Study on pseudospark switch with high repetition frequency with double-pulse triggering

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Abstract

The pseudospark switch works in the left branch of Paschen curve with low gas pressure, which has the advantage of short electrode breakdown time (<10ns), large pulse current (>100kA), and long lifetime, etc. High pulse repetition frequency (PRF) pseudospark switch has important applications in food processing, sewage treatment, high energy laser system, sonar syste, and other fields, the pseudospark switch with a PRF of kHz-level is needed. This paper focuses on the pseudospark switch with double-pulse trigger structure, and the corresponding relationship between the two trigger voltages and current is calculated respectively, and the influence of the two pulses on the trigger process is analyzed. Then the pseudospark switch with this structure is tested with the anode voltage of 10kV for different voltage and gas pressure. The results show that the minimum trigger voltage is only 100V, and the switch can work stably with high repetition frequency.

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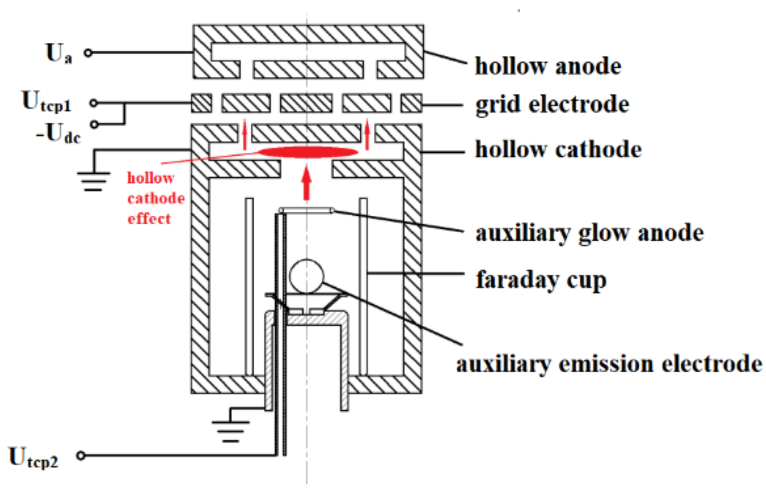
Introduction: In engineering practice and scientific research, the increasing development of pulse power technology also requires the subsequent progress of switching devices, especially in the field of high PRF has urgent application needs and huge space for development, such as in the military field, for underwater communication and underwater confrontation, the need for 10 kHz to 100 kHz with sonic high repetition frequency switches. High power and high repetition frequency switches of GW class kHz are also required in high energy laser weapons[1]. In daily life and industrial production, high pulse repetition frequency switches can greatly improve work efficiency in sewage treatment, food processing and other fields[2-3]. The existing pulse power technology switches include solid switches, thyratron switches, field distortion switches, pseudospark switches and so on. However, only the pseudospark switch can combine high power and high PRF performance. In the Z-pinch nuclear fusion device, the pseudospark switch is the only switch with PRF operation capability[4]. Therefore, the pseudospark switch with high repetition frequency is one of the leading directions of the development of high power pulse field in the world.

Double-pulse triggering structure: V.D. Bochkov et al. [5-6] of the Russian Institute of High Current Electronics developed a series of commercial high repetition frequency pseudospark switches (TPI type). All of them adopt the structure of glow discharge and double-pulse triggering, and the PRF reaches 20kHz.

Based on the electrode structure of glow discharge and double-pulse trigger [7], we designed the high PRF pseudospark as shown in Figure 1(a), which is composed of hollow anode, grid, hollow cathode and glow trigger structure, and the trigger structure includes auxiliary glow discharge anode, auxiliary emission electrode and Faraday cup, its photo shown in Figure 1(b). Dual pulse triggering is divided into main-trigger voltage U_{tcp1} and pre-trigger voltage U_{tcp2}. The U_{tcp2} is applied to the auxiliary glow discharge anode, and the U_{tcp1} is to the grid. The electronic path is shown in the arrow in Figure 1(a). In order to verify the effectiveness of double-pulse triggering and the influence of pre-trigger and main trigger pulses on the discharge process, this paper tests the pulse repetition frequency performance of the structure under different gas pressure and trigger voltage, and simulates the trigger unit to observe the influence of different trigger voltages on the cathode current.



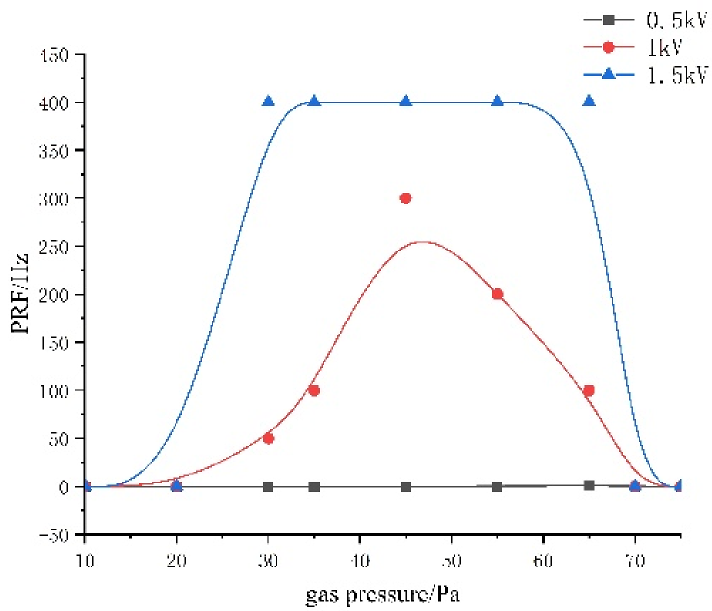
(a) structure

(b) picture of products

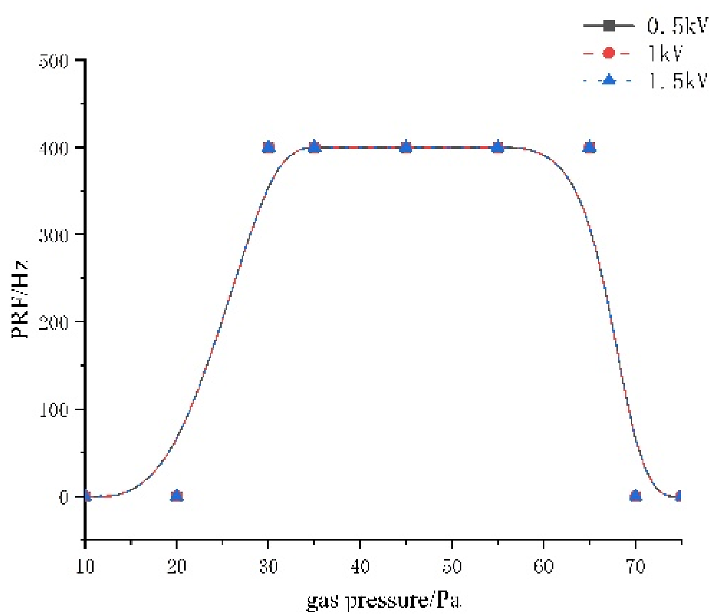
Fig 1 Glow discharge - double pulse triggering pseudospark switch: (a) structure; (b) picture of products

*PRF influenced by pre-trigger voltage U_{tcp2}:*Based on the anode voltage E_a=10kV, the influence of the pre-trigger voltage U_{tcp2} on the PRF is obtained, as shown in Figure 2.

As shown in Figure 2(a), when the main trigger voltage is low U_{tcp1}=0.3kV, increasing the U_{tcp2} can significantly improve the pulse repetition frequency characteristics. The application of the U_{tcp2} corresponds to the process of initial electron generation. The larger the trigger voltage, the stronger the spatial electric field, the faster the electron migration rate, the more intense the collision ionization, while the faster the hollow cathode effect is generated. When the main trigger voltage is higher U_{tcp1}=1kV, as shown in Figure 2(b), increasing the U_{tcp2} at this time has almost no impact on the PRF performance.



(a) U_{tcp1}=0.3kV



(b) U_{tcp1}=1kV

Fig 2 The influence of different U_{tcp2}(0.3kV、0.5kV、1kV) on PRF: (a) U_{tcp1}=0.3kV; (b)U_{tcp1}=1kV

For this reason, simulation verification is carried out for the case of higher main trigger voltage U_{tcp1}. Figure 3 shows when the U_{tcp1} is 1kV, the influence of different pre-trigger voltages U_{tcp2} (0.3kV, 0.5kV, 1kV) on the trigger current. Appropriately increasing the U_{tcp2} (from 0.3kV to 0.5kV) can improve the current growth rate. However, continuing to increase the U_{tcp2} to 1kV corresponds to the current rise speed can be seen to decrease. This is because when the U_{tcp2} = 0.5kV, the current is close to saturation, and further increase of the U_{tcp2} at this time will cause some electrons to be directly pumped to the anode, resulting in the weakening of impact ionization and the weakening of current.

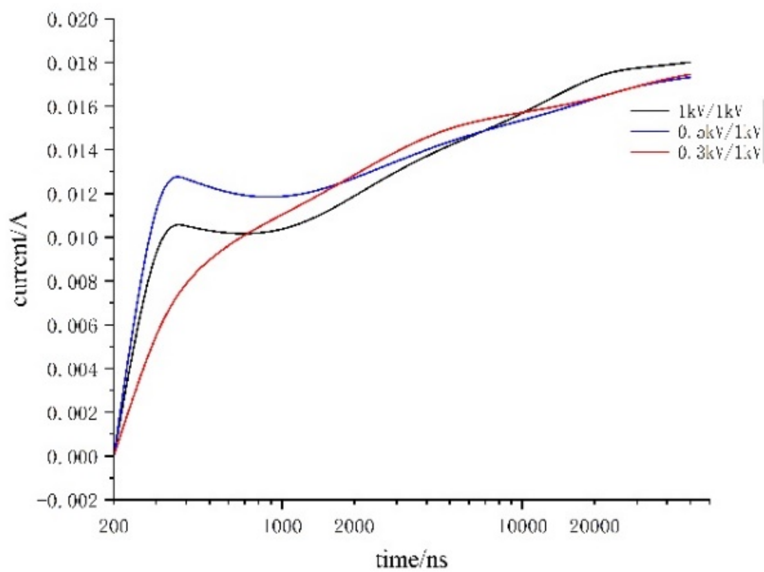


Fig 3 When the U_{tcp1}= 1kV, trigger current influenced by the U_{tcp2} (0.3kV, 0.5kV, 1kV)

*PRF influenced by main-trigger voltage U_{tcp1}:*When the gas pressure is fixed at 50Pa and the anode voltage E_a=10kV, the variation diagram of the repetition frequency with the U_{tcp1} (0-5kV) is obtained at different U_{tcp2} (0.5kV, 1kV, 1.5kV), as shown in Figure 4.

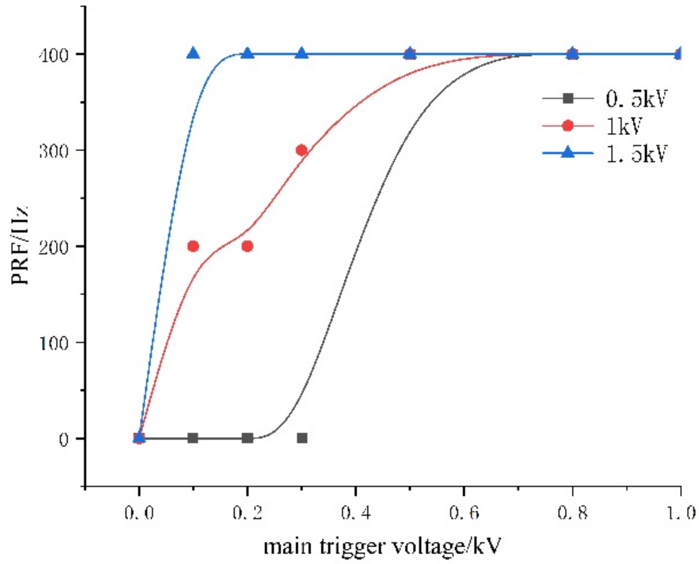


Fig 4 Under different U_{tcp2} (0.5kV, 1kV, 1.5kV), the PRF changes with the U_{tcp1}

When the main trigger voltage U_{tcp1}[?]0.3kV, PRF performance significantly improves with the increasing of U_{tcp2} (from 0.5kV to 1.5kV), while when the U_{tcp1} [?]0.8kV, the U_{tcp2} has little effect on the PRF. It can be seen that the lower $U_{tcp2}$is, a higher U_{tcp1} is needed to improve the initial plasma concentration. Conversely, when the U_{tcp2}increase, the initial plasma concentration is large enough, and it will just need a very small U_{tcp1} to pump the initial plasma to the main gap. For example, under the U_{tcp2}=1.5kV, only 100V main trigger voltage allows the switch to operate stably at 400Hz. After testing and verification, the U_{tcp1} can maintain the 400Hz PRF in the larger range of 0.1~5kV.

Conclusion: In this paper, the double-pulse triggering glow discharge structure is used to realize the high PRF pseudospark, and the test is carried out under different gas pressure, pre-trigger voltage and main-trigger voltage respectively. The results shows the minimum trigger voltage required to achieve stable trigger is about 100V, according to the test results, the simulations, about under different gas pressures, the influence of two trigger voltages on the current, carried out. Finally, combined with the simulation and test results, the influence of pre-trigger and main trigger voltage on the discharge process is summarized respectively, that is, the initial plasma is generated by pre-trigger voltage, and the main trigger pulse is responsible for pumping plasma into the main gap.

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