BEHAVIOR OF AIR EXPOSURE OF MEDIUM β (=0.45) NIOBIUM SC CAVITY

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Abstract

We are developing the superconducting medium β structure to upgrade proton energy from 400 MeV to 600 MeV in the KEK/JAERI joint project (phase II). In this development, we have to establish a reliable final horizontal cavity assembly procedure in order to realize the excellent performance in the accelerator. So far we know with β=1 sc cavities that the performance of the niobium sc cavity electropolished, high pressure water rinsed, and then baked, has no degradation with a long term air exposure followed by high pressure water rinsing. Recently we tested whether this finding is true for the medium β(=0.45) structure using a very excellent cavity with Ep=68MV/m (Hrf = 1750 Gauss). Our preliminary experimental result shows a different behaviour from β=1 cavities. Qo was lowed by factor 3 or 4 after air exposure. The Qo-degradation was improved by additional baking, but the achievable field gradient was limited to Ep=50 MV/m. In this paper, we will present the experimental results.

1 INTRODUCTION

A medium β(=0.45) sc niobium cavity was successfully developed at L-band (1300MHz) and demonstrated the high gradient performance: 53 MV/m in surface peak field (Ep) at KEK in 1997 [1]. Medium β structures have RF characteristics of higher ratios in Ep/Eacc and Hp/Eacc, comparing with β=1 electron cavities. The former means it to be more sensitive to field emission and the latter signifies it to make thermal quench more easily than β=1 cavities. Thus, the final cavity assembly process might be more sensitive than β =1 cavities.

As a next step, we have to investigate the final clean cavity assembly in order to have such an excellent performance in real accelerators. Recently L.Lulje et al. have found with L-band β=1 cavities that if bake is carried out once electropolished cavities with an excellent high gradient performance: acceleration field Eacc=40 MV/m, the performance is still kept against a long term air exposure followed by HPR, and any additional bake is no needed after the air exposure [2]. This fact was confirmed at KEK too [3]. We need to make sure whether this new finding is true for medium β cavities. In this paper, the excellent cavity performance of Ep = 68 MV/m and Qo= $2x10^{10}$ was tested with air exposure.

2 EXPERIMENT AND RESULT

2.1 Baseline performance

The medium β=0.45 1300 MHz single cell niobium cavity, which had a rather good performance with Ep=53 MV/m and Qo = (7 – 2.5) x 10^9 at 2K in the first report [1], was removed material by 50 µm with KEK standard electropolishing procedure. After electropolishing, it was rinsed with HPR, assembled in KEK class 10 clean room, evacuated with bake (120°C for 2days), and cold tested in a vertical cryostat at 1.5K to make sure the baseline performance. The result is presented in Fig.1. At the first excitation curve measurement (●), multipacting (two-point 1st order) occurred from Ep=30 MV/m but was successfully processed out and disappeared. After the RF processing, Qo and Ep both jumped to better performance (○). Finally Ep achieved 68 MV/m with Qo=10^{10}. No x-ray was observed all over the field range. The surface peak field of 68 MV/m corresponds to Hp=1750 Gauss. This might be the critical field limitation by niobium superconductivity [4]. This performance is same as that of our L-band β=1 best cavities with Eacc=40 MV/m.

2.2 Air exposure experiment

After this baseline measurement, the cavity was disassembled and exposed to air in our class 10 clean room for 10 days. Then it was HPR rinsed again, assembled and vacuum evacuated without bake. The cavity was cold measured at 1.5K. The result is shown in Fig.2 (▲). In this excitation curve measurement, no x-ray was observed all over the range. The obvious Qo degradation (Qo-slope) occurred from a rather low field: Ep=5MV/m. Qo values at high fields were lowered by a factor 4 due to the Qo-slope. The filed was thermally limited at Ep=57 MV/m. This result is evidently different from β=1 cavities.

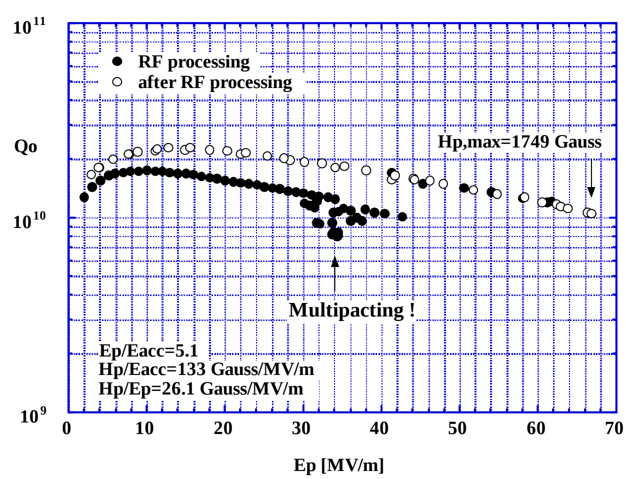

Figure 1: Baseline performance

We suspected the degradation by a poor HPR rinsing. This cavity has a very flat surface due to the medium β structure. Therefore, we doubted the uniform water jet hitting on the surface during HPR rinsing. After the measurement, the cavity was treated with the HPR rinsing again. Then it was cold test after the same procedure. The result is presented in Fig. 2 (▼). The Qo degradation was not improved, even became worse. No x-ray was observed all over the range in this second measurement too.

In the next, we suspected hydrogen Q-disease as the cause of the degradation. The cavity was warmed up to 100K after the second measurement and exposed to this temperature for 16 hours. Then cold test was carried out. The result is presented in Fig.2 (×). The result was no different from the second measurement.

Finally to see the baking effect on the degraded performance, we carried out bake at 120°C for 2 days, then made cold test. The result was shown in Fig.2 (●). The Bake improved the Qo-slope but increased the residual surface resistance about 10 nΩ. As a result Ep was limited to 50 MV/m. No x-ray was observed.

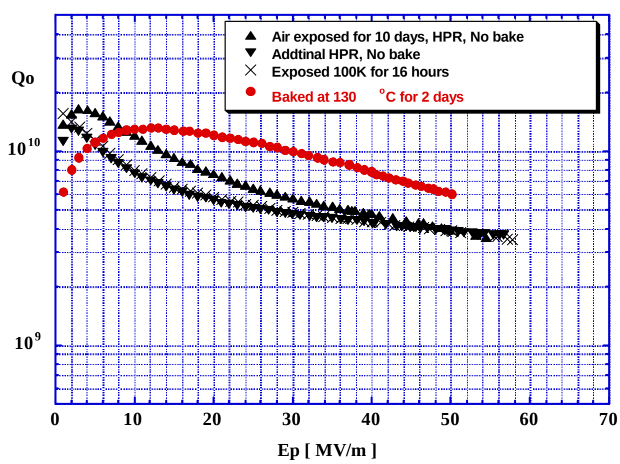

Figure 2 : Results of air exposure experiment

3 DISCUSSIN

As described above, the finding about air exposure at β=1 L-band cavities is not true for the medium β (=0.45) cavity. Therefore one must be more careful in the final cavity assembly. The medium β cavity has to escape from a long-term air exposure in the cavity assembly procedure. Use of argon gas will solve this Qo degradation. It has been confirmed with β=1 cavities [3].

A characteristic of air exposure is seen in surface resistance (Rs). In figures 3 – 5, Rs is plotted as a function of Ep. In the baseline measurement (normal case), Rs consists of two components: proportional to 1/Ep, proportional to Ep^2. The first component is often observed in other laboratories but the mechanism is not yet understood.

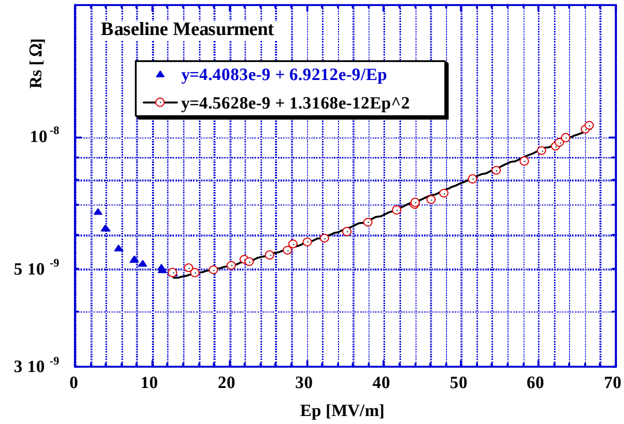

Figure 3: Rs [Ω] in baseline test as a faction of Ep

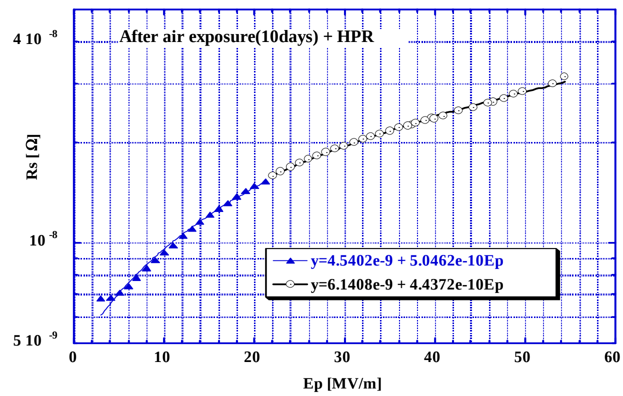

Figure 4: Rs [Ω] after air exposure + HPR

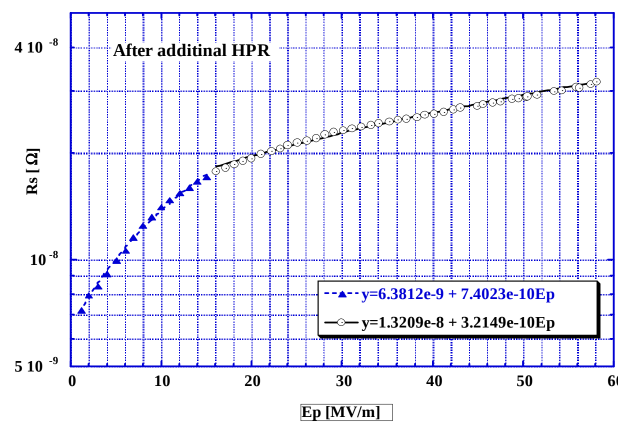

Figure 5: Rs [Ω] after additional HPR rinsed

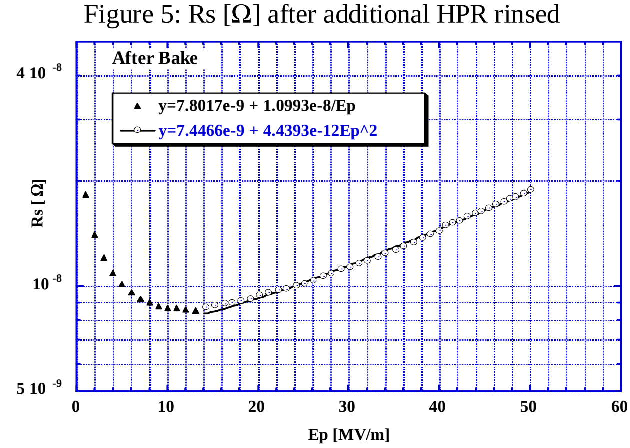

Figure 6: Rs [Ω] after baked

The latter is Ohomic loss. After the air exposure, both two comments turn to be proportional to Ep. The first component will be from a very weak superconductor on magnetic filed. The second one is also weak with magnetic field but it has threshold around 575 Gauss. By the additional HPR, although coefficients in the Ep dependence and the threshold are changed, still the same Ep dependence is kept. The bake turn them the same Ep dependence as normal case. These weak superconductors will be two phase of NbxOy by oxidation of niobium. Bake diffuses oxygen on the surface into bulk niobium. Weak superconductors will recover superconductivity of the niobium.

4 SUMMARIES

1) The recent finding by Lulie et al.: the excellent cavity performance of Eacc= 40 MV/m (critical limit) is still kept against air exposure followed HPR is not true for the medium beta cavities.
2) Therefore one has to be more careful about final cavity assembly. Air exposure after final HPR has to be avoided to keep the excellent performance. Use of argon gas will solve this problem, which has been confirmed in L-band β=1 sc cavities at KEK.
3) The performance degradation by the air exposure is due to appearance of a surface resistance linearly increasing with field.

5 REFERENCES

[1] K.Saiot et al., “Development of 1.3 GHz Medium-β Structure with High Gradient”, Proc. of the 8th Workshop on RF Superconductivity, October 6 – 10, 1997, Abano Terme (Padova), Italy, pp. 534 – 539.
[2] L.Lujie, private communication
[3] K.Saito, “Basic Study for Degradation Free Final Horizontal Cavity Assembly with High Gradient Niobium SC Cavities”, in this workshop.