ON POSSIBILITY OF EXTERNAL MAGNETIC FIELD APPLICATION FOR ELECTRICAL INSULATION OF ELECTRODES

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To investigate the influence of spatially-nonuniform external magnetic field on electrical strength of interelectrode gaps, PIC-simulation of DC breakdown has been performed. Preliminary results have shown breakdown delay due to applied external magnetic field of 0.6 T and higher in reference electrode geometry.

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INTRODUCTION

The method to focus charged particles in linac based on a combination of phase-alternating and magnetic focusing is proposed and is under study at the Institute of Plasma Electronics and New Acceleration Methods of NSC KIPT. It has been suggested to use permanent magnets made of neodymium-iron-boron (NIB) or samarium-cobalt (SC) alloy placed inside drift tubes for external magnetic field generation. These magnets are placed with either like or unlike magnetic poles in the adjacent tubes. Numerical simulations of beam dynamics demonstrated that external magnetic field facilitates focusing of accelerated proton beams [1]. However, the influence of such magnetic field on electrical strength of drift tube gap has not been sufficiently studied. In Ref. [2] described is the experimental stand for studies of high-frequency gap electric strength with applied external magnetic field and the computational technique for magnetic circuit calculation in proton linac sections with combined alternating-phase and magnetic focusing.

As has been shown in Ref. [1], like-pole orientation of permanent magnets inside the adjacent drift tubes looks more interesting. If this is the case, magnetic field lines have component parallel to the drift tube face and this fact allows for possible magnetic insulation taking place between the tubes. This paper begins studies into influence of magnetic field generated by permanent magnets onto electrical strength of an in-between electrode gap. As a starting point, DC breakdown is considered.

SIMULATION MODEL AND RESULTS

To perform simulation, a choice has been made in favor of 2D ArcPIC code (see Ref. [3]) which was developed to model the breakdown in CERN DC spark system geometry. This code is electrostatic and includes solution for the Poisson equation, Boris scheme for equations of motion, Fowler-Nordheim field emission of electrons, neutral atom emission, basic set of collisions calculated according to the Monte-Carlo algorithm and an external driving RC-circuit. To lessen computational demands and simulation runtime, geometrical, electrical and other parameters are scaled in such a way that the breakdown would develop within 2…3 ns [4]. This feature has been taken into account while running the simulations.

Geometry and simulation parameters have been chosen from Ref. [4]. The code has also been updated to implement the influence of external spatially nonuniform magnetic field with r- and z-components. To calculate magnetic field distribution generated by NIB magnets, the program FEMM (see Ref. [5]) has been used. Then the data obtained by the FEMM program are tabulated and passed to the main time-loop of the ArcPIC code. Example of such calculation is presented in Fig. 1.

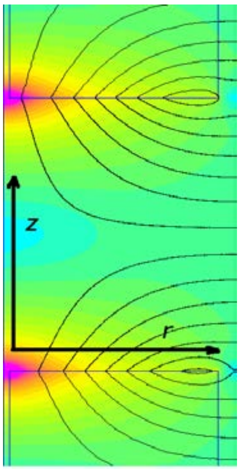

Fig. 1. External magnetic field topology

This paper focuses on an initial stage of breakdown development. General view of current and voltage evolution corresponding to the mentioned process is presented on Fig. 2.

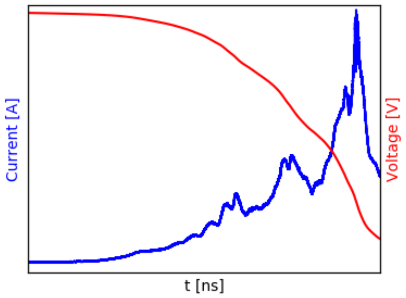

Fig. 2. Typical current and voltage evolution of breakdown from simulation

Several simulation runs have been performed for different values of external magnetic field. Fig. 3 depicts the current evolution calculated in these simulations. As can be observed from this figure, the current curve demonstrates both the left (that corresponds to magnetic field induction less than 0.6 T) and the right shifts (for magnetic induction greater than 0.6 T) with respect to the reference simulation with no magnetic field applied. It may be that the transverse component of the weak applied magnetic field could not outperform the combined force of focusing by the longitudinal component of this magnetic field and acceleration by the accelerating gradient in the gap in its effect on electrons. As the result, the plasma sheath is forming faster and the breakdown is developing earlier. Still, the question remains open.

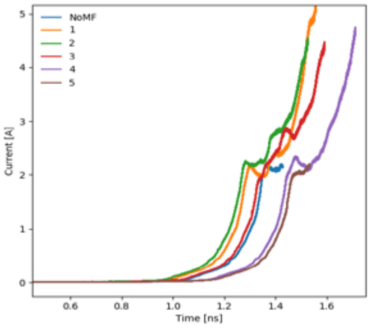

Fig. 3. Simulated current evolution for different magnetic field induction:
1 – $|B|_{max}$=0.24 T; 2 – $|B|_{max}$=0.41 T; 3 – $|B|_{max}$=0.57 T;
4 – $B|_{max}$=0.62 T; 5 – $|B|_{max}$=0.76 T;
NoMF – no magnetic field applied

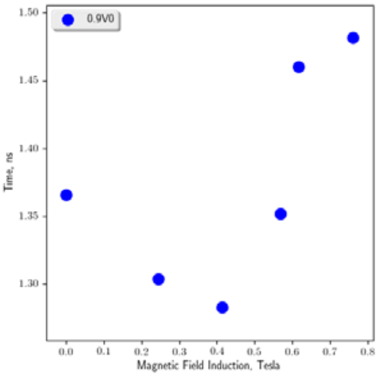

Fig. 4. Voltage fall times as a function of external magnetic field induction

Fig. 4 illustrates how fast the voltage across the gap falls to 90% of its initial value for different applied external magnetic field. As simulation results indicate, such fall in voltage makes the breakdown unavoidable. It is also worth mentioning that although the simulations were interrupted after the voltage drops to 60% or less of its initial value, the curve retains its shape.

CONCLUSIONS

The simulation results for external magnetic field influence on electrical strength of the in-between-electrode gap have shown that permanent magnets' field could delay the breakdown at least in DC case and at medium value of magnetic field induction. It allows one to presume that in RF case simulation by choosing well certain parameters the breakdown delay could be increased to ensure gap electrical insulation. The studies are being continued.

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О ВОЗМОЖНОСТИ ПРИМЕНЕНИЯ ВНЕШНЕГО МАГНИТНОГО ПОЛЯ ДЛЯ ЭЛЕКТРИЧЕСКОЙ ИЗОЛЯЦИИ ЭЛЕКТРОДОВ

О.Н. Шулика

Для исследования влияния пространственно-неоднородного внешнего магнитного поля на электрическую прочность зазоров проведено PIC-моделирование развития пробоя при постоянном напряжении. Полученные предварительные результаты показывают задержку пробоя при магнитном поле, большем 0,6 Тл, в рассматриваемой геометрии электродов.

ПРО МОЖЛИВІСТЬ ВИКОРИСТАННЯ ЗОВНІШНЬОГО МАГНІТНОГО ПОЛЯ ДЛЯ ЕЛЕКТРИЧНОЇ ІЗОЛЯЦІЇ ЕЛЕКТРОДІВ

О.М. Шуліка

Для дослідження впливу просторово-неоднорідного зовнішнього магнітного поля на електричну міцність міжелектродних проміжків проведено PIC-моделювання розвитку пробою при постійній напрузі. Отримані попередні результати вказують на затримку розвитку пробою при магнітному полі, більшим 0,6 Тл, у геометрії електродів, що розглядається.