VARIOUS OBSERVABLES OF TW ACCELERATOR STRUCTURES OPERATING IN 100MV/m OR HIGHER AT X-BAND FACILITY, NEXTEF OF KEK

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Abstract

Under the CERN-SLAC-KEK collaboration, we have been developing the high gradient TW accelerator structures. One of the main focuses is the feasibility study of CLIC accelerator structure at X-band. A high power facility, Nextef, was established at KEK in 2007. A few structures have been tested, including an un-damped disk-loaded structure successfully tested beyond 100 MV/m, a heavily damped structure being tested now and a structure made in a quadrant configuration. These structures follow the same accelerating-mode RF parameter profile of the CLIC design, called CLIC-C, but showed very different features at high gradient operation. Various observables, such as dark current, vacuum activity, light emission, breakdown rate, and so on, were measured. We discuss the high gradient phenomena related to these observables.

INTRODUCTION

The collaboration program of the feasibility study on CLIC [1] accelerator structure was started since 2007 mainly lead by CERN, SLAC and KEK. At test facility Nextef of KEK, we have been testing three prototype structures to date. Last year, we have proved the operation of 100 MV/m [2]. Since then, we have tested two more structures, both equipped with heavy damping feature with magnetically coupled damping waveguides facing the accelerator cell. The surface temperature rise within a pulse has been recognized as a possible cause of breakdown trigger, though the mechanism not understood. The two structures tested last year are classified in this group with high surface pulse temperature rise. In the present paper are described those structure test results in various aspects of the high gradient performance to understand the physics behind.

TEST ACCELERATOR STRUCTURES

The test structures were electrically designed by CERN [3]. All the structures are equipped with 18 accelerating cells. The information on fabrication is listed in the Table 1. The un-damped structure (T18) and damped structure (TD18) was made each as one of the twins through SLAC –KEK collaboration based on GLC/NLC technology [4]. Another structure, called Quad_#5, was made by KEK with CuZr material [5].

The structures were tested with 60Hz at NLCTA of SLAC and with 50Hz at Nextef of KEK. Each one of the twins (T18_Disk and TD18_Disk) was tested at each laboratory, while the quadrant Quad_#5 described in this paper was tested at KEK.

HIGH GRADIENT TEST RESULTS

The test results compiling all those from SLAC and KEK are discussed [6].

Processing

The processing trends of all the three structures are shown in Fig. 1. The nominal target of the study is 100MV/m with 240 nsec. Here the square pulse was applied in the present study, though the actual pulse shape of linear collider use consists of ramping time and flat top.

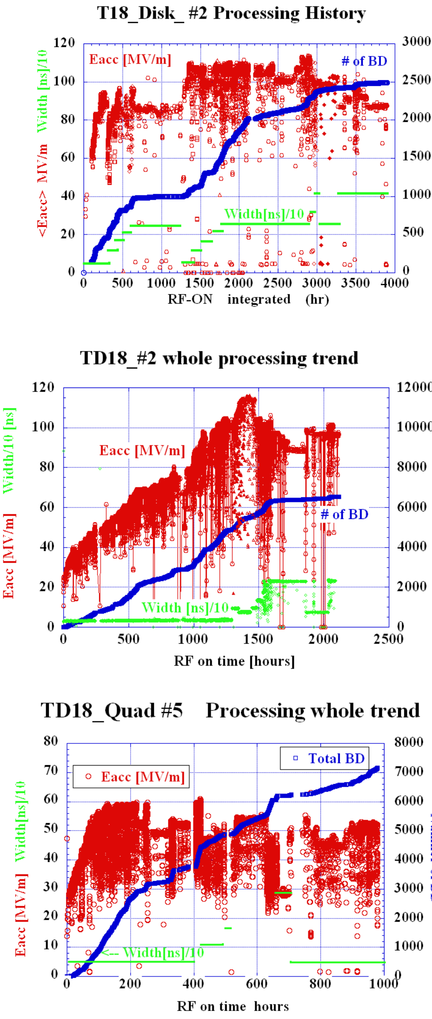

Figure 1: Processing trend of three structures.

Table 1: Tested Three Structures

Structure	**Unit**	**T18 Disk_#2**	**TD18 Disk_#2**	**TD18 Quad_#5**
Make		SLAC/ KEK	SLAC/ KEK	KEK
Material		OFC	OFC	CuZr
Machining		Diam. turning	Milling +turning	Milling only
Heat treatment		>1000C	>1000C	Non
Nominal reached level	MV/m ns	100 240	100 240	60 50
RF-ON period	hrs	1200*	1600	200#
Number of breakdowns	1	1600	6500	2800#
Dark current at 80 MV/m	µA	3	35	-
Field at dark current 10µA	MV/m	90	73	40

* Subtracted the period of 80MV/m run.

\# No more advances beyond.

The processing was performed semi-automatically by a control program, starting with a short pulse width such as 50 nsec. After reaching the top power level, it increased the width stepwise by 50-100nsec jump. In the early stage of the processing, we typically observed vacuum increase. When we observe a vacuum pressure increase by more than several 10^{-6}Pa, the program slows down or stays the ramping of power level. When a big breakdown happens, we stop the next pulse and restart from a lower power level after waiting for a few tens of seconds. This breakdown is identified by an abrupt burst of the Faraday cup current, either upstream or downstream and mostly both, in addition to the big reflection in RF power.

All the trends of the processing of the three structures are shown in Fig. 1. There are several points to be noted comparing three structures.

1. T18_Disk went up most quickly.
2. TD18_Disk ramping was very slow comparing to T18_Disk, though it reached finally the nominal level.
3. TD18_Quad could not be processed above 60MV/m.
4. All suffered from a few to several thousands of breakdowns.

Dark Current

We understand that the dark current can be one of the measures of the processing. Fig. 2 shows the evolution of the dark current for the TD18_disk case, where the amount has reduced by three orders of magnitude at 50 MV/m level from 100 µA to 100 nA as seen in the top figure.

The field enhancement factor was deduced from these data with modified Fowler-Northeim formula as shown in the middle figure. All the data taken can be fit well with this formula and resultant field enhancement factor beta was deduced as shown in the bottom figure. It decreased from 70 to 40 through the processing.

It was found from the comparison of measured and simulated dark current spectrum that the last few cells of T18_Disk mainly contribute to the dark current [7]. Applying simply this result into the TD18_Disk case, because of almost the same accelerating field distribution along the structure, it is worthwhile to see the beta values multiplied by the surface field at the last accelerating cell. The results are shown in the bottom figure, where the reached maximum surface electric field is taken from Fig. 1. It is interesting that it stayed constant at about 5~7 GV/m range through the processing.

Vacuum Activity

At the very early stage of the processing, we typically observed a vacuum base pressure increase of the order of a few to several 10^{-6} Pa as shown in Fig. 3. The main components are mass number of 2, 28 and 44, but not 18.

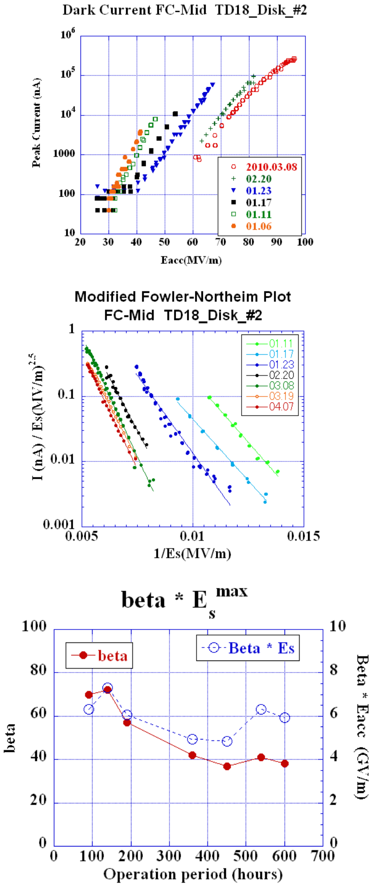

Figure 2: Dark current of TD18_#2. Inserted numbers represent month and day of the measurement.

After passing through this stage, the vacuum pressure of T18_Disk did not show any variation in the base pressure level. However, both TD18_Disk and TD18_Quad showed the pressure increase every time it passed low power level such as several MW. It usually happened after they were kept at much higher power level or after more than a few hours of off period. The typical situation is shown in Fig. 4 for the case of TD18_Disk. This vacuum pressure increase was not accompanied by any breakdowns. One of the possible candidate explanations is the multipacting in the HOM waveguides.

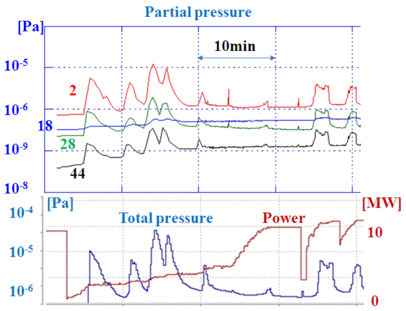

Figure 3: Partial pressure of TD18_Quad_#5 as power varied.

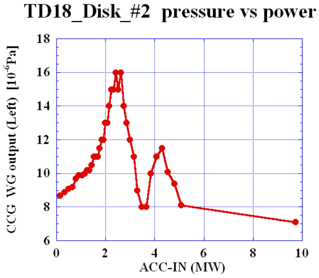

Figure 4: Pressure variation vs power in TD18_Disk_#2.

Breakdown Location

BD location can be identified from the timing of the abrupt increase of the reflection pulse and the fall of the transmitted pulse. Typical example is shown in Fig. 5. It shows the more frequent breakdowns towards downstream side. This characteristics seems common to all the three structure tested and presented in this paper.

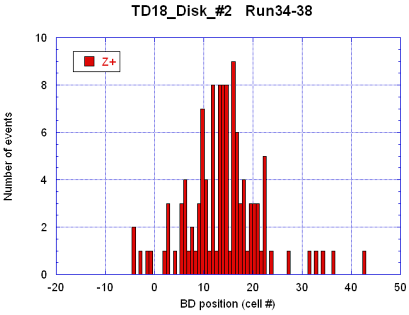

Figure 5: Breakdown location.

Breakdown Timing

The breakdown timing can be evaluated from the falling timing of the transmitted pulse. Typical falling time distribution is shown in Fig. 6. It is one of the typical features that the timing increases toward the end of the pulse.

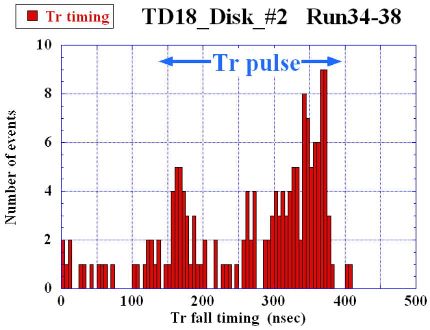

Figure 6: Breakdown timing by Tr fall timing.

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