Utilizing Impedans Semion for Ion Energy Measurements in the Advancement of Piezoelectric Energy Harvesting for Space Applications

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Introduction

Understanding and evaluating the properties of materials in the space environment are essential for ensuring the lifetime and reliability of spacecraft under extreme conditions of space. Low Earth orbit (LEO), situated about 200–700 km above the Earth's surface, is commonly used for satellite communication and remote sensing but poses significant challenges due to its hard environment. At these altitudes, atomic oxygen (AO) constitutes around 80% of the atmosphere and can cause serious damage to the surface of spacecrafts which travel at speeds of 7-8 km/s. To mitigate the risk, recent research has focused on piezoelectric energy generation using PZT materials, simulating LEO conditions to mitigate AO impacts.

A recent publication from Science Direct highlights the importance of the Impedans Semion system in developing piezoelectric energy harvesting methods through hypervelocity atomic oxygen impacts in Low Earth Orbit (LEO). Semion measurements were crucial for assessing atomic oxygen impact velocities in a simulated oxygen plasma environment. This research presents a novel approach to energy generation in space, where resources are scarce and efficient energy solutions are vital.

Experimental setup

The equipment and its experimental schematic used to simulate the LEO environment is illustrated in figure 1 (a) and (b). A 13.56 MHz radio frequency (RF) plasma gun was utilized for generating oxygen plasma to simulate the impact of AO in LEO. The vacuum pressure was maintained at the range of 10 mTorr, and the power input was maintained at 150 W for continuous and stable operation of the plasma chamber. A Semion Retarding field energy analyzer (RFEA) from Impedans was used to measure the ion energy and ion flux density to understand the piezoelectric response of a PZT plate placed inside the plasma chamber.

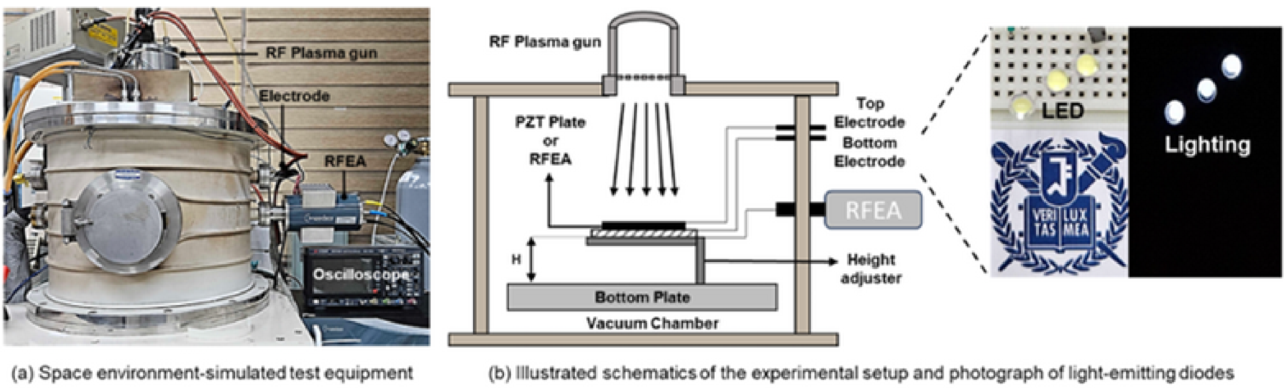


Figure 1 (Left) Photograph and Schematic illustration of space environment-simulated test equipment setup.

Results

It was seen that the exposure of PZT to AO impact at hypervelocity increased the electrical response measured by the piezoelectric device as the effective flux increased. Fig.2 shows the results of PZT exposure under different effective AO flux conditions obtained by varying the height of PZT plate.

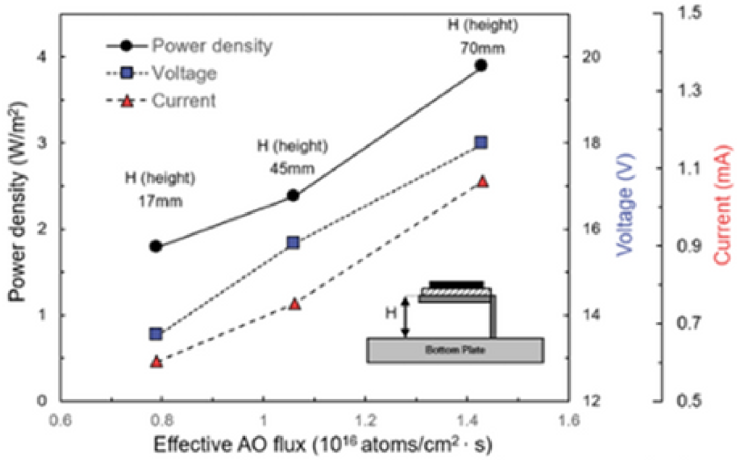
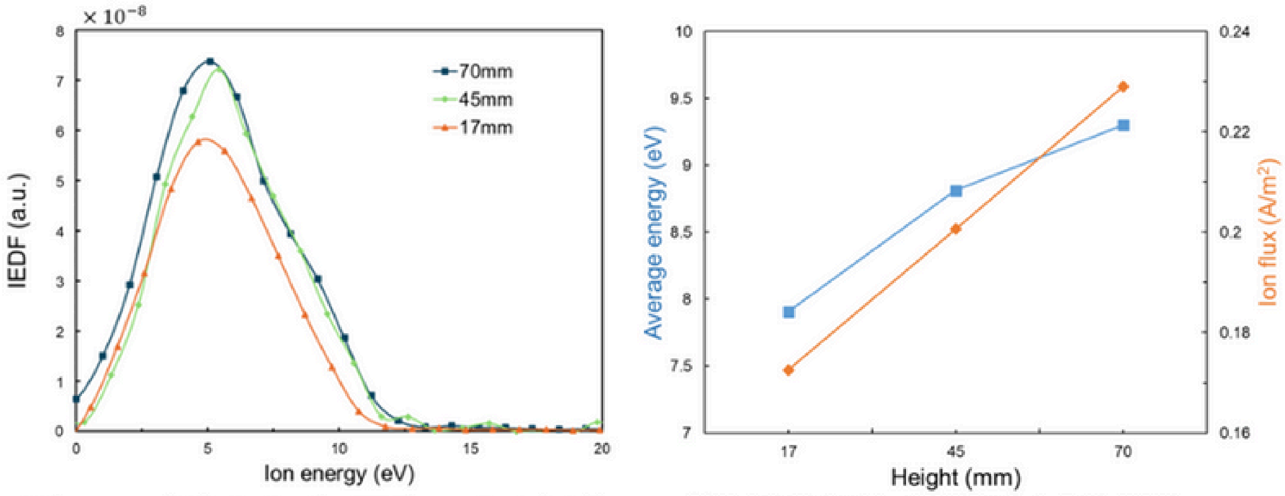


Figure 2 Output power density, voltage and current graph of different effective AO flux indicating the Performance of the piezoelectric effect by AO impact on PZT plates.

The ion energy distribution functions (IEDF) were measured to compare the impact velocities of atomic oxygen within the LEO environment and within the plasma state of the equipment as shown in figure 3. The RFEA was located on the height adjuster. Ion energies were measured at three different heights based on the H values of 17mm, 45mm, and 70mm.

Figure 3 Measurement of plasma properties by RFEA.



(a) Ion energy distribution function (IEDF) according to height
(b) Average ion energy and ion flux according to height

Figure 4 Characteristics of oxygen plasma simulating AO.

Fig. 4(a) shows the IEDF measured as a function of height. As a result, the IEDF exhibited a distinct single peak in ion energy. Moreover, the ion energy peak of the oxygen plasma generated by the equipment occurred approximately within the 5 eV range. This observation indicated a similarity to the energy exhibited when AO in LEO impacted spacecraft and the value of the ion energy peak increased as the height increased. Additionally, Fig. 4(b) displays the results for different effective AO flux levels. Both the average ion energy and ion flux increases with effective AO flux.

Summary

Utilizing Semion measurements, it was shown that the oxygen in the peak plasma state of the instrument had an energy of 5 eV, and confirmed that the average ion energy and flux increased when the effective AO flux increased. As the effective flux of AO increased, both the voltage and current measured in the PZT increased, and as a result, the power density also increased showing a linear correlation between electrical power and effective AO flux. The findings clearly indicated piezoelectricity during the hypervelocity impact of AO on the plate.

Impedans Semion provided critical measurements of ion energy and flux, aiding in the understanding of atomic oxygen's impact on PZT plates. These experimental results indicate that applying a thin layer of piezoelectric materials to spacecraft surfaces could enhance performance, either independently or in conjunction with solar cells.

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