Material Selection for the Masses and Wires (1)

Chihiro Tokoku

October 26, 2011

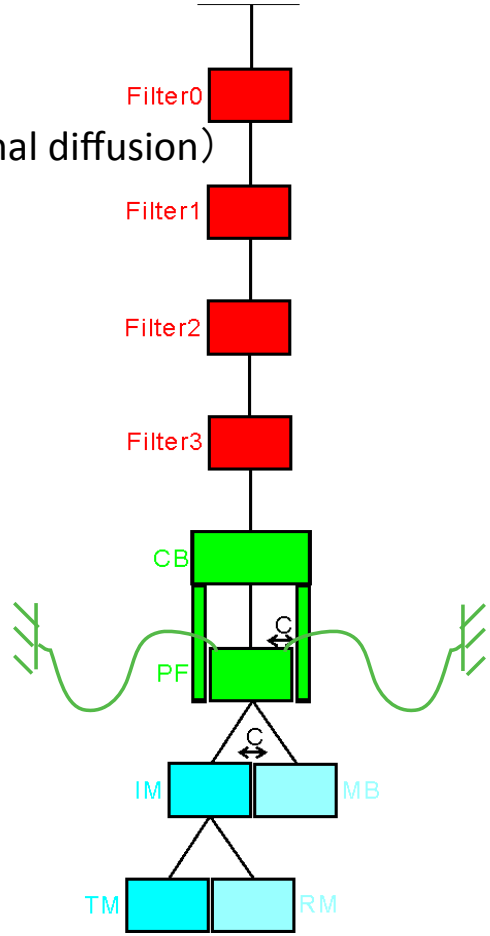
Material Selection for the Masses

Objective

- Material Selection for the Upper Mass, Recoil Mass for the mirror, and some other parts.
- Environment Condition:
  - 15-20K. UHV.
  - Weight and size must be almost the same with its counterweight (~30kg for a item).

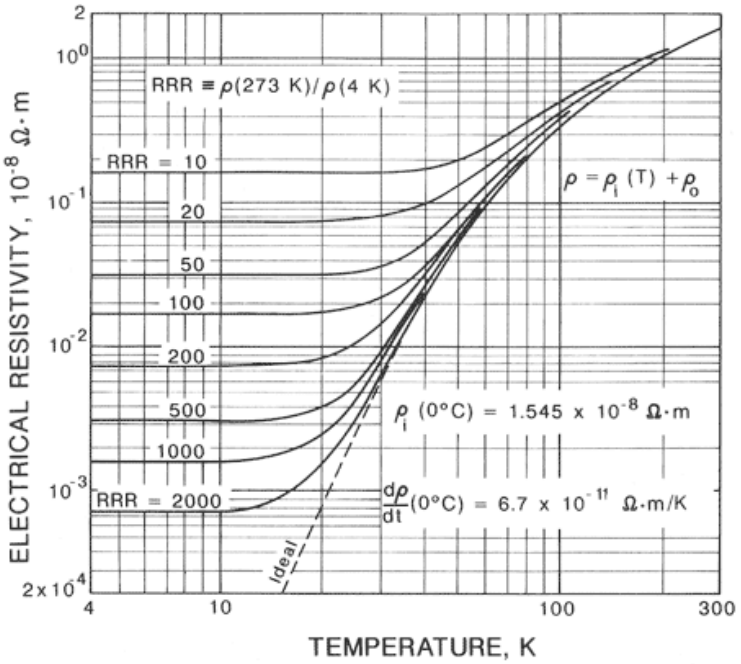
Required Specifications

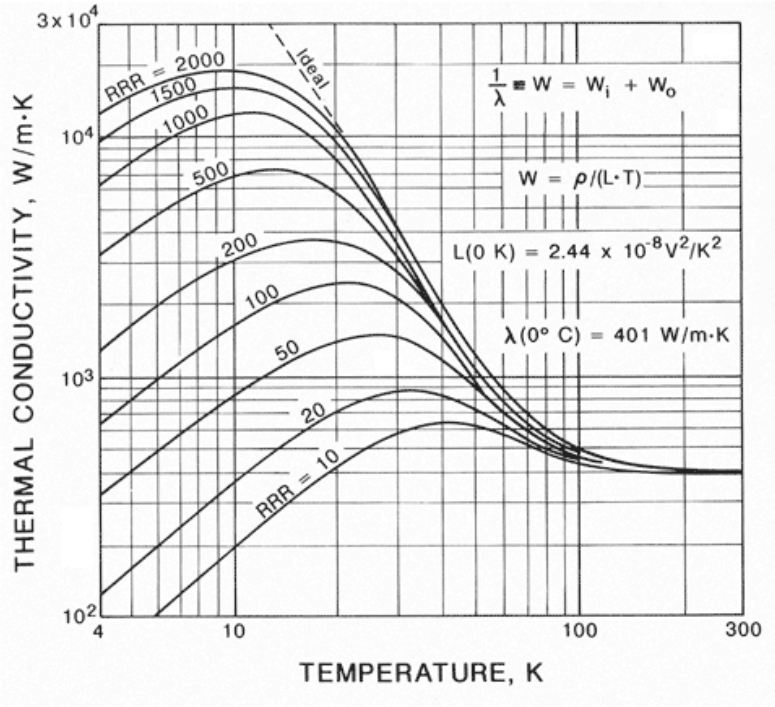
- Physical Properties
  1) Higher Thermal Conductivity (Reducing thermal road, promoting thermal diffusion）
  2) Larger Young's Modulus (Reducing Internal Oscillation) --?
  3) Smaller Specific Heat (Saving cooling power）
  4) Smaller Residual Resistivity Ratio (Avoid Eddie Current Dumping)
  5) Smaller Magnetism (Prevent being attracted by magnets)
  6) CTE (no specific requirement?)
- Others
  7) Machineability
  8) Availability (huge bulk, ~100kg, solid?)
  9) Price
- Other Instruments?
  CLIO :
  VIRGO :
  LIGO :

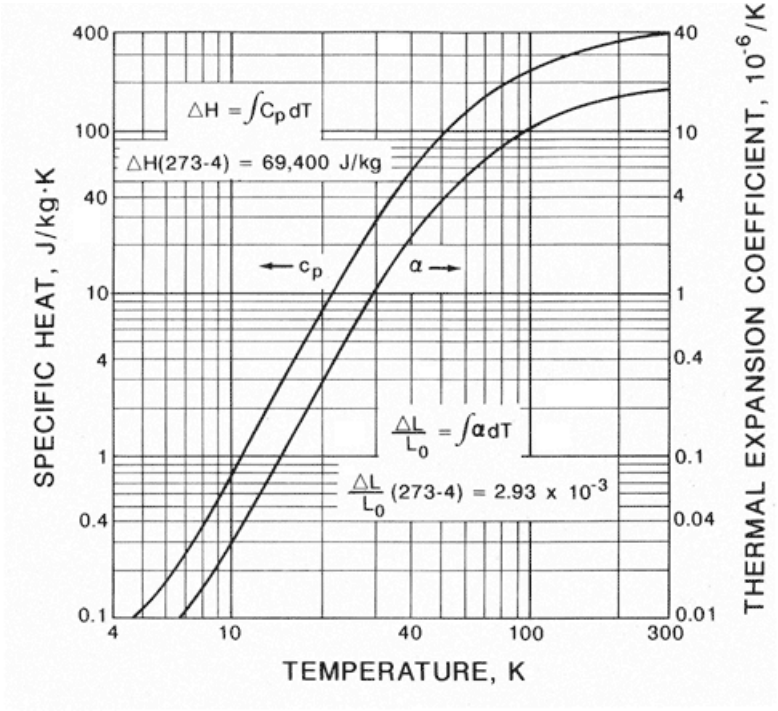


Properties at Cryogenic Environment

	Density [E+3 kg/m3]	Thermal Conductivity [W/m/K]	Young's Modulus [GPa]	Specific Heat [J/kg/K]	Resistivity [uΩm]	CTE [E-6/K]
Oxygen Free Copper	8.9	~3000@4.2K ~2000@30K ~460@100K ~395@300K	0.35@300K	96@50K 255@100K 389@300K	Figure	1.0@30K 10.7@100K 18.3@300K
Beryllium Copper	8.25	130@300K		233@300K		17.5@300K
Tellurium Copper	8.9	356@300K		385@300K		
Al6061-T6	2.71	71@60K 98@100K 159@300K	0.33@300K	~10@20K ~80@100K 960@300K	~0.02@20K ~0.04@300K	24@300K
Ti6Al4V	4.43	~2@20K ~10@300K	0.342@300K	~8@20K ~130@100K	<0.01@5K ~2@20K ~2@300K	8.8@300K


ELECTRICAL RESISTIVITY, 10^{-8} Ω·m
RRR ≡ ρ(273 K)/ρ(4 K)
RRR = 10
20
50
100
200
500
1000
RRR = 2000
ideal
ρ = ρi (T) + ρo
ρi (0°C) = 1.545 x 10^{-8} Ω·m
dρ/dt (0°C) = 6.7 x 10^{-11} Ω·m/K
TEMPERATURE, K


THERMAL CONDUCTIVITY, W/m·K
RRR = 2000
1500
1000
500
200
100
50
20
RRR = 10
ideal
1/λ ≡ W = Wi + Wo
W = ρ/(L·T)
L(0 K) = 2.44 x 10^{-8} V^2/K^2
λ(0° C) = 401 W/m·K
TEMPERATURE, K


SPECIFIC HEAT, J/kg·K
THERMAL EXPANSION COEFFICIENT, 10^{-6}/K
ΔH = ∫Cp dT
ΔH(273-4) = 69,400 J/kg
← cp
α →
ΔL/L0 = ∫α dT
ΔL/L0 (273-4) = 2.93 x 10^{-3}
TEMPERATURE, K

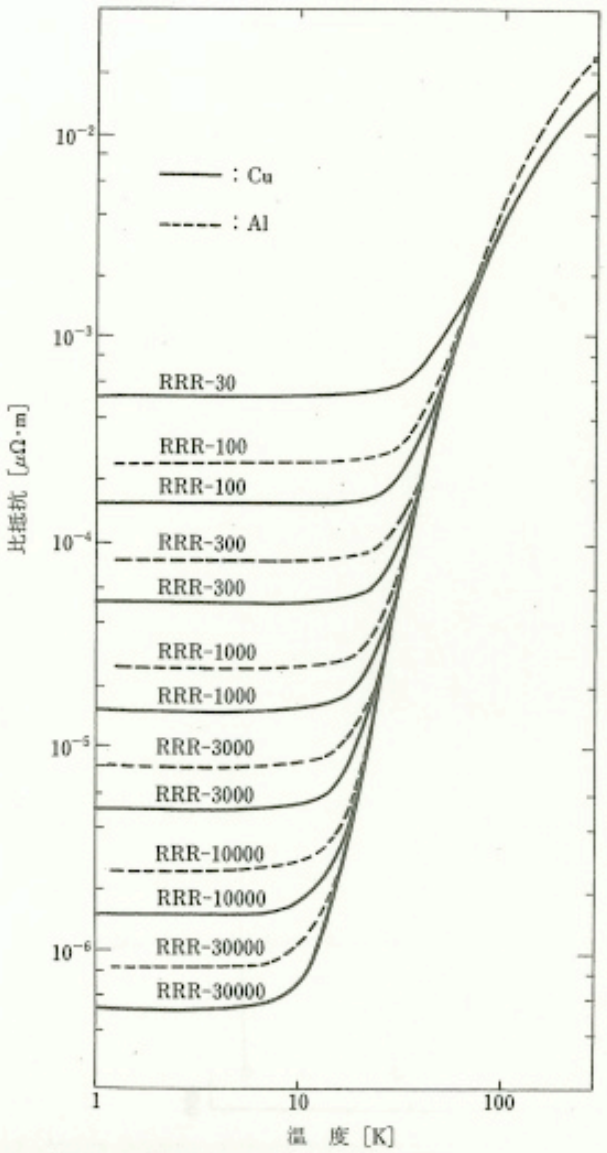


図 3・16 無酸素銅および純アルミニウムの比抵抗
[Handbook on Materials for Superconducting Machinery (1977)]
(RRR は残留抵抗比)

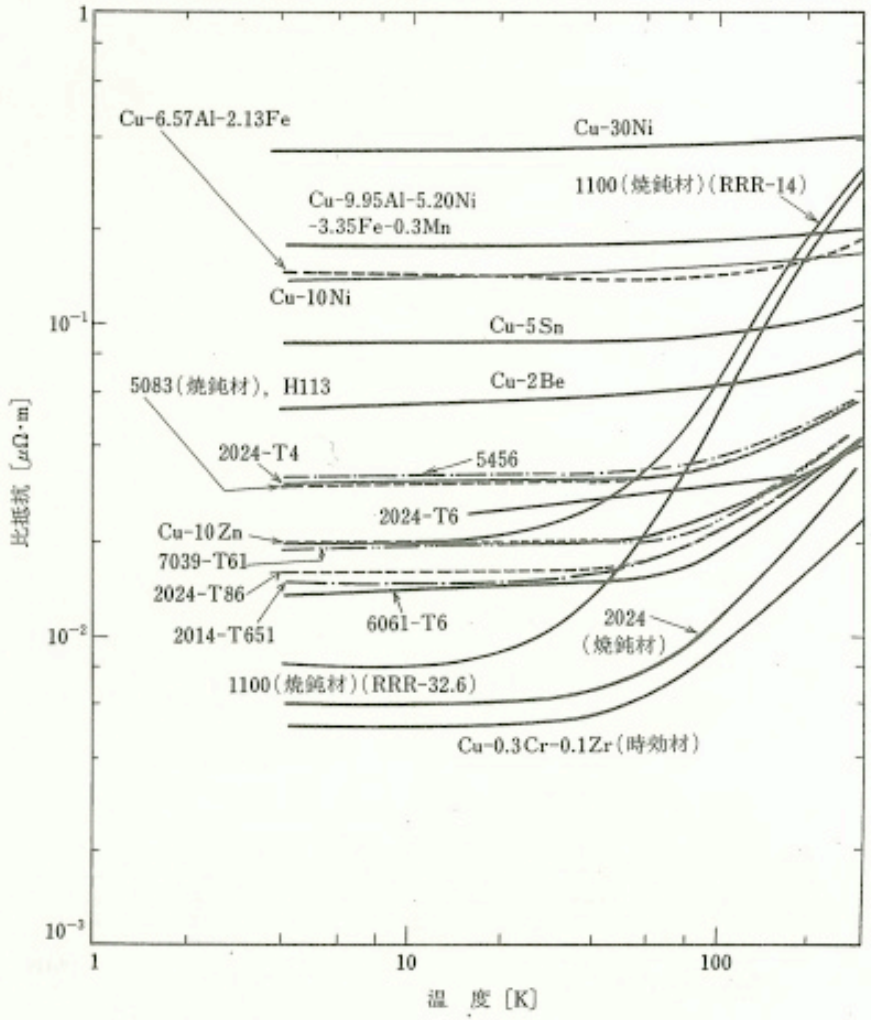


図 3・17 銅合金およびアルミニウム合金の比抵抗
Cu-0.3 Cr-0.1 Zr は[梅澤, ほか 1988], ほかは[Handbook on Materials for Superconducting Machinery (1977)]

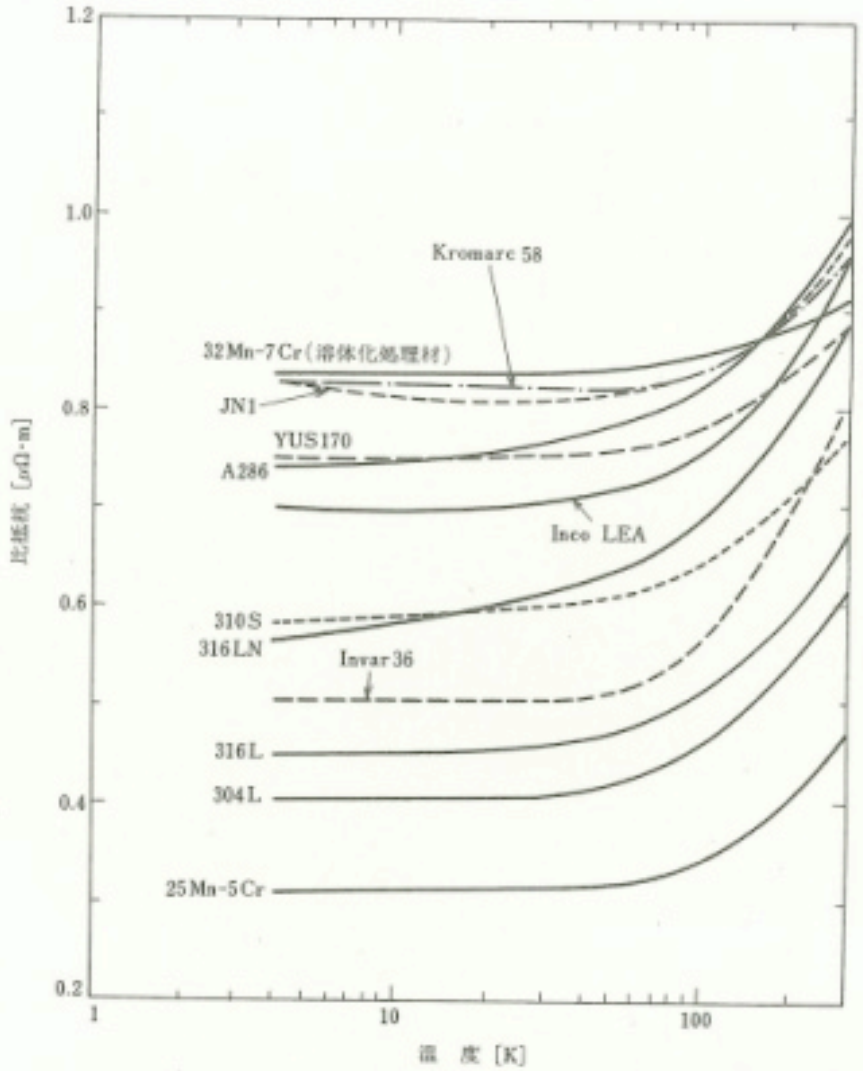


図 3・18 鉄基合金の比抵抗
[梅澤, ほか 1990 b]

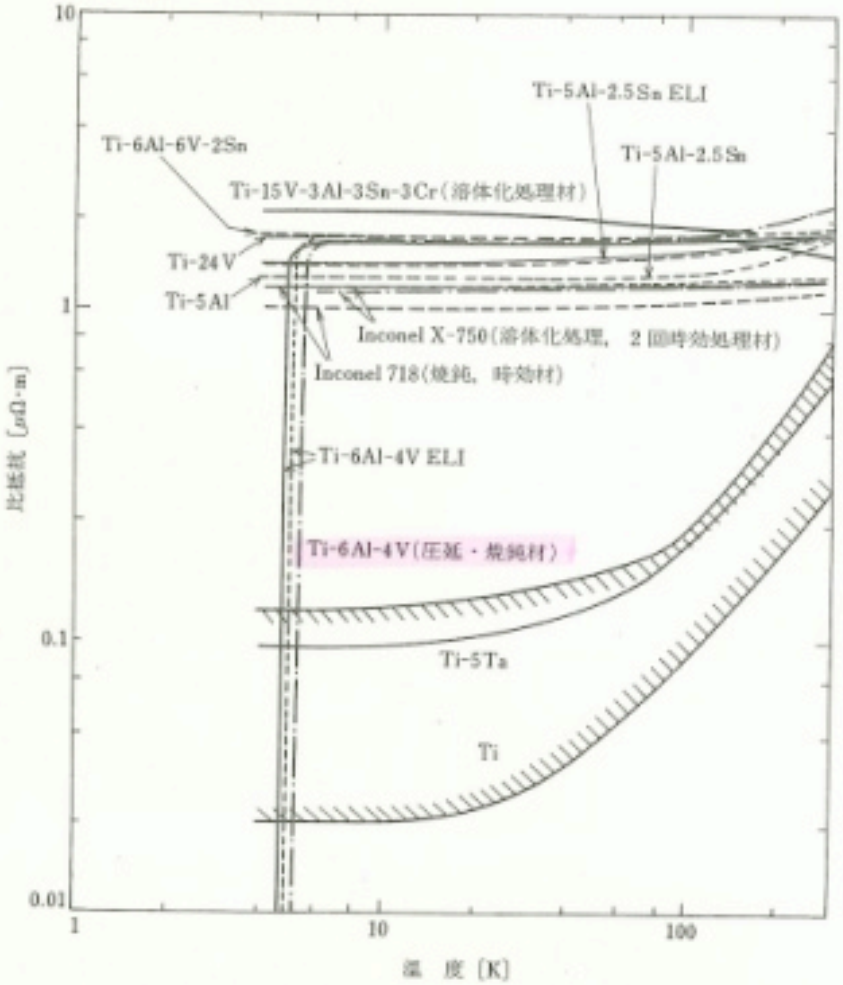


図 3・19 ニッケル基超合金およびチタン合金の比抵抗
Inconel×−750, 718 のデータは[Handbook on Materials for Superconducting Machinery (1977)], ほかのデータは[梅澤, ほか 1990 a]

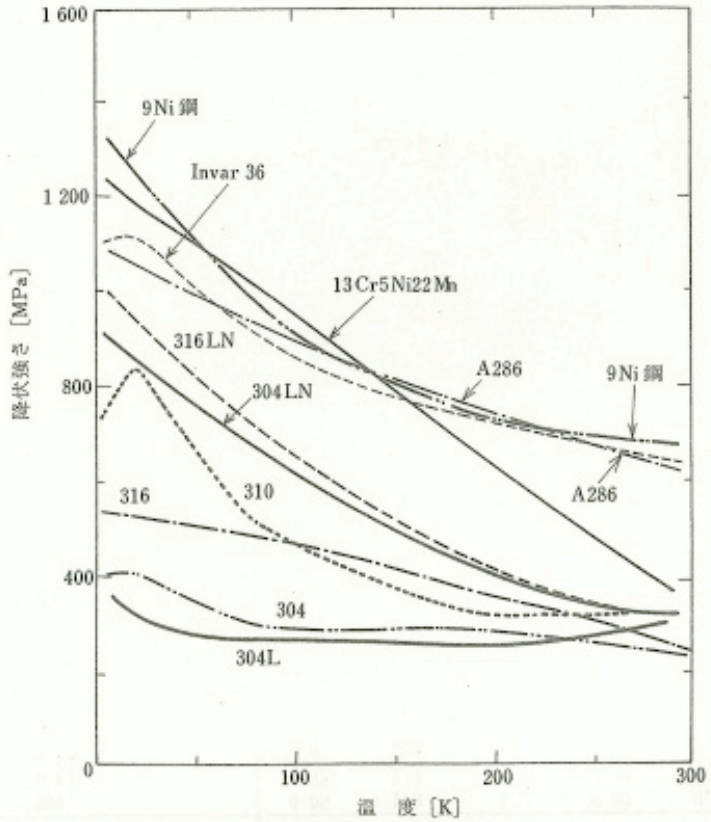


図 3・2 鉄基合金の降伏強さ
[Handbook on Materials for Superconducting Machinery (1977)]
[Tone, S., et al.: Advances in Cryogenics Engineering, vol. 30 (1984)]

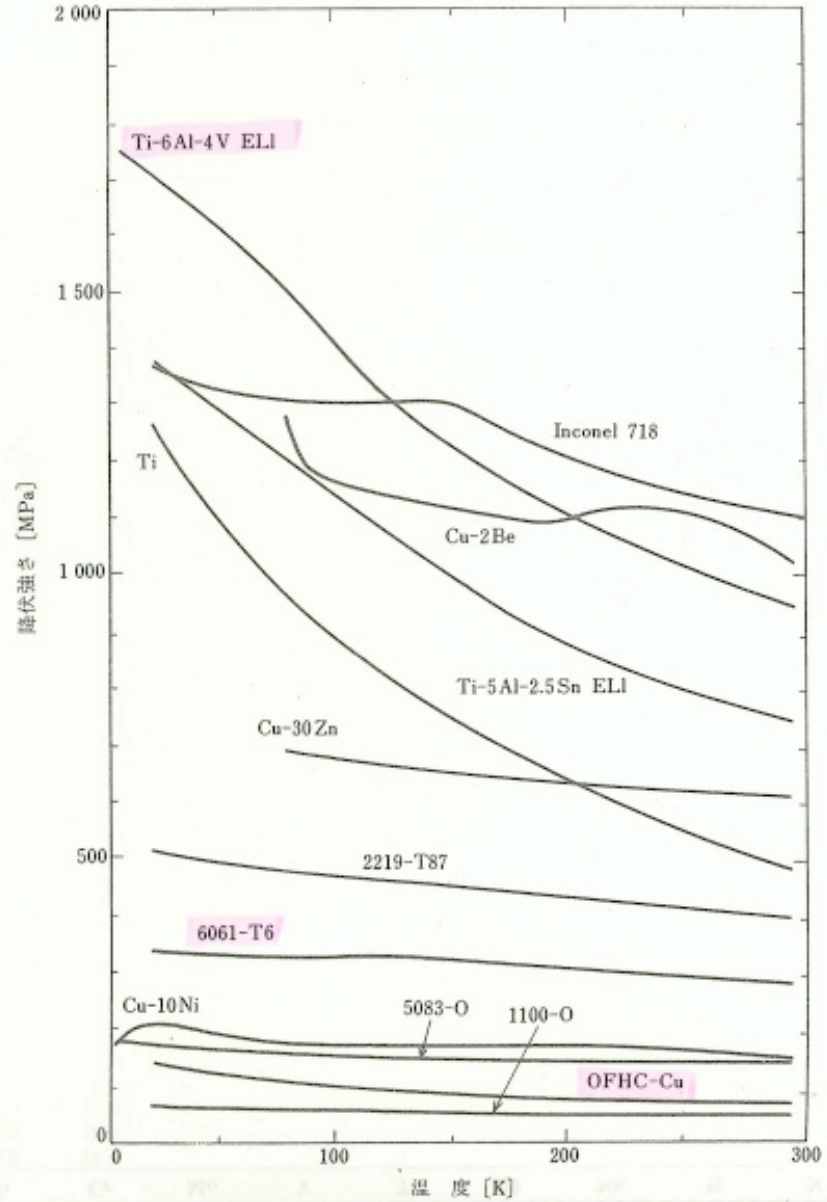


図 3・3 非鉄金属の降伏強さ
[Handbook on Materials for Superconducting Machinery (1977)]

Material Selection for the Wires

- Suspension wire for the mirror and masses. Expected little as a thermal path?
- Conditions

  Used with a couple of wires, suspend the mass or mirror from the upper mass.

  ex) In case of Sapphire, L400mm, ϕ1.8mm (with 4 wires).
- Required Specifications

  1) Light Weight (Reducing Violin-mode)

  2) Larger Young's Modulus

  3) Stronger Tensile Strength (Prevent cutting off)

  4) Higher Q Factor (Stable Oscillation)
- Other Instruments

  - CLIO: Sapphire (L400mm、ϕ1.8mm×4), Experienced "Bolfur" (ϕ0.1mm)

  - VIRGO: Thin Copper wires, ribbons made of CuBe3, Steel wires (ϕ0.6mm)

- Candidates and their Issues

  * Tungsten: kink

  * Stainless Steel: Magnetism

Properties of Wires at Cryogenic Environment

*Room Temp	Density [E+3 kg/m3]	Thermal Conductivity [W/m/K]	Tensile Strength [MPa]	Young's Modulus [GPa]	Resitivity [uΩ/m]	
Tungsten						
SUS?						
Ti6Al4V						
Bolfur (0.1mmD)	7.6		~3500	156.8	140	

Future Works

- Search vendors.
- Experimentally confirmation (RRRs, thermal conductivities, and some other parameter).
- Feedback to designing and simulations of the payload.

おまけ

“Astro-Black”

http://www.tobika.co.jp/products/index.html