June 30, 2015, ICMC2015, Tucson, Arizona, USA

Cryogenic Materials V: Structural Materials 17:30-17:45

Tensile properties and conductivities of a precipitation hardened and cold-rolled Cu-0.3Cr-0.1Zr alloy at cryogenic temperature

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Outline

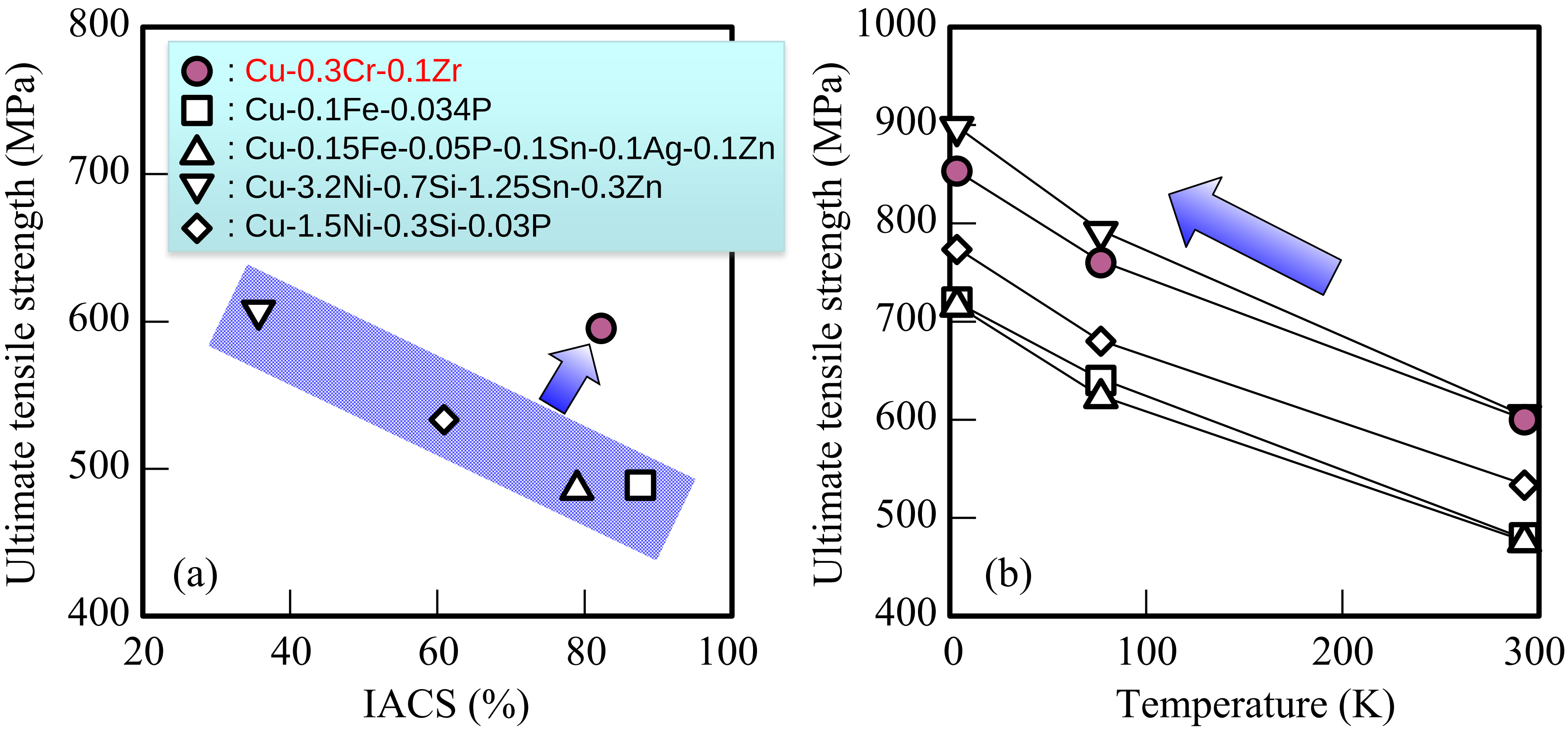
- The National Research Institute for Metals (NRIM, now National Institute for Materials Science, NIMS) has accumulated physical and mechanical properties at cryogenic temperatures for structural metallic materials since 1980s.
    1. O. Umezawa, in: Handbook of Superconductivity and Cryogenics, edited by Cryogenics and Superconductivity Society of Japan, Ohmsha, Tokyo, 1993
    2. O. Umezawa and K. Ishikawa, Cryogenics, 32, 873-880 (1992)

- Precipitation hardened copper-based alloys were the candidate of a high strength and high conductivity structural material at cryogenic temperature.

- Tensile properties and conductivities of precipitation hardened and cold-rolled Cu-0.3Cr-0.1Zr alloy were evaluated as a bulk material at cryogenic temperature in this study.
    - Tensile properties
    - Electrical resistivity
    - Thermal conductivity
    - Magnetization

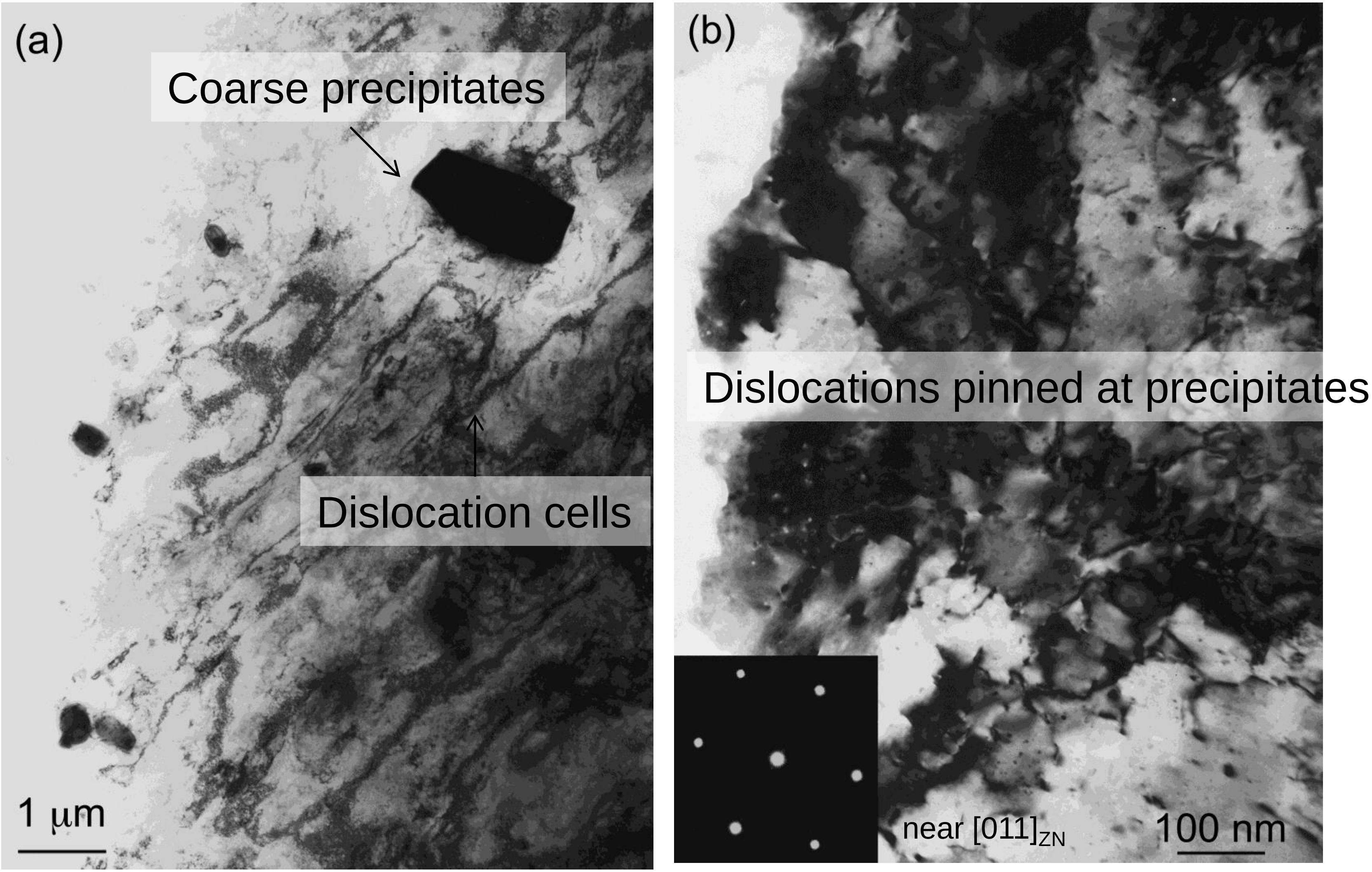
Precipitation hardened copper-based alloys developed as the lead frame in device

an excellent combination of high strength and high electrical conductivity in the heavily cold-rolled condition (99% reduction)



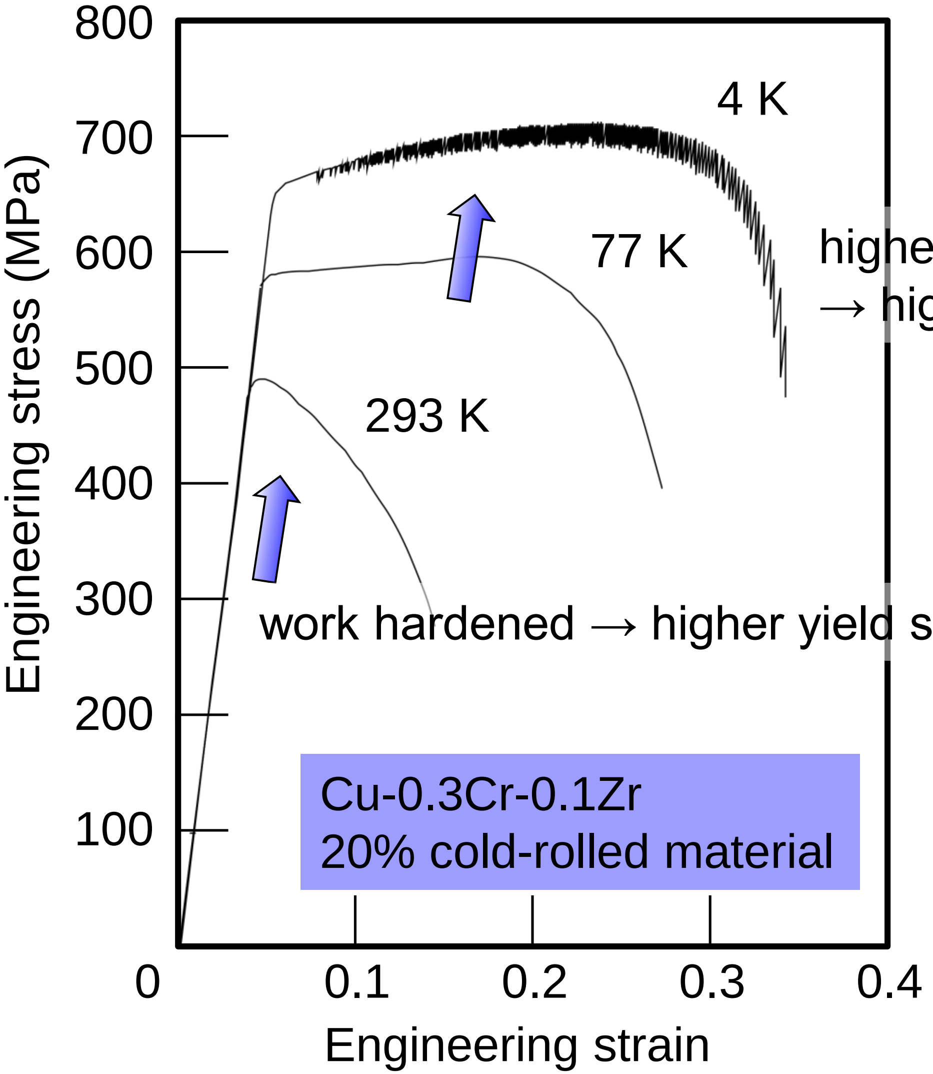
IACS: international annealed copper standard

Cu-0.3Cr-0.1Zr cold-rolled sheet



TEM bright field image with cold-rolled reduction of 99%:
(a) precipitates of intermetallic phases and dislocation structure, and (b) dislocations in the matrix.

Load - displacement curves

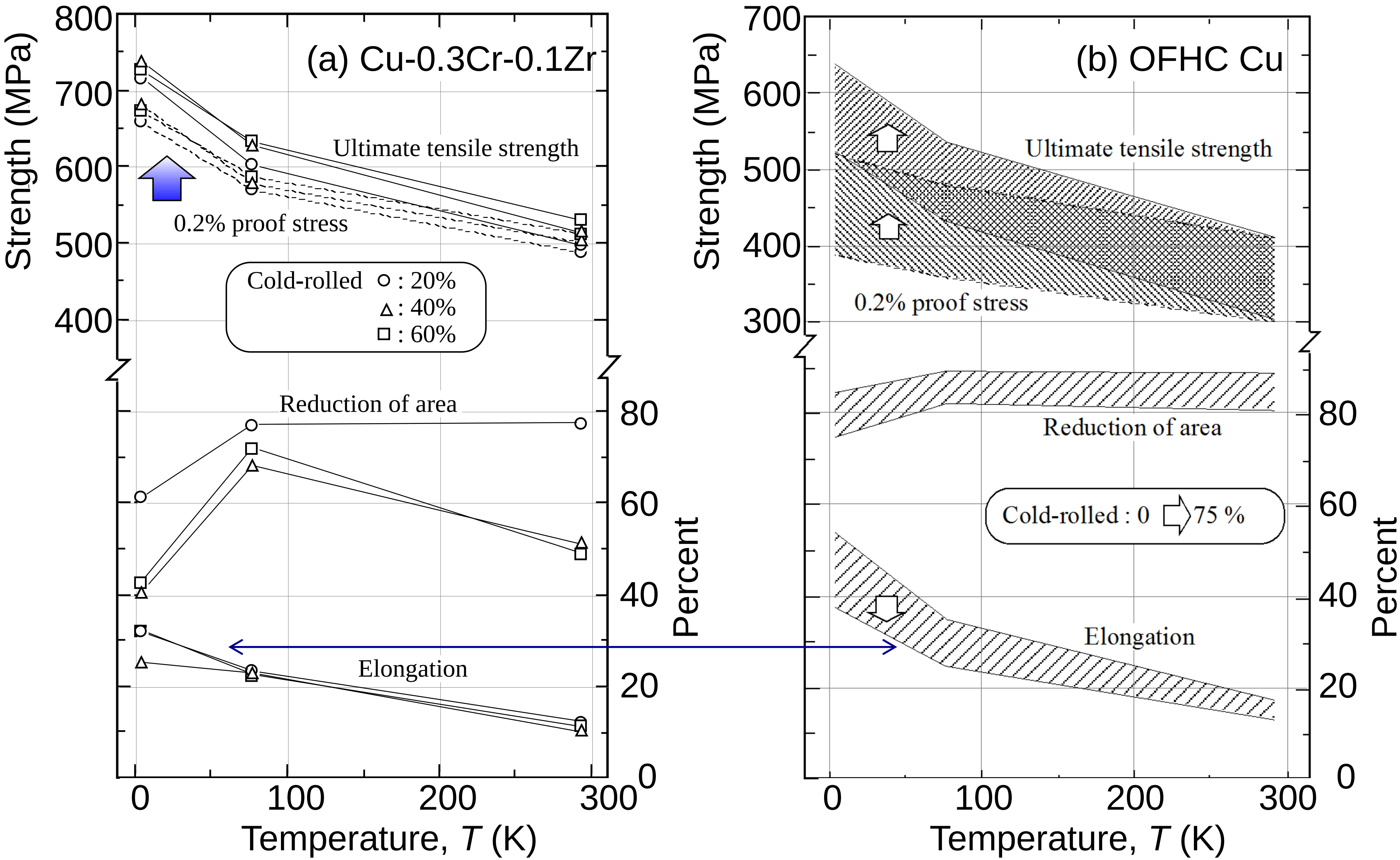


higher work hardening ratio,
→ higher homogeneous elongation

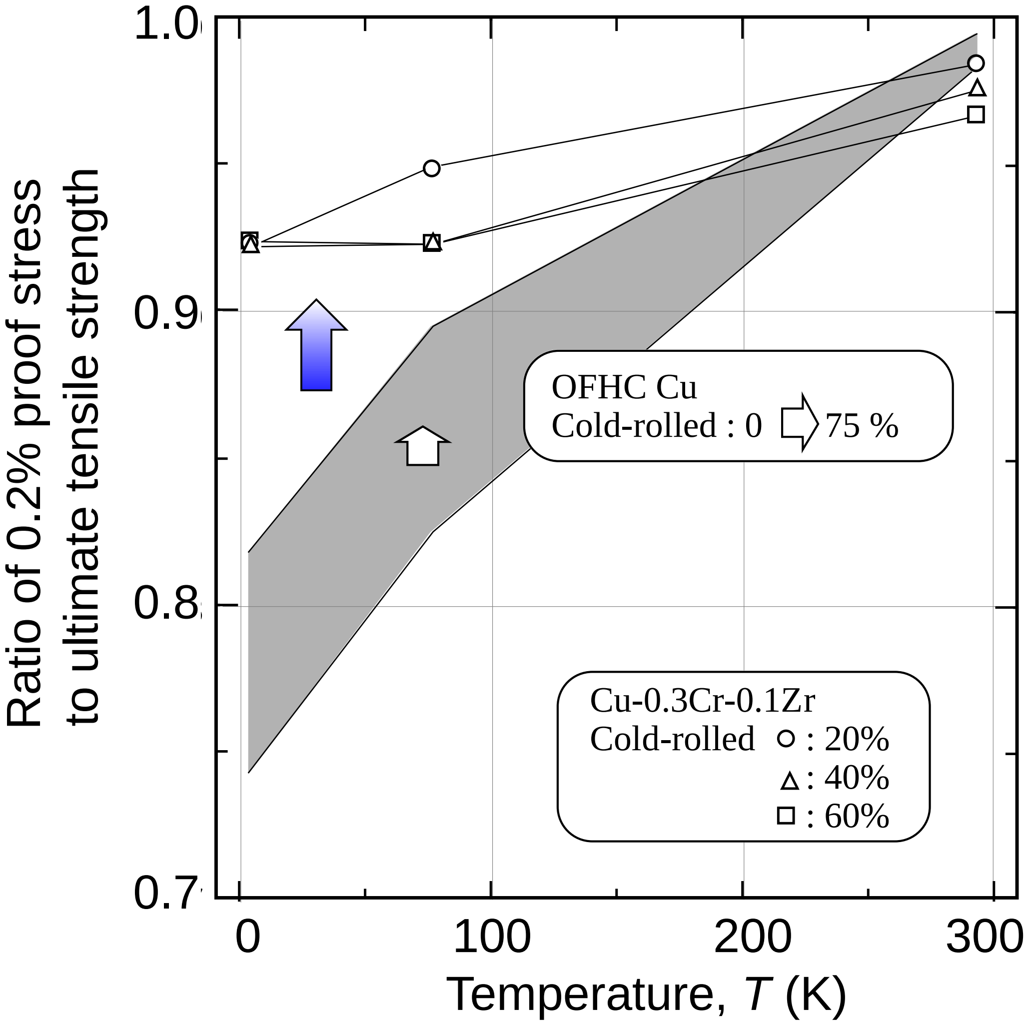
work hardened → higher yield stress

Cu-0.3Cr-0.1Zr
20% cold-rolled material

Tensile properties



Yield ratio



Ratio of 0.2% proof stress to ultimate tensile strength of Cu-0.3Cr-0.1Zr alloy and OFHC Cu as a function of temperature.

Electrical resistivity

$$r = r_D + r(T) = (r_{Chem} + r_{Phys}) + r(T)$$

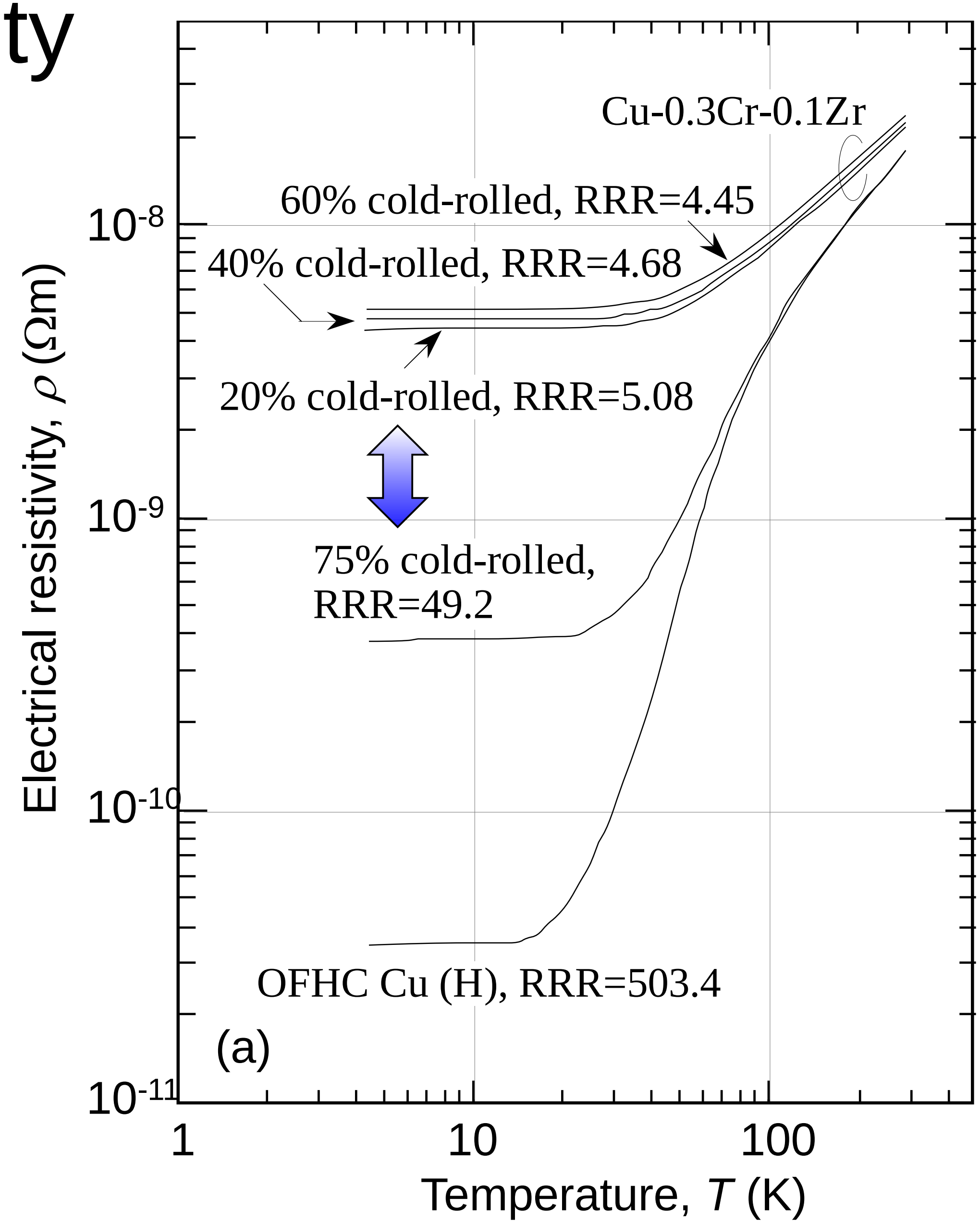
$$s = 1/r$$

↑ solutes

↑ lattice defects

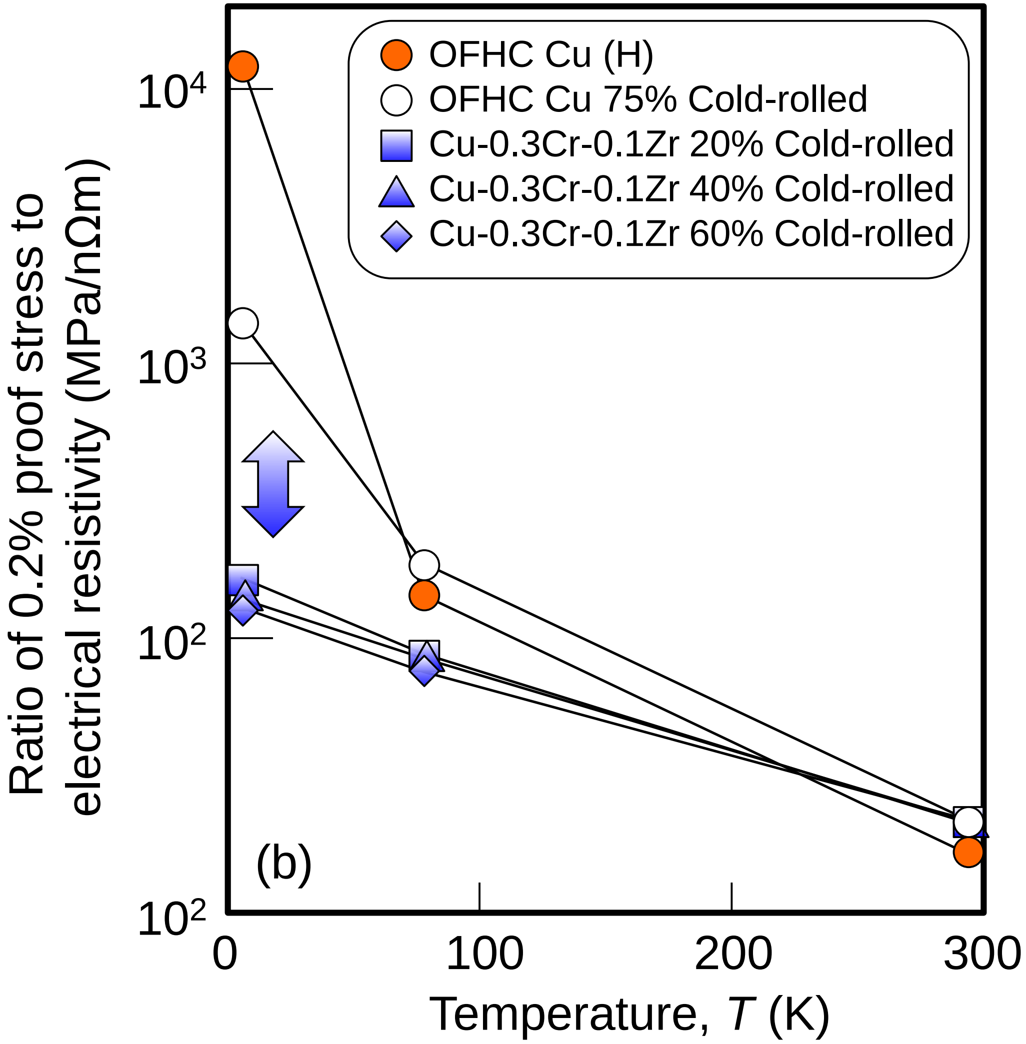
↑ phonon

DC four-point probe technique



Electrical resistivity of Cu-0.3Cr-0.1Zr alloy and OFHC Cu as a function of temperature.

Ratio of yield strength to resistivity

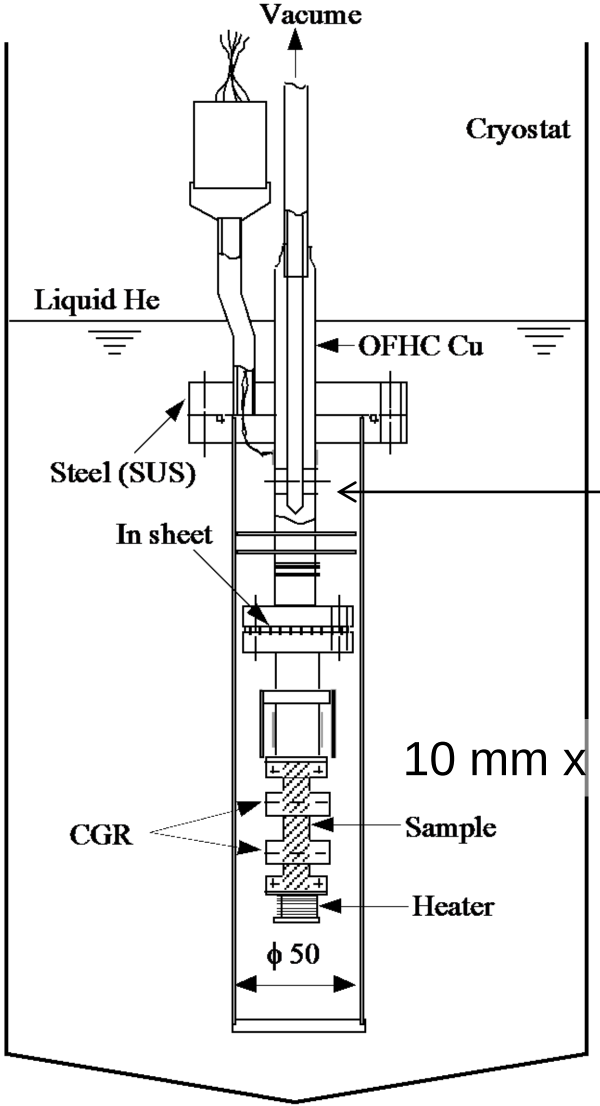


Measurement system for thermal conductivity at cryogenic temperature

Steady state heat flow method:
from 3.5 K to 60 K

The temperature gradients along the samples were measured.

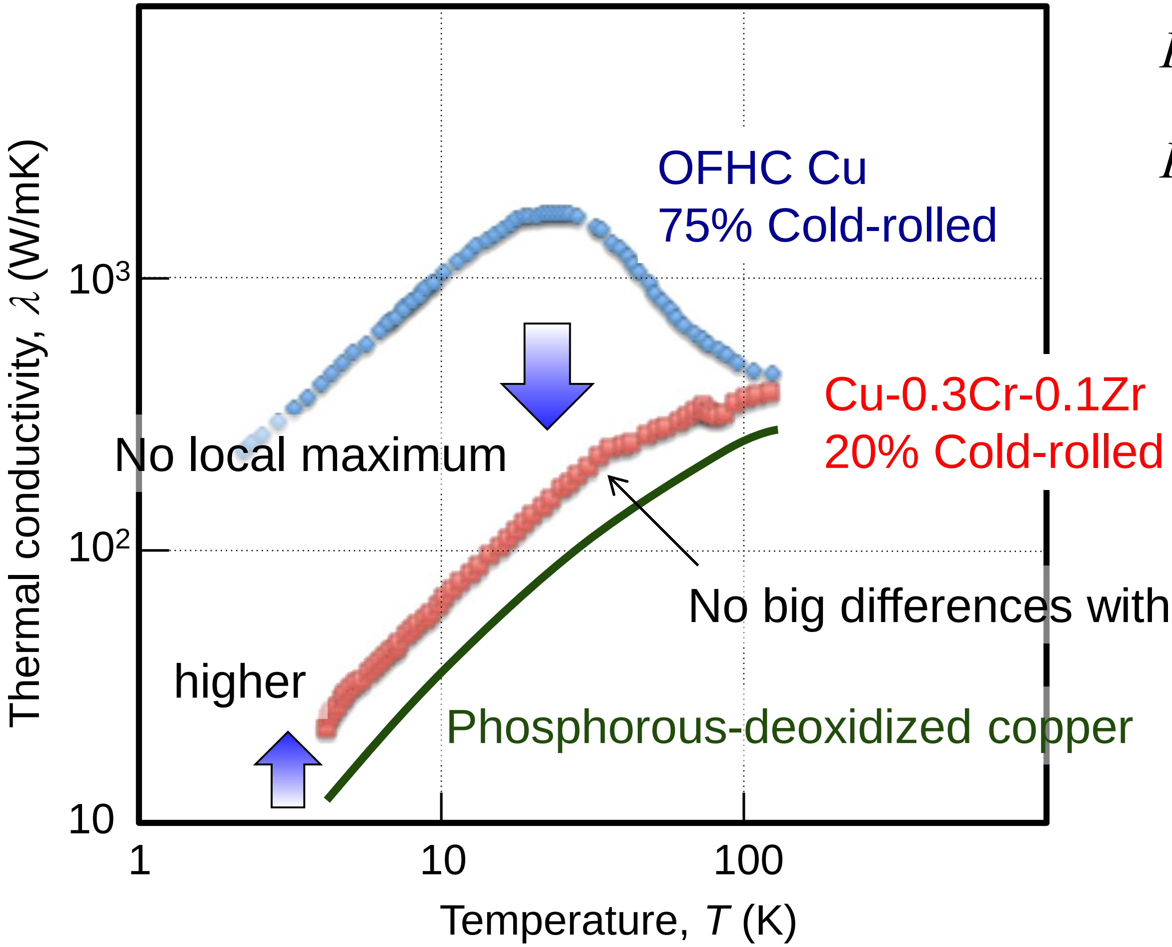
- The distance between the thermometers: 20 mm
- The sample temperature: the mean value of the two



evacuated to 10^{-5} Pa

10 mm x 4 mm x 50 mm strips

Thermal conductivity



No local maximum

higher

No big differences with cold-rolling condition

Widemann-Franz Law

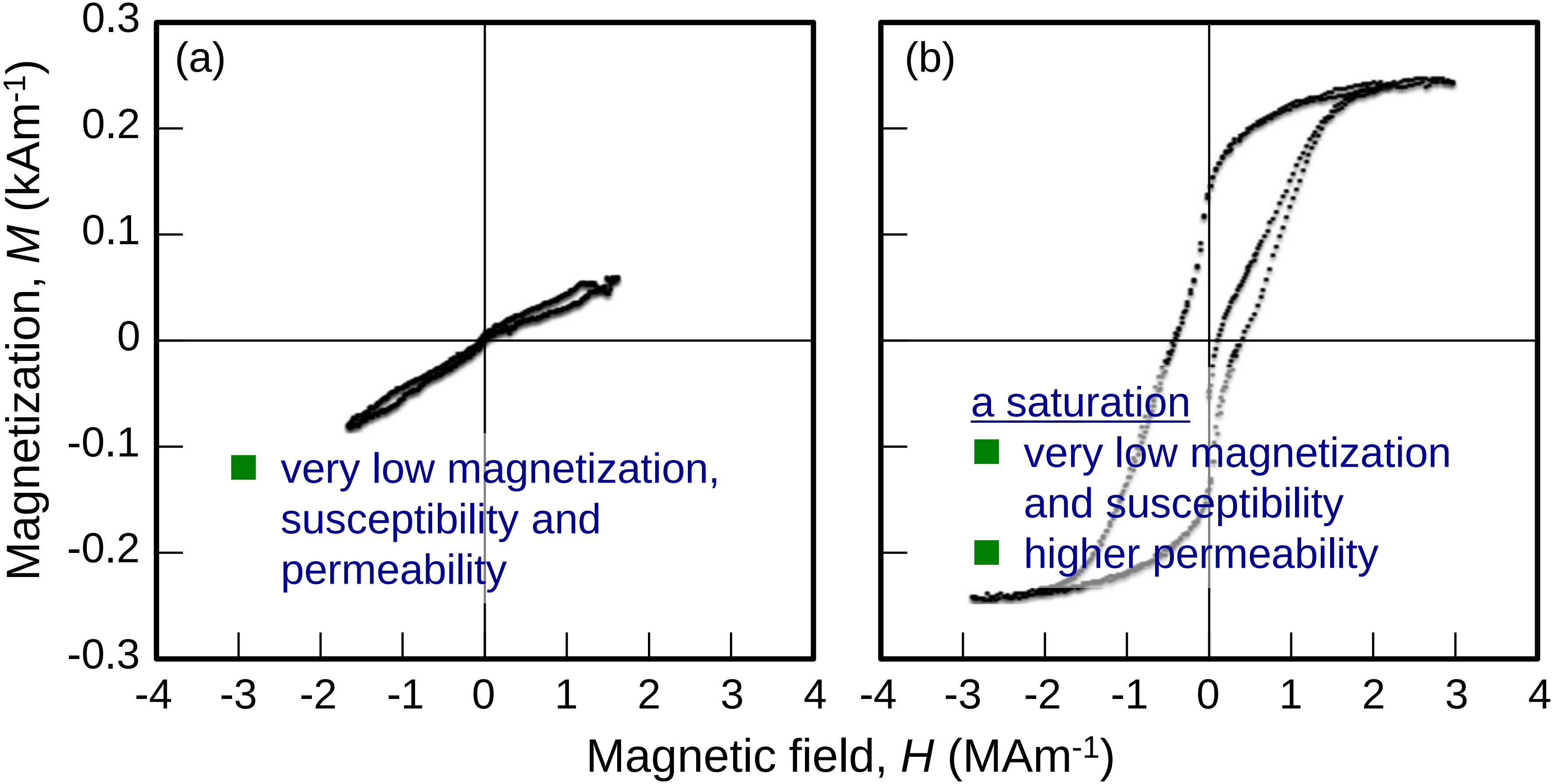
$$K / s = L \times T$$

$$K = \frac{L \times T}{r_D + r(T)}$$

L: Lorenz number
(2.44x10^{-8} WΩK^{-2})

Magnetization

3 mm-diameter cylinder
The shearing correction by demagnetizing factor, N=0.27



- very low magnetization, susceptibility and permeability

a saturation

- very low magnetization and susceptibility
- higher permeability

Magnetization curve of heavily cold-rolled sheet at 4.2 K for (a) Cu-0.3Cr-0.1Zr alloy and (b) Cu-0.15Fe-0.05P-0.1Sn-0.1Ag-0.1Zn alloy by a vibrating-sample magnetometer.

Conclusions

The tensile properties, electrical resistivity, thermal conductivity and magnetization were determined at cryogenic temperature for precipitation hardened and cold-rolled Cu-0.3Cr-0.1Zr alloy in comparison with OFHC Cu.

- The Cu-0.3Cr-0.1Zr alloy exhibited an excellent combination of high strength and high conductivities at the temperature range of 4 K to 300 K.
- The Cu-0.3Cr-0.1Zr showed higher yield ratio and lower the ratio of yield strength to electrical resistivity at cryogenic temperature than OFHC Cu.
- The Cu-0.3Cr-0.1Zr alloy exhibited high electrical and thermal conductivities, excellent non-magnetic stability and very low magnetic permeability at 4.2 K, although its slight solid solubility in copper resulted in the higher resistivity and lower thermal conductivity than OFHC Cu.