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Experimental Study on Plasma Ignited Single-base Propellant using SEM and EDS

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To explore the reaction mechanism in the plasma-propellant interaction, plasma ignition and conventional ignition experiments were carried out on a single-base propellant. Figure 1 is the schematic diagram of experimental loop for plasma ignition. The samples after ignition were analyzed by scanning electron microscopy (SEM) and X-ray energy dispersive spectroscopy (EDS).

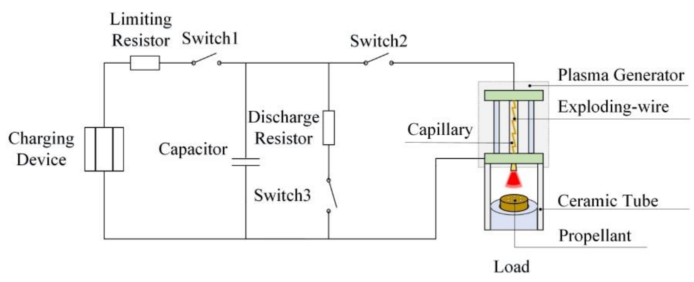


Figure 1. Schematic diagram of experimental loop for plasma ignition

In the plasma ignition experiments, a PFN circuit was used to discharge the exploding wire, which resulted a dense ionized plasma, whose composition was derived from the wire and sometimes from decomposed capillary material; this plasma sprays into the propellant and ignites the propellant. The morphology analyses of samples surface were executed by a scanning electron microscope (SEM) and element analyses of samples surface are performed by a X-ray energy dispersive spectroscopy (EDS).

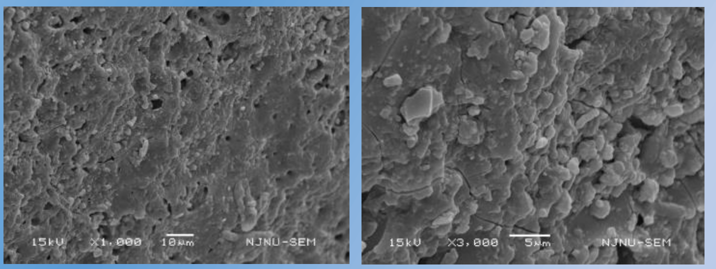


Figure 2. SEM photographs of single-base propellant ignited conventionally

Conventional ignition achieved ignition by accumulating the whole energy to make the propellant surface reach a certain temperature threshold which was reflected by the uniform surface of the propellant ignited conventionally, as shown in Figure 2.

In Figure 3, there are obviously cracks with visible separation between the two sides. These are actual cracks and might be caused by the physical impact of the plasma jet. The voids and cracks on the surface of propellant created by reaction with plasma provide microchannels for the subsequent plasma jet to enter the propellant, which benefit the diffusion of plasma and heat spread. Therefore, combustion rate increased and the whole combustion process would be shortened.

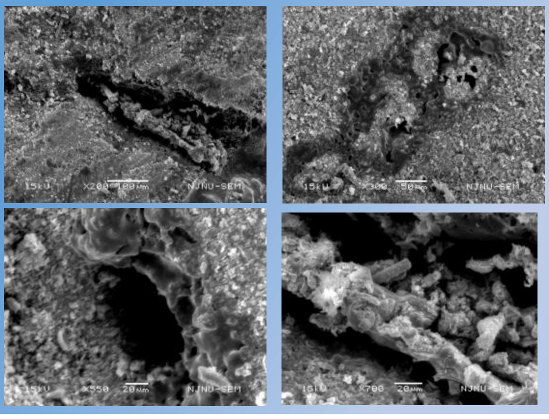
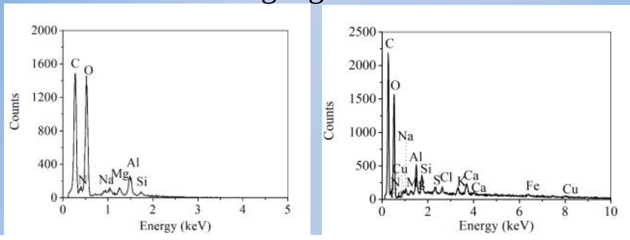


Figure 3. SEM photographs of single-base propellant ignited by plasma

Pores and cracks in Figure 3 generated on the surface of propellant by unrestricted plasma may lead to local combustion or incomplete combustion in an open environment. If in a high-pressure environment, such as the initial nitrogen environment of dozens of atmospheric pressure, plasma ignition can achieve complete combustion of a single grain.



(a) (b)

Figure 4. Energy spectrum of single-base propellant ignited conventionally(a) and by plasma(b)

Comparing the qualitative analysis of energy spectrum of samples ignited in two ways, as it is shown in Figure 4, the number of elements in the surface layer increased in the condition of plasma ignition.

Table 1. Quantitative Analysis Results of Main Elements in Conventional Ignition

Element	ZAF	Atom(%)	Element(Wt %)
C-K	2.181	40.35	33.89
O-K	5.933	48.39	54.15
N-K	6.970	10.34	10.12
Al-K	1.970	0.60	1.14

Table 2. Quantitative Analysis Results of Main Elements in Plasma Ignition

Element	ZAF	Atom(%)	Element(Wt%)
C-K	2.419	44.87	37.36
O-K	6.456	44.03	48.84
N-K	8.054	8.93	8.67
Al-K	1.945	0.73	1.37

Quantitative analysis results of main elements are as shown in table 1 and 2. In the condition of plasma ignition, the atomic percentages of N and O were lower than that in the conventional case. Atom percentage of N was 1.41% lower and atom percentage of O was 4.36% lower. It is considered that the chemical reaction rate of propellant ignited by plasma was faster than that of propellant ignited conventionally, which made the content of N and O remaining on the surface of propellant decrease.