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.

DESCRIPTION OF CAVITIES & PROCESSING HISTORY

Nineteen single cell cavities and four 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 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.

Table1. Polishing and Bake Sequences for the Cavities

<table>
<thead>
<tr>
<th>Cavity No.</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 3, 4, 9, 11, 13, 14, 15, 16, 17, 18, 20, 23, 25, 26</td>
<td>EP → bake</td>
</tr>
<tr>
<td>10, 12</td>
<td>CBP → bake</td>
</tr>
<tr>
<td>7, 19</td>
<td>EP→CBP→EP→bake</td>
</tr>
<tr>
<td>6</td>
<td>EP→CBP→bake</td>
</tr>
<tr>
<td>22, 24</td>
<td>CBP→EP→bake</td>
</tr>
<tr>
<td>5</td>
<td>CBP→bake→EP→bake</td>
</tr>
</tbody>
</table>

MEASURING AND CALCULATING THE H2 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.

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 degased hydrogen in units of torr-L.

**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 3 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).

![Figure 1. Typical H₂ Partial Pressures of an Electropolished Cavity, a Tumbled Cavity, and an Empty Chamber Within 300°C to 300°C](image1.png)

![Figure 2. Shaded Area Between the Cavity and Baseline H₂ Pressure Curves](image2.png)

![Figure 3. Comparing Degassed H₂ in Electropolished vs. Tumbled Cavity](image3.png)

*Between the single-cell cavity and nine-cell cavity*

Figure 4 shows the amount of hydrogen when comparing the single cell and nine cell cavities. Cavities # 1-15 are single-cell cavities, and the cavities # 22-26 are nine-cell cavities. Cavities # 6, 7, 10-12 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.

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REFERENCES