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INVESTIGATION ON 1, 3 AND 9-CELL SRF ELLIPTICAL CAVITIES MADE OF LARGE GRAIN NIOBIUM*

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Abstract

Large grain (LG) Nb is directly sliced from niobium ingot. LG Nb sheet has larger crystal size than that of fine grain (FG) Nb which is forged and rolled, and normally used as the SRF cavity materials. It is expected that higher Q-value can be achieved using LG Nb sheet. And, effective reduction in material cost can be also achieved by LG Nb since forge and rolling process are skipped. On the other hand, there are some difficulties in fabrication since it has large deformation due to strong anisotropy. Cavity fabrication facility (CFF) in KEK has been fabricated 1, 3 and 9-cell elliptical cavities made by LG Nb and RF tested in vertical cryostat. In this talk, the fabrication process and test results from these cavities will be presented.

INTRODUCTION

Several 1.3 GHz SRF cavities made by LG Nb from different supplier were fabricated at CFF and tested at superconducting test facility in KEK as listed in Table 1 [1][2][3]. Cavity shape are Tesla-Like [4] and Tesla [5]. R1 cavity made of high purity LG Nb which residual resistivity ratio (RRR) is ~500 first fabricated and tested. Then, R5 cavity made of low purity LG Nb which RRR is ~100 was fabricated and tested. Since R1 achieved acceptable results, 9-cell cavity made of same material as R1 which is named KEK-2 was also fabricated and tested. Since a special chemical process is necessary to separate tantalum and niobium, the production cost of low tantalum contained niobium is higher. Even though, RRR of LG Nb used R10 and R10b are 242 ~ 298, it contains higher ratio of tantalum to achieve effective cost reduction. The ratio of tantalum of LG Nb used for R10 and R10b are more than 1000 ppm. (It is less than 100 ppm in case of R1.) Two 9-cell cavities named KEK-4 and KEK-5 were fabricated using same material as R10 and R10b.A examples of LG Nb are shown in Figure 1.

PERFORMANCE TEST

Following several surface treatments are usually applied to completed cavity before performance testing in KEK;

1. Initial electropolishing of 100μm
2. Annealing of 750 ˚C for 3 hours in a vacuum furnace
3. Frequency tuning (for multi-cell cavity)
4. Second electro polishing of 20μm ~ 30μm
5. Baking of 120 ˚C for 47 hours.

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Table 1: List of Fabricated LG Cavities

Cavity	Supplier	RRR	Cell	Shape
R1	Tokyo Denkai	496	1	Tesla-Like
R5	CBMM	107	1	Tesla-Like
KEK-2	Tokyo Denkai	496	9	Tesla-Like
R10/10b	CBMM	242~298	3	Tesla-Like
KEK-4/5	CBMM	242~298	9	Tesla

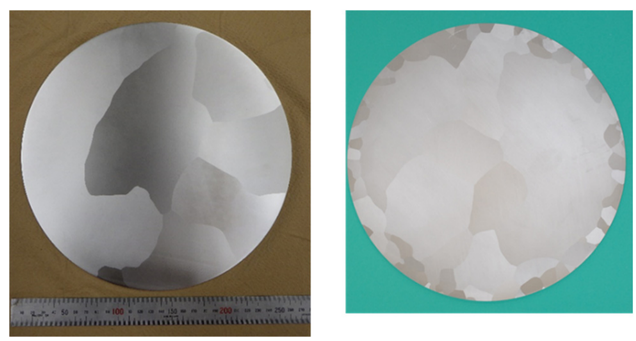

Figure 1: Examples of LG Nb. Diameter of left slice is 260 mm and supplier is CBMM. Diameter of right slice is 290 mm supplied by Tokyo Denkai.

Cavities are then cooled down to around 2 K in a vertical cryostat filled with liquid helium then RF tested. This test is called vertical test (VT). Remaining environmental magnetic field in cryostat is 5 mG ~ 10 mG. These magnetic field was not cancelled during measurements except 2nd VT of R10. VT of KEK-5 is not finished.

Figure 2 shows the VT results of each cavity at π-mode. R1 cavity reached more than 40 MV/m in most of tests. On the other hand, the maximum gradient of R5 cavity is only 30 MV/m. KEK-2 achieved 38 MV/m. R10 and R10b achieved maximum gradients of 38 MV/m and 42 MV/m respectively. KEK-4 achieved 29 MV/m and quenched. KEK-4 will be measured again after removing defect which causes quench.

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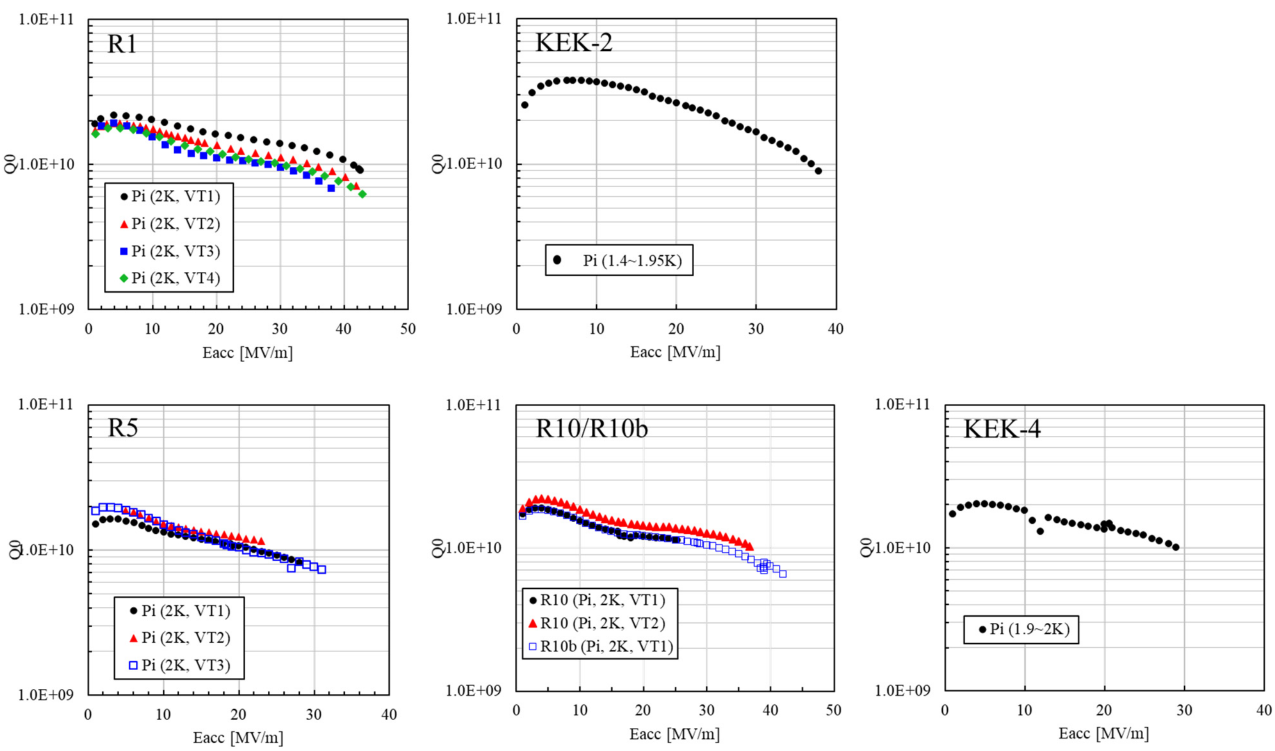

Figure 2: VT results of each cavity.

TECHNICAL ISSUES OF LG CAVITY

Even though, most of cavities achieved acceptable performance, there are several technical issues using LG Nb as cavity material

Large Deformation

Since LG Nb has large crystal size, it has strong anisotropy which causes large deformation after press forming. Figure 3 (left) shows roundness of equators in LG half-cell after press forming measured by CMM. Roundness is the difference of circumradius and inradius. Roundness of LG cavity is much worse than that of FG average. There is not a big effect of annealing before press forming can be seen in roundness. A special jig which forces equator to exact circle which is not used for FG cavity fabrication is necessary of LG cavity welding as shown in Figure 3 (right).

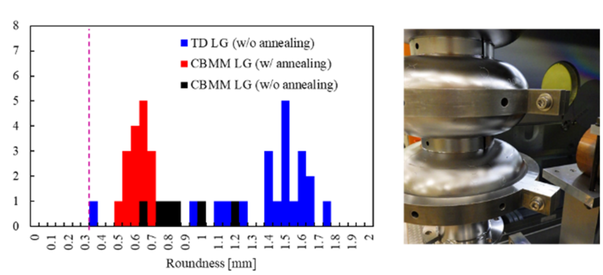

Figure 3: (Left) Roundness of equator in half-cells. (Right) A special jig for welding.

Different Characteristics

In LG Nb case, RRR varies largely even in same ingot. It varies from 242 to 298 for LG Nb used for R10 and R10b.

A mechanical strength differs even in same slice since it largely depends on crystal orientation.

Because of characteristics described above, it is difficult to guarantee same material quality when we treat LG Nb. Further study is necessary to employ LG cavity into real accelerator.

CONCLUSION

Several SRF cavities were fabricated using LG Nb from different suppliers. Completed cavities were then measured its performance in vertical cryostat. Cavities using LG Nb which RRR is more than 240 achieved more than 35 MV/m.

LG Nb has strong anisotropy which leads large deformation after forming. This makes fabrication process more complex. LG Nb also has different mechanical strength even in same slices. Hence, it is difficult to guarantee the cavity strength against He pressure. Further studies to solve this problem is necessary for actual use of LG cavity to accelerator.

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