Power coupler R&D in KEK/COI

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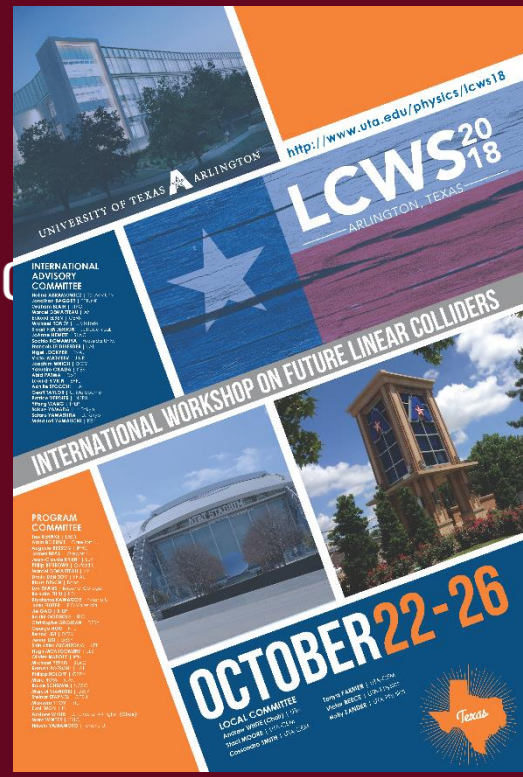

Y. Yamamoto (KEK), on behalf of power coupler R&D team

MEMBER LIST

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- Y. Okii (Nomura plating Co., Ltd.)
- E. Montesinos, C. Julie (CERN)
- W. Kaabi, H. Guler (LAL/IN2P3)
- C. Arcambal, E. Cenni, F. Aurelien (IRFU/CEA)

Outline

- **R&D programs in F.Y. 2018**
- **COI facility in KEK**
- **R&D status for ceramic property**
- **RRR measurement for copper plating**
- **Summary**

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R&D programs in F.Y. 2018

Item	Joint researchers	Priority	Cost	Purpose
Surface/volume resistivity for ceramic		**High**		Evaluation by same measurement system with same shape of ceramic
Relative permittivity and dielectric loss angle for ceramic		**High**		Evaluation by same measurement system with same shape of ceramic
Secondary electron emission for ceramic	TETD	**High**		Evaluation by same measurement system with same shape of ceramic
RRR of copper plating	Nomura plating	**High**		R&D for low cost/high efficiency method
Crosscheck of RRR	IRFU/CEA(FJPPL), DESY	**High**		Reliability check for different measurement systems
Adhesion test for copper plating	TETD, Nomura plating, IRFU/CEA(FJPPL)	Middle		Check for adhesion of copper plating
Leak tight test for RF window at 70 K	TETD	Middle		Reliability check under cold environment
Ultrasonic rinsing test for TiN coating-free ceramic	IRFU/CEA, LAL/IN2P3(FJPPL)	**High**		Peak power check for TiN coating-free ceramic
TiN coating study	TIGOLD	Middle		R&D for low cost/high efficiency method

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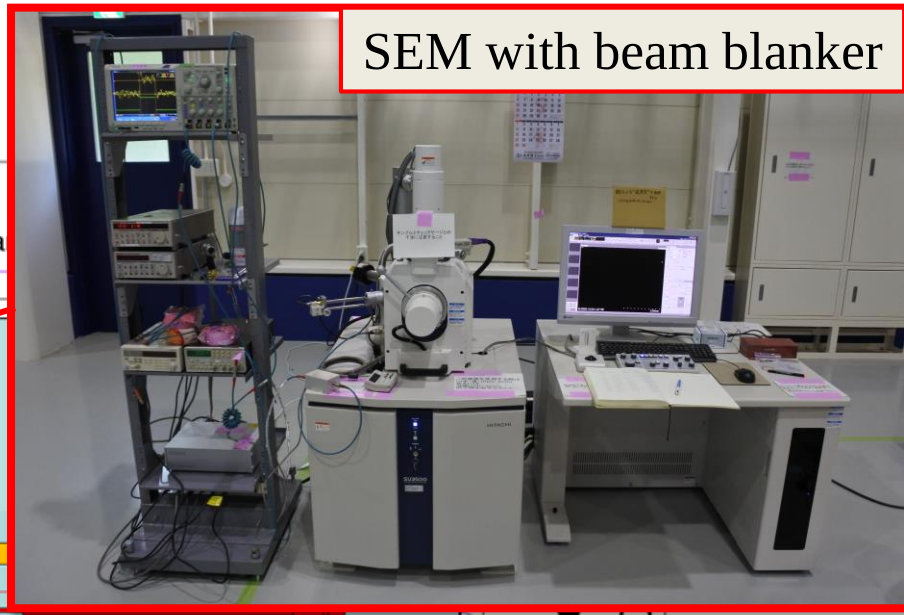
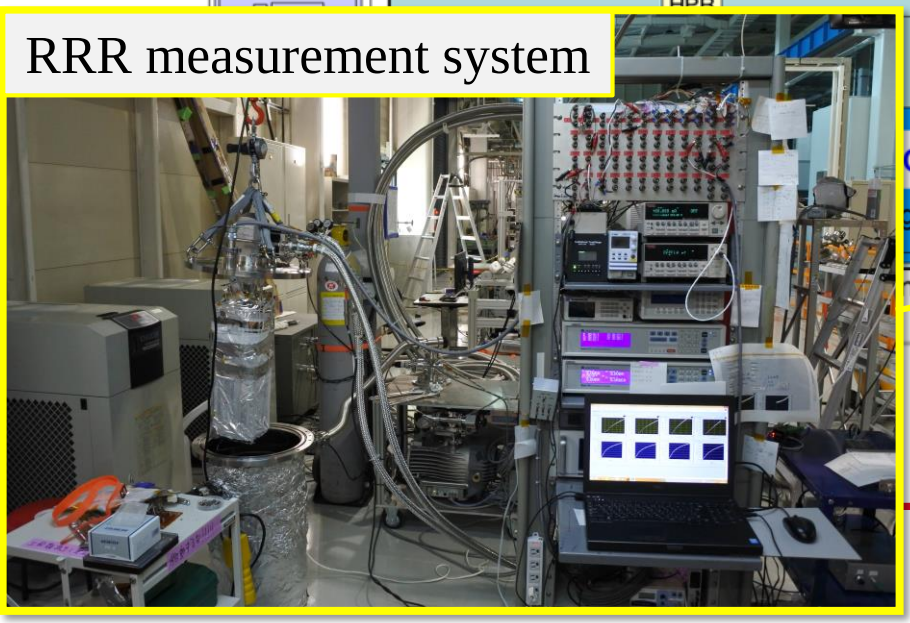
COI facility in KEK

Construction completed in F.Y. 2015

SEM with beam blanker



RRR measurement system



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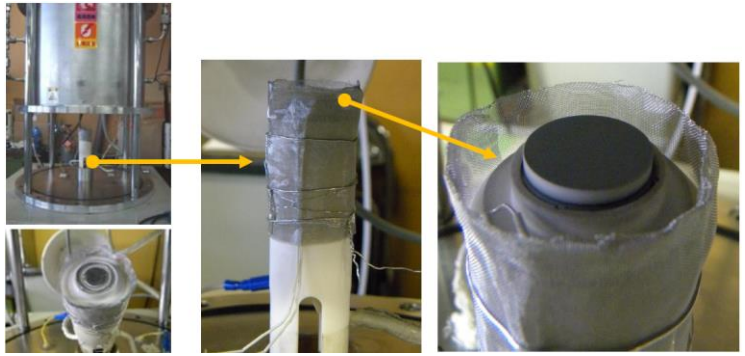
Ceramic samples

Vendor	Ceramic name	Measurement item	Coating
NGK/NTK	HA95 (production stopped)	δ_{SEE}	TiN / Free
KYOCERA	LSEEC	δ_{SEE}	Free
	A479B	δ_{SEE}	TiN / Free
	AO473A	δ_{SEE}	Free
	LSEEC	ρ	Free
	A479B	ρ	TiN / Free
	LSEEC	ε, tanδ	Free
	A479B	ε, tanδ	Free
WESGO	AL300	ρ, δ_{SEE}	TiN / Cr_2O_3 / Free
	AL995	ρ, δ_{SEE}	TiN / Cr_2O_3 / Free
	AL300	ε, tanδ	Free
	AL995	ε, tanδ	Free
COORSTEK	AD-995-LT	δ_{SEE}	TiN / Free
	AD-995-LT	ε, tanδ	Free
	AD-995-LT	ρ	Free
FERRO TEC	AM997Q	δ_{SEE}	Free

Research on Ceramic Property

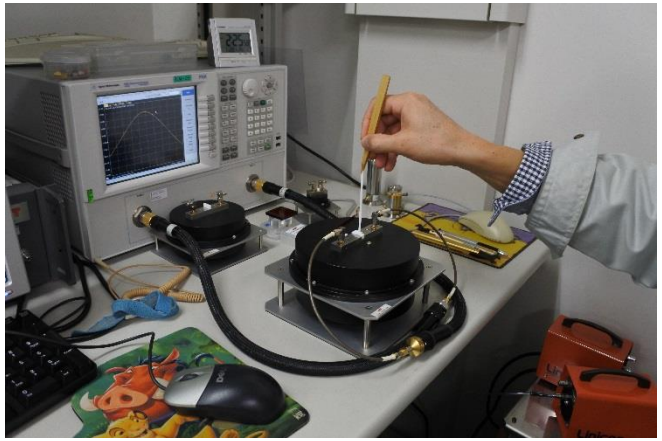
KEK is investigating properties for eight kinds of ceramics fabricated by five companies

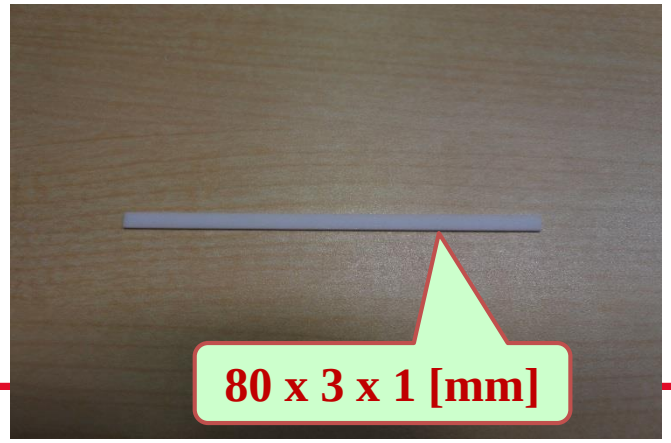
Surface/Volume resistivity



Φ20 x 2 [mm]

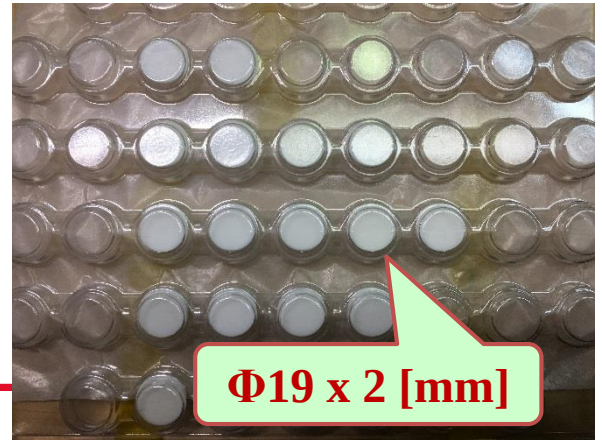
Relative permittivity
Dielectric loss angle





80 x 3 x 1 [mm]

Secondary electron emission



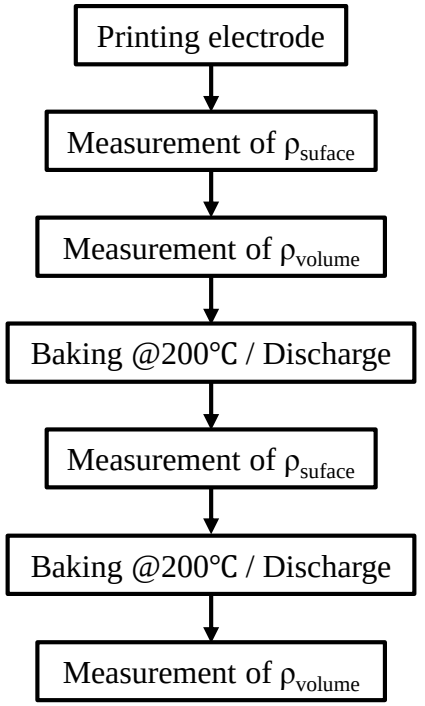
Φ19 x 2 [mm]

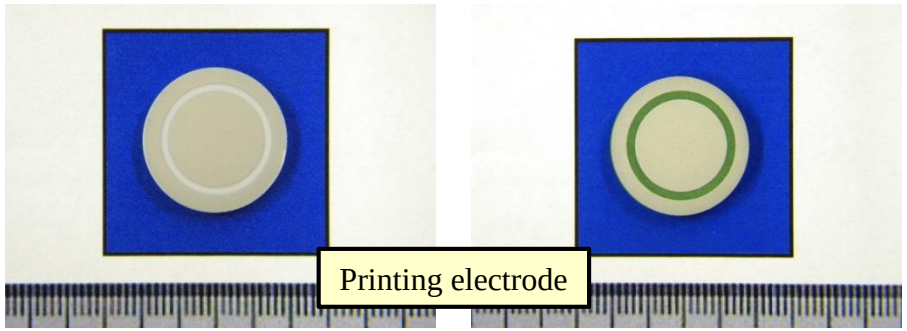
preliminary

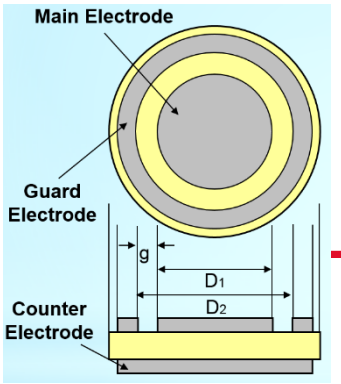
Surface/volume resistivity measurement

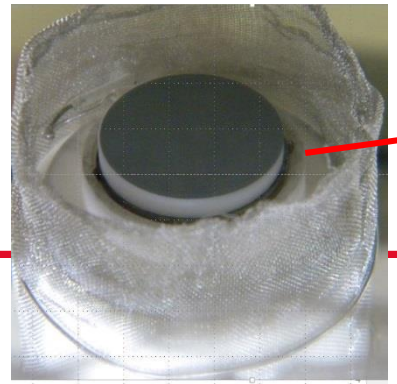
Vendor	Ceramic name	Coating
NGK/NTK	HA95	TiN / Free
KYOCERA	LSEEC	Free
	A479B	TiN / Free
WESGO	AL300	TiN / Cr_2O_3 / Free
	AL995	TiN / Cr_2O_3 / Free
COORSTEK	AD-995-LT	TiN / Free

Sequence of measurement

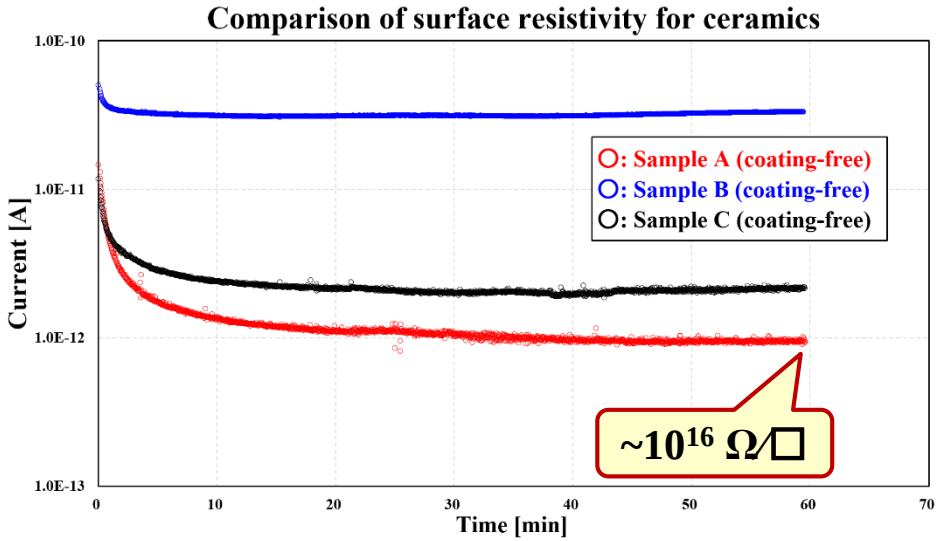


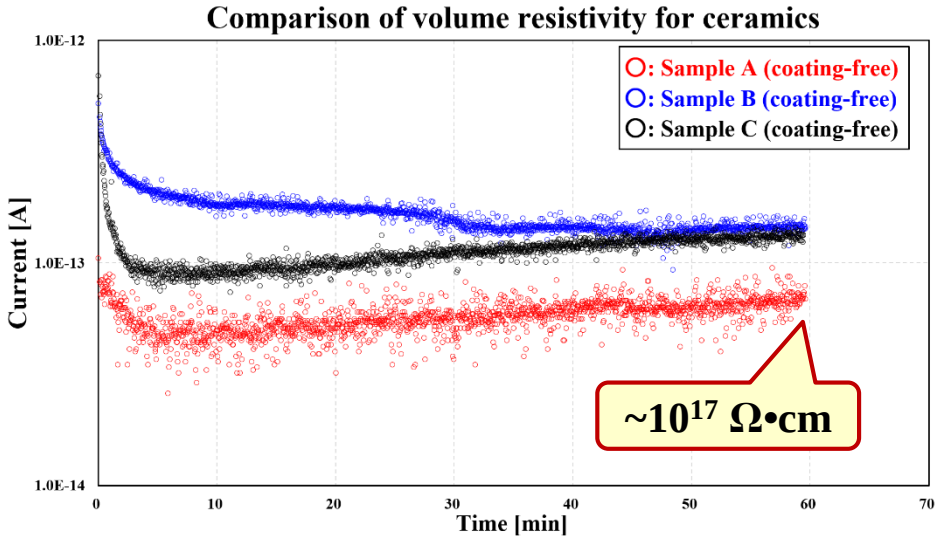






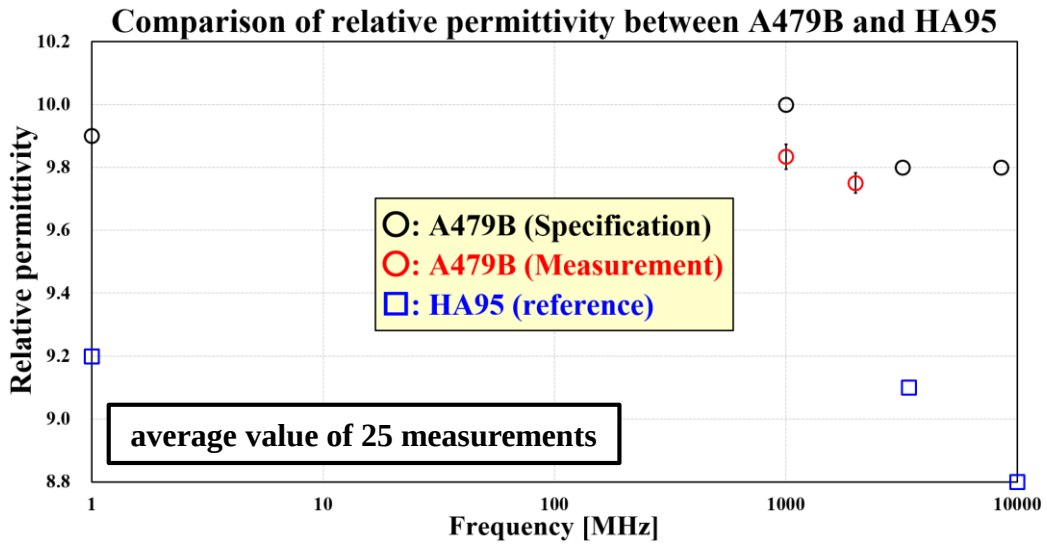
Japan Fine Ceramics Center (JFCC)

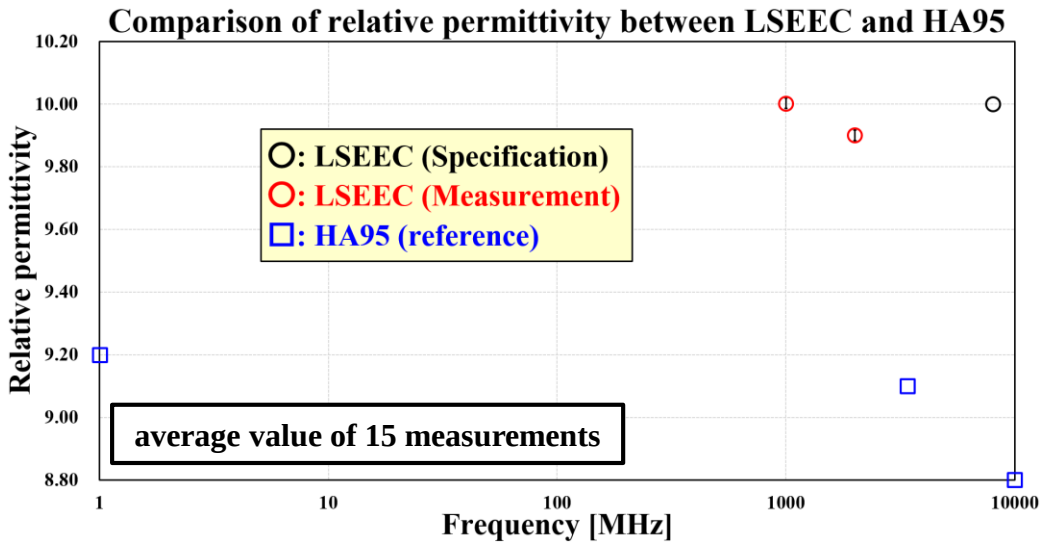


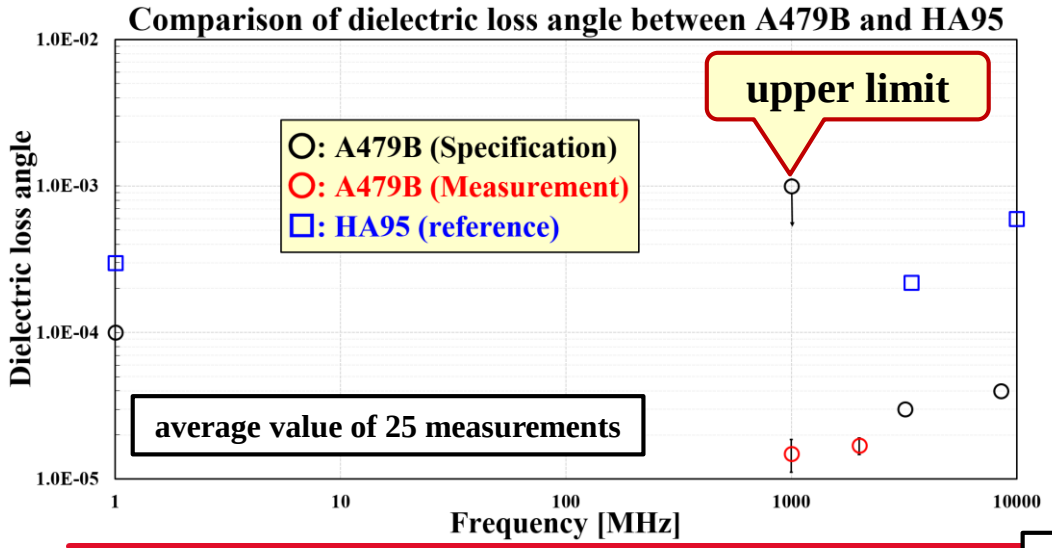


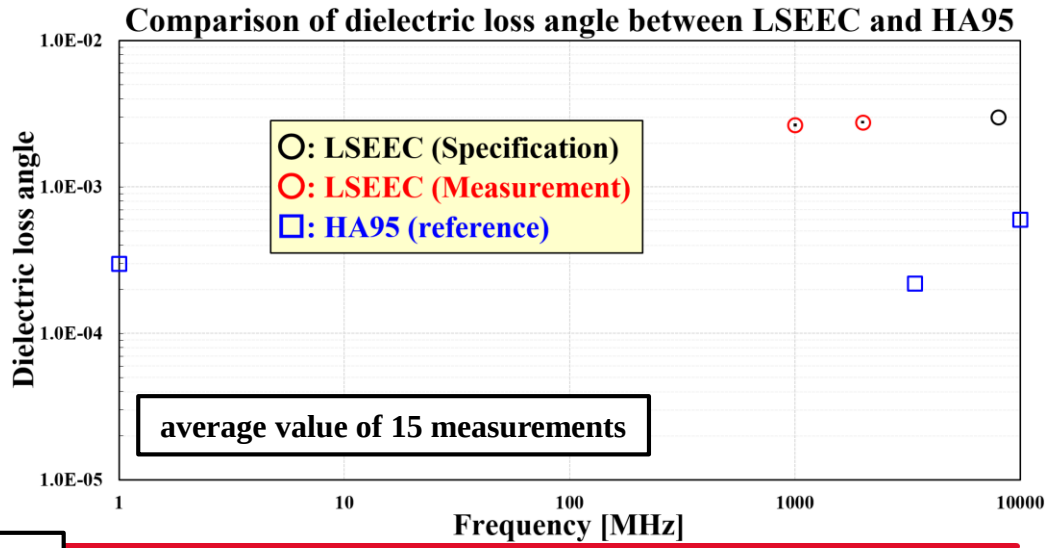
preliminary

ε and tanδ measurement





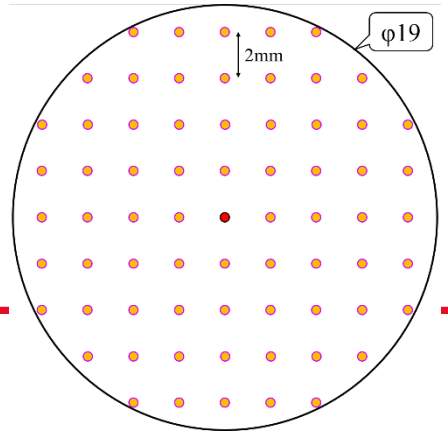




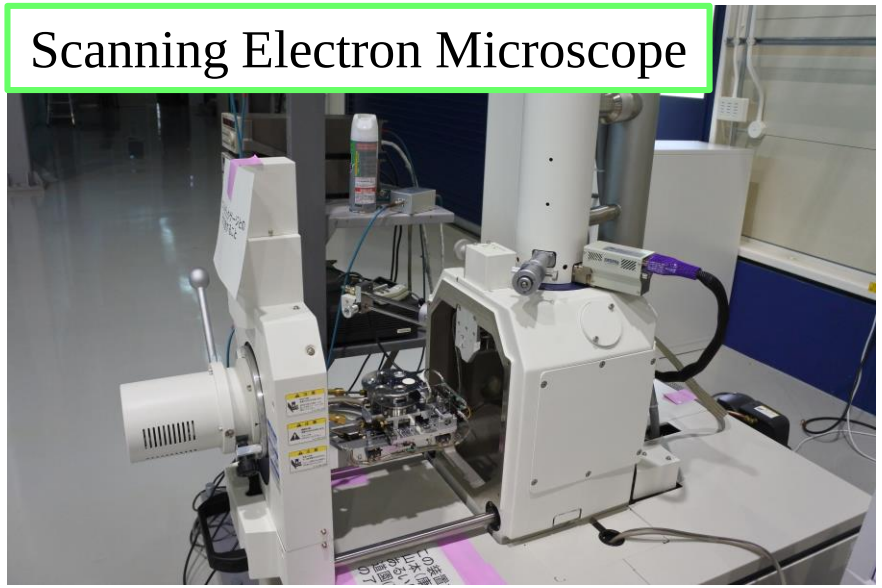
AET Japan

Measurement method for δ_{SEE}

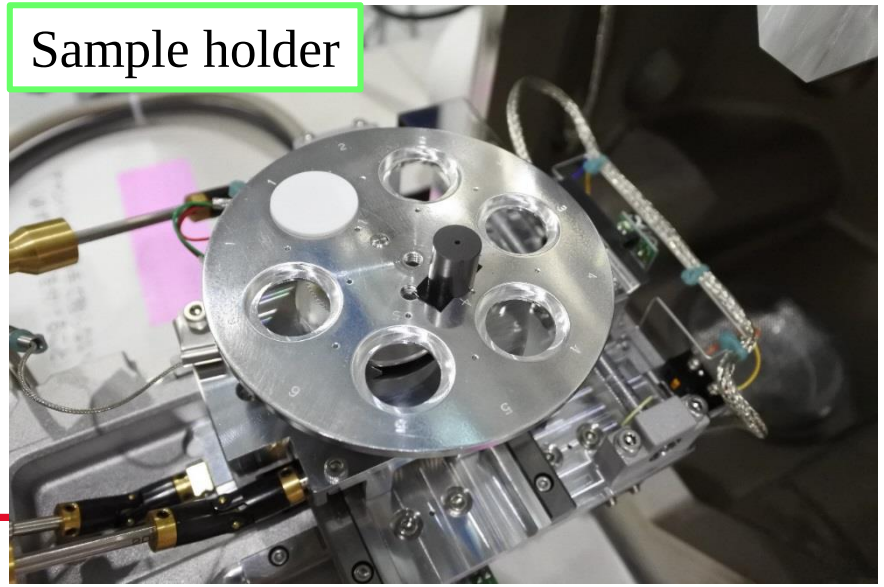
- Use of pulsed beam by beam blanking system
- Pulse width: 1 msec
- Ceramic shape: 19 mm (diameter), 1~3 mm (thickness)
- Magnification: x200
- Primary beam current: ~ 100 pA
- One shot at one point (2 mm pitch) → see below!
- Bias voltage: +50 V for primary beam current
  –50 V for absorption current
- Injection method: Area injection for ceramic
  Point injection for carbon
- Four times measurement at each energy
- Consistency check for primary beam current
- Measurement time: 2~3 hours per sample



Scanning Electron Microscope



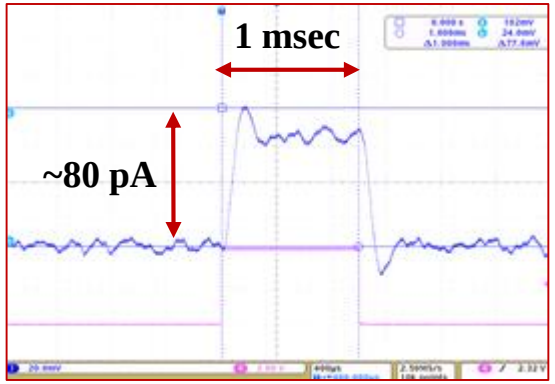
Sample holder

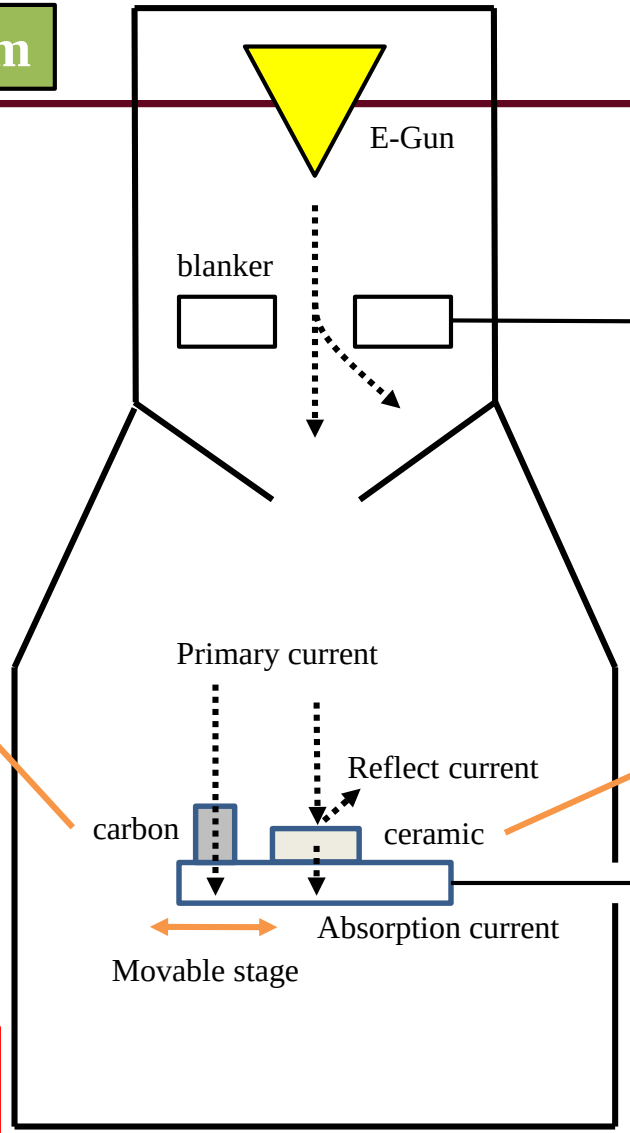


Schematic view of measurement system

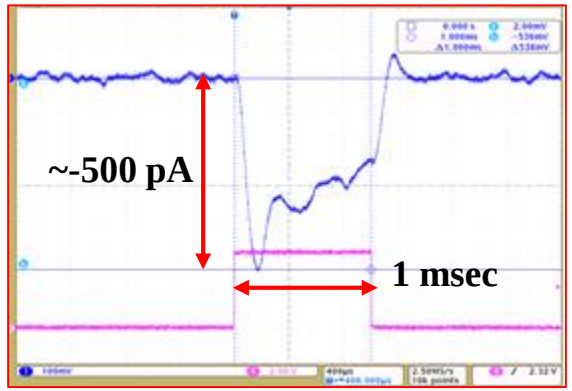
primary beam current

absorption current





Function generator



+50 V for primary current
–50 V for secondary current

Bias module

I → V

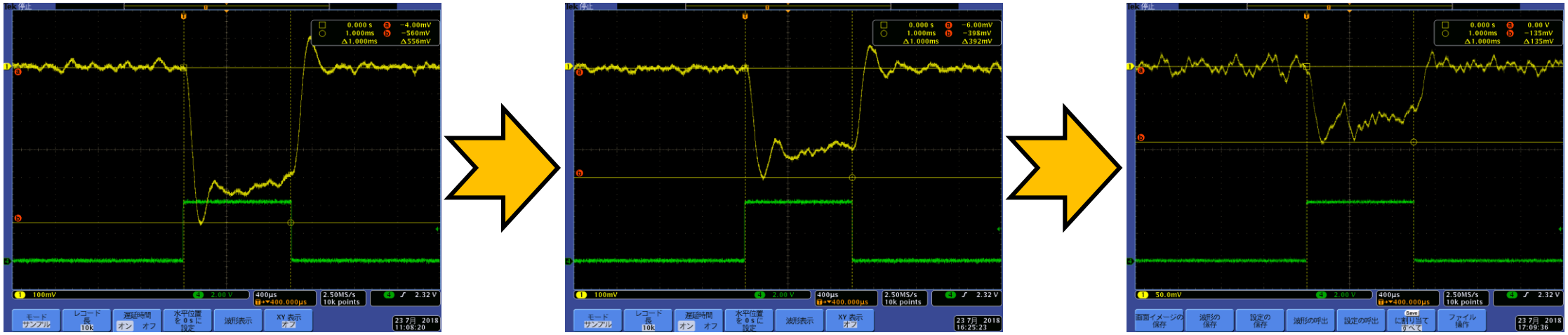
Current-voltage converter (Current amplifier)
(Gain: 10^9; 1 nA ↔ 1 V)

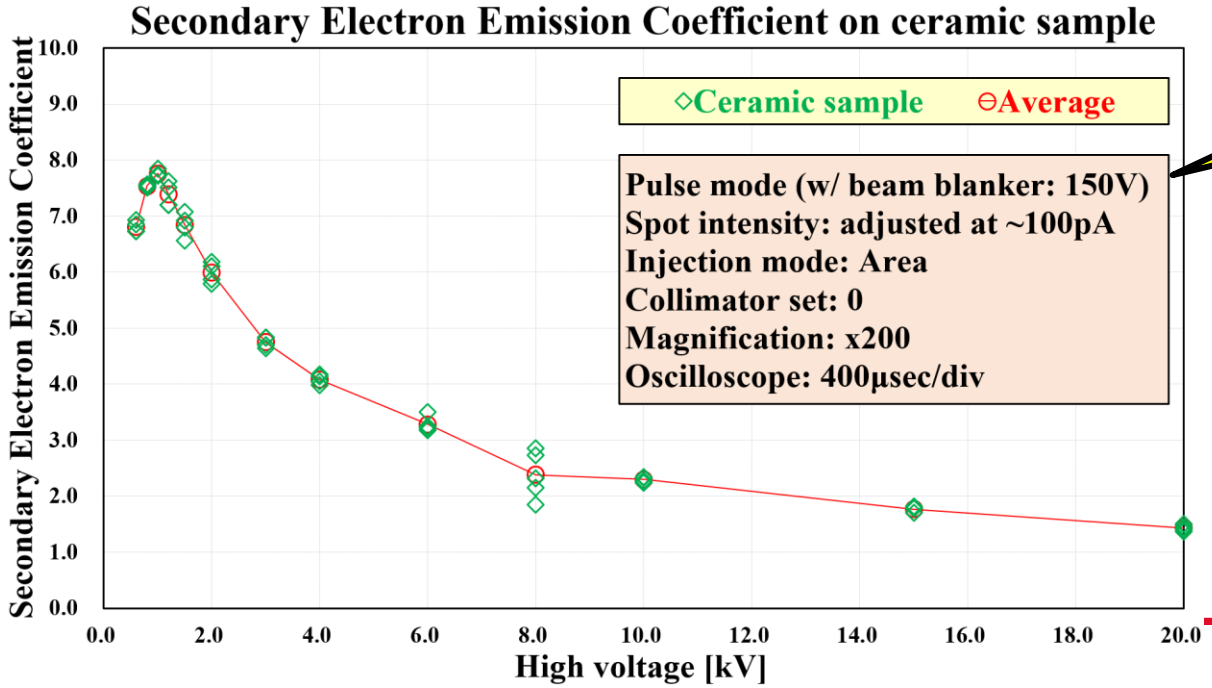
Oscilloscope

Figure/Text data stored

$$I_{primary} = I_{absorption} + I_{secondary}$$
$$\delta_{SEE} = I_{secondary} / I_{primary}$$

First result for δ_{SEE} measurement



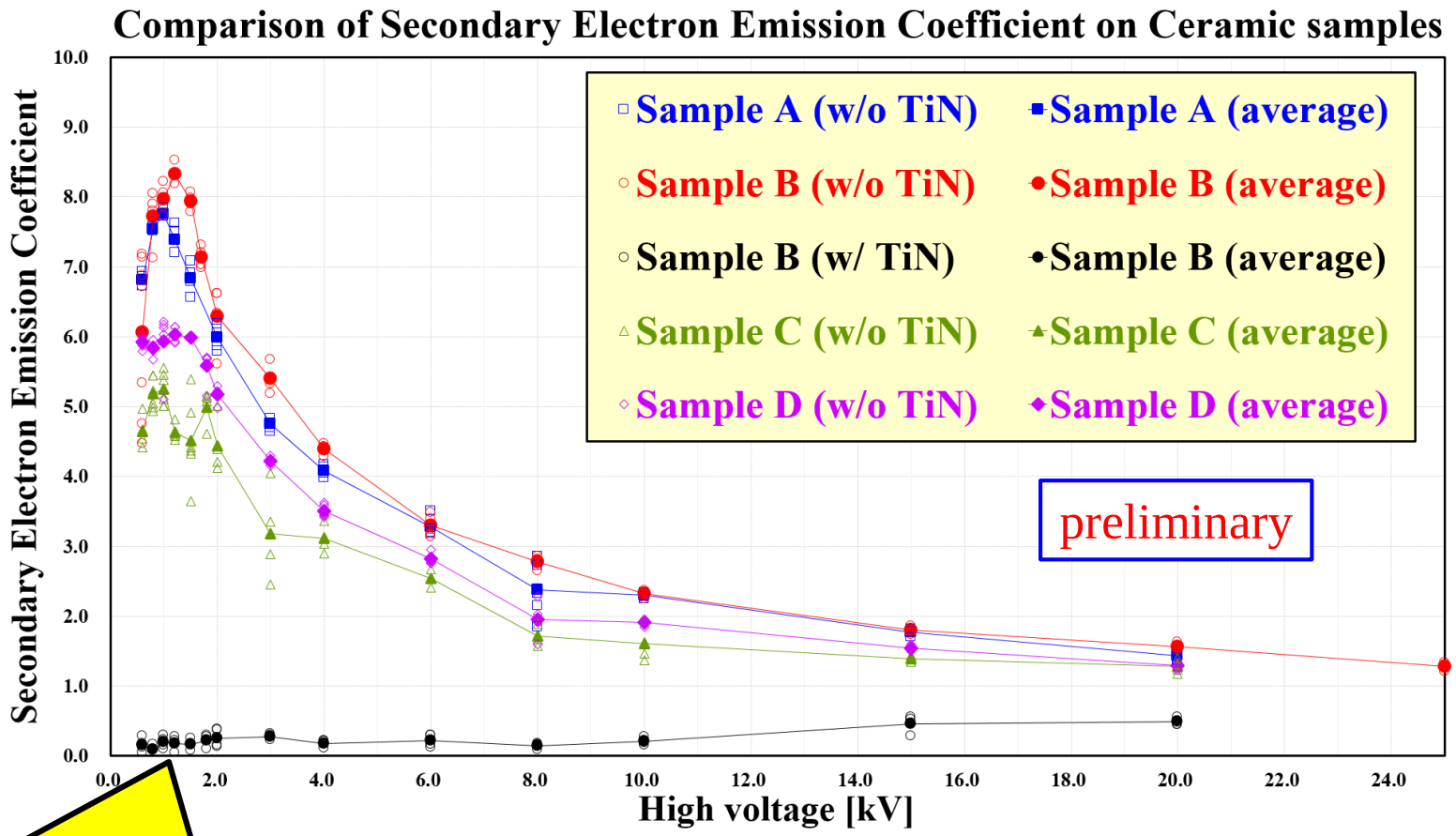


First successful result

Future prospect:

- Comparison of ceramic type
- Comparison between w/ and w/o TiN coating
- Comparison of rinsing procedure
  - Ultrapure water rinsing
  - Ultrasonic rinsing
  - Ozonized water rinsing

Comparison of δ_{SEE} for some kinds of ceramics



TiN coated ceramic had drastically lower δ_{SEE}!
But, more detailed investigation is necessary.

Outline

- **R&D programs in F.Y. 2018**
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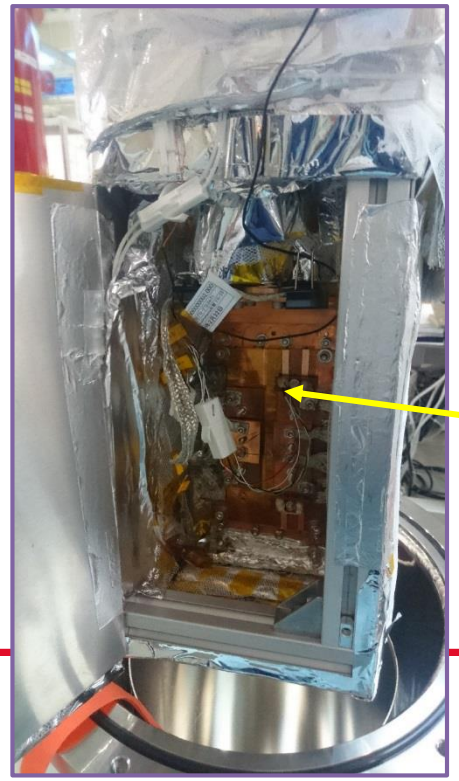
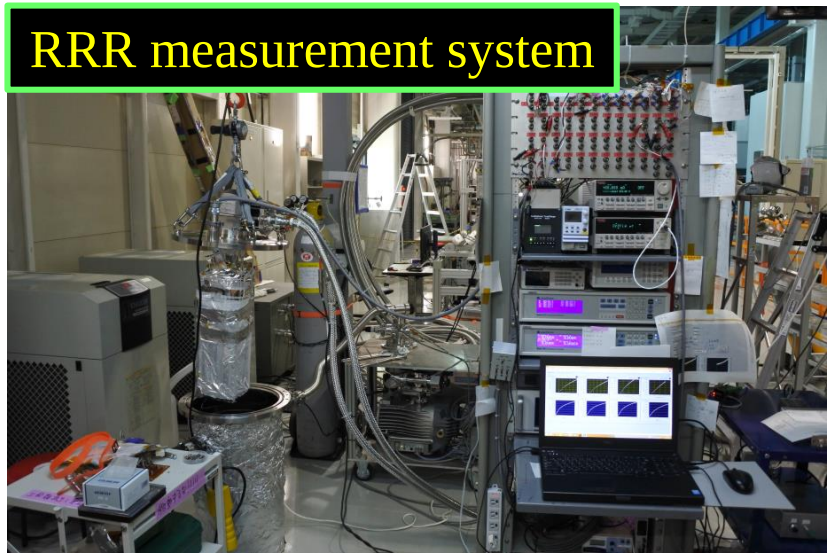
Measurement method for RRR

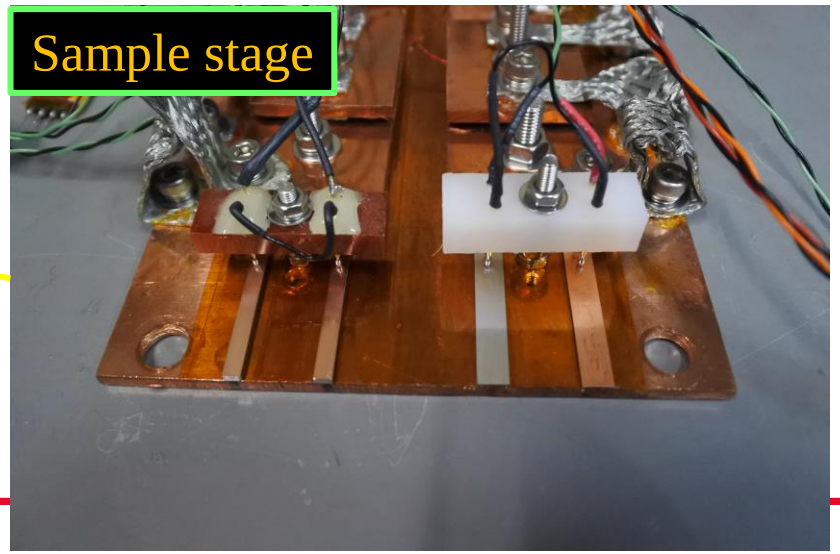
- Four-point probe method
- Temperature range: 4~300 K
- 4 samples measured per cycle
- One cycle per day
- Not necessary for dewar (closed system)
- Current: 1~100 mA
- Sample shape: 150 x 5 x 0.5 mm
- Thickness of copper platting: 20 μm



RRR measurement system



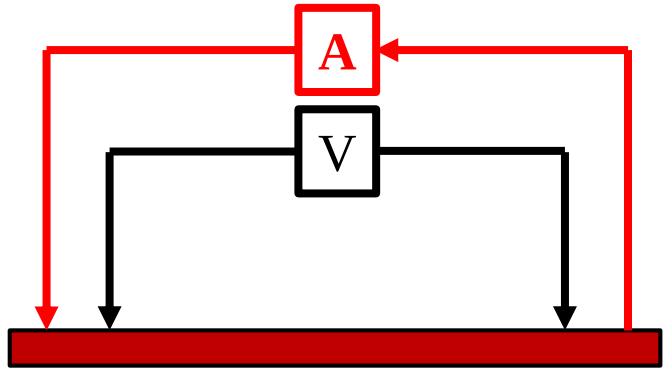
Sample stage



$$\frac{1}{\rho} = \frac{1}{\rho_{SUS316L}} + \frac{1}{\rho_{copper\ plating}} \leftrightarrow \rho_{copper\ plating} = \frac{1}{\frac{1}{\rho} - \frac{1}{\rho_{SUS316L}}}$$

$$RRR = \frac{\rho_{300K}}{\rho_{4K}}$$

Four-point probe method

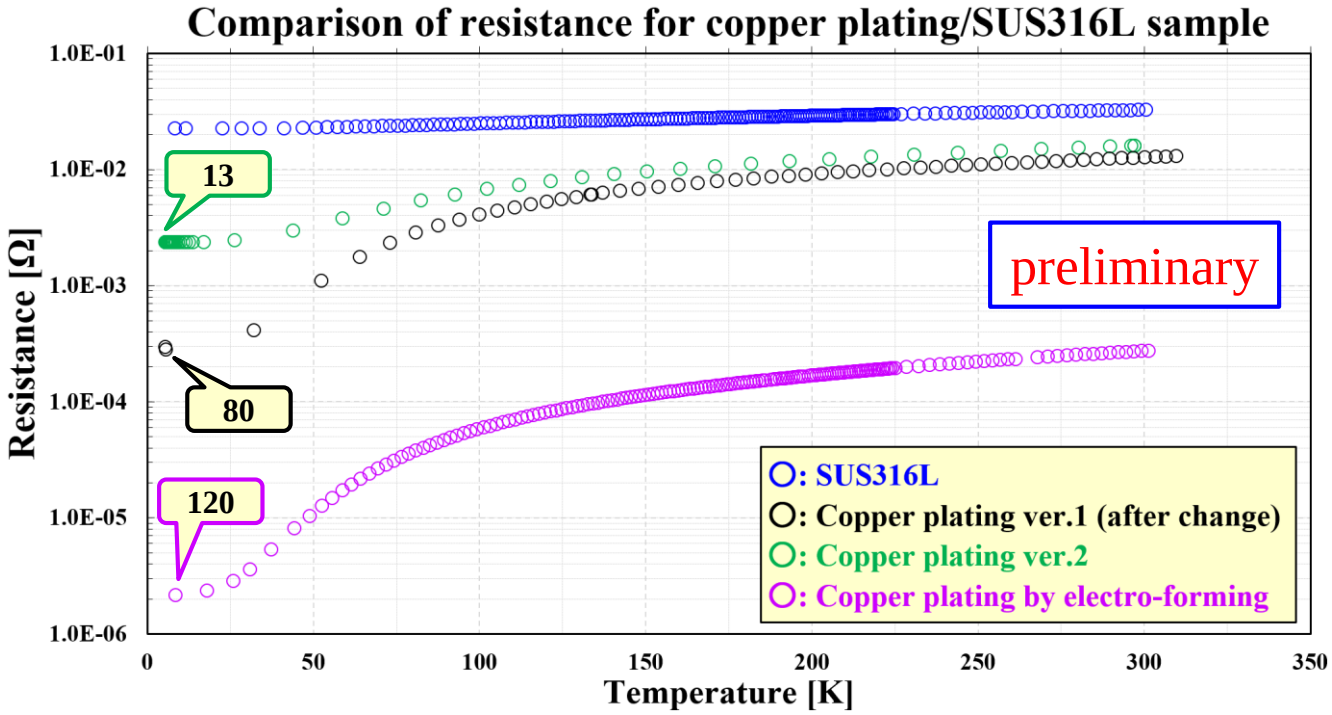


Copper plating sample

Recent results for RRR measurement

- The commissioning test was successfully done
- Copper plating samples from ver.1 to ver.3 were fabricated and tested
- Crosscheck test for RRR was successfully done by IRFU/CEA and DESY
- Copper plating by electroforming method was no problem
- We are investigating cause for lower RRR for thin copper plating samples (~20 μm)

Sample	#	Plating bath	Process to fabricate
Version 1	4	Copper Pyrophosphate ($Cu_2O_7P_2$)	Copper plating → Wire cutting
Version 2	5	Copper Pyrophosphate ($Cu_2O_7P_2$)	Wire cutting → Copper plating
Version 3	6	Copper Pyrophosphate ($Cu_2O_7P_2$)	Electroforming
Version 4	?	Copper Pyrophosphate ($Cu_2O_7P_2$)	Outside company (under fabrication)
Version 5	?	Copper Sulfate ($CuSO_4$)	Outside company (under fabrication)



Future prospect for copper plating R&D

- Searching optimum condition for **thin** copper plating
  - Contamination dependence
  - Temperature dependence
  - Acid difference (copper pyrophosphate, copper sulfate)
- Investigating heat treatment (brazing process) effect
  - 800℃ or 400℃
- Peeling test (adhesion test)
  - Ultrasonic rinsing
  - Tape

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- **Power coupler R&D is under progress in KEK/COI**
- **Ceramic property measurement is steadily on-going**
- **RRR measurement for copper plating is also under progress**
- **These results will be presented in SRF2019 (hopefully summarized)**

Thank you very much for your attention