Recent results of N-doping /N-infusion at KEK/J-PARC

TTC High-Q Working Group Meeting

2017/Sep/8

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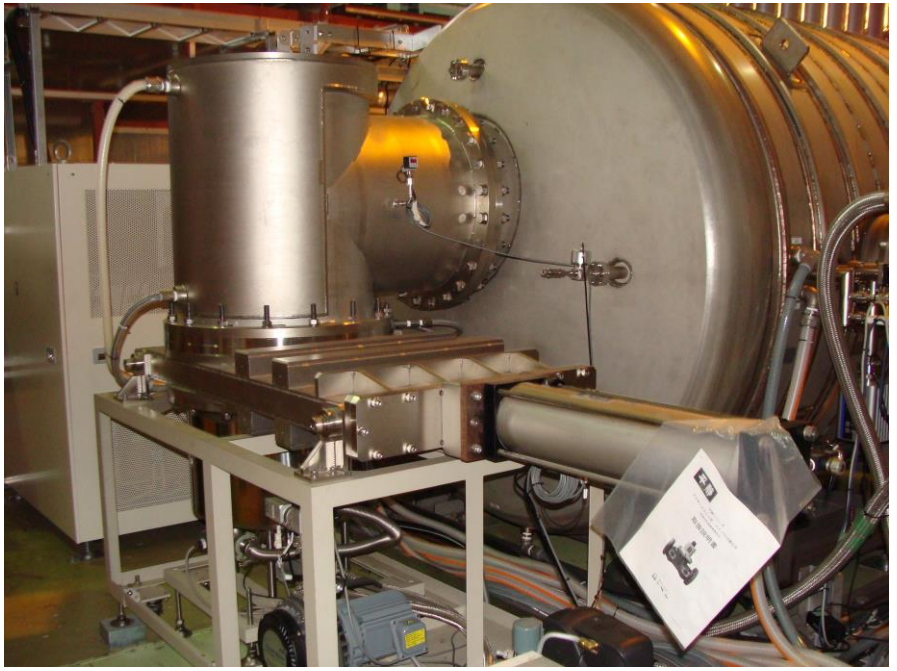
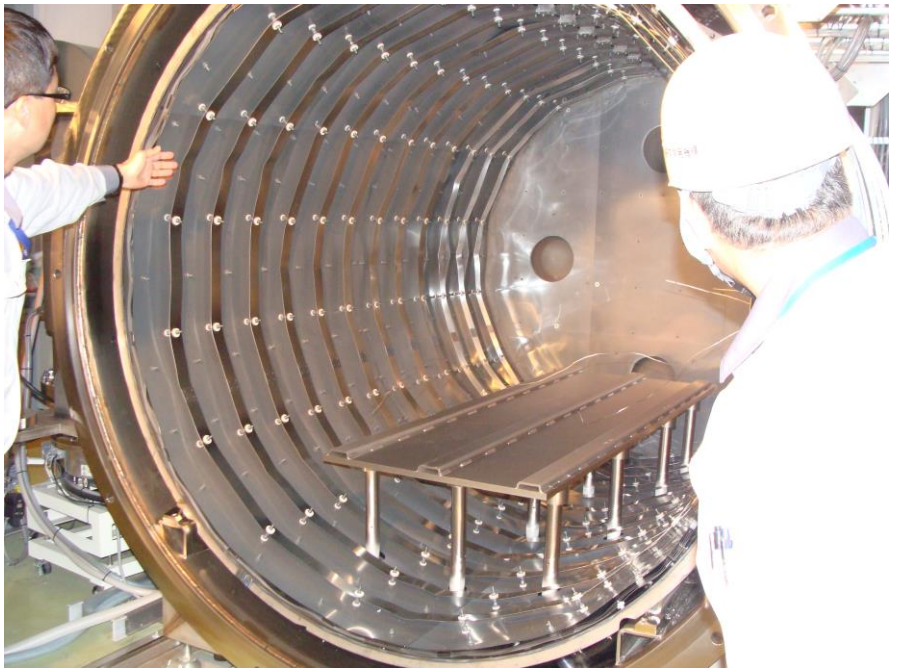
on behalf of KEK SCRF group, JAEA vacuum group, MHI-MS

Outline

- Introduction
- J-PARC furnace
- N-doping results at J-PARC
- N-infusion results at J-PARC
- Summary

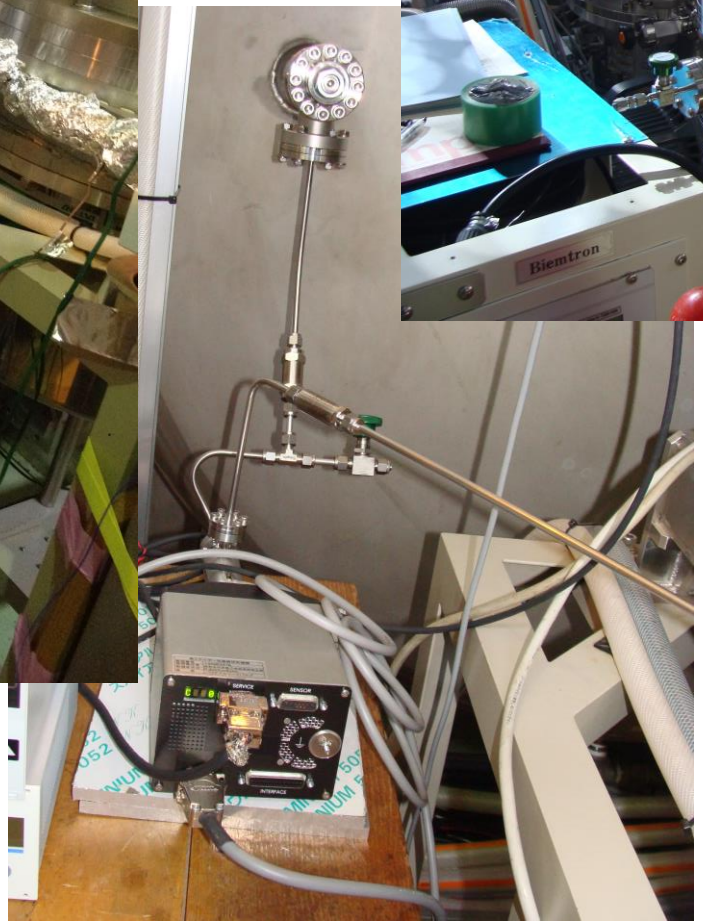
N-dope/N-infusion trial using J-PARC furnace





- J-PARC has oil-free furnace with cryo-pump(10,000 litter/sec) and three TMPs(3,000 litter/sec x 3).
- Vacuum level reached to ~1e-6 Pa.
- Normally used for degassing of beam-duct and components.

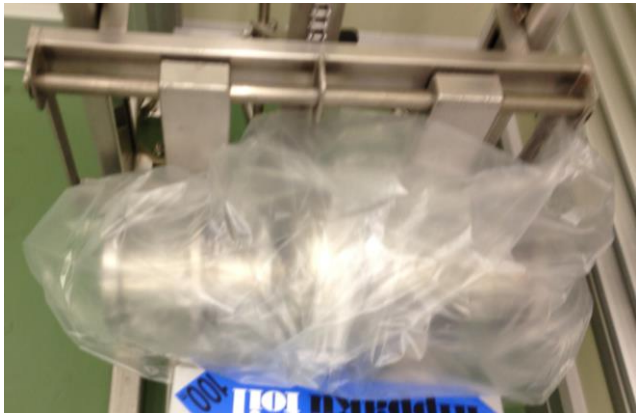
N-injection system

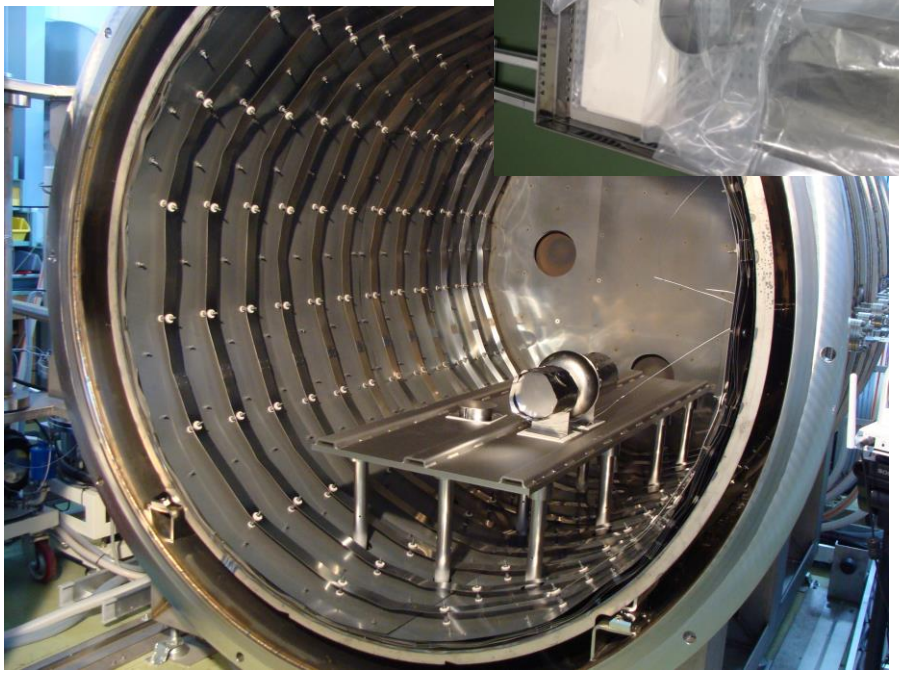


- Nitrogen pressure is controlled by variable leak valve
- Cryo-pump is closed and TMPs are off during N-injection. Small pump set, TMP and scroll, pump the furnace.

Cavity preparation for heat treatment

- HPR (flange open) 2 hours, drying one night
- Cavity was double-packed inside class-1000
- Nb cap & foil was ultrasonic cleaned with degreasing, drying inside class-10, packed inside class-1000
- Transport to J-PARC
- Setup into J-PARC furnace

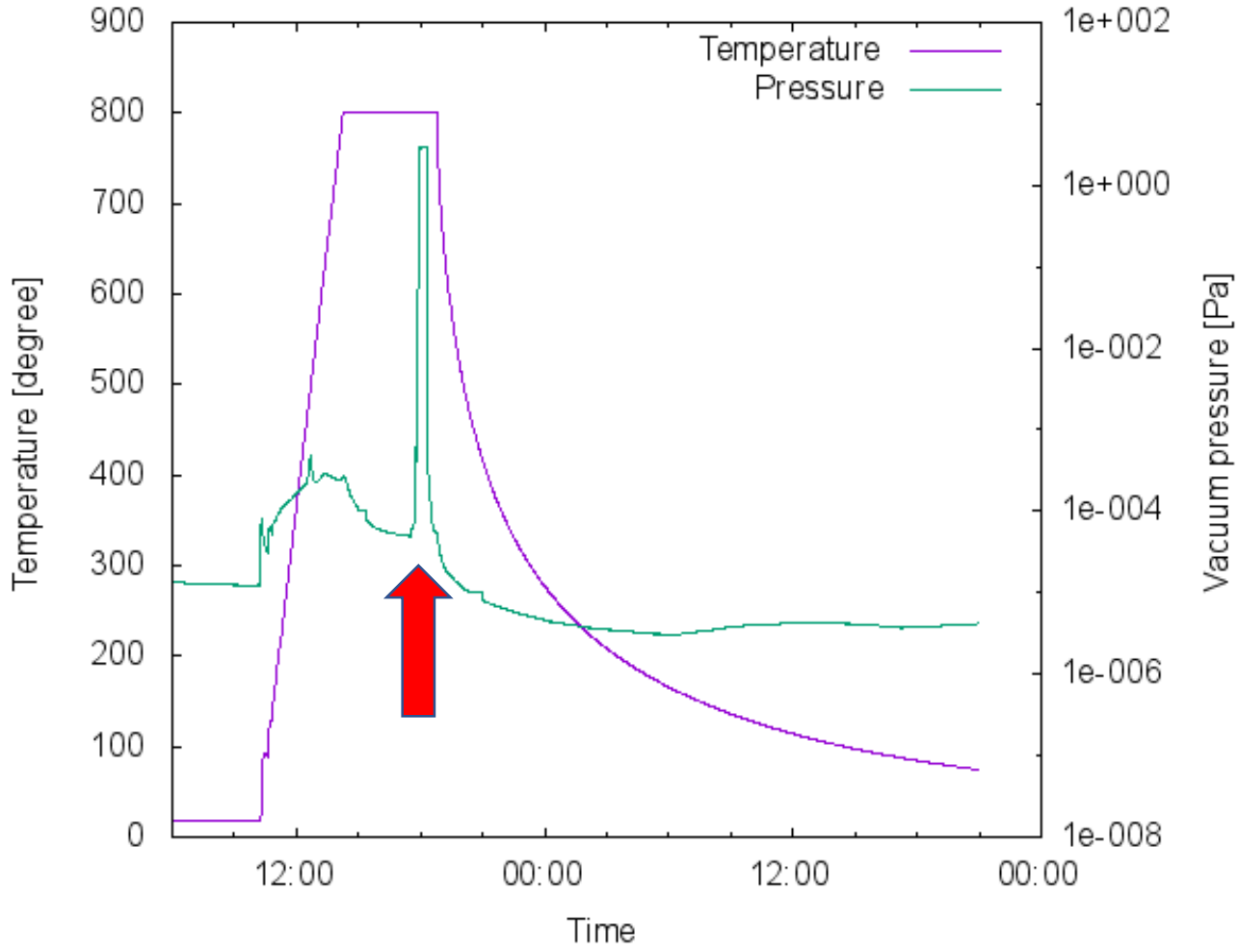




N-dope

N-dope (J-lab parameter)

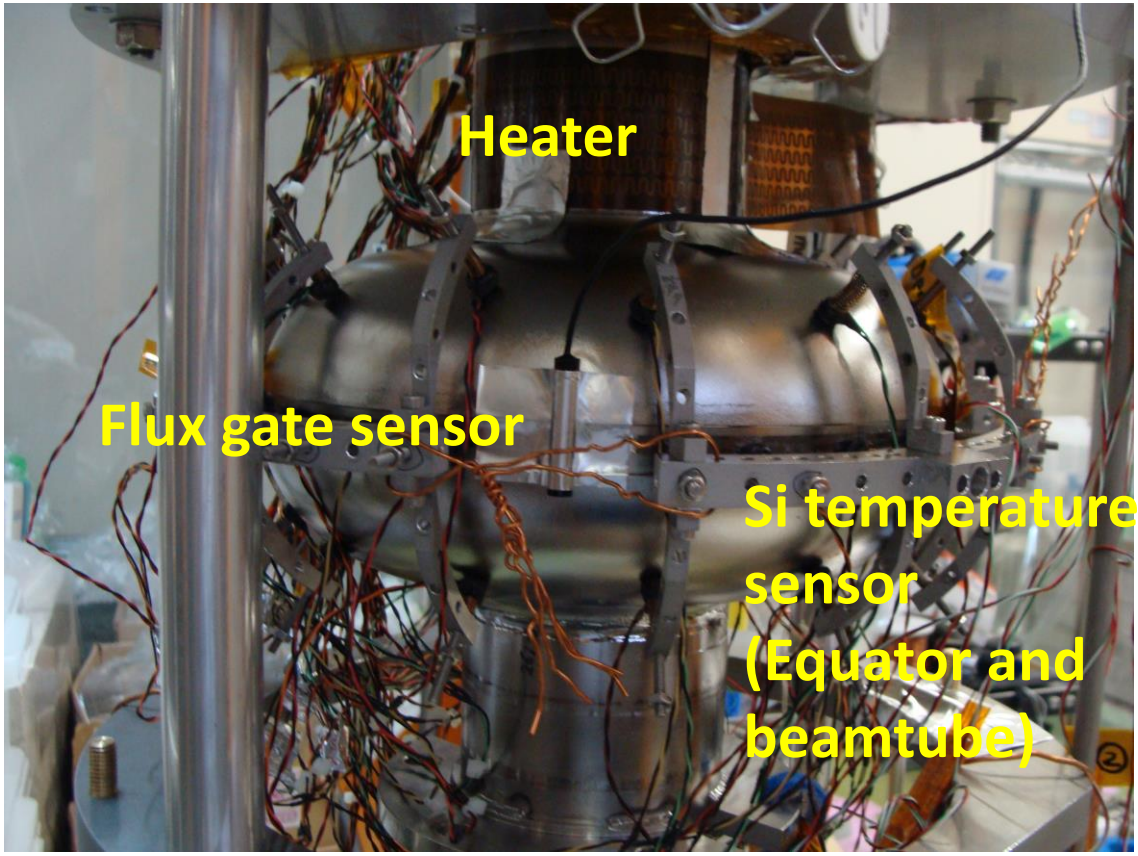
800 deg, 3 hours
800 deg, 20 min, N 2.7Pa
800 deg, 30 min
Cooldown



KEK tried J-lab N-doping parameter.

Typical vertical test setup

※ Pictures are for different measurement.
※ But setup of sensors and coil are same.

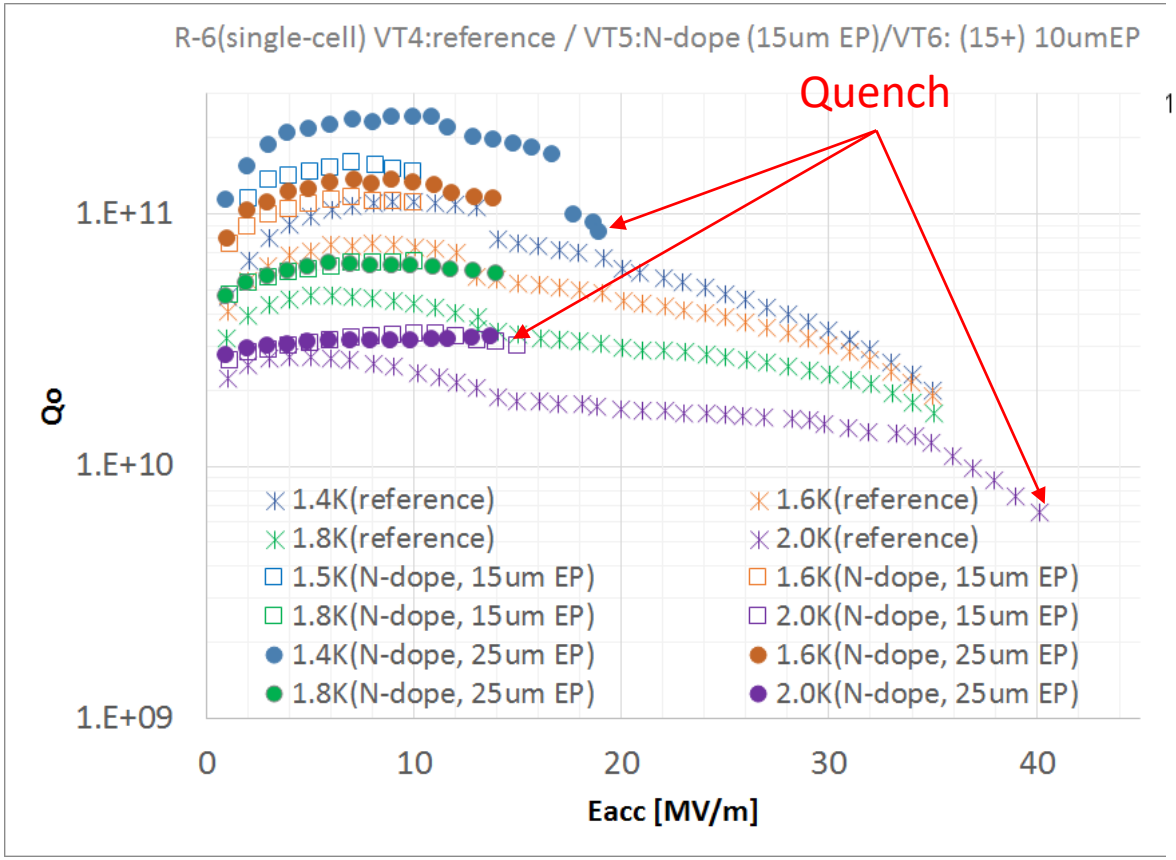


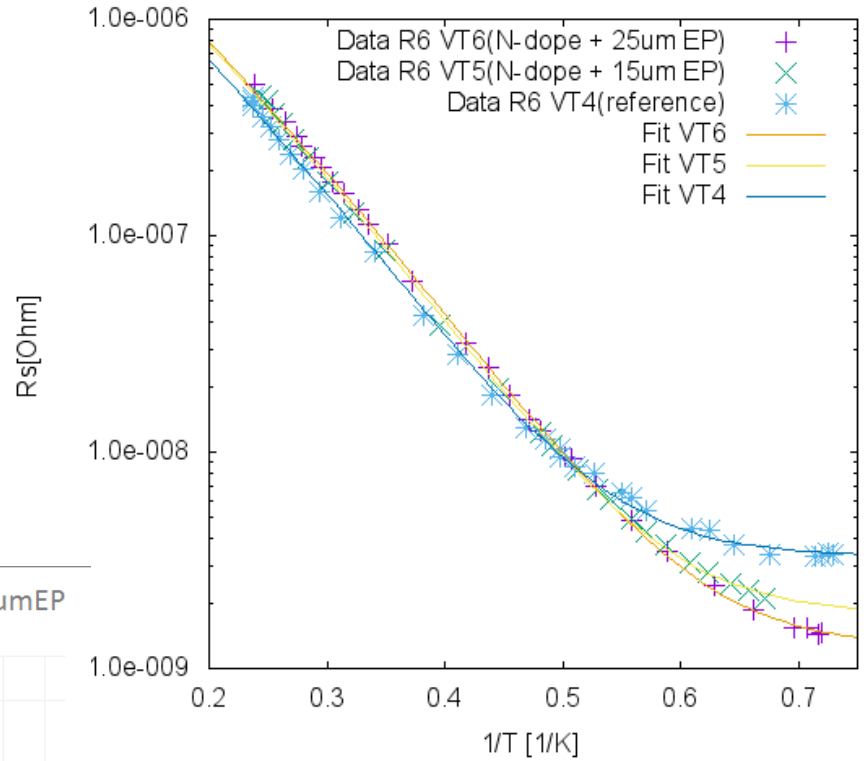
Flux gate sensor, Si temperature sensor, heater and solenoid coil were used.

VT results of N-doping

VT4(reference measurement)
N-doping
15um EP → VT5
Additional 10um EP →VT6

- Magnetic field canceled. (< 1mG)
- Cooled down with thermal gradient





VT4(reference) Rs=3.3nΩ
VT5(N-dope) Rs=1.8nΩ
VT6(add EP) Rs=1.2nΩ

- Very high Q up to high field
- Q = 2.4e11@11MV/m, 1.4K
- Q = 3.3e10@14MV/m, 2.0K
- Quench at 19MV/m
- No field emission
- First success in Japan

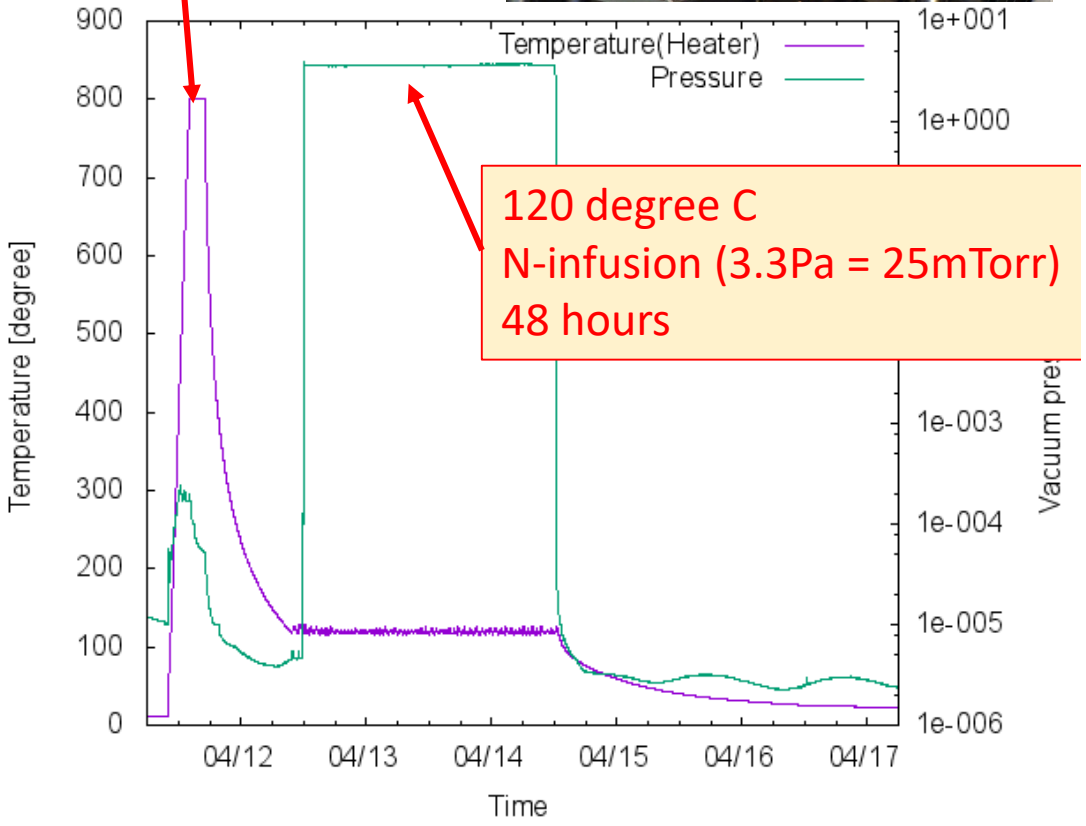
N-infusion

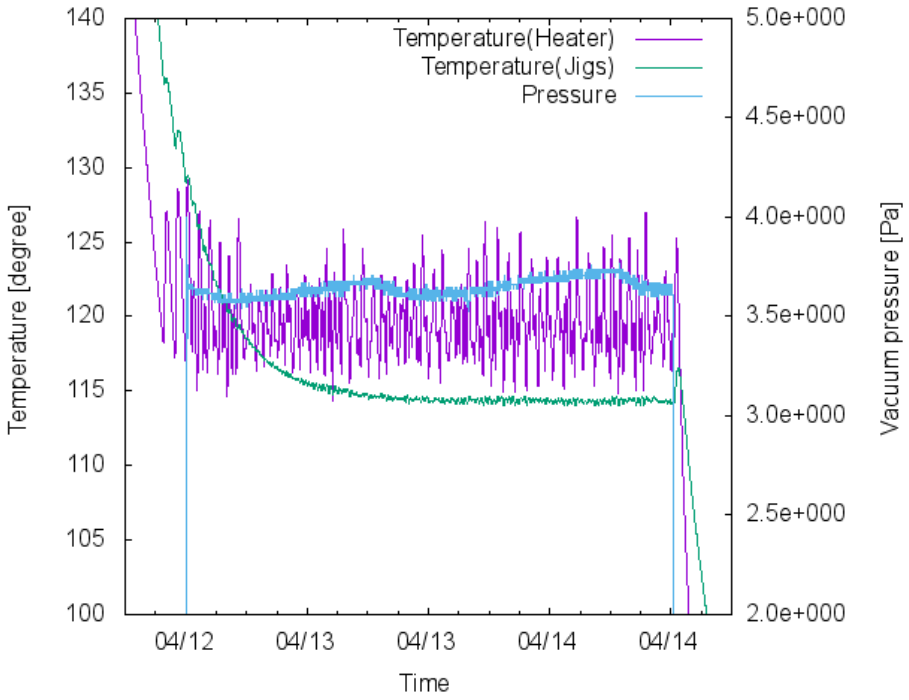
N-infusion(FNAL parameter)

- Pressure is stabilized less than 0.1Pa
- Different vacuum gauges at different positions show around 0.3 Pa offset.
- Temperature is stabilized with +/- 5 degree.
- Temp. offset ~ 5 degree between furnace and jigs.

800 degree C
3 hours

120 degree C
N-infusion (3.3Pa = 25mTorr)
48 hours

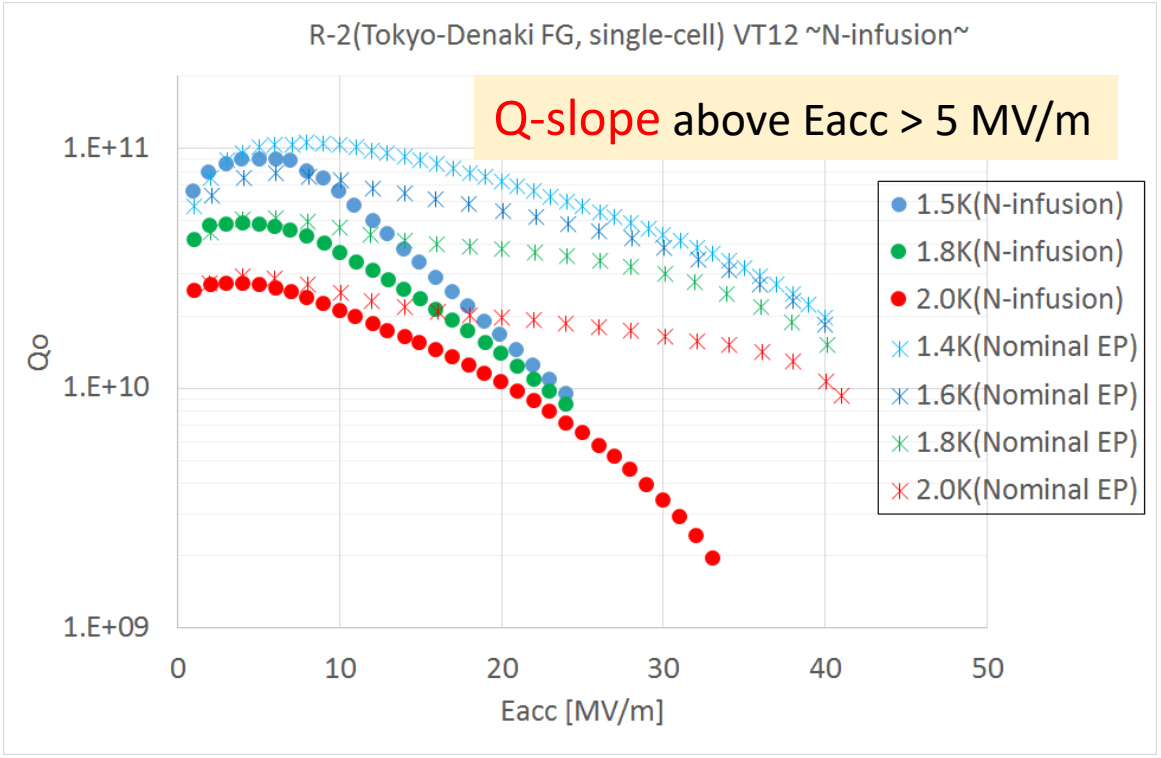


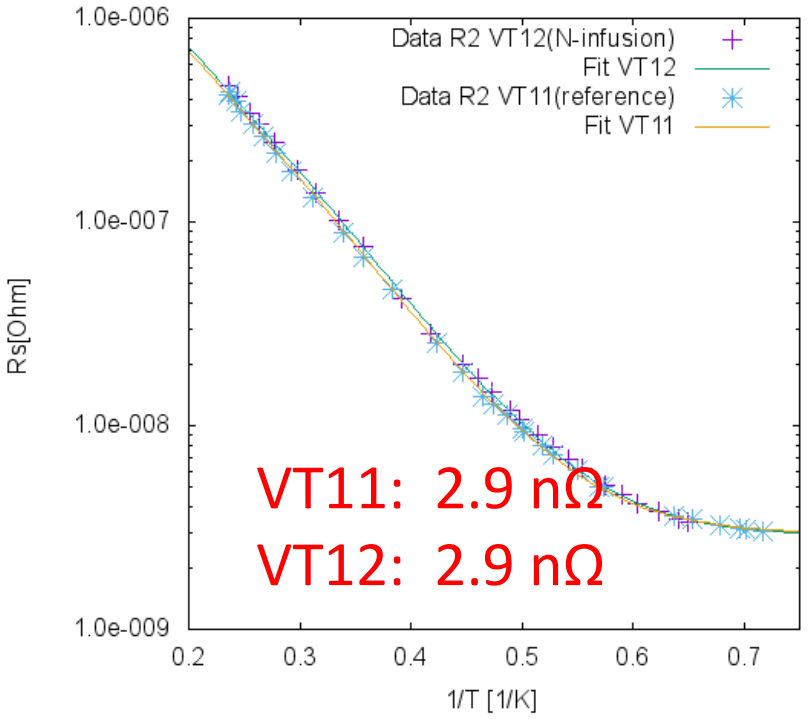


VT results for N-infusion

- Transfer to KEK
- HPR (No EP applied)
- Assembly

- Magnetic field canceled. (< 1mG)
- Cooled down with thermal gradient



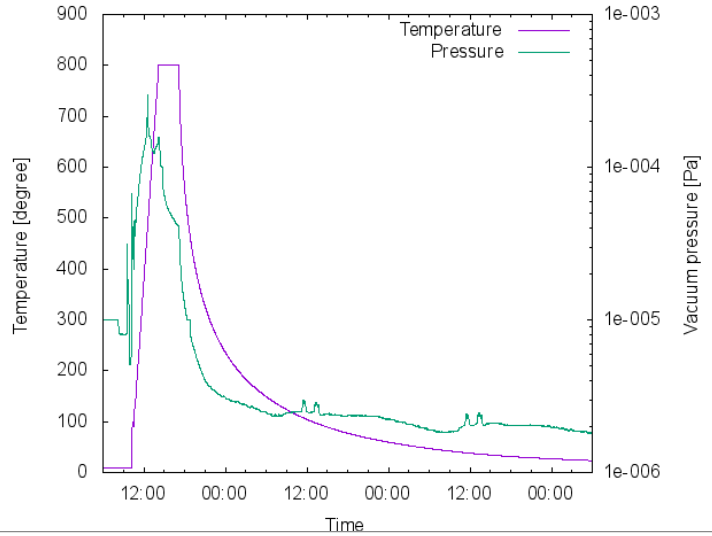


- Degradation was observed for > 5 MV/m
- Eacc was limited at 33MV/m by quench at 225 degree equator
- No field emission

Test for furnace (Heat treatment without EP)

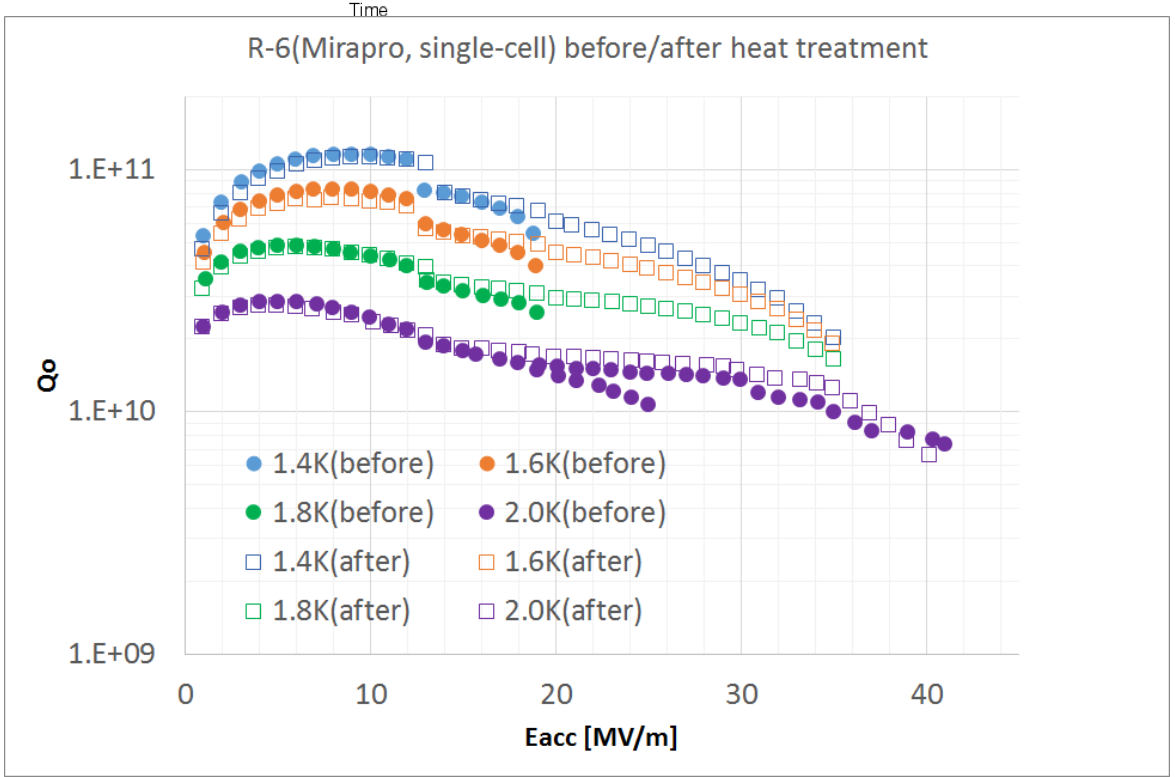
1) 800 degree, 3hours (w/o Nitrogen) ⇒ HPR ⇒ Assembly ⇒ VT
2) 800 degree, 3hours + 120 degree, 48hours (w/o Nitrogen)
⇒ HPR ⇒ Assembly ⇒ VT

① Heat treatment (800 C, 3h) and VT



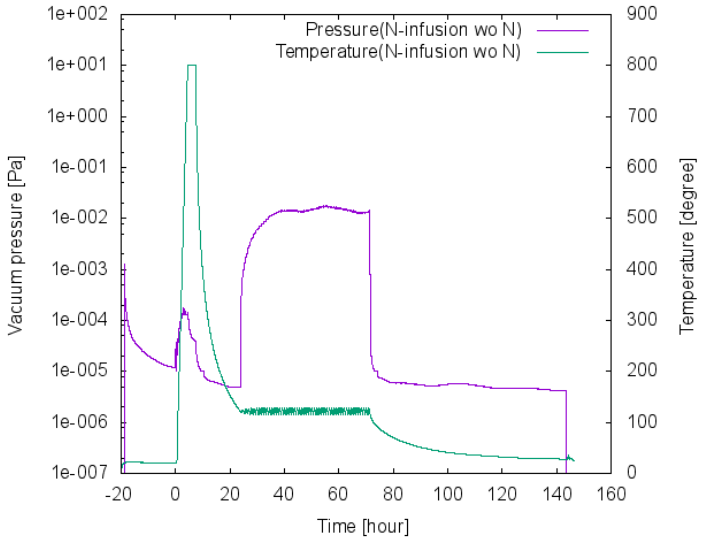
- 800℃, 3hours heat treatment at J-PARC furnace
- Transfer to KEK with double-packed
- HPR
- Assembly
- 120℃ baking
- Vertical test

No EP was applied!



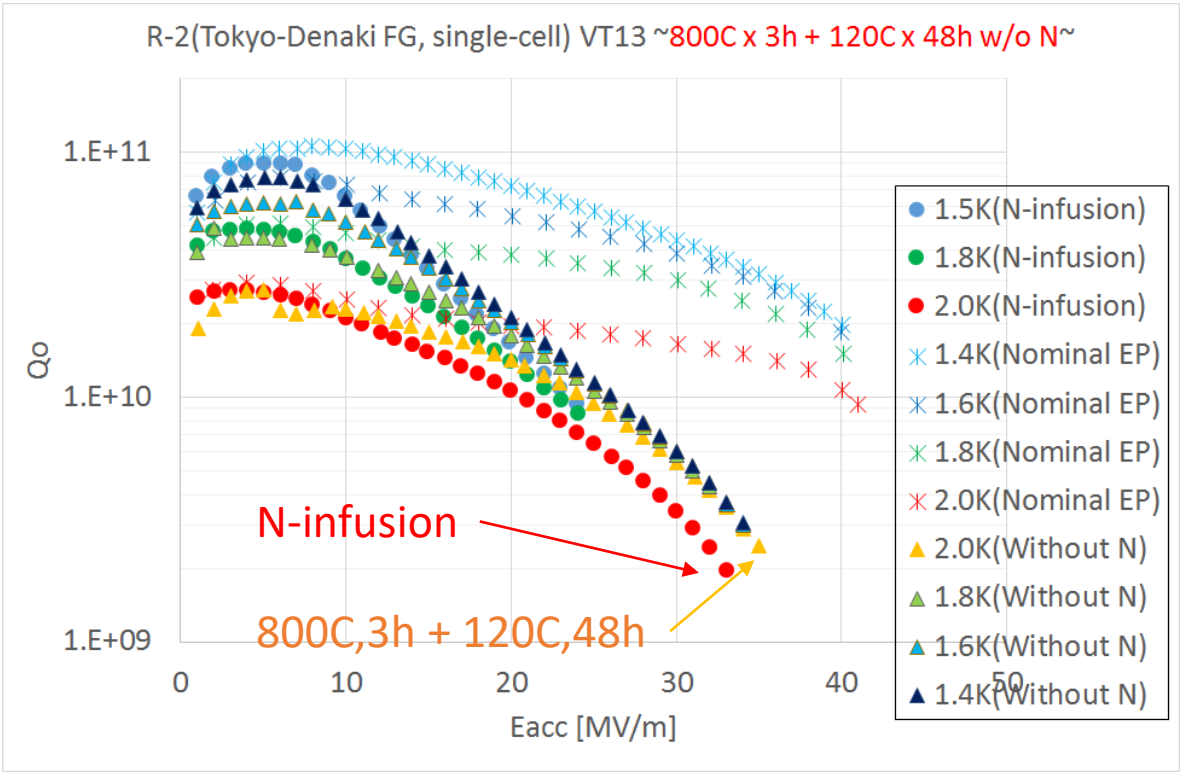
No degradation!!
Cavity performance was reproduced.

② 800℃, 3hours + 120℃, 48 hours w/o Nitrogen



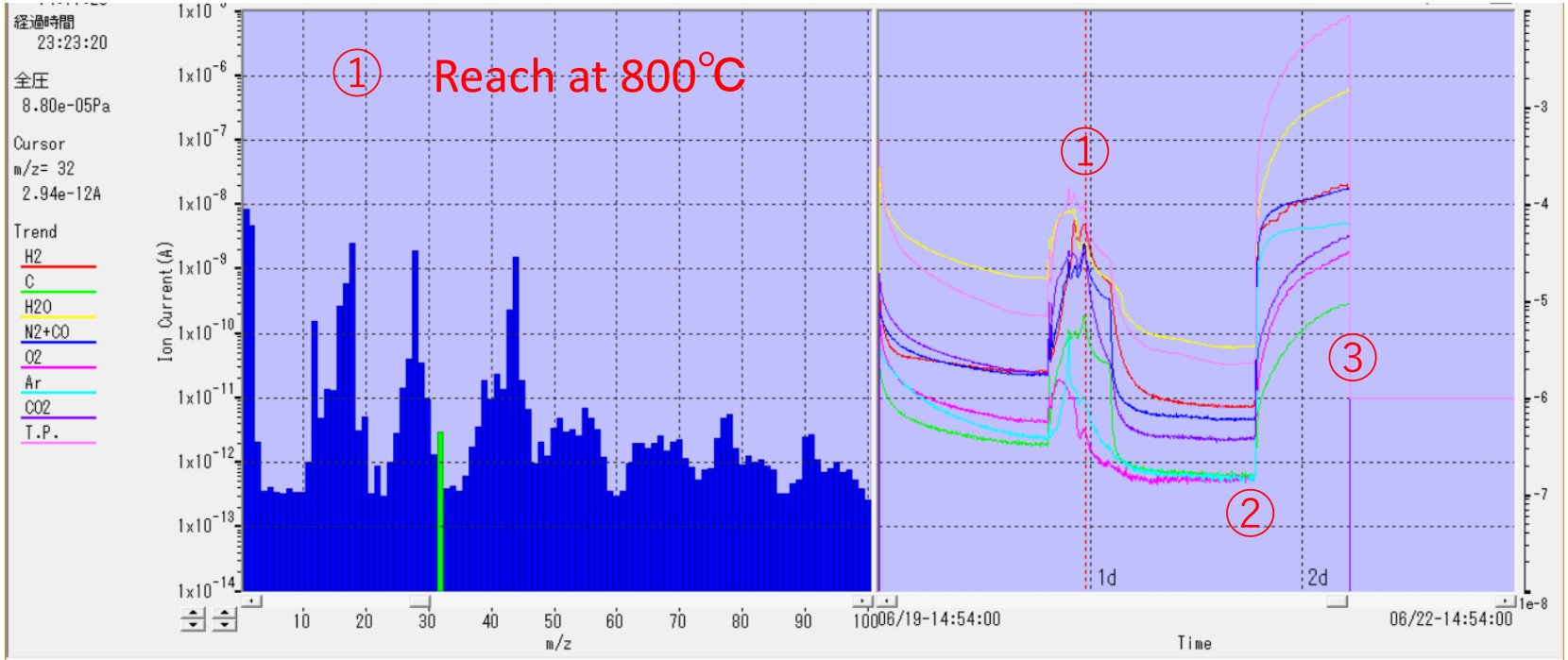
[Vacuum condition during 120 degree]

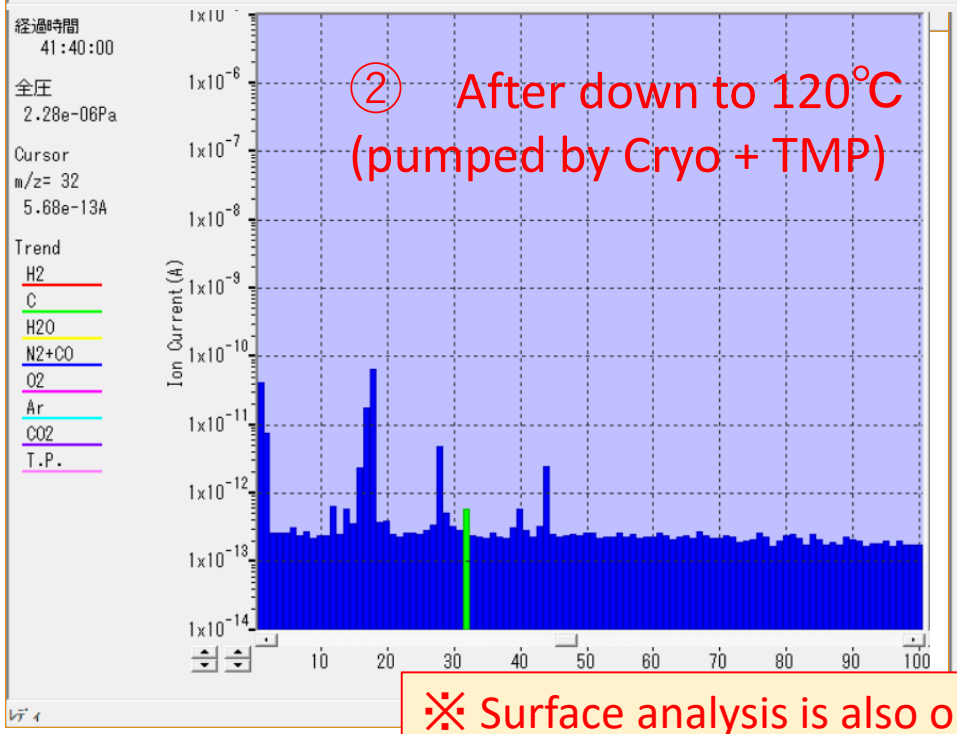
- Valve of cryopump was closed
- TMP OFF
- Vacuum pumping by small pumping system(TMP and scroll)
- Vacuum level worthened to 1.7e-2 Pa (Around 0.5% of Nitrogen level)

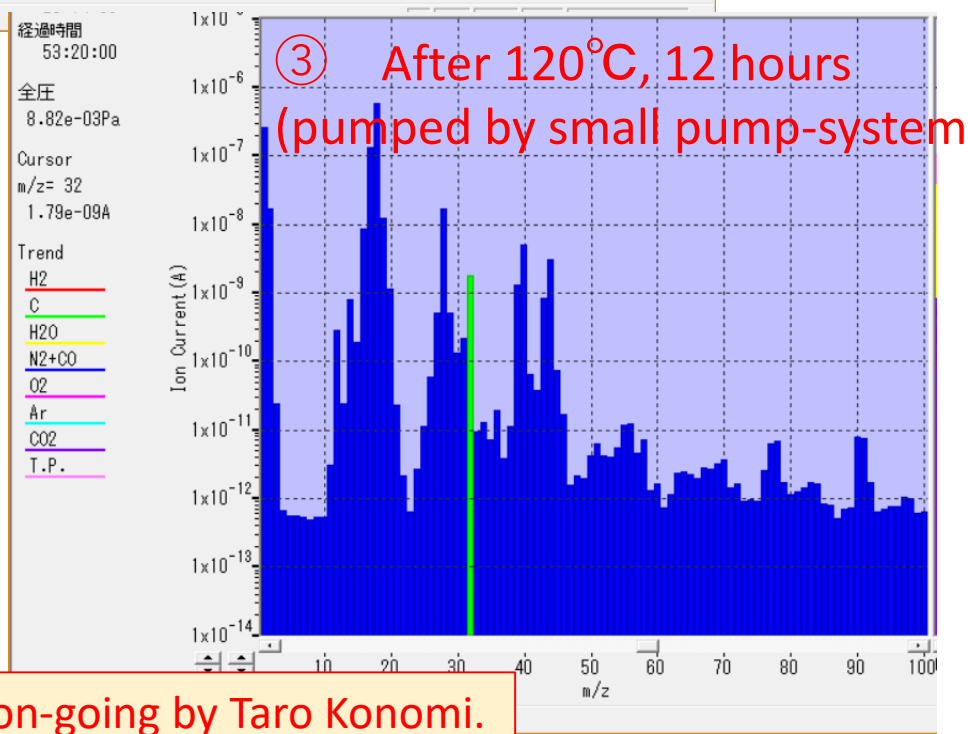


- Refresh surface by 10um EP after N-infusion
- 800C, 3h + 120C, 48h (No Nitrogen)
- HPR and assembly (No EP, No baking)
- Vertical test

- Q-slope above Eacc > 5 MV/m
- Almost same performance with N-infusion







※ Surface analysis is also on-going by Taro Konomi.

Questions for other labs

I would like to know…

- What is situation for pumping system during N-infusion?
- How much is vacuum background level during N-infusion?
- How is RGA spectrum during N-infusion?

Summary

- N-dope and N-infusion study is on going at KEK to realize high performance of SRF cavities.
- Currently R&D is on-going using J-PARC furnace, which is pumped by a cryo-pump and TMPs.
- N-doping was successful. High-Q was obtained for 10-15 MV/m.
- N-infusion was carried out. Degradation occurred at more than 5 MV/m.
- Degradation seems to come from background vacuum level during 120 degree N-infusion.
- We will try to push to realize N-infusion technique for high performance SRF accelerators.

Backup slide

KEK furnace for N-doping

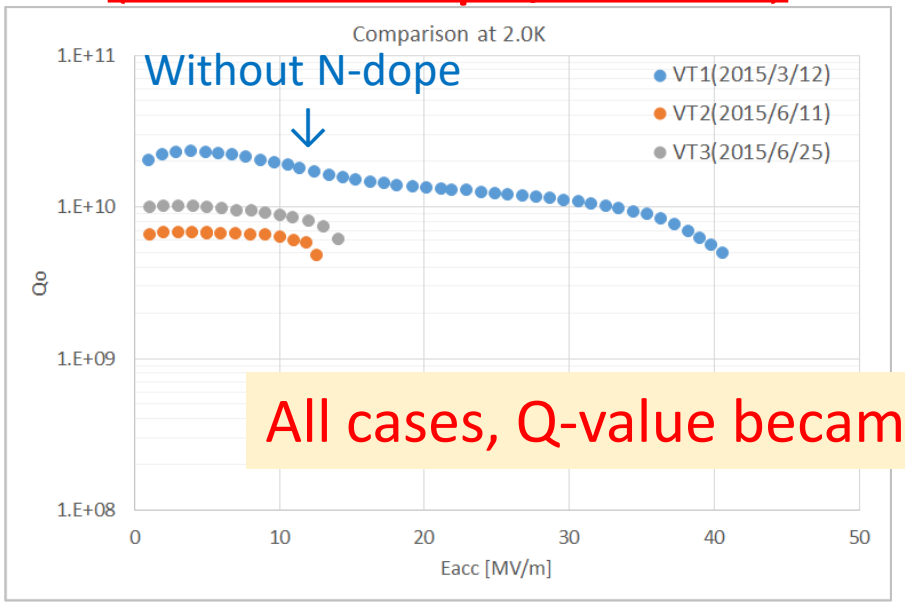
Large furnace for 9-cell cavity

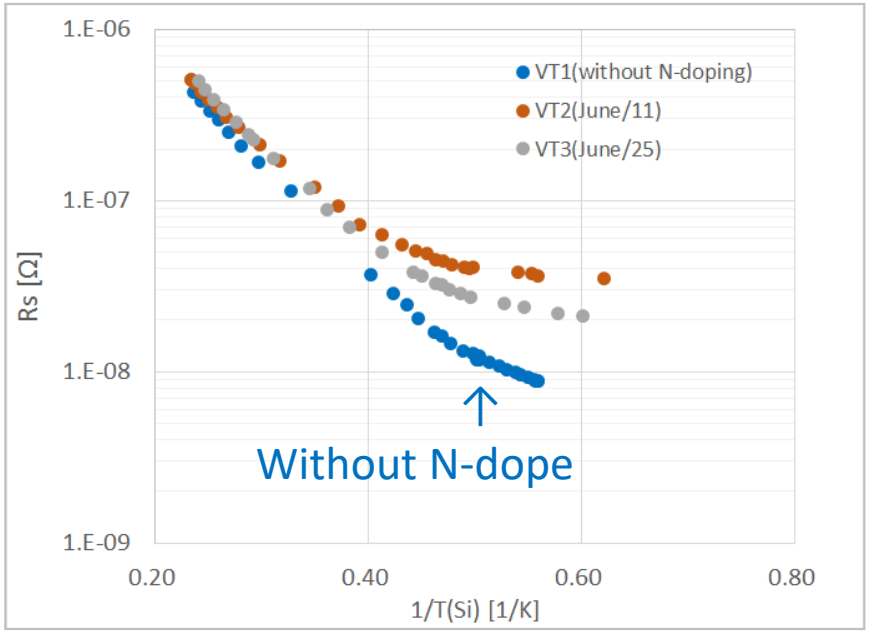
Diffusion pump without N-trap

Small furnace for single-cell cavity

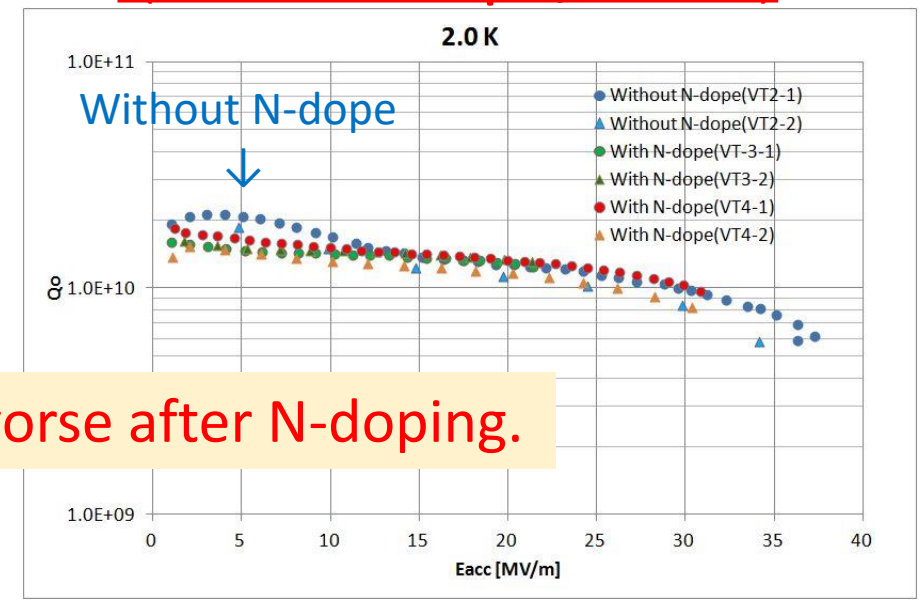
Diffusion pump with N-trap

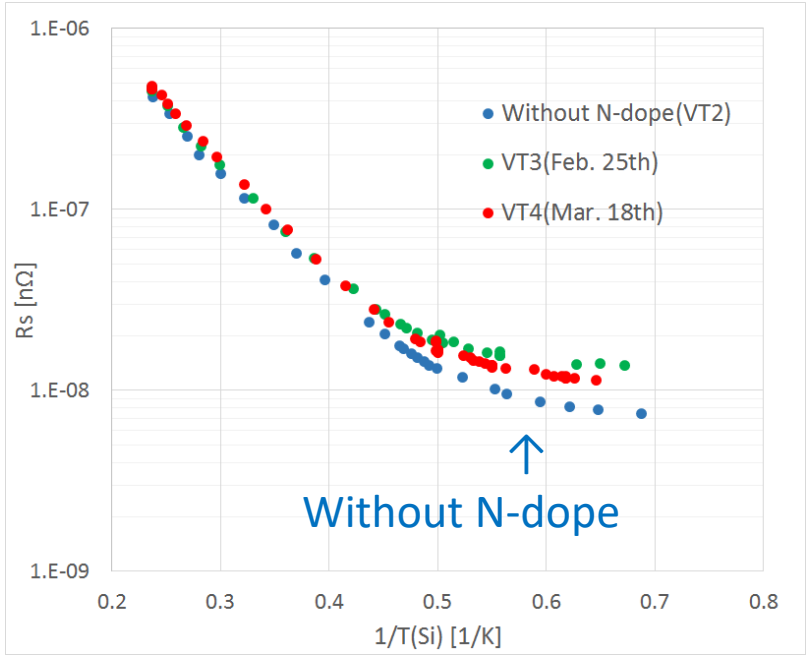
Results for large furnace (2.7Pa N-dope, 20min)





Results for small furnace (3.3Pa N-dope, 2min)

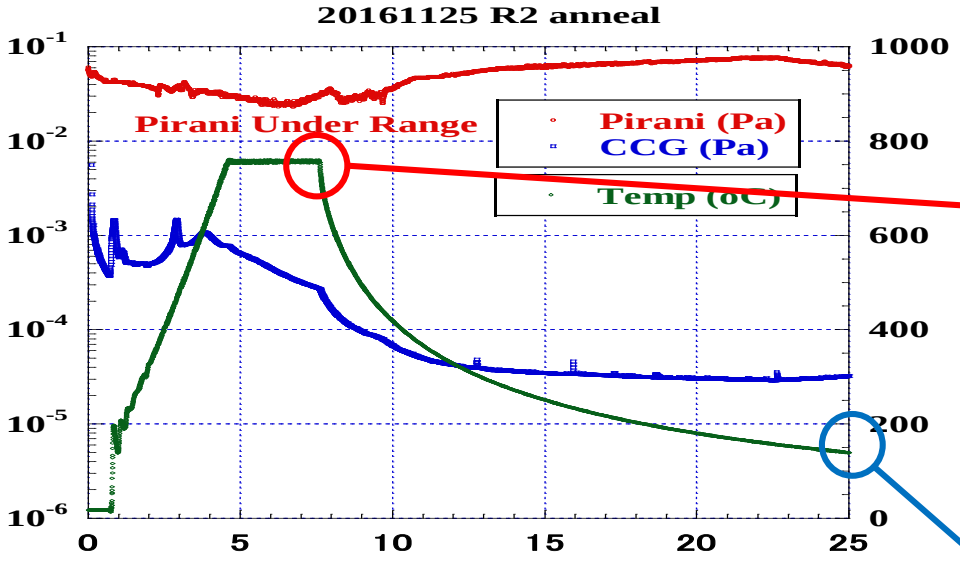


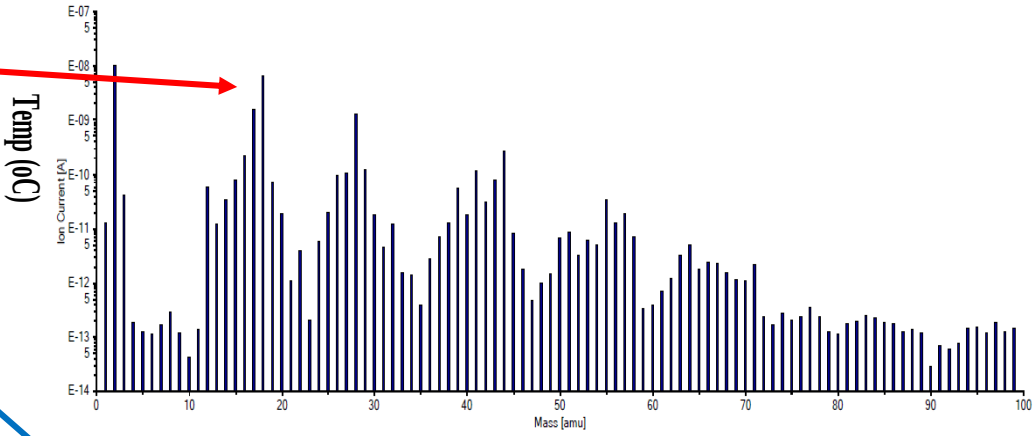


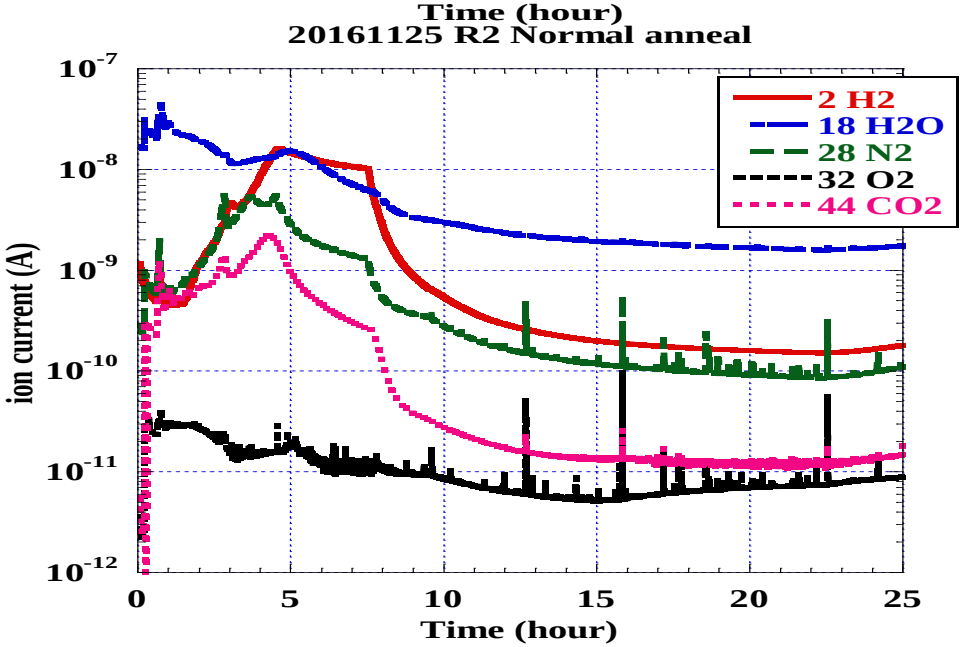
All cases, Q-value became worse after N-doping.

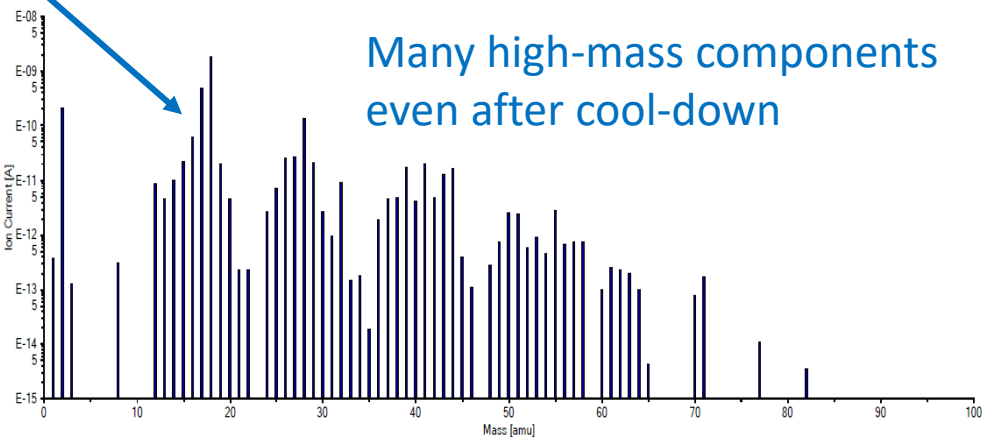
RGA spectrum of KEK big furnace

No RGA data for KEK small furnace









Many high-mass components even after cool-down