HYDROGEN DEGASSING STUDY DURING THE HEAT TREATMENT OF 1.3-GHZ SRF CAVITIES

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Abstract

Superconducting radio frequency (SRF) cavities undergo a number of processes as part of its manufacturing procedure in order to optimize their performance. Among these processes is a high temperature hydrogen degas heat treatment used to prevent 'Q' decrease. The heat treatment occurs in the processing sequence after either chemically or mechanically polishing the cavity. This paper summarizes the hydrogen measurements during the heat treatment of a sample of chemically and mechanically polished single-cell and nine-cell 1.3-GHz cavities. The hydrogen measurements are analyzed according the polishing method, the polishing history, the amount of time that the cavity was baked at 800°C, and the temperature ramp rate.

INTRODUCTION

The performance of superconducting radio frequency cavities is most important fact for a high gradient accelerator. However it is limited by field emission and thermal magnetic breakdown.[1] Most of the SRF cavities receive surface treatment to improve the performance of the cavity. A high temperature heat treatment degases the hydrogen gas that comes from the polishing process. High temperature heat treatment provides some stress-relief in the material in addition to degassing hydrogen gas [2] Hydrogen degassing studies were carried out at Jefferson Laboratory and Institut fuer Kernphysik using defference cavity. [3-4] The goal of the analysis in this paper was to evaluate whether a dependency exists between the cavity surface processing techniques, the kind of cavity and the hydrogen evolution during the heat treatment. The different polishing techniques and sequence are described. The methodology of determining the amount of degassed hydrogen is explained. Finally, the conclusion shows a comparison of the hydrogen amount.

DESCRIPTION OF CAVITIES & PROCESSING HISTORY

Nineteen single cell cavities and three nine-cell cavities, all 1.3-GHz cavities, were analyzed. All had a variety of processing steps. The cavities were polished using either EP (Electropolishing) or CBP (Centrifugal Barrel Polishing, or tumbling) to a mirror finish. [5]

The EP process polishes the surface using electrical current in acid solution at 30°C. It is a type of chemical polishing. The CBP (or tumbling) process polishes the surface using material (media) for many hours between 30°C and 50°C. It is a type of mechanical polishing.

The 800°C heat treatment takes place after the cavities were polished. During the heat treatment the temperature ramp rate was either 3°C per minute or 10°C per minute and the soak time at 800°C was either 2 hours or 3 hours. Table 1 shows the various sequences that different cavities experienced. It is noted that the amount of material removed during polishing did not correlate with the amount of degassed hydrogen.

Table 1: Polishing and Bake Sequences for the Cavities

Cavity No.	Process
1, 2, 3, 4, 9, 11, 13, 14, 15, 16, 17, 18, 20, 23, 25, 26	EP / bake
10, 12	CBP / bake
7, 19	EP / CBP / EP / bake
6	EP / CBP / bake
22, 24	CBP / EP / bake
5	CBP / bake / EP / bake

MEASURING AND CALCULATING THE H_2 AMOUNT

The vacuum furnace has a SRS 100 residual gas analyzer that measures the partial pressures of gasses during a bake. The RGA sits outside the furnace's hot zone and on the opposite end of the chamber's cryopumps. Figure 1 shows the hydrogen partial pressure curves for an electropolished cavity, a tumbled cavity and the baseline from an empty chamber for a temperature soak of 3 hours and a ramp rate of 3°C per minute. Of interest is the pressure data within the temperature range of 300°C to 300°C, as is shown in Figure 1.

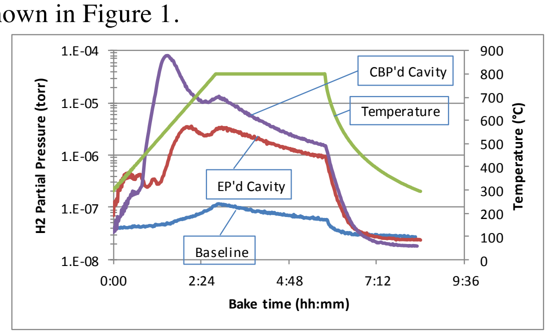

Figure 1: Typical H_2 partial pressures of an electropolished cavity, a tumbled cavity, and an empty chamber within 300°C to 300°C.

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A baseline hydrogen pressure curve was established by baking an empty furnace chamber. The empty chamber sat at room temperature at a vacuum pressure on the order of 1E-8 torr for eighteen days before the bake cycle started.

To calculate the total amount of degassed hydrogen from a cavity during a bake, the cavity's hydrogen pressure curve was integrated. The baseline hydrogen curve is also integrated, and the difference between the two values is the shaded area shown in Figure 2. This value is then multiplied by the effective pumping speed (~500 L/s) within the furnace to provide the total degassed hydrogen in units of torr-L.

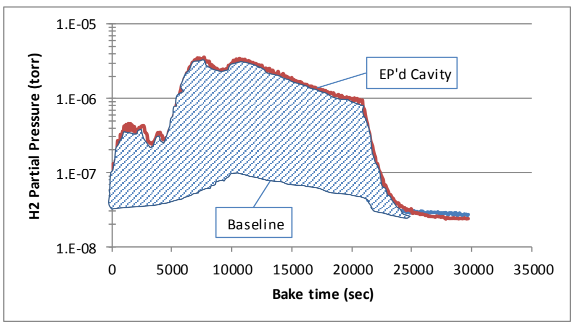

Figure 2: Area between the cavity and baseline H_2 pressure curves.

HYDROGEN ANALYSIS

Between Tumbled Cavity and EP Cavity

This section shows that tumbled cavity has a larger amount of hydrogen than the electropolished cavity. The tumbled cavities showed a hydrogen peak at temperatures between 500°C and 600°C. The hydrogen peak was typically an order of magnitude higher than the hydrogen level during the 800°C soak. Figure 2 compares the hydrogen amount for tumbled and electropolished cavities that had a three hour soak and a temperature ramp rate of 3°C per minute (cavities numbered 1 through 12). Cavities numbered 6, 7, 10, 11 and 12 were tumbled cavities. The rest of the cavities were electropolished.

Figure 3 shows the large of amount of hydrogen in the tumbled cavities compared with the electropolished cavities. It is likely that an electropolished cavity emits a small amount of hydrogen compared to the tumbled cavity. The H^+ ions that are produced tend to go into the cathode rather than the niobium surface. Also, the oxide surface layer which is produced during EP process prevents H^+ ions from penetrating easily into the niobium material. On the other hands, during the CBP process, the niobium oxide layer disappears and the H^+ ions can penetrate into the niobium material. Once the CBP process is complete, the oxide layer is reformed. During the heat treatment process, the oxide layer is removed and any hydrogen loaded into the niobium is released.

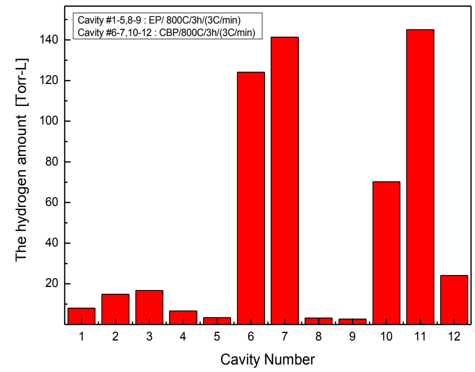

Figure 3: Comparing degassed H_2 in electropolished vs. tumbled cavities.

Between the Single-Cell Cavity and Nine-Cell Cavity

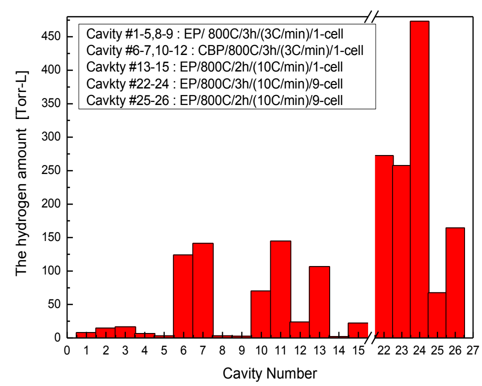

Figure 4: Comparing degassed H_2 in single-cell vs. nine-cell cavities.

Figure 4 shows the amount of hydrogen when comparing the single cell and nine cell cavities. Cavities 16-20 are single-cell cavities, and the cavities 22-24 are nine-cell cavities. Cavities 19, 22 and 24 are tumbled cavities. The nine-cell cavities show the degassed hydrogen amount more than nine times of the hydrogen amount from single-cell cavities, as expected.

By Polishing History

Each cavity received different kinds of polishing and polishing time, listed in Table 1. Two observations were found by comparing the polishing histories of the cavities. One observation confirms again that the amount of degassed hydrogen comes from the electropolished cavity is significantly less than the amount of hydrogen from the cavity that received CBP. The second observation is that the hydrogen amount from CBP cavity is larger no matter how many EP processes it received. So it turned out that EP process cannot remove hydrogen gas that comes from the CBP process. But when there is a baking process between CBP process and EP process, the baking process removes the hydrogen gas from the cavity that is left from the CBP process.

CONCLUSIONS

This paper describes how the hydrogen data was collected and how the amount of hydrogen was calculated. The degassed hydrogen amount from electropolished and tumbled cavity was analyzed. It was confirmed that tumbled cavities degas a large of hydrogen gas compared with electropolished cavities and the basic principle was explained in the section of hydrogen analysis. It was found that the EP process cannot remove hydrogen gas that comes from the CBP process. Once the cavity received CBP process before baking, regardless of whether or when the cavity was EP'd the cavities degases a large of hydrogen amount. In comparing the single cell and nine-cell cavities, it was expected that the degassed hydrogen amount would be more, correlating with surface area. The amount of hydrogen from nine-cell cavities was much than expected. More studies will be done to understand the reason. The increasing rate of hydrogen amount to determine the real pump capacity and calculating the RGA accuracy has to be studied further in order to optimize the heat treatment process.

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