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# The characters of small space debris impact inducing discharge

Hongwei Li, Jianwei Han, Minghui Cai, Zhenlong Zhang, Fengshi Wu

**Abstract**—It's well-known that hypervelocity impact can produce gas and plasma. So when space debris impact with spacecraft the impact induced plasma has very high density and conductivity which can constitute a discharge channel and triggering discharge. This was been regarded as the mechanism of space debris impact inducing discharge and was proved by Mengu Cho's research. Except plasma the gas produced by hypervelocity has effect on discharge too but only mentioned by Shu Lai. This paper gives the research about the effect of natural gas on space debris impact inducing discharge. It was founded that when the electric field was weak the gas has little effect in the discharge process but when the electric field was strong enough the gas has vary big effect in the discharge. Furthermore when the impact velocity was so low that can not produce plasma by the impact but can produce gas if the electric field was strong discharge can also be detected.

Based on the experiments of 200 micrometer particles impact inducing discharge the characters of space debris impact inducing discharge were given out. It was founded out that when the voltage between the electrodes with one millimeter gap was higher than 50 volt discharge can be triggered by the impact. When the discharge was triggered the voltage between the electrodes was down to about 20 volt. The resistance of the plasma was very low which can be less than 50 ohm. The discharge can last about several microseconds to several hundred microseconds that depends on the voltage and the impact velocity.

**Keywords**—Small space debris; Discharge

## I. INTRODUCTION

Spacecraft charging and discharging is a big threat to spacecraft. Much research was carried out to restrict spacecraft charging and discharging effects. Till now reason and mechanism for spacecraft charging is clear relatively but

the reason for discharging is still unclear. Since the discharging mechanism was very complicated only a few research has been carried out. And many factor was been regarded can triggering discharging. Small space debris impact is an important reason for spacecraft discharging since the impact can introducing high density plasma that can triggering discharge.

There are so many small space debris on the orbit which will impact on the spacecraft unavoidably and can inducing discharge. This effect has already been ragarded as the biggest risk of small space debris but research about this is rare relatively. Mengu Cho's research have proven that impact of space debris with diameters larger than 1mm can inducing sustain arc on high voltage solar cells. Hongwei Li's experiments indicated that the impact of space debris with diameters larger than 0.2mm can inducing discharge too. Based on those researches this paper gives the basic characters of small space debris impact inducing discharge.

## II. FACILITY

The experiments were carried out on the plasma drag particles accelerator and figure.1 gives the picture of it. The accelerator can accelerate particles with diameters between 10 $\mu$ m and 1mm and the particles velocity is up to 15km/s. The accelerator will accelerate many particles during one accelerating process since the particles is so small.



Fig.1 The picture of plasma drag particles accelerator

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The accelerator was composed by capacitors, coaxial gun, compression coil and the vacuum chamber. The capacitors were been charged to high voltage from 10KV to 25KV to store energy and was triggered to discharge through the coaxial gun to ionizing the working gas which was flow into the coaxial gun into plasma. After that the plasma was been accelerated by the compression coil to very high velocity up to about 30km/s and then accelerating the particle to high velocity at the end of the compression coil where the particles was been placed. The particle was been accelerated immediately and then fly about 6m in the vacuum chamber until impact on the target. The vacuum chamber was composed by a target vacuum chamber, an accelerating vacuum chamber and a flying tube. The vacuum chamber was pumped to less than  $5 \times 10^{-3}$ pa and before the accelerator starts to accelerate the particle. But During the accelerating process the vacuum was been disturbed and the vacuum pressure was about several Pa that can affect the experiment. A mylar film was placed in the flying tube so that the vacuum pressure in the target chamber maintain to  $10^{-2}$ pa during the accelerating process.

### III. EXPERIMENTS

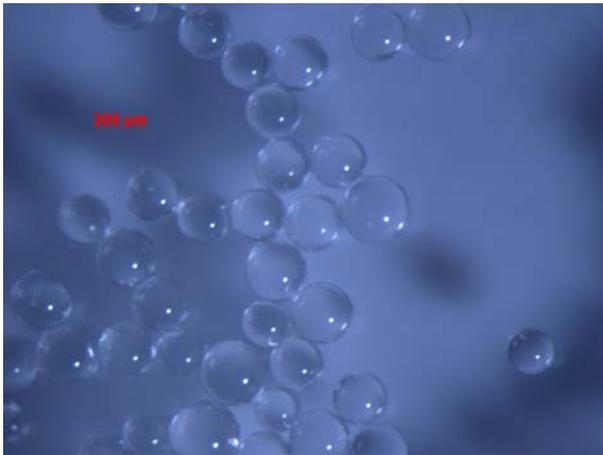


Fig.2 Picture of the glass ball

Glass balls with diameters about 200 micron was used to accelerated by the accelerator and impact on the specimen in the experiments. The glass ball was shown in Fig2. The accelerator can accelerate several particles in one time and the impact position is distribute on the target. So a specially designed specimen was used in the experiments. This specimen can make sure that when the particles was impact on any place of the specimen a discharge can be triggered. Fig3 shows the specimen and the experiment circuit diagram. The specimen was made by deposit metal electrode on the

insulator the electrodes is 1mm wide and the clearance between electrodes is 1mm too. The voltage between the electrodes can be changed through the power supply and the circuit diagram. The discharging current and voltage between the electrodes before and after the impact inducing discharge can be recorded in the oscillograph.

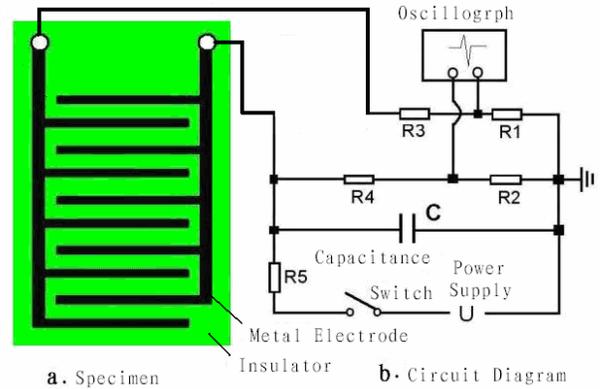


Fig3.The specimen and the circuit diagram

The impact signals and the velocity of the particles were detected by the piezoelectric sensor and the photoelectric sensor. The piezoelectric sensor was placed at the back of the specimen and can detect the impact signal by the impact shock wave. The photoelectric sensor was place at the front of the specimen and can detect the impact signal by the impact flash which was connected to the producing of the impact plasma. So the photoelectric sensor can only detect the impact that has high velocity to producing plasma and the piezoelectric sensor can detect all the impact signals.

### IV. SUMMARY

#### A. The threshold for impact inducing plasma

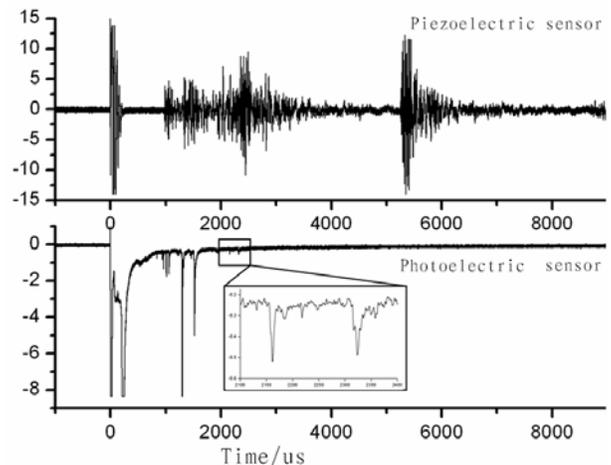


Fig.4 The impact signal detected

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The threshold for impact inducing plasma was detected by the photoelectric sensor and the piezoelectric sensor. The piezoelectric sensor can detecting any impact signal and the photoelectric sensor can only detect the impact which has very high velocity that can inducing impact flash and plasma. So if the impact velocity is relatively low the impact can not inducing plasma the photoelectric sensor will not detect the signal but the piezoelectric sensor can detect it. Fig4 is the typical result of the impact signals detected by the photoelectric sensor and the piezoelectric sensor. Based on several results it was clear that the threshold for impact inducing plasma is about 2.5km/s. Fig5 shows an typical impact flash signal. The impact flash can last to about ten microseconds.

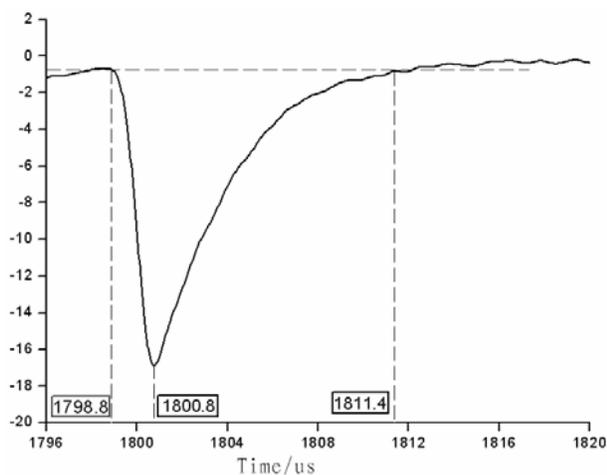


Fig.5 Typical signal of impact flash

#### B. The effect of gas on impact inducing discharge

When the impact velocity is so low that there were no plasma induced there are only gas induced if the voltage on the specimen between the electrodes is high there will inducing discharge too. This is because gas can trigger discharge too when the voltage is high. This was proved by our experiments. In the experiment it was founded that when the impact velocity is 1km/s which can not inducing plasma discharging can be detected if the voltage between the electrodes was higher than 300 volt. On the other hand if the voltage is low there were no discharging signals. Further more if the voltage is high and the impact can not inducing plasma the discharging current and the discharging light can both be detected. That means that the gas was been ionizing into plasma and the characters is similar to the high velocity impact inducing discharge.

The impact flash detected by the photoelectric sensor when the voltage between the was zero was pulse signals and the

width of which is from a few microseconds to about 10 microseconds. And when the voltage between the electrodes is less than 100 volt the impact flash signal was the same like before and the time of discharging current was the same like the impact flash. But when the voltage between the electrodes is more than 300 voltage the impact flash is no longer a pulse signal and the last time is much longer up to several hundred microseconds. Typical signals of this light signals was shown in fig6. This means that when the voltage is high the gas plays the main role in the discharging process.

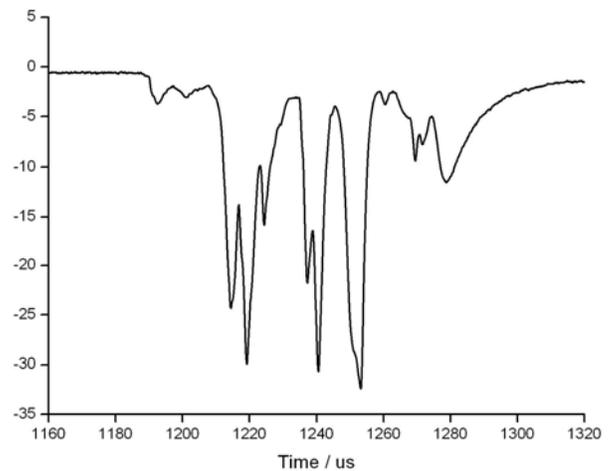


Fig.6 The light signal in impact inducing discharge

#### C. The characters of impact inducing discharge

Based on the experiments of 200 micrometer glass ball particles impact inducing discharge the characters of space debris impact inducing discharge were given out. It was founded out that when the voltage between the electrodes with one millimeter gap was higher than 50 volt discharge can be triggered by the impact with velocity higher than 2.5km/s. And this can be regarded as the voltage threshold for impact inducing discharge in this condition.

When the voltage between the electrodes is high the velocity for impact inducing discharge can be about 0.6km/s. Even there was no plasma the impact induced gas can be ionized into plasma by the electric field and inducing discharge. And the ionizing voltage for the impact gas was about 300 volt.

The impact current in the impact inducing discharge can be up to several ampere that depends on the voltage between the electrodes and the resistance in the discharging circuit.

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That's because the resistance of the plasma was very low which can be less than 50 ohm. When the discharge was triggered the voltage between the electrodes was down to about 20 volt. The discharge can last about several microseconds to several hundred microseconds that depends on the voltage and the impact velocity.

#### ACKNOWLEDGMENT

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