Plasma Processing for In-Situ Field Emission Mitigation of Superconducting Radiofrequency (SRF) Cryomodules

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Superconducting radio-frequency (SRF) cavities are key components of modern particle accelerators, and the continuous improvement of their efficiency is critical to realize affordable and more powerful particle accelerators which are needed to carry out pivotal high energy physics experiments.

State-of-the-art SRF cavities are very efficient devices that can achieve accelerating gradients up to about 50 MV/m during vertical RF test. However, when assembled together into a string of cavities – the main component of a cryomodule – it is possible that contaminants which field emit as the electromagnetic field is established in the resonator may be introduced. Field emission is one of the main limiting factors of cavities operating in accelerators and it occurs whenever contaminants, like dust, metal flakes or even absorbates, are present on the surface of the cavity high electric field region. Field emission reduces the maximum achievable accelerating field and generates free electrons that may interact with the beam, damage or activate the beamline. Indeed, once the accelerated electrons strike on the cavity walls, or along the beamline, they can dissipate heat and generate radiation. In the most severe cases the heat generated cause the cavity superconducting state to quench via thermal breakdown [1].

One practical method that can be used to mitigate this problem is in-situ plasma processing [2]. The development of a processing that can be applied in-situ is extremely advantageous, since it enables the recovery of the cryomodule performance without the need of disassembly the whole cryomodule, which is an extremely expensive and time-consuming process. On the other hand, plasma processing only requires the cryomodule warm-up to room-temperature and the subsequent processing of the contaminated cavities. The entire process is reasonably quick and involve a limited number of personnel.

Currently, plasma processing has been applied to SNS cryomodules and thanks to this effort the SNS accelerator, previously limited by field emission at 939 MeV, is now capable of operating at the design energy of 1 GeV [2-4]. A plasma processing procedure has been developed also for LCLS-II cavities [5,6] and soon will be tested in the LCLS-II HE verification cryomodule. In both cases, plasma ignition relies solely on the RF antennas assembled to the cavities in the cryomodule. The plasma ignition methodology is dependent on the cavity RF frequency, type of RF antennas and RF coupling. Because of this, a proper methodology shall be developed for each type of cavity and cryomodule to be plasma processed.

In addition, the current methodology is based on the cleaning of the SRF inner surface from carbon contamination only. Therefore, in order to reach the maximum accelerating gradient of a cavity without field emission – which is the ultimate goal of this effort, the methodology needs to be optimized in order to be able to clean the inner cavity surface from a large variety of contaminants.

With this LOI we advocate for further developing the plasma processing, so that the technique can be applied on a large variety of cavities and implemented in several existing and future accelerators, such as: LCLS-II HE, PIP-II, ILC, CEBAF, eRHIC and FRIB.

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