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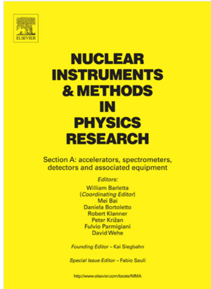

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In-situ plasma cleaning to decrease the field emission effect of half-wave superconducting radio-frequency cavities

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Abstract: The in-situ plasma cleaning technique using the chemical reactive oxygen plasma to remove the hydrocarbon contaminants, the outmost layer of the inner surface of the HWR cavity, has been explored at Institute of Modern Physics, CAS. For the purpose of cleaning the HWR cavity in the cryomodule by plasma, an offline apparatus for the plasma discharge study was set up, which duplicates the assembly of the cavity inside the cryomodule. Plasma ignition procedures were investigated. And the plasma parameters such as free electron number density, electron temperature and dissociated oxygen atom intensity were diagnosed by optical emission spectra to optimize the operation conditions for plasma in-situ cleaning of the HWR cavity. To evaluate the efficiency of the plasma in-situ cleaning of the HWR cavity, the related experiments were carried out on the vertical test stand. The results show that the hydrocarbon contaminants on the inner surface of the cavity were removed, and the maximal available accelerating gradient of the cavity was improved by 29% due to the mitigation of field emission inside the cavity after plasma cleaning. Details of these experimental results and observations are discussed in this article.

Key words: in-situ plasma cleaning, half-wave SRF cavity, optical emission spectra, contamination, field emission effect

1. Introduction

Superconducting radio frequency (SRF) cavities are the essential component in SRF accelerators, which provide energy for charged particles. Compared to the normal conducting cavities, SRF cavity has the advantages of much higher accelerating gradient and lower power dissipation [1]. However, the performance of state-of-the art SRF cavities is mainly limited by the field emission inside the cavities, which is typically caused by the inner surface contaminations of the cavities, such as foreign particles of sizes large enough to cause field enhancement, as has been seen over the years from experimental data these can be removed by high pressure rinsing. And the foreign chemical components such as hydrocarbons and absorbed residual gas are hardly removed by the standard cleaning method [2-3]. Many efforts have been made by the SRF community for the development of the in-situ techniques to improve the accelerating gradient of SRF cavities in cryomodule. Nowadays, the high power pulse (HPP) [4] conditioning technique and helium processing (HP) [5] technique are routinely used, whose functions are attributed to the modification of the surface morphology of the cavity. However, the contaminants covered on the inner surface of SRF cavity cannot be removed completely, therefore, the improvement of the performance of SRF cavities processed by these techniques are limited, furthermore, its mechanisms are still not clear enough. Fortunately, recent studies of in-situ plasma processing provide an effective solution for the field emission issue.

Mammosser *et al.* are the early team that introduced the plasma cleaning technique into the SRF community, and they had developed the plasma ignition technique successfully in the 5-cell elliptical cavity that used in the CEBAF at Jefferson Lab [6]. The study by Tyagi *et al.* indicated that the

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