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KANSAI UNIVERSITY

新日本電工

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Disruptive Energy Technology Demonstration Satellite, DENDEN-01

First Space Demonstration of Battery Temperature-Stabilizing Device for CubeSats Using Solid-Solid Phase Change Material

Breakthrough in CubeSats: Power-Free Battery Thermal Management Successfully Demonstrated in Space

Kansai University (Chairperson of the Board of Trustees: Keiji Shibai) has confirmed the battery temperature-stabilizing effect of an inorganic solid-solid phase change material (SSPCM) jointly developed with Nippon Denko Co., Ltd. (President: Yasushi Aoki). This device was installed on the 1U CubeSat "DENDEN-01" and successfully demonstrated its functionality in space.

The device (Figure 1) was mounted on DENDEN-01, a CubeSat developed by Kansai University and its collaborators (Project Manager: Associate Professor Masaki R. Yamagata, Faculty of Chemistry, Materials and Bioengineering) . DENDEN-01 was deployed from the International Space Station (ISS) on December 9, 2024 (JST). After deployment, communication tests successfully retrieved satellite telemetry, confirming that the battery maintained its targeted operating temperature range without dropping below the lower temperature limit, even in cold conditions. This is the world's first successful space demonstration of an inorganic SSPCM-based temperature-stabilizing device for on-board equipment.

Key Points of This Announcement

- Successful space demonstration of a battery temperature-stabilizing device using solid-solid phase change material.
- Maintains battery temperature within the appropriate range, even under extreme space conditions.
- Potential future applications in satellites to improve electric power system stability in space environments.
- This breakthrough contributes to the advancement of satellite power system reliability, offering a power-free thermal management solution for next-generation space missions.

About DENDEN-01

DENDEN-01 is a 1U CubeSat selected for the "J-CUBE Program," an initiative jointly organized by the Japan Aerospace Exploration Agency (JAXA) and the University Space Engineering Consortium (UNISEC) at the end of fiscal year 2021. The J-CUBE program provides opportunities for domestic universities and colleges to deploy CubeSats from the Japanese Experiment Module "Kibo" aboard the International Space Station (ISS).

DENDEN-01 is carrying out on-orbit demonstrations of various energy technologies and high-load missions, including a temperature stabilizing device for power supply utilizing solid-solid phase change materials (SSPCM). These demonstrations will contribute to the future development of Nanosatellites including CubeSats.

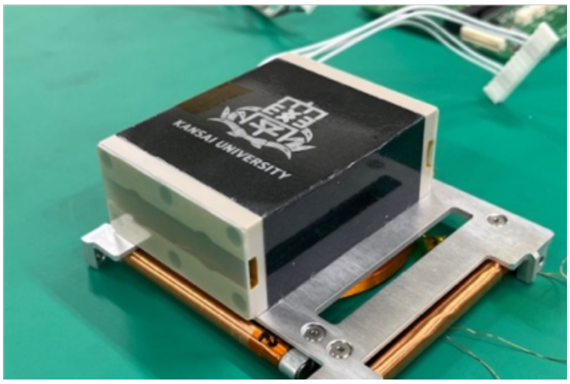

Figure 1 Battery temperature-stabilizing device installed on DENDEN-01.

References

DENDEN-01 Project Official Website

https://denden01.kansai-u.space/en

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The device (Figure 1) was mounted on DENDEN-01 (Figure 2), a CubeSat developed by Kansai University and its collaborators (Project Manager: Associate Professor Masaki R. Yamagata, Faculty of Chemistry, Materials and Bioengineering) . DENDEN-01 was deployed from the International Space Station (ISS) on December 9, 2024 (JST). After deployment, communication tests successfully retrieved satellite telemetry, confirming that the battery maintained its targeted operating temperature range without dropping below the lower temperature limit, even in cold conditions. This is the world's first successful space demonstration of an inorganic SSPCM-based temperature-stabilizing device for on-board equipment.

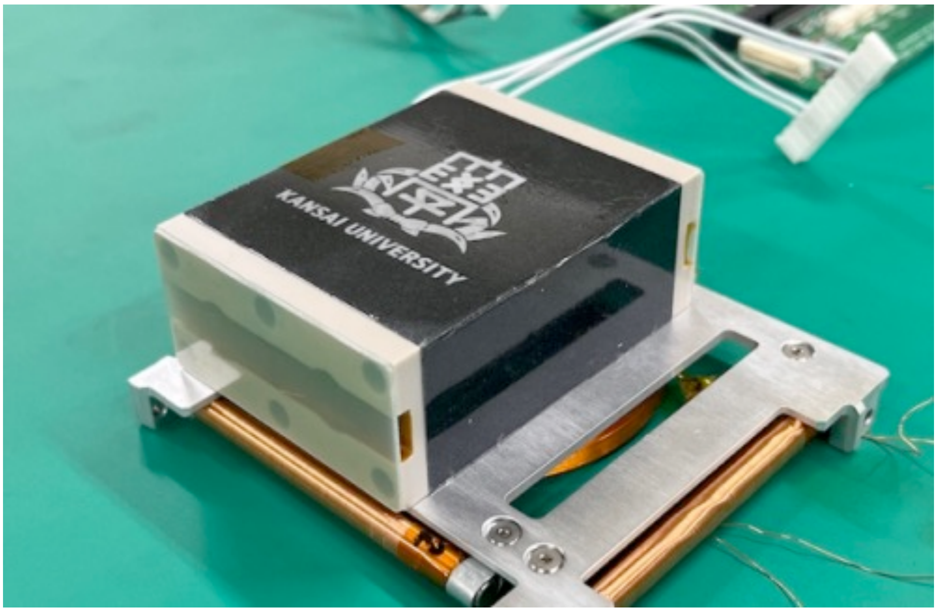


Figure 1 Temperature stabilizing device for the power system of CubeSats, using a solid-state phase change material (SSPCM) as a battery container (black component).

Figure 2 Flight model of the CubeSat "DENDEN-01".

Device Overview and On-Orbit Demonstration

As shown in Figure 3, the temperature-stabilizing device is mounted at the bottom of the DENDEN-01 (on the –Z panel side) and encloses two cylindrical lithium-ion battery cells. Temperature measurements were conducted not only on the device itself but also on the communication module, the largest onboard component, which is installed on the +Z panel side. In addition, temperature data of the satellite's external structural panels were collected. Specifically, the –Z panel, closest to the device, and the +Z panel, adjacent to the communication module, were measured as reference values for their respective surrounding temperatures.

Figure 4(a) shows the temperature variations of the battery (BAT) with SSPCM, the communication module (COM) and the structural panels (-Z and +Z panels) during the transition from sunlight to eclipse on December 25, 2024. While the temperatures of the structural panels and the communication module dropped sharply, the battery with the temperature stabilizing device maintained a nearly constant temperature, confirming that the SSPCM effectively mitigated rapid temperature change in the battery by regulating heat storage and release. Figure 4(b) shows temperature data recorded on December 26, when the satellite re-entered sunlight after an eclipse. On this day, the sunlight duration was the shortest during the early operational period, exposing the satellite and on-board equipment to particularly low temperatures. Under these conditions, the temperature of the communications module dropped to –8°C, while the battery successfully maintained its target minimum of 0°C.

These results clearly demonstrate the effectiveness of the developed SSPCM in preventing rapid temperature changes and maintaining the battery within an appropriate temperature range in the space environment.

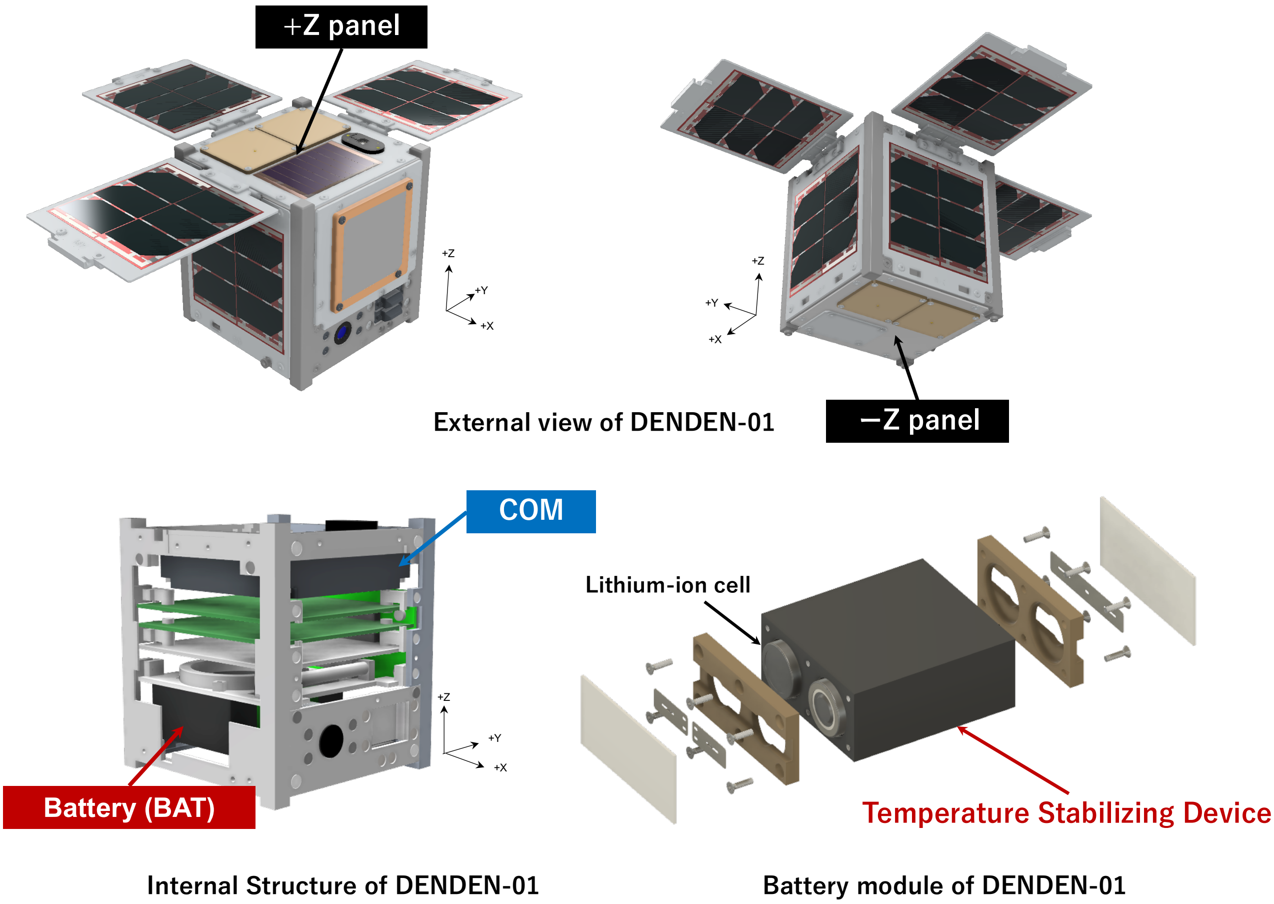
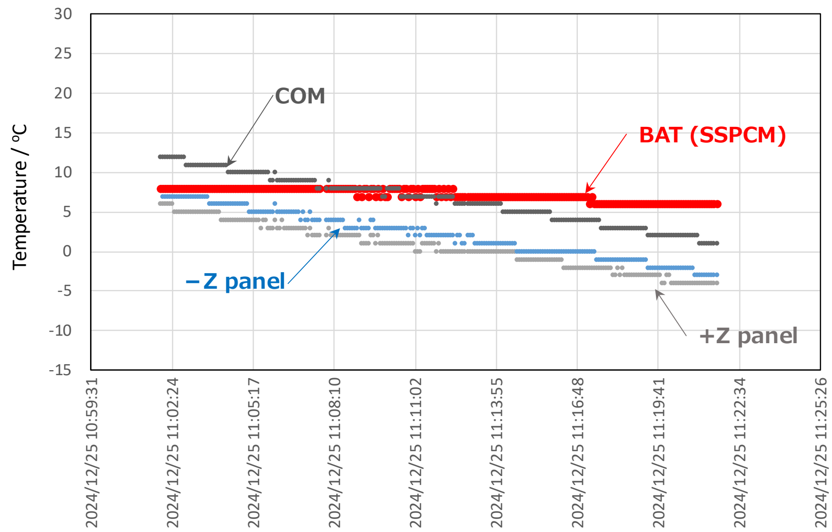


Figure 3 External view of DENDEN-01 (with deployed solar paddles) and internal structure, including the configuration of the on-board battery.

(a)



(b)

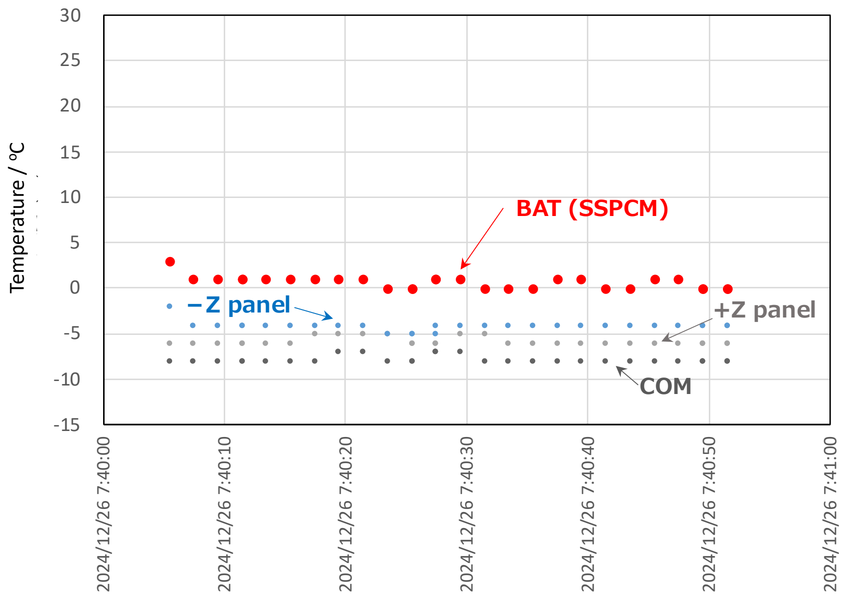


Figure 4 Temperature profiles of the Battery Temperature Stabilizing Device (BAT) using the SSPCM, on-board communication module and structural panels (-Z and +Z panels): (a) data from December 25, (b) data from December 26.

Addressing Our Material Challenges for CubeSats

Satellites weighing less than 100 kg are classified as micro/nanosatellites, and among them, CubeSats - which adhere to a standardized unit structure of 10 cm per side - are increasingly being developed worldwide. However, CubeSats have low thermal capacity and face significant power, weight, and size constraints, making them particularly vulnerable to the harsh temperature fluctuations of space. A key challenge for DENDEN-01 is to improve the low-temperature performance of on-board power systems - exposure to extreme cold can severely degrade battery performance, leading to satellite failure. To address this issue, Kansai University and Nippon Denko Co., Ltd. jointly developed a vanadium dioxide (VO_2)-based SSPCM optimized for space conditions by tailoring its phase transition temperature and phase change response characteristics. Under the leadership of Associate Professor Masaki R. Yamagata and his research group, this SSPCM was successfully integrated into a temperature-stabilizing device for CubeSats. This breakthrough technology is expected to enhance CubeSat operations by reducing power consumption while ensuring stable battery performance within an appropriate temperature range.

The successful space demonstration confirms that the temperature-stabilizing device utilizing SSPCM is a promising thermal management solution for CubeSats as well as micro/nanosatellites, with potential applications beyond power systems to a wide range of onboard components. Moving forward, the DENDEN-01 mission will continue evaluating the performance of SSPCM under real space conditions, contributing to the advancement of next-generation satellite technologies.

Related Information

For more details on the DENDEN-01, please refer to the press release dated June 25, 2024:
https://x.gd/2zRJ4

Official website of the DENDEN-01 Project
https://denden01.kansai-u.space/

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https://www.nippondenko.co.jp

Supplementary Information

*1 Solid-Solid Phase Change Material (SSPCM)

SSPCM is a phase change material (PCM) that stores and releases thermal energy through its phase transitions. While conventional PCMs typically transition between solid and liquid phases, SSPCM achieves this through a phase transition between two distinct solid crystal structures. This unique property eliminates the risk of liquid leakage or vaporization, making SSPCM particularly suitable for use in the vacuum environment of space.

*2 CubeSat

A CubeSat is a class of nanosatellites based on standardized units, with each unit (1U) defining the dimensions 10 × 10 × 10 cm. Over the past decade, the rapid expansion of commercial space activities has led to a global increase in the development of CubeSats for Earth observation, communications, and other applications. This standardized platform allows for low-cost mass production and launch.

Contacts

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