OPTICAL INSPECTION OF SRF CAVITIES AT DESY

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Abstract

Since 2008, the prototype of a camera system, developed at KEK/Kyoto University, for the optical inspection of the inner surface of cavities is available at DESY.
Its variable-angle and intensity illumination system provides sufficient contrast for an in-situ search for surface defects in high resolution. Such defects may limit the gradient when causing a quench.
A large sample of prototype cavities for the European XFEL has been inspected and provides a large inventory of data for analysis. The comparison of features in the optical inspection and hotspots in the temperature mapping during RF-measurements of the cold cavities gives evidence for correlations.
Consecutive inspections of cavities in different stages of the surface preparation process allow a monitoring of the evolution of surface defects.

INTRODUCTION

In its first year of operation at DESY more than 20 nine-cell cavities have been inspected with the Kyoto camera system [1]. The high resolution pictures obtained with the system allow the locating and study of defects on the inner cavity surface in a way that was not possible before without cutting samples from the cavity.
Categorizing these defects and link the information obtained in optical inspection to the one from temperature mapping during RF-test may help to further understand gradient limiting mechanisms and improve the yield of high gradient cavities.

COMPARISON OF T-MAP MEASUREMENT AND OPTICAL INSPECTION

During the vertical RF-test of a cold nine-cell cavity heating areas that indicate the position of a quench are routinely located by a rotating array of thermo-sensors on the outer surface (T-map).
Optical inspection of the respective inner surface revealed a correlation between the hotspot and visible defects in several cases.

One example for the match of quench location and a clearly visible defect found by optical inspection is Z130. In the first vertical test the cavity was limited by quench without field emission at 17.3 MV/m. For further investigations the cavity was cut out of its He-vessel. The only surface treatment before the second test was high pressure water rinse (HPR).
The second vertical test was performed with T-map; all nine modes of the cavity were measured. In the π-mode the cavity was limited by quench at 16.6 MV/m.

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For the 3/9- and 1/9-π-mode the heating location was found by T-map on the equator of cell 5 (see left part of Figure 1). Cell 5 was limited by quench at 22 MV/m in the 3/9-π-mode.
Optical inspection of Z130 was carried out after the vertical test. At the area corresponding to the heating during quench in 3/9- and 1/9-π-mode, a circular pit of about 700 μm diameter is visible on the edge of the equator welding seam (right part of Figure 1).

Samples have been cut from Z130 for a detailed analysis of the surface [2]. The defect in the equator of cell 5 was found to be up to 200 μm deep. No inclusion of foreign material was detected in the defect by EDX.

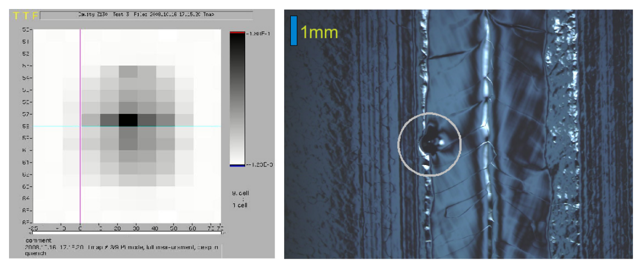

Figure 1: Quench location found by T-map (left) and optical inspection picture of respective area (right) in Z130.

Figure 2 shows another correlation between T-map measurement and optical inspection that was found in Z142. During the vertical RF-measurement heating of the quench was located by T-map near the equator of cell 6 (left part of Figure 2) . In the π-mode the cavity was limited at 20.6 MV/m by quench without field emission.
Optical inspection of the respective area after the test revealed a defect in the heat affected zone next to the equator welding seam (right part of Figure 2). The defect is a pit of elliptical shape with a semi-minor axis of about 300 μm and a semi-major axis of about 500 μm.

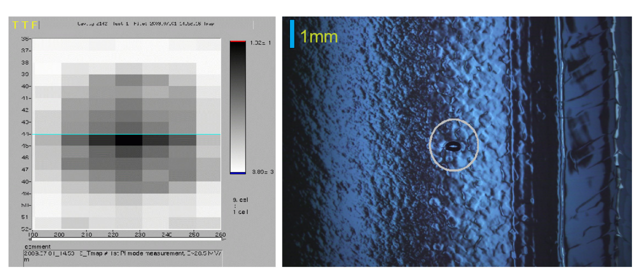

Figure 2: Quench location found by T-map (left) and optical inspection picture of respective area (right) in Z142.

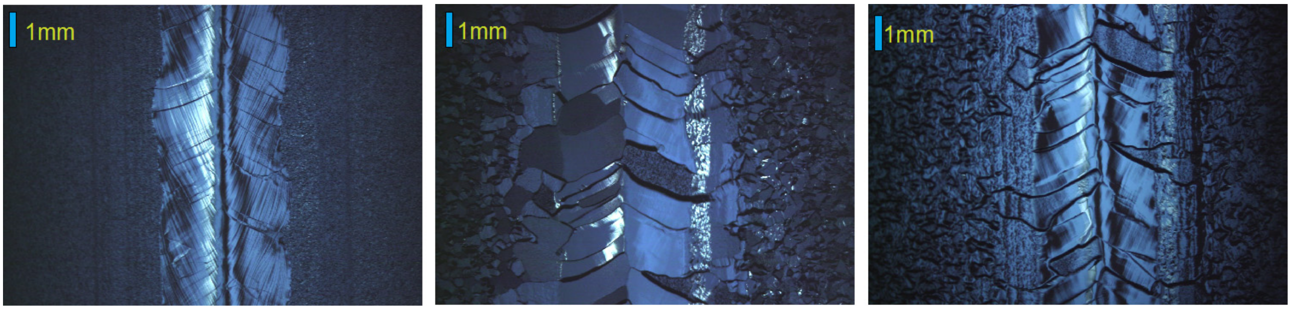

Figure 3: Equator welding seam of cell 1 in Z137: Before chemical treatment (left), after main EP (center) and after final EP (right).

DIFFERENT STAGES OF SURFACE PREPARATION

Performing optical inspection at different stages of the surface preparation process allows to study the formation and evolution of defects. A batch of 4 cavities (Z134, Z136, Z137 and Z142) from the 6th production series of cavities for TTF/FLASH [3] was and is inspected after several steps of the surface preparation process:

- before surface preparation ("as received")
- after main-EP
- after final EP and RF-test

In the optical inspections before surface preparation and after the main-EP all equator and iris welding seams are inspected. After the RF-test the welding seams are inspected once more. In addition, the areas of heating located by T-map, that may also be situated outside the welding seam areas, are inspected.

Figure 3 shows a series of three pictures taken at the same spot of the equator welding seam of cell 1 in Z137. The left picture shows the cavity before the surface treatment. The equator welding seam of cell 1 looked normal and similar to the other eight equator welding seams.

After the main surface removal of 108 µm by EP, cell 1 looked different to the other cells (centre picture of Figure 3). Large steps have appeared at the grain boundaries on the welding seam and in the heat affected zone. Complete grains on the welding seam look matte and very rough. This effects are visible along the complete equator of cell 1. None of the other eight cells showed similar effects.

The final EP has smoothed the structures on the equator and the surface is much more shiny (right picture of Figure 3). However the large steps at the grain boundaries remain.

In the vertical test Z137 was limited at 25.2 MV/m by quench. T-map measurement located heating of the quench in the heat affected zone next to the equator of cell 1.

Possible explanations for the behaviour of cell 1 during main-EP are under investigation.

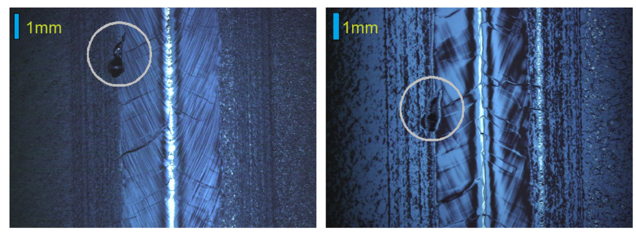

Figure 4: Defect on equator welding seam in cell 1 of Z136: before surface treatment (left) and after main-EP (right).

During the optical inspection of Z136 before surface preparation three defects of up to around 1 mm in size have been found on the equator welding seam of cell 1 and in the heat affected zone next to it. All three defects lie within few cm of the welding seam. An example picture is given in the left part of Figure 4. The defect looks like a circular pit of about 600 µm diameter, accompanied by molten material sitting on the surface.

After the main surface removal of 108 µm by electro-polishing the defects are smoothed but still present (see right part of Figure 4). Final surface treatment of Z136 is scheduled and the subsequent RF-measurement with T-map will reveal, whether the remainder of one of the defects causes a quench or not.

The presence of the defects before any chemical treatment of the cavity indicates that their formation is linked to the welding process itself.

SUMMARY

Comparison of T-map and optical inspection shows correlation between the heating location and visible defects for Z130 and Z142. In Z136 and Z137 defects were spotted at an early stage of the preparation process and tracked through different stages of surface preparation. Final surface preparation, vertical test with T-map and subsequent optical inspection of Z134 and Z136 is awaited before end of 2009.

ACKNOWLEDGEMENT

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REFERENCES

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