Research on combustion characteristic between plasma ignition and high-energy nitramine gun propellant

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1 Introduction

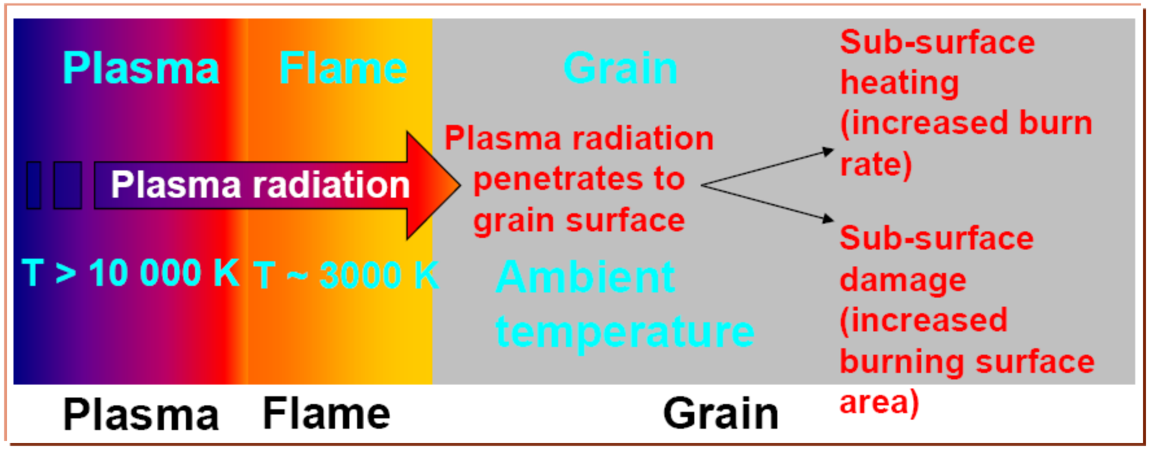
The ETC launch system is composed of

◆a pulsed power source

◆a plasma generator

◆a combustion chamber.

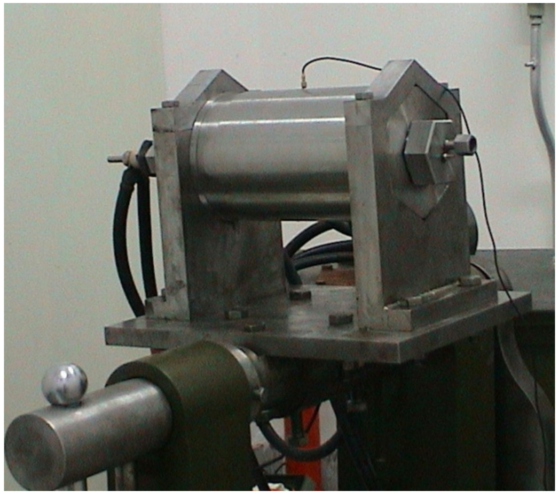
The injected plasma is taken as an ignition source in the ETC launch system.



ARL’s results show that 30% of the plasma ignition is caused by plasma radiation while BAE’s results show that plasma radiation has few effects on the plasma ignition.

QinetiQ believes that the enhancement of the plasma ignition is determined by the release of latent heat energy.

A series of experiments was conducted



- ◆The open air ablation test
- ◆The interrupted burning test
- ◆The closed bomb test

with different ignition methods and charging voltages were carried out.

Finally, the plasma ignition mechanism will be presented.

2 Experimental setups

2.1 The open air ablation test

The ablation test was conducted in the open air to investigate the starting stage of the plasma ignition. ablation dominates in the plasma-propellant interactions. The experimental setup is illustrated in Fig.1

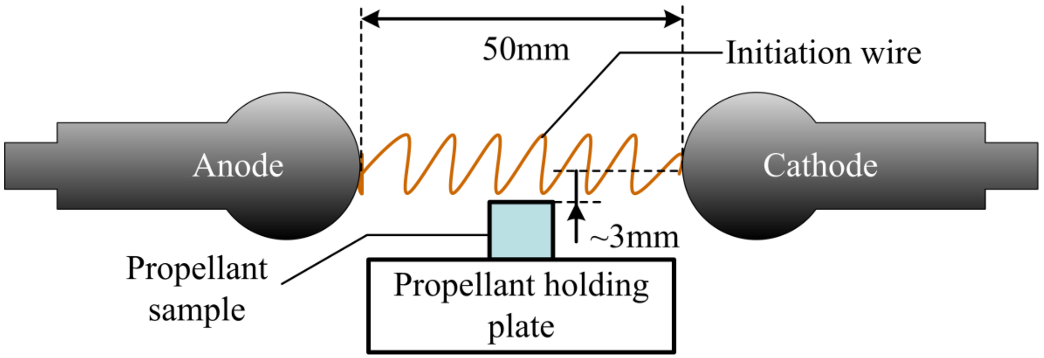


Fig.1 Experimental setup

2.2 The interrupted burning test

The interrupted burning test was carried out with a charging voltage of 7 kV.

2.3 The closed bomb tests

The closed bomb test system is composed of the pulsed power source, the closed bomb and the plasma generator. Both the conventional ignition and plasma ignition were studied.

3 Results and discussion

3.1 The open air ablation test

Few tiny holes could be observed in Fig.2 (a). The propellant ablated by plasma sublimated into gas, resulting in tiny holes.

From Fig.2 (c) and (d), whole RDX particles could be found near the tiny holes. In the open air, the gaseous products diffuse in the air. There is no second ignition on the surface of the propellant.

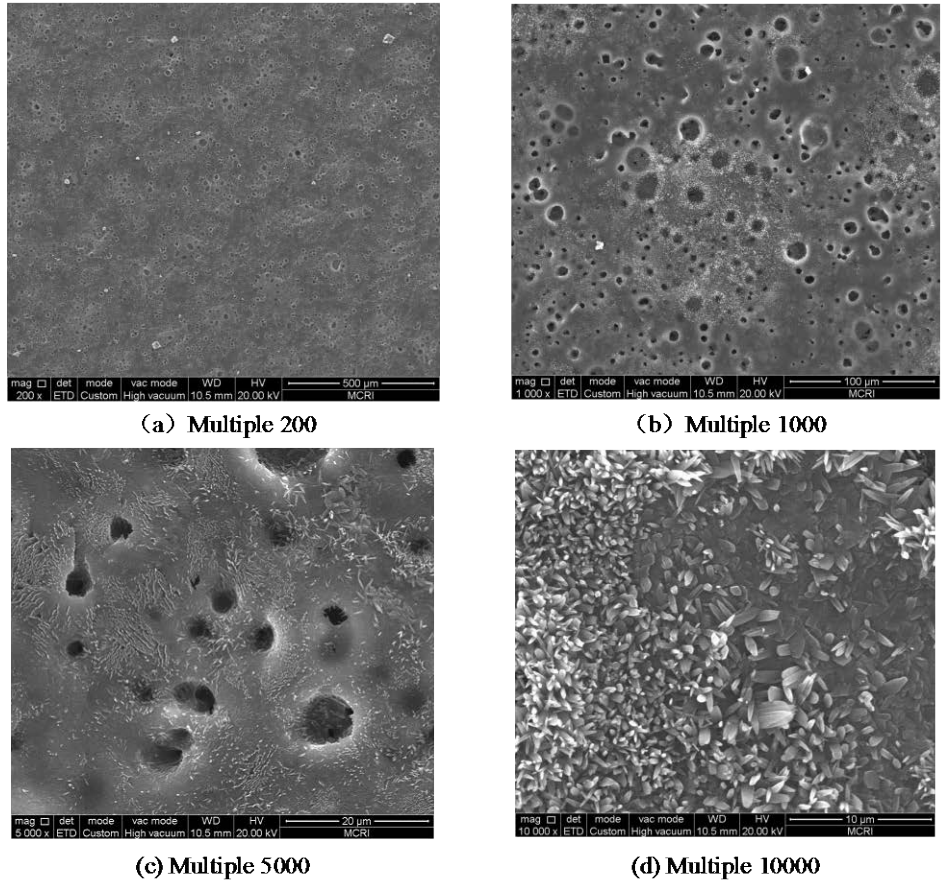
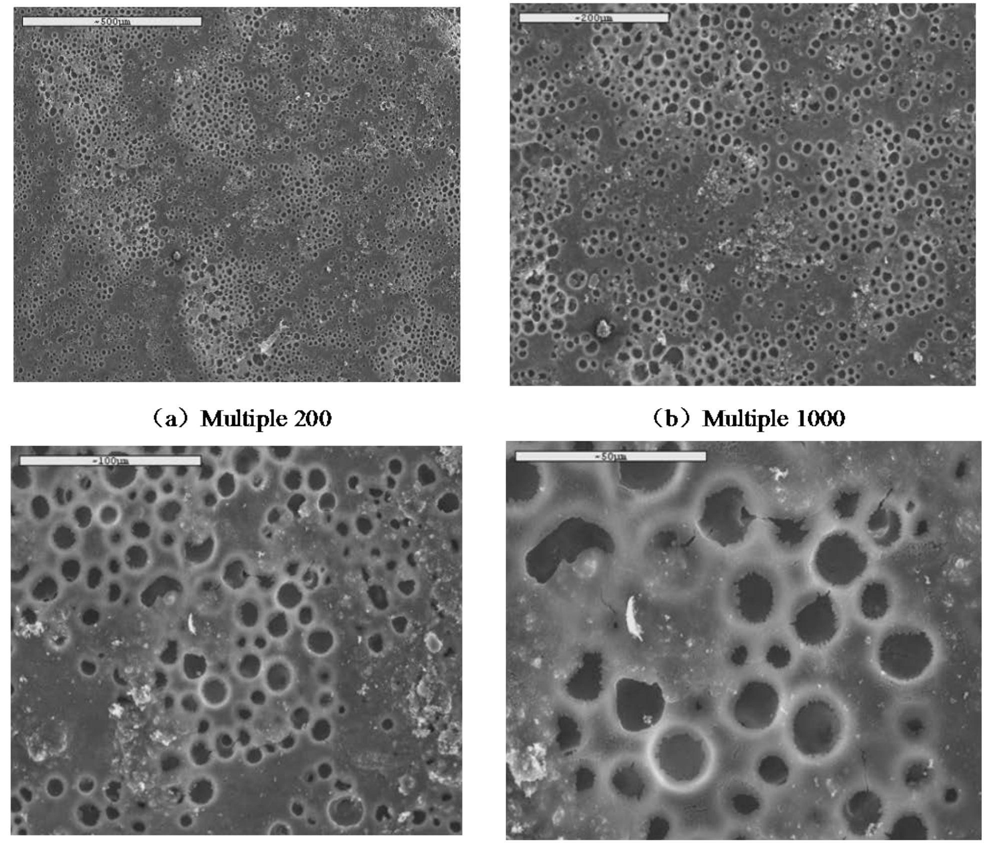


Fig.2 The surface conditions after the ablation test

3.2 The interrupted burning test

The interrupted burning test was carried out with a charging voltage of 7 kV. Compared with Fig.2 (a), more tiny holes could be found in Fig.3 (a). The tiny holes grow larger after ignition (see Fig.3 (b) and (c)). There are no whole particles near the tiny holes (see Fig.3 (d)).



(a) Multiple 200 (b) Multiple 1000

(c) Multiple 5000 (d) Multiple 10000

Fig.3 The surface conditions after the ablation test

3.3 The closed bomb tests

The rise rate of the p-t curve in the plasma ignition mode is higher, which indicates that the burning rate of the plasma ignition is larger.

The tiny holes might explain this higher burning rate as they increase the surface area of the propellant. However, the energy released by plasma is much lower than that released by the gunpowder. Therefore, the maximum pressure of the plasma ignition is lower.

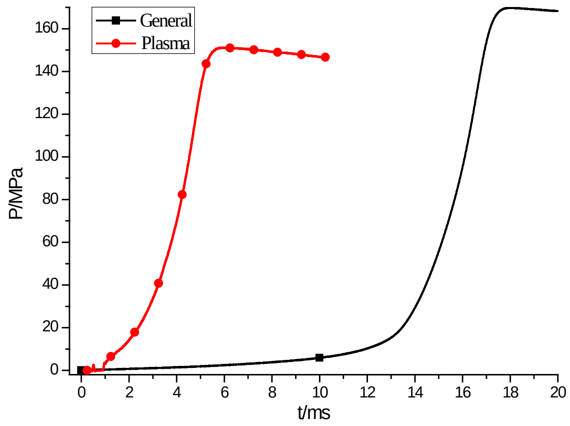


Fig.5 The p-t curves of high-energy nitramine gun propellants in different ignition modes

The initial stage of the plasma ignition under different charging voltage is different. For 5.05 kV, the pressure increases slightly. For 7.89 kV, the pressure reaches 10 MPa very quickly. An inflexion point can be easily seen from the curve.

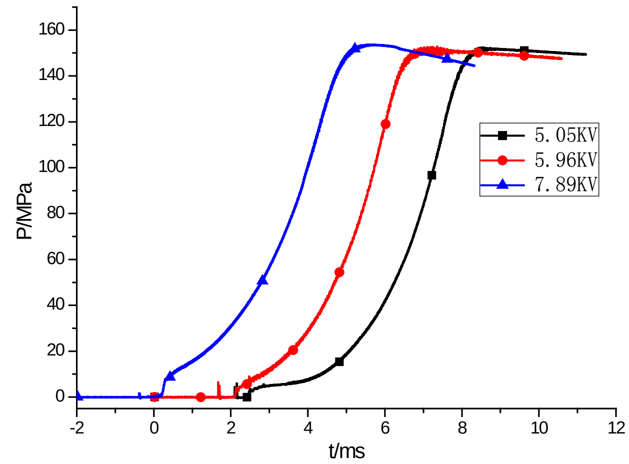


Fig.6 The p-t curves of different charge voltage

The maximum pressure under the charging voltage of 7.89 kV is a little higher than other. It indicates that the larger input energy could result in the higher maximum pressure.

The above results show that the plasma ignition process is that firstly the propellant is ablated into a gaseous state and then the propellant is ignited by the mixture of plasma and the gaseous propellant.

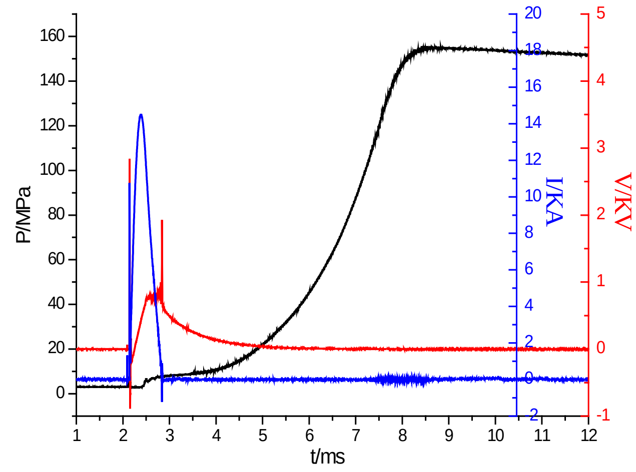


Fig.7 The testing curves of 5.05KV charge voltage

3.4 The ignition mechanisms

The plasma ignition could be divided into three stages.

◆The ablation stage is that the propellant surface is ablated by the plasma produced by the electrical explosion of the metal wire and the ablation of the liner material.

◆The ignition stage is that the propellant with tiny holes is ignited by the mixture of the ablated gaseous propellant and the plasma.

◆The combustion stage is that the propellant burns steady.

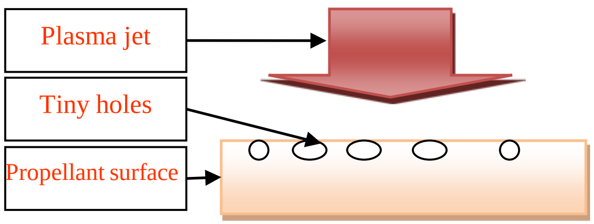


Fig.8 The plasma ignition sketch map of gun propellant

4 Conclusions

- ◆The formation of the tiny holes is the result of ablation and the ablation is sublimation due to the high temperature of plasma.
- ◆The tiny holes increase the surface area of the propellant, which contributes to the ignition. The mixture of the ablated gaseous products and the plasma fills the tiny holes quickly. The tiny holes then evolve into hot spots.
- ◆Under the high charging voltage, the propellant could ignited by plasma completely, simultaneously and immediately.

5 Acknowledgments

◆This research was done by gun propellant team.

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Thanks!