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Endurance and operation of ionic liquid lithium secondary battery in space successfully addressed without anti-vacuum reinforcements

1 OVERVIEW

The ionic liquid lithium secondary battery developed by Professor Masashi Ishikawa and Associate Professor Masaki Yamagata of Kansai University (Suita City, Osaka, President: Harushige Kusumi) was placed in orbit around the Earth aboard the artificial satellite HODOYOSHI-3 on June 20 of this year. Subsequently, it became the first ionic liquid battery to be successfully charged and discharged in orbit on August 5, followed by a successful long-period charging and discharging test on October 27. Based on the data acquired, it was found that the battery had suffered little deterioration due to the effects of the space environment, despite its long period in space. Because this secondary battery uses ion liquid with low vapor pressure as the electrolyte, it was successfully made into a storage battery for use in space with only a thin and flexible aluminum laminate armor. This makes it a lightweight, thin, and compact battery that requires no rigid anti-vacuum exterior or resin mold, which had been unavoidable with conventional batteries for space use. The results were presented at the Space Sciences and Technology Conference in November, as well as the Battery Symposium, generating strong reactions from researchers and developers of batteries and devices for use in space. Some information on this development was also introduced at the U.S. NASA Aerospace Battery Workshop held at the same time, attracting a lot of attention from aerospace developers in the U.S. At present, it has marked approximately six months in orbit, and is expected to be adopted as a compact, safe, and highly reliable storage battery that can be applied even in the extreme environments of aerospace engineering.

2 DEVELOPMENT HISTORY OF IONIC LIQUID LITHIUM SECONDARY BATTERY FOR SPACE USE

The ionic liquid lithium secondary battery was developed by Professor Masashi Ishikawa and Associate Professor Masaki Yamagata of Kansai University, who conducted material development and battery design. It was mounted on the technological demonstration module of HODOYOSHI-3, an artificial satellite developed by Professor Shinichi Nakasuka of the University of Tokyo. For details about how the professors developed the battery, and how it was mounted on the satellite, see our University Press Release No. 10, dated June 23.

http://www.kansai-u.ac.jp/mt/archives/pdf/150107_e_ionic0623.pdf

(Reference) Information about HODOYOSHI satellites from Professor Nakasuka is provided here (Website for Faculty of Engineering, the University of Tokyo).

http://www.t.u-tokyo.ac.jp/epage/release/2014/2014061701.html

After the satellite was launched, Professor Masashi Ishikawa and Associate Professor Masaki Yamagata of Kansai University, Associate Professor Yoshitsugu Sone of the Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (JAXA), and Professor Shinichi Nakasuka of the University of Tokyo concluded a research agreement and launched the mission jointly. Professor Shinichi Nakasuka of the University of Tokyo, and Dr. Yoshihiro Tsuruda, Dr. Yoshihide Aoyagi, and Researchers Toshiki Tanaka and Ken Matsumoto from his laboratory were in charge of satellite operation. In-orbit battery operation was mainly handled by Associate Professor Sone of JAXA, Mr. Kohei Tanaka of the Graduate University for Advanced Studies, and Professor Ishikawa and Associate Professor Yamagata of Kansai University, as well as iElectrolyte LLC, a venture company managed by several persons including the latter two researchers and Dr. Michiyuki Kono, who were responsible for battery characteristic analysis.

3 MAJOR OUTCOMES AND FUTURE PROSPECTS

As already described, the results of operation tests on a satellite were presented in detail at the Space Sciences and Technology Conference in November this year, as well as the Battery Symposium. It is a thin battery with a capacity of approximately 1 Ah and a maximum voltage of 4.2 V. It was designed as a compact storage battery that can be installed in the components required and in the quantity required, even in the limited space available in an artificial satellite. The key material used here is a solvent-free electrolyte called FSI-type ionic liquid developed by Professor Ishikawa, et al. It is practically the only ionic liquid that can be used as the electrolyte of a high-output lithium ion battery, and its characteristics of being flame-resistant and having virtually no vapor pressure have led to the development of a thin battery for use in space with only a simple aluminum laminate armor.

An important fact is that this storage battery can exist stably in space with a flexible exterior, and has shown the same performance as an identical battery kept on Earth for comparison. Because it passed an ultra-high vacuum test that simulated space and showed no deterioration in an irradiation test equivalent to more than five years of exposure to cosmic radiation in ground tests before launch, the parties involved expected good results in space. However, nine months passed between battery manufacture until launch, during which it was subjected to

Ionic liquid lithium secondary battery developed by Professor Ishikawa, et al. of Kansai University (top) and the ionic liquid lithium secondary battery that was mounted on the technological demonstration module of HODOYOSHI-3. It is capable of operating under extremely high vacuum with only a simple laminate armor (bottom).

transfer to the launch site (Russia), followed by high Gs and extreme vibration during the rocket launch and five months in space. In spite of these severe conditions, we consider the fact that the thin laminate battery they developed demonstrated no deterioration other than that which similarly occurred in the battery that remained on Earth is of great significance.

The previously described three organizations that concluded the joint research agreement will play core roles in future research and development of ionic liquid lithium secondary batteries for satellites, and the venture company iElectrolyte LLC will be responsible for product development. It is expected that the battery will mark the beginning of a new generation of safe and highly reliable storage batteries for use under extreme environments such as aerospace applications. We hope to announce more information as it becomes available in the future.

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