LOW TEMPERATURE BRAZING TECHNIQUE FOR ACCELERATORS

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Abstract

Low temperature brazing methods have been proposed to join SiC (Silicon Carbide)-ceramic to copper while at the same time reducing deformation of the resultant structures.

Low temperatures brazing alloys such as Sn(90%)-Au(10%) which has a 309 ˚C melting temperature have been used with success. The technique will be used for the Shintake type (choke mode) HOM (Higher Order Mode) free accelerating structure operating at a frequency of 5712 MHz, and for high power SiC dry type rf-loads for the LC1 linear collider.

1 INTRODUCTION

From the experimental results of SLC and LEP, it is estimated that the Linear Collider-1 (LC1) project, which is proposed for the next generation of high energy physics research, will be required to have collision energies in the 0.5 to 1 TeV region [1].

Multi-bunch beam operation is essential for the high luminosity needed by physics experiments. Thus, progress in HOM free structures is one of the most important R&D issues in realization of the linear collider.

In 1992, T. Shintake proposed a very simple choke mode type HOM free accelerating structure which would not suffer from the wake field problem. It was used to successfully accelerate a beam at KEK (July, 1994) with an accelerating gradient of 50 MV/m and an input rf-power of 120 MW [2, 3].

At that time, the structure did not have any HOM absorbers, because the main purpose of the experiment was to confirm the performance of the novel structure with an accelerating field gradient of up to 50 MV/m, and to compare the HOM power measurements with calculated values. Further, it was decided that at the time, brazing technology was perhaps a bit inadequate for application to the high power structures.

The next step of the R&D program was begun in 1995. A C-band (5712 MHz) high power choke mode type HOM free structure is now being developed.

SiC-ceramic is one of the best materials for a microwave absorber and has been adopted for the high power dummy load at the KEK-PF linac and the ATF injector [4]. SiC ceramic type HOM absorbers will be installed and an in-line dummy load also will be loaded on the last few cells.

This paper will describe the experimental results of low temperature brazing to join copper and SiC-ceramic.

2 LOW TEMPERATURE BRAZING MATERIALS

Conventional high temperature brazing materials for SiC such as Ti-BAg-8 (Titanium-Copper-Silver alloy) have a melting temperature in the range of the 850-900 ˚C. Thus, it is impossible to use it to join a large area of SiC to copper, because of large internal stresses that would remain at the junction between the two materials. SiC-ceramic and copper have very different thermal expansion coefficients of $\sim 4.6\times10^{-6}$ and $\sim 2\times10^{-5}$ respectively. Therefore when using Ti-BAg8 it is typically necessary to insert a thin (~1 mm) filler of Tungsten (W) or Molybdenum (Mo) to reduce the internal stresses at the junction. The filler shim is inserted between the SiC and copper, and has the same shape and area as the SiC. The thermal expansion coefficient of W and Mo is about $\sim 5\times10^{-6}$.

Low temperatures brazing methods have already been widely using in the semiconductor industry because of environmental concerns. Sn (tin) alloys are the most commonly used low temperature brazing materials, because they have wide range of brazing temperatures depending on the percentage of the component elements, see Table 1.

Table 1: Typical Sn alloy low temperature materials

ELEMENTS	MELTING TEMPERATURES (˚C)
Sn - Bi	139
Sn - Au	217, 252, 280, 309, 498
Sn - Sb	246, 320, 325, 425
Sn - Ag	221, 480, 724

Furthermore they can be used for vacuum seals even at very high vacuums since they have low vapor pressures. For this study, we used a Sn-Au alloy composed of 90% Sn and 10% Au.

3 BASIC CHARACTERISTICS OF A SiC CERAMIC HOM ABSORBER

SiC powder is produced by a chemical reaction between silicon-dioxide (SiO_2) and carbon-black (3C) powder at a temperature in the range of 1500 to 1800 ℃ in an inert atmosphere:

$$SiO_2 + 3C = SiC + 2CO. \quad (1)$$

SiC-ceramic may be made from SiC power by sintered in a vacuum furnace at 2100 °C. The basic characteristics of the SiC-ceramic are listed in Table 2.

SiC-ceramic has some very attractive characteristics for application to an HOM absorber or a high power vacuum rf-load. In particular: (1) Large heat conductivity, (2) Exceptionally large hardness and abrasion-proof properties, (3) Light weight, (4) Excellent heat and oxidation resisting properties, and (5) High chemical stability against most reactive chemicals, gases, etc. Further it is important to note that SiC-ceramic has a large microwave loss with a broad-band frequency response as measured by microwave network-analyzer in this study.

Table 2: Basic characteristics of SiC ceramic

Density (g/cm^2)	3.14	
Hardness (Knoop, kgf/mm^2)	2900	at room temp.
Thermal conductivity (cal/cm•s•°C)	0.19 0.14	at room temp. at 600 °C
Thermal expansion coefficient (1/°C)	4.6 x 10^{-6}	room temp. to 1200 °C
Oxidation weight gain (mg/cm^2)	0.015	at 1200 °C for the 24 hours
Resistivity (Ω•cm) at DC	5 x 10^5 7 x 10^{-1}	at room temp. at 800 °C
Dielectric constant	31	at 2856 MHz
Loss tangent	5 to 6 x 10^{-1}	0.5 to 20 GHz

4 APPLICATION TO THE CHOKE MODE STRUCTURE

We started with a very basic study using samples small in size and with simple shapes. A low temperature brazing Sn-Au material with a melting temperature of ~309 °C was used.

First, a brazing test was carried with OFHC (Oxide Free High Conductivity) copper to copper to find the optimum temperature (candidates: 300, 325 and 350 °C). The test samples had a simple bar shape 2 cm in diameter and 5 cm long as shown in Figure 1.

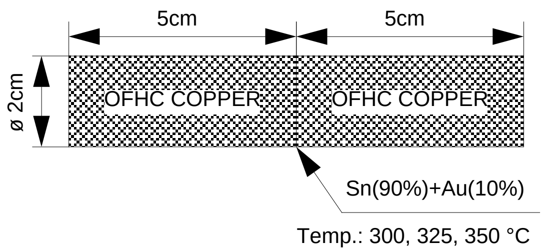

Figure 1: OFHC copper samples.

Next samples of SiC-ceramic and OFHC copper having the same 2 cm diameters and lengths of 2 cm and 5 cm were assembled as shown in Figure 2.

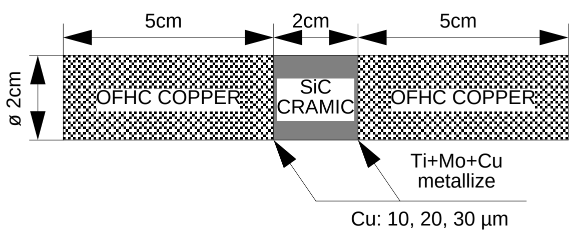

Figure 2: SiC-ceramic and OFHC copper samples.

The SiC-ceramic samples were metallized on both ends with Ti+Mo+Ni+Cu, because at low temperatures neither the SiC-ceramic nor the copper surfaces wet well. In this study, the thickness of the Ti+Mo+Ni layer was held constant, and Cu with three different thicknesses of 10 µm (samples #1 & #2), 20 µm (samples #3 & #4) and 30 µm (samples #5 & #6) were tested. Each sample was stacked together as shown in Figure 2, and a brazing cycle at 325 °C was done in a vacuum furnace.

The quality of brazing was tested by measuring tensile strength. The six samples were fractured at the join between the SiC-ceramic and the copper bars with results listed in Tables 3 and 4.

Table 3: Tensile strength of Cu - Cu brazed joints

	Temperature (°C)	Fracture Force (kgf)	Tensile Strength (kgf/cm^2)
#1	300	265	143
#2	300	598	233
#3	300	273	252
#4	325	290	196
#5	325	132	282
#6	325	290	298
#7	350	249	79
#8	350	255	81

From Table 3, the data shows that the optimum brazing temperature is 325 °C for the Sn(90%)Au(10%) alloy. Joints made at this temperature should have tensile strengths sufficient for accelerating structures.

Table 4: Tensile strength of SiC-ceramic - copper joints, parameterized by thickness of the Cu metallization.

	Thickness of Cu (µm)	Fracture Strength (kgf)	Tensile Strength (kgf/cm^2)
#1	10	265	84
#2	10	598	190
#3	20	273	87
#4	20	290	92
#5	30	132	42
#6	30	290	92

From Table 4, we see that the resulting tensile strengths were quite variable, but in all cases less than 33% of the pure Cu - Cu joint (at 325 °C). Nevertheless, with the exception of sample #5, the samples have at least 80 kgf/cm^2 tensile strengths, which should be adequate for fabrication of the choke mode HOM free acceleration structure and also conventional structures. The vacuum leak rate of all samples at the junction was lower than the detector sensitivity.

Figures 3 and 4 show the fractured cross- sectional view of the Cu-Cu and the Cu-SiC-ceramic-Cu samples.

5 CONCLUSIONS

Sn-Au low temperature brazing at 325 °C in a vacuum furnace was successful in joining SiC-ceramic to OFHC copper bars. The vacuum leak rates of all the samples were lower than the detector sensitivity. The samples have tensile strengths on the order of 260 kgf/cm^2 for the Cu-Cu and 80 kgf/cm^2 for the SiC-ceramic-Cu joints.

Thus, it was concluded that the low temperature brazing method has enough tensile strength to fabricate choke mode structures as well as other conventional structures. Further, it should result in reduced structural deformation caused by the brazing process [5].

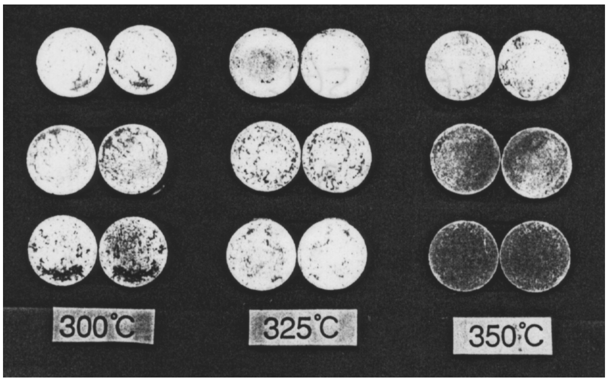

Figure 3: Fractured cross sectional view of the Cu-Cu joint.

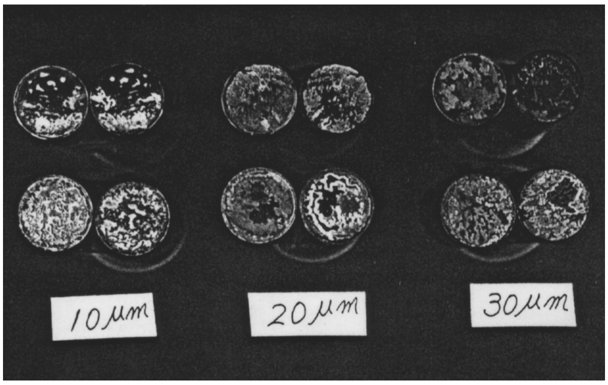

Figure 4: Fractured cross sectional view of the Cu-SiC-Cu joint.

6 ACKNOWLEDGMENTS

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