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PRE-STUDY OF CEPC SRF CAVITY*

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Abstract

CEPC will use 650 MHz cavities for the collider and 1.3 GHz cavities for the Booster. Each booster cryomodule contains eight 1.3 GHz 9-cell cavities, which is similar as LCLS-II, E-XFEL and ILC. Each collider cryomodule contains six 650 MHz 2-cell cavities, which is totally new. Therefore, the pre-study mainly focuses on the 650 MHz 2-cell cavity. N-doping and vertical tests of 650 MHz 1-cell and 2-cell cavities have been carried out at IHEP, which have achieved good results. A test cryomodule, which consists of two 650 MHz 2-cell cavities, has also begun as the first step to the full-scale cryomodule.

INTRODUCTION

Baseline layout and parameters for CEPC Ring SRF system have been public [1]. There're two SRF sections in total, and each one has two SRF stations. There're 10 cryomodules per station, which consist of six 650 MHz 2-cell cavities each. Hence, there're 240 650 MHz 2-cell cavities in total. RF and Mechanical design of these cavities have been completed. And fabrication of prototype cavities has also been finished. The vertical test goal is 4E10@22MV/m, while the horizontal one is2E10@22MV/m. Both these targets are extremely high to reach, so N-doping would be adopted. In recent years, it has been proposed and proven to increase Q of superconducting cavity obviously, which lowers the BCS surface resistance. N-doping research had begun at IHEP since 2015. There've been initial progress, which mainly focused on Nb samples and 650 MHz 1-cell cavities. After N-doping, the Q values of both 650 MHz 1-cell cavities increased at low fields obviously. Besides, prototypes of 650 MHz 2-cell cavities have finished vertical test and the results are quite good.

N-DOPING RESEARCH OF NIOBIUM SAMPLES

Niobium samples were nitrogen doped at OTIC, as Fig. 1 [2, 3]. The furnace in Fig. 1 is equipped with two cryo-pumps in order to keep ultra-clean, which is key for N-doping. Different methods were tried to achieve the best effects. To verify that, experiments of secondary ion mass spectrometry (SIMS), scanning electron microscope (SEM), transmission electron microscope (TEM) and other experiments were carried out.

Figure 1: Furnace for N-doping at OTIC.

Results of SIMS is shown as Fig. 2 and Fig. 3. After N-doping (3Pa@800C for 2 min), intensity of N atom increased obviously, as well as NbN.

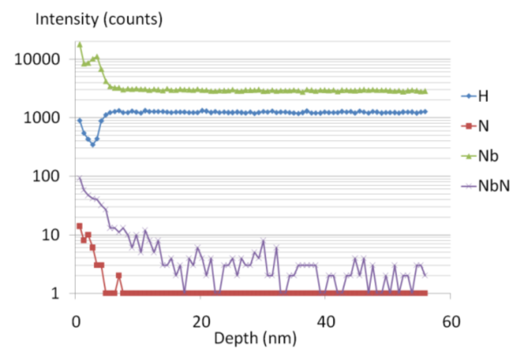

Figure 2: SIMS results before N-doping.

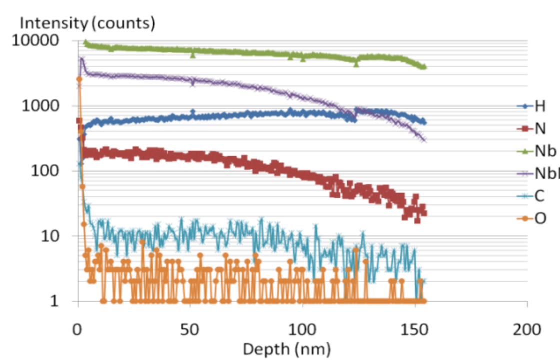

Figure 3: SIMS results after N-doping.

SEM images also show formation of nitride precipitates clearly, as Fig. 4.

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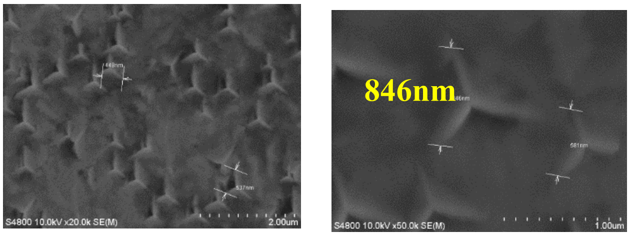

Figure 4: SEM images of Nb sample.

Diffraction patterns of TEM is shown as Fig. 5. The left picture of pure Nb shows only clean niobium with no impurities. The right of Nb N-doped shows poor nitride phases. It is similar as FNAL [4].

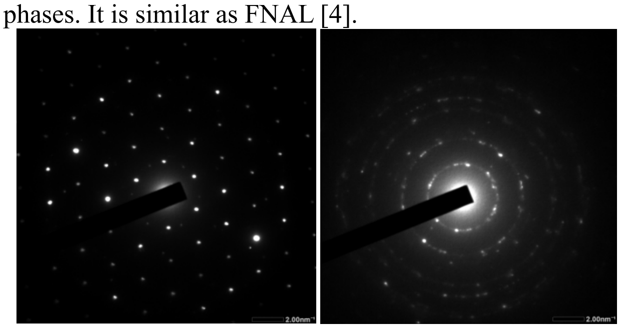

Figure 5: Diffraction patterns of TEM (left: pure Nb; right: Nb N-doped).

650 MHZ 1-CELL CAVITIES

Several 650 MHz 1-cell cavities have been fabricated for N-doping research. Because the EP facility is still under construction, these cavities were all processed with BCP. Before N-doping, baseline vertical tests of these cavities have been held as Fig. 6 and the results are shown in Fig 7. Helmholtz coils and flux gates are used for magnetic flux expulsion research. Meissner effect of superconductor has been observed during cavity cool-down.

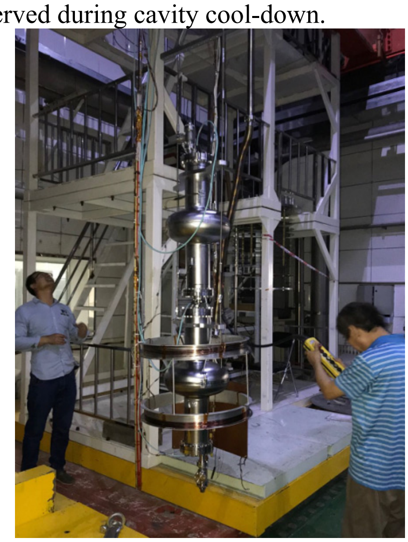

Figure 6: Vertical test of 650 MHz 1-cell cavities.

There're two vertical tests of 650S4# cavity. Before the 1st test, the HPR was done with two times. During the test, field emission began with Q-slope at low field (~10 MV/m). So we did the HPR with four times before the 2nd test. Then field emission was much weaker and the gradient reached 36 MV/m with no quench.

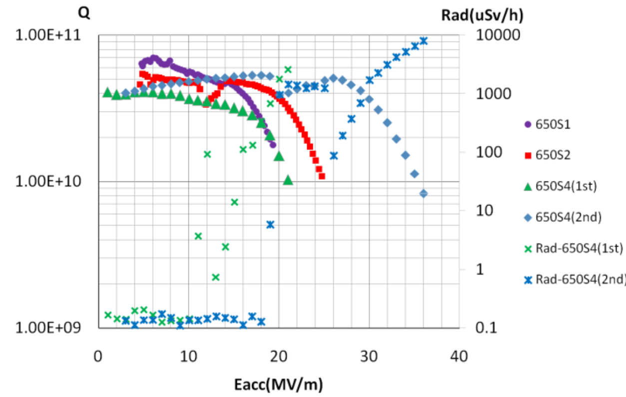

Figure 7: Vertical test results of 650 MHz 1-cell cavities.

N-doping of 650 MHz 1-cell cavities has also been carried out and initial results have been got. Q values of two cavities both increased at low fields (<10MV/m) [5].

650 MHZ 2-CELL CAVITIES

RF design of 650 MHz 2-cell cavities have been introduced in SRF2017 [3]. Cell shape and main parameters are shown as Fig. 8 and Table 1.

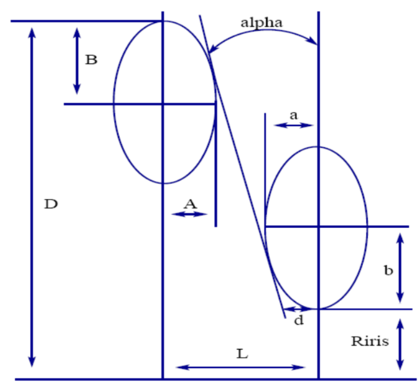

Figure 8: Profile of cell shape.

Table 1: Main Parameters of 650 MHz 2-cell cavity

Parameters	Value	Units
D	204.95	mm
Riris	78	mm
b/a	1.1	
alpha	3.2	degree
R/Q	105.5	Ω
G	284	Ω
E_{peak}/E_{acc}	2.38	
B_{peak}/E_{acc}	4.17	mT/(MV/m)
k	3.05	%

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Fabrication of three cavities were completed in late 2017. All these cavities had received post processing for vertical test, which include bulk BCP, annealing, light BCP and HPR. Vertical test of 1# 650 MHz 2-cell cavity was held at Peking University on 11st May, 2018, as Fig. 9 [6]. And the 2# was held at IHEP on 13rd Jul, 2018. Both results are shown as Fig. 10.

Figure 9: Vertical test of 650 MHz 2-cell cavity.

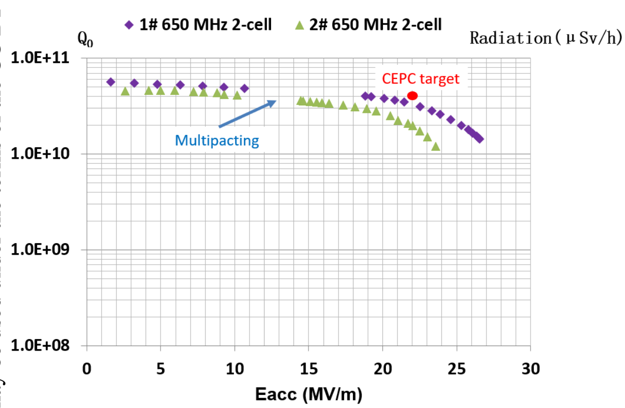

Figure 10: Vertical test results of 650 MHz 2-cell cavities.

The results of two cavities shown in Fig. 10 are both good, especially the 1# cavity. It reached 4E10@19.2MV/m, which is close to the CEPC target (4E10@20MV/m).

DRESSED CAVITIES FOR CRYOMODULE

The 650 MHz 2-cell cavity with Helium vessel and tuner has also finished design work, as Fig. 11. The mechanical performance has been optimized to minimize the Lorentz forcedetuning (LFD), df/dp and the peak stress. Thickness of cavity wall is adopted as 4 mm, and stiff rib 3 mm [7]. Novel design is adopted for Helium vessel. After optimization, mechanical design has reached the requirements finally.

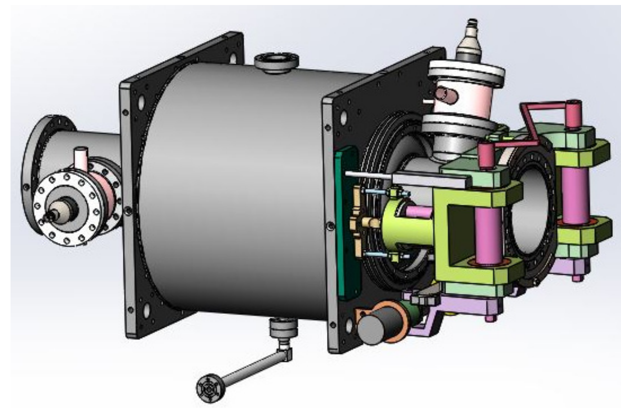

Figure 11: 650 MHz 2-cell cavity with Helium vessel and tuner.

CONCLUSION

The Pre-study of CEPC SRF cavity have begun, which mainly focus on 650 MHz 2-cell cavity. A test cryomodule with two cavities is underway and may be completed in 2019 [8]. The high Q and gradient are expected to achieve during horizontal test, which is the first step to the full-scale cryomodule of six cavities.

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