IDENTIFICATION AND EVALUATION OF CONTAMINATION SOURCES DURING CLEAN ROOM PREPARATION OF SRF CAVITIES*

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Abstract

Particles are one possible cause of field emission issues in SRF cavity operations. During clean room cavity preparation, several processes could contribute to the generation of particles. One of them is friction between hardware during assembly and disassembly. It is important to understand the behaviours that generate and propagate particles into cavities. Using a single cell cavity, particle shedding between flanges and other materials have been tested. The number of particles is recorded with an airborne particle counter, and the generated particles are examined with microscope. The migration of particles into a cavity due to different movements is studied. Suggestions are made to reduce particle generation and prevent contamination of the cavity interior area.

BACKGROUND

The preparation process of an SRF cavity can significantly influence its performance. Chemical polishing, mechanical polishing, thin film deposition, and the most recent trend of heat treatment while carefully introducing foreign materials are all methods to establish a surface condition that provides satisfying quality factor and accelerating gradient. To make the most out of these surface conditions, it is important to prevent other factors, such as field emission due to contamination, from degrading cavity performance. Field emission has been reported in some circumstances to be caused by micro particles inside the cavity [1]. Various cleaning techniques have been explored and introduced to avoid or reduce particles during cavity production [2, 3]. Exanimation of particle existence at different stages, from surface preparation [4], cleaning [5], storage [6], and cleanroom assembly [7], to vacuum component operation [8], has received wide attention. In this study, we aim to identify and understand the nature of micro particles during clean room preparation, especially assembly and disassembly, of SRF cavities.

EXPERIMENT

Preparation of Cavity and Components

A Tesla shaped 1.3 GHz single cell cavity made from large grain niobium was used for this study. The cavity was cleaned in an ultrasonic tank filled with detergent solution for about an hour. It was then rinsed thoroughly with ultrapure water and dried in air. The cavity was transferred to clean room and received high pressure rinse with ultrapure water. It was then dried in the clean room and ready for assembly.

Hardware to be assembled onto the cavity was cleaned separately in another ultrasonic tank with detergent solution. Then they were thoroughly rinsed with ultrapure water, dried in air, bagged, and transferred into clean room for assembly.

Assembly and Disassembly

Only one of the two beam pipe flanges was assembled in this study; the other one was used for holding the particle counter. A Lighthouse Solair 3100 airborne particle counter was used to monitor particle counts inside the cavity. It detects particle sizes from 0.3 µm to 10 µm. The accumulation mode was used in the experiment. The stainless steel collector and rubber hose connecting the collector was supported by a cleaned PVC tube inserted into the cavity along the beam pipe. One end of the PVC reached the middle of the assembly side of beam pipe. The other end of the PVC tube was mounted onto a PVC flange and fixed to the other beam pipe flange with spring clamps.

Assembly and disassembly at both horizontal and vertical orientations were studied. For vertical assembly, the bottom beam pipe flange was assembled. Before assembly, the stainless steel flange was blow-cleaned with ionized nitrogen gun; the aluminum magnesium alloy gasket was wiped with alcohol and blow-cleaned with ionized nitrogen gun. The particle counter was started and kept running until the particle counts reached zero, which means any particle counts detected later was caused by assembly movements. After the experiment, data from the particle counter were exported for analysis.

Particle Sampling and Characterization

Before assembly, surfaces of flange, gasket, bolt, nut, and washer were sampled with clean carbon tape. During the assembly and disassembly, carbon tape was attached near the particle counter collector as well as the interior of the cavity beam tube. After disassembly, the carbon tape was covered up to prevent exposure to the atmosphere, until the time they were transferred into scanning electron microscope (SEM) for analysis. Energy dispersive spectroscopy (EDS) was used for elemental analysis of the particles.

RESULTS AND DISCUSSION

Figure 1 shows particles collected from surfaces of different assembly hardware, including stainless steel bolt, stainless steel washer, silicon bronze nut, aluminum

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magnesium alloy gasket, and stainless steel blank flange. The composition of these particles from EDS analysis is also shown. This reminds us that surfaces of parts are not particle free even after ultrasonic cleaning. In production practice, parts are blow-cleaned with nitrogen gun before being used on assembly. It should be kept in mind that particles are everywhere even in the clean room. Care should be taken to avoid movements that transfer particles to unwanted surfaces.

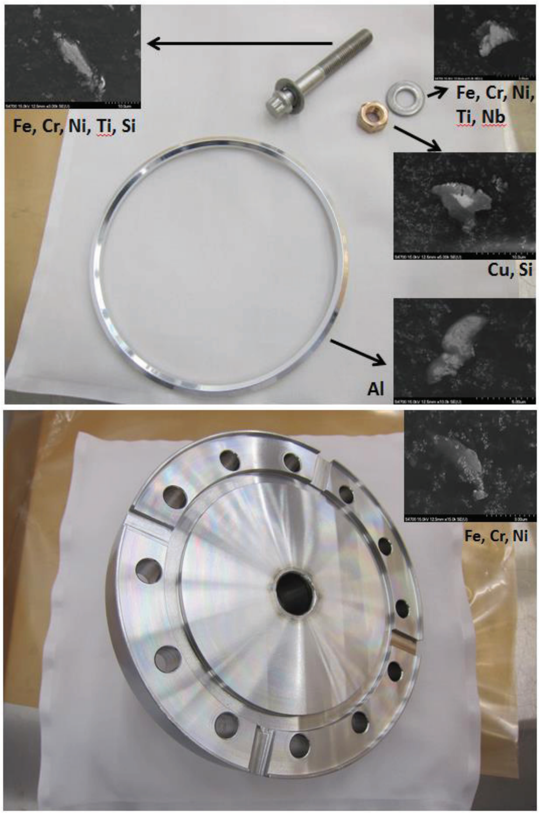

Figure 1: Particles found on assembly hardware after ultrasonic cleaning, before assembly.

Figure 2 shows the horizontal assembly configuration and 0.3 µm particle counts during assembly-disassembly experiment. Fig. 3 shows the particles collected on the carbon tape attached near the particle counter collector entrance. The composition of some of these particles matched that of the assembly hardware. For those particles that showed different composition from the assembly hardware, they might be transferred from other surfaces in the surrounding environment. For example, indium particle may come from the tools nearby for making indium seal.

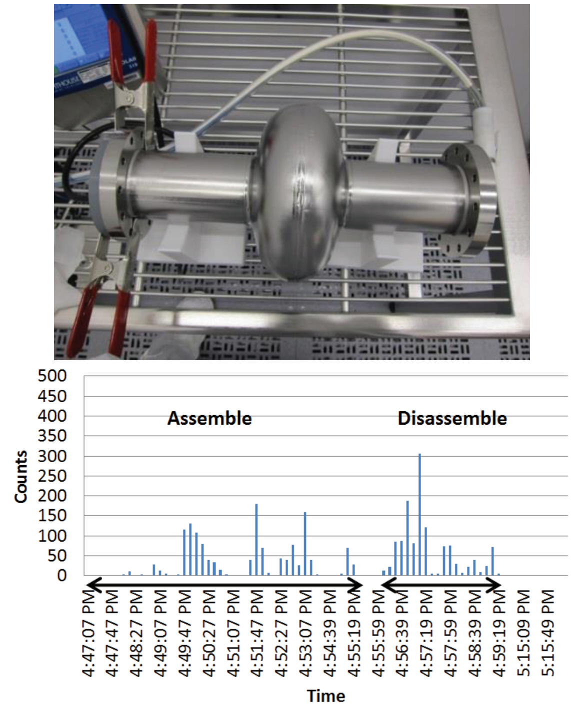

Figure 2: Horizontal assembly-disassembly setup and 0.3 µm particle counts.

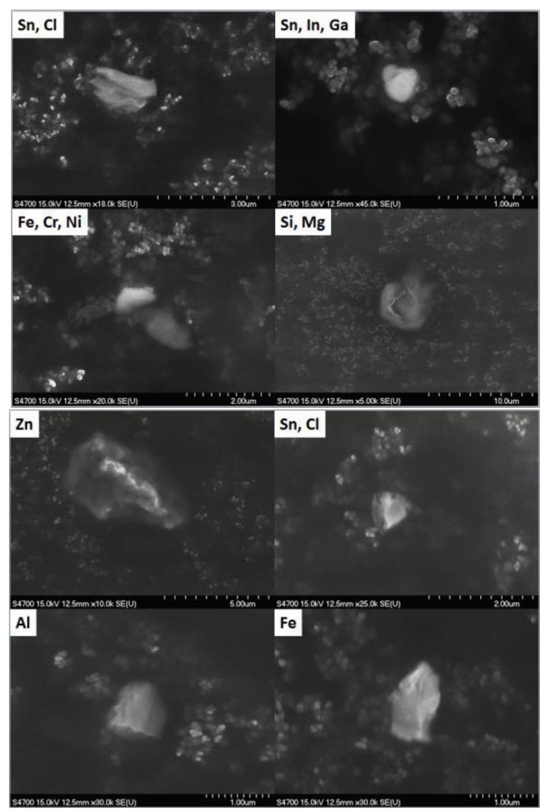

Figure 3: Particles found during horizontal assembly-disassembly experiment.

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Figure 4 shows the vertical assembly configuration and 0.3 µm particle counts during assembly-disassembly experiment. Fig. 5 shows the particles collected on the carbon tape attached near the particle counter collector entrance. No particles were found on the carbon tape attached to the beam tube inner wall. Fewer particles were found from the carbon tapes in the vertical setup experiment. In terms of particle source, again, some of these particles come from the assembly hardware, while some of them may come from the environment.

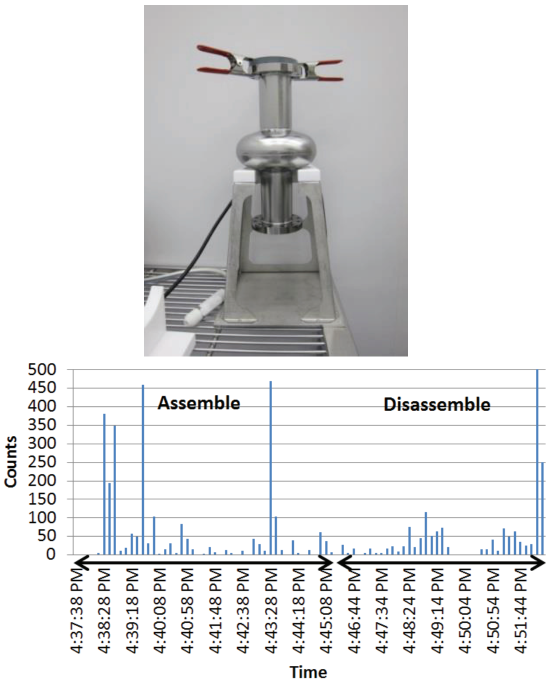

Figure 4: Vertical assembly-disassembly setup and 0.3 µm particle counts.

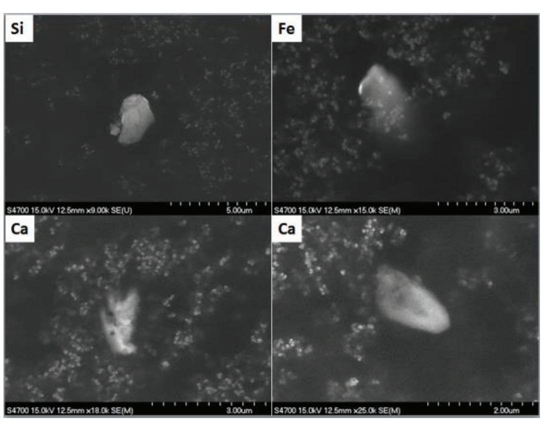

Figure 5: Particles found during vertical assembly-disassembly.

Figure 6 shows the 0.3 µm particle counts of vertical assembly-disassembly done by cleanroom assembly technician, with cavity held on a lift normally used during cavity assembly. This is a setup closer to production practice except that, the particle counter inserted into cavity was causing air flow which would not exist in real production assembly, and assembly was done outside the cavity assembly cubicle. The particle count was significantly lower than the assembly done by trainee, which indicates that skills and assembly setup are important for reducing particle generation.

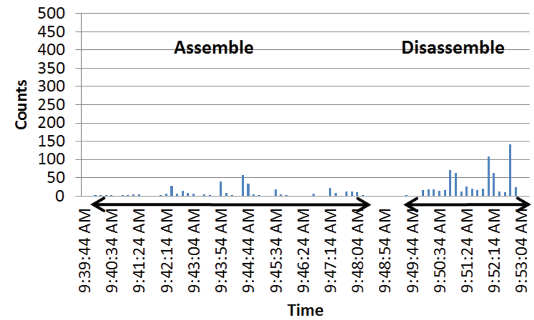

Figure 6: 0.3 µm particle counts during vertical assembly-disassembly done by cleanroom assembly technician.

After assembly-disassembly, the bolt holes and seal surface of the flanges are expected to have huge particle counts. Cleaning of bolt holes and seal surface was done by wiping with alcohol, with particle counter monitoring. Counting from bolt holes was done by blowing from beam pipe opening side of the flange and collecting on the other side. Fig. 7 shows the counts of 0.3 µm particle during and after cleaning. The particles counts from wiped bolt holes are significantly reduced compared to unwiped ones.

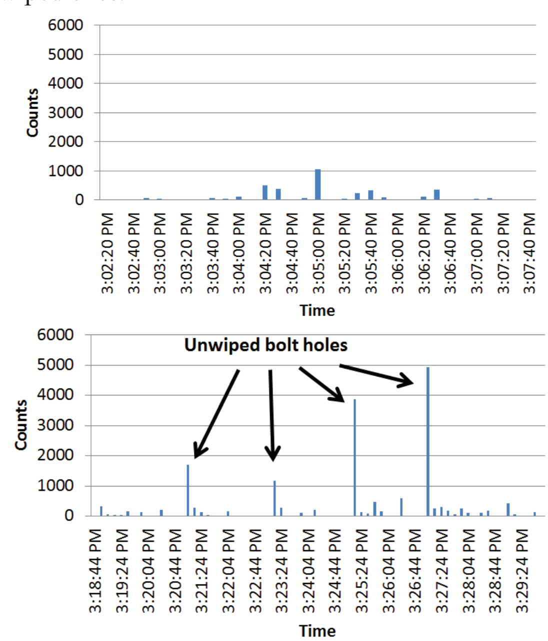

Figure 7: 0.3 µm particle counts during cleaning of seal connections. A) Wiping bolt holes with cavity positioned horizontally; B) Bolt hole particle counts with and without wiping.

SUMMARY AND FUTURE WORK

Particles still exist on parts surface even after ultrasonic cleaning. From composition of particles collected inside the cavity, both surrounding atmosphere and assembly hardware can contribute to contamination.

Contacting between metals easily generates more particles; therefore, the movement of the fasteners should be as light as possible. Practice can reduce particle generation, even if avoiding particles are almost impossible. Wiping helps cleaning bolt holes efficiently after disassembly.

Drawback of this setup is that, the particle counter caused additional air flow inside the cavity, which is not representative for the reality during production cavity assembly and disassembly. In reality, even particle is generated at flange, if there is no inward air flow, particles should not enter cavity. However, later operation may cause particle migration inside the cavity. Nonetheless, this experiment can still be used as a measure of evaluating assembly skills. Work will be continued in investigating particle existence in cavity assembled the same way as routine production process.

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