Surface observation of Scanning Field Emission Microscope and Cu/Mo, Cu/S.S Clad-material Cell Development for High Gradient X-band Structure

XB-10 Workshop
30 November 2010

KEK
Y. Higashi
Contributors

KEK
T. Higo, S. Matsumoto, K. Yokoyama, N. Kudo
Zhang Xiaowei

SLAC
S. Tantawi, V. Dolgashev

INFN
S. Spataro
Outline

• Scanning Field Emission Microscope
• Hard materials single cell SW structure (no high temperature bonding or brazing)
• In-situ microscopic observation of metal surface
Motivation

• The fabrication technologies for X-band high gradient accelerating structures have been studied at KEK with SLAC, INFN and CERN. A scanning field emission microscope has been developed at KEK for the observation of the microscopic surface defects which may be related to the breakdown trigger.

• It is theoretically discussed and experimentally shown that the surface damages due to the pulse surface heating may cause the breakdowns. We propose accelerating structure cells which are composed of clad material with the hard copper in the high pulse surface heating area (to mitigate pulse heating damage) and the high melting point material (Mo, Stainless Steel) in the high electric field area (to mitigate breakdown damage). Such cells are being prepared for the studies of fundamental breakdown phenomena.

• Material fatigue due to the pulse heating is of importance for high gradient structure design. We propose microscopic precise is-situ observation of the fatigue phenomena. These measurements are under preparation at SLAC/KEK.
High Gradient study

In-Situ Observation
1. Observation of surface deformation due to pulse heating using laser interferometer (ready)
2. Pulse heating temperature measurement by IR (ready)
3. High resolution microscopy (ready)
4. Particles observation using laser scattering (under studying)

Materials
1. Cu/Mo, Cu/Stainless Steel Single Cell SW structure (almost ready)
2. 6N, Mo 4mm choke SW structure (fabrication)
3. Cu/Beryllium alloy

Surface Treatment
1. Chemical Polishing
2. Electro Polishing
3. Dust Free
4. High Temp. Vacuum Baking (control residual gas content)
Scanning Field Emission Microscope Configurations

- Tungsten tip: < 1 micron radius
- Tip movement: linear stage + PIEZO mover
- Gap: 1 micron
- XY stage stroke +/- 6mm (rough 50mm)
- High voltage ~1 KV
- Pico-ammeter: ~pA resolution
- In-situ gap sensor: 0.1 micron resolution
- Microscope
- Residual Gas Analyzer
- Vacuum gauge
- Vacuum level: 10^-8 Pa
- Chamber size: 400 mm diameter and 300 mm height
Experiment Preparation

- Parallelize sample surface and stage movement
  - $<0.5 \mu m/5mm$ stroke
- Vacuum chamber baking
  - $150 \text{ deg.C}$ for 10 hours
- W-tip aging
  - $200V@\sim1\mu m$ gap for 10 min period
- Absolute gap measurement
  - Capacitance gauge, PIEZO actuator
Measurement circuit of Scanning Field Emission Microscope
Scanning Field Emission Microscope

- Chamber inside
- W tip radius <1μm
- Scanned surface
Sample and moving stages

- PIEZO actuator
- Capacitance gauge
- W-Tip
- Sample
- XY stage
Surface Scan

Etched surface

2mm scan

Mirror surface
Current for Different Bias

![Graph showing current for different bias levels at various time points with labels for 40V, 50V, 60V, 65V, and 'Light on'.]
Measured field emission distributions
We found no surface damages after scanning on mirror surface

Before scanning

After scanning
Etched surface scanning

Possible breakdown pits
PMT and Emission-current signals during breakdown event
Example of XY scan, 2µm resolution, bias=200V
2010/10/15
Hard material, Cu/Stainless Steel and Cu/Mo Single Cell SW structure development

It is theoretically discussed and experimentally shown that the surface damages due to the pulse surface heating may cause rf breakdowns. We propose accelerating structure cells which are composed of clad material with the hard copper in the high pulse surface heating area (to mitigate pulse heating damage) and the high melting point material (Mo, Stainless Steel) in the high electric field area (to mitigate breakdown damage). Such cells are being prepared for the studies of fundamental breakdown phenomena.
Hardness change due to annealing temperature for different copper and copper alloys
Hardness measurement results after HIP of Cu/SUS and Cu/Mo

Stainless Steel ring

[SUS316L] Cu/SUS

[SUS316L] Cu/Mo

5N-Mo
No high temperature bonding or brazing
Single cell SW structure

Be carefully studying rf contact and vacuum shelling
1C-SW-A3.75-T2.6-TripleCh-Mo
Triple choke structure
Assembly test

Silver coated ring with edge
Electro Polishing of Mo
Electro Polishing of Copper
In-situ observation of RF pulse heated surface

Material fatigue due to the pulse heating is of importance for high gradient structure design. We propose microscopic precise is-situ observation of the fatigue phenomena. These measurements are under preparation at SLAC/KEK.
How to observe in the RF pulse
A new pulse heating cavity for In-situ observation

Design and fabrication by SLAC
A new choke cavity for In-Situ observation

Design and fabrication by SLAC

A new choke cavity fabrication
November 24 at SLAC
Laser interferometer for in-situ observation of pulse heating surface

YAG laser ($\lambda=532\text{nm}$) 4W

Sample

High speed CCD Camera + (I.I)

Microscope

350mm
Test of the microscope spatial resolution

170 μm wire

25 μm wire

Sample surface
Observation of fringe pattern

Fringe \((\lambda/2)=0.266\mu m\)

Surface gradient

Fringe \((\lambda/2)=0.266\mu m\)
Main specifications of microscope and interferometer for in-situ observation rf pulse heating

- Microscope (350 mm distance)
  - View area: 2x3 to 4x6 mm depend on zoom
  - Spatial resolution: 7 μm max

- Laser interferometer
  - View area: 2x3 to 4x6mm depend on zoom
  - Spatial resolution: 5 μm max
  - Surface gradient: 0.1μm/10μm
Thermo Vision CPA-T340 (Chino Co. Ltd.)

Specifications

Measured temp.: 0~350 degC
Resolution: 0.08 deg. C
Frame-rate: 60 Hz
Laser Pointer for target
Measured area: 30x30mm
Interface: USB
summary

• Scanning Field Emission Microscope
  Test was started but sophisticate physics data of the surface defect is not yet observe.

• Hard materials single cell SW structure
  (no high temperature bonding or brazing)
  Cells fabrication completed. Surface treatment and rf contact with good vacuum shelling engineering is under studying. Needs more 1 month. They will be shipped to SLAC by end of next January

• In-situ microscopic observation of metal surface
  Bench test will be started with existing cavity at KEK after this workshop.
  Then will be shipped to SLAC by the end of this year