PRECISE FABRICATION OF X-BAND DETUNED ACCELERATING STRUCTURE FOR LINEAR COLLIDER

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The precise frequency control of the dipole modes in all of the cells in a structure in addition to the control of the accelerating mode is one of the key issue to realize a detuned structure for the main linac of the linear collider. The present approach is to machine the accelerating cell precisely with the use of the ultra-precision machines and keep the precision through the following fabrication processes such as the diffusion bonding aiming at the precision of the dipole-mode frequency better than 0.01%. In addition to this frequency control, the cell alignment should be a few micro meters and this criteria will be accomplished by the precise machining of the outer surfaces of the cells followed by the alignment along a good vee block.

In the present paper are presented some of experimental results on the fabrication of 30cm-long structures. The bonding at the temperature above 800˚C was found reliable to obtain the vacuum tight junction. The change of the accelerating mode frequency was found to be less than 1MHz out of 11.4GHz but it seems to have a pressure dependence. The study of 132-cell bonding test was also performed and the alignment of 40 microns along 1.2m stacking was obtained though a severe trouble happened to the jiggings.

Based on these experiences, the possibility of a precise fabrication method for the detuned structure in full size is discussed.

I. INTRODUCTION

Two most important issues to keep the long-range wake field in the accelerating structures of the linear colliders operated in a multi-bunch scheme are (1) frequency control of the dipole mode and (2) alignment of the cells in the structure. In the design of JLC[1], the relative tolerance of the frequency is 10^{-4} and the alignment of the order of a few micrometers. In addition to these characteristics, the structure should be operated in fairly high accelerating field with less dark current and they should be made in mass production of several thousands of them.

Keeping these in mind, the study on a precise fabrication has been started[2]. Even if the cells are machined in very good precision, the brazing process introduced large frequency shift due to the process. Therefore, we decided to study the possibility to apply a diffusion bonding technique between flat surfaces at a lower temperature and with a low pressure[3].

In the present paper are described some of the performances and characteristics relevant to the diffusion bonding for the cells which are fabricated in ultra-precision lathes and discuss the feasibility of this methods to the fabrication of the structure of linear collider main linacs.

II. MACHINING CELLS

As a first step of the study, some 30-cm long constant-impedance structures were fabricated. The dimensions of the cells was described elsewhere[3].

The positioning of the bite is controlled by comparing the outer diameter of the machined cell to the reference periodically. The most important parameters of the cells, the frequencies and the outer diameters of the machined cells were checked from cell to cell. Typical results are shown in the Fig. 1. The frequencies of the cells are measured using dummy flat surface with choke to trap the mode with a similar field pattern to that of the accelrating mode. The standard deviation of the measured frequencies is 0.1MHz/11.4GHz which is small enough for the detuned structure. The deviation of outer diameters from the reference value is ±0.5µm, which should be kept to realize the alignment of the cells along the structure better than one micrometer.

III. DIFFUSION BONDING

In order to make several thousands of structures, it is necessary to join nearly one million cells. Therefore, it is important to apply a method with good reliability and

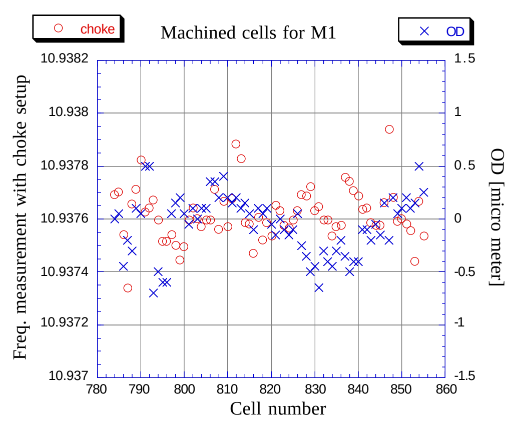

Fig. 1 Measured frequencies (solid circle) and outer diameters (crosses) of the cells for 30cm structures.

Table 1. Typical parameters of three 30cm-long structures.

Type	units	1	2	3
Insert		Au	Non	Au
Thick	μm	2	-	1
Temp	˚C	890	800	800
Period	min	10	60	10
Pressure	g/mm^2	10	3	5
Vacuum		OK	OK	OK
Δf	MHz	~ -1.0	~ 0	
$\delta F_{\pi/2}$	±MHz	0.5	0.7	0.5
$\delta\phi$	degree		±1˚	±1.2˚
Exp(-τ)	dB	-1.494	-1.273	-1.31
Q / Q_{cal} †	%	81	95	93

† Calculated from the attenuation along the structure, Exp(-τ).

cheapness for the mass production. The frequency change due to the brazing sometimes become several MHz, which is not allowed for frequency control point of view. Therefore, the extensive studies on the joining methods without liquidizing the materials for joining have been performed[3].

A. 30cm structures

Typical parameters which were applied to make 30cm-long structures are listed in Table 1. In addition to those parameters of the bonding process, the reliability of vacuum tightness largely depends on the quality of the bonding surface. The flatness of the present machining is better than 0.3μm over full 80mm in diameter and the surface roughness is set to 50nm.

As shown in the table, the control of the accelerating mode frequency was kept less than 1MHz. One of the measurement of the frequencies of the pseudo π/2 mode in the cells of a structure before and after the bonding are shown in Fig. 2 for the case of type 2. The measurement was performed by detuning the adjacent cells using two plungers equipped with antenna and measuring transmission between those antennas. The frequency shift due to this type of bonding is quite small, though there was a slight dependence on z-position along the structure, which may reflect the dependence of the pressure applied to the junction.

B. Frequency shift dependence on pressure

All the bondings are performed in vertical furnaces at present. Therefore, for the case of full-size structure, the extra weight of more than 50kg due to the self weight above the relevant cell is added and the contact pressure at bottom is 3 to 4 times larger than that of the top. In Fig. 3 are shown the dependence of the frequency shifts due to the bonding of type 2 on the pressures applied to the bonding surface. The frequency shift of the mode with high phase advance per cell is large, reflecting the dimensional change of z-direction. This may also introduce big changes in frequencies of the higher modes with nodes in a cell such as those of TE111 and TM111. This effect on the accelerating modes can be canceled by applying dimensional offsets for the cells to maintain the frequencies along the structure. In addition, this kind of changes should be smooth function along the structure and therefore it does not perturb the HOM frequency distribution much. The detailed dependence along the full-size structure will be tested soon.

C. Search of other parameter regions

One of the way to reduce this frequency change is to lower the bonding temperature. An example of five-cell stack at 750˚C for one hour at $2g/mm^2$ was also came out in vacuum leak tight. As shown in Fig. 4, the frequency change due to the bonding is less than 0.2MHz/11.4GHz for all of the modes in the TM010 pass bands and less than 0.6MHz for those of the HEM11-like modes.

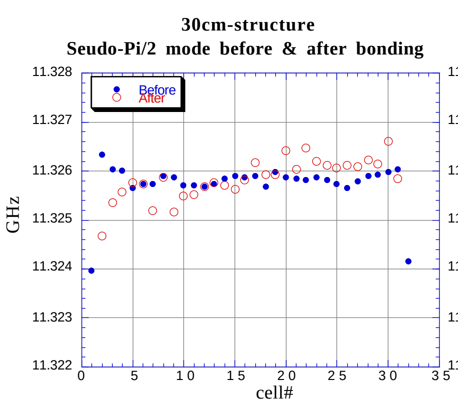

Fig. 2. Frequencies of pseudo π/2 mode in a 30cm-long structure. Solid circles are those before bonding and open circles are those after.

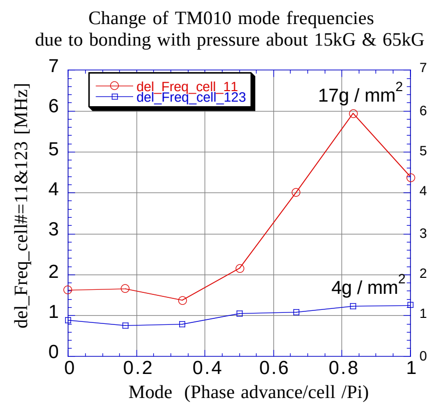

Fig. 3. Frequency differences of the TM010 modes due to the bonding of type 2 with two different pressures applied. The lower pressure corresponds to that at top and the heavier to that at bottom.

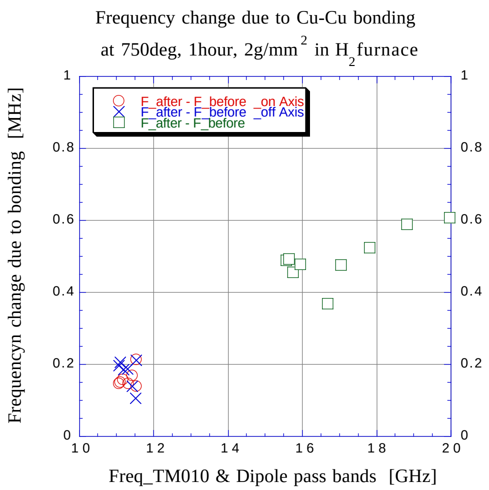

Fig. 4 Frequency shift due to diffusion bonding at lower temperature. Data sitting neat 11.4GHz are those of TM010-like mode while those at 15 to 19GHz dipole modes.

Another test diffusion bonding even at 500˚C came out to be also leak tight where the pressure of 5g/mm^2 was applied between the surfaces with the roughness of 20nm.

From these examples, we hope that there will be a better parameters for the bonding possible at lower temperature than 800˚C.

IV. ALIGNMENT

The outer diameter of all the cells are machined to be better than 0.5µm as in Fig. 1 or better. The concentricity among the outer wall, beam hole and the cell wall is better than 0.2µm, which is automatically fulfilled because the machining is performed without re-setting of the cell. Therefore, the cells can be aligned by putting each of them on a precise vee block. If the alignment is preserved during the following processes, especially the bonding process, we can expect the alignment better than a few microns.

One of the 30cm structures was fabricated followed this idea. The alignment before the bonding was 1µm and that after bonding about 4µm[4].

The same method was applied to a 1.2m, 132-cell bonding test with the parameter the same as type 2. The alignment before bonding was better than 10µm but that obtained after bonding was 40µm. The global characteristics of the alignment after bonding was a simple bending of a half wave length in one direction. We hope to obtain much better alignment by modifying some of the jiggings. The total length was shrinked by about 0.5mm, which correspond to about 4µm per junction. This is comparable to the value, 3µm shrinkage per junction, for the case of diffusion brazing at 890˚C for 10 minutes. This characteristics may have to be considered seriously especially in the bonding of a long structure in vertical furnace.

V. SUMMARY

Several 30cm-long structures were fabricated using diffusion bonding technique. The frequency change due to this bonding above 800˚C was about 1MHz or less though there might be a dependence on the pressure between bonding surface. The alignment of the cells in short structure was better than 4µm, while that of the test of 132-cell bonding was 40µm. The revision to obtain better alignment will be performed soon. Other parameter regions are being studied to find the optimum on frequency control and good alignment in addition to the reliable vacuum sealing.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

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