Efforts to Suppress Field Emission in SRF Cavities at KEK

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Abstract

Our main objective is to achieve as high as possible quality factors Q_0 and maximal accelerating voltages E_{acc} within 1.3 GHz superconducting radio frequency (SRF) cavities. Beside an adequate surface treatment, key to achieve good performance is a proper assembly in the clean room prior cavity testing or operation. In this contribution we present the methods and results of our efforts to get a better understanding of our clean room environment and the particulate generation caused during the assembly work. Furthermore, we present the measures taken to suppress filed emission, followed by an analysis of vertical test results of the last six years.

Motivation

Since field emission (FE) degrades the cavity performance, it has to be avoided. Thus, pollution of the inner cavity surface with particulates has to be avoided.

Sources of particulates:

- Environment
- Generation during assembly process

→ We have to understand both

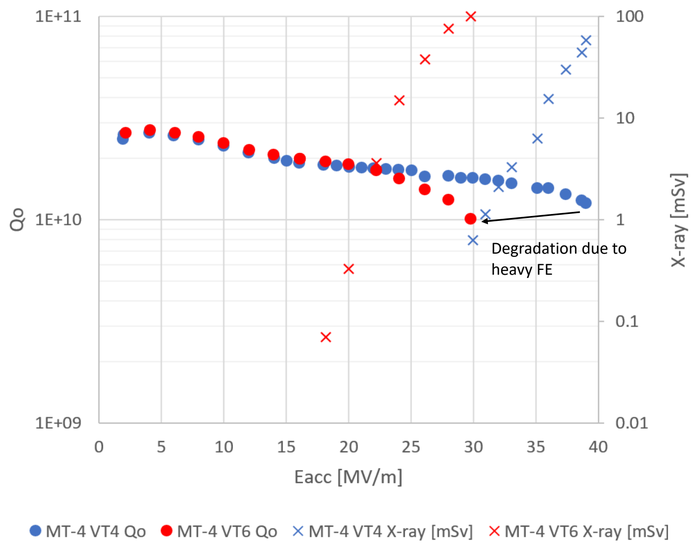

Figure 1: Q0 & X-ray [mSv] vs Eacc [MV/m] of same 1.3 GHz 9-cell cavity without (blue) and with (red) field emission

Example Workflow of Cavity Treatment before Test

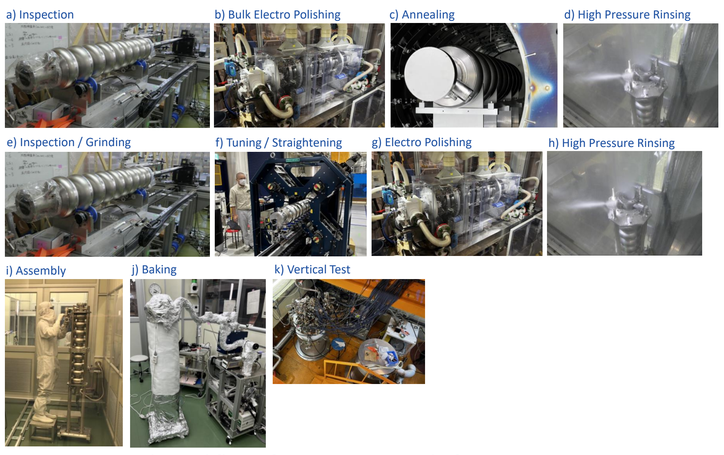

Figure 2: Example workflow of cavity treatment before test

Clean Room Survey

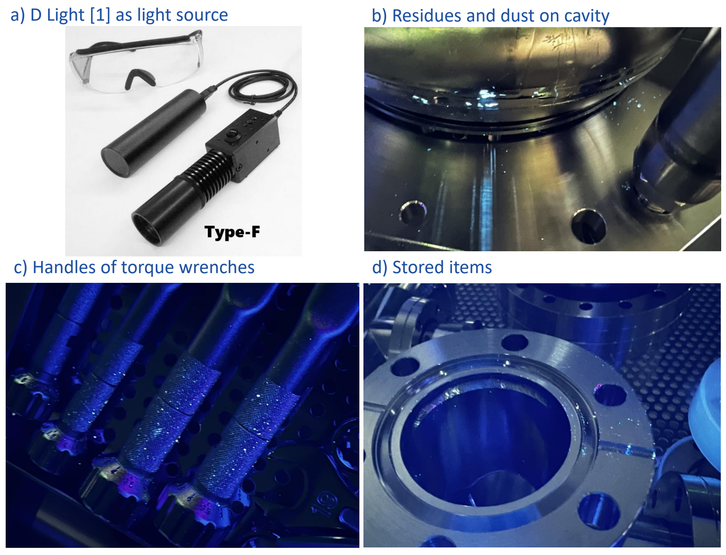

Figure 3: Pictures recorded in STF and COI clean rooms with D light, while the ambient light was turned off

- Using the D-light both allowed a survey of dust and dirt on surfaces of the clean room
- In some areas cleaning was necessary and was applied
- It was not feasible to clean every last corner → avoid whirling up dust from there

Study on Particulates Created During Assembly

- Study performed together with SHIN NIPPON AIR TECHNOLOGIES CO.,LTD
  Ambient lighting is turned off
- Green laser light is transmitted through the area of interest
- Laser light is scattered by particles
- Scattered light is recorded by a video camera

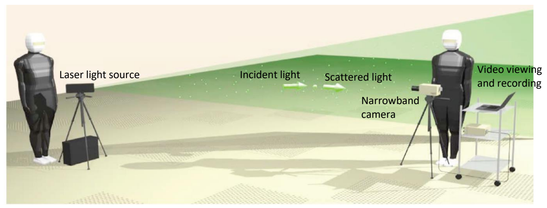

Figure 4: Principle of particle detection and visualization [2]

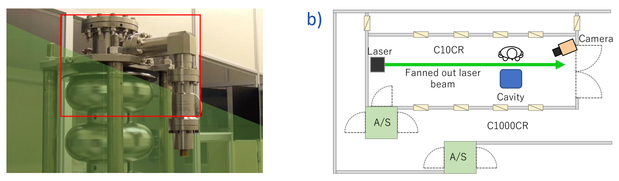

Figure 5: a) Cavity after assembly of attachment, b) schematic of setup

Figure 6: Clean blowing with ion gun and particle counter before assembly (15 s)

Figure 7: Release of bolts of blind flange using a hex key and hands (15 s)

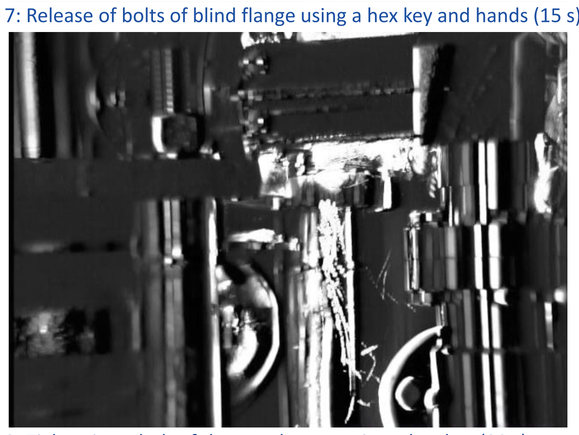

Figure 8: Tightening a bolt of the attachment using a hex key (20 s)

Lessons learned

- The typically used particle counter detects only a small fraction of particulates being present
- Despite the laminar downwards airflow in the clean room some particulates showed an upwards movement
- Thorough cleaning of the port to be assembled and its surroundings is imperative
- Loosening and tightening blots creates new particulates
- Slow and careful movement is required

Further Measures to Reduce FE

- Exchange of ion gun in STF class 10 clean room (from Simco Top Gun to Keyence SJ-L005G)
- Replacement of scroll pumps at the pumping station in the STF class 1000 clean room and at the STF vertical test stand with dry pumps
- Iris grinding in order to remove all possible defects followed by EP2

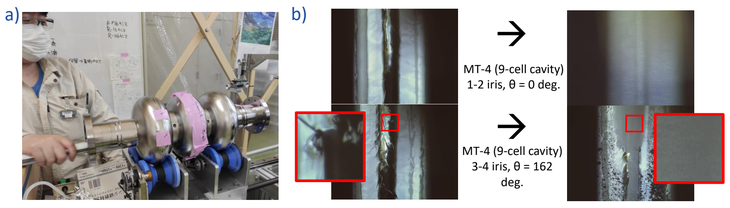

Figure 9: a) Iris grinding of a 3-cell cavity, b) Examples of iris surfaces before and after grinding

History of Field Emission at KEK

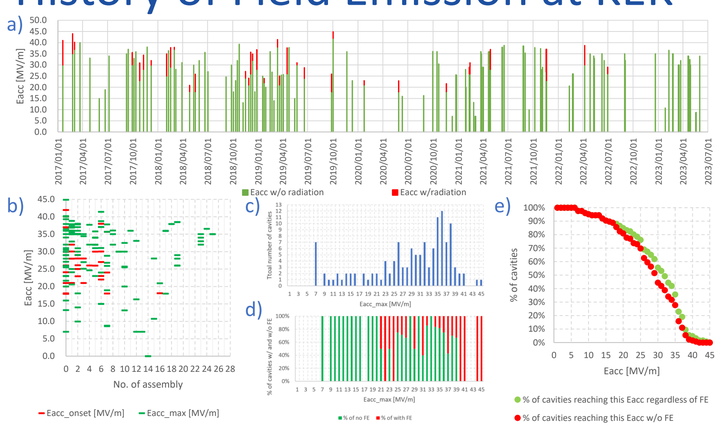

Figure 10: **Single cell** 1.3 GHz cavities: a) Gradients reached at 2 K during VTs, b) max and onset E_{acc} vs assembly, c) E_{acc} histogram, d) % of FE occurrence, e) percentage of cavities reached the E_{acc} with and without FE

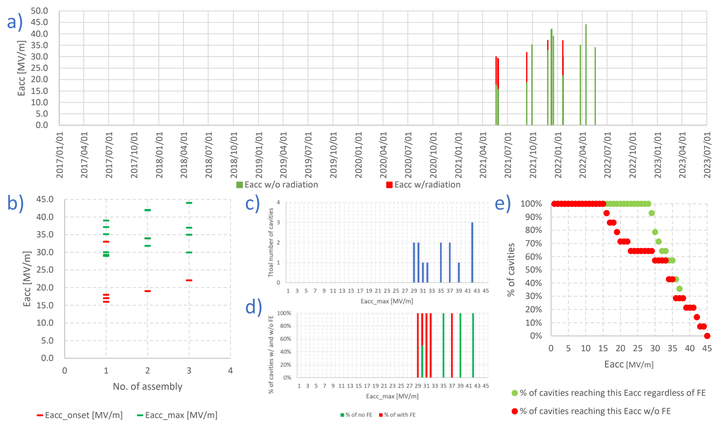

Figure 11: **3-cell** 1.3 GHz cavities: a) Gradients reached at 2 K during VTs, b) max and onset E_{acc} vs assembly, c) E_{acc} histogram, d) % of FE occurrence, e) percentage of cavities reached the E_{acc} with and without FE

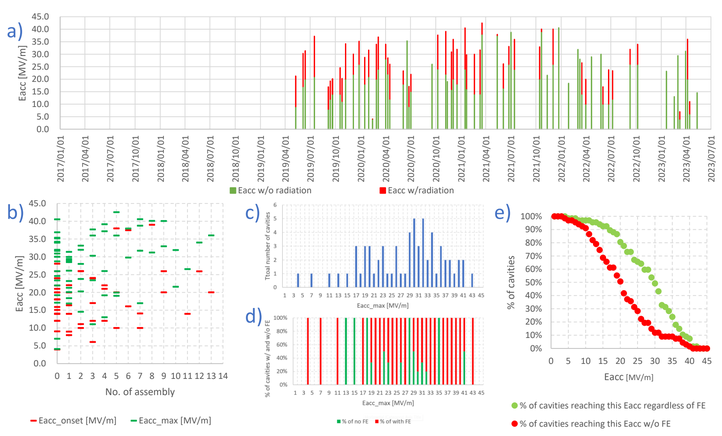

Figure 12: **9-cell** 1.3 GHz cavities: a) Gradients reached at 2 K during VTs, b) max and onset E_{acc} vs assembly, c) E_{acc} histogram, d) % of FE occurrence, e) percentage of cavities reached the E_{acc} with and without FE

	Single cell	3 cell	9 cell
Number of VTs	128	14	69
VTs with radiation	37 (29%)	7 (50%)	53 (77%)
VTs without radiation	91 (91%)	7 (50%)	16 (23%)
Mean onset E_{acc} [MV/m]	27.3	22.7	18.0
Mean ratio (onset/max)	0.83	0.69	0.63

Table 1: Statistics of FE occurrence per cavity type during VTs at KEK

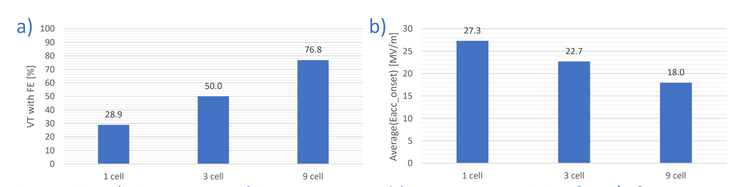

Figure 13: a) Percentage of FE occurrence, b) Average onset E_{acc} [MV/m]

Conclusion

- Usage of D light gave us a good understanding of assembly environment
- Gained insight in particle creation and movement
- Confirmed rules for behavior during assembly
- Assembly work planning, documentation, and analysis is similar to a Plan, Do, Check, Act (PDCA) cycle, which is a well-established tool in quality management
- Further measures to reduce field emission as e.g. iris grinding, exchange of tools and equipment, etc.
- Clear improvements for single-, 3- and 9-cell cavities in FE statistics
- With on all points above, we have and are constantly improving the quality of our assembly processes

References

[1] SNK, https://www.snk.co.jp/particle/product5.html
[2] SNK, https://www.snk.co.jp/particle/engineering1.html

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