RESEARCH OF NITROGEN DOPING IN IHEP*

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Abstract

Recently, nitrogen doping (N-doping) technology has been proved to increase Q_0 of superconducting cavity obviously, which lowers the BCS surface resistance. After N-doping, Q_0 of 9-cell 1.3 GHz cavity can be increased to $3*10^{10}$ at E_{acc} = 16 MV/m, while $1.5*10^{10}$ without N-doping [1]. Since 2013, there have been over 60 cavities nitrogen doped at FNAL, JLAB and Cornell. The Circular Electron Collider (CEPC) has been proposed by IHEP in China, while requests Q_0=4e10@E_{acc}=15.5 MV/m for 650 MHz cavity. It's hard to achieve without N-doping. So research of N-doping was begun in cooperation with Peking University in early 2015. Experiments of niobium samples have showed that nitrogen concentration at niobium surface increased a lot after N-doping. After then, several single-cell 1.3 GHz cavities completed vertical tests, but there're no successful test results of Q_0 increasing, yet.

INTRODUCTION

IHEP is collaborating with Peking University to explore new technologies and methods in order to fabricate dramatically lower-loss superconducting cavities adopting nitrogen doping technique introduced by FNAL, JLAB and Cornell [2]. It has been verified to be effective for both 1.3 GHz and 650 MHz superconducting cavities, as Figure 1 and Figure 2 shows [3].

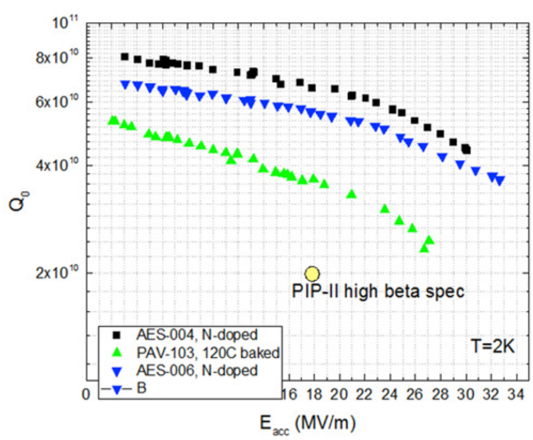

Figure 1: Nitrogen doping of 650 MHz cavities.

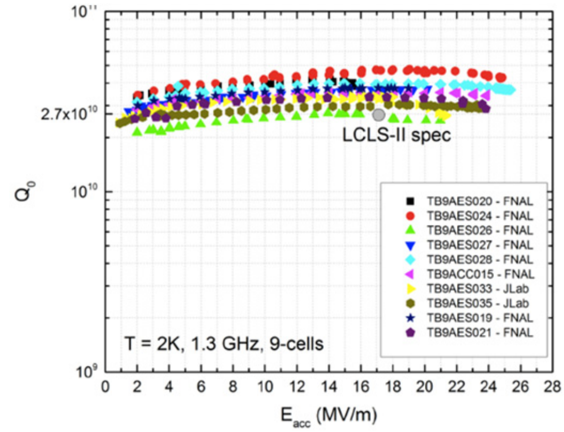

Figure 2: Nitrogen doping of 1.3 GHz cavities.

Recently, CEPC project is proposed by Chinese high energy physicists, which contains more than 600 superconducting cavities (1.3 GHz and 650 MHz). So it's eager to increase Q_0 of cavities to minimize cryogenic capital and operating cost. Firstly, niobium samples were nitrogen doped both at IHEP and Peking University. Different methods were used to achieve that nitrogen enters into niobium surface and exists for long. To verify that, experiments of secondary ion mass spectrometry (SIMS) and auger electron spectroscopy (AES) were done. Finally, a method of N-doping was found to be useful. Secondly, a single-cell 1.3 GHz cavity was N-doped adopting the same technique. Because there's no electro-polishing (EP) facility, plasma cleaning has been used to improve the cavity inner surface. Thirdly, Vertical test was held, and the performance of cavity N-doped was bad. Besides EP, other reasons are also investigated nowadays.

ANNEALING WITH NITROGEN ABSORPTION

According to experience overseas, all the doping techniques consists of similar procedures, which are all useful. As the beginning of research, niobium samples were made for nitrogen absorption experiments.

There're two furnaces used for N-doping. One is at IHEP, as Figure 3. The other is at Peking University, as Figure 4.

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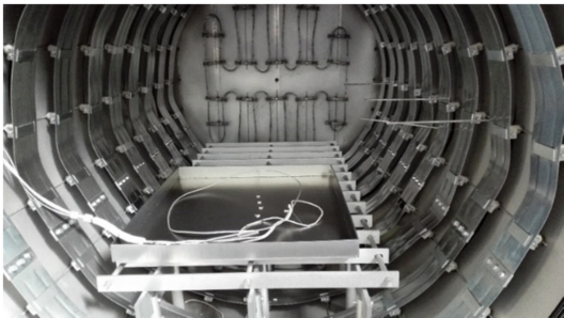

Figure 3: Furnace at IHEP.

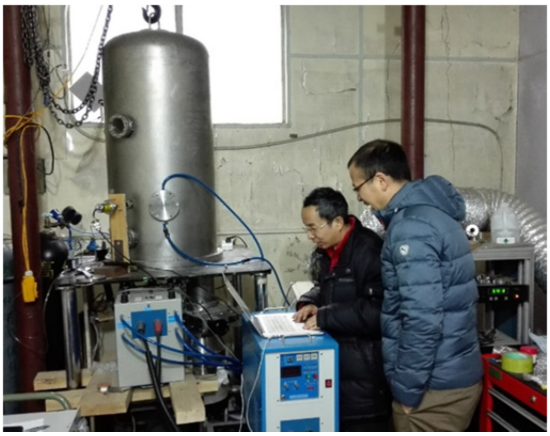

Figure 4: Furnace at Peking University.

Annealing begins with a standard ILC/XFEL 800℃ annealing 3 hours for hydrogen outgassing. The vacuum pressure remains at about 2e-3 Pa. Following, nitrogen gas is injected into the furnace and vacuum pressure is kept at 2.8 Pa for about 30 minutes. Then, nitrogen is pumped out and niobium is annealed for another 30 minutes at 800℃, followed by natural cool down of the furnace. The temperature profile (blue line) and vacuum pressure (red dash line) of furnace are shown in Figure 5.

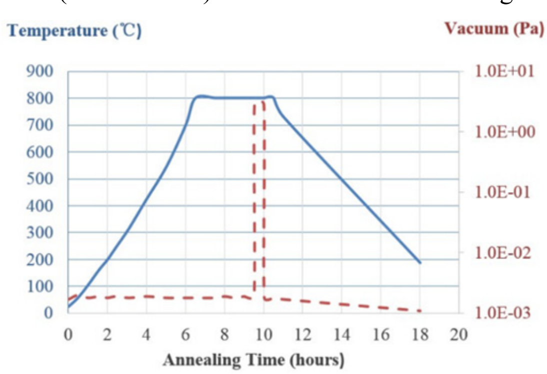

Figure 5: Annealing with nitrogen injection.

During the nitrogen injection period, the Vacuum valves are opened to avoid vacuum worse. It's different from American labs, which close all vacuum valves.

After N-doping, niobium samples were brought to Tsinghua University for surface experiments, which includes secondary ion mass spectrometry (SIMS) and Auger electron Spectroscopy (AES). Both experiments have indicated that nitrogen in niobium surface didn't increase, which meant that the N-doping technique had no success yet. Figure 6 is the picture of SIMS at Tsinghua University. There're 7 niobium samples on the disk.

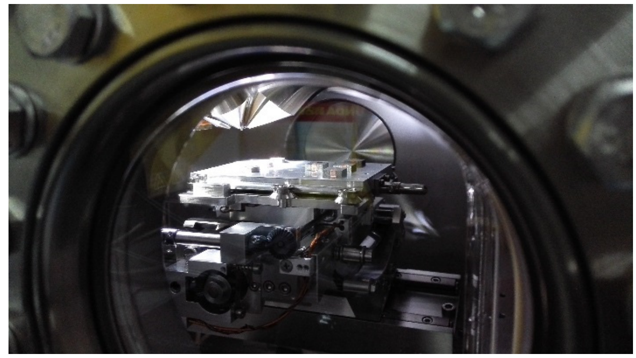

Figure 6: SIMS at Tsinghua University.

Then, the N-doping experiment was improved and carried out at Peking University. At this time, SIMS and AES have both proved that nitrogen concentration increased by over 10 times.

VERTICAL TEST FOR CAVITY N-DOPED

On the basis of niobium samples, single–cell 1.3 GHz cavities were N-doped. There's no EP equipment useful for us for the reason of chemical pollution, so plasma cleaning was adopted to treat the cavity inner surface. After high pressure rinsing (HPR), vertical tests were held. But Q_0 didn't increase as assumed. Besides EP, other kinds of reasons are also studied right now.

CONCLUSION

Research of N-doping has been begun at IHEP and Peking University. There have been no successful results, yet. So more study and cooperation with foreign colleagues are needed in future.

ACKNOWLEDGMENT

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