High field experiment with narrow waveguide

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Introduction

- We have been studying on the characteristics of different materials on high-gradient RF breakdown at Nextef (New X-band Test Facility at KEK).
- We have performed experiments by using a reduced cross-sectional waveguide that has a field of approximately 200MV/m at an RF power of 100MW.
- Today’s presentation is about a status report of the high-gradient testing of copper(Cu002) and stainless-steel waveguides(SUS003).
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   - Design
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Narrow Waveguide Design

Rectangular Waveguide: WR90

Wavelength converter: Width 22.86(λ_g ~ 32.15 mm)
- 14mm (λ_g ~ 76.59 mm)

Cosine taper (~1 λ_g): Height 10.16 mm - 1 mm

a field gradient of 200 MV/m
at an RF power of 100 MW

a group velocity of around 0.3c
Fabrication

- Narrow waveguide consists of 4 pieces.
- They were bonded by brazing in a hydrogen furnace at the KEK mechanical engineering centre.

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<th>Cu-002</th>
<th>SUS-003</th>
<th>Cu-004</th>
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<tr>
<td>Anneal</td>
<td>500 °C</td>
<td>1020 °C</td>
<td>500 °C</td>
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<td>Processing</td>
<td>milling, WEDM</td>
<td>milling</td>
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<td>Cleaning</td>
<td>CP</td>
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<td>Bonding</td>
<td>Cu/Au/Ni, hydrogen furnace</td>
<td>Cu/Au, hydrogen furnace</td>
<td>Cu/Au hydrogen furnace</td>
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<td>VSWR @11.424 GHz</td>
<td>1.4</td>
<td>1.12</td>
<td>1.02</td>
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</table>

- Annealing in a hydrogen furnace
- Processing by milling and and wire electrical discharge machining (WEDM)
- For the E-plane where the electric field is applied, the surface was finished by milling.
- The pieces were chemically polished 10 µm in an acid solution.
2. Experimental Setup
   - CU002 at XTF
   - SUS003 at Nextef
   - Scheme of RF Processing
Cu002 Setup for High-Power processing @XTF

- Narrow waveguide
- Acoustic sensors
- PMT 1, 2, 3, 4
- High power Dummy Load

The first high-power test of copper (Cu002) was done at XTF (previous X-band Test Facility at KEK).
SUS003 Setup for High-Power processing @ Nextef

- PPM Klystron
- Narrow waveguide in 5mm lead shield
- Acoustic sensors
- High power Dummy Load
- PMT 1, 2, 3, 4

- Cu002
  - tested at XTF (06.11 ~ 07.01)
  - Moving to Nextef (~ 07.04)
  - Using for system checking (~ 07.05)
- SUS002
  - Tested at Nextef (~ 08.01)

We are on going high power testing of stainless-steel(SUS003) at Klystron Test Stand.
- Basically, working an interlock system when a reflect power is larger (vswr>1.4) and vacuum becomes worse to protect RF components.
- Options:
  - We control fixed time step and power step.
  - We had many rf break down in a short time after breakdown cause worse vacuum condition.
  - We are able to do processing during only day time (9:00 -20:00).
We're seeking for ways of processing.

Controlling time step (flexible)

Controlling power step by limiting Vac. (flexible)

Processing time is almost 24
3. Results of High-Power Testing

- Breakdown location
- RF Pulse width vs. Max. Electric Field
- RF Power vs. number of BD events
- Accumulated number of breakdown events vs. \( P \times T^{0.5} \) during processing
- Observation of Cu002 surface
Breakdown location

Acoustic sensors

Area of frequent breakdowns

PMT6
PMT5
PMT5
PMT4
PMT3
PMT2
PMT1
SUS003 attained higher electric field than Cu002 with few break down events.
RF Power vs. number of BD events

- Many breakdown events at pulse width of more than 100 ns and at the power of 20 MW.
- Few RF breakdown events at 50 ns and 100 ns.
- We had a guard window problem around 200 ns.
Accumulated number of breakdown events vs. P*T^0.5 during processing

Cu002 had much BD events than SUS003.

The temperature related parameter, P*T1/2, attained approximately 400 MW·ns1/2 of Cu002 and 1000 MW·ns1/2 of SUS003.

P*T^0.5 - the product of RF power and the square root of the pulse width.
We are trying to measure the BD rate after processing.

We put on the constant power every four hours at 50 Hz.


Many breakdown damages were seen on the E-plane surface.

The surface is intensively damaged, and it could also melt due to breakdown.
Observation of Breakdown surface (top) by SEM and Laser Microscope
Summary

- RF breakdown studies on different materials have just started.
- Prototype Cu002 and SUS003 had been tested under different system conditions.
- The number of breakdown events of SUS003 are less than that of Cu002. However, there’s the possibility of being caused by different systems.
- We’re seeking a processing scheme and an estimating BD rate.
- We’re preparing to observe the surface of SUS003 after high-power processing.
- We’re going to test Cu004, other stainless-steel waveguides, and plan to test different materials in the future.