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MULTIPACTOR DISCHARGE IN SHORT 5-GAP 80 MHz IH STRUCTURES

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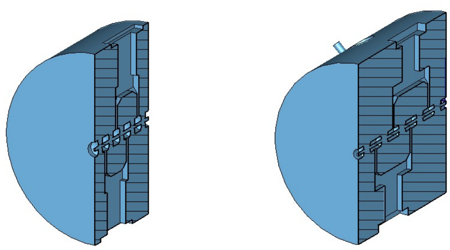
Abstract

The results of numerical simulations of multipacting discharge in accelerating Interdigital H-type (IH) cavities are presented in this paper. Optimal design parameters were selected to reduce the number of multipactor electrons. The localization of multipactor trajectories in the short 5-gap 80 MHz IH cavities at various levels of accelerating voltage is considered.

INTRODUCTION

The multipactor effect[1-4] is a phenomenon in radio frequency devices, where secondary electron emission in resonance with an alternating electric field leads to exponential electron multiplication, possibly damaging and even destroying the RF device.

Figure 1 shows the 3D models of the considered 5-gap Interdigital H-type cavities: β=0.06 (a) and β=0.1 (b). This paper investigates the location and possible expansion of the multipactor discharge at different voltage levels.



(a) (b)

Figure 1: 3D models of the 80 MHz IH cavities.

In this structure, there are two main areas where a multipactor discharge can occur (see Fig. 2): the gap region at low voltages (up to 10 kV), and the region of the external surface of the resonator and the side walls – at high voltages (up to 4 MV)[5].

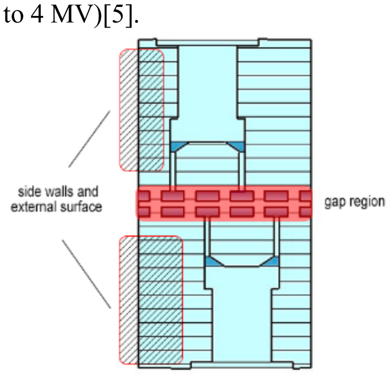


Figure 2: Dangerous areas.

GEOMETRICAL MODIFICATION

To decrease the number of multipactor trajectories, the geometry of the drift tube has been modified. The straight angled tubes were replaced with the drift tubes with a bevel (see Fig. 3).

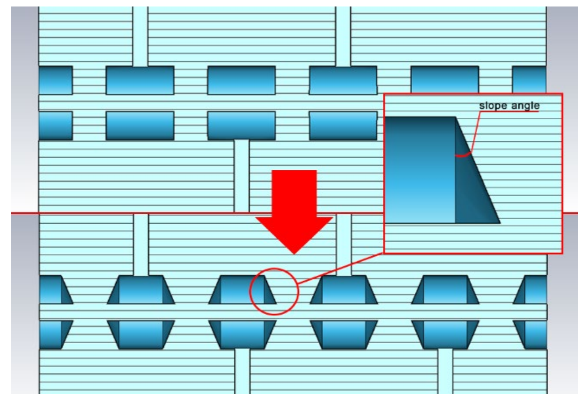


Figure 3: Geometrical modification of the drift tube.

The value of the slope angle of the bevel was selected considering the shunt impedance graph (see Fig. 4).

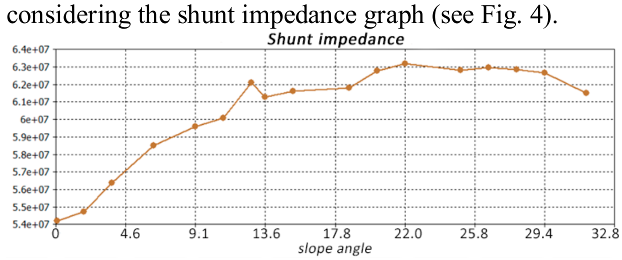


Figure 4: Shunt impedance dependence of the slope angle.

The maximum value of the shunt impedance corresponds to the slope angle of 22°.

THRESHOLD VOLTAGE

The gap voltage [6] at which two-point multipacting of order n can occur can be calculated using expression (1).

$$V = Ed = \frac{d^2(2\pi f)^2 m}{(2n-1)\pi e}. \tag{1}$$

The results of the theoretical calculation of threshold voltage are summarized in Table 1.

Table 1: The Results of Theoretical Calculation of Threshold Voltage Levels

	Short gap	**Long gap**
Working voltage, MV	1.5	3.5
Threshold voltage (structures without bevel), kV	1.5	5.1
Threshold voltage (structures with bevel), kV	2.3	7.0

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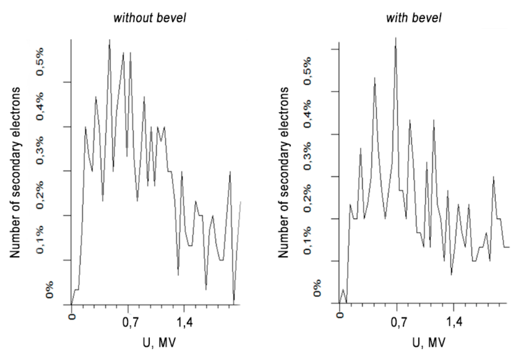
It is seen that potentially dangerous gap voltage at which multipacting can occur is up to 7 kV.

NUMERICAL MODELING

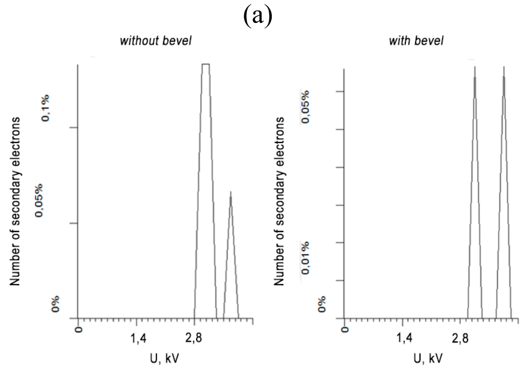
For the investigation of multipacting discharge effects the MultP-M code [7-9], developed at MEPhI, has been used. The electromagnetic field is exported from the CST studio [10].

Figure 5(a) shows the number of surviving electrons versus the RF voltage in the IH structure with and without a bevel. The low voltage range was considered separately.

Figure 5(c) shows the diagram RF phase / U. For each pair of RF phase and U, the code tracks the trajectories of 100 electrons randomly distributed over the structure. Each square in Fig. 5(c) corresponds to the voltage level and RF phase electron collision at which multipactor trajectories are detected.



(a)



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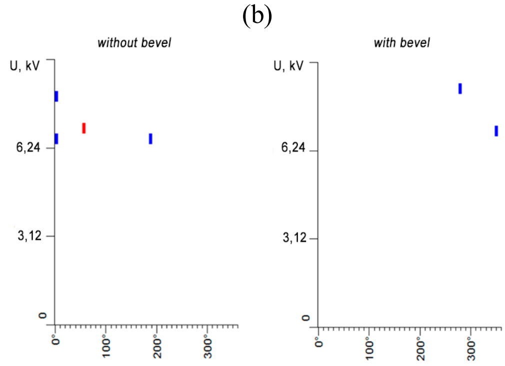
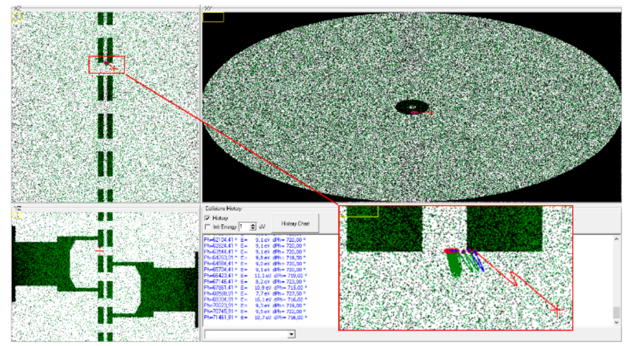


(c)

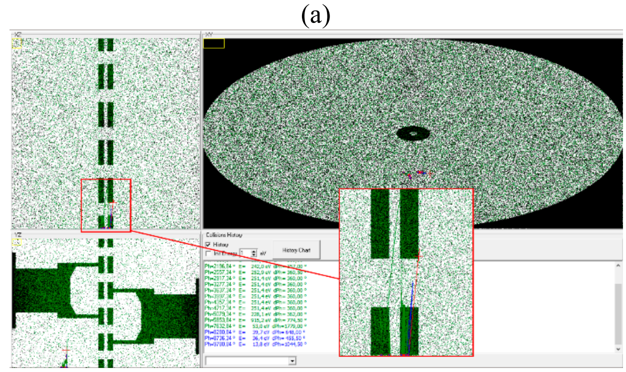
Figure 5: (a) Number of surviving electrons versus voltage level: (a) wide range, (b) low voltage range; (c) diagram RF phase / Voltage.

Thus, in structures with a bevel, there is a smaller increase in the number of particles compared to structures without a bevel. The RF phase / Voltage diagrams show that there is a smaller number of multipactor trajectories in the gap region of structures with a bevel.

Examples of Multipactor Trajectories



(a)



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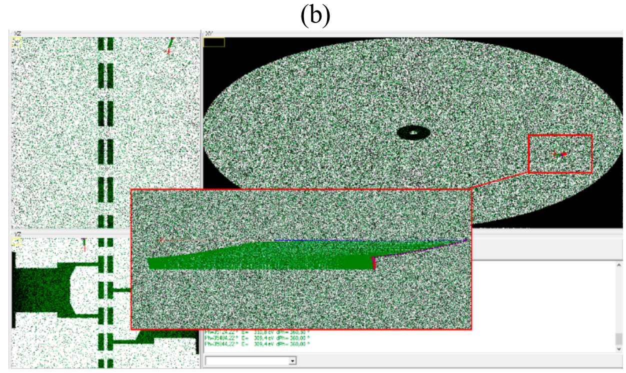

(c)

Figure 6: Example of the multipactor trajectories at a different voltage: (a) U=2.8 kV; (b) U=0.47 MV; (c) U=1.97 MV.

It can be seen from Fig. 6 that as the voltage increases, the multipactor trajectories shift closer to the outer surface of the considered 5-gap Interdigital H-type cavities.

CONCLUSION

Thus, the calculation results confirmed the effectiveness of the proposed design change in suppressing the multipactor discharge. Critical regions of multipactor avalanches at different levels of the accelerating voltage are identified.

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