Prototype of high-temperature vacuum prober from 300 K to 1200 K for continuous 3-omega thermal measurements

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JST-CREST

SF15.14.07: A Prototype of High-Temperature Vacuum Prober from 300 K to 1200 K for Continuous 3-Omega Thermal Measurements

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3:45 PM - 4:00 PM CEST (Mon, May 23)

High Temperature (HT)

High Temperature - Applications

- Materials Science
- Sensors in harsh environment (military, nuclear plants, aircraft, automotive, space …)
- Energy harvesting …
- Power devices (aging, failure, …)

Thermal conductance/conductivity

- ❖ Bulk materials/stacks
- ❖ Thin films/coatings

- Cross-plane
- in-plane
- Nanostructures (PnC, …)
- Suspended nanofilms
- Surface Phonons Polaritons (SPhP)
- Radiations (near-field, far-field)…

	Hot wire	Laser Flash	TDTR/FDTR	3-omega
Max Temperature reported	1300 K	~1273 K	1000 K APL 111, 151902 (2017)	**750 K ~ 780 K** ← **Weak point**
Interest	bulk	bulk	Bulk, micro-nano structures, thin films	Bulk, micro-nano structures, thin films, **radiations, anisotropy**

Jannot, Int. J. Th.Sci, 160, 106672 (2021)

Nishi, HT Mat. & Proc. 39 (2020)

Rost, APL 111, 151902 (2017)

Cahill, RSI 61, 802 (1990)
Su, Int J Thermophys 35 (2014)

1-General requirements for 3-omega thermal measurements

- Sweep **frequencies** ($V_{3\omega}$ □ when $\omega\uparrow$)
- Sweep input **current** ($V_{3\omega} \alpha\ i^3$)
- Sweep holder **temperature**

Lock-in amplifiers (LIA)
(time constant, sensitivity)

Total number of experiments is quite large : n(F) x m(i) x p(T)

Averaging LIA signals on 10 periods (at least)

Challenging !

Need of CONTINUOUS electrical measurements

2-Market overview for a HT vacuum prober

- NEXTRON (~1050 K) small chamber
- INSTEC (~1000 K)
- LINKAM (~1000 K) small chamber
- ApolloWave (~900 K)
- NAGASE (~800 K)
- ARS Rock Gate (~800 K)
- VIC Int. (~800 K)
- RDEC-MMR (~730 K)
- MICROXACT (~700 K)
- OYAMA (~700 K)
- JANIS /Lakeshore (~675 K)
- WIT Korea (600 K) small chamber

- [NASA (800 K) *IEEE Trans Instrum&Meas, 54,1, (2005)*]

Main issue of most Vacuum Probers:
intermittent contact at HT
(to prevent damages on solder parts ...)

↓

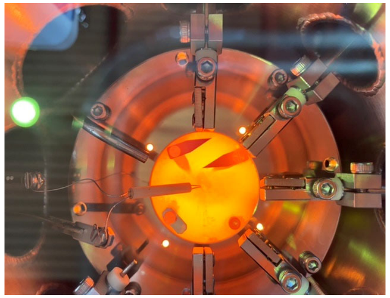
Need to engineer a prototype of HT prober to reach 1200 K

3-Prototype of HT prober (Hisol Japan): main features

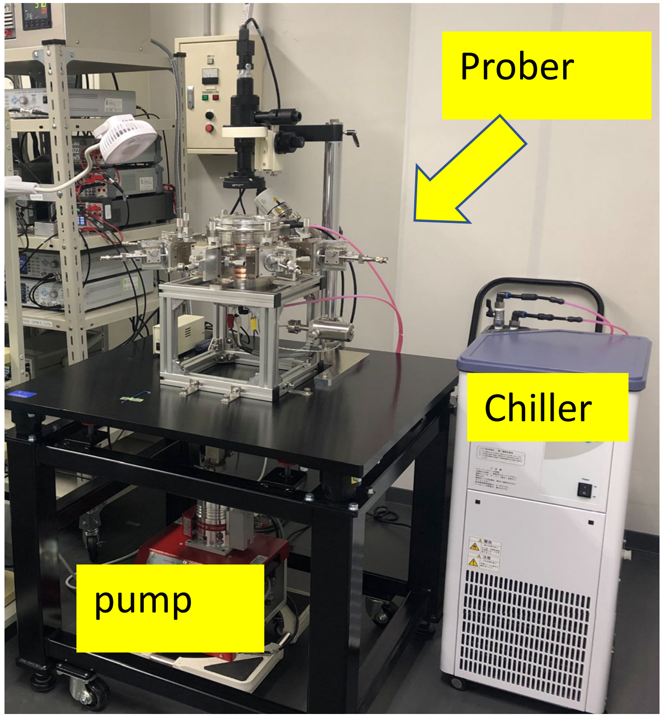
- RT to 1200 K
- 6 probes (DC to 1 MHz)
- Continuous measurements
- 2 inches sample

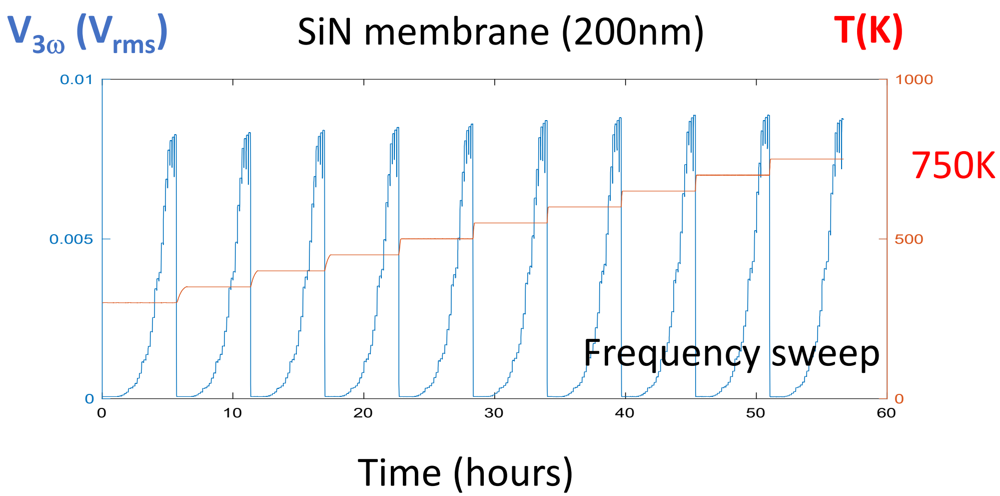
- SiC heater (RT to 1400 K)
- Efficient cooling : tips, quartz window, sidewalls
- Thermocouples on SiC heater & top plate
- Tip motion ~ 200 um at 1200 K → large pads

SiC

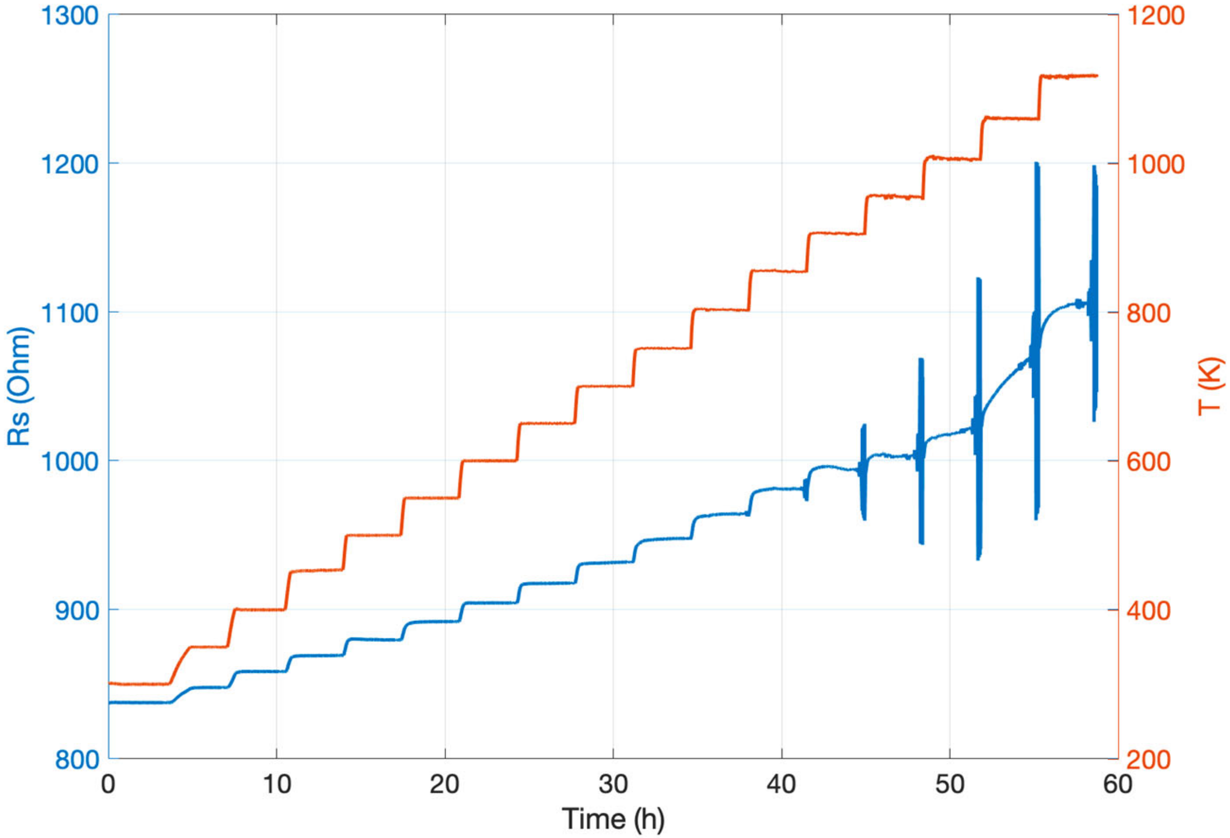


Inconel top plate





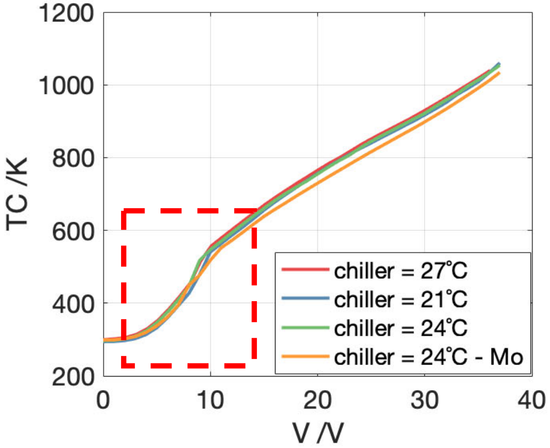
Cr/Pt Micro-resistance from 300K to 1100K

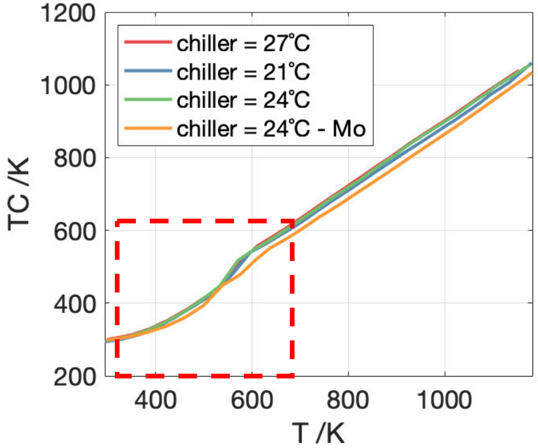


During each temperature step, we perform a frequency sweep that will change the Rs value due to heat transfer. The peaks are not related to the prober but to the running experiment.

3-Temperature calibration

Top plate Temperature (K)

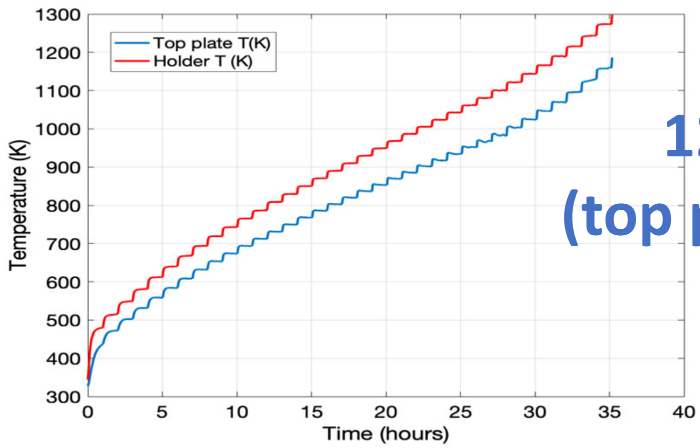




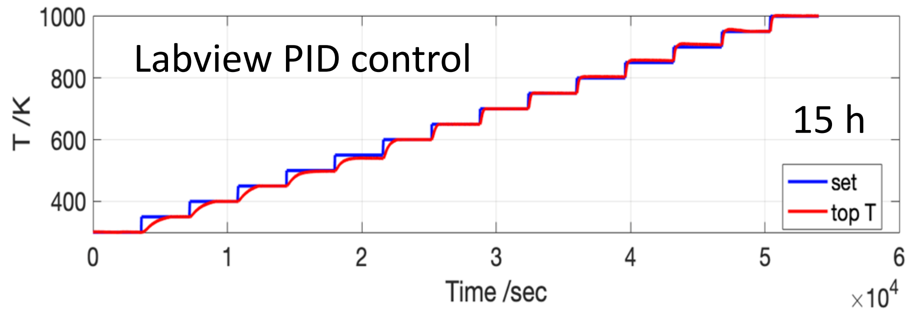
High power DC source

SiC temperature (K)

1300 K - holder



1200 K (top plate)



Heat losses due to the cooling power (chiller), and the number of tips connected to the sample, …

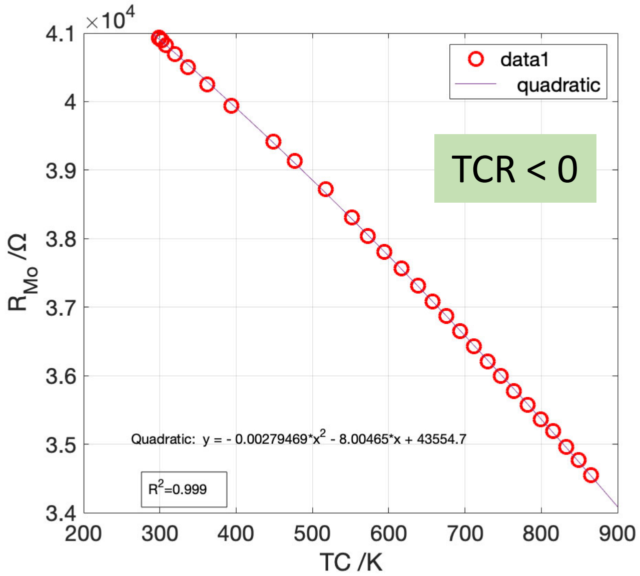
☓ **Standard temperature controller (RKC900, ET3504)**

☑ **Home-made Labview PID controller**

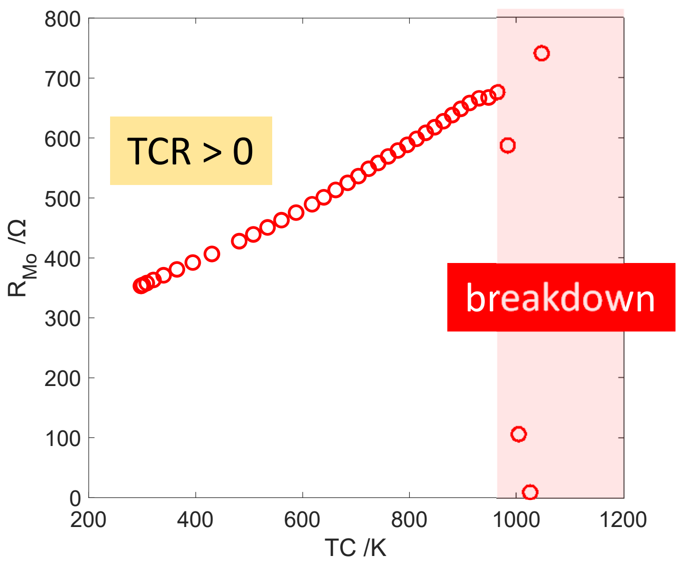
4- Molybdenum micro-resistance

100nm thick, 4um in width, 1mm in length

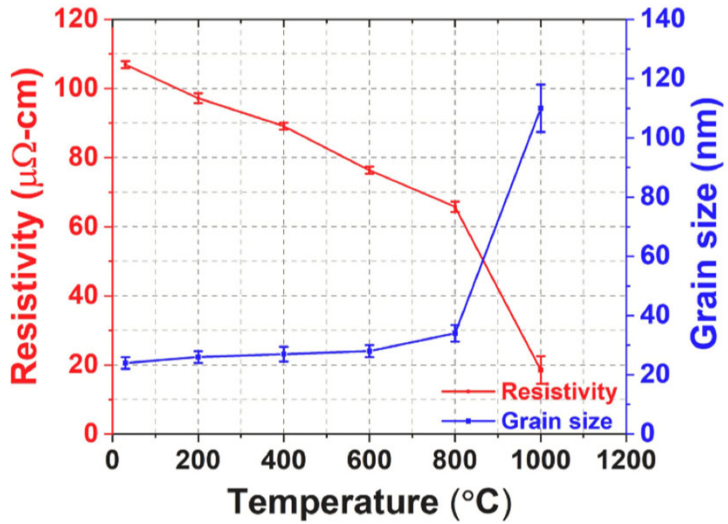
Before annealing



After annealing (1000 K)



Langoju, Superlattices and Microstructures (2021)

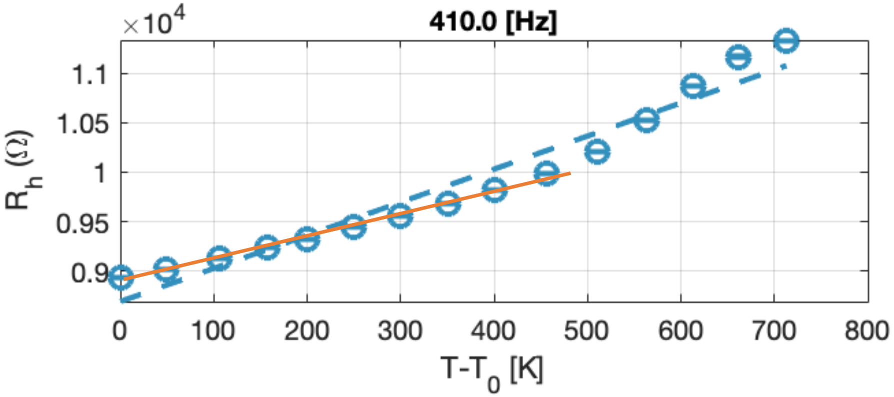


Difficulty

Choice of thin film micro-resistance suitable for HT experiments

(Mo, Cr/Au, Ti, Cr/Pt, W,…)

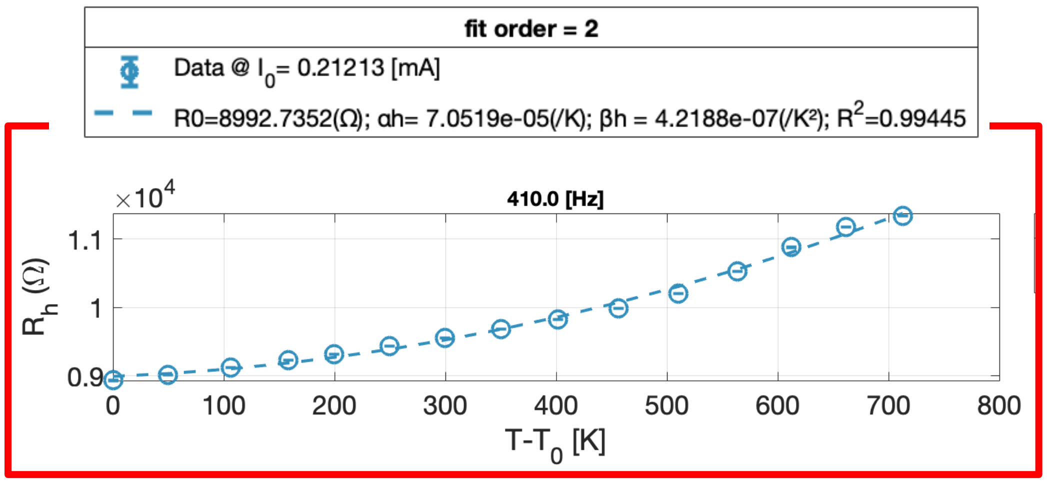
4- Mo micro resistance (300K ~ 1000K)



Difficulty

R(T) is non linear in a wide range of temperature

$$R(T) = R_0[1 + \alpha(T - T_0) + \beta\,(T - T_0)^2 + \cdots]$$



Revise the 3ω equations with non linear TCR to extract ΔT_h and ΔT_s