[WEPAB144] A New Flux Concentrator Made of Cu Alloy for the SuperKEKB Positron Source

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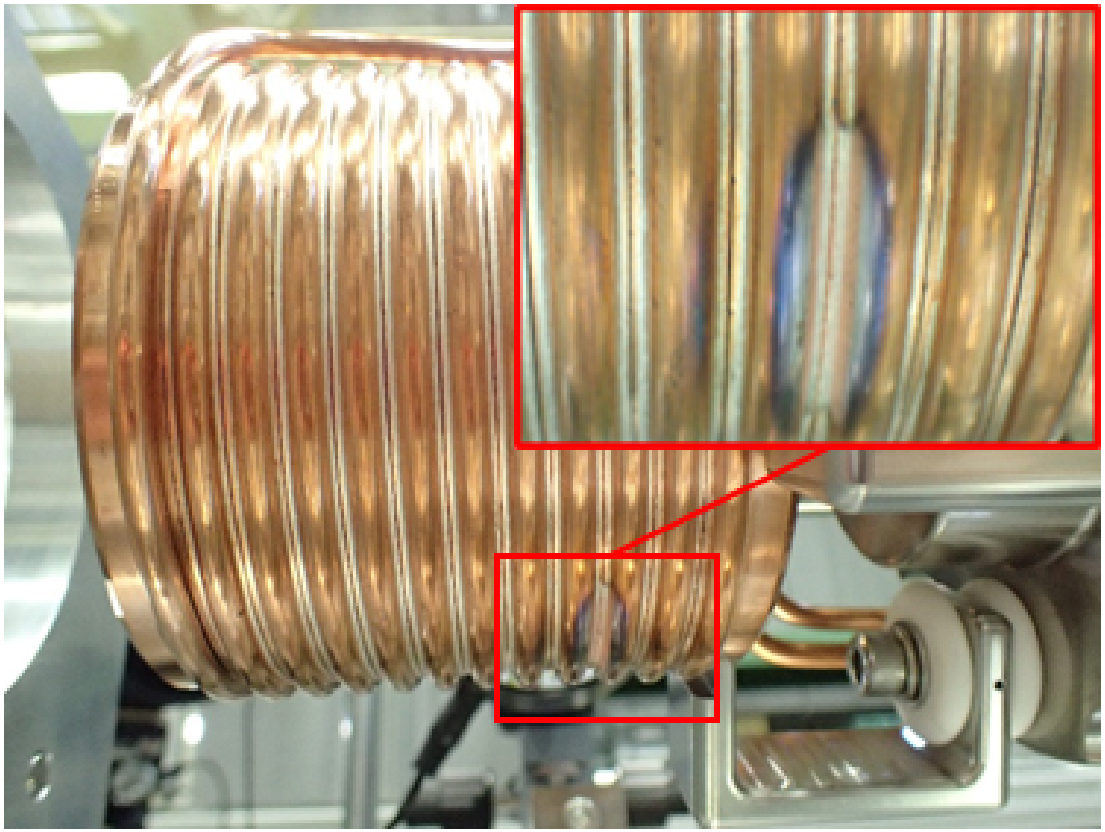
Introduction

- Flux Concentrator (FC) is one of a important device for positron source.
- Higher magnetic field by higher current is desired for better positron yield.
- Strong Lorentz force cause deformation on the coil.
- The gap between each turn of the coil is as narrow as 0.2 mm while the voltage across the gap is as high as 1 kV.
- Discharge is a serous problem.



Change material from pure Cu to Cu alloy which shows better mechanical property

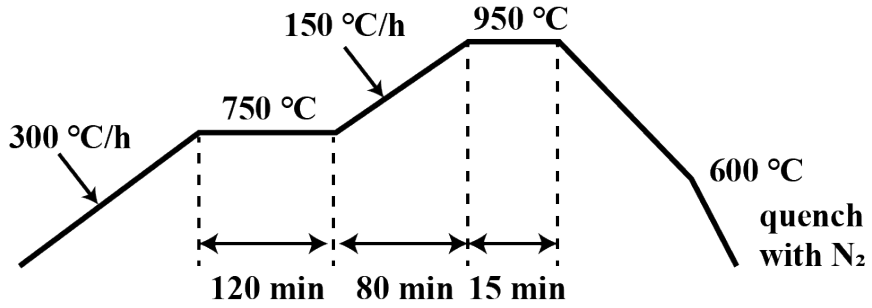
Requirement for material

- In addition to good mechanical property
  - Good brazing property
  - Good thermal property

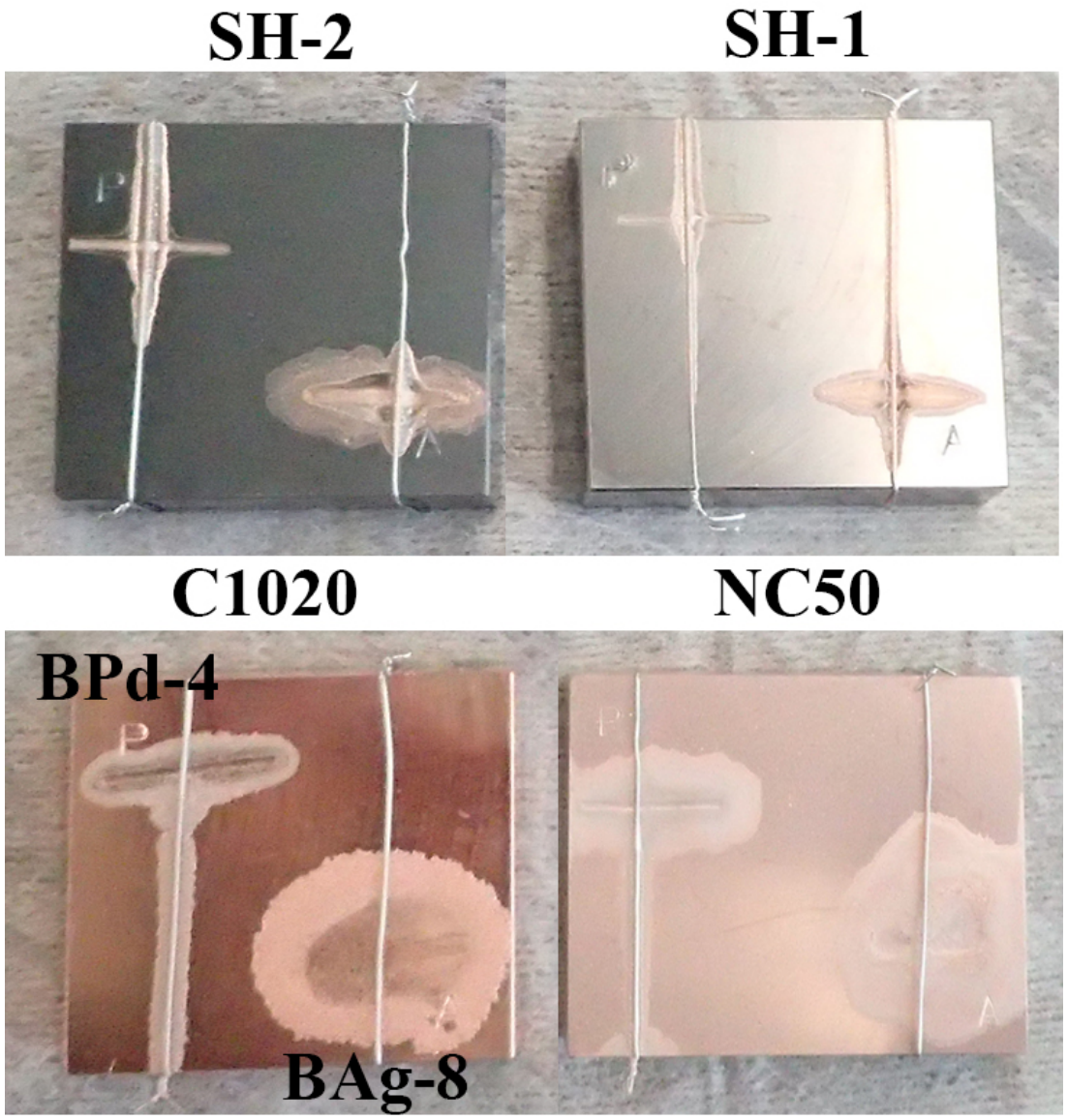
  is necessary.
- Three different Cu alloys (SH-1, SH-2, NC50) were evaluated along with pure Cu for comparison.
  - SH-1 : CrCu
  - SH-2 : CrCuZr
  - NC50 : CuNiSiCrSn
  - Pure Cu : C1020 (JIS)

Brazing property

- Two types of brazing materials (BPd-4 and BAg-8) were tested.
- The brazing materials were fixed on the samples by wire.
- The samples were heated in a vacuum furnace
- Combination of NC50 and BAg-8 showed good result.



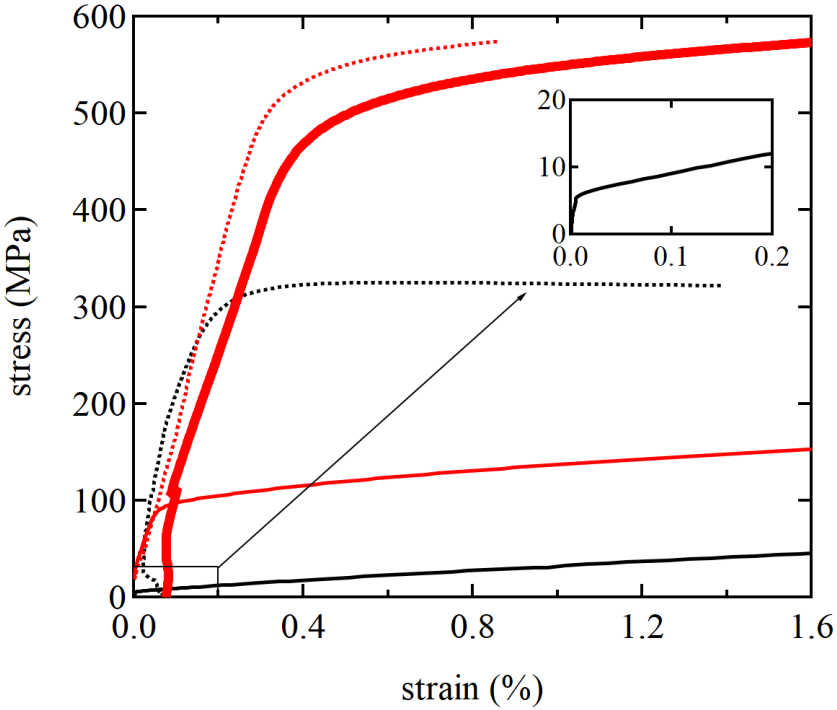
Temperature profile of the brazing test.
The same profile was used for preparing samples of mechanical test.



Results of brazing test

Mechanical property

- Yield strength of pure Cu is 322.3 MPa and 12.9 MPa before and after heat cycle respectively.
- Yield strength of NC50 is 551.8 MPa and 109.7 MPa before and after heat cycle respectively.
- Yield strength of NC50 get recovered to 513.3 MPa by aging
- The value is almost the same as original NC50 value and 40 times higher value than that of pure Cu after heat cycle.



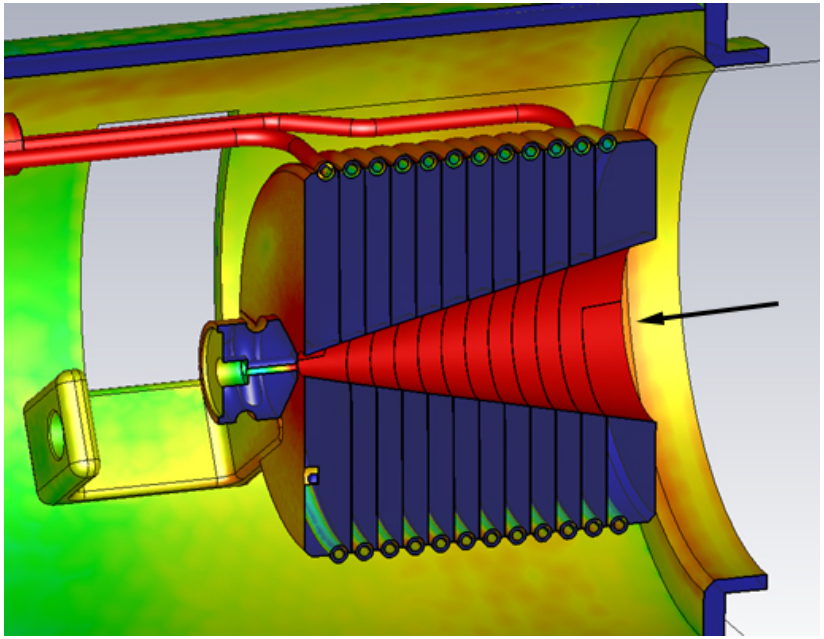
A strain-stress graph of NC50 (red) and C1020 (black).
Dashed line : before heat cycle
Solid line : after heat cycle
Thick line : after heat cycle and aging

Table 1: Summary of mechanical and electrical properties of tested materials

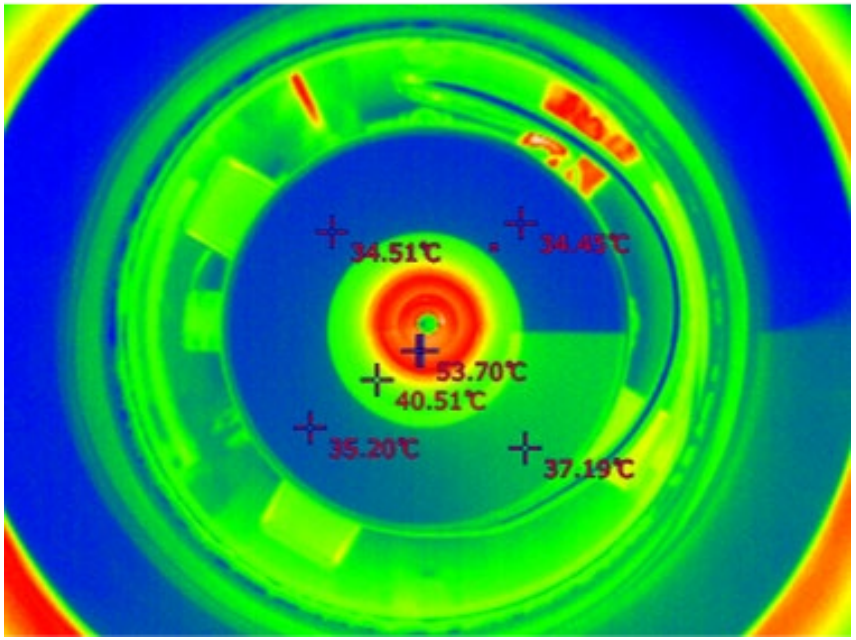
material		C1020		SH-1		SH-2		NC50		
heat cycle		no	yes	no	yes	no	yes	no	yes	yes and aging
electrical conductivity	%IACS	102.2	102.1	90.8	76.0	81.1	68.5	50.3	25.1	48.8
hardness		87.4	30.4	71.6	60.0	45.9	55.8	95.3	61.2	95.4
tensile strength	MPa	327.4	232.1	402.6	237.2	443.1	238.3	648.7	323.7	658.8
elongation	%	21.6	54.4	36.8	56.8	32.6	51.4	14.8	46.6	10.6
yield strength	MPa	322.3	12.9	293.6	57.9	348.2	40.8	551.8	109.7	513.1

Thermal property

- Thermal conductivity of NC50 is half that of pure Cu.
- Pulsed current flows surface of the FC.
- Surface temperature of the FC made of NC 50 was monitored by a infra-red camera.
- Maximum temperature is about 55℃ during full current (12 kA) operation.
- This is acceptable for stable operation.



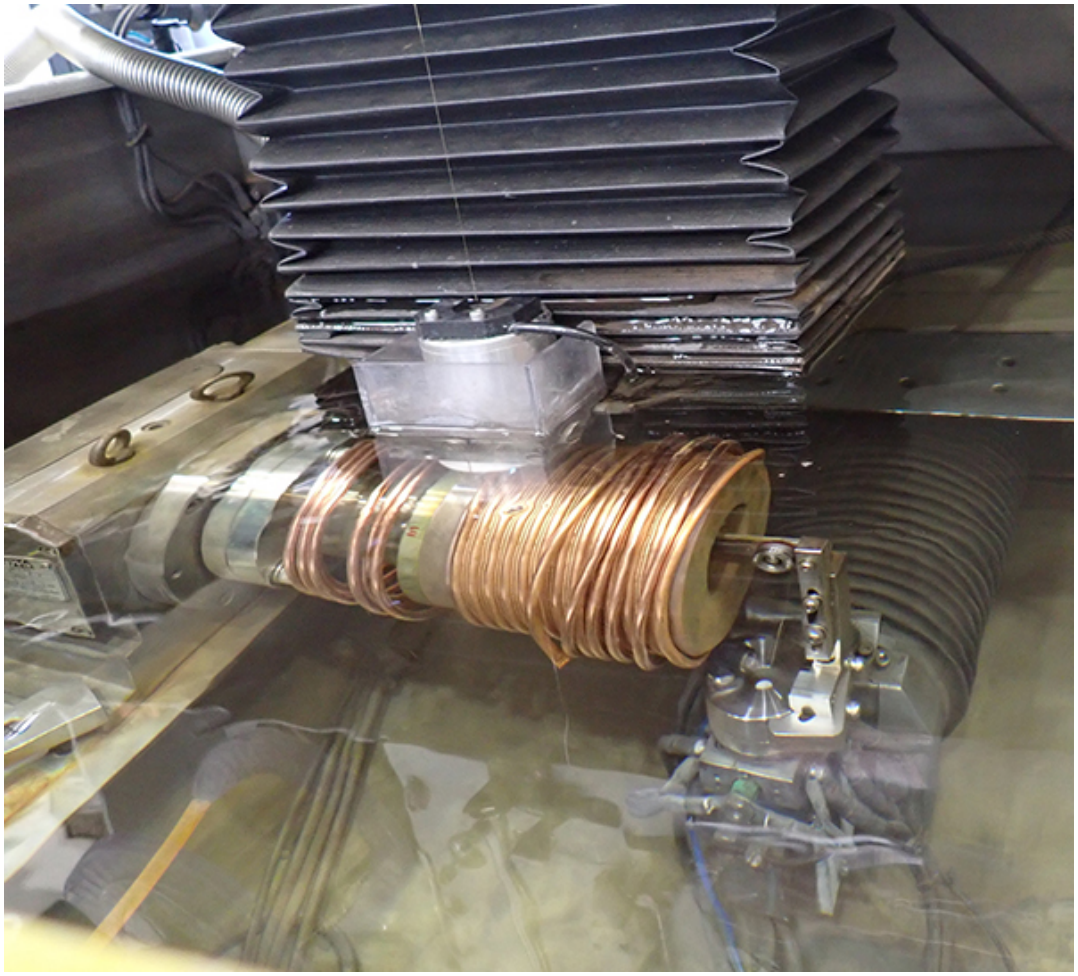
Heat generation distribution by pulsed current simulated by CST studio.



Temperature distribution of the FC measured by a infra-red camera.

Manufacturing procedure

- Make groove outside and taper inside from the NC50 cylinder by lathe.
- Braze Cu pipe to the NC50 block in a vacuum furnace. At the same time solution treatment was done choosing the brazing temperature as high as 950 deg.
- Aging the NC50 block in the in a vacuum furnace.
- Make 0.2 mm wide spiral slit by the special Wire Electric Discharge Machining (WEDM) which has cranked wire guide (right figure).



Wire Electric Discharge Machining (WEDM) of the FC

Summary

- Mechanical and brazing properties of three Cu alloys were evaluated along with pure Cu.
- NC50 shows good brazing property and 40 times higher yield strength than that of pure Cu.
- A new FC made of NC50 was manufactured and installed.
- Although the thermal conductivity of the NC50 is low compared with pure Cu, temperature of the FC in operation is acceptable.
- It has been in operation since Oct. 2020 without any problem such as discharge.