In-Situ Plasma Processing Developments of 1.3 GHz ARIEL Cavities

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Abstract

Superconducting RadioFrequency (SRF) technology is a key component in many particle accelerators operating in a continuous wave, or high duty cycle, mode. The on-line performance of SRF cavities can be negatively impacted by the gradual reduction in the accelerating gradient that can be attained within a reasonable field emission level. Conventional cleaning procedures are both time- and resource-exhaustive as they are done *ex-situ*. As such, *in-situ* techniques are quite attractive. Plasma processing is an emerging *in-situ* method of cleaning which utilizes a mixture of oxygen and an inert gas to chemically remove hydrocarbon-based field emitters through plasma. At TRIUMF's Advanced Rare IsotopE Laboratory (ARIEL), an R&D program is in place to develop plasma processing procedures using fundamental power couplers on 1.3 GHz ARIEL 9-cell cavities. Single cell and multi-cell processing has been performed off-line. The studies involve varying the input parameters and testing the effectiveness of the treatment through RGA analysis. The progress on the developments will be reported.

Motivations

Currently ARIEL is delivering 30 MeV beams to the ISAC facilities at TRIUMF using three 1.3 GHz 9-cell ARIEL SRF cavities. Rare Isotope Beam (RIB) production depends logarithmically on beam energy, so cavity degradation inhibits yield drastically. Typical cleaning procedures can take upwards of two months from cyromodule disassembly, so shorter downtime techniques are desired.

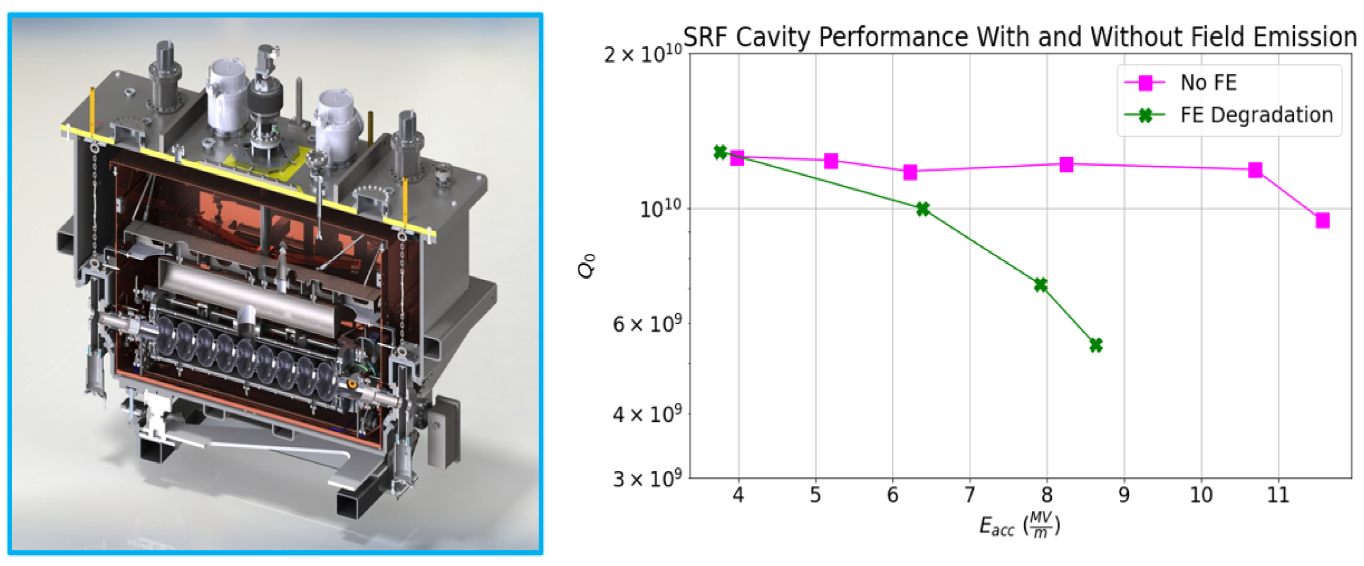

Figure 1: ARIEL injector cryomodule (left). Q-factor and accelerating gradient curves before and after field emission onset (right).

Plasma Mechanism

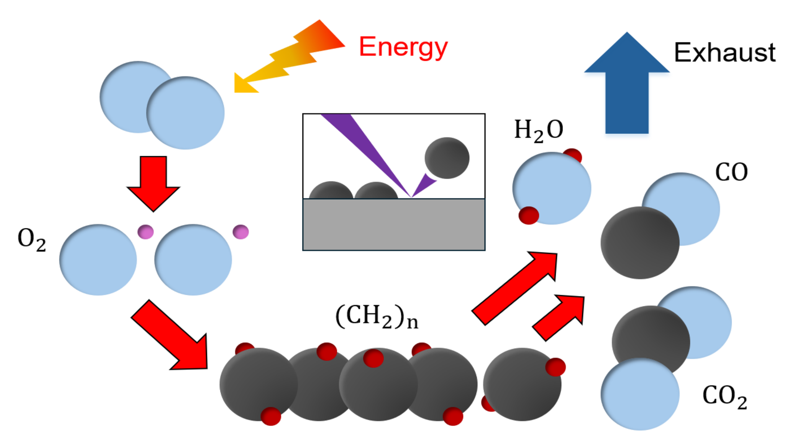

Figure 2: Plasma processing illustration.

- RF glow discharge is created within a cell.
- Particle collisions create free e^-'s, which crack O_2 molecules.
- Radical Oxygen molecules react with hydrocarbons to form volatile byproducts.
- Exhaust is then pumped out of the system.

Single Cell Bench Tests

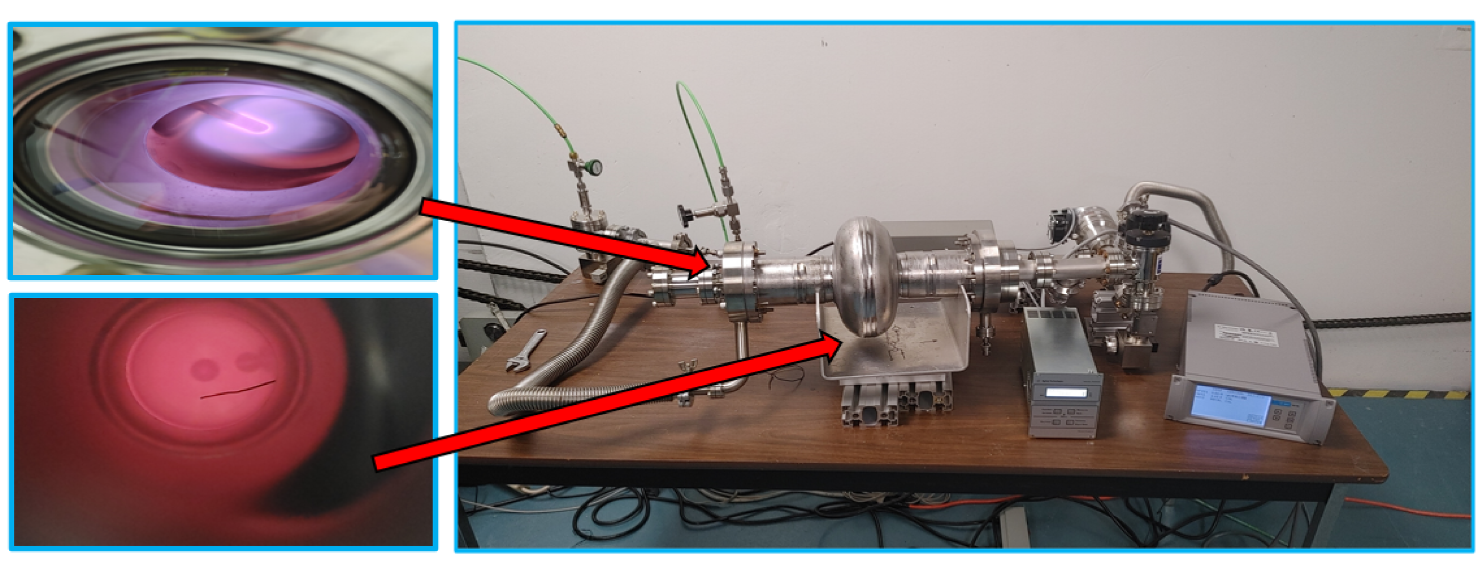

Figure 3: Coupler plasma (top left) and cell plasma (bottom left) for the single cell assembly (right).

RGA Scans

A Residual Gas Analyzer (RGA) is utilized for its mass spectrometry capabilities. Two forms of plasma are assessed using the RGA:

- He-CH_4: Used to pollute the inner cavity surface with Carbon.
- He-O_2: Used to chemically clean the inner cavity surface.

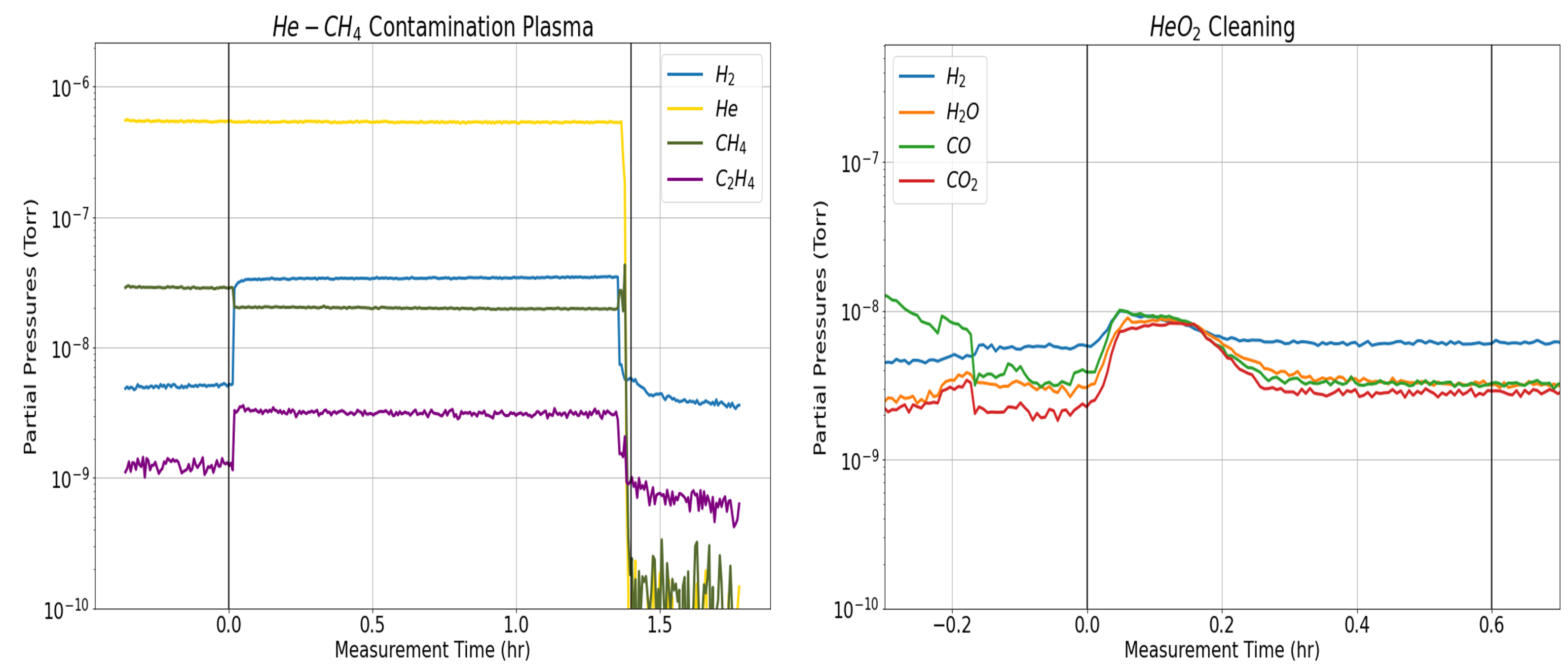

Figure 4: He-CH_4 contamination plasma RGA PvT scan (left). He-O_2 cleaning plasma RGA PvT scan (right).

Recipe Comparisons

The effectiveness of plasma at cleaning hydrocarbons is dependent on the cavity pressure and the gas-to-gas ratio. To directly compare each recipe, the contaminant curves are normalized using the scheme:

$$\frac{PP_P - PP_{NP}}{P_{CAV}} \quad (1)$$

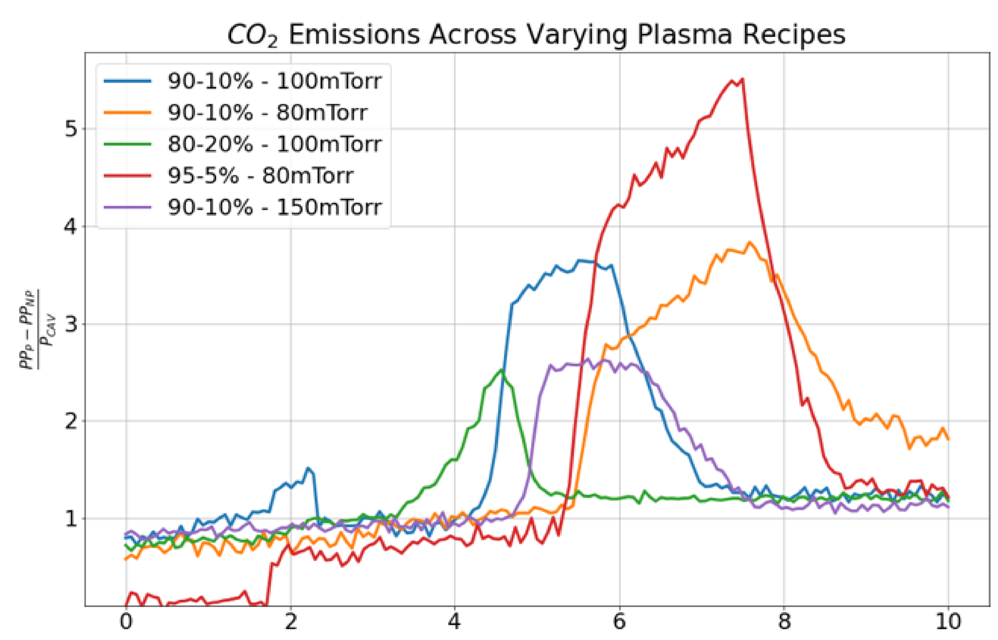

Figure 5: CO_2 yield between various plasma recipes.

9-cell Plasma Movements

Multi-cell cavities pose a unique problem. The field patterns within the cavity can change depending on the driving frequency, each producing unique plasma behavior. Currently, a scheme is being developed that aims to utilize each field pattern to clean each of the nine cells sequentially.

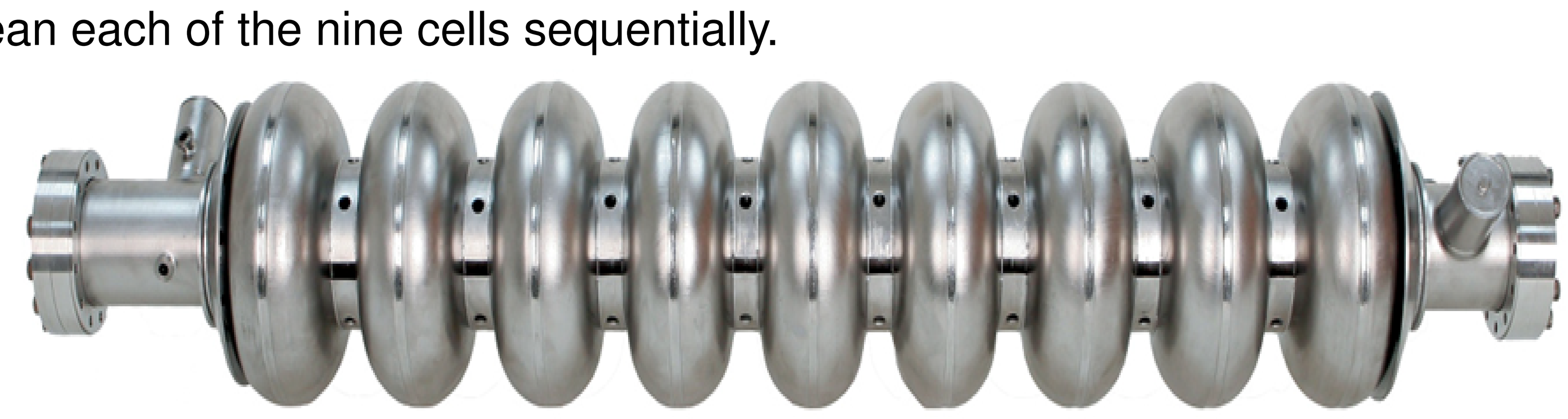

Figure 6: A 1.3 GHz TESLA 9-cell SRF cavity.

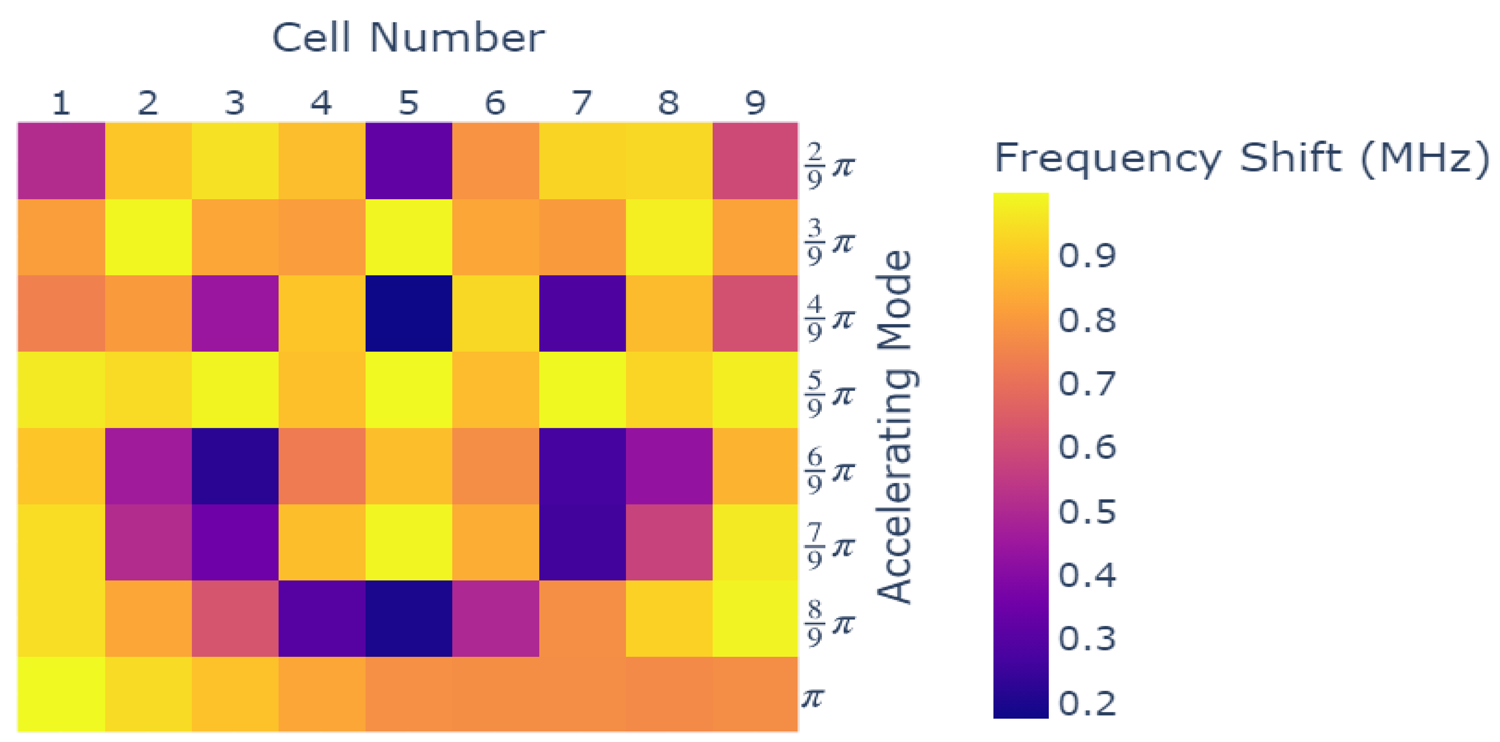

Figure 7: A predictive plasma location model using each igniting mode's bead-pull field profile.