ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPGW078

PROTOTYPING OF BRAZED MM-WAVE ACCELERATING STRUCTURES*

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Abstract

A braze technique is developed for high-gradient W-band accelerator structures. Thin spacers were used to set the final gap between blocks during the braze process and provide precise control of the operational frequency. To demonstrate the robustness of this technique, we show cold testing results after the various manufacturing steps to monitor and track frequency changes throughout the process, and we show excellent quality of the fabricated test mm-wave structures.

INTRODUCTION

Advanced fabrication and prototyping of metallic rf structures play a fundamental role in advancing accelerator technologies particularly at mm-wave and THz frequencies. With the scaling of the rf structure up to these frequencies [1], conventional fabrication techniques do not achieve the required accuracy and tolerances. Improved manufacturing techniques including diffusion bonding and brazing of split-blocks produce high quality structures when successfully implemented. Development of advanced split-block CNC machining for THz accelerators are strongly leveraged at SLAC to produce high quality beamline components and accelerator structures. Based on these technologies, several structures were developed for mm-wave and THz accelerator applications [2]–[5]. Furthermore, systematic studies of rf breakdown probability in high-gradient mm-wave accelerating structures are being performed [2], [3] to quantify the performance and merits of these accelerating structures.

BRAZED MM-WAVE ACCELERATOR STRUCTURES

Here, we report on the brazing process of W-band single-cell accelerating structures that were fabricated from two split blocks. The main purpose of this study is to investigate the potential impact of the braze joint on frequency shift of the accelerating mode. In particular, we aim at producing single cell W-band accelerator structures with a frequency of the π-mode within <.5% in order to match the rf high power source, since the latter (in our high gradient work [6]) has fixed frequency. We have fabricated test W-band structures from two split oxygen-free copper (OFC) blocks, with four cells per block. Each cell has three identical coupled cavities [6]. In Figure 1 we show an example of the fabricated W-band split block consisting of three coupled cavities operated at the π-mode [6]. The S-parameters of the cavity as measured using a Vector Network Analyzer with coaxial probes are also shown in Figure 1. This fabrication process is closely related to split-block diffusion bonded accelerating structures which were recently reported to operate at high-gradient However the invistigated braze process deployed here has the potential to overcome consistent fabrication defects around the cell iris [6]. When cavities are joined with diffusion bonding at mm-wave or THz frequencies, the resulting gap

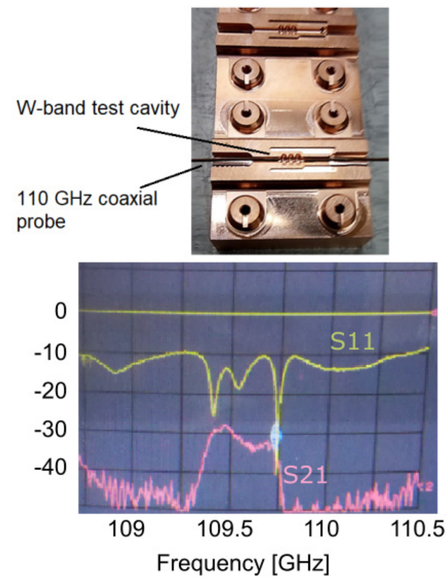

Figure 1: Photo of one of the W-band blocks for braze test (top), and the S parameters measured using mm-wave vector network analyzer with coaxial probes (bottom).

at the iris produces a local field enhancement which is not desireable for high-gradient operation.

We briefly describe in the following the braze process that we have used to produce 13 W-band structures so far in this series. Once the blocks were fabricated they were ultrasonically cleaned and cold tested. Around the alignment pins, 0.001 inch thick Cu spacers were placed in order to set the final gap between blocks during the braze process therefore controlling the final frequency of the π-mode. Cold tests were also done with the spacer. After that, the blocks were cleaned and acid etched, then cold tested again with the spacers. The blocks then underwent the braze process. Around the cavities, 0.002 inch thick braze foils were designed to melt and bond the cavities, and bridge the gap in the cavity walls. During the braze process, the structure is heated above the melting point of the foil but below the melting point of the spacers and the copper blocks. Additionally the structure is clamped together so

* Work supported by the U.S. Department of Energy under contract numbers DE-AC02-76SF00515.

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that the melted foil would assume the gap set by the 0.001 inch spacers.

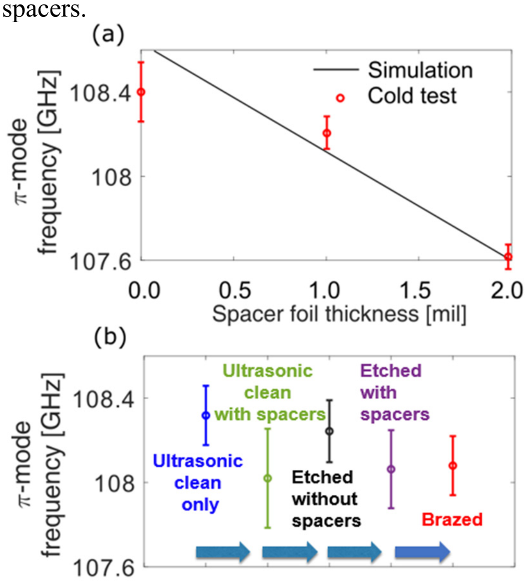

Figure 2: (a) Simulation versus cold test results of the π-mode resonance frequency varying as a function of the spacer foil thickness. (b) Measured frequency of the π-mode throughout the various braze processes.

Before cold testing, simulations were carried out varying the small gap between the block and monitoring the frequency shift. This was done to confirm that there would be significant shift in resonance frequency due to the gap, and that there would be an inversely proportional relationship between the two (Figure 1(a)). Cold testing after the UHV cleaning and etching with the spacers accurately predicts braze results within less than 20 MHz as seen from Figure 2(b). The standard deviation in the cold test data in the shifts must also be considered. Furthermore, our tests show about 220 MHz frequency shift between the cavities with and without the spacers. This reasonably agrees with our simulation shift. These results show that not only could one reasonably predict the post-braze frequency using pre-braze tests, but also that one can correct that frequency by changing spacer size. In fact, we can obtain precisly obtain the desired spacer thickness by etching standard material foils.

After the braze, we have sectioned some of the W-band structures for quality checks. This is done to image the braze joint and potentially correlate the frequency shifts with the joint thickness. In Figure 3(a) and (b) we show two sets of cavities (with their code names 7-8,A and 5-6,A respectively) that were sectioned and imaged using a Keyence VK-X1000 3D Laser Scanning Microscope that provided 3D surface topology of the cavity. The results in Figure 3 show excellent braze joint quality as the joint between the two split blocks are barely visible. Note that although Figure 3(b) shows iris displacement possibly due to pin misalignment, such features are not the main focus of this study and the braze process developed here is independent of this issue.

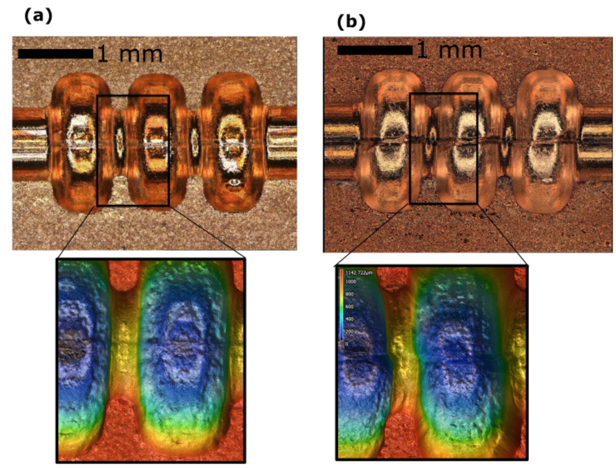

Figure 3: Photo of two sectioned samples of W-band accelerator cavities after brazing (top), and zoomed in images of the surface topology of the cavity (bottom).

CONCLUSION

We have presented cold test results of W-band accelerator cavities throughout our developed braze process. The π-mode resonance frequency is shown to be stable before and after brazing thanks to the accurate placement of a spacer foil that sets the final gap between the split blocks. Moreover, post-brazing quality checks through imaging of the cavities have shown excellent joint quality.

ACKNOWLEDGMENT

We thank M. Cardoso for structure fabrication, A. Nguyen for brazing the structures, and D. Miller for imaging the structures.

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