30 GHZ HIGH-GRADIENT ACCELERATING STRUCTURE TEST RESULTS

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Abstract

The CLIC study is high power testing accelerating structures in a number of different materials and accelerating structure designs to understand the physics of breakdown, determine the appropriate scaling of performance and in particular to find ways to increase achievable accelerating gradient. The most recent 30 GHz structures which have been tested include damped structures in copper, molybdenum, titanium and aluminum. The results from these new structures are presented in this paper.

INTRODUCTION

The CLIC study team is testing different materials and accelerating structure designs in order to find ways to increase achievable accelerating gradient to meet the performance requirements of CLIC. An initial part of this study consisted of testing a series of identical-geometry 30 GHz structures with Cu, W and Mo irises in CTF2 limited to 16 ns pulse length [1]. A new test stand at CTF3 [2] allows testing up to and beyond the CLIC pulse length. It was first used to investigate two 30 GHz Mo and Cu-iris structures (new but identical to the ones previously tested in CTF2) [3-4]. Several structures (scaled to 11.424 GHz) have also been tested at the NLCTA at SLAC during the past few years [5-7].

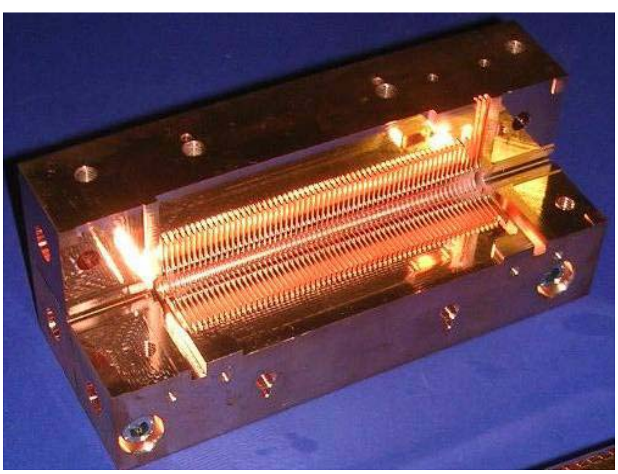

Figure 1: Picture of the HDS60 Cu

This paper reports on the main results of the last five high power tests carried out at CTF3 on four different structures. A complete description of these tests can be found in [8]. Three different geometries (HDS11, HDS60S and HDS60L) and four different materials (Cu, Mo, Ti and Al) were tested during the second half of 2006. The HDS60 structure was tested in two different configurations. We will call HDS60L [S] the one in which the first cell was the larger [smaller] aperture cell. The eleven cells of the HDS11 structures are identical to that of the first cell of the HDS60L.

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Table 1: Main parameters of the HDS11, the HDS60L and the HDS60S structures.

	HDS60L [S]	HDS11
Frequency [GHz]	29.985	
Number of cells	60	11
Phase advance per cell	60^o	
Beam aperture [mm]	1.9 [1.6]	1.9
v_g/c [%]	8 [5]	8
Fill time [ns]	5.2	0.8
E_{surf} / E_{acc}	1.8 [1.7]	1.8
P_{INC} [MW] for 100 MV/m in first cell	43.6 [24.0]	43.6

CONDITIONING HISTORY

Due to space constraints, the conditioning history of just one representative high power test will be discussed in this paper.

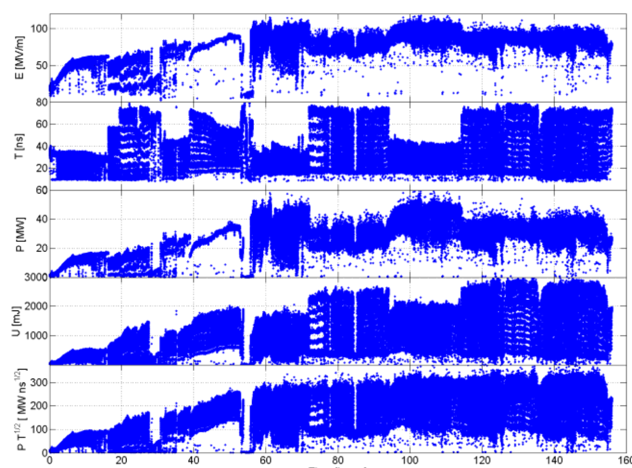

Figure 2: Evolution of the peak accelerating gradient (E), the pulse length (T), peak incident power (P), pulse energy (U) and the $PT^{1/2}$ over the conditioning history of the HDS 11 Ti.

It took around 155 hours to complete the conditioning of the HDS11 Ti. The evolution of the most important characteristics of the rf pulses used are shown in Figure 2. Short pulses (~30 ns) were used at the very beginning.

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However, the pulse length was increased to 70 ns after less than 20 hours because of constraints in the available peak rf power. In general, the availability of enough rf power determined the conditioning pulse length used. Short pulses were used whenever it was possible. No progress was observed during the last 80 hours. In fact, the performance seemed to degrade over that time.

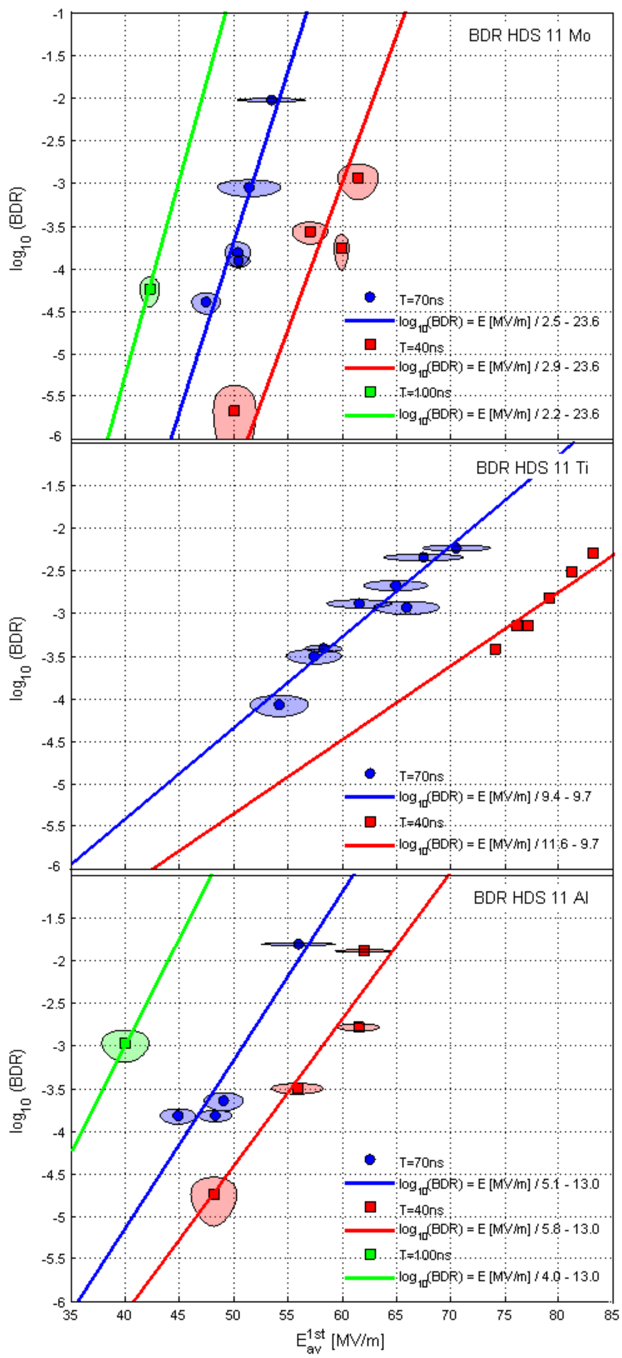

Figure 3: Breakdown rate probabilities of the three HDS11 structures for different pulse lengths and accelerating gradients in the first cell. We have assumed that the pulse length dependence does not change with breakdown rate in the linear fits.

BREAKDOWN RATE PROBABILITY

The breakdown probability at the conditioning limit is quite high (~10^{-1}) but becomes lower as the gradient is lowered. Since CLIC will contain about 10^5 accelerating structures, the required breakdown rate will be of the order of 10^{-6}. In order to help estimate the required gradient back-off from conditioning to stable gradient, the breakdown probability as a function of gradient for different pulse lengths has been measured during the five high power tests. The results of these measurements are shown in Figure 3 and Figure 4.

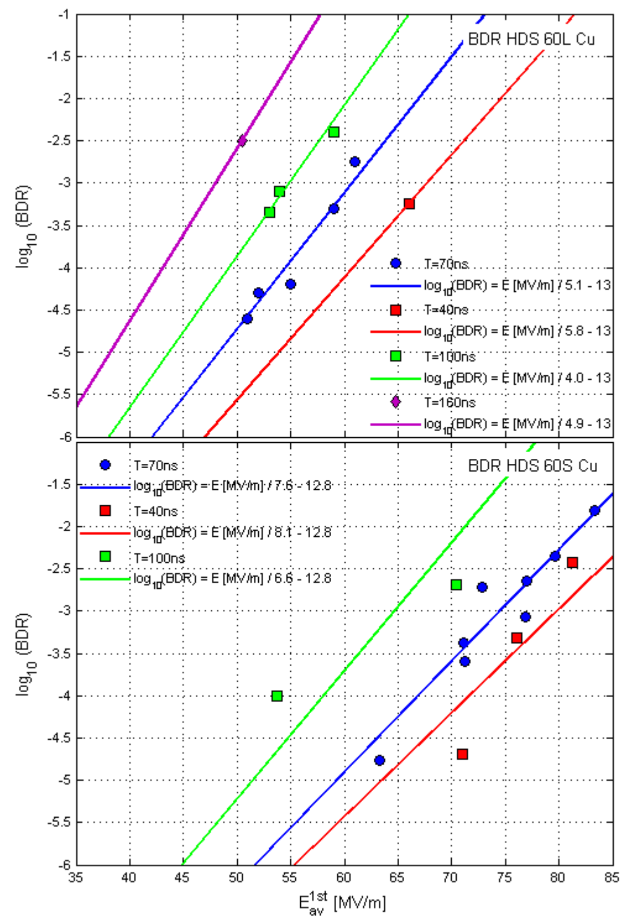

Figure 4: Breakdown rate probabilities of the two configurations of the HDS60 structure for different pulse lengths and accelerating gradients in the first cell. We have assumed that the pulse length dependence does not change with breakdown rate in the linear fits.

PULSE LENGTH DEPENDENCE

Figure 5 shows the summary of the pulse length dependences at 10^{-3} breakdown rate. Despite the moderate small differences in the dependence among different materials, their relative performance with respect to each other does not change in the range of pulse lengths studied. The dependence on pulse length seems to be stronger than previously observed in copper structures tested at the NLCTA. Although, this difference may be intrinsic to the HDS geometry, it could also be explained

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by measurement errors due to drifts of the power source and/or a difference in the definition of pulse length. Further analysis needs to be done to clarify this point.

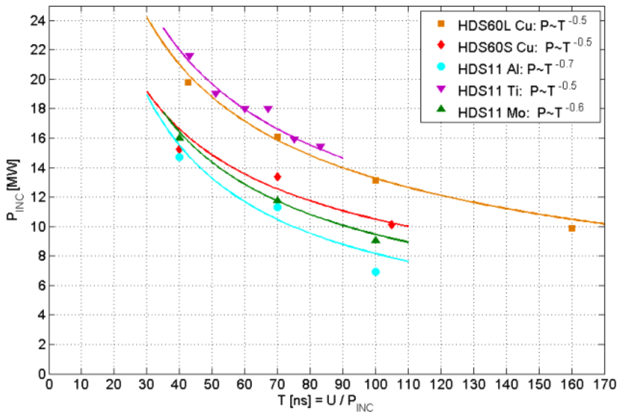

Figure 5: Pulse length dependence of the HDS11 and HDS60 structures at 10^{-3} breakdown rate.

INSPECTION OF THE SURFACE

The surfaces of the structures were observed with an optical and a scanning electron microscope (SEM). Figure 6 and Figure 7 show the damage produced on all the structures by the high power tests (especially dramatic in the case of Ti and Al where metallic cones were formed in the high electric field regions).

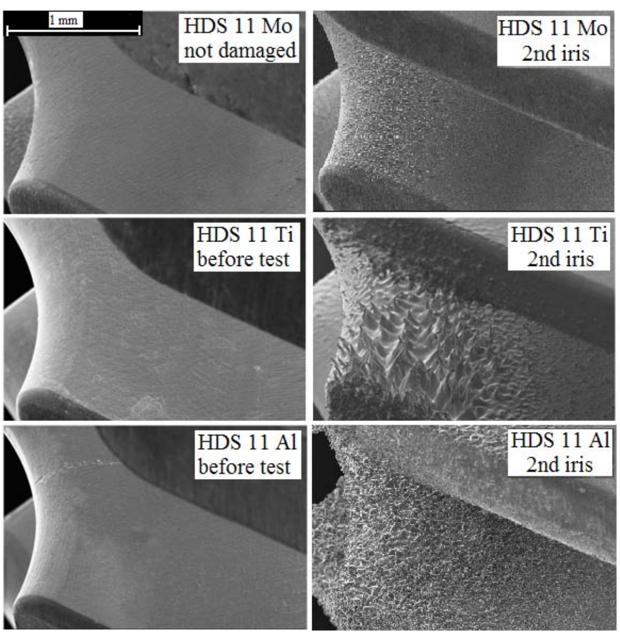

Figure 6: SEM images of damaged (right) and undamaged (left) irises of the three HDS11 structures.

It is interesting to observe how the damage decreases slowly along the HDS60L (where the electric field is almost constant along the whole structure) while it quickly decreases in the HDS60S (where the electric field rapidly goes down). It seems that the accelerating gradient along the structure should increase in order to maximize the energy gain per structure.

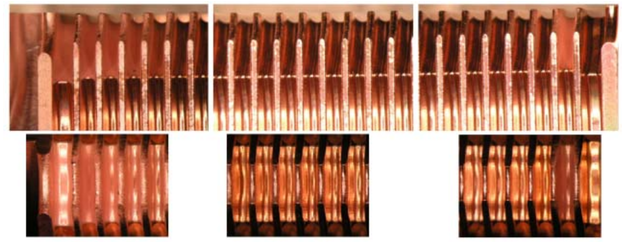

Figure 7: Side and top view of several of the end and central cells of a HDS60 quadrant after the high power tests were finished.

CONCLUSIONS

As was shown in the previous section, the structures were heavily damaged during the high power tests. Therefore, some of the conclusions listed here will need to be verified with additional tests in which the characterization of the structures is done before the damage is produced.

- The performance of the first generation of structures based on quadrant technology seems to be lower than that of circular structures. A second generation of HDS type structures which includes significant improvements will be tested in the near future.
- Neither Al nor Ti nor Mo performed better than Cu at the required CLIC breakdown rates and pulse lengths (i.e. no justification exists to replace Cu).
- Pulse length dependences of HDS type structures may be stronger than for circular structures.
- Improvements in the stability of the power source are required to improve the characterization of new structures.

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