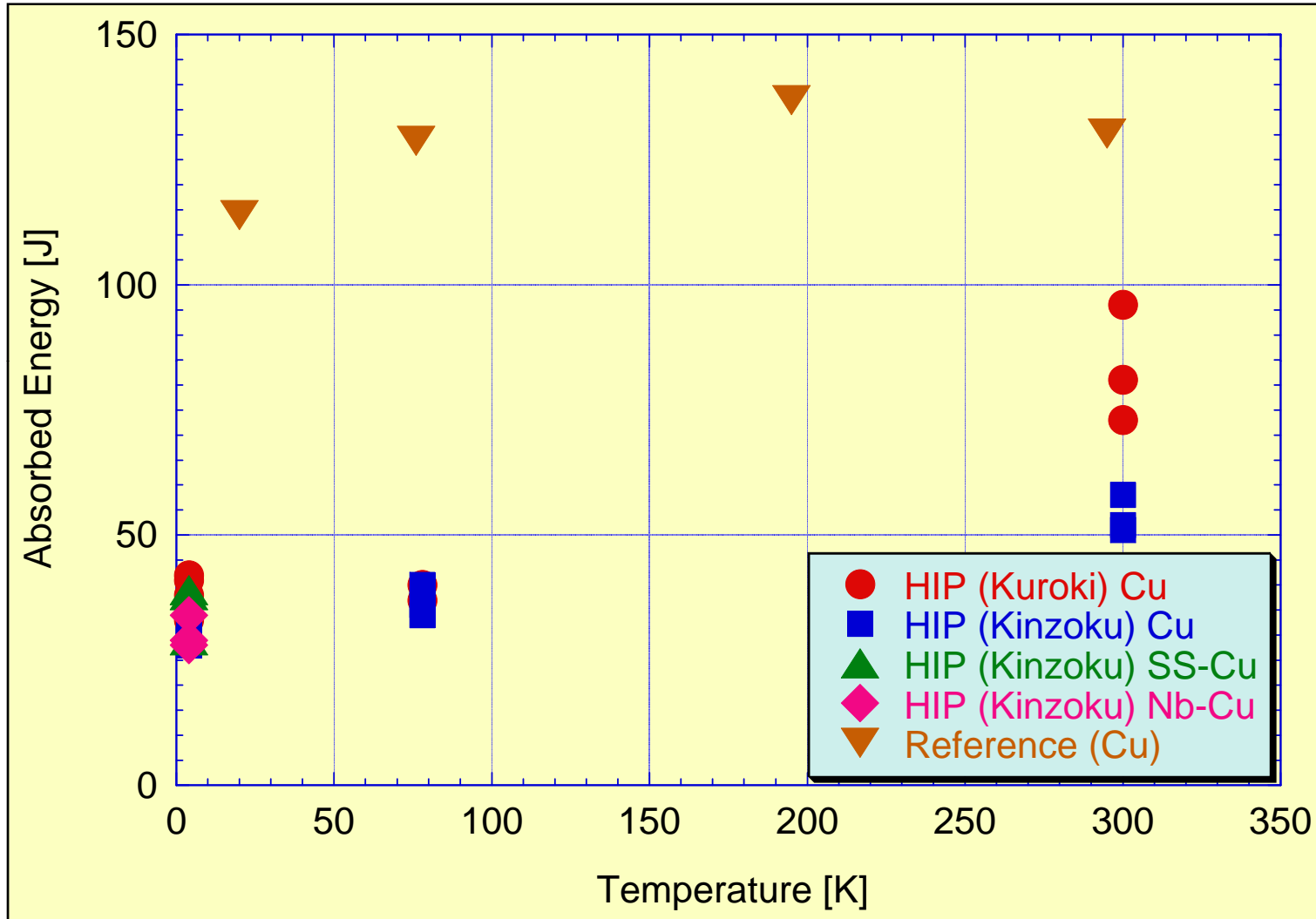




Modulus of elasticity







Reference: http://www.copper.org/resources/properties/144_8/144_8.html



Summary of HIP specimens tests

- Tensile Tests
 - Unclear linear region in stress-strain relation
 - Yield strength and modulus of elasticity not well defined
 - Strength degraded at low temperatures
 - Elongation contains some gaps between broken parts
- Impact Tests
 - No difference of impact strength between the specimens from 2 companies
 - No clear difference of impact strength by notch positions
 - Impact strength (absorbed energy) degraded at low temperatures comparing with oxygen-free copper data