Preliminary Study on Microwave Emission from Space Debris Impacts

（デブリ衝突で生じるマイクロ波放射に関する基礎研究）

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Abstract

Space debris are traveling at the velocity of 7-8 km/s in a low Earth orbit and the collision between space debris and spacecraft will be tremendous damage. Space debris impact (i.e. hypervelocity impact) generates not only mechanical phenomena such as crater, and secondary debris but also electrical ones such as radiofrequency (RF) emission, plasma generation, flash emission, and variation in electrical potential of the impacted target. The mechanism of RF emission has been researched, but the conclusion has been not reached yet. The impact experiments using the two-stage light gas gun of ISAS/JAXA were conducted. We measured the electrical phenomena at the same time and investigated microwave emissions depending on the hardness of target materials.

1. Introduction

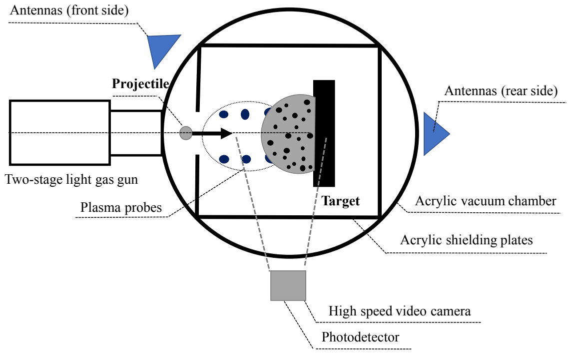
Space debris are traveling at the velocity of 7-8 km/s in a low Earth orbit, and the collision between space debris and spacecraft will be tremendous damage[1)]. Hypervelocity impact generates not only mechanical phenomena such as crater, secondary debris but also electrical ones such as RF emission[2)], plasma generation, flash emission, and variation in electrical potential of the impacted target. So far, the mechanism of RF emission has been investigated[3,4)], but the conclusion has not been reached yet. In this paper, hypervelocity impacts experiments using a two-stage light gas gun of ISAS/JAXA were conducted. We measured electrical phenomena at the same time to clarify the characteristics of microwave emission. We investigated the dependence on the hardness of target materials.

2. Methods

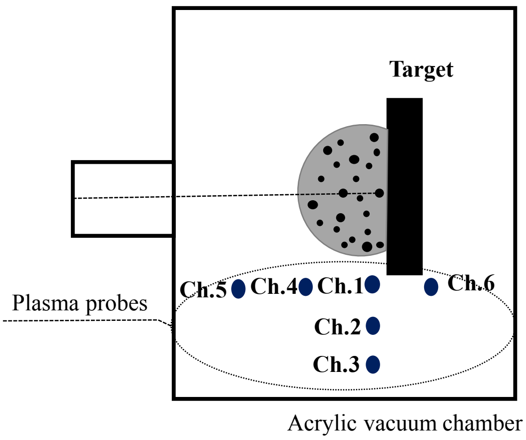
Figure 1 shows experimental setups of the two-stage light gas gun, an acrylic vacuum chamber, and measuring systems. The gun accelerated a 7mm-diameter nylon sphere with an impact velocity of approximately 7km/s as a projectile. The projectile impacted to a target at an angle of 90 degrees. We selected a 1050 pure aluminum, 6061 and, 7075 aluminum alloy plates with a size of $110mm \times 110mm \times 40mm$ as targets. In the chamber, the pressure was set at several pascals.

The high-speed video camera which is HPV-1 made in Shimadzu Co. was used for observing the propagation of the flash. The photodetector consists of a high-speed Si PIN photodiode of S3071 and a current-to-voltage conversion amplifier of C8366 made in Hamamatsu Corporation. The photodetector was used for measuring an intensity of the flash. The camera and the photodetector were located at the perpendicular to the target. Double probes were used for detecting the plasma current. The electrodes used a cylinder wire with a diameter of 2mm and a length of 10mm. An applied voltage was 9.2V between electrodes and the flowing current was measured. Probes were set on both front and rear sides. Probes on the front side were used for investigating the propagation of the plasma generation. The electrical potential was measured by monitoring the difference between the potential of the ground and one of the target. The target was isolated from the ground.

Microwave measurement was used for antennas with the frequency bands of 300MHz, 2.1GHz, and 5.8GHz. The receiving systems are shown in Fig. 2. In the receiving system of the 300MHz band, the receiving signals are amplified through a low noise amplified and directly recorded to a digital storage oscilloscope (DSO). In the receiving systems of 2.1GHz and 5.8GHz bands, we amplified the receiving signals and applied for the heterodyne system because DSO cannot measure signals at the frequency bands of 2.1GHz and 5.8GHz. The antennas were set on the front side and the rear one of the target.

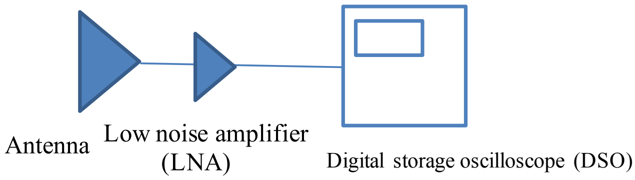


(a) Upper view

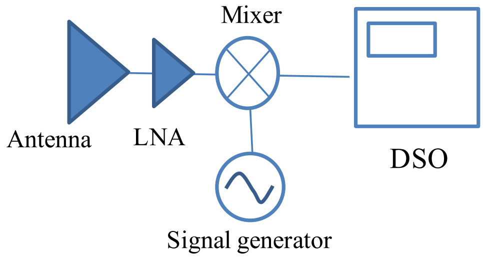


(b) Side view

Fig. 1 Experimental setups of the two-stage light gas gun, an acrylic vacuum chamber and measuring systems.



(a) 300MHz band



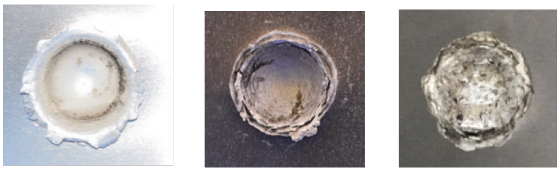
(b) 2.1GHz and 5.8GHz bands

Fig. 2. The receiving systems for measuring microwave emissions.

3. Results & Discussion

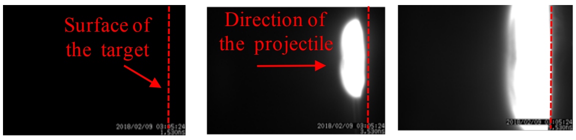
The craters of aluminum targets can be seen in Fig. 3. The damage of the crater in 1050 pure aluminum is the biggest. The appearance of light propagation is shown in Fig. 4. The flash propagates from the impact point to the edge of the chamber. Figure 5 shows results of the simultaneous observation after the impact on the 1050 pure aluminum plate. The intensity of flash from the photodetector is shown in Fig. 5 (a). The rise-time of intensity was defined as the impact start time. Plasma current was measured as shown in Fig. 5 (b). Plasma current on a front side (ch1-ch.5) of the target was measured for dozens of microseconds, but one on a rear side (ch.6) was not measured. The variation of electrical potential in the target was observed during dozens of microseconds in Fig. 5 (c) Microwaves on the front side are as shown in Fig. 5 (d). The amplitude of microwaves was calibrated by deducting the gain of LNA. We confirmed the start time of emitting microwaves delayed compared with one of the other phenomena.

Microwaves emit intermittently and consist of sharp pulses with a periodic time of several nanoseconds. Microwaves on both front and rear sides are received as shown in Fig. 6. The duration time of emitting microwave on both sides is approximately 5ms. The duration time of emitting microwaves is totally different from one of the other phenomena. Microwaves were received, but plasma current was not observed on the rear side. Therefore, we clarified that microwaves emit regardless of the plasma generation. In the case of 6061 and 7075 aluminum alloys targets, the maximum amplitude of microwaves seems to be different as shown in Fig. 7. We suggest that microwave emissions are related to the hardness of target materials.



(a) 1050　(b) 6061　(c) 7075

Fig. 3. Craters of the impacted targets.



-0.718μs　1.282μs　3.282μs

Fig. 4. The propagation of the flash.

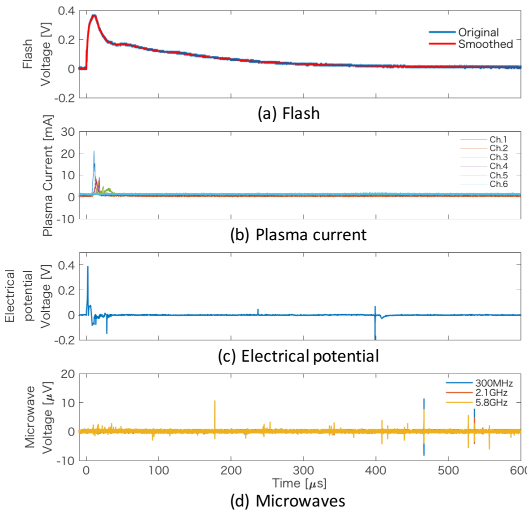


Fig 5. Comparison of each electrical phenomenon.

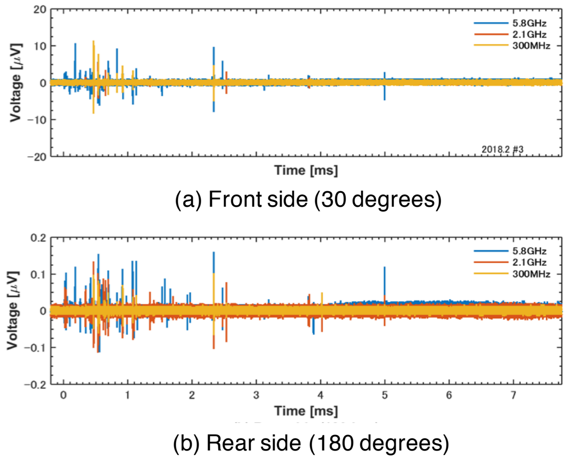


Fig. 6. Comparison of microwaves between front and rear sides.

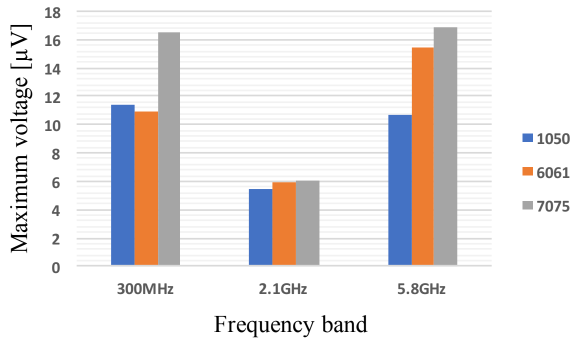


Fig. 7. Comparison of maximum amplitude of microwaves depending on target materials.

4. Conclusions

Hypervelocity impact experiments using the two-stage light gas gun were conducted. We measured electrical phenomena of microwave emissions, light emission, plasma generation, variation in electrical potential at the same time and confirmed that microwaves emit regardless of plasma generation. The degrees of microwave emissions seem to be different depending on the hardness of target materials. As our future work, we will compare with the experimental results and numerical analysis, and clarify the mechanism of microwave emission.

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